GREGORIAN REFORM OF THE CALENDAR

PROCEEDINGS OF THE VATICAN CONFERENCE TO COMMEMORATE ITS 400th ANNIVERSARY 1582 - 1982

EDITED BY

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DEDICATION

We dedicate this book to the memory of Daniel J.F.K. O'Connell, S.J. who, as Director of the Vatican Observatory, President of the Pontifical Academy of Sciences and a scientist keenly interested and well versed in both the historical and modern aspects of calendar reform, was called upon on many occasions by the several Popes whom he served to advise them on current movements for calendar reform.

THE EDITORS

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PREFACE

Although this book is published as a Commemoration of the 400th Anniversary of the Gregorian Reform of the Calendar, its nature is not simply commemorative but it is intended to serve as a stimulus to further reflection, scholarly or otherwise, upon the calendar. With hardly, I believe, an exception we all experience that strange phenomenon of the almost inverse proportionality between the importance of many common factors in our lives and the degree of attention that we give to them. Among such factors is the role of the calendar in our daily activities. How many of us give any attention to how and why the calendar is structured the way it is? Could it be structured otherwise, perhaps even better? Yet the calendar forms the basis for the rhythm of our various daily activities. We take holyday weekends, have blue Mondays, envy those who work bankers' hours and experience a host of other phenomena, all of which we take for granted. Do we reflect, for instance, that the duration of the hour and the length of the week have no basis in natural astronomical phenomena, even though both are of very long usage? The week, infact, is the only calendar period which has survived all calendar reforms without interruption. On the other hand the three "natural" periods are the day, the month and the year, arising from the relative motions of the earth, moon and sun; the incommensurability of these periods is the fundamental reason for the long and continuing history of calendar reform, a part of which is recorded in this book. The Prelude (Chapter I), as a matter of fact, is intended to introduce us to those fundamental parameters with which the construction of any calendar must reckon and, in so doing, it makes us aware of such marvels as the fact that with modern caesium clocks we now have a measurer which is much more constant than the period being measured, namely, the rotation period of the earth.

Much of history is an interplay of various institutions: social, economic, religious, political, etc. Nevertheless, the true nature of many significant historical events is due to the interplay of individual characters staging their activities against the background of the institutions. While the emphasis of Chapter II of our book is upon the institutions and, for obvious historical reasons, principally upon the Churches, Chapter IV presents selected principal characters involved in the Gregorian reform of the calendar: Christoph Clavius, Aloisius Lilius and Ignazio Danti.

The rhythms of human life are dependent upon the rhythms of the universe. While this book is replete throughout with references to astronomical phenomena, Chapter III addresses explicitly several of the more important astronomical aspects of the calendar reform. The Gregorian reform took place during the time when the long-standing geocentric models of the solar system were being increasingly challenged. While the practical urgencies of the reform did not require taking sides in what we might summarily call the Ptolemaic-Copernican controversy, Chapter III does indicate some interesting aspects of the interplay between contested astronomical models and the calendar reform. One can hardly refrain from recalling that within a short thirty years or so after the Gregorian reform (Galileo was first summoned before Cardinal Bellarmine in 1616) the Church was, for reasons far removed from calendar reform, beginning to take sides, and as it turns out the mistaken side, in the Ptolemaic-Copernican controversy.

The focal point of our book is, of course, the discussion of the reform decree itself, given in Chapter V, where the role of institutions and individuals, highlighted in Chapters II and IV, are brought together with a harmonious treatment which deals explicitly, among other questions, with the deliberations of the reform commission and the contents and authority of the reform itself.

The many factors involved in the reception of the new calendar, not least of which is the dynamic sociology which still goes on today among the various Churches and civil institutions, is treated in Chapter VI. No human task, least of all one which responds to human conventions susceptible to the wear and tear of time, is ever finished. In the Postlude (Chapter VII) a resume of more recent attempts at calendar reform and, in particular, a very interesting proposal for a universal calendar are presented.

We have, indeed, in preparing this book been "fortunate", as John Paul II stated in his address to the conference, "to be able to pursue research in that area where we seek to blend the rhythm of human life in society with fundamental rhythms of the universe in which we live". It is hoped that this book may provide a wider participation in that good fortune.

If I may be allowed to make one last, pedestrian perhaps, remark: in reading this book regular reference to the *Glossary of Technical Terms* at the end may prove most useful.

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Director Vatican Observatory

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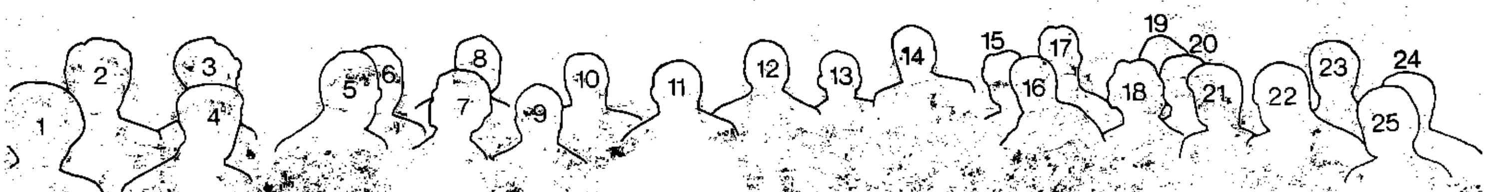

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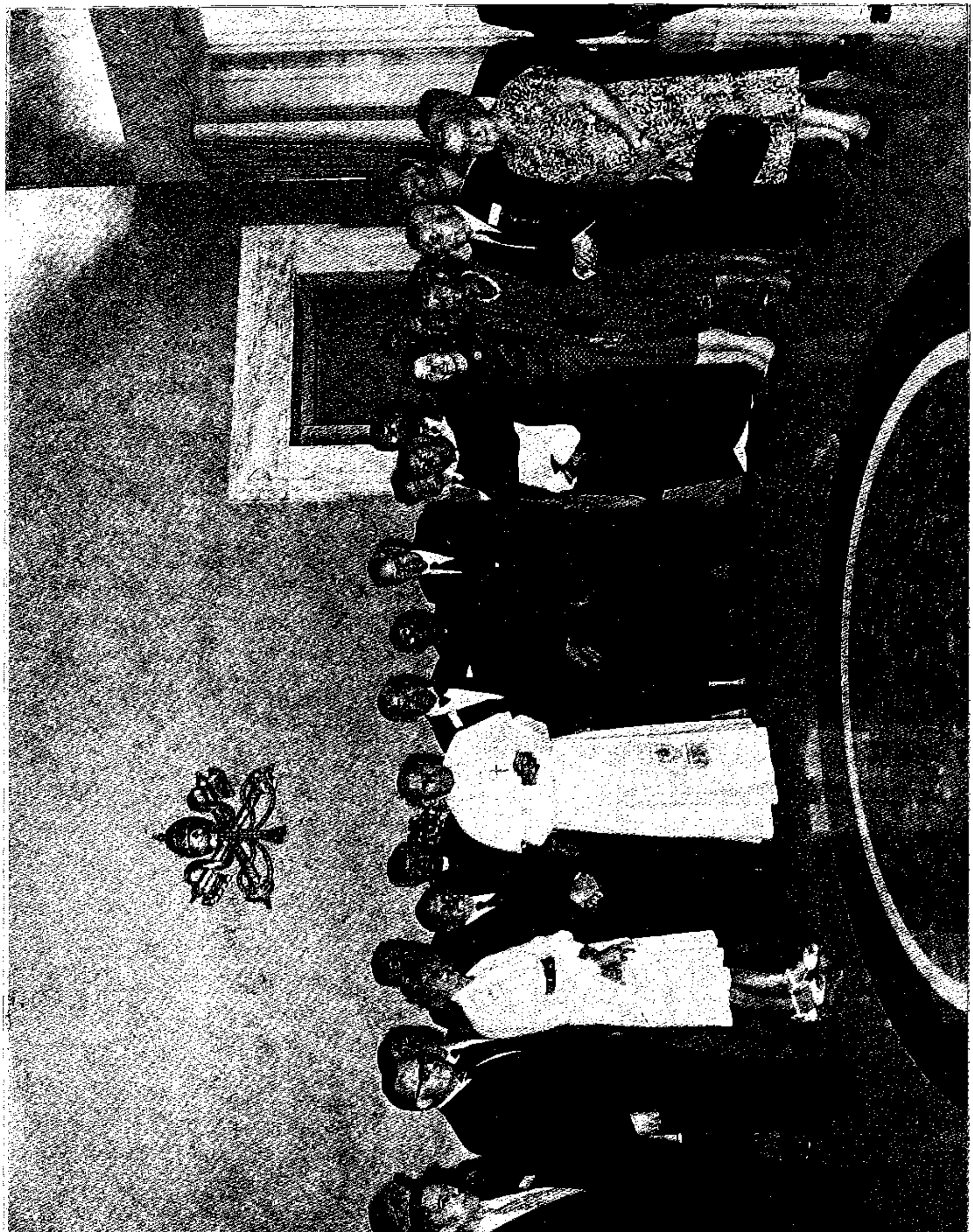

PAPAL AUDIENCE

On 31 August, 1982 His Holiness John Paul II received, in the Throne Room of the Apostolic Palace at Castel Gandolfo, the participants at the Conference to Commemorate the 400th Anniversary of the Gregorian Calendar Reform. On that occasion the following address was delivered.

ADDRESS OF HIS HOLINESS JOHN PAUL II

Reverend Fathers,
Dear Ladies and Gentlemen:

1. *I wish to express my heartfelt gratitude to you for this visit which you make on the occasion of these days of study which are aimed at commemorating the 400th anniversary of the reform of the calendar that took place under my predecessor, Pope Gregory XIII. I realize that your work is sponsored by the Pontifical Academy of Sciences and the Pontifical Vatican Observatory, two institutions for which I have a very real affection since they form a valid link between the life of the Church and the world of scholarly research in the sciences and the history of science, a link which I deem to be of tremendous assistance both for the life of the Church and the cultural aspirations of mankind as a whole. As you know, I have emphasized many times that it is necessary for this relationship between faith and science to be constantly strengthened and for any past historical incidents which may be justly interpreted as being harmful to that relationship, to be reviewed by all parties as an opportunity for reform and for pursuing more harmonious communication. In brief, it must be the sincere desire of all to learn from history so as to gain insight into the positive direction that we must take together in the future.*

2. *In fact, from the topics which I note you are discussing these days it is clear that you desire through your historical researches to help all of us understand better what*

has already taken place in such a fundamental area of human society as the establishment of a sound calendar. Your program indicates your recognition of the profound personal interest which the Church has had and continues to have concerning calendar revisions since such work influences the occurrence of religious feasts which constitute, as it were, the rhythm of the Church's daily life. Your examination of both the astronomical and sociological aspects of the calendar reform will surely help for a more harmonius understanding of what has happened and what remains to be accomplished in the area of calendar reform. In particular your examination of how the Gregorian Calendar was received by various societies and by various Churches will surely be of great help to all of us in these days when we sincerely seek a strengthening of that unity which Christ desired for his Church.

3. *You are, I believe, fortunate to be able to pursue research in that area where we seek to blend the rhythms of human life in society with the fundamental rhythms of the universe in which we live. I say you are fortunate because you are given the opportunity to help others to recognize that unity between man and creation which testifies to the existence of the one Creator of us all.*

It is a pleasure for me to share these brief thoughts with you. I assure you of the Church's appreciation for your efforts since she sees in this work the promotion of the common good for all persons. In a special bond of good will I join myself to you and to your loved ones. May Almighty God bless all of you with joy and happiness and may he grant to your endeavours every success.

OPENING REMARKS

It is my pleasurable duty this morning to welcome you all on behalf of the Pontifical Academy of Sciences to this commemorative conference on the occasion of the 400th anniversary of the institution of the Gregorian Calendar. The eternal city of Rome where we meet today has been associated, of course, with regulations for various calendars for more than two millenia and has been the place for the first major calendar reform by Julius Caesar. The perfection of that reform by Pope Gregory XIII was, like all great achievements, as simple as it was effective and has served well both the civil and the ecclesiastical purposes of society.

It is highly appropriate that the world should remember the work of Pope Gregory XIII who apart from his institution of the new calendar was responsible for the foundation of some of the most remarkable scholarly institutions of the Church such as the Gregorian University, the great English and German colleges in Rome and many other educational institutions all over Europe which have flourished up to the present time. In St. Peter's you can see both the Cappella Gregoriana which was built by him and his tomb on which a special panel commemorates his calendar reform.

This meeting is being held under the joint auspices of the Pontifical Academy of Sciences and the Vatican Observatory and we meet here in the seat of the Academy, the Casina which was built in 1560 as a summer house for Pope Pius IV, a predecessor of Pope Gregory.

As you all know the main task of arranging this meeting has been in the hands of Father George Coyne, the Director of the Vatican Observatory and thus today's successor of Father Clavius.

Just a year ago Father Coyne and I were involved in another meeting, held in this very room under the auspices of the Pontifical Academy. At that meeting we looked back not just on the last 400, but on some 15,000 million years! I refer to a Study Week on the subject of "Astrophysical Cosmology" the proceedings of which have recently been published and may be of interest to some of you. That Study Week was an exceptionally successful and very happy conference, and I cannot wish anything better for this meeting than that it should be equally pleasant and productive.

And now it gives me great pleasure to open formally this conference to commemorate the 400th Anniversary of the Gregorian Calendar.

H.A. Brück

Pope Gregory XIII

I.

PRELUDE

BASIC UNITS IN CHRONOLOGY AND CHRONOMETRY *

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University of Aarhus

Chronology and Chronometry

In most *chronology*, or time reckoning, the basic unit is the *day*. Time reckoning is all about *counting* an unbroken succession of days by making them up in various appropriate bundles. Some of the bundles, such as the week, are artificial and comprise integral numbers of days. Their use presents no problem more complex than counting inches in sets of 36, called yards. But other time intervals used in calendars, notably months and years, are based — like the days themselves — on astronomical periods. The complexity of calendars is due mainly to the *incommensurability* of the astronomical periods on which they are based.

Chronology cannot decide if its basic unit is constant or not. Mere counting does not reveal if earlier and later days of the succession are of equal duration. So we must turn to *chronometry*, or scientific time measurement, until recently a pursuit only for astronomers. But still the problem of *constancy* for any chosen time measure remains *unsolved*. For it is impossible to store temporal "units" of the past, say seconds, for comparison with later seconds. Any measure of time is completely conventional, and constant only in so far as we have defined that it be constant. Its use for measuring other phenomena without contradiction between theory and observation adds to its expedience and strengthens our belief in the fitness of its definition. Chronometry, however, cannot but *count* units believed to be constant, even though its counting goes with sophisticated techniques.

* This paper is a synopsis of a more detailed study published as "Ancient Ephemeris Time in Babylonian Astronomy", *Journal for the History of Astronomy* 14 (1983), 47-60. It is based upon the main conclusions of "The Full Moon Serpent. A Foundation Stone of Ancient Astronomy?", *Centaurus* 24 (1980), 51-96.

Day, Year, Period of Caesium Radiation

From Greek Antiquity until well into the twentieth century the standard rod for measuring time was the *day* defined by the period of rotation of the earth on its axis, and determined by astronomers from transit observations of the sun — solar day — or of fixed stars — sidereal day. The second was defined as the fraction 1/86400 of the day. To within the accuracy of observation the mutual relationship between sidereal time, the irregular apparent solar time, and the even flow of mean solar time was clearly understood. From the eighteenth century man-made clocks were developed that were accurate enough for interpolating time between the observations. With the same entity, the day, as the basic unit in both chronology and chronometry there came to exist a quite strict relationship between astronomical measures and the calendar.

From about the middle of the nineteenth century onwards, still more refined dynamical theories for the motion of the moon failed to represent the observed lunar motion. This suggested that irregularities stemming from friction and other causes were negligible in the orbital motions of the sun (earth), moon and planets, but not so in the daily rotation of the earth. The earth does not rotate at a uniform rate. The day does not make for a constant measure. So, during the 1950s "ephemeris time" was introduced as the independent variable of the accepted dynamical equations of planetary motion with the tropical — or seasonal — *year* as the fundamental measuring unit. In 1956 the second was defined as the fraction 1/31556925.9747 of the tropical year at A.D. 1900 January 0, 12^h ephemeris time. And since 1960 ephemeris time is used for the tabular argument in the fundamental ephemerides of the sun, moon and planets.

Over the last fifty years man-made equipment for time keeping has been developed to be more stable than the rotating earth, namely quartz clocks from 1929 onwards, atomic clocks from the late 1940s and, most recently, atomic clocks controlled by caesium oscillators. These have led to the introduction, from 1 January, 1972, of "international atomic time" with a second defined as the duration of 9192631770 *periods of the radiation* corresponding to the transition between two hyperfine levels of the ground state of the caesium atom 133. Thus during the last decade basic chronometry has been detached from astronomy. Each of the current days does not comprise exactly 86400 (atomic) seconds whence occasional insertion of a leap second is necessary to ensure that noon arrives at 12 o'clock sharp.[1]

Synodic Month

To be sure, the refinements of modern chronometry are of no direct consequence for our calendar which remains a scheme for counting days, even if they are known to be of unequal duration. Nonetheless, there may have been an indirect influence of chronometry upon calendar reform. The history of exact chronometry began in Babylonian astronomy of the last five centuries B.C., possibly by the assumption of an ancient parallel to ephemeris time. Eventually this came to create problems for Medieval and Renaissance astronomy and may, therefore, have delayed the reform of the Julian calendar.

The independent variable in the Babylonian ephemerides of Full Moons or of New Moons is the line number, or the lunation number, with the basic interval of *one synodic month* between consecutive lines, irrespective of how many days you count within the different months. Theoretically the number of days becomes a derived result, arrived at only by the combination of several columns of the ephemerides. In their planetary ephemerides the Babylonian measured time in *tithis*, defined as 30th parts of the synodic month.[2] With the month as the basic measure this choice is convenient, and in cases where the difference matters nobody would risk confusing tithis with days of which, on the average, only 29.5 are necessary to complete a month. Furthermore I suggest that the Babylonians used a *"Metonic year"* defined as 235/19 times the synodic month. This year falls short of the sidereal year by 14 minutes, and it exceeds the tropical year by 6 minutes. The former difference can easily be detected from simple observations over an extended period, and I believe that it was well-known to the Babylonians. It is difficult, however, by primitive means to provide observational evidence for the latter difference between Metonic and tropical years, and probably the Babylonians did not care about this matter.

To sum up: Time measurement by Babylonian astronomers, using the synodic month as the fundamental period and with approximations to days and years expressed by simple numerical relations to the synodic month, appears aptly termed *ancient ephemeris time.*

Ancient Ephemeris Time

Figure 1 presents a type of survey of ancient ephemeris time and of its empirical basis and predictive power in lunar and solar theory. It dis-

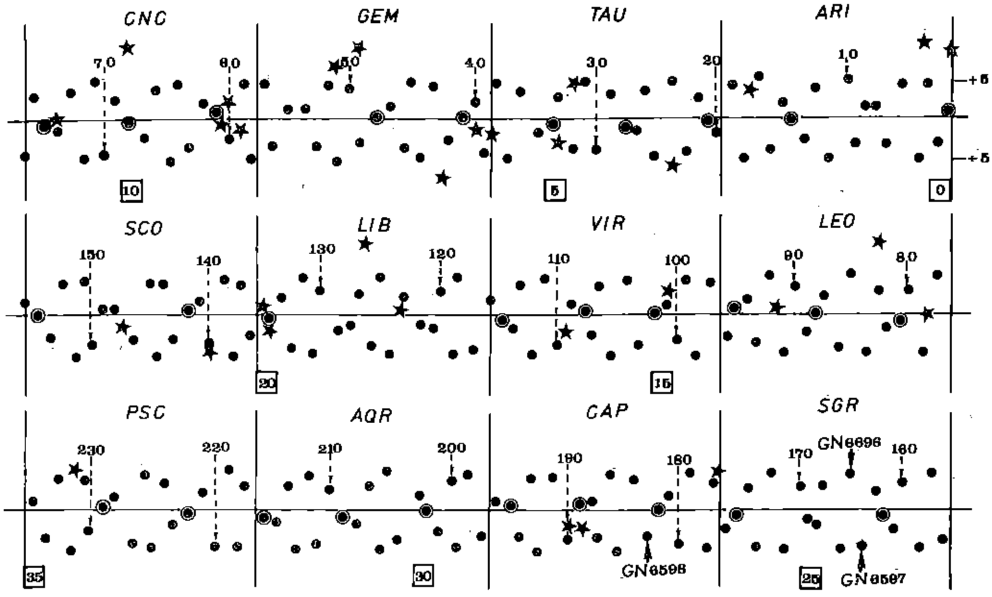

FIG. 1. Map of the zodiac for the epoch 450 B.C. with positions of the 235 Full Moons from 469 B.C. to 451 B.C. Lunar eclipses are marked by circles around the Full Moon dots.

plays 235 consecutive Full Moon positions marked simultaneously on a map of some 31 Babylonian Normal Stars within the zodiac. On the whole the figure shows a nice serpent pattern consisting of 35 sinusoidal waves that span the zodiac twice, and create thereby 35 knots of intersection in the neighbourhood of which lunar eclipses can occur. The twenty-nine Full Moons closest to the ecliptic were actually eclipsed, and they are circled in the figure.

The Metonic 19-year cycle of 235 lunations comprises approximately not only 254 (= 19 + 235) revolutions of the moon in relation to the fixed stars (sidereal months), but also 255 revolutions of the moon in relation to the nodes of the lunar orbit (draconitic months). The distance of the moon from the nodes of its orbit determines lunar latitudes and, in cases of small latitudes, also lunar eclipse magnitudes. So the quasi-resonance, within the Metonic cycle, between the increases in lunar longitude and in lunar latitude makes an eclipse period out of the cycle, and it ensures that the serpent of Figure 1 remains an almost rigid structure which in the long run drifts slowly in relation to the fixed stars. The drift rate proves to be governed by the cycle of 65 years = 804 synodic months during which period any eclipsing knot moves to the next following Full Moon position.

As for the necessary empirical basis, keeping account with naked eye observations of lunar eclipses over, say, two centuries suffices to infer quite securely: (a) that the 19-year cycle is an eclipse period connecting lunar eclipses at a definite position among the stars; (b) that 35 such positions (knots) exist along the zodiac, about 10° apart and pregnant with lunar eclipse warnings; (c) that lunar eclipses never occur in between two knots; and (d) that the whole string of eclipsing knots slides slowly to the East among the stars. These facts do not produce by necessity the conception of the entire Full Moon serpent which I constructed from modern tables. They show, however, that it is legitimate, in the context of a rational reconstruction, to assume knowledge of the backbone of the serpent pattern on the part of naked eye astronomers. And that much is nicely reflected in a cuneiform text: "In 19 years the moon will approach the place of the Normal Stars where it approached before. Where there was a lunar eclipse, it takes place [again]. If [the moon] passed by [a Normal Star] high, or if it passed by low, it will repeat this in your year".[3] Thus the Babylonians knew that 19 years make for an eclipse cycle.

Using the Full Moon serpent as the conceptual vehicle, more specific data concerning particular eclipses allows the numerical calibration of simple formulas — or of Babylonian ephemeris columns — for determining longitudes and latitudes of Full and New Moons, and eclipse magnitudes. Omitting any detailed calculation I mention only that the results can be referred to the numbers in Figure 1. Here the Full Moon positions in longitude are numbered consecutively from 1 at the beginning of Aries to 235 at the end of Pisces, and within quadratic frames numbers are found for the thirty-five eclipsing knots. Finally GN (= Goldstine Number)[4] is the independent time variable numbering the Full Moons continuously; thus, GN 6597 goes with the Full Moon in June 468 B.C. The corresponding position in longitude comes out as number 164, and within the serpent pattern knot number 24 results, and in addition one sixth part of a serpent wave. The latter fraction leads to a lunar latitude of roughly $-4°$, and it is obvious that no eclipse can occur.

The long range quality of Babylonian ephemerides is attested by the fact that continued fraction approximations to their best "draconitic" period relation, 5923 draconitic months = 5458 synodic months, leads to the selection of eclipse cycles listed in Table 1. Here the Babylonians knew and made extensive use of the Saros cycle of 223 months. But also the

3

TABLE 1. Eclipse cycles of *p* lunations with *q* intervening eclipse warnings.

p	q	Remarks
5	1	
6	1	
41	7	
47	8	1/5 Meton cycle
88	15	
135	23	
223	38	Saros cycle
358	61	Eternal cycle

"eternal" cycle appears to have been within their reach. This period of 358 lunations, and just below 29 years, was used by Oppolzer in his *Canon der Finsternisse*,[5] and rediscovered by J.N. Stockwell who built on it a compact set of tables for determining eclipses over a period of 70.000 years.[6] Perhaps equally impressive is the information that Babylonian "formulas", calibrated by data spread over two or three centuries in antiquity, unambiguously predict the occurrence and positions for all four solar and three lunar eclipses in A.D. 1982, including lunar eclipse magnitudes close to the values given in Oppolzer's *Canon.*

Thus a self-contained theory of lunar syzygies with lunations numbers as the independent variable can be extremely stable and accurate. It would therefore seem quite justifiable to take the synodic month as a standard measure of time and to infer that lunation intervals, as counted in days, appear unequal only because the days themselves are of different duration. We cannot know for certain the Babylonian way of thinking about the role in chronometry played by days and months respectively. But the case for basic months, considered as constant by choice, and derivative days of variable duration is no more strange than the habit of taking daylight to last for twelve hours of different duration according to the season of the year.

Year Lengths, Longitudes, and "Precession"

To fix on a *"Metonic" year length* of exactly 235/19 times the synodic month is equivalent to reckoning by definition *constant longitudes for the serpent step positions* in Figure 1. I suggest we use the label "Metonic" for such longitudes, Λ. With the choice of zero longitude being arbitrary I take Figure 1 as the norm and simply estimate Metonic longitudes from the figure. Thus the lunar eclipse of 9 January, 1982 at position no. 64 had the Metonic longitude of $\Lambda = 100°$.

Now primitive observation displayed the eclipse right under Castor in Gemini as sketched in Figure 2, whence we infer: Λ (Castor, A.D. 1982) = 100°. But in Figure 1 this star is found above position no. 49, and its Metonic longitude comes out to be only: Λ (Castor, 450 B.C.) = 76°.5. One cannot avoid the conclusion that the stars themselves have drifted at the *Metonic rate of "precession"*, determined accurately to within a few minutes of arc by

$$\Delta\Lambda \text{ (stars)} = 23°.5 \text{ per } 24.3 \text{ centuries} = 58' \approx 1° \text{ per century.}$$

This also implies that a Metonic century equals a sidereal century minus 1/360 of a sidereal year, and we get accordingly for the *sidereal year*.

$$A^* = 36000/35999 \cdot 235/19 = 12;22,07,33 \text{ synodic months,}$$

which surpasses the Metonic year by 1/2911 month, or 14.6 minutes.

This structure of Metonic/sidereal standards can be drawn quite securely from simple but systematic eclipse observations over a period of a few centuries. The standard Babylonian value for the sidereal year was 12;22,08 synodic months, and Hellenistic astronomy used the rate of precession 1° per century in unison with a Metonic-like year of 12;22,06,18 $\approx$ (235 − 1/12000)/19 synodic months. So it appears likely that Metonic years and longitudes came to play a key role for the generation of precise measures in Babylonian astronomy; and that they proved a reliable basis, and therefore became canonical and remained so also for Hellenistic astronomers. And note that the whole enterprise works well in the context of ancient ephemeris time, quite independently of any count of days, not to mention seasonal or tropical years.

Having gained, however, a reliable count of days for, say, the basic synodic month, one can immediately derive day measures for the remaining periods. Recently D. Rawlins has deciphered two Vatican Greek MS lists of ancient year lengths as counted in days.[7] The results reproduced here

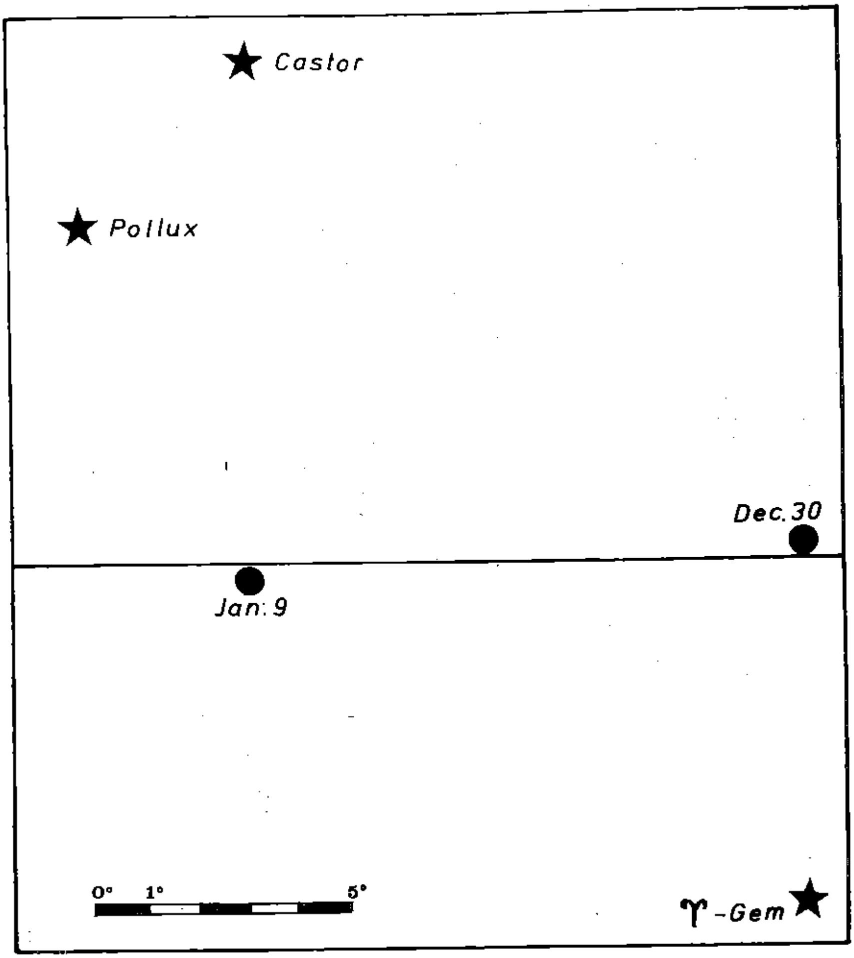

FIG. 2. Sketch of two lunar eclipses in 1982, as sighted immediately below Castor at knot 4, and as expected at knot 3 above γ-Geminorum.

in Table 2, most convincingly support my thesis. In three cases we face integral day approximations to multiples of the Metonic 19-year cycle. And except for the first and obviously crude approximation, all the values, together with those from the *Almagest*, cluster round the sidereal and Metonic years respectively within the limits of half a minute. All possible rates of Metonic precession that can be derived from the Table 2 data fall between an "Aristarchian" value of 57′ and a "Babylonian" one of 62′

TABLE 2. Six ancient year lengths according to D. Rawlins's interpretation of Vatican Greek MSS, compared with *Almagest* values and modern standards.

no.	authority	year length 365^d +	remarks
1	Meton, Euctemon, Philip, Apollinarius	;15,47,22 ... = $6^h\,18^m\,57^s$	$= 6940^d/19$
2	Babylonians	;15,25 = $6^h\,10^m$	two sexagesimal places
	Almagest	;15,24,32 ... = $6^h\,9^m\,49^s$	precession = 1^o/cent.
3	Aristarchus	;15,23,41 ... = $6^h\,9^m\,28^s$	$= 55519^d/8 \cdot 19$
	Modern	;15,23,32 ... = $6^h\,9^m\,25^s$	sidereal
4	Aristarchus	;14,48,54 ... = $5^h\,55^m\,34^s$	
	Modern	;14,48,37 ... = $5^h\,55^m\,27^s$	Metonic = 235/19 months
5	Sudines	;14,48,09 ... = $5^h\,55^m\,16^s$	$= 111035^d/16 \cdot 19$
	Almagest	;14,48 = $5^h\,55^m\,12^s$	two sexagesimal places
6	Chaldeans, Babylonians	;14,47,19 ... = $5^h\,54^m\,56^s$	
	Modern	;14,33,02 ... = $5^h\,49^m\,13^s$	tropical

per century. No ancient year length whatever is reported close to the actual tropical year.

The Tangle of Tropical Standards

How did the notion of tropical longitude and year length creep into Hellenistic astronomy at all? Hipparchus succeeded in establishing reliable positions of the Sun in relation to the equinoxes. But in the end he retained the Metonic year, that is, the Metonic rate of increase in solar longitudes, and three centuries later Ptolemy took over the entire Hipparchian model for the motion of the Sun without changing one iota. So the *Almagest* solar theory kept a Metonic soul tied to a tropical body only temporarily around the middle of the second century B.C. Furthermore Ptolemy — wittingly or in good faith — covered up the Metonic character of the theory, introducing the explicit notion of tropical longitude based on the

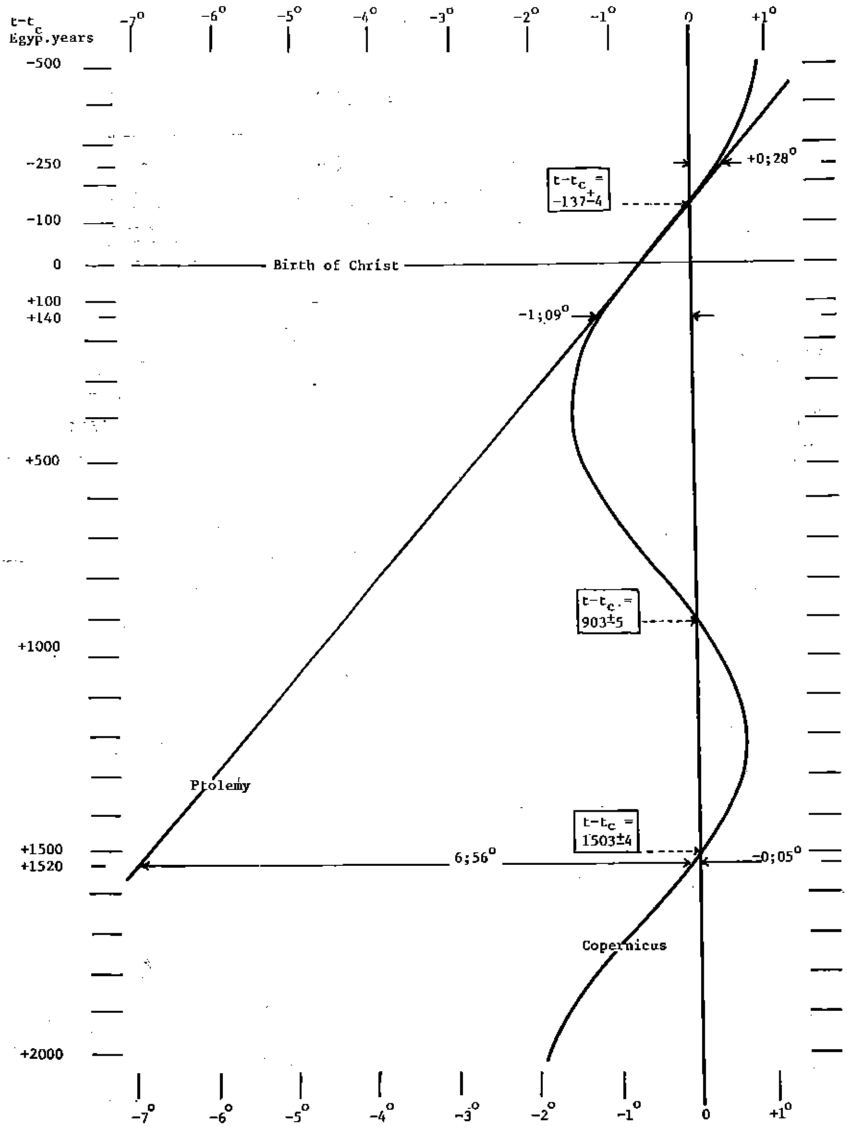

FIG. 3. Tropical errors of Ptolemaic and of Copernican mean solar motion throughout the centuries.

sun's return with respect to itself — that is, with respect to the oblique circle made by it (the ecliptic).

This eventually produced a tangle for astronomy from Thābit ibn Qurra in ninth-century Baghdad through Copernicus in sixteenth-century Frauenburg. They were bound to believe that the *Almagest* tables of mean solar motion represented real tropical longitudes in antiquity. Accordingly they introduced theories for long term variations in the length of the tropical year, i.e. in the "mean" solar motion, coupled to variations in the rate of precession. So in effect they found quasi-steady sidereal rates of motion and a reliable and quasi-constant length for the sidereal year.

The details of this story have been repeatedly documented over the last decade.[8] Here it suffices, therefore, to refer to Figure 3 which displays as a function of time the errors in Ptolemy's and Copernicus' tables for the tropical mean motion of the Sun. We see that the *Almagest* was correct in Hipparchus' time, but went astrat by 1° in Ptolemy's and by 7° in Copernicus' time. Copernicus' tables imitate those of the *Almagest* to within 2′ during four centuries in antiquity, and they hit reality twice again, namely around A.D. 900 and in Copernicus' own time. However, Copernicus' measure of the tropical year, variable as it was, had to appear problematic for the purpose of a calendar reform. In return Copernicus learned to explain the assumed variations in the rate of precession by long term tiltings of the earth's axis. So the chronometric problems clinging to Ptolemy's pseudo-tropical year provided Copernicus with a key motive for adopting a heliostatic cosmology.

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II.

HISTORICAL ANTECEDENTS

THE ECCLESIASTICAL CALENDAR AND THE LIFE OF THE CHURCH

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1. *Introduction*

As Christianity spread from Palestine throughout the Roman Empire it came into contact with several different systems of time reckoning, three of which were destined to play a particular role in the development of the ecclesiastical calendar created by the Church as its first contribution to scientific culture. The establishment of this calendar is — in its briefest outline — the subject matter of the following pages in which many important details have been left out in order to make the essential features stand out more clearly.

Each of the three systems behind the ecclesiastical calendar was founded upon an astronomical basis. Their diversity stems from the mathematical properties of two astronomical constants. The first of these is

$$1 \text{ mean tropical year} = 365.2422 \text{ mean solar days}$$

as the average period of the annual revolution of the sun from one vernal equinox to the next following and, accordingly, also the period of the changing seasons of the solar year. The second is

$$1 \text{ mean synodic month} = 29.53059 \text{ mean solar days}$$

as the average period of the monthly revolution of the moon from one conjunction with the sun to the next following and, therefore, also the period of such lunar phenomena as conjunction (or the astronomical new moon), first visibility (the civil new moon), and opposition (full moon).

We notice, firstly, that neither of these periods is an integral number of days. In consequence, they cannot be used as such for calendaric purposes since a calendar is essentially a list of integral days numbered according to a certain system characterising the calendar in question.

Secondly, the two periods are incommensurable in the sense that the tropical year does not contain an integral number of synodic months, but an average of

$$\frac{365.2422}{29.53059} = 12.368266\ldots \text{ months}$$

Expressing this number approximately as $12 + p/q$ months (where p and q are integers prime to one another) we have

$$1 \text{ year} = (12 + p/q) \text{ months, or}$$
$$q \text{ years} = (12\ q + p) \text{ months}$$

A relation of this form is a "period relation" between the year and the month. Developing in continued fractions we get the following approximations for p/q

$$\frac{1}{2}, \frac{1}{3}, \frac{3}{8}, \frac{4}{11}, \frac{7}{19}, \frac{123}{334}, \ldots$$

some of which we shall meet again in a historical context. We notice that the use of such period relations in time reckoning means that only the m e a n motions of the Sun and Moon are taken into account whereas their inequalities, or equations of motion, are ignored.

Since the Church grew out of the Synagogue the first Christians both in Palestine and in the Diaspora would be accustomed to the Hebrew calendar [1] the principal features of which can be learned from the Old Testament, supplemented by the Talmud and the *Antiquitates Judaicae* by Josephus. It was essentially a lunar calendar with the month as the principal calendaric unit of time. A month began on the evening when the crescent of the new moon was first visible after sunset in the western sky. This event was determined by direct observation by a committee of officials appointed by the Sanhedrin of Jerusalem which afterwards announced it in public. This method would lead to a calendar month of either 29 or 30 days and, since the average synodic month is very nearly

29½ days, there would be about the same number of "full" and "hollow" months of 30 and 29 days respectively. The months were numbered from one to twelve. After the Babylonian exile some of them appear with Babylonian names.

This purely lunar system was insufficient because a number of religious festivals were stipulated by the Law to be held not only on certain days of the month, but also at a certain time of the year or in a particular season. Thus the Jewish Passover with the eating of the Paschal Lamb must take place on the night of the 14th day of the month of Nisan (when the moon was full). But since the Passover was a spring festival this month had to be placed in springtime, that is in a season which recurs with a period of one solar year which is 11 days longer than the traditional lunar year made up of

$$6 \text{ full} + 6 \text{ hollow months} = 6 \times 30 + 6 \times 29 \text{ days} = 354 \text{ days.}$$

In consequence, the solar year would fall behind the lunar year by a little more than one month in three years, or — otherwise expressed — the beginning of the lunar year would move backwards through the seasons. In order to overcome this inconvenience and to keep the Nisan in place as the first month of a year beginning in the spring, one resorted to the device of intercalating an extra month about every third year. The decision to create such an "embolismic" year of 13 lunar months was taken by the authorities in Jerusalem on the basis of crude observations of, for instance, the state of the vegetation which would show that spring was near at hand (cf. *Luke* 21, 30). There is no evidence that the vernal equinox played any role at all in this procedure. The statement by Josephus that the Greek month Xanthicus is the same as the Hebrew Nisan which is the first month of the year *when the sun is in Aries* [2] provides information for his Hellenistic readers, but is not a principle of the Hebrew calendar.

The rather vague and arbitrary character of this modified luni-solar calendar meant that no one would be able to determine the beginning of the month of Nisan relative to another (non-Jewish) calendar, except by communicating with a local Jewish community which again had to rely on a proclamation from Jerusalem. This circumstance had several consequences for the early history of the ecclesiastical calendar, as we are going to see below.

A special feature of Hebrew time reckoning was the seven day week as a particular unit of time. It had no astronomical connotation whatever and could be continually observed by the simple expedient of counting days. Within the week the individual days were not named but numbered from one to seven, the only exception to this rule being the Sabbath (the seventh day) and sometimes also the preceding Day of Preparation.

The Alexandrian calendar represented a very different system of time reckoning.[3] It originated in the Old Egyptian calendar which was based upon a unit of time called

$$1 \text{ Egyptian year} = 365 \text{ days.}$$

This period was divided into 12 equal months of 30 days each, plus five extra or "epagomenal" days placed between the end of the 12th month Mesore and the beginning of the first month Thoth. Each month was subdivided into three equal period of ten days called decans. Since neither the year nor the month had anything to do with astronomical phenomena this extremely simple and rational calendar could be maintained without observations, simply by the counting of days (cf. the Jewish week). Since the Egyptian year was about six hours shorter than the tropical year the New Year's day was floating through the seasons at the rate of about one day in four years, returning to its original position in 1460 years, the so-called sothis period. An attempt to remove this peculiarity was made in 239 B.C. by the famous Canopus decree which instituted a leap year of 366 days (increasing the number of "epagomenal" days to six) once every four years. The same idea was adopted by the astronomers who in 708 A.U.C. (46 B.C.) planned the calendar reform of Julius Caesar. Its fundamental unit of time was

$$1 \text{ Julian year} = 365\tfrac{1}{4} \text{ days.}$$

This was a better approximation to the tropical year than the Old Egyptian year. In consequence, the beginning of the new year on Thoth 1 no longer floated but always fell in late summer, more precisely on August 29 (of the Julian calendar), or on August 30 in a year preceding a leap year. Otherwise the Julian reform in Egypt retained both the five "epagomenal" days, the twelve equal months, and their old Egyptian names.

The Roman calendar was much more deeply influenced by the reform.[4] In late Republican times Rome had a luni-solar calendar with 12 unequal months forming one lunar year beginning on March 1. The months of March, May, July (Quintilis) and October had 31 days each, while

February had 28 and the rest 29, making a total of 355 days. To assure some agreement with the solar year an extra month of 23 days was sometimes intercalated between February 23 and 24 by a proclamation from the *pontifices* who were responsible for the religious feasts and also for calendaric questions in general. This was done on vague criteria and confusion often followed. The Julian reform was directly motivated by the fact that the calendar year was about three months ahead of the seasons when Caesar took office.

The Roman months were subdivided by means of three specially named days called *kalendae*, *nonae*, and *idus*. The *kalendae* was always the first day of the month. In March, May, July and October the *nonae* fell on the 7th and the *idus* on the 15th, whereas in the other months they fell on the 5th and 13th respectively. Dates were expressed as so many days before one of the named days, as in *ante diem quintum Idus Martias* = March 11. A different subdivision was achieved by the *nundinae*, or *dies nundinarum* which originally fell with nine day intervals and on which markets were held.

The Julian reform made several changes in this system. Firstly, the length of some of the months was so increased that an ordinary year contained 365 days. The result of this adjustment has survived until the present day. Secondly, every fourth year was made a leap year, or *annus bissextilis*, because the extra day was intercalated between February 23 and February 24 (*sextilis kalendae Martias*). New Year's Day was moved from March 1 to January 1. The intention clearly was to replace the old lunar year by a solar year keeping pace with the seasons so that equinoxes and solstices fell on fixed dates. The vernal equinox was supposed to be on March 25.[5]

Besides these three systems the ancient world was filled with a great variety of lunar, solar or luni-solar calendars of local importance which we must here pass over in silence as being of no consequence to the establishment of the ecclesiastical calendar.

2. *The Attitude of the Early Church*

It has often been said that being an historical religion Christianity was obliged to give serious attention to the problems of time reckoning and eventually to develop its own system. This is no doubt true; but it is equally true that this development was a very slow and gradual process and certainly not one of the primary objectives of the Early Church. Thus the New Testament writings reveal an original indifference towards chronology that only gave way to a more positive attitude under the pressure of various issues arising in liturgy, theology, or ecclesiastical policy.

In a famous passage St. Paul blames those who observe *days and months and times and years* (*Gal.* 4, 10), taking this as a proof of a weakened faith in God alone in favour of astrological superstition. In another place he exhorts his disciples not to allow anyone to judge them according to what they eat or drink, *or in respect of a holiday, or of the new moon or of the Sabbath, which are a shadow of things to come* (*Col.* 2, 16-17). Here the attack is directed against the belief that Christians are bound to observe the Jewish discipline as regulated by the Hebrew calendar. To St. Paul this is no longer necessary since the liberation from the bondage of the Law implies among other things that also the liturgical prescriptions of the ancient Israel have become obsolete. Moreover, one notices in St. Paul an unmistakable indifference towards time reckoning as such. He saw no reasons to give precise dates of the principal historical events in the life of the New Israel, just as it never occurred to him to date his own letters. Behind this attitude we can discern his eschatological conviction that the Second Coming was imminent. The temporal order was running out and there was no reason to pay attention to purely temporal matters (cf. *Rom.* 13, 11-12).

But elsewhere in the later writings of the New Testament there is evidence of at least two reasons which in the course of a generation or so persuaded the Early Church to take time reckoning more seriously. The first motivation for this change of attitude was liturgical. Already the *Acts* reveal the fact that the first Christian communities only slowly abandoned the worship of the Temple and the Synagogue. In consequence, they accepted the Jewish seven day week as the temporal frame of their liturgical life, but soon with a significant change of emphasis. St. Paul might feel free to discard the Sabbath as a holiday of obligation, but he also found that it was a convenient day for preaching the gospel to Jews in the Diaspora (cf. *Acts* 13, 5; 13, 14; 13,42; 14,1; 16,13; 17, 1; 17, 10; 18, 4; 18, 19 and 19,8). But at the same time there is plenty of evidence that the communities of converts acquired the habit of meeting on the first day of the week in order to celebrate the Eucharist on the very day on which Jesus rose from the dead (cf. *Acts* 20,7). Although St. Paul's own instructions for this celebration (1 *Cor.* 11, 23 f.) did not prescribe any particular day of the week for this central act of Christian as distinct from Jewish worship, the custom prevailed with the result that the Jewish

"First day of the Week" became the "Day of the Lord" (cf. *Rev.* 1, 10) and outshone the Sabbath in dignity.

The second reason for a renewed interest in time reckoning was the necessity of defending the Incarnation and the true humanity of Jesus against the docetic tendency to regard his suffering as more apparent than real, a tendency which can be clearly discerned behind many of the polemic remarks of the New Testament writers.[6] In 1 *John* 4,2 the profession of Christ as *come in the flesh* is made the criterion of having the Spirit of God. In 2 *John* 7, it appears that many deny this, and in *Col.* 2,9 St. Paul underlines that in Christ *dwelleth all the fulness of the Godhead bodily.* How strong docetic ideas had become at the turn of the century can be seen from the assumption of St. Irenaeus that the Gospel of John was written in order to confute them.[7] Even if this may not be the case there is no doubt that the Gospels as we know them were given their final shape at a time when it was realised that the best way of defending the reality of historical events is to refer them as precisely as possible to definite places and definite times related to the ordinary course of history. Accordingly all the four Gospels abound in dates and places. Thus Jesus was born in Bethlehem in Judaea in the days of Herod the King (*Matt.* 2,1) when Augustus was Caesar in Rome and Cyrenius governor of Syria (*Luke* 2, 1-2). Similarly, his passion, death and resurrection were placed in a chronological framework of which more will be said below. Everything considered, we must conclude that it had become extremely important, for purely theological reasons, to place the events of the birth and death of Christ in a solid temporal frame in order to counter allegations that they had no true historical reality. How well the Evangelists succeeded is another question which belongs to New Testament studies with which we are not here concerned. But it is worth noticing that this new chronological awareness did not extend beyond the unique events in the life of Christ. Beyond this limit the first Christian writers were not prepared to go. In particular their own activity seemed, in the eschatological perspective, of too slender importance to be provided with precise dates, not even such consequential events as the travels of St. Paul or the otherwise carefully reported Council of Jerusalem (*Acts* 15).

3. *The Post-Apostolic Age*

The new awareness of the importance of calendaric questions extended into the post-apostolic age when it was realised that the Parousia was delayed and temporal matters inevitably occupied much of the time of the leaders of the expanding Church. In the Apostolic Fathers of the second century A.D. we can locate at least three different areas in which the interest in calendaric matters gained momentum. This new phase saw the final victory of the Day of the Lord over the Sabbath, the introduction of fixed Feast Days in the calendar, and the beginning of the Easter controversy.

The shift from the last to the first day of the week as the proper day for Christian worship did not go smoothly or unchallenged. The first Christians came from Jewish circles and felt themselves bound to observe the Sabbath. As late as perhaps around the turn of the second century the author of the *Epistle to Diognet* directs his sarcasm against *their superstition about the Sabbath* (...) *and the show they make of the fast days and new moons*, brandishing such practices as *ridiculous and undeserving of consideration.*[8] But already a century earlier the author of the author of the *Epistle of Barnabas* felt the need of a more theological defence of the custom of *joyfully celebrating the eighth day — the same day on which Jesus rose from the dead, after which he manifested himself and went up to heaven.*[9] This legitimation of the first day by a reference to Christ seemed to be contradicted by the many passages from the Old Testament on the special status of the seventh day which he faithfully quotes. Against such passages he quotes *Isaiah* 1, 13 as a Biblical counter argument. But more impressive is his realisation that all the calendaric prescriptions of the Law are just so many bastions around the sacrificial worship of the Old Covenant and therefore made useless after the unique and final event of the sacrifice of Christ.

A particularly interesting element of this defence of the Day of the Lord is the attempt to explain the Sabbath away by a non-literal interpretation of the third Commandment. The first six days of the week represent six periods of one thousand years in each of which the world has toiled in labour and pain. When they have elapsed all things will come to an end, and all creation will enjoy happiness and rest for a seventh millenium which is the true Sabbath of which Holy Scripture is speaking. This milleniarism[10] became a popular idea adopted by St. Irenaeus,[11], St. Justinus Martyr,[12], and numerous other writers. In the third century it was eagerly combated by Origen[13] in the East, just as St. Augustine[14] later killed it in the West by an allegorical interpretation of *Rev.* 20, 1-6. Nevertheless, a great number of Medieval chronicles and Hexaëmerons continued to divide the history of the world in thousand year periods. How strongly the idea appealed to the popular imagination appears from the anxiety with which the coming of the sixth millenium was expected in the years before A.D. 1000.

Thus during the second century the seven day week established itself in a safe position in worship as well as in discipline. The *Didache*[15] shows that already around A.D. 100 it is the frame of the Christian practice of fasting on the fourth and the sixth day — not on the second and the third *as the hypocrites do,* which is a somewhat specious interpretation of *Matt.* 6, 16. One hundred years later the same custom is attested in Tertullian[16] and Clement of Alexandria.[17] This development was no doubt made easier by the fact that the seven day week was by now known all over the Empire as an astrological unit of time with each day "governed" by a particular planet and named after it. This practice was unacceptable to Christians who chose to denote the days of the week in the traditional Jewish manner by numbering them, the only exception being the Day of the Lord, or *dies dominica.* The other days were called *feria* 2^a-6^a, using the Roman name for a feast day of every day of the week. This system is known in Tertullian,[18] although Bede[19] ascribes it to Pope Sylvester I (314-335). However, in civil life the planetary week occupied a strong position. A concordance between the ferial numbers and the planetary names of the days is found in St. Augustine.[20]

The post-apostolic age also gradually realised that the Christian community was not only historically rooted in the past but also itself the witness of events dignified or important enough to be put on record, such as the accession of bishops and — more than anything else — the death of martyrs during persecutions. This process is difficult to follow since all the extant lists of such dates are from the fourth century or later, such as the Roman calendar of A.D. 354,[21] the *Breviarium Syriacum*[22] from 441, and the fifth century compilation known as the *Hieronymianum.*[23] They all contain material pertaining to much earlier days which it is impossible to check. There are a few notable exceptions to this rule in the form of reports of martyrdoms by contemporary authors or even eye witnesses. Presumably the earliest example is the *Martyrium Polycarpii* according to which the Bishop of Smyrna was burned at the stake *on the second day in the beginning of the month of Xanthicus, the day before the seventh kalends of March, on a great Sabbath, at the eighth hour. He was arrested by Herod, when Philip of Thralles was High Priest, and Statius Quadratus Proconsul, during the unending reign of our Lord Jesus Christ.*[24] This eye witness account was sent to the Phrygian church at Philomelium and to *all the brotherhoods* *of the holy and universal Church.* The author obviously intended to date the martyrdom as precisely as possible informing his readers that:

1) the time of the day was the eighth hour, presumably reckoned from sunrise, and thus equivalent to two in the afternoon;

2) the day of the week was a sabbath called "great", an epithet of unknown meaning;

3) that the day of the month (expressed in some Greek calendar, presumably the one used locally) was the second of the month of Xanthicus and (expressed in the Roman calendar used by the court which condemned the martyr) also the day before the 7th kalends of March;

4) that it happened in a certain year indicated by the period of office of two Roman officials, the Proconsul and the High Priest, the latter presumably being the president of the *Commune Asiae.* However, the author omits to mention the reigning Emperor so it is difficult to establish the era (usually reckoned from the accession of the Emperor) to which he would have referred according to ordinary usage. That this was a conscious omission is clear from the concluding reference to the unending reign of Christ which has a polemical point directed against the transitory reign of a human being whose claim to divinity was the immediate cause of the death of the martyr. In any case the contemporaries of the author would no doubt know which year it was in contrast to later scholars who have never been able to agree on the question. There seems to be two possibilities, A.D. 155 Feb. 23, or A.D. 177 Feb. 23, with perhaps a majority in favour of the former date.[25]

The letter also tells how the bones of the martyr were taken away and interred in a decent place *where the Lord will permit us (. . .) to assemble and celebrate his martyrdom — his "birthday" — both in order to commemorate the heroes who have gone before, and to train and prepare the heroes yet to come* [26] — words which clearly reveal the grim context of the new historical awareness among Christians. During the following time such commemorations became an important element of the liturgical life of the Church as it appears in many passages in Tertullian, St. Hippolytus, St. Cyprian, and many other writers. This development made it imperative for the bishops to keep records or lists of the martyrs commemorated in their own dioceses, with indications of the day of the anniversary whereas the actual year of the martyrdom was of less importance for an annual commemoration.

From the calendaric point of view it was important that these dates were as a matter of course stated in terms of the civil calendar used in the diocese, or in the Julian calendar used by the authorities throughout the Empire, as in the report on St. Polycarp quoted above. Thus the commemoration of martyrs led the Church to adopt the civil calendars for ecclesiastical use without feeling any misgivings about this concession to the world in which it lived. Since each community naturally would commemorate its own martyrs before all others its calendar would become significantly different from the calendars used in other communities. Thus each diocese gradually developed its own liturgical calendar which embodied sacred memories and traditions that were not easily abandoned. This would often lead to confusion for two different reasons.

In the first place local traditions made it difficult to agree on the dates of a number of feasts which in the course of time were adopted by the universal Church. Thus about A.D. 200 Clement of Alexandria [27] mentions that Christmas was celebrated on November 18 and the Annunciation on May 20, whereas some bishops placed Epiphany on January 6 and others on January 10. The first mention of December 25 as Christmas Day is found in the Roman calendar of A.D. 354. As this date prevailed it was necessary to translate the Annunciation to March 25. However this confusion over fixed holidays was of much less consequence than that which arose out of local customs with respect to the movable feast of Easter and the dates of Pentecost and Lent derived from the Easter date.

In the New Testament there is no direct mention of movable feasts, with the single exception that St. Paul thought it important to hurry his departure from Miletus in order to reach Jerusalem in time for the Day of Pentecost (*Acts* 20, 16).[28] Looking back to apostolic time the fifth century historian Socrates wrote *that the Apostles had no thought of appointing festival days, but of promoting a blameless and pious life. And it seems to me that the feast of Easter has been introduced into the Church from some old usage, just as many other customs have been established.*[29] This is a precise observation, the "old usage" being, of course, the Jewish Passover the annual recurrence of which would naturally remind converts living close to Jewish communities that this was also the time of the year at which Christ had died and risen again. There is no doubt that some kind of solemn Easter celebration was common already in the beginning of the second century although the Apostolic Fathers are silent about it until about A.D. 200 when an Easter celebration with burning wax candles is mentioned in the *Letter to Diognet*.[30] Thereafter it is frequently mentioned by many third century authors. But its antiquity is well attested already in the middle of the second century when we first hear of the problem of how to determine the proper day for the feast.

There is no reason here to enter into the complicated history of the Passover as a Jewish spring festival at which a lamb was sacrificed and eaten with unleavened bread and the Great Hallel was sung in commemoration of the Exodus from Egypt. It is enough for our purpose to notice that the Law ordained that the Paschal Lamb must be slaughtered on the day beginning at nightfall on Nisan xiv (*Lev.* 23, 5; *Num.* 28, 16; *Deut.* 16, 1), Nisan being the first month of a lunar year beginning in the spring. So much is clear. On the other hand it is a problem how the Last Supper and the Passion of Jesus were related to the liturgical events of the Passover. In the synoptic gospels it seems that the Last Supper was a proper Passover meal (*Matt.* 26, 17 f.; *Marc.* 14, 12; *Luke* 22, 8) in which case the Passion must have been on Nisan xv. But according to *John* (13, 1; 19, 4) it happened on the Day of Preparation. However, all four gospels agree that the Resurrection took place on the first day of the week and on the third day after the Passion. The fact that the Passion of Jesus was referred to a date of a lunar month in the Jewish calendar, whereas the Resurrection was referred to a day of the week, contained the germs of the long controversy which on several occasions threatened the unity of the Church.

According to Eusebius [31] the bishops of "all Asia" (Asia Minor including Antiochia in Syria) maintained that the death of Jesus ought to be commemorated on Nisan xiv and the Resurrection three days later, regardless of the day of the week on which these days fell. But in all the rest of the world (including Alexandria, Palestine and Rome) the opinion prevailed that the Resurrection must be celebrated on a Sunday and the Passion on the preceding Friday, regardless of the date of Nisan on which these days fell. These opposite practices were somewhat inaccurately referred to as the "eastern" and "western" systems respectively,[32] and the supporters of the eastern practice became known as "quartodecimans" because of their adherence to Nisan xiv.

According to St. Irenaeus [33] the first attempt to reconcile the two parties was made when Bishop Anicetus of Rome (c. 154 - c. 166) received a visit from Polycarp of Smyrna who tried to convince him that the eastern practice had apostolic authority and ought to be observed in Rome and everywhere else. Anicetus refused, maintaining (as Popes do) that he had to abide with the customs of his predecessors, and the two prelates amicably agreed to differ. But the problem remained unsolved and continued to cause unrest in the East with several (now lost) treatises on the proper celebration of Easter carrying wood to the fire. Towards the end of the century the Roman Bishop Victor I (189-198) made a new effort to end the quarrel, ordering synods to be held throughout the Church to suppress quartodecimanism. When a synod at Ephesus held by Bishop Polycrates refused to obey he was threatened with excommunication. In consequence St. Irenaeus of Lyon wrote on behalf of the bishops of Gaul a strong letter [34] to the Pope, advocating liturgical pluralism in the Church. The Pope stepped down, and the quartodeciman Church of Ephesus remained in communion with Rome.

This incident is a well known element of the history of the Roman Supremacy, but it would be wrong to view it in the exclusive light of ecclesiastical policy. In a wider perspective one has to admit that quartodecimanism was not only a nuisance preventing Christians from celebrating their greatest annual feast together. It was also a reactionary force in so far as it linked the Christian Easter with the Jewish Passover in a way which prolonged the dependence of the Church on the Synagogue. The reason is simple — neither the quartodecimans nor anybody else had the possibility of knowing when it was Nisan xiv except by asking the Jewish authorities who arbitrarily decided when the spring was sufficiently advanced to enable them to select a particular month as the Nisan of the new year. This essential need of information to be obtained only from Jewish quarters might in the long run have prevented the Church from liberating itself from an unacceptable dependence on the Synagogue.

4. *The First Easter Canons*

If quartodecimanism had to be eliminated it became a point of vital importance to be possessed of methods which would enable the Christian communities to determine the proper date of Easter independently of information received from the Synagogue. This problem presented the first challenge of a scientific nature which the Church had to meet in order to preserve its liturgical unity and independence. We are very badly informed of how this challenge was met by the opponents of quartodecimanism during the second century, since practically all the Paschal treatises from this time have been lost; an exception is the *Peri Pascha* of the quartodeciman Bishop Melito of Sardis (d.c. 190) which has recently been recovered.[35]

The difficulties of solving this problem were many, given a number of preconditions which never seem to have been questioned. Thus it was clear that Easter should roughly coincide with the Passover since this could be inferred from the Gospels, in spite of the abhorrence which some later churchmen felt at celebrating Easter "together with the Jews". Furthermore, the authority of the Old Testament was great enough to prevent abandoning the month of Nisan as the period of the year within which the feast had to be held, although the Nisan had no place in any non-Jewish calendaric system. Therefore the problem could be solved only if three definite questions could be answered.

Question I was how the concept of "spring" could be defined so that the Nisan could be identified within a non-Jewish calendar, or, in other words, was it possible to define as it were a "Christian Nisan" fulfilling the conditions laid down in Holy Scripture? This was essentially a question of defining the concept of "spring" in a way which would be objective and, therefore, universally applicable. In the following we shall denote the "Christian Nisan" by capital letters as NISAN and the days of this month by Roman numerals.

Question II was to decide on which days of such a Christian Nisan the Passion and Resurrection ought to be celebrated, given that the Resurrection had to be commemorated on a Sunday.

Question III was how to make the Easter dates available to local Churches all over the world so that simultaneous commemoration would be assured.

There is no doubt whatever that the only place where these problems could be properly tackled was Alexandria, the intellectual capital of the Hellenistic world where there was, all through the first Christian centuries, a competent school of astronomers and experts in time reckoning. Its best known representatives were the non-Christian scholars Ptolemy in the second and Theon in the fourth century. We do not know whether the Metropolitan Bishop of Alexandria consulted these experts. But it is certain that the Early Church in many places looked to Alexandria as the city where information about Easter could be obtained. In the third century we hear of Alexandrian bishops sending letters to other Churches before Easter, announcing the date on which the feast was going to be observed in Alexandria. This was the case of Bishop Demetrius (d.c. 232) who wrote such Paschal letters to the bishops of Rome, Antioch and Jerusalem,[36] and also of Bishop Dionysius the Great (d.c. 264) who wrote to the otherwise unknown Flavius, Domitius and Didymus, presumably suffragan bishops in Egypt.[37] This custom prevailed long after the Easter problem had been settled, and the universal practice of bishops sending pastoral letters to their clergy during Lent is a direct outcome of the dependence of the Early Church on Alexandria for obtaining information on Easter. But it must have been clear that this was no really suitable way of answering Question III, since such letters might not reach the most distant Churches of the world in good time before the celebration.

The earliest indication of how the Alexandrian Church went about this business is found in Eusebius's account of Dionysius's letter to Domitius and Didymus in which he *published an eight year Easter Canon at the same time as he stated that Easter should never be celebrated until after the vernal equinox.*[38] This is all we know since the Canon of Dionysius is no longer extant. But it is sufficient to warrant a number of important conclusions. Thus it is clear that Dionysius was aware of the importance of Question I, answering it by stating that spring begins at the vernal equinox which the Alexandrians placed on March 21 (in the Julian calendar). That he also took Question III into account follows from the statement that his Easter Canon covered a period of eight years during which his suffragans would not have to worry about the Easter problems. But even more important from a historical point of view is the fact that the existence of this Canon of eight years is sufficient proof that the Alexandrian Church did not use the advanced theoretical methods of accounting for the motion of the Moon which Ptolemy about A.D. had published in his *Almagest.* Instead they relied on the older practice of using period relations based only on mean motions. In consequence, when the words "Sun" and "Moon" occur in the following they always mean the "mean" Sun and the "mean" Moon.

In fact, an eight year period (based on the approximation $p/q = 3/8$ derived above on page 18) had been known to Greek astronomers for centuries. It was called the *octaëteris*[39] and stated that

$$8 \text{ years} = 99 \text{ months.}$$

The importance of such a relation for the Easter problem is obvious. Suppose that the Easter full moon occurs on a certain date of a given year. When 99 months have elapsed the moon will again be full, and if this interval really is eight years this will happen on the same date. In other words the date of the Easter moon will repeat itself after the passage of eight years. In consequence, if the Easter dates are known for eight consecutive years they will also be known for the period of the following eight years, and so on. The problem is whether the octaëteris is a good period relation. We find by calculation

$$8 \text{ Alexandrian years} = 8 \times 365.25^{d} = 2922.000 \text{ days}$$
$$99 \text{ synodic months} = 99 \times 29.53059^{d} = 2923.528 \text{ days}$$

so the agreement is good, but not perfect. The eight years will have elapsed one day and a half before the moon has passed through 99 complete revolutions with the result that the expected Easter moon after eight years would be delayed by 1½ day. It is impossible to know if Dionysius was aware of this error and did something to correct it; but there is nothing which would prevent him from realising the inexactitude since the (correct) value of the synodic month (correct to one third of a second) was known since the time of Babylonian astronomy and could be had from the *Almagest*.

We have dwelt so much upon the Dionysian canon because it indicated the method adopted by the Church in Alexandria and used in numerous variants everywhere else all through Antiquity and the Middle Ages. From a scientific point of view this had the deplorable consequence that the whole of the impressive structure of Greek theoretical astronomy — the crown of Hellenistic science — became irrevelant to the life of the Church and was allowed to fall into oblivion in the West when the Roman Empire fell and ancient science proved unable to survive in the new surroundings. On the other hand it is understandable that the Church was led to adopt the essentially simple expedient of the period relations. Once established they were universally applicable and could be used by any bishop or priest without any astronomical education at all.

That the Roman Church of the third century followed essentially the same course as its Alexandrian sister is also attested in Eusebius who tells that "Bishop" Hippolytus (d.c. 236) — who was not a bishop, but a presbyter and the most important theologian in Rome at his time — *wrote a book about Easter in which he gave an Easter canon valid for 16 years.*[40] Here we are on much surer ground than in the case of Dionysius for, although the book is lost, the canon was recovered in the form of an inscription on the base of a statue of Hippolytus found in 1551 during excavations in Rome, and perhaps made during his lifetime. It is now in the Vatican Library. In 1737 a copy was placed in the Basilica of San Lorenzo in Damaso.[41]

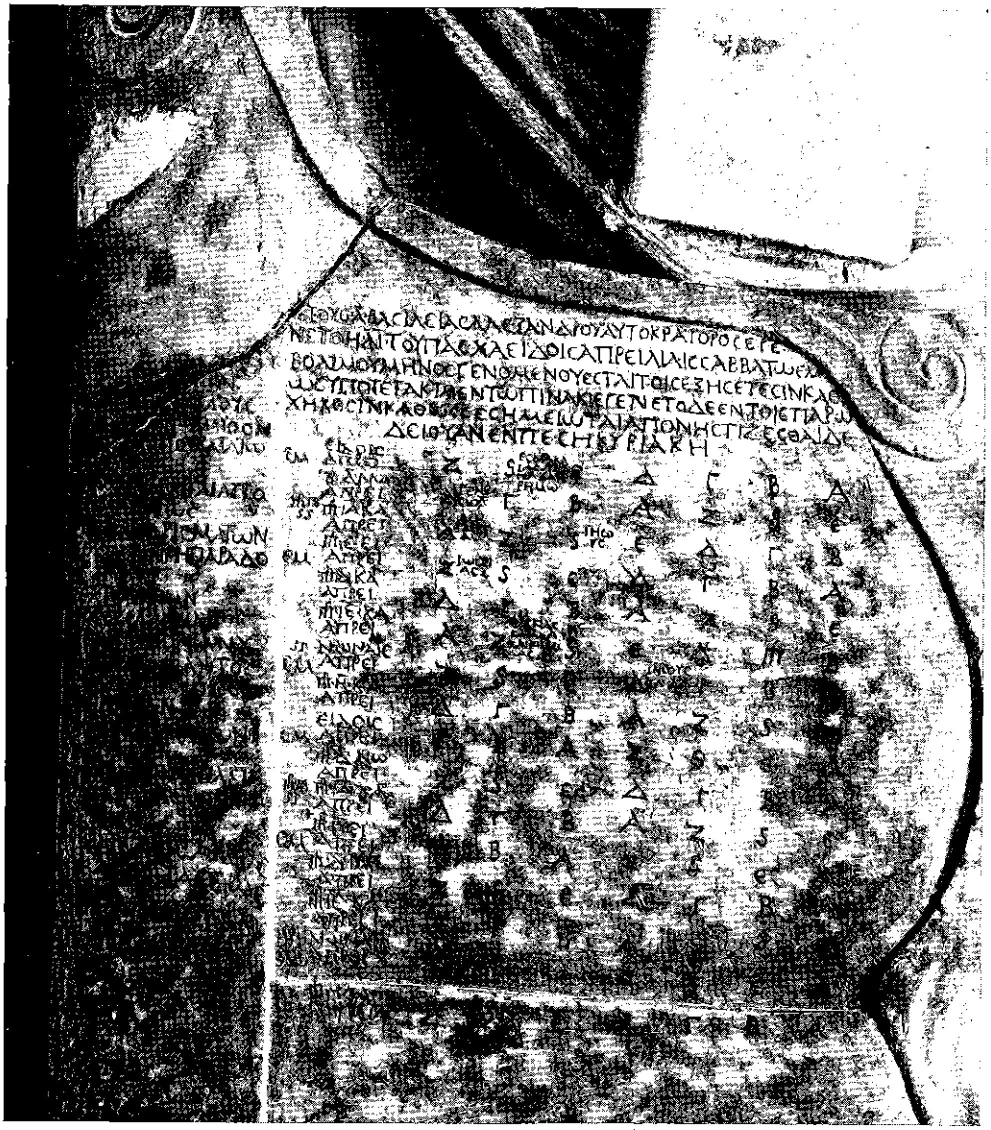

FIG. 1. Easter Canon inscribed on the base of the statute of Hippolytus discovered in 1551 during excavations in Rome and now located at the entrance to the Vatican Library. See page 35 for a description.

Besides a catalogue of the writings of Hippolytus the inscription (which is in Greek) contains two tables. The first of these is introduced by a short text stating that *In the first year of the reign of the Emperor Alexander the xiv of Easter fell on the Saturday of the Idus of April when there was an embolismic month. In the following* ⟨years⟩ *it will occur as stated in the table. In preceding* ⟨years⟩ *it occurs as it is indicated.*[42] The only Roman Emperor by the name of Alexander was Alexander Severus who reigned A.D. 222-235. Thus the first year of the table is 222. It contains seven columns of 16 lines, each line corresponding to a year in a 16 year cycle. The first entry for A.D. 222 is

ΕΙΔΟΙΣ ΑΠΡΕΙ Ζ

which means that in this year the Easter full moon occurred on April 13 on a day with the ferial number Z = 7, i.e. on a Saturday. This was precisely the case since there was a full moon on that very date.[43] Column I continues in this way for another 15 years ending with A.D. 237. To find the date of Easter Sunday we must turn to the second table (on the other side of the base of the statue) where we for the first year of the cycle find IA KA MAI, or April 21. All the relevant information that can be extracted from the two tables is presented in the following synopsis in Table 1 in which column I gives the number of the year in the cycle; column II gives the same year in the Christian era; column III gives the date of the Easter moon, or NISAN xiv; column IV gives the ferial number and weekday of the same date; column V gives the date of Easter Sunday.

The note SS = 66 means that the Julian year in question is bissextile, while EM indicates that the corresponding lunar year contains an embolismic month.[44]

It is not difficult to reconstruct the way in which the dates have been computed. Starting with the full moon A.D. 222 April 13 Hippolytus added an ordinary lunar year of 354 days which brought him to another full moon on A.D. 223 April 2. Another addition of 354 days led him to A.D. 224 March 21 (taking the leap year into account). Still another addition of the same interval would have produced the full moon A.D. 225 March 10. But this must have seemed too early so he let 225 be an embolismic lunar year of 384 days, adding which he arrived at A.D. 225 April 9 as the date of the Easter moon of that year. The same principle is followed throughout the remaining years of the cycle.

Column V shows that in general Easter Sunday is the first Sunday

TABLE 1. Synopsis of the Easter Table of Hippolytus

I	II	III	IV	V
1	222	April 13 EM <+354>	7 = Saturday	April 21
2	223	April 2 <+354>	4 = Wednesday	April 6
3	224	March 21 SS <+384>	1 = Sunday	March 28
4	225	April 9 EM <+354>	7 = Saturday	April 17
5	226	March 29 <+354>	4 = Wednesday	April 2
6	227	March 18 <+384>	1 = Sunday	March 25
7	228	April 5 SS <+354> EM	7 = Saturday	April 13
8	229	March 25 <+384>	4 = Wednesday	March 29
9	230	April 13 EM <+354>	3 = Tuesday	April 18
10	231	April 2 <+354>	7 = Saturday	April 10
11	232	March 22 SS <+384>	4 = Wednesday	March 25
12	233	April 9 EM <+354>	3 = Tuesday	April 14
13	234	March 29 <+354>	7 = Saturday	April 6
14	235	March 18 <+384>	4 = Wednesday	March 22
15	236	April 5 SS <+354> EM	3 = Tuesday	April 10
16	237	March 25 <+384>	7 = Saturday	April 2

following the Easter moon. The only exception is that when the full moon occurs on a Saturday, Easter Sunday is postponed a week, presumably in order not to celebrate the Resurrection of Christ on that day of the lunar month on which he died or lay in the grave.

This simple canon leaves several questions unanswered. Firstly, why did Hippolytus choose A.D. 222 as the first year of his cycle? It may be that it was the era of a new emperor, but another possible reason is that the full moon of April 13 implies a new moon on January 1, when there actually was a first visibility. Secondly, one must ask for the criteria which Hippolytus used to decide when to use an embolismic instead of a common lunar year. It is clear that this had nothing to do with the vernal equinox which, according to the Roman calendar, was March 25, for there are Easter moons as early as March 18 in both the 6th and the 14th year of the cycle. Now March 18 was the day on which the sun entered the sign of Aries according to the Romans,[45] and it may well be that Hippolytus took this as the *terminus a quo* for the Easter moon in order to place his own NISAN in the spring as ordained in Holy Scripture. However, this is no more than a reasonable guess. It follows that so far as we can see today Hippolytus did not succeed in removing the arbitrary definition of the NISAN which was mentioned above.

A third question is how Hippolytus came upon the idea of a 16 year cycle which was otherwise unknown in ancient astronomy? Now a glance at the synopsis above shows that the dates of the moons in the first half are precisely the same as in the second half of the table. This indicates that this strange 16 year cycle was constructed simply by letting one 8 year cycle follow upon another. Accordingly, Hippolytus must have known the octaëteris. Another question is whether he knew it from Alexandria where it is reasonable to suppose that it was used by Bishop Demetrius who was almost an exact contemporary of Hippolytus.[46] But it does not seem necessary to assume an Alexandrian influence since some kind of octaëteris has apparently been used by the Romans in much earlier times.[47] The question cannot be answered in a definite way. But even if Hippolytus may have used an Alexandrian canon he must have reworked it considerably, transposing it from the Alexandrian to the Roman calendar. Moreover, the simple Alexandrian octaëteris would not in itself have led him to create a cycle twice as long. The reason why he did this may, perhaps, be found when we consider the problem of the continuation of the 16 year cycle. It is true that its second half reproduces the lunation dates of the first half — but it does not reproduce the days of the week on which the Easter moons occurred. Thus April 13 of year I was a Saturday, whereas April 13 of year IX was a Tuesday. Now the inscription on the statue contains seven consecutive 16 year periods beginning as shown in Table 2. It is seen that at the beginning of each new 16 year period the day of the week of the Easter moon would simply have moved one day backwards relative to that of the previous period, completing a full turn through the week in seven such periods.

TABLE 2.

Cycle	Year	AD	Moon	Weekday
I	1	222	April 13	Saturday
II	17	238	April 13	Friday
III	33	254	April 13	Thursday
IV	49	270	April 13	Wednesday
V	65	286	April 13	Tuesday
VI	81	302	April 13	Monday
VII	97	318	April 13	Sunday
[VIII	113	334	April 13	Saturday]

It is extremely tempting to assume that Hippolytus reduplicated the octaëteris in order to obtain this beautiful simplicity. This would also explain why he published precisely seven cycles covering a total of 112 years, for after this long period the weekdays of the Easter moons would repeat themselves during another 112 years. Thus the seven continuations were no arbitrary choice, but essential to bring out one of the new and characteristic features of Hippolytus's canon which, accordingly, it would be more appropriate to describe as a 112 year than a 16 year cycle.

All this was very interesting — if only it had worked. But there is no indication whatever that Hippolytus was aware that the octaëteris lost a day and a half and his own cycle three days of their total number of lunations, and that his canon would have gone hopelessly wrong long before the 112 years had elapsed. Nevertheless, his canon commands respect for the interesting ideas inherent in it and also because it seems to have been the first to reveal to the Romans the essential simplicity of computing Easter by period relations. It was left to his successors to remedy the defects of his fundamental relation and to perfect the idea of relating the Easter moons to the days of the week by a simple and straightforward scheme. This was precisely what they tried to do.

In fact, several such attempts were made. In A.D. 243 a revised 112 year cycle was published by an unknown Roman computist together with an extant treatise of the Easter problem which Mabillon placed among the works of St. Cyprian.[48] It placed the Easter moon of the first year of the cycle on April 12 where the canon of Hippolytus had March 18; the actual date was March 23. The accompanying text is noteworthy for its attempt — claimed to be based on divine inspiration — of determining the NISAN of the year of the creation of the world, this primordial event being placed at the vernal equinox (March 25) with the moon created on March 28/29 as a full moon (since it was created to illuminate the night). This became a standard topic of later calendaric science and Biblical exegesis, and led to the date of March 4 as the absolute *terminus a quo* of the NISAN.[49]

From the scientific point of view a much more interesting development occurred with the introduction of the Easter *Laterculus* (i.e. little tablet) of an otherwise unknown Augustalis. It is now lost, but it has been possible to reconstruct it.[50] It covered the years A.D. 213-312, but was based on a period relation never heard of before, stating that

$$84 \text{ Julian years} = 1039 \text{ synodic months.}$$

Since

$$84 \text{ Julian years} = 30681.0 \text{ days}$$

and

$$1039 \text{ synodic months} = 30682.3 \text{ days}$$

the agreement was much better than of the octaëteris, not to mention the Hippolytan cycle. But perhaps even more interesting is the fact that an 84 year period would not only reproduce the dates of the Easter moon with an error of a little more than one day; it would also precisely repeat the weekday of any such moon since 84 years $= 3 \times 28$ years, 28 years being the shortest period in which the days of a seven day week repeat themselves in a calendar in which one year in four is a leap year. Thus Augustalis succeeded in perfecting the weekday scheme of Hippolytus. Later the 28 year period acquired the name of the *cyclus solaris*.[51]

Historically speaking the most important part of the *laterculus* was Augustalis' procedure for determining the lunar year of 354 days (or 355 in leap years) relative to the solar year of 365 or 366 days respectively. This was done by means of a fundamental concept called the *epactae* of the year and defined as the age of the moon on January 1. If this number is known one can easily find the date of the first new moon of the year, and therefore, also the beginnings of the succeeding months of 29 or 30 days. The same applies to the full moons, and in particular to the first full moon after or upon March 25 (the vernal equinox).

From one year to the next following the epact must increase by 11 since 11 days is the difference between the solar and the lunar year. Thus if the epact is 1 in the first year of the cycle, it must be 12 in year II and 23 in year III. It would be 34 in year IV if the month of January had been long enough. This not being the case, one subtracted 30 from the epact, giving year IV the epact 4 and making an embolismic year with an intercalated lunar month. This would have to be done 30 times in 84 years in which a total of $30 \times 30 = 900$ days would thus be added to the number of lunar days. But since the difference between 84 solar and 84 lunar years is $84 \times 11 = 924$ days, this would not be enough, in the sense that after the expiration of a complete period the age of the moon would be 24 days. This inconvenience was removed by intercalating six extra days which artificially increased the age of the moon to 30 days with the result that the epact became the same in the first year of each 84 year period. The six extra days were evenly spaced with intervals of 14 years. In each of these years the age of the moon on January 1 was per definition increased by one day — a procedure which became known to the Latins as the *saltus lunae*.[52]

The epact and the saltus lunae were the permanent contributions to Latin time reckoning by Augustalis. It inaugurated the Easter computus by epacts which were adopted by subsequent calendaric systems, such as the *Old Supputatio Romana* from A.D. 312,[53] and the *Cyclus Pascalis annorum lxxxiiii* covering the years 354-437,[54] with the slight difference that here the *saltus lunae* was placed with 12 years intervals inside the main period, thus avoiding a *saltus* at the beginning of a new cycle.

5. *Nicaea and After*

The victory of Constantine over Maxentius on 28 October, A.D. 312 at the Milvian Bridge outside the walls of Rome heralded a new era in the history of the Church. Early in 313 in the so-called "Edict of Milan" (which was not an edict and not published at Milan) the new Emperor of the West announced that *it is not our task to prevent religious liberty. The power to deal with matters of faith must reside in the judgment and* *desire of the individual in agreement with his own free will.*[55] The new toleration meant an end to the persecutions, enabling the Church to operate in the open, although in close connection with the secular state as personified in the Emperor. This had important repercussions on all the aspects of Christian life, the problems of time reckoning included.

One immediate consequence was the imperial enforcement of the seven day week. A decree from A.D. 321 enjoined urban citizens — but not farmers — to abstain from work on Sundays and forbade the courts to use this day for litigation.[56] Also military exercises in the army were restricted so that soldiers would have time to worship the God of their choice. That the Emperor referred to the first day of the week as the *dies solis* cannot have pleased the Christians, but it placated the numerous worshippers of the sun in the army. According to an inscription Constantine also destroyed the old *nundinae* periods by moving the official market days to the first day of the week.[57] Later in the fourth century the obscure Council of Laodicea decreed abstention from any work on Sundays [58] (also in the country) and in A.D. 400 the Emperor prohibited games and theatrical performances.[59]

Under the new auspices there was also a new possibility of dealing with the Easter problem on a universal scale. Already in A.D. 314 the Western Council of Arles decided that from then on *the Pascha of the Lord shall be observed by us on the same day at the same time all over the world* — per omnem orbem — asking the Pope to ensure uniformity by issuing Paschal Letters to all Churches.[60] But this was easier said than done. On the one hand, the *canones* of Arles were not accepted in the East; on the other, the Council did not prescribe any universably applicable method of computing Easter. The problem remained unsolved and was accordingly placed on the agenda of the first Ecumenical (although predominantly Eastern) Council of Nicaea in A.D. 325, convened by the Emperor to suppress Arianism and resolve the Meletian schism in Egypt, but also to impose a liturgical uniformity with respect to the observation of Easter as a prerequisite for the unity of an Empire in which the Christian population may by now have become the majority.

Unfortunately we are badly informed of the deliberations at the Council on this particular matter. The final Canon 20 decreed that prayers on Sundays and during the time of Pentecost should be said standing, but had nothing on the Easter controversy.[61] What we have is a letter from the Council to the Church of Alexandria saying that *the dispute over our Holy Pascha is ended (. . .) so that all Eastern brothers will from now on* *celebrate Easter as you do, they who formerly did not comply with the Romans, nor with you, nor with others of those who maintained the original Easter custom.*[62] This was followed by a circular letter from Constantine himself to the effect that *at this meeting the question concerning the most Holy Day of Easter was discussed, and it was resolved by the unanimous judgment of all present that this feast ought to be kept by all and in every place on one and the same day.*[63] Thus the decision of Arles became law also in the East. It was justified by the Emperor in a letter with anti-semitic overtones, stating that *it was unworthy that (...) we should follow the practice of the Jews who have defiled their hands with enormous sin,* and continuing with the preposterous assertion that *we have received from our Saviour a different way of celebrating Easter which is followed at once in the city of Rome and in Africa, throughout Italy and in Egypt.*

The Council was not able to change old customs overnight. In A.D. 341 the Council of Antioch felt obliged to stress the importance of not *keeping Easter together with the Jews,*[64] and even later (in 364) the Council of Laodicea spoke of the still existing quartodecimans as schismatics on a par with Novatians and Photinians.[65] But on the whole the Eastern bishops seem to have complied with the decision of Nicaea, understanding the situation so that the task of computing Easter should be performed by the astronomically competent Alexandrians on behalf of the whole Church. More than a hundred years later this arrangement was still referred to in a letter (dated 15 June, 453) from Pope Leo I to the Emperor Marcianus.[66] After Nicaea the most important question would then have been if the Church of Egypt was able to undertake this task to the satisfaction of all.

This was by no means certain. In their general euphoria over having settled the question the Fathers of Nicaea were too optimistic, and Rome and Alexandria were still divided on a number of details, although the general principles were the same. One potential source of discord was the fact that the Alexandrians placed the vernal equinox on March 21, although we are not sure whether they actually tried to confirm this date by astronomical observations. On the other hand the Romans clung without compromise to their own traditional date of March 25. This had consequences for the *termini* of Easter, that is the first and last day on which Easter Sunday could fall. This led to numerous minor controversies which cannot here be described in detail. From a theoretical point of view it was of much greater interest that while the Romans stuck to their 84 year period, the Alexandrians had, even before Nicaea, adopted a much better cycle. The fundamental period relation (called the "Metonic cycle" after a fifth century B.C. astronomer in Athens)[67] presupposed that

$$19 \text{ tropical years} = 235 \text{ synodic months.}$$

Replacing the tropical year by the Julian year we find

$$19 \text{ tropical years} = 6939.75 \text{ days}$$

and

$$235 \text{ synodic months} = 6939.69 \text{ days}$$

so that the Metonic 19 year period — the *enneakaidekaëteris*, or the *decemnovennalis cyclus* — proved more promising than any other period relation we have met with above. Although this relation had been known to astronomers for centuries it does not seem to have been applied to the Easter computation until the time of Anatolius, a scientifically competent Christian who after a remarkable academic and public career in Alexandria became bishop of Laodicea (A.D. 268) where he died (c. 282). His book *On Easter* is lost except for a long passage in Eusebius.[68] It mentions a 19 year cycle beginning in a year when there was a new moon of the first month (i.e. the lunar NISAN) on Phamenoth 26 in the Egyptian or on the 11th kalends of April in the Roman calendar. This would agree with A.D. 277.[69] Otherwise the extract is not very informative, except that we are told that Anatolius would not have Easter before the entrance of the Sun in Aries, that is, before the Sun had passed the astronomical equinox. The principal purpose of his treatise may well have been to stress this principle which all Alexandrians adopted without hesitation. Accordingly it must have been implicit in the decision of Nicaea which, therefore, modified the traditional Roman position without mentioning it. The reason must be that a Council of Eastern bishops (with a few representatives from the West) would have no other lunar calendar in mind than the one they already knew from their own intellectual capital and most famous see.

A later version of the Anatolian system has been ascribed to Eusebius, but this cannot be verified.[70] On the other hand, there is no doubt that the construction of an Easter table based on the 19 year cycle would present no great problem in Alexandria where the Church actually used the system, as one can see from the Paschal Letters of St Athanasius who had been present as a secretary at the Council of Nicaea. After his accession to the see of Alexandria in A.D. 328 he published annual letters with Easter dates computed on a 19 year cycle.[71] During much of the post-Nicene period the collaboration between Alexandria and Rome seems to have worked very well. Since the computing methods were different discrepancies would inevitably occur. Nevertheless, it is a fact that, for many years after the Council, Rome and Alexandria succeeded in keeping Easter on the same day.[72] The reason can only have been that, in general, Rome accepted the Paschal Letters from Alexandria, and that occasional disagreements were settled by direct negotiation. But this harmony did not survive. As St Augustine noticed,[73] the year 387 was particularly confused, the Alexandrians celebrating Easter on April 25, the Romans on April 18, and the Churches of Gaul on March 21.

About this time the situation changed in a significant way, with far reaching consequences for computistic science in the West. What happened was that the Western Church became acquainted with not only the annual results of the Alexandrian Easter computation, but also with the basic principles by which they were obtained. Unfortunately it is difficult to follow this development, much of the most important source material being lost. But we know that on at least two occasions the West was presented with Alexandrian-made Easter tables covering long spans of years. Such a table was sent by the Alexandrian Bishop Theophilus (385-412) to the Emperor Theodosius I (379-395). It covered a period of one hundred years beginning with the first Easter of the Emperor's reign (i.e. A.D. 380). This was an arbitrary number of years, but it was long enough to display five complete 19 year cycles. In the fifth century Theophilus' successor (and nephew) Cyrillus of Alexandria sent a similar table to the Emperor Theodosius II (401-450). It contained exactly five complete cycles covering the 95 five years A.D. 437-531. Both these tables are lost, apart from the fifth cycle of the Cyrillan table,[74] buth the preface to Theophilus' table has been preserved in Greek,[75] and the covering letter of the Cyrillan table in Armenian.[76] There is also a Latin *Prologus Cyrilli* [77] which was believed to be a much later fabrication [78] until a slightly different version could be dated to sometime between A.D. 449 and 532.[79]

Theophilus's Preface obviously aimed at convincing the Emperor of the superiority of the Alexandrian system by explaining a number of reasons why other systems lead to error. One such cause is the ignorance (read: in Rome) of the true date of the vernal equinox (March 21) before which date the celebration of Easter is prohibited by the Law. Another reason is that if NISAN xiv is a Sunday it is absolutely necessary to postpone Easter Day another week. Otherwise the feast would begin with the breaking of the fast on the evening of NISAN xiii which likewise is against the Law. In consequence it may happen in some years that Easter is moved into the second month of the lunar year. This, too, violates the Law but is a minor offence compared with the awful sin of breaking the fast on a Saturday.

This propaganda for well known Alexandrian customs was, from a historical point of view, of less importance than the fact that the Easter tables of Theophilus and Cyrillus showed Western computists how the 19 year cycle was constructed, the period of 235 lunations being pieced together by four components, viz.[80]

(1) 114 full months	$= 114 \times 30^d$	$=$	3420.00^d
(2) 114 hollow months	$= 114 \times 29^d$	$=$	3306.00^d
(3) 7 embolismic months	$= 7 \times 30^d$	$=$	210.00^d
(4) 4¾ leap year days		$=$	4.75^d
making a total of			6940.75^d

But this is precisely one day more than 19 Julian years. Accordingly this extra day had to be suppressed by a *saltus lunae* similar to that known to the Romans from the *Laterculus*, but somewhat differently arranged in the Alexandrian system. Here the age of the moon on the first day of the first year of the cycle was defined to be zero (not one as in the Roman system). It increased by 11 days each year and, as in the Roman system, an embolismic month of 30 days was intercalated at the end of the common lunar year of 12 months every time the epact would have surpassed 30 on the first day of the new year. This procedure reduced the epact by 30 at the same time as it determined the position of the seven embolismic years within the cycle of 19 years. At the beginning of the 19th year the epact would be 18 times $11 = 198 \bmod 30 = 18$ days. Consequently it would be $18 + 11 = 29$ at the beginning of the next cycle which is too small by one. Now if in a certain year one lunar day is left out, the epacts of all the following years must increase by one, and the next cycle will start with the correct epact $29 + 1 = 30 = 0 \bmod 30$. The omission of such a day is precisely the *saltus lunae*. It usually occurred in the 18th or 19th year of the cycle.

This scheme made it possible to derive the date of the Easter Moon from the epact of the year. A different problem was to find the day of the week on which this moon occurred, and thereby the date of Easter

Sunday. This was achieved by providing the table with the *dies concurrentes*, i.e. the ferial number (i.e. the number of the day within the week) of March 24. Why this date was chosen is not clear.[81]

6. *The Alexandrian System in the West*

The Alexandrian computus arrived in the West backed by two strongly supporting factors. Firstly, it must immediately have become clear to Western experts that the 19 year cycle was superior to anything previously known to the Latin world. It was based on a very accurate period relation and the business of administrating the *saltus lunae* was simpler than in any other system. Also it was easy to understand since it based the Easter computation on the notion of the epact of the year with which Western scholars had long been familiar. Secondly, since the 19 year cycle had been used by the Alexandrian Church for fulfilling the task imposed upon it by the Council of Nicaea, the mistake arose that the 19 year cycle as such had been imposed by the Council and invested with its ecumenical authority.[82] Both factors contributed to the final victory of the Alexandrian system in the West, although only after a long struggle with traditional Western methods. The rather poor state of our sources makes it difficult to follow this struggle in detail, and we shall not here enter into the many vexing and controversial questions of how and when the tables of Theophilus or Cyrillus were adopted by churches in the West.[83]

One important consequence of this increased knowledge of the Alexandrian cycle was that Latin scholars and churchmen were now able to compute Easter according to both Greek and Latin methods. Therefore, they were also able to foresee in advance when there would be discrepancies. This new situation is the background of the letter of 15 June, A.D. 453 from Pope Leo I to the Emperor Marcianus in which the Pope expressed his concern with the fact that the table of Theophilus showed Easter day in A.D. 455 on 25 April. This late date was unacceptable to the Roman Church and the Emperor is therefore asked to use his influence to avoid this *nimis insolens et aperta transgressio*.[84] In the same and also in the following year the Pope also asked for the support of Bishop Julian of Carthage in his attempts to persuade the Emperor to take a hand in the matter.[85]

The Emperor's reaction is not known, but it may well have been negative since we now witness a determined effort by the Roman Church to investigate the whole Easter problem by the help of ecclesiastical experts without any appeal to the secular powers. In or before A.D. 457 the Roman Archdeacon Hilarus wrote to Victorius of Aquitaine asking him to examine carefully the causes of the discrepancies between the several Easter computations *tam de Graeco translata quam a Latinis condita.*[86] This Victorius is otherwise unknown, except as the author of some elementary arithmetical tables,[87] but it would seem that he was the best calendar expert known to the Roman authorities of his time.

In his reply Victorius first reviewed the three systems of Easter computation which were most frequently used, viz. (1) the 84 year cycle of the old Roman *Laterculus*, (2) the 95 year cycle of the Greeks, and (3) a 112 year cycle with a *saltus lunae* at 12 year intervals; this must be the Pseudo-Cyprian table mentioned above. He then points to one obvious cause of discrepancies, viz. that the *saltus* is defined and placed in different ways in these three systems. In this connection he makes the penetrating remark that there must also be something wrong with their alleged cyclic character. For if, for example, there exists a true cycle of 84 years then both the 95 and the 112 year systems should repeat the Easter moons after 84 years, and this they do not. Another source is the lack of agreement on where the NISAN should be placed within the Julian calendar. The Latins maintain that this lunar month should begin on one of the 29 days from March 5 (this is a mistake for March 4) to April 2, with the Easter moon occurring on one of the days from March 18 to April 15. This does not agree with the Greek choice of March 8 - April 5 as the *termini* of the first day of NISAN, leading to an Easter moon between March 21 and April 18.

Having brought some of the causes of the shortcomings of the previous systems of computation out into the open, Victorius proceeds with an attempt to improve upon his predecessors. This seems to him rather audacious since so many others have failed, but there is still hope since *apud deum non est acceptio personarum.* His presuppositions are: (1) that the vernal equinox falls on March 21 according to the Council of Nicaea (i.e. according to the Alexandrian usage); (2) that the 19 year cycle gives a true account of the behaviour of the moon; and (3) that the age of the world can be derived from chronological information in the Old Testament as shown in the chronicle of Eusebius and its continuations by St Jerome and St Prosper of Aquitaine.

Assuming the world to have been created in the *annus mundi* one, on Sunday March 25, with the moon created as full on March 28/29, Victorius reveals that he did not realize that these traditional Roman dates (known from Pseudo-Cyprian) had to be changed if the Alexandrian date of the equinox was adopted; however, this does not destroy the core of his argument which rests upon the result reached by the theological chroniclers that the Passion of Christ happened in the *annus mundi* 5229, in the year of the consulate of the two Gemini (i.e. A.D. 28). Dividing 5229 by 19 one finds that Christ died in the fourth year of a 19 year cycle starting at the time of the Creation, and that the crucifixion on NISAN xiv took place on March 26. Having established this date Victorius could then proceed with the computation of all subsequent Easters during 430 years. This brought him up to his own time (A.D. 457). But continuing the computation for another 102 years into the future it was "quickly disclosed" that the Easter dates began to repeat themselves after the 430 + 102 = 532 years: *patefacere properavi, quae summa ita cunctarum, quibus exempta est, seriem regularum sua revolutione conplectitur, ut eodem tramite et in id, unde est orta, revocetur et ad finem pristinum denuo circumacta perveniat.*

This was the strange way in which the famous 532 year cycle was discovered. However incredible it may seem to us there is no evidence whatever in Victorius's text that he was led to it by realizing the fact that

532 years = 19 (the period of NISAN xiv)
times 4 (the period of the leap year)
times 7 (the period of the Sunday)

or that he supported his experimental derivation of the cycle by this simple relation. Therefore, we must conclude that the first true Easter cycle was discovered almost by accident.[88] The superiority of the new cycle was obvious. Where all the previous cycles had provided series of repeating dates of the Easter moon, this was the first which showed a periodic recurrence of the date of Easter Sunday. Add to this the fact that it covered a very long span of years, thereby liberating generations of bishops from having to worry over Easter, one would think that the battle was over, and that the Alexandrian computation had won a final victory. In the historical perspective this was indeed the case. But there were a number of particular features of Victorius's solution which prevented it from being immediately acceptable.

Appended to Victorius's letter is a complete list of Easter dates for a full 532 year cycle beginning with the *annus Passionis* (A.D. 28). This table gives in: Col. I: the year of the cycle; Col. II: the two consuls of the year until A.D. 457; Col. III: the date of the Easter moon in the Roman calendar; Col. IV: the NISAN of the Easter moon; Col. V: the date of Easter day in the Roman calendar; Col. VI: the NISAN of Easter day. A detailed analysis of this table shows a number of features which would please neither the Greeks nor the Romans.[89]

Since the first year of the cycle was placed as the fourth year of an Alexandrian 19 year period Victorius was forced to place a *saltus* (in year 19 of the Alexandrian cycle) in the 16th year of his own cycle, and then with intervals of 19 years. This meant that the Victorine *saltus* occurred in the sixth year of the 19 year cycle actually used in Alexandria, which referred to the era of Diocletian (A.D. 284) but not to the year of Creation. In consequence the Victorine and the Alexandrian Easter would differ by one day in 13 out of the 19 years of the Alexandrian cycle. Furthermore, Victorius was unable to keep his Easter date within the traditional limits of the Roman Church. Thus in the 37th year of his cycle he placed Easter day on April 22, in the 48th year on April 23, and so on in numerous other cases. He does not comment on this departure from Western tradition which was the obvious price to be paid for having an Easter Canon of such a long span of years. Accordingly it met with opposition and did not immediately supplant earlier Roman cycles or the new Cyrillan table which was preferred by many churches in the latter half of the fifth century, particularly in North Africa.

7. *The Christian Era*

The occasional extremely late dates of Easter in both the Cyrillan and the Victorian tables were a source of continual vexation to the Romans. Under Pope John I (523-526) history repeated itself in so far as the Roman authorities were led to take action very much as in the time of Leo I. This time the trouble was that Victorius had placed the Easter of A.D. 526 on 19 April. This was inside the limits acceptable to Rome, but since this date was also NISAN xxii it was deemed too late, and controversy could be foreseen. The Pope asked two secretaries to go into the matter and just as Hilarus had consulted Victorius, the Primicerius Bonifatius and the Secundicerius Bonus enlisted the aid of an expert scholar by the name of Dionysius Exiguus, who is otherwise known as the compilator of one of the first collections of Canon Law.[90] The result was a number of writings in which Dionysius dealt with both the immediate and the perennial problems of the Easter computation. Among these is a treatise addressed to an otherwise unknown Bishop Petronius, followed by a continuation of the Cyrillan table for a new period of 95 years. It was explained in a letter to the two *cerii*, and finally accompanied by a series of *Argumenta*, or mathematical procedures for determining all the calendaric characteristics of the year.[91]

In his letter to Petronius, Dionysius explained that the 19 year cycle had been introduced by the Council of Nicaea and accordingly was invested with high ecclesiastical authority for which reason it had been used as basis of the 95 year tables of Theophilus and Cyrillus. Now the Cyrillan table would expire in A.D. 531, and Dionysius simply provided it with a new continuation covering the years 532-627. In front of this table he placed the last 19 year cycle of Cyrillus which was thus rescued from oblivion. But here Dionysius introduced a change of far-reaching consequences. The last cycle of Cyrillus covered the *Anni Diocletiani* 228-247 (or A.D. 512-531) whereas the first cycle of Dionysius referred to the *Anni Domini Nostri Jesu Christi* 532-550.

In his letter to Petronius Dionysius explained that he did not want to use his Easter table to perpetuate the memory of an impious persecutor of the Church, but preferred to count and denote the years from the Incarnation of our Lord, in order to make the foundation of our hope better known and the cause of the redemption of man more conspicuous — *noluimus circulis nostris memoriam impii et persecutoris innectere, sed magis elegimus ab incarnatione domini nostri Jesu Christi annorum tempora praenotare; quatinus exordium spei nostrae notius nobis existeret et causa reparationis humanae, id est, passio redemptoris nostri, evidentius eluceret.*[92] In this inconspicuous way was the Era of the Incarnation first introduced in the history of the calendar. We do not know if Dionysius was moved to make this momentous innovation by otherwise unknown tendencies of his own time, or if his introduction of the *Anni Domini* was an original idea, motivated by reasons similar to those which had made the author of the *Martyrium Polycarpii* suppress the name of the Emperor under whom the great martyr of Smyrna had died.

Now the Era of Diocletian had become known to Christians as the "Era of the Martyrs" and was, as such, held in some veneration in spite of its connection with an emperor of infamous memory. It gave way only slowly to the new Dionysian era which, nevertheless, was predestined to conquer the whole Church and later also most of the non-Christian world. Of this Dionysius can have had no premonition, and it did not occur to him, for instance, to date his own letters according to the new principle. For the sake of brevity we shall not here consider the long historical process during which the Christian Era was finally accepted.

It follows from what was said above that Dionysius identified the year A.D. 532 with the *annus Diocletiani* 248, implying that the Incarnation took place in 753 A.U.C. Why he did so is not clear. It may have had something to do with the old tradition that Christ died on March 25 at the age of 30. For according to the table of Dionysius, Easter A.D. 563 would fall on March 25 (NISAN xv). Consequently it would have occurred on the same date 532 years earlier, i.e. in A.D. 31 in which year Christ would have died at the age of 30 if he were born in A.D. 1. However, this explanation is only a surmise and it would be useless here to go into this question, or into the age-long dispute over the impossibility of making the Dionysian Era of Christ conform to the information in the Gospels on the time of the birth of Jesus.[93]

The first cycle of Dionysius' Easter table is reproduced in Table 3 (with Arabic instead of Roman Numerals).

TABLE 3. First cycle of Dionysius' Easter table.

I	II	III	IV	V	VI	VII	VIII
B 532	10	0	4	17	Non. Apr.	3 Id. Apr.	20
533	11	11	5	18	8 Kal. Apr.	6 Kal. Apr.	16
534	12	22	6	19	Id. Apr.	16 Kal. Mai.	17
535	13	3	7	1	4 Non. Apr.	6 Id. Apr.	20
B 536	14	14	2	2	11 Kal. Apr.	10 Kal. Apr.	15
537	15	25	3	3	4 Id. Apr.	2 Id. Apr.	16
538	1	6	4	4	3 Kal. Apr.	2 Non. Apr.	18
539	2	17	5	5	14 Kal. Mai.	8 Kal. Mai.	20
							ogd.
B 540	3	28	7	6	7 Id. Apr.	6 Id. Apr.	15
541	4	9	1	7	6 Kal. Apr.	2 Kal. Apr.	18
542	5	20	2	8	17 Kal. Mai.	12 Kal. Mai.	19
543	6	1	3	9	2 Non. Apr.	Non. Apr.	15
B 544	7	12	5	10	9 Kal. Apr.	6 Kal. Apr.	17
545	8	23	6	11	2 Id. Apr.	16 Kal. Mai.	18
546	9	4	7	12	Kal. Apr.	6 Id. Apr.	21
547	10	15	1	13	12 Kal. Apr.	9 Kal. Apr.	17
B 548	11	26	3	14	5 Id. Apr.	2 Id. Apr.	17
549	12	7	4	15	4 Kal. Apr.	2 Non. Apr.	20
550	13	18	5	16	15 Kal. Mai.	8 Kal. Mai.	21
							hend.

The general outlay of the table shows that Dionysius thought the 19 year cycle to be made up of an 8 year period marked ogd. (i.e. *ogdoadas*) followed by an 11 year period marked end. (*hendecadas*). The headings of the eight columns of the table are as follows.

I: *Anni Domini Nostri Jesu Christi.* — The number in this column indicates the year according to the new era. The letter B denotes a bissextile year.

II: *Quae sint indictiones.* — This column contains the number of the year within a traditional cycle of 15 years (of fiscal origin) which was much used for the dating of documents, in connection with e.g. the consuls of the year, or the year of the reign of the emperor. The use of the *indictio* reduced confusion and made forgeries more difficult. The *indictio* has no importance whatever for the Easter computation. Nevertheless, Dionysius introduced it in the Easter table, presumably in order to fix the *anni domini* in relation to a calendaric parameter which was better known.

III: *Epactae, i.e. Adiectiones Lunares.* — We have already met the *epactae* in the old Roman *Laterculus* of Augustalis in which it was the age of the moon on 1 January. In the Alexandrian system, followed here by Dionysius and later by Bede, the epact is the age of the moon on 22 March, a date which may have been chosen because it was the earliest possible date of Easter Sunday. Another innovation was that the changing of the epact from one year to the next following took place on 1 September, a date close to the beginning of the Alexandrian new year on Thoth 1 (29 August) when the epact was changed in the East.

IV: *Concurrentes dies.* — Here there is no change, the numbers in the column being the ferial numbers of 24 March.

V: *Quotus sit Lunae Circulus.* — This is the number of the year within the 19 year lunar cycle. As such it is the most important parameter in the Dionysiac system, enabling the computist to find the Easter date in any year of the cycle, since there is a one to one correspondence between the epact and the number in Column V. It seems strange that Dionysius did not introduce a special technical term for this important parameter which the later Middle Ages honoured by the name of the *aureus numerus*, or Golden Number, no doubt because it was more and more considered the key to the whole Easter computation, and sometimes written in golden ink in the calendars.

VI: *Quota sit Luna xiiii Paschalis.* — This is the date of NISAN xiv for each year of the cycle expressed in the Roman calendar. It varies from 12 Kal. Apr. (21 March = the Alexandrian vernal equinox) to 14 Kal. Mai. (18 April).

VII: *Dies Dominicae Festivitatis.* — This is the date of Easter Sunday. It falls between 11 Kal. Apr. (22 March) and 8 Kal. Maias (25 April) which are the Easter *termini* in the system of Dionysius. Consequently, as this system was gradually adopted in the West, the Romans had to abandon their traditional resistance to late Easter dates and accept April 25 as the ultimate limit.

VIII: *Luna ipsius Diei Dominici.* — This is the NISAN-date of Easter-Sunday, or, in other words, the age of the moon on Easter day.

In his *Argumenta de titulis paschalis Aegyptiorum* Dionysius explained how all these parameters could be computed by procedures which are easily translated into a modern mathematical notation.[94] Thus *Argumentum II* states that the indiction is the remainder when the number of the year A.D. is increased by three and the sum divided by 15, or

$$\textit{indictio} = \text{A.D.} + 3 \bmod 15$$

a formula which implies that the Christian era began in the fourth year of an indiction period. Since no year has the indiction zero the indiction is taken to be 15 if the division comes right. *Argumentum III* shows how to find the epact, or *adiectio lunaris*, by: (1) finding the remainder of the year divided by 19; (2) multiplying the result by 11; and (3) finding the remainder of this product dividing by 30. Consequently, the

$$\textit{epactae} = (\text{A.D.} \bmod 19) \times 11 \bmod 30$$

Argumentum IV gives a rule for finding the *concurrentes dies*, also called the *adiectio solis*, or *epacta solis* (and defined as the ferial number of 24 March). The corresponding formula is

$$\textit{concurrens dies} = (\text{A.D.} + \frac{\text{A.D.}}{4} + 4) \bmod 7$$

where fractions are ignored when dividing by 4.

Argumentum V says that the number of the year in the current 19 year cycle is

$$\langle \textit{aureus numerus} \rangle = \text{A.D.} + 1 \bmod 19$$

We shall not here go through all the *Argumenta* of Dionysius but only underline their short and precise mathematical form which presented all the intricacies of the Easter computation, and of the calendar in general, in a clear and succinct way, illustrating them by numerical examples.

It is interesting to notice that Dionysius was honest enough to draw Bishop Petronius's attention to the fact that the new continuation of the Cyrillan 95 year period did not constitute an Easter cycle in the true sense of the word. Like the Cyrillan period it was simply a succession of 19 year periods each of which were cyclic with respect to the epact and the date of NISAN xiv, but unable to bring either the *concurrentes dies* or the date of Easter Sunday back to their initial values, for the simple reason that the days of the week follow a 7 year period which is not a part of period of 95 years. Thus, without mentioning it, and presumably without intending to do so, Dionysius had pointed to a weakness of his own system from which the *Cursus Paschalis* of Victor of Aquitaine did not suffer. It is all the more remarkable that he never mentioned the 532 year cycle at all. Dionysius belonged completely to the pure Cyrillan tradition, and it is a testimony to historical confusion that the MSS of his letter to Petronius are headed *Libellus de cyclo magno paschae DCCCII annorum*, even if this is also a copyist's error for *DXXXII annorum*.[95] Also the next 95 year continuation (A.D. 626-721) by Abbot Felix Cyrillitani remains in the same tradition, ignoring the great Easter cycle. This was also the case of Isidor of Sevilla whose great encyclopedia *Libri Etymologiarum* (before A.D. 636) mentioned Victorius in passing, but was silent about his cycle, copying instead (not without error) the Easter dates of Dionysius.[96] In spite of a decision of the Council of Orleans (A.D. 541) that all priests should use the canon of Victorius [97] we must conclude that the great cycle did not really attract the attention of scholars or churchmen of the sixth and seventh centuries.

8. *The Achievement of Bede*

The Easter tables of Victorius and Dionysius covered different spans of years. Moreover, the 532 year cycle was a real, self-repeating Easter cycle whereas the 95 year period was an arbitrary number of five successive 19 year cycles of NISAN xiv. But the two systems agreed on the fundamental principle of accounting for the behaviour of the moon by means of the 19 year Metonic cycle inherited from Alexandria. Therefore, regardless of whether the Victorian or the Dionysian system was adopted, the Alexandrian *computus* had won a final victory and was never again to be challenged in the Church universal. So in a way the history of the establishment of the ecclesiastical calendar could be said to end here in the Dark Age of the sixth century when the culture of the ancient world in the West began to give way to what became known one thousand years later as the Middle Ages.

However, although the victory had been won it had to be consolidated. A number of problems of very real, although secondary importance, remained to be solved. Firstly, the various churches had to make up their minds whether they would follow Victorius or Dionysius, i.e. whether the common Metonic period should be developed into a complete 532 year cycle, or remain an element of an arbitrary series of 95 years. Secondly, the general principles of the Easter computation had to be disclosed and explained in such a way that they could be assimilated and applied locally everywhere in the Church at a time when travelling and communication were becoming increasingly difficult, and local churches had to rely on their own intellectual resources more than ever before. Thirdly, there was still room for a number of technical improvements of the computational procedures. These three objectives occupied the time of the computists of the Middle Ages. They were fortunate in having been given an example by a scholar of genius whose works set the standard of the whole Medieval computus as such, to the extent that it was difficult for later authors to achieve a comparable precision and clarity of exposition.

The seventh century saw a great outburst of collections of calendaric and computistical material all over Western Europe, culled from such sources as the *Prologue* of Theophilus, the *Praefatio Cyrilli*, the letters and *Argumenta* of Dionysius, and other works. An example of this new genre is the so-called *Canon Paschalis* attributed to Anatolius,[98] but in reality a seventh century work, probably written in Ireland.[99] Another genre was the encyclopedia with the *Libri XX Etymologiarum* by Isidor of Sevilla as the best and most widely used example. It dealt among other things with the fundamentals of astronomy (Liber III D), including the behaviour of the moon (III D, 33-34), but also with time reckoning (V, B) and the Easter cycle of Cyrillus (VI, 13), everywhere paying more attention to the etymologies of the technical terms than to their precise definition or scientific relationship. How long lived this tradition was is apparent from a Merovingian *Computus Paschalis* from A.D. 727.[100]

6

which began by explaining that the *computus* of the Latins was called *mina* by the Hebrews, *ciclus* by the Greeks, *calculus* by the Macedonians, and *latercus* by the Egyptians ⟨sic⟩, continuing by maintaining that *Sol de solempnitate dicitur, quia solus pro diem lucit*, etc.

The science of time reckoning was rescued from this unprofitable and often nonsensical verbiage by the great scholar whom posterity called the Venerable Bede (c. 673-735), an English Benedictine who spent all his life teaching, writing and doing research in the monastery of Yarrow near Durham. Practically all his many works were composed for the benefit of his students in the monastic school and soon found their way into the curriculum of other schools in Britain and on the Continent. Three among these works, supplemented by a couple of letters, are of immediate importance to the history of time reckoning. Best known today is Bede's *Historia ecclesiastica gentis Anglorum* which was an outstanding achievement in Medieval historiography, based on research into original sources such as documents — some of them brought from archives in Rome — and interviews with people who knew.[101]

But the *Historia* also has a place in the history of time reckoning as the first historical work which consistently made use of the Christian Era introduced by Dionysius. It had long been a custom to make notes of historical events in the margin of Dionysian calendars so that they were automatically related to the *anni domini* of Dionysius. Bede adopted the same chronological framework for his general exposition of the history of Britain. The first date in the book is found right in the beginning where it is said that Julius Caesar became Consul in 693 A.U.C. and 60 years before the birth of our Lord (Liber I, Ch. 2) from which we can conclude that Bede adhered to the Dionysian hypothesis of the year 753 A.U.C. as the year of the Incarnation. In the final chapter of the work (V, 24) is a chronological summary of a series of important events dated in years A.D.

Moreover, Bede's *Historia* is an illustrative and illuminating account of how serious the Easter problem still was in the seventh century, particularly in a missionary country on the outskirts of Europe into which Christianity had penetrated along different routes, imbuing both the British, the Saxons, the Scots and the Irish with different and sometimes incompatible traditions, not least with respect to the celebration of Easter. Thus, in A.D. 605, Laurentius — the second Archbishop of Canterbury — is shocked by the unorthodox behaviour of the Scots (i.e. Irish) who kept Easter on NISAN xiv-xx (II, 4). In A.D. 623 Pope John IV had to remind them that Easter must necessarily fall on NISAN xv-xxi as "proved" by the Council of Nicaea. In the same letter we hear of a late outburst of quartodecimanism among the Scots where a number of people maintained that Easter ought to coincide with the Hebrew Passover (II, 19). In A.D. 664 the Scottish-educated King Oswy of Northumbria kept Easter on the same day on which his Kentish Queen Eanfleda revealed her Roman proclivities by keeping Palm Sunday (III, 25), — a disastrous incident which later in the same year led to a heated discussion at the Synod of Whitby. Here the Scottish-Irish practice was defended by the Northumbrian Bishop Colman who invoked the authority of S. John, while the Roman position was maintained by the Southern Bishop Wilfried who claimed both Nicene and Petrine authority for this practice, maintaining that *a few men in a corner of a remote island should not be preferred before the universal Church of Christ throughout the world.* In the end the King decided to abolish the Northern system and to adopt the Roman, since St. Peter held the keys of the Kingdom of Heaven and had to be followed also in this matter (III, 25). Nevertheless, the monks at Iona did not reform their ways until A.D. 715 (III, 4).

This situation is the background of the works in which Bede explicitly dealt with computistic problems. In A.D. 703 around the time when he was ordained a priest at the age of 30 he wrote a brief *Liber de temporibus* for the benefit of his students.[102] It contained 16 short chapters defining and describing the most fundamental concepts and procedures in a clear and unadorned language.. The intention of the author clearly was to inoculate his pupils against both the Irish (Scottish) tradition and against the childish approach of Isidor. Roman ways are underlined by placing the vernal equinox on March 25 and Easter on NISAN xv-xxi. The 19 year cycle of Cyrillus is copied and explained as the combination of an 8 year *ogdoades* and an 11 year *hendecades* the individual errors of which cancel out by their juxtapposition. Some of the Dionysian *Argumenta* appear in Ch. 14. It is also explained that the *epactae Solis* (or the *concurrentes dies*) repeat themselves after 28 years; but there is no mention of the great 532 year cycle of Victorius. The work ends with Ch. 16 defining the six ages of the world in terms borrowed from the tradition of St. Jerome and St. Augustine, but with other years for the beginning of each period. The final words of the book referred to the *Sexta ⟨aetas⟩ quae nunc agitur, nulla generationum vel temporum serie certa sed, ut aetas decrepita ipsa, totius saeculi morte finienda,* — a sombre note which caused a certain David to charge Bede with heresy, an accusation which he firmly rejected in his letter *De aetatibus saeculi* addressed to the monk Plewin at Hexham.[103]

The *Liber de temporibus* was a typical example of a brief textbook for a monastic school, with short and clear definitions but no theoretical explanations. No wonder that *some brothers found it far more condensed than they wanted, especially respecting the calculation of Easter, which seemed most useful.*[104] They persuaded Bede to write a longer and more detailed treatise which was finished in A.D. 725 and is known as the *De temporum ratione.*[105] Covering the same ground and constructed along the same lines as the earlier book it was 15 times as long and filled with a wealth of theoretical, technical and historical detail which would satisfy even the most curious student, but still leaving out much which *could be written, but had better been dealt with orally* (Ch. 16), — a remark which reveals that also the major work was intended for the classroom. It became widely used all through the Middle Ages and is still extant in more than one hundred MSS of which forty odd were produced before A.D. 900. This popularity was well deserved. It is no exaggeration to say that no scientific work of comparable value appeared in the Latin world before the 13th century.

An immediate consequence of this wide use of the book was that practically all later computists followed the terminology used by Bede. He did not create very many new technical terms, but his consistent use of well known words in an unambiguous way defined the canonical language of Medieval computistical practice which from now on realised its proper nature as a well-defined and self-reliant branch of the mathematical sciences.

A certain number of new topics in the book represent Bede's personal contribution to the contents of the *computus*. As an example may be quoted a rule for finding the sign of the zodiac in which the moon is found when it has a given age (i.e. on a given date of the lunar month) (Ch. 17). To make this extra clear the same relation is expressed by means of a diagram (Ch. 19) which was later a standard element of computistic treatises. The notion of the epact is made more general by a method of finding the age of the moon on the first day of every month (Ch. 20). The possibility of describing the motion of the moon relative to the zodiac (or, more precisely, to the ecliptic) rests upon a period relation stating that

$$19 \text{ years} = 235 + 19 = 254 \text{ tropical months}$$

which follows from the relation on which the Dionysian cycle was founded since the moon has to make an extra 19 revolutions around the heavens in order to catch up with the sun after 235 lunations. Since a tropical month is 27.3216 days the motion of the moon relative to the zodiac can be described by a series of 27 or 28 letters of the alphabet. Bede uses a simplified system, however, of only 14 *litterae signorum.*

There are several other such curiosities of no importance at all for the Easter computation. Later the motion of the moon through the twelve signs of the heavens became a major topic for a revived Medieval astrology, a subject which is absent from Bede's book, apart from a couple of quotations from the Hexaëmerons of St. Basil of Caesarea and St. Ambrose cited without comment (Ch. 28). Highly original, on the other hand, is the famous Ch. 29 *De concordantia maris et lunae* in which Bede described the tides and their dependence on the moon, partly basing his account on personal observations which enabled him to realise the delay now known as the "establishment of port".

A special feature of the work is the historical setting of much of the material. Bede seems to have believed in the value of the history of science for teaching purposes. Moreover, his historical acumen led to critical discoveries. For instance, his analysis of the months and their names in ancient calendars enable him to prove that the received text of the Anatolian canon had been corrupted, as he revealed in a letter *De aequinoctio vernali* to the priest Vvichtedum.[106]

As in the shorter *Liber de temporibus* the Easter computation is solidly based on Dionysian principles as embodied in the 19 year cycle. But now at long last the great 532 year cycle appears in the very last Ch. 55 *De circulo magno paschae.* It is clearly explained that this cycle can be derived by multiplying the 19 year cycle with 28, and it is underlined that it really makes the Easter Sunday dates repeat themselves. Bede also states that he had provided the book with a complete 532 year cycle beginning in the year 532 *dominicae incarnationis* (when the first Dionysian table started) and continuing until A.D. 1063.[107] The Christian era is dealt with in Ch. 47 *De annis dominicae incarnationis* in which the Dionysian hypothesis A.D. 1 = 753 A.U.C. is accepted, although, as it seems, with some unspoken reservations.

9. *The Medieval Computus*

With the great work of Bede the science of the *computus* had acquired a solid basis. His *De temporum ratione* was a comprehensive monograph, dealing with all the problems of time reckoning both civil and ecclesiastical, and later computists returned to it time and again for guidance when they composed their own treatises. The need for such new expositions arose from the fact that the medieval computus was not only a recondite subject for specialists engaged in producing the actual calendars used in the various dioceses all over the world. From the very beginning it was also an important part of the curriculum of the schools, and as a subject of teaching it always enjoyed a particular status as an indispensable element of Christian learning, even on the elementary level. Again and again St Augustine was quoted for a remark which became a commonplace in all computistical treatises, viz. that *Quatuor sunt necessaria in Domo Domini, scilicet grammatica, musica, canones, et computus.*[108] Grammar was a prerequisite for the preaching of the word of God; music for praising Him in the liturgy of mass and office; canon law for governing the life of the Church and dispensing the sacraments in the proper way; and computus for the correct timing of the ecclesiastical feasts.

Among all these disciplines taught to novices in the monasteries of Europe the *computus* alone represented the exact sciences, keeping some understanding of a mathematical approach to reality alive during the centuries when science in other fields were at a rather low ebb. Here we can mention only a few outstanding representatives of this tradition. First among them was Alcuin (d. 804) whose *De cursu et saltu lunae* [109] implanted the tradition from Bede in the schools of the Carolingian Empire. He was followed by Hrabanus Maurus (d. c. 856) who, in the first great Benedictine school in German lands, taught time-reckoning (and other subjects as well) according to his extant *De computo* [110] from 820, in dialogue form. From the following century we have another *Liber de computo* by one Helpericus monacus Sangallensis [111] and shortly afterwards (ab. 1004) a manual by Byrthfert, a monk of Ramsey in Huntingdonshire.[112] A remarkable section on time reckoning was part of the *Hortus deliciarum* written by the Abbess Herrad of Landsperg (1167-1195) for the instruction of the nuns in her Alsatian convent; it contained a complete 532 Easter cycle of which the section for A.D. 1175 ff is shown in Figure 2.[113] Each year is represented by a square in which we find the date of Easter indicated by a *littera punctata*, the number of days from Christmas day to the first sunday in Lent (*Invocavit*) and indicated by dots (the number of weeks) and vertical strokes (the remaining days), and finally the ferial number of Christmas day the year before (Herrad's New Years Day).

In the second half of the 12th century the old monastic learning began to give way to a new scholastic style, caused by the recovery of much

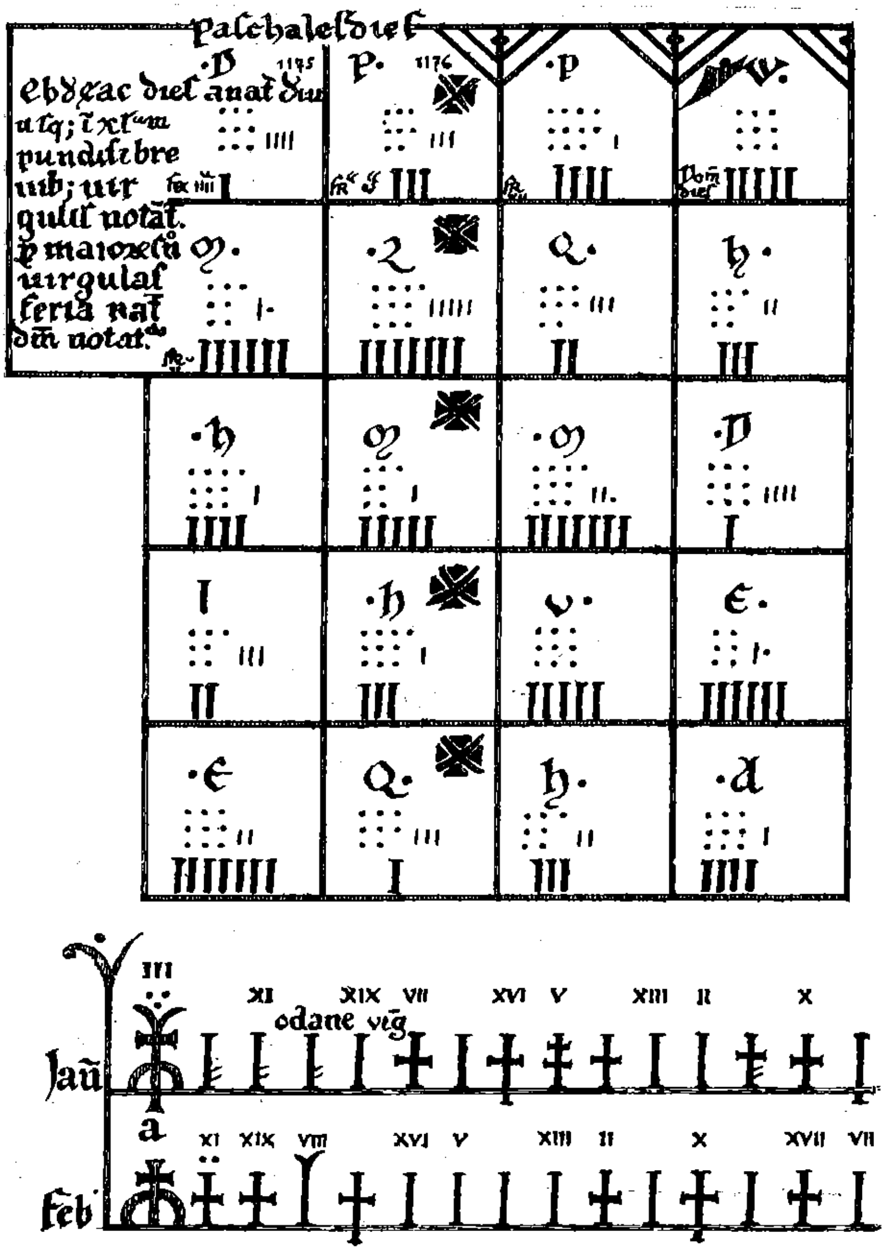

Fig. 2. From Herrad of Landsperg's *Hortus deliciarum*. Above the 20 squares contain the Easter date for the years 1175-1174 (as explained on page 60). Below are two lines from her calendar, showing the beginnings of January and February. The dates are marked by vertical strokes which on feast days are provided with one or two horizontal strokes. Below January 1 is the dominical letter A. The Roman numerals indicate golden numbers. Reproduced from GINZEL III, 230.

of the ancient and Arabic literature and giving rise to the reorganisation of the schools as universities with a greatly extended curriculum; not least the liberal arts in general and astronomy in particular profited by this development which, among other works, made Ptolemy's *Almagest* available in Latin translation. This created a new situation by establishing the possibility of making time reckoning an astronomical science based on planetary theory instead of a mere computistical procedure based on period relations. Nevertheless, the old ways persisted for a long time, creating new manuals full of strange pedagogical tricks. Thus in A.D. 1200 the *Massa Compoti* [114] of Alexander of Villedieu (in Normandy) presented the whole lore of the calendar in the form of a Latin poem of 509 lines; the very numerous extant MSS shows the great popularity it enjoyed in the later Middle Ages. Later in the 13th century an otherwise unknown Magister Anianus published another versified exposition called the *Computus metricus manualis* [115] in which he explained a mnemotechnic device connecting the golden number with the joints of the fingers of the left hand.

It is impossible in a single paper to follow all the variations played by the Medieval computists on the themes inherited from Dionysius and Bede. However, in this final section it may be useful to round off the historical exposition of the previous paragraphs with a brief account of some of the major concepts of the Medieval *computus*, presented in a non-historical setting as an aid to understand the general features of Medieval calendars.

With respect to the year much ambiguity survived all through the Middle Ages. Although the Christian era became universally adopted during these centuries there was still no agreement as to when the year began.[116] As we saw above Herrad of Landsperg reckoned the year from Christmas Day. This was the "Christmas style" or *stylus nativitatis*, sometimes also called *stylus curiae Romanae* since it was often used by the Papal Chancellery. In the civil calendar it was more common to use the *stylus communis* which placed new year's day on 1 January; since this was the feast of the circumcision of Jesus this system was also called *stylus circumcisionis*. In another system the year began in March as in the pre-Julian Roman and some old Germanic calendars. Still another *stylus annunciationis* or *stylus incarnationis* placed new year's day on 25 March which was both the feast of the Annunciation and the old Roman vernal equinox. This custom prevailed in England until the Gregorian Calendar was introduced in 1752. Finally one also had a movable year beginning at Easter, either on Good Friday or on the following day after the *benedictio fontis.* This motley of styles is one of the reasons of the intricacies of Medieval chronology.

Another reason is the many different methods of dating the days of the month. The Middle Ages never completely abandoned the old system based on the *kalendae*, *nonae* and *idus*, but as time went on it was supplemented by a variety of other systems. Already before A.D. 1000 many calendars contain the *dies mensis* reckoned from one to 31; this made dating much more easy; for example, now the *dies sexta Aprilis* followed immediately after the *dies quinta Aprilis*, whereas in the old system this passing of one day would imply a shift from the *nonae Aprilis* to the *8th idus Aprilis.* A strange compromise between the two methods originated in 8th and 9th century Italy and became known as the *consuetudo bononiensis*, or the Bologna custom; here the days were counted forwards from the first of the month in the first half of the present month, but backwards from the first of the next month in the second half of the month.[117] Much more popular, however, was the custom of dating a day relative to a saint's day. Thus 24 June was *dies nativitatis Sti Joannis Baptistae*; 23 June was the *vigilia* of the same day, and 1 July its *dies octava.* Finally a late and rather strange development led to the *Cisiojanus*-system in which each month was correlated to a Latin verse with a number of syllables equal to the number of days of the month.[118] One *Cisiojanus* verse for January ran as follows:

> Cisio Janus Epi sibi vendicat Oc Feli Mar An
> Prisca Fab Ag Vincen Ti Pau Po nobile lumen

where 1 January corresponds to *Ci*, 2 January to *si*, etc. Many of the syllables are derived from the name of the day in the calendar. In consequence the *Cisiojanus* might change from one diocese to another, just as the religious orders would compose verses in which their own saints were prominent.

Turning now from the year and the month to the week the Middle Ages preserved the ancient custom of denoting the weekdays by ferial numbers. The problem was to determine the day of the week corresponding to a given day of the year. We have already mentioned the *concurrentes septimanae*, that is the ferial number of 24 March from which the dates of possible Easter Sundays could be easily found. Other parameters were also connected with 24 March, such as the *regulares solares*, or *regulares mensium.* These were numbers which added to the *concurrentes* would give the ferial number of the first day of each month throughout the year. In the same way one could find the weekday of NISAN xiv (the Easter moon) by adding the *regulares paschae* to the *concurrentes*.[119] This system of accounting for the weekdays by numbers was supplemented by another system using *literae calendarum* according to the correlation

Jan	1	2	3	4	5	6	7	8	9
	A	B	C	D	E	F	G	A	B

and so on throughout the year. In order not to have this correlation perturbed by the intercalary day of a leap year one gave both 24 and 25 February the same letter F so that 1 March would always get the letter D, April 1 the letter G, and so on. It follows that all the days of the year denoted by the same letter must fall on the same day of the week. The question was which weekday that would be.

In order to handle this problem the *litera calendarum* corresponding to the first Sunday of the year was singled out and given the name of the *litera dominicalis*, or the Dominical Letter.[120] If 4 January is a Sunday the dominical letter of the year is D and all days denoted by D are Sundays. Since a common year comprises 52 weeks plus one day the dominical letter must move one letter backwards in the alphabet from one year to the next following. Leap years were given two dominical letters of which the first (in alphabetic order) referred to Sundays after 24 February and the second to Sundays before the intercalary day. In this way the dominical letter will return to the same position after 28 years so that it can be used as an indicator of the position of the year in the 28 year *cyclus solaris* according to the scheme

Dom. letter	GF	E	D	C	BA	G	.....	A
Year of cycle	1	2	3	4	5	6	.....	28

which implies that a solar cycle began in 9 B.C. which was a leap year beginning on a Monday.

Perhaps the most important development took place with respect to the 19 year *cyclus lunaris* after which the dates of the Easter moon repeat themselves. Here the Medieval computists faithfully adhered to the scheme which we know from Dionysius Exiguus, but with some formal changes which greatly influenced the shape and style of Medieval calendars. As we have seen the number of the year in the Dionysiac cycle was correlated to the epact of the moon and was, therefore, in itself determining the date of NISAN xiv. But historically considered this number did not occupy a very conspicuous position, and Dionysius did not attach a specific name to it. In Bede the motion of the moon is characterised by a series of 59 symbols.[121] The first 20 days of a period consisting of one full and one hollow moon in succession were denoted by the first 20 letters A-U of the alphabet; the next 20 days by the same letters provided with a dot after the letter, and the final 19 days by the letters A-T with dots in front of them. These *literae lunares* could be arranged in a table with 19 columns and 59 lines from which it was easy to find the age of the moon during the first two months of each year of the lunar cycle. Since the same symbol corresponds to the same age of the moon, and thus in particular to the same kind of lunation, the table could also be used to find the dates of new or full moons. Continuing the table for another two months one would cover the period in which Easter would fall. The symbols corresponding to dates between the limits of Easter Day (22 March-25 April) became known accordingly as the *literae paschales.*

But already shortly after Bede's time [122] this system began to give way to another method which was at the same time both simpler and more sophisticated. Now the number of the year in the lunar cycle was acknowledged as the most important parameter, — although it had to await the coming of the *Massa Compoti* (A.D. 1200) before it was given the technical denotation of the *numerus aureus*, or Golden Number. It was so defined that the Golden Number was one in the year of the cycle in which the lunar epact (referred to 22 March) was zero. The following year (with the epact 11) got the golden number two, and so on in a way which could be easily presented in the form of a small table.[123]

In principle a given year had only one golden number, indicating the age of the moon on a definite date. If the golden number is one, the age of the moon is zero on a date with this number (in a perpetual calendar). On the following date the age of the moon is one, i.e. equal to the golden number. Since this happens on 23 March in the first year of the cycle it must also happen two lunations, or 59 days earlier, i.e. on 23 January. Accordingly 23 January is marked by the number *one* in the calendar. The following lunations could be found by the usual succession of full and hollow months with the result that the last new moon of the first year would occur on 13 December, and the first of the new year on 12 January. This date was then marked in the calendar by the number *two*. In this way all the new moon dates of all the 19 years of the cycle could be exposed

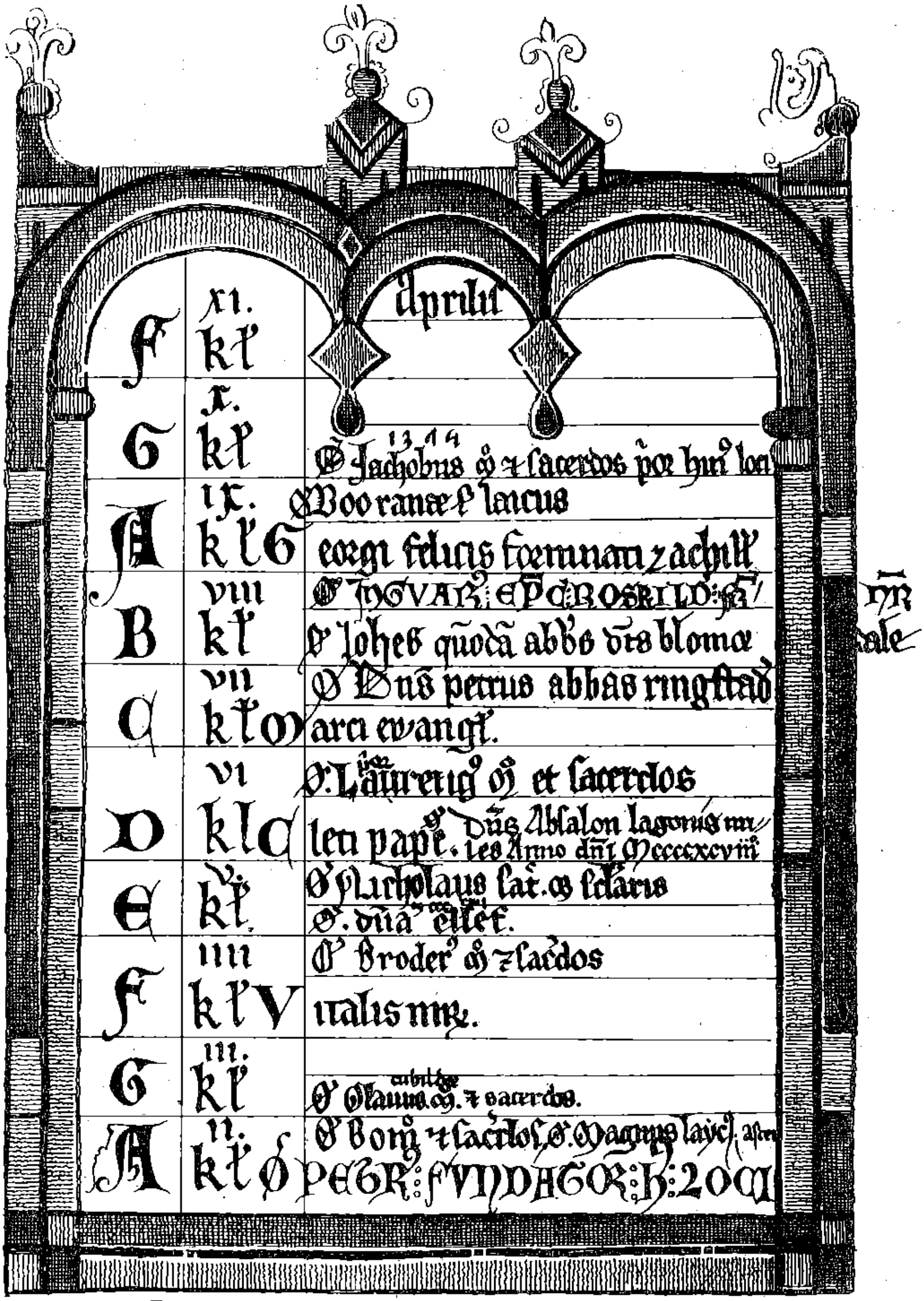

FIG. 3. The end of April in a simple calendar from about 1130, showing *literae calendarum*, Roman dates, saints' days, and obituary notices. From the monastery of Nestved in Denmark. Reproduced from Langebek, *Scriptores Rerum Danicarum*, IV, 305, Hafniae 1786.

TABLE 4.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3	—	3	—	11	—	19	8	16	16	—	13
2	—	11	—	11	—	19	8	16	5	5	13	2
3	11	19	11	—	19	8	—	5	—	13	2	—
4	—	8	—	19	8	16	16	—	13	2	—	10
5	19	—	19	8	—	5	5	13	2	—	10	—
6	8	16	8	16	16	—	—	2	—	10	—	18
7	—	5	—	5	5	13	13	—	10	—	18	7
8	16	—	16	—	—	2	2	10	—	18	7	—
9	5	13	5	13	13	—	—	—	18	7	—	15
10	—	2	—	2	2	10	10	18	7	—	15	4
11	13	—	13	—	—	—	—	7	—	15	4	—
12	2	10	2	10	10	18	18	—	15	4	—	12
13	—	—	—	—	—	7	7	15	4	—	12	1
14	10	18	10	18	18	—	—	4	—	12	1	—
15	—	7	—	7	7	15	15	—	12	1	—	9
16	18	—	18	—	—	4	4	12	1	—	9	—
17	7	15	7	15	15	—	—	1	—	9	—	17
18	—	4	—	4	4	12	12	—	9	—	17	6
19	15	—	15	—	—	1	1	9	—	17	6	—
20	4	12	4	12	12	—	—	—	17	6	—	14
21	—	1	—	1	1	9	9	17	6	—	14	3
22	12	—	12	—	—	—	—	6	—	14	3	—
23	1	9	1	9	9	17	17	—	14	3	—	11
24	—	—	—	—	—	6	6	14	3	—	11	19
25	9	17	9	17	17	—	—	3	—	11	19	—
26	—	6	—	6	6	14	14	—	11	19	—	8
27	17	—	17	—	—	3	3	11	19	—	8	—
28	6	14	6	14	14	—	—	19	—	8	—	16
29	—	—	—	3	3	11	11	—	8	—	16	5
30	14	—	14	—	—	—	19	8	—	16	5	—
31	3	—	3	—	11	—	—	—	—	5	—	13

by the numbers from 1 to 19 distributed on 235 dates within an ordinary calendar for one year as shown in Table 4.

It is seen that these golden numbers usually increase by 8 from one position to another which is found one or two days below the first. This is a consequence of the fact that 99 lunations comprise 8 years plus about 1½ days (cf. the old octaëteris).

Although this presentation of the golden numbers implies no new principles it became of great practical importance as a simple means of finding the date of the Easter moon. A simple calculation according to the *Argumentum V* of Dionysius would provide the

$$\text{golden number} = \text{A.D.} + 1 \bmod 19$$

A glance at the calendar would then locate this number somewhere in February or March whereafter it would be easy to count the days forward to the first full moon which occurred within the limits of NISAN xiv (8 March - April 5). Then the date of Easter day would follow from the *concurrentes*, or the *literae paschales*, or in general from the dominical letter.

To conclude we must remember that the whole *computus* as briefly described here presupposed that the 19 year lunar cycle was a good period relation. That it was a period relation implied that all lunations determined in this way would be mean lunations, taking no account of the equation of the moon, and therefore unable to deal with the behaviour of the observable, true moon. This did not bother the computists who consciously adopted the date of the mean full moon as their NISAN xiv. But another question was whether the period relation was sufficiently precise to be applied over many centuries without corrections. We have seen that 19 Julian years are about 0.06 days longer than 235 synodic months. This means that in about 16 cycles the discrepancy between the true and the computed age of the moon would amount to about one day. Already Bede seems to have been aware of this problem since he devoted a special chapter (43) of the *De temporum ratione* to the question *Quare luna aliquoties maior quam computatur pareat.*[125] However, he chose to do nothing about it and so did all his successors until the 13th century when astronomically competent scholars in the universities began to subject the 19 year cycle to a critical analysis. This was the case of both Robert Grosseteste and Petrus Philomena de Dacia whose calendars tried to give more precise times for the lunations than those derived from the primitive cycle. It was also the case of Roger Bacon whose large *Computus naturalium* from 1263-65 advocated a reform of the traditional practice. But with such attempts we are already touching upon the pre-history of the reform of the calendar, and this subject is outside the scope of the present paper.

REFERENCES

Abbreviations

BEDA	=	the texts edited by C.W. Jones in *Bedae Opera de Temporibus*, Cambridge, Massachusets, 1943.
DACL	=	*Dictionnaire d'Archéologie Chrétienne et de Liturgie.*
DTC	=	*Dictionnaire de Théologie Catholique.*
EUSEB	=	Eusebius of Caesaraea, *Historia Ecclesiastica.*
GINZEL	=	*Handbuch der mathematischen und technischen Chronologie*, Bd. I-III, Leipzig, 1906-14 (reprinted 1958). This standard work has superseded Ideler's much quoted work with the same title, Berlin, 1825-26.
HAMA	=	O. Neugebauer, *A History of Ancient Mathematical Astronomy*, Berlin-Heidelberg-New York, 1975.
ISIDOR	=	Isidore of Sevilla, *Libri XX Etymologiarum*, recn. W.M. Lindsay, Oxford, 1911.
JONES	=	The introduction to *Bedae Opera de Temporibus*, ed. C.W. Jones, Cambridge, Massachusets, 1943.
KRUSCH (1880)	=	B. Krusch, *Studien zur christlich-mittelalterlichen Chronologie, I: Der 84-jährige Osterzyklus und seine Quellen*, Leipzig, 1880.
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KRUSCH (1938)	=	B. Krusch, *Studien zur christlich-mittelalterlichen Chronologie, III: Die Entstehung unserer heutigen Zeitrechnung*, in *Abh. d. Preuss. Akad. d. Wiss.*, Philos.-hist. Klasse, Nr. 8, Berlin 1938.
LITHBERG	=	N. Lithberg, *Computus med särskild hänsyn till runstaven och den borgerliga kalendern*, Stockholm, 1953 (a translation of this important work in Swedish into one of the major languages would be of great value).
MOMMSEN	=	*Monumenta Germaniae Historica, Scriptores Antiquissimi*, Vol. IX, ed. Th. Mommsen, Berlin, 1892.
PG	=	J.P. Migne, *Patrologiae cursus completus: Series Graeca*, Vol. 1-162, Paris, 1857-1912.
PL	=	J.P. Migne, *Patrologiae cursus completus: Series Latina*, Vol. 1-221, Paris, 1884-1864.
VAN WIJK	=	W.E. Van Wijk, *Le nombre d'Or. Étude de Chronologie Technique*, La Haye, 1936.

1. On the Hebrew calendar in general, see GINZEL II, 1-119. - Cf. J. Van Goudoever, *Biblical calendars*, Leiden, 1959.
2. Josephus, *Antiq. Jud.* III, 10, 5.
3. On the Alexandrian calendar, see GINZEL I, 150-237, in particular 222 f. - Cf. HAMA, 1064.

4. On the Roman calendar in general, see GINZEL II, 160-293, in particular pp. 285 f. for the intricacies of the *nundinae* reckoning. - Cf. A. Kirsopp Michels, *The Calendar of the Roman Republic*, Princeton, 1967.

5. The old Roman vernal equinox on March 25 was a conventional date unconnected with the entrance of the sun into Aries, cf. GINZEL II, 281 ff. - See also the Roman calendar printed in PL 27, 675-682 where *Sol in Ariete* is placed on the 16th Kal. April. = 17 March. On the origin of this system see HAMA, 594 ff.

6. On these tendencies in general, see G. Bareille, DTC IV² (1910), 1484-1501.

7. St. Irenaeus, *Adv. Haer.* III, 2, 1; cf. also the antidocetic polemics in St. Ignatius, *Ep. ad Trall.* 9-10.

8. *Epist. ad Diognetum*, 4; I have quoted the Apostolic Fathers from the translation by J.A. Kleist s.j. in *Ancient Christian Writers*, No. 6, Westminster, Maryland, 1948.

9. *Epist. Barn.* 15, 9.

10. On milleniarism in general see G. Bardy, DTC X² (1929), 1760 ff.

11. St. Irenaeus, *Adv. Haer.* V, 31, 1.

12. St. Justinus, *Dial. Tryph.* 80-81.

13. Origen, *De princ.* II, 11, 2.

14. St. Augustine, *De civ. Dei*, XX, 7. - It should be noticed that the rejection of milleniarism did not prevent St. Augustine (or St. Jerome) from assuming a historical scheme of six ages of the world; but these were of varying length and their limiting years had to be determined from chronological information derived from the Old Testament. Cf. E. Portalié, in DCT I² (1937), 2444 ff.

15. *Didache*, 8.

16. Tertullian, *De jejunio*, 2.

17. Clemens Alex., *Strom.* 7, 12.

18. Tertullian, *De jejunio*, 2. - On the Roman *feriae* see GINZEL II, 184 ff.

19. Beda, *De temporum ratione*, Ch. 8, in BEDA, p. 195 ff.

20. St. Augustine, *In Ps. 93*; PL 37, 1192; cf. ISIDOR, V, 30, 9.

21. Edited as part of the *Chronographus Anni CCCLIIII*, in MOMMSEN, 71 ff.

22. It was discovered in 1886 by Wright, *Journ. sacred lit.* (1866), 45 ff.

23. PL 30, 435-486. It is not an authentic work of St. Jerome.

24. *Martyrium Polycarpii*, 21, transl. J.A. Kleist, op. cit., note 8, 100.

25. The later date was defended by H. Grégoire et P. Orgels in *Analecta Boll.* 69 (1951), 1-38; but see H. Marrou, ibid., 71 (1953), 1-20.

26. *Martyrium Polycarpii*, 18.

27. Clemens Alex., *Strom.* I, 21.

28. St. Paul's words in *1 Cor.* 5, 7 ff. have sometimes been construed as evidence of an Easter celebration already in Apostolic times.

29. Socrates, *Historia ecclesiastica*, V, 22.

30. *Epist. ad Diogn.*, 12.

31. EUSEB, V, 26.

32. It seems that the 'Eastern' Easter practice was observed in Rome until ab. A.D. 120; see H. Leclercq, DACL XIII² (1937), 1524.

33. St. Irenaeus ap. EUSEB V, 27.

34. The letter of St. Ireneus is preserved in EUSEB, V, 27.
35. Melito's *Peri Pascha* was found in 1940 in a papyrus. It is edited (with a French translation) by O. Perler in *Sources Chrétiennes*, Vol. 123, Paris, 1966.
36. According to Eutychius, *Annales*, PG 3, 989.
37. EUSEB, VII, 20-21; cf. F.C. Coneybeare, "Newly discovered letters of Dionysius of Alexandria", *Eng. hist. rev.* 25 (1910), 111-114.
38. EUSEB, VII, 20.
39. On the history of the Greek octaëteris, see GINZEL II, 373 f.; cf. HAMA, 584 ff.
40. EUSEB, VI, 22.
41. See H. Leclercq in DACL VI[2] (1925), 2419-2483 for the extensive literature on the subject, and for a new transcription of the text (based on photographs). An earlier version by A. Boucher in his *De doctrina temporum*, Antwerp, 1664, is reprinted in PG 10, 875-884.
42. After Leclercq, op. cit., note 41, col. 2425-26.
43. According to H.H. Goldstine, *New and full moons 1001 B.C. to A.D. 1651*, Philadelphia, 1973 (Memoirs of the Amer. Phil. Soc., Vol. 94) from which also other lunation dates quoted in the following are taken.
44. The table is here re-examined because of a number of errors and unneccessary complications in Leclercq (see note 41 above) although I have relied upon his transcription.
45. Cf. op. cit., note 5 above.
46. O. Neugebauer, HAMA, 569, n. 8 states that Demetrius used the octaëteris. This is a reasonable guess. He also maintains that it was transmitted to Rome and used by Hippolytus; but of this there is no direct evidence.
47. On the octaëteris as a Roman cycle, see GINZEL II, 234 ff.
48. JONES, 13 spoke of this particular 112 year table as an extended revision of Hippolytus's 16 year cycle; but if the interpretation offered above is correct, already Hippolytus himself extended his table to 112 years. The relations between the Hippolytan and the Pseudo-Cyprian tables need further investigation. The Pseudo-Cyprian text was edited by John Fell, revised by John Wallis and published with notes by Henry Dodwell; it is reprinted in PL 4, 1021-1054.
49. JONES, 12 ff.
50. KRUSCH (1880).
51. The term *cyclus solaris* was unknown to Bede but appeared in an anonymous *Liber de computo* from A.D. 810 or earlier, published by Muratori, *Anecdota*, Milan, 1697-98. It is printed in PL 129, 1273-1372, in part. 1322. - Cf. VAN WIJK, 115.
52. The term *saltus lunae* was unknown to ISIDOR but was used by BEDA, 255. - For its history in general see Jones in BEDA, 375 ff.
53. Edited in MOMMSEN, 62-64.
54. Edited by MOMMSEN, 739-43.
55. According to EUSEB X, 5. Cf. the different version in Lactantius, *De mortibus persecutorum*, 48.
56. Eusebius, *Vita Constantini*, IV, 18-20; cf. Sozomenos, *Historia ecclesiastica*, I, 8, and *Codex Iust.*, III, 15, 2.
57. GINZEL III, 186, after *Corpus inscr. lat.* III, No. 4121.
58. Canon 29, Mansi, *Sanctorum Conciliorum Amplissima Collectio*, II, 1759.
59. *Cod. Theod.* XV, 5; cf. GINZEL III, 186.

60. Canon 1, Mansi, *Concilia* II (1759), 463.
61. Canon 20, Mansi, *Concilia* II (1759), 635.
62. Theodoret, *Historia ecclesiastica,* I, 9.
63. Eusebius, *Vita Constantini,* III, 13, 17; cf. Theodoret, op. cit., I, 10.
64. Canon 1, PG 67, col. 60.
65. Canon 7, PG 67, col. 70.
66. PL 54, 1055-58. - Marcianus was the East Roman Emperor in Constantinople.
67. On the Metonic cycle in general, see HAMA, 354 ff. and 622 ff.
68. EUSEB VII, 32-33. This presupposes that the *Sti Anatolii Alexandrini Canon Paschalis* is a spurious work, perhaps written in Ireland or at Iona in the seventh century, see C.H. Turner, "The Paschal Canon of 'Anatolius of Laodicaea'", *Eng. hist. rev.*, 10 (1895), 699-710. The text is printed with Boucher's commentary in PG 10, 209-252.
69. GINZEL III, 233.
70. A 19 year canon by Eusebius is mentioned by St. Jerome, *De viris illustribus*, 61, PL 23, 207, and following him by ISIDOR VI, 17, and BEDA, *De temporum ratione*, Ch. 44.
71. The 13 known Paschal Letters by St. Athanasius were recovered in 1847 in a Syriac version. A few other fragments have survived in Greek. They were published by F. Larsow, *Die Festbriefe des hl. Athanasius,* Lpz.-Göttingen, 1852. - A reconstruction of the Athanasian Easter Canon has been attempted by VAN WIJK, 11.
72. According to JONES, 27.
73. St. Augustine, *Epist. 23.*
74. It is preserved in a copy by Dionysius Exiguus, ed. KRUSCH (1938) 69, but in a 'Roman' Arrangement which must be a fabrication by Dionysius himself.
75. PG 65, 47-52.
76. Published by F.C. Coneybeare, *The Armenian version of Revelation,* London, 1907, 215-221. It shows that Cyrillus constructed his table for 6 × 19 years = 114 years, ending with A. Diocl. 228 (A.D. 512).
77. PL 129, 1275-78.
78. KRUSCH (1880), 89-98.
79. JONES, 39 ff. (edition and Eng. transl.).
80. JONES, 31 ff.
81. See the various hypotheses mentioned by GINZEL, III, 144. The explanation offered by JONES, 33, cannot be the true one.
82. JONES, 71 ff.
83. See JONES, 34 ff., and C.W. Jones, "The Victorian and Dionysian Paschal Tables in the West", *Speculum* 9 (1934), 408-421.
84. PL 54, 1057.
85. JONES, 55 ff.
86. The letter is printed with Victorius's reply in MOMMSEN, 677 ff. An improved version of the text is due to KRUSCH (1938), 16-26.
87. They were later ascribed to Bede and placed among his works in PL 90, 645 ff.
88. JONES, 64.
89. See the more detailed analysis in JONES, 66 ff.
90. PL 67, 135-346.

91. The critical edition by KRUSCH (1938), 63 f. has superseded the earlier text printed in PL 67, 453 ff.
92. KRUSCH (1938), 64.
93. On this debate see the remarks in JONES, 70 ff. and GINZEL III, 178 ff.
94. O. Neugebauer, "On the Computus Paschalis of 'Cassiodorus'", *Centaurus* 25[4] (1982), 292-302.
95. KRUSCH (1938), 63 did not comment on this error which is absent from the version in the PL 67.
96. ISIDOR VI, 17.
97. PL 67, 467 n. (b).
98. The text is printed in PG 10, 209-252.
99. JONES, 82 ff.
100. Ed. KRUSCH (1938), 53-57.
101. There are very many editions and translations of this famous work. I have used the recent translation by L. Shirley-Price, *Bede: A history of the English church and people*, London, 1955.
102. BEDA, 295-303.
103. See JONES, 132 ff. - The letter is in BEDA, 307-315.
104. See the Prologue to the *De temporum ratione*, in BEDA, 175.
105. BEDA, 175-291.
106. BEDA, 319-325; cf. JONES, 139.
107. The table is printed (with a later continuation) in PL 90, 859-878.
108. I have not been able to verify this quotation in the work of St. Augustine. It has a non-Augustinian, monastic flavour and seems to be of a later date.
109. PL 101, 979-1002.
110. PL 107, 670-728.
111. PL 137, 18-48.
112. Ed. S.J. Crawford, London 1929 (for the Early English Text Society). Much of the Manual is printed as glossae to Bede's *De temporum ratione* in PL 90, 293 ff.
113. After C.M. Engelhardt, *Herrad von Landsperg*, Stuttgart-Tübingen, 1818; cf. GINZEL III, 230.
114. Ed. VAN WIJK, 52-64, followed by a French translation and commentary.
115. D.E. Smith, *Le comput manual de magister Anianus*, Paris, 1928. Cf. S.B. Gaythorpe: The lunar hand-calendar of Magister Anianus, *Journ. Brit. Astr. Ass.* 69 (1960), 80-87.
116. GINZEL III, 153 ff.
117. GINZEL III, 121 ff.
118. GINZEL III, 122 ff., cf. LITHBERG, 33-56.
119. GINZEL III, 143 ff.
120. GINZEL III, 124 ff., cf. LITHBERG, 57-65.
121. *De temporum ratione*, Ch. 23, in BEDA, 224 ff.
122. As proved by LITHBERG, 67.
123. See the table in LITHBERG, 224.
124. From LITHBERG, 76.
125. BEDA, 257 ff.

THE WESTERN CALENDAR - "INTOLERABILIS, HORRIBILIS, ET DERISIBILIS"; FOUR CENTURIES OF DISCONTENT

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> [*Kalendarium*] *est intolerabilis omni sapienti, et horribilis omni astronomo, et derisibilis ab omni computista.*
>
> Roger Bacon, *Op. ter.*, cap. 1 xvii

When it comes to calendars, we are most of us realists.[1] Although a calendar is essentially a means of referring a particular event to a day or a year unambiguously, so that other events may be correlated with it, the calendar is a system of names that have taken on a life of their own. It is a system of associations — of religious sentiment with season, for example, and of season with Name. "Rough winds do shake the darling buds of May", said Shakespeare at some date after the Gregorian reform, but well over a century before his own country had adopted it. He would have been ill served by his fellow countrymen had the seasons been allowed to slip through the calendar to a point where May became a winter month. There you have an obvious problem that most can see; but the Church's calendar is less obvious, for it is not only bound to the seasons; it is bound to three sorts of natural phenomena, or at least idealized natural phenomena, namely those marking the limits of year, month, and day. We, with our cut and dried view of time-keeping, we who gather together to celebrate events four hundred tropical years after they have occurred, are all too easily inclined to overlook the real reason for all the fuss in the middle ages about calendar reform. It was not primarily a matter of losing ten or eleven days of one's life (which seems to be the only consequence the average student of history is aware of), or of getting the agricultural cycles back to where they had once been in the calendar. (Had early Jewish history been known, where Passover was made to coincide with the earing of the corn, medieval astronomers would perhaps have been consumed with less scientific self-righteousness.) It cannot be said too often that the problem was more than that of getting the right value for the length of the tropical year, and inventing a rule to give a high level approximation to it. The real key to the movement for reform was the desire to celebrate Easter at the "correct" time. This was of concern, as Bacon said, to the computist and the wise, as well as to the astronomer; but of course it was of central importance to *every Christian*, for whom the death and resurrection of Christ were the most important events in human history.

1. *The Early History of the Christian Calendar and Its Astronomical Frame*

The "correct" time of Easter. It is hard to look into the history of Easter celebration without growing despondent at the excesses of misplaced scientific zeal to which it testifies. I have to say this at the outset, because I shall shortly be judging my characters by their scientific worth, that is, accepting their premisses as to the way in which Easter should be computed, and assessing the extent to which they managed to satisfy those premisses. As for Easter, the rule finally agreed was that it must be celebrated on the *Sunday next after (and not on) the 14th day of the Paschal moon, reckoned from the day of the new moon inclusive.* The Paschal moon is *the calendar moon whose 14th day falls on, or is the next following, the vernal equinox, taken as 21 March.*[2] At last we can see why the Gregorian reform mattered so much. The vernal equinox used to determine Easter was a conventional one, just as the calendar moon was conventional; both were clearly meant to be *good* conventions, and yet as the centuries went by, they both got steadily worse, judged by the phenomena. You might ask who cares, if they are truly conventional, whether Moon and equinox correspond with the phenomena. Not all theologians agreed as to the rightness of celebrating Easter when the positions of Sun and Moon are propitious, and some even thought that to insist on the "correct" (historical) disposition of Sun and Moon was to court astrological principles. This is not an aside to the subject of our meeting, for the scientific chronologists whose praises we are here to sing are the very ones who wanted an exact correspondence with the phenomena!

As for those Christians who wanted Easters to fit the historico-astronomical pattern, Dante is the supreme example.

Conventions as to Moon and equinox were inevitably imperfect, when measured against the phenomena — that, after all, is what the astronomical sciences are all about — but unfortunately the debate was often entangled with one over conventions having nothing to do with the observable. When scholars argued, for instance, for the use of the 84 year cycle in preference to the 19 year cycle, they would not have been inconsistent had they said, in effect, that they knew that it gave inferior results, but that there were virtues in the whole church sticking to the same deviation from the empirical norm. And yet the empirical test was *available*. In arguing, on the other hand, for or against an Easter falling as late as days xxi and xxii of the moon, only traditions could help. (The traditions included, of course, traditions of inclusive and exclusive counting!).

There are several possible ways of presenting the conventions of the first, empirical, kind, but there is nothing to be gained by losing ourselves in a sea of figures, so I will confine myself to two rough and ready assessments, one of the "slip" of the lunar cycle, the other the "drift" of the vernal equinox. (I use these words to avoid confusion). Suppose there are m days (actual) in a lunation. Those using a 19-year cycle (235 calendar months in 19 years) say in effect that the length of an average year is $235\,m/19$ days. They do not have to accept a Julian year, but if they do so their calendar year will be too long by $(365\frac{1}{4} - 235\,m/19)$ days, judging it, that is to say, by the length of the year implied by their lunar calendar *in conjunction with* a value for the lunation. Suppose now that *we* supply a reasonably good figure for this — say 29.530589 days, which is acceptable for our purposes (to a small fraction of a second) for the whole of our era. It is easily verified that if this and the "Metonic" ratio be accepted, the Julian year must be 0.00324 days too long. If we accept the Julian calendar as our norm, then we can say that the lunar calendar based on the "Metonic" cycle slips by one day in roughly 308 years. I shall here denote this important parameter by "M", and suppose that as a reasonable ideal, $M = 308.5$ during the historical period under review. Note that the value of M has nothing to do with the figure we should offer if asked independently for the length of the tropical year. It is a measure of the *joint* efficiency of two conventions, "Julian" and "Metonic" (although other conventions could be substituted for either of them), judged by the counting of days and the phases of the Moon.

To get an idea of the superiority of the 235/19 convention, as against the main historical alternatives, all taken with a Julian calendar, the old 99/8 convention (99 months making 8 years) leads to a slip of one day every 5 years, roughly speaking; the 136/11 convention slips by a day in roughly 7 years; and the 1039/84 convention slips by a day in roughly 66 years. One could make other comparisons, for example, between expectations, based on the calendar used, and those based on astronomical tables, such as the Toledan or Alfonsine. They would not be very different from mine. For the time being it should be enough to realise that a good observer of new moons (and lunar phases are not easy to observe in themselves) would have been very dissatisfied with any but the 235/19 convention within a century or so, at most, of the drafting of the moon tables he inherited; and that even tables drawn up on that convention (or its equivalents taking a 76-year cycle) would have shown their weaknesses within perhaps five or six centuries. Bede, in chapter 43 of his *De ratione temporum* (A.D. 725; a long work, since his brethren found the shorter *De temporibus* of 703 incomprehensible), noted that the full moon was ahead of its date as tabulated. Eclipses were often recorded as being ahead of the new moon of the tables. But more significantly, Robert Grosseteste gave a quantitative assessment of the accumulating error. In 304 years, he wrote, the moon is $1^d\ 6^m\ 40^s$ older than the calendar says.[3] Here he chose 304 as being four full cycles of 76 years. The minutes and seconds are minutes (sixtieths) of a *day*, and sixtieths of them — a point that some commentators have not appreciated. On this reckoning, the tables slip out of phase by one day in 273.6 years. Grosseteste's, like my 308.5, was a *calculated* figure, and had nothing to do with his own observations. In fact it rested on an approximation of $29^d\ 31^m\ 50^s$ (again minutes of a day) for the lunation, taken from Ptolemy but agreeing with *all* other serious writers, if we round off beyond the seconds, on this convention. (Ptolemy had 29; 31, 50, 04, 09, 20).

The other conventions empirically testable are the tropical year length implicit in the Julian calendar itself, and the date assigned to the equinox. The length of the year may be taken as 365.2423154 days at the origin of our era, decreasing by about 6.13×10^{-6} days per century. Thus in the year 1000 the tropical year differed from the Julian by 0.00768 days, which means that on this account the whole calendar was drifting by one day in a little over 130.1 years. For the year 1500 the drift was one day in about 128.6 years. I will call the reciprocal of this number (J) the "Julian excess", so that the true length of the tropical year is $(365\frac{1}{4} - 1/J)$ days. The Gregorian reform effectively took $J = 400/3$, or 133.3. A better figure for 1582 would have been 128.5. (As a working rule, accurate to the nearest 0.1, the value of J for the year Y A.D. (between 1 and 1600) is given by $130.1 - Y/1000$). As we shall see, the general opinion prevailing in the sixteenth century was that $J = 134$, although there were rival opinions. The advantages of a system wherein we discount three bissextile (leap-year) days every four centuries are considerable, however.

The question then arises, where are we to find our value for J? One of the most striking things about the late middle ages is that very few of the figures quoted in this connection originated in the Christian world itself, vigorous though astronomical activity was. Even more significant — and I think there is a lesson to be learned here about the tenuous nature of medieval feeling for anything meriting the name of scientific progress — are the erratic and unprincipled changes in the values accepted for J. The reason is very simply the eclecticism of the time. Admittedly the Ptolemaic value of 300 is not much in evidence after the thirteenth century, but three important early sources, namely Al-Battānī, Thābit ibn Qurra, and Az-Zarqellu (Arzachel as I shall call him), with respectively $J = 106$, 130, and 136, all come to the surface regularly, and do so long after the Alfonsine 134, which enters the world of the church calendar around the mid-fourteenth century, a good seventy years after the original recension of the tables. (More precisely, when the value is implicit in "Alfonsine" work, rather than explicit, one finds $J = 134.2$) I shall discuss these unsystematic changes of heart as they occur. Finally, for future reference, I note that Clavius claimed that for the Gregorian reform the mean of Copernicus' maximum and minimum values for the tropical year was accepted, namely $365^d\,5^h\,49^m\,16.4^s$, the mean of $365^d\,5^h\,55^m\,37.7^s$ and $365^d\,5^h\,42^m\,55.1^s$. The corresponding values for J are 134.2 (mean year), 329.4 (max.) and 84.3 (min.). The vital 134.2 is the Alfonsine value, and no juggling with figures is going to prove or disprove Clavius' contention, which must be left to the historian. Provisionally, we can say that the weight of Copernicus' authority was added to a long-discussed Alfonsine parameter.

The last empirical decision concerns the date of the vernal equinox and the rules for its adjustment — both necessary for a strictly "phenomenological" Easter calculation, if not for a workable civil calendar. If tropical coordinates are used in the theory of the Sun, then the "movement of the eighth sphere" (corresponding to the modern precession of the equinoxes, and in the middle ages often taken to be of the nature of a trepidation) is of no immediate consequence, and I shall have little occasion to mention it again. The drift of the equinoxes through the calendar by reason of the incommensurability of the Julian and tropical years is something of which I have spoken already; but I should add, for those who have not given the matter any thought, that the equinox's precise hour (and sometimes even day, when we are in the neighbourhood of the day division)[4] moves about in roughly six hour units from one year to the next, thanks to the odd quarter day in the tropical year. Most writers on the calendar are content to name the *date* of equinox (or solstice), "for the present time", showing at once their unscientific approach. As for the date, the general assumptions were that for the vernal equinox in the time of Julius Caesar, 25 March was correct; that at the time of the Council of Nicaea the date was 21 March, the canonical date; and that the current date was (from say 1200 onwards) of the order of ten days earlier. I will illustrate the dangers of these assumptions with an example. The Florentine monk John Lucidus, in a work on the emendation of the calendar written in 1525, and published in 1546, argued that since the equinox in Caesar's time was 25 March and since that in his own day it was 10 March, it had moved 15 days in 1590 years, making J = 106.[5] This comforted him, for it gave al-Battānī's figure! In fact the interval of 1590 years is not an integral number of leap year cycles; and in 64 B.C. (− 63, but an error for 45 B.C.), the first year after a leap year, the equinox was approximately 9 a.m on 23 March, at Greenwich. (In Florence roughly 45 minutes earlier.) In 1525, it was at nearly 5 a.m on 11 March (Greenwich). The difference would lead one to suppose that J = 130.4, substantially different from 106. Of course Lucidus was dependent on traditions he was simply incapable of veryfying. He would have been only marginally safer had he turned to such astronomical data as those of *Almagest* for his information as to the date and time of an early equinox.

2. *Growing Dissatisfaction and Grosseteste's Proposal for Reform*

Complaints over the drift of the dates of equinoxes and solstices were as common in the early middle ages as those over the inadequacies of the ecclesiastical lunar calendars. Conrad of Strasburg, writing in the year 1200, commented on both phenomena, and set the retreat of the winter solstice at ten days, from the 25 March of antiquity.[6] The figure of ten days became canonical in some quarters for three centuries (although there was often confusion as regards the "base" date, since 21 March was that accepted by the Council of Nicaea) even though its progression was the very matter under discussion. Conrad offered no programme of reform, but Grosseteste had done so perhaps before 1220, and Sacrobosco by perhaps 1232. So many are the difficulties of dating their writings — for example on the sphere — that the line of influence here is hard to establish with certainty, but generally speaking Sacrobosco seems to follows Grosseteste rather than lead him; and on the calendar he yet seems more superficial. As already explained, Grosseteste favoured a 76 year cycle (4×19), although since this slips by a day in approximately three centuries (see above) he recommended discarding one day in the lunar calendar exactly every three centuries. He emphasized that the earliest Easter terminus must be 14 March rather than 21 March.[7] He stressed the importance of precise measurements of the length of the tropical year, and in his review of earlier data (Hipparchus/Ptolemy, al-Battānī, Thābit, and others), as well as in his admiration for the lunae-solar cycle of Arab time-reckoning, he set a fashion that would last until the seventeenth century and beyond in Christian intellectual circles. Sacrobosco, by contrast, looked back to more conservative sources, including Bede, who had said that the Julian year is too long by a twelfth part of an hour (and thus $J = 12 \times 24 = 288$), and Eusebius, who had said that in the year of Christ's birth there was a new moon at 23 March. For my "M", the slip of the lunar calendar, he based his calculation on Ptolemaic data — but with more approximations than Grosseteste and made recommendations as to a shift in the lunar calendar of four days (23 January to 19 January, 1232). He was prepared to go against the Council of Nicaea as regards his final scheme, and in this he helped to prepare the ground for more radical later reformers. As for the ten day error in the date of equinox, he recommended tampering with leap years — omitting the bissextile day for a period of forty years, thus shifting the calendar by the right amount. He never made it clear that he had seen all the implications (especially of the interlocking of lunar and solar calendars) of his scheme, but his writings complement those of Grosseteste, and they provided patterns for future debate.[8]

Both by his criticism of Grosseteste and his borrowings, Campanus of Novara made it clear that he had the Oxford chancellor and bishop of Lincoln very much in his thoughts as he wrote on the calendar.[9] What marks Campanus out from the great majority of contemporary computists — take Vincent of Beauvais, for instance, as an almost exact contemporary, still under Conrad's influence, but having somewhere picked up a value of 120 for J —[10] is his astronomical expertise. It is not that Grosseteste and Sacrobosco were incompetent, but that Campanus was a practised calculator, *au courant* with much of the astronomy then creeping into Europe from the Islamic world; and here the theory of trepidation is a good example of something capable of separating sheep from goats. Like Grosseteste he was an admirer of the lunae-solar calendar (with its 30 year cycle of a 354 day year, into which 11 days are intercalated), as indeed was Roger Bacon, who in turn seems to have been an admirer of Campanus. (Bacon in 1267 named him as one of the four best contemporary mathematicians, and the English connection is an interesting one. Although it is not proven that he ever left Italy, he might have accompanied Cardinal Ottobono to England in 1265-8; and — whether or not *in absentia* — there is a good chance that he held the benefice of Felmersham in Bedfordshire from those years onwards).[11] Perhaps his insistence that the cumulative errors in the Easter computus be corrected "by astronomical instruments and tables" carried some weight, but if so, there was no very obvious flurry of activity in the empirical determination of equinox and paschal full moon by his readers.

3. *Clement IV, Bacon, and His Time*

Much the same might be said of Roger Bacon, but with Bacon the whole subject takes on a new ecclesiastical dimension, with the sort of papal interest necessary — but unfortunately not sufficient — for an accepted programme of reform. Bacon's entire career pivots around the papal mandate sent by Clement IV in 1266, and preceded (5 February, 1265) by a request by Clement (strictly speaking this was before he became pope, and was thus writing as Guy de Foulques) for a copy of his comprehensive philosophical writings about which rumours were then circulating. The *Opus maius*, no less than the *Opus minus*, a supplementary work with a suitably eulogistic introduction and dedication to Clement, not only reached papal eyes, but it came at papal behest; and the somewhat mysterious passage in the papal mandate that has been seen by some as an allusion to alchemical secrets might very well, it seems to me, be no more than a reference to an earlier suggestion (by Bacon to Foulques) concerning calendar reform.[12] Note, incidentally, that a passage on the calendar occurs, word for word, in the *Opus tertium*[13] and in the *Opus maius*,[14] and that this repeats sentences taken from Grosseteste's *Computus*.[15] Bacon himself acknowledged that other computists had found fault with the calendar before him; but one point is worth mentioning, namely his statement to the effect that J = 130, which he later changed to 125, both better than

Ptolemy. The first, admittedly, is found in other writers quoted from Thābit,[16] and need not have been original, whilst the second seems to rest on a calculation of the sort I gave earlier from the monk Lucidus, as liable to lead to appreciable error. Now it is that since the equinox in 140 A.D. (Ptolemy) was 22 March, and in 1267 13 March, the drift is to be reckoned as one day in 1127/9 (approx. 125) years. He was not to know that Ptolemy's measurement was 30^h in error.

Bacon's reform proposals, in brief, were thus the removal of a day every 125 years, together with either the adoption of the lunae-solar year of the eastern nations or a thoroughgoing astronomical approach to the fixing of Easter, even using Hebrew tables! If we are to divide our history into periods, Bacon would seem to mark the end of the first significant period of initiatives to reform. At more or less the time of his exchanges with Clement, the Alfonsine tables were being prepared, but they were not to penetrate northern Europe effectively for another seventy or eighty years,[17] and even after their arrival we shall find echoes of our first "heroic" age, the age of Grosseteste and Sacrobosco, Campanus and Bacon. After Bacon we find occasional evidence of equinox determinations — as for instance in the tract "to show the falsity of our calendar" by a brother "John of S." (not Sacrobosco) around 1273.[18] This is an important period, too, for the composition of computi: especially noteworthy from the point of view of his influence is William Durand (not Durand of St. Pourçain) and his *Rationale divinorum officiorum* of around 1280. This fundamental work in the history of western liturgy — and the first non-biblical work to appear in print, namely in 1459 — was in eight books, of which the last is a computus. Several computi appeared around the year 1292 (a year that can never be taken with confidence as a year of composition, even when it appears in titles, since it marks the beginning of a new lunar cycle, i.e. has golden number 1, whether on the 19 year or 76 year convention), including those of Peter of Dacia [19] and William of St. Cloud. William, who was writing for Mary of Brabant, Queen of France, helped to establish a fashion that cannot have failed to promote a sense of the fundamental importance of astronomy in the matter of the calendar. He added much highly technical material to his own — the solar altitude at noon, hours of new moon, diurnal and nocturnal arcs, and a table that allowed the conscientious calculator to make corrections to the basic table (covering four years only) of the entry of the Sun into the zodiacal signs, and *a fortiori* into Aries. Of course, this sort of conscientiousness led to the discovery of error and hence to frustration. Was it not Bacon who had drawn Clement's attention to the fact that in 1267 the Church was a week out, in its celebration of Easter? But then, frustration is the spur to reform.

4. *Changing Styles in Astronomical Tables. Firmin of Belleval, John of Murs, and Clement VI*

Apart from his *kalendarium regine*, William of St. Cloud compiled a planetary almanac — that is, an ephemeris, giving in his case planetary positions for twenty years commencing 1292, and based on the Toledan and Toulousan tables.[20] A whole generation later, such good astronomers as John of Murs and Geoffrey of Meaux were relying on the same well worn sources. John, in his work beginning "Autores calendarii nostri duo principaliter tractaverunt..." says categorically that the tables of Toulouse are the best available, and this in 1317; while in a calendar running from 1320 to 1340 (and therefore compiled around 1319 or 1320) Geoffrey said that he preferred the Toledan tables to the Alfonsine![21] This is the time of the Parisian reception of the later tables, and they were to make their presence felt in English circles shortly afterwards; and yet the Toledan tables were still in circulation in some quarters a century later. In his later work (1337?) on the art of the computus, John of Murs proposed certain reforms of a fairly conventional sort: he made complaints about the casual and inaccurate way computists had of expressing themselves; proposed that ten days be dropped either by suppression of the bissextile intercalation for forty years (Sacrobosco's proposal) or the shortening of a suitable number of months by a day each; and canvassed for the 76-year lunar cycle, which Grosseteste had done long before. The Church was not, however, in desperate need of anything more than the thirteenth century authorities, duly sifted, could provide, and John of Murs certainly had ecclesiastical interests at heart, as is clear from the advice he gave in response to Clement VI's request of 1344. (In the work of 1317, if indeed it was his, he had deplored the way in which the Jews had ridiculed Christians for their error in the date of Easter in 1291. This sort of complaint was not uncommon in the middle ages, and one must suppose that here we have another stimulus to reform, not exactly ecumenical, but anticipating some of the ecumenical motives of the fifteenth century.)

On 25 September, 1344 (rather appropriately, since the day was that of St. Firmin, Bishop of Amiens) Pope Clement VI wrote to Firmin of Belleval in the diocese of Amiens and to John of Murs, canon of the church of Mazières in the diocese of Bourges, inviting them to Avignon to consider and advise on the correction of the calendar.[22] Their expenses were to be met by the bishops of Amiens and Paris. The resulting treatise by the two scholars [23] begins by referring to the papal mandate, and names the cardinal of Rodez as the man who directed their work. The Easter calculation was uppermost in the pope's (and hence their own) reckoning; the solar calendar offered a simpler astronomical problem but a harder ecclesiastical one. If the equinox were to be moved through the calendar, what of the celebration of such fixed feasts as Christmas by the schismatic sects? What hopes for church unity, if different groups were to celebrate feasts on different days? Better to leave the solar calendar alone? Of course ideally they would have liked to shorten one year by the appropriate amount, even though it lead to tumult in the courts of princes, not to mention difficulties over civil contracts. In all their estimates of the true astronomical situation, be it noted, they were at last using the *Alfonsine* tables, with $J = 134$, for instance, and $M = 310.7$.[24] Solar reckoning apart, the lunar calendar should be adjusted, they said, by setting back the golden numbers (written down the side of calendars) by a day every 310 years. They expressed a preference for bringing the calendar Moon back to reality before instituting this scheme. (The calendar moon was then 4 days out.) To clarify matters, they prepared a calendar volvelle, of a general type well known to most students of the computus — and that meant most university students.

Firmin and John suggested that the reform take effect from the year 1349, the first after a leap year, and the first of golden number 1 after their report. This report was ready by 1345 ("Sanctissimo in Christo patri ac domino..."), but Clement was subject to many distractions in the four year interval. There was his struggle with the emperor Louis of Bavaria, ending in Louis's excommunication and death in October 1347; there were his protracted negotiations with the Greek emperor John Cantacuzenus, and with the Armenians, in the interests of church unity; and his resistance to the claims of the kings of England, Castile, and Aragon to a share in ecclesiastical jurisdiction, now in the interests of French unity; and then there was the terrible plague of 1347-8. By comparison, the calendar must have seemed a trifle. At all events, the joint report was not heeded. Clement died in 1352 and was buried at Auvergne. Ironically, his tomb was destroyed by Calvinists in 1562, during the final sessions of the Council of Trent.

If the Avignon reformers got nowhere, at least it can be said that papal patronage concentrated their minds, and gave rise to a moderately coherent proposal. One of the marks of those reforms that were proposed without strong ecclesiastical support is their tendency to eclecticism, and to a rather hopeless rehearsal of complaints. There are several plaintive fourteenth century texts surviving that for these reasons seem to me to be lacking in intrinsic interest. Here I might mention Robert Holcot, whose criticism, set down in Oxford around 1330, is very largely taken from Grosseteste, and John de Thermis, who in writing for Innocent VI in 1354 ("Easter in 1356 will be wrongly celebrated by five weeks") was perhaps even making use of so old an authority as Vincent of Beauvais.[25] There is the case of the English Franciscan John Somer, who is reputed to have written a work beginning "Corruptio calendarii horribilis est", but of this it is impossible to speak with any certainty, and those opening words do ring of the quotation from Roger Bacon with which I began this chapter. Such works were not, of course, the prerogative of the Western Church. The Greek church too had its would-be reformers, and there was also some interesting Jewish work on the calendar, but these are matters outside my scope. I will content myself with two or three references to influential writings. First, Nicephoras Gregoras' treatise on calendar reform:[26] the work was submitted to Andronicos II in 1324, and might at that time have seemed an irrelevancy to an emperor whose thoughts were chiefly occupied with making war on his grandson. Second, the solar and lunar tables of Levi ben Gerson: these are especially interesting because they represent an approach of two faiths. Levi lived in southern France, and in his tables used the Christian months and years, rather than the Jewish calendar and the rules derived from the Torah, doing so on the grounds of relative simplicity. It is unlikely that the claim was widely acknowledged by Levi's co-religionists, for as we have seen, and shall see again, there were many Christian supporters of the Jewish and Islamic calendars, while very shortly afterwards Immanuel Bonfils of Tarascon drew up a set of tables written in Hebrew for the Jewish calendar which not only became very popular in its original form, but was even translated into Byzantine Greek.[27]

5. *Pierre d'Ailly and the Councils of Rome and Constance*

The next important move within the Western Church came in the second decade of the fifteenth century, in the context of the Councils of Rome and Constance, and thus as one small — and to most contemporary observers no doubt trivial — aspect of deliberations aimed at countering the religious anarchy brought about by the Great Schism. Since I shall later introduce the proceedings of other Councils, it will be as well to point out here the important difference between those held under the threats implied by the Schism, when the question of the authority of the General Councils themselves (and their ability to limit papal authority) was one of the chief matters for dispute, and later and more effective reforming Councils, in particular that at Trent, where at last principles of discipline and dogma could be effectively settled, and where the greater threat came from without, rather than within, the Roman Church.

The first great fifteenth century Councils were the outcome of a meeting at Livorno between cardinals of both papal courts. Meeting in July 1408, they appointed the calendarically auspicious 25 March, 1409 for the meeting of a united General Council. This proved to be exceedingly well attended by both sides. Meeting at Pisa, it moved so quickly that by 5 June there was agreement of sorts on the dismissal of both popes — Benedict XIII and Gregory XII — as schismatics and heretics. Neither would withdraw, and thus the election of Peter Philargi, Archbishop of Milan (as Alexander V), now meant there were *three* claimants to the papal throne. Alexander did not live long. Within a year he was followed by John XXIII (Baldassarre Cossa), who was certainly not the pillar of virtue needed to end the Schism. There was an abortive Council of Rome in 1412, and then — under pressure from Sigismund, king of the Romans — another at Constance on 1 November, 1414. The three great objects of the meeting concerned faith, unification, and reformation. The calendar might seem to fall under all three heads, but it can hardly have attracted much attention, in view of the alternative excitements — the scandalous degradation and burning of Hus, the endless nationalistic struggles, especially those aimed at minimising the effects of the Italian vote, and the hounding of Pope John from the city as a prelude to his formal deposition. In fact within three years of the Council's first meeting a state of affairs had been reached where two claimants — John and Benedict — had been deposed, and the third, Gregory, had resigned. On 11 November, 1417 Oddo Colonna (Martin V) was elected pope, and the Schism was at an end. Not that the ecumenicity of the Council, or the legality of its actions, ceased to be matters for debate; but there is something to be said for judging schisms by the simple device of counting popes, and now there was only one.

This is a part of the background to the reforming polemics of the cardinal and scholar Pierre d'Ailly (c. 1350 - c. 1420). D'Ailly had a number of commentaries to his name — on the *De anima* and *Meteorologica* of

Aristotle, for instance, and on Sacrobosco's *De sphaera* — and he had been Chancellor of the University of Paris from 1389 to 1395. A critic of astrology, he was deeply imbued with it, and there is no doubt that a part of his concern with the calendar and chronology was a product of his belief that the Church was swayed by cosmic influences to which great conjunctions of Saturn and Jupiter were almost as important a guide as the scriptures. (He did, admittedly, modify the old doctrine: influences on the Christian and Jewish faiths was indirect, since they were more *resistant* to the celestial influence than were rival faiths.) [28] He was no great mind. It is hard to speak of plagiarism at a time when the notion of intellectual property was generally so vague, but even by the standards of his day he must be counted a plagiarist,[29] and in his plea for an improved calendar he borrowed heavily from his predecessors, especially Bacon. He was bishop of Cambrai when he was made cardinal in 1411, and at the Rome Council in the following year he tried to interest John XXIII in calendar reform. In his *De concordantia astronomice veritatis et narrationis hystorice* he wrote of discordant observations of the equinoxes (John of Saxony, Henry Bate, the Alfonsine tables, etc.), the Easter problem, and so on. He is best remembered, though, for his plea at the Council of Constance: calendrical calculation is more important to the Faith than financial calculation![30] As Kaltenbrunner remarked, the Cardinal's work is more important for the personality of its author than for its intrinsic merits.[31] He relied on Gerland, Grosseteste, Sacrobosco, and especially Bacon, from whom he copied whole sections — but I note that he was not so old-fashioned as to prefer Bacon's value for J to the 134 of the Alfonsine tables. A polemicist rather than an astronomer, he knew the importance of good titles: we may indeed use the *Arab* years and months, as Grosseteste said, to reckon lunations accurately, but we can do as well, and with greater authority, if we use the tables of the *Greeks and Hebrews*, "et ideo si quis considerat tabulas eorum ad occasum Jerusalem, plenam in his reperiat veritatem". Straight out of that other great polemicist, Bacon, of course![32]

John XXIII acknowledged the convincing character of Pierre's critique, and said that astronomers consulted had recommended these measures: each full moon on or next after the vernal equinox to be the spring full moon; Golden Numbers to be adjusted by four days; certain amendments to *termini*.[33] A decree of 1412 had no consequences, and although the subject was twice brought up at Constance (1415 and 1417), there was again no effective result. Pierre d'Ailly's initiatives might as well never have been taken.

6. *Nicholas of Cusa and the Council of Basel-Ferrara-Florence*

The next concerted attempt at calendar reform within a conciliar context was at Basel, although yet again more than one city was eventually connected with the Council in question. It had been decided at Constance that the pope convoke a Council at Pavia in 1423. Plagues, and other problems, led to its dissolution after transferring to Siena. Basel was chosen for a next meeting in 1431, but Martin V died before meetings began, and his successor, Eugenius IV, in part disenchanted by the status accorded to the papacy by many of the Basel delegates, and in part wishing to meet in an Italian town more accessible to Greek delegates with whose church it was hoped a union might be achieved, tried to dissolve the Basel assembly before the end of 1431. He was unsuccessful, and was obliged to accept a great many unpalatable decrees — especially unpalatable being the reassertion of the ruling at Constance that the decisions of a General Council take precedence over those of a pope. For the sake of completeness it should be mentioned that after Eugenius convened a Re-union Council at Ferrara in 1437, remnants of the Basel assembly claimed to depose him, and elect a new pope (Felix V), but the offspring of this new schismatic movement were never very influential, and finally submitted to Rome (Nicholas V) twelve years afterwards. As for the Ferrara assembly, which ultimately moved to Florence, again to escape plague, its affairs chiefly concerned union with the several Eastern churches. It is to Basel we should look for the proposal for calendar reform associated with the name of Nicholas of Cusa.

It was as a young man of about thirty that Nicholas of Cusa went to the Council of Basel in 1431, to plead the case of Ulrich von Manderscheid, claimant to the archbishopric of Trier. Already recognized for his accomplishments in canon law, not to say historical scholarship,[34] Nicholas quickly became one of the leading lights of the conciliar faction — arguing for the supremacy of an ecumenical Council in his *De concordantia catholica* of 1433, but taking the side of the papal faction on questions of church unity, so that, for instance, he was one of an embassy sent to Constantinople in 1437. His name occurs in John of Segovia's account of the Basel attempt at calendar reform.[35] On 18 June, 1434 a letter was read out to the assembly, drawing attention to the scandalous state of affairs, the derision of unbelievers, and so forth, and suggesting that a commission of expert astronomers be nominated to put matters right. The cardinal of Bologna was chosen to select scholars for the work, and in March 1437, in the refectory of the Minorites, their report was presented by Nicholas of Cusa. His talent for historical scholarship no doubt stood him in greater stead than his astronomical knowledge, which has been much exaggerated; but by now, as we have seen, the calendar had become virtually a historical problem. The proposals made were not very remarkable. Seven days should be dropped from June 1439, and a day should henceforth be inserted into the calendar every 304 years. The shortcomings of such a solution are more evident to us than they were to the assembly, for it seems that the only amendment proposed was by a certain Hermann, monk of Cloister N., who wanted the seven days to be dropped either from May or October.[36] The Commission was given the power to institute the reform, but prematurely, for this was the time of the secession (and attempted suspension) of Eugenius, and in the resulting turbulence within the Church there was no chance of the general acceptance of the reform for the time being. Had the attempt at reform been successful, we should no doubt have been gathering five years hence (or fifty-five) to celebrate the fact, and Nicholas of Cusa would inevitably have stolen the limelight, as is the wont of Famous Men. He did, after all, write a tract in 1436 in connection with the Basel Council, undoubtedly: *De reparatione calendarii.*[37] From it we can say that he knows his texts, his Ptolemy, Albategni, Sacrobosco, and the Alfonsine tables, and yet takes $J = 150$. Taking M, conventionally, as 304, he assesses the error in the Moon's position as $4^d\ 15^h$, apparently by dividing the year (1436) by 304 — giving the slip in the Golden Number correctly, by the lights of the parameter 304, but not the correct lunar position. The fact that the Basel commission placed so much emphasis on the preservation of Dominical letters (by dropping exactly a week from the calendar) suggests, though, that Hermann was the "expert" behind the scenes, and perhaps it is just as well that they were not successful, for there would almost certainly have been an outcry from better astronomers than they.[38]

Whether or not my next instance of a reform proposal has anything to do with the Basel Council, or whether its apparent date of 1434 is a mere coincidence, I cannot say. Its author was Richard Monk, an Oxford man of whom relatively little is known. If I pay more attention to his manuscript remains than they seem to merit, this is simply because he has not — unlike most of the writers I discuss here — been seriously discussed before. What I find attractive about his proposal is its refreshingly radical nature, although it must be said that it was as unrealistic as it was radical.

7. *Richard Monk, the "Year of the World", and a Muslim Comparison*

Richard Monk's calendrical tables are all that we have by him, and they are unfortunately accompanied by virtually no explanatory text. The tables are found only in MS Laud Misc. 594 in the Bodleian Library, where their author is described as "chaplain of England". In fact we know a little of his life from a lawsuit, recorded in the Calendar of Close Rolls,[39] where we find under 4 December 1439:

> Richard Monke of London, chaplain, to Thomas Gosse, mercer. Recognisance for £ 20 to be levied etc. of his lands and chattels and church goods in the City of London. Condition, that he shall abide and keep the award of John Stopyndoun clerk keeper of the chancery rolls concerning all debts, trespasses, debates, etc. between the parties to this date, *and certain opinions of certain articles of the science of astronomy.* [My emphasis]. Thomas Gosse to Richard Monke, [like] recognisance to be levied [etc.].[40]

It seems a strong likelihood that the point at issue was a calendrical one, although of this one cannot be certain. It is reasonably clear that Monk's views on biblical chronology were well known, and possibly controversial, for in MS Ashmole 369, which once belonged to John Dee, he has written "falsum" above a statement to the effect that there were 4909 years from the origin of the world to the birth of Christ, "secundum R.M. inchoando annum ab equinoctio vernali".[41] This must refer to Monk, for the date can indeed be extracted from his tables.

Perhaps the most interesting thing about Monk's tables is his use of the Egyptian year of 365 days, the year favoured by a few of the best astronomers of later centuries, but not the usual churchman's choice. His system was obviously heavily bound up with certain numerological tenets bearing on his chronology, and this was becoming increasingly the case in calendar work — as evidenced by Nicholas of Cusa, Paul of Middelburg, Scaliger, and Petavius.[42] Monk gave what he considered to be the "true year of the world" (on his reckoning), which he believed ran in seven cycles each of 924 years, and he correlated those years with the year of Christ, both "according to the Church" and "according to the truth". [A specimen entry from the seventh cycle: year of the world 6336 = year of Christ 1449 (true) = year of Christ 1427 (Church).] [43] A key to his system is a 33 year cycle (and 924 = 24 × 33). His months have either 30 or 31 days (months 3, 5, 7, 10, and 12 have 31), and since day 21 of the very first of his months correlates with the conventional 1 April, he was clearly beginning his cycles at what he judged to be the current equinox. In fact in a table for the true place of the Sun in the ninth sphere, this was given for day 1 (presumably complete) as $0^s\,0°\,59'\,08''$; and we note that the meridian in question was not Oxford, or Rome, or London, or Jerusalem, but "the place of the world between East and West", elsewhere called "the middle of the world" ("super situm medii mundi"), and presumably the place usually called Arin. He included much straightforward conversion material which it is unnecessary to consider here — such as dominical letters on the different ways of reckoning years, "primaciones" (Golden Number, beginning of the lunar cycle) according to the Church and from the origin of the world, and so on. He gave the entry of the Sun into Aries for the Oxford meridian, as a concession to his acquaintances, showing us that he took mid-world to be about 82° east of Oxford. But the most unusual thing about his system is its cycle of 33 Egyptian years.

It must first be said that Monk takes the Moon for granted, and concentrates on a calendar for the Sun. What his views on the Easter problem were, I cannot say. Secondly, I doubt whether his system is very profound. At the end of his tables are "tabule Solis vere atque perpetue" with a short canon that suggests no great sophistication. He there explains that a knowledge of the motion of the solar apogee is necessary if we are to find the true place of the Sun in the ninth sphere, as is that of the motion of the eighth sphere (equivalent to our precession of the equinox). In a final table he claims to offer a combined correction term for every degree of every sign, an extraordinary mish-mash, if I have analysed it correctly, of the "equatio diametri dimidii circuli" in the Thābit theory of trepidation (maximum $4°\,18'\,43''$) and the standard Ptolemaic theory for the solar equation. I point out this fact here since I think it would be a mistake to look too deeply for genius in his main calendrical tables, which I will now summarize.

The Egyptian year of 365 days Monk calls the "year of the world". The "zodiac of the sphere of the Sun" (0° to 360°) is the eighth sphere, in solar theory, and its degrees are correlated with two quantities: (i) the time interval between the moment at which the Sun reaches those individual degrees, and midnight; (ii) true motus at the nearest midnight. Another table gives the Sun's positions in the ninth sphere for each day of the 365-day years of his system. They are, of course, not the same on successive years, and this is where his 33 year cycle is needed. Monk assumed that 33 years of 365 days are exactly 8 days short of 33 tropical years. He accordingly gives us a table correlating the year of the 33 year cycle with what he calls "revolutions of the years of the world". A specimen entry may be taken to explain it: "year 30" found opposite "revolution 98° 1′" means that after 30 tropical years have passed, the earth has turned [7 times plus] 98° 1′.

No explanation of the way the calendar was to be implemented has survived, and some doubt attaches to Monk's intentions as to intercalation. A rigorous application of the principle of the 365-day year, the "year according to the truth", without intercalary days, would mean a continuing drift of the seasons through the calendar. The acceptance of a set of annual calendars, 33 in all, for a 33-year cycle, suggests that he had some sort of intercalation in mind. Perhaps he meant to run two calendars in harness, or perhaps the "true" years of the world were only for chronologists, for *conoscenti*. Without his intercalation plans we can say no more than that, at worst, his 33-year calendar would have made the seasons oscillate within the calendar with an amplitude of eight days. His contemporaries would surely have found this unpalatable. Easter, already a movable feast, would simply have moved differently (as far as its labelling was concerned, which is what we are talking about when we talk of its movable nature), but now a bigger problem arises with the placing of saints' days. This would surely have led Monk into far stormier waters than the "conventional" reformers were encountering, had his scheme ever come to the attention of the Church's counselors. As it was, however, it seems likely that at best it served as a topic for local academic discussion.

What Monk did is of interest for other reasons. His ideas bear comparison with those implicit in the Muslim calendar, and also (a separate issue) with some proposals by al-Khayyāmi (1048?-1131?). The Muslims had in a sense rejected in an even more radical fashion than Monk the agricultural year, that is, the solar year, by taking as a "year" 12 consecutive lunar months. This "year", drifting steadity through the seasons, implies that in about 33 tropical years an *extra* "lunar" year (i.e. 34 in all) will have been counted. This relationship could well explain part of the attraction of Monk's scheme, in his own eyes, although that is doubtful. The possibility of influence from al-Khayyāmi (the well known algebraist, polymath, and above all poet "Omar Khayyam") poses more interesting historical problems. He was at Isfahan for eighteen years with the best astronomers of the time under his guidance, where they compiled the "Malik-shāh astronomical tables", and where in 1079 he presented a plan for calendar reform, also writing a history of earlier reforms.[44] He followed a 33-year cycle for his Malikī era (or Jalālī era; in honour of Shams al-Mulūk, khaqan of Bukhara in the first case or Jalāl al-Dīn Malik-shāh, the Seljuk sultan at Isfahan in the second), selecting eight years out of the 33 as leap years of 366 days. This is so reminiscent of the solution later offered by Monk that one wonders whether there was some link — for example through Tūsī? —, but if so I have not found it. I have calculated some of the data for the entry of the Sun into Aries on *Alfonsine* principles, and found them to fit quite closely with Monk's data (although about ten hours out from reality; they are given for noon); but the interesting thing about the 33 year cycle is that it yields an appreciably *different* year length from the Alfonsine ($J = 131.9$ rather than 134.2). The value is indeed an improvement; but one should be sparing of superlatives, since to accept a particular solar cycle is always to accept some sort of compromise, and does not tell us what precise year length its user accepted.

8. *From John of Gmunden and Regiomontanus to Paul of Middleburg and the Fifth Lateran Council*

As the fifteenth century went by, the calendar debate began to accrue a corpus of subsidiary problems. An improved historical awareness led to discussions of what was the "correct" date to which the equinox must be restored — that for the time of Christ, of Caesar, of the origin of the world, or some other? Adjustment of the lunar calendar was occasionally mixed up with the problem of the precise date of the creation of the world — was it spring or autumn, for example? What is the "correct" meridian for Easter calculation? When the equinox nears the end of a day at the meridian of Rome, it will be the next day in Jerusalem. Some of the best astronomers were content to make long-lasting and usable calendars setting forth both fact and convention — as did John of Gmunden, for example, in Vienna. Judging by the number of extant manuscripts of his (and similar) works, and the large number of sixteenth century editions, they were more in demand than was a reform. Regiomontanus was another who, rather than fulminate over risible errors in Easter, set to, and tabulated solar and lunar positions using the most reliable astronomical information available, and derived another table of mistakes in the projected dates of Easter from 1477 to 1532. This sort of thing must have raised appreciably the general level of awareness of the calendar's faults. At the same time, the calendar was occupying an increasingly important place in the consciousness of people other than the clergy. The introduction of printing shifted the centre of gravity of learning, especially through the agency of vernacular texts, of which an excellent example is the *Compost et Calendrier des Bergiers*, the "shepherd's calendar" so often printed, from 1493 onwards, not only in French but in English, German, and Dutch.

It was no doubt Regiomontanus' ephemeris that led Pope Paul Sixtus IV to invite him to Rome with a view to recommendations for calendar reform; but the death of the astronomer, in his prime, occurred on 6 July 1476, shortly after his arrival.[45] Although reform tracts continued to appear sporadically, no serious papal initiatives were taken for more than thirty years — and then at last with the Fifth Lateran Council (1512) it seemed that reform was at hand. The Council had its origins in strife reminiscent of that at Basel, and earlier at Constance. Louis XII of France organized a schismatical "General Council" at Pisa in 1511, as a stick with which to chastise Pope Julius II, who responded with his own Council. This was continued after his death, by Leo X his successor, until 1517, the year of Luther's revolt. Politically successful — witness the concordat with Francis I of France — and also successful from the point of view of the papal party — since it established papal ascendency over General Councils — the Fifth Lateran Council did little to silence demands for the suppression of abuses within the Church, but in regard to the calendar it produced a polemicist in the tradition of Roger Bacon, Pierre d'Ailly and Nicholas of Cusa, namely Paul of Middelburg.

Paul of Middelburg was an old hand at astronomy, at least that of an astrological cast. Coming from Middelburg on Walcheren in Zeeland, and educated at Louvain, he moved nearer the orbit of the papal curia in 1479, when he went to teach astronomy at Padua. In 1480 he became physician to the duke of Urbino, and from 1494 until his death in 1533 (when called to Rome by Paul III with a view to making him a cardinal) he was bishop of Fossombrone. Most of his fourteen printed works, all published after his move to Italy, are in some way concerned with prognostication, but it was he who became bishop, and Savonarola — as Thorndike pointed out — who wrote against astrology and who yet went to the stake.[46] In 1491 he wrote a tract "mirum tibi fortasse in debitum...",[47] in which he exorted Pope Innocent VIII to reform the calendar, and his interest in the subject seems to have been of long standing, for Petrus de Rivo (1442-99), an old adversary at Louvain, had in 1488 written on this topic a work directed against him: *De anno, die et feria dominicae passionis et resurrectionis.*[48] In 1513 Paul of Middelburg published his most ambitious work, *Paulina de recta Paschae celebratione* [etc.], printed at Fossombrone. It opened with letters to Leo X, Maximilian, the College of Cardinals, and the

Lateran Council. On 16 February 1514 Leo invited him to the Council. He went to Rome, and was duly given presidency over the commission set up to produce a new calendar.

In his *Paulina*, and especially in his letter to the Council (printed, for instance in the monumental collections of Council proceedings by J.D. Mansi),[49] Paul of Middelburg offers a rather aggressive and often unjustified critique of his predecessors, but he does put his *laissez-faire* arguments reasonably well. In brief, he was in favour of leaving the solar calendar as it stood, of simply recognising the fact that the equinox had moved to March 10 (as he thought — in fact wrongly for two out of four years of the leap-year cycle in his time), and of allowing it to drift through the calendar by a day (as he thought) every 134 years (i.e. the Alfonsine figure). He was afraid that dropping a number of days from the calendar would upset too many people, and he criticised Marcus Vigerius (cardinal from Sinegaglia) in particular for wishing to drop no fewer than 14 days, thus bringing the calendar in line with Pliny's. (He had also implied J = 100.) Paul criticised his old adversary Petrus de Rivo for an "Egyptian calendar according to Bede"; and Pierre d'Ailly for flirting with the purely lunar Muslim calendar, and for certain opinions as to Easter limits. As for Paul's second constructive proposal, for the lunar calendar, and for the "Golden Number which had turned into lead", he would effectively leave the cycle as it was, except that the month containing the *saltus lunae* should be taken with one of the embolistic months as a pair, one being always full and one hollow. This would reduce the number of embolismus from seven to five. Finally, he wanted the lunar calendar to be set back a day every 304 years (cf. Cusanus).[50] He wanted the lunar months to be named after the Egyptian months, perhaps thereby hoping to remove traces of Muslim astronomy from Christian writings, and surely not consciously flattering his now deceased opponent Petrus de Rivo by imitation. This would do for Rome: he could not worry about the Greeks, who were already deep in error. Things had changed since the time of Cusanus and Eugenius IV, when hopes of reconciliation ran high.

The proposals were to be considered in the tenth session of the Council, planned for 1 December, 1514. (If successful, the cycles would have been declared to have started on 1 January of jubilee year 1500, when — a sign from God — the mean conjunction of the Sun and Moon at the Rome meridian occurred, at mid-day.) Letters were sent from the papal curia to all important Christian monarchs asking them to get the opinions of their astronomers. Thus Maximilian in turn made enquiries of those at Vienna, Tübingen and Louvain — and since the letter to Vienna was dated 4 October, 1514, less than two months ahead of the decisive meeting, the time margin was clearly being cut very fine.[51] Too fine for the English, I regret to say. In the *Letters and Papers, Foreign and Domestic, of the Reign of Henry VIII* there are four letters from Leo X, and no evidence of any reply from Henry.[52] On 21 July, 1514 the original request was sent, couched in conventional terms (errors in Easter giving cause of ridicule to Jews and heretics), and asking that Henry send either his best theologian and astronomer or the opinions of the same. In a letter of 1 June of the following year Leo laments that the greater number of requests, like that to Henry, have remained unanswered, and hopes that answers will come in time for a discussion at the eleventh session. On 10 July, 1516, and again on 8 December, 1516, the request was repeated in the same terms. One can hardly accuse the curia of not trying, or the English of enthusiasm for a subject they had once made very much their own. Nearly seventy years later, writing for Henry's daughter Elisabeth, in a highly nationalistic vein, John Dee noted that "none had done more skilfully than another subject of the British sceptre Royal, David Dee of Radik", by which he meant Roger Bacon, whose letter to Clement he transcribed. Paul of Middelburg, Dee added, followed the precepts of Bacon but was loth to acknowledge his debt, even reprehending his teacher over the date of Christ's passion. It was as a result of Bacon's letter to Clement V, said Dee, that Paul set to work and *called on Copernicus to advise*.[53]

9. *Copernicus and His Supposed Influence*

Here is one of the thornier problems of the history of calendar reform — or at least it has been treated as such. Here I can only discuss it in a peremptory way, taking as my starting point the fact that among those listed by Paul of Middelburg as having actually replied to the papal requests is "Nicolaus Copernicus Warmiensis".[54] The two could well have met in Italy, for Bernardino Baldi says they were friends.[55] The story that Copernicus was asked to *attend* the Council might stem from these small beginnings, but the earliest statement to that effect occurs in two letters written by Galileo to defend his Copernican opinions.[56] (Perhaps his misunderstanding, if such it was, arose from a misreading of the dedicatory epistle, to Paul III, of *De revolutionibus*.) A third issue, on which opinion has been divided in recent years, and one not without relevance here, is whether Copernicus had anything substantial to offer by way of new data, and in particular, whether the Gregorian reformers used his data for the year and month. That they did so is a conclusion drawn from so authoritative a writer as Christopher Clavius. Broadly speaking, the counter-argument is based on the fact that the Gregorian reform rested on proposals by Aloisio Giglio, who espoused Alfonsine parameters.[57] The last question is not at all as simple as it first appears to be. Clavius, whatever his views about Copernican cosmology — and they were extremely sceptical — did acknowledge with reservations that Copernicus was an authority on astronomical measurements such as are needed for the calendar, and it is not surprising that he and the commission should have wished to heed the Prutenic tables. For the Moon, Giglio designed his system of epacts around the assumption that $M = 312.5$, and the Gregorian followed suit. (Eight days are dropped in 2500 years.)[58] This is the Prutenic (Copernican) figure sure enough, corresponding to a lunation of 29.530592361 days. The Alfonsine figure of 29.530590860 yields $M = 310.7$. We recall the fearful monotony with which M was taken as 304; and indeed J.J. Scaliger once explained how epact systems could be made to fit that old favourite figure, as though it wall still relevant (in 1583). Thus far it seems that our modern "Copernicans" have the right of the argument; but when it comes to the solar year, Giglio's and Gregorian sources are harder to settle in this way. As already pointed out, J is for them simply 400/3, or 133.3. An approximation to the Alfonsine 134.2? In fact if the Giglio biographers tell us that he favoured that figure, took it from the Alfonsine tables, and was instrumental in its being accepted by the Gregorian reformers, then there is, from this point of view, an end of the matter. But Clavius wanted to cover other possibilities. He quoted the maximum ($365^d\ 5^h\ 55^m\ 37.7^s$) and minimum ($365^d\ 5^h\ 42^m\ 55.1^s$) lengths of the tropical year according to Copernicus, and took the mean value. If we calculate the value of J corresponding to the mean, we find 134.24. Perhaps this "Alfonsine" figure tells us something about Copernicus. It certainly tells us that calculation alone is not a sure guide to historical influence. It also tells us that great reputations can be a delusion and a snare. As far as my own theme is concerned, I can leave Copernicus' influence to my colleagues with the observation that if indeed he affected attitudes on the character of the needed reform, this does not show clearly until long after his death, and then in two respects: in the matter of the lunar calendar, and in his having shaken confidence (by discussing variable procession) in the *constancy* of the tropical year over long periods of time. Another interesting hypothesis regarding the origin of the Gregorian year is founded on a comparison of the lengths of the tropical year as given or inherent in the Alfonsine tables, the *De revolutionibus*, and the Prutenic tables respectively. If these values of the year are expressed in days and sexagesimal fractions of a day they all begin with 365; 14, 33, differing only from the third sexagesimal onwards. Consequently, all three sources agree if the length of the year is rounded off to 365; 14, 33 days, — a value which gives *exactly* the Gregorian intercalation.[59]

10. *The Outcome of the Fifth Lateran Council*

At the beginning of June 1516 the Pope summoned the Commission and certain cardinals to discuss the whole question, and Paul of Middelburg prepared a report, his *Secundum Compendium correctionis Calendarii*, impressum... Romae pridie nonas Junii 1516. (It includes the list of some, who had responded to the request for criticism, one such name being that of Copernicus, as we have seen.) With an 8 July letter to heads of state Leo sent a modified *Compendium*, since printed by Mansi, and also Marzi.[60] Another appeal followed on 10 July. Some opinions were obtained, as already explained, but Paul's and Leo's efforts ended in failure. The last session of the Council (16 March, 1517) was preceded by a congregation of 13 March. As the pope was informed by Cardinal Giulio de' Medici, the Bishop of Fossombrone wanted the question of the calendar to be settled, and tried hard to persuade each of his colleagues, but in the end was denied his wish.[61] The topic was not introduced to the final session, and I suppose that in the end one may possibly ascribe the failure to a strengthening of conservatism, but certainly to a measure of scepticism in the ranks of the non-experts, confronted by experts who could not agree among themselves.

Their reasons for disagreement were various, and not very startling. Georg Tanstetter and Andreas Stiborius, for instance, answering from Vienna, liked a *fixed* date for the vernal equinox, and wanted an adjustment of a day every 134 years.[62] They wanted a printed table for 1500 years, with equinoxes and spring new moons: it was, they said, foolish to get so attached to the Golden Numbers that they were preferred to the truth. They noted the geographical problem: should Lisbon and Canton [Catigara] celebrate Easter according to local phenomena, even if — as might happen, in consequence — this were to mean doing so eight days apart? Should the Rome meridian be accepted as standard? Johannes Stöffler took a similarly severe astronomical approach: we should stick to astronomical tables, for truth is better than fiction. He tabulated Easters between 1518 and 1585 according to the usage of the Church, of the Fathers, and his local "truth" (the meridian of Tübingen and his Alfonsine tables serving to establish this). Like Paul of Middelburg, he claimed rationality for his principles, but of a different sort, for he would have had Easter of 1571 celebrated on 18 March, while Paul would have had it on 15 April.[63] As for the meridian, why Rome? (Do we detect the stirrings of German independence in all this?) Why not the Western Isles (the Fortunate Isles) of Ptolemy's geography, or even the islands newly discovered by the kings of Castile and Portugal? So much for the claims of Jerusalem. From Paris a certain (unidentified) doctor sent strong objections, known only from Paul's answer.[64] Broadly speaking it seems that even the expert astronomers were divided, not about the need for accuracy, but as to whether or not it was achievable by the use of the old techniques using simple cyclical relationships and procedures.

One of the more important consequences of the initiatives taken at this time is that they stimulated interest in the astronomical problems of the calendar, especially in Italy. The letter to Florence from the curia was for some reason more detailed than at least some of the others sent out on 10 July, 1516, and the Republic responded in a very laudable way, posting up a printed document (September 1516) on all principal churches and other buildings in its territory, inviting competent persons to occupy themselves with the problems of calendar reform.[65] I mentioned earlier a work by a Florentine monk Jo. Lucidus (1525, printed 1546), which was a symptom of Florentine enthusiasm, a phenomenon well charted by Marzi. It is as well to remember that at the Council of Trent, not far in the future, and at later Councils, questions were not decided by nations as in the past, but by a majority vote, and that the Italians would always have a numerical preponderance. In a strong sense, Italian interest in this matter was crucial.

11. *The Council of Trent and a "Forgotten Reform"*

Pressure to hold another General Council came from many quarters, but most importantly from the Emperor Charles V, confronted with the task not only of defending the Faith, but of keeping the peace in his own territories. A Council was planned for 1537, in Mantua, but the Protestants invited would not take part in an assembly in Italy, added to which there were political complications and delays, so that the Council summoned by Paul III to meet at Trent on 1 November, 1542 did not begin there until 13 December, 1545. (Trent, though south of the Alps, was on Imperial territory.) Even then there were further delays. A plague led to a temporary removal to Bologna, although the German bishops generally refused to move; proceedings were suspended by Paul III (1549) and recommenced by his successor Julius III (1551-2), to be ended when the troops of the Elector of Saxony seemed to threaten them. At last Pius IV summoned the bishops to Trent for the third time in 1560, the work of the Council beginning in January 1562. The 25th and last session was held on 4 December 1563. This most important of Councils — whose decrees and canons are so well known — was thus a quarter of a century in the convening.

At the last session of the Council the Pope gave orders that the Breviary and Missal should be reformed — which meant that attention be paid to the calendars that were an essential part of them. The new Breviary was ready by 1568, with one small change in the calendar: the Golden Numbers were moved up by four places (so that, for example, the first occurrence of I is no longer 23 January but 19 January). In a short explanatory passage the reader was told that it would in future be necessary to move the Golden Numbers up a place every 300 years beginning in 1800.[66] (This, in short, is to accept M = 300.) As van Wijk comments, this forgotten reform of the calendar was scarcely ever mentioned in later professional discussions. It was emphatically not the reform for which astronomers had been clamouring.

The Council of Trent led to the printing of a number of works on the calendar, some of them prepared at an earlier date. One such example that is notable for its contents was by Petrus Pitatus (Verona, 1564, written 1539).[67] He discussed the rule of Easter — he favoured continuation of the existing rule, on moral grounds — and drew up a lunar calendar for 1539-1805. He argued for the same sort of lunar calendar adjustment as in the Breviary (now with M = 304), but he also wanted to have no fewer than 14 days dropped from the solar calendar, to bring it back (as he thought) to that of its founder, Julius Caesar. Most significantly for later history, accepting a value of 134 for J, he compromised and pleaded for the rule whereby three out of four centennial years be ordinary (non leap-years). This is, of course, the Gregorian rule. As when Columbus stood the egg on its end, he broke the rules, but did so very gently. More reminiscent of Alexander's handling of the Gordian knot than of Columbus' egg was Luther's comment on the Easter problem. He would have had it a fixed day of the month, and was very dismissive of the ancient rationale. Calendars, he thought, have nothing to do with faith; they are a question only of worldly authority. It is obviously a very fine line that separates reformers from revolutionaries.

12. *John Dee as a Historian*

By its very nature, calendar reform turned a large proportion of its practitioners into chronologists, if not historians. In an essentially scientific subject this produced — and we have seen many examples — an unfortunate brand of eclecticism in all but the best writers, and where there should have been a coherent system, sectarianism and petty nationalism often prevailed. As we know, by something of a miracle, and notwithstanding the conservatism of many of its members, the Gregorian commission somehow managed to agree upon, and obtain acceptance for, a simple and even elegant reform — not such that it would have astonished Conrad or Grosseteste, but an excellent solution to those who refused to accept Luther's axiom. We know how national and religious discord stood in the way of its universal and immediate acceptance. What I should like to append, as a tailpiece to my story, is an example of a way in which those same forces led to a mildly distorted history of the subject, if "history" is the right word. I have in mind John Dee, graduate of Cambridge, editor of Euclid, and familiar with entities as diverse as angels and navigational instruments. Dee was a frequent visitor to the continent, where he had many friends, and yet his advice to Queen Elizabeth in *A Playne Discourse* (1582) [68] was excessively insular. It is of interest for another reason, however, namely the way in which it reveals Dee's use of some of the many medieval manuscripts he owned. And it is worth remembering that it was revived as one of the documents thought relevant at the time Lord Chesterfield finally brought his country into line with Gregorian Europe, 170 years after 1582. (The British parliament is performing a rather similar historical exercise at this very moment, in connection with islands first sighted by one of Dee's acquaintances.)

The bull of Gregory XIII ordering the use of the reformed calendar (24 February, 1582) was followed very soon afterwards by a proclamation by the English Queen (28 April, 1582) "declaringe the causes of the reformation of the Calendar and accomptinge of the years, hereafter to be observed, to accord with other countryes next hereto adjoyninge beyond the seas". By 25 March, 1583 Dee had produced his report, and — as already intimated in connection with the Copernicus problem — the Lord Treasurer's advisers in turn reported (for the benefit of the Lords of the Council), in essence, that although they liked Dee's ideas they thought it more convenient to go along with the Gregorians. This did not happen. Liberal as had been the mathematicians, the clergy — Archbishop Grindal and Bishops Aylmer, Piers, and Young — were unanimous in recommending further discussion, amounting to a rejection of the scheme originating in the see of Rome.

Dee's *Playne Discourse* opens with an elementary introduction to the problem, after which it has a curious historical dial around which are the great names in the history of the calendar — ending prematurely with "Regina Elizabeth Reformatrix anni civilis juxta epocham Christi" (10-11 for the explanation).[69] Among the names is that of Simon Bredon, one of Dee's national heroes, and I am reasonably sure that Dee got all his information about Bredon from what is now MS Digby 178, at least half of which he owned.[70] Bredon was

> a naturall subiect to the Brytish scepter Royall, with other Mathematicall students and Skilfull masters in Astronomy, being in his company assistant, at Oxford, Anno Christi 1345... [and] made diverse excellent observations, which now, in due tyme, being publyshed, may be very profitable for the veritie Astronomical. (15)

Dee then set down in Latin the record as he found it "many years since". I will not reproduce it, but point out that it comes fairly certainly (with one small copying mistake) from the manuscript I mentioned and that it concerns a series of noon positions of the Sun around equinoxes and solstices, together with interpolations to derive the times of entry into the four signs: Aries, Cancer, Libra, and Capricorn. Dee gave no year (!) but this was 1341. He then went on to express the pious hope that "we had many such records of observations so diligently and precisely made", to lead us to a certain knowledge of heavenly motions But of course the positions he recorded were not observations at all, but positions calculated by William Reed on the basis of the Alfonsine tables.[71] Dee was on safer ground when he set down observations by Copernicus (17) and himself (for the years 1553-5), and indeed a considerable part of his tract is devoted to explaining along Copernican lines how the year from vernal equinox to vernal equinox is not equal to the year from autumnal equinox to autumnal equinox, "which point (perhaps) to some young Mathematiciens maie seeme halfe a Paradox" (30). He relied heavily on the Prutenic tables. (As with Clavius, this does not make him a Copernican from the point of view of his accepted cosmology, a question that has occupied the thoughts of students of Dee.) He had a touch of the Holbrook disease, converting true longitudes of events in the ecliptic as between different meridians, such as London "about $1^h\,48^m$ west of Koningsberg", and expressing the results to *sexagesimal fifths.* (32 ff.) His favoured meridians were London, Königsberg, Jerusalem, and Bethlehem, but not, of course, Rome.

I mentioned elsewhere Dee's transcripts of Bacon (whom he seems to have claimed as a kinsman) and Grosseteste.[72] When he cited Ptolemy and Albategni, he was taking his information from his compatriots' works, and this goes for his values for the parameter I called J (he noted values of 300, 106, 128, 115, 125, 120). (See pp. 31, 53, 54.) What he was most anxious to do was establish the correct time and date of the vernal equinox, and for all his talk of observations, he rested his answers for the most part on the calculations of others — for instance of Michael Mästlin of Heidelberg (38). Much of his text is occupied with showing that the "Romanists" were mistaken to dock 10 days, rather than 11, from the calendar. But *how* to remove the eleven days? He favoured dropping the last day of each month from January to September, and the two last from October (p. 48). It is interesting to see that in his little calendar for 1583,[73] commented on in the Lord Treasurer's report, he had a scheme for dropping only *ten* days, and this in such a way as not to interfere with Trinity Term or any Feast Day! It seems that he was prepared to compromise with Rome, at last. In his *Playne Discourse* he had been more confident. "He rejoiced greatly that although [Elisabeth] was not consulted by the Roman Bishop" he will be obliged to acknowledge her Majesty's act "to be the most bewtifull flower of opportunity to bowlt owt and ymbrace the veritie..." (48). The bad verses later in the Ashmole codex do not match the prose, and I regret to say that the overall quality of the work, which left aside the more problematical lunar question, was a pale shadow of the Gregorian recommendations. But to be thwarted by four English bishops! His suspicion of church councils was justified. What was so special about the Nicene Council, that the Romanists should have chosen it for their "principall marke"? (43) He wished to work from the *Epocha Christi,* he said, for we should prefer the "Trinitie Cownsell", that is, Father, Son, and Holy Spirit. A very refined form of nationalism, of course.

13. *Some Conclusions*

With the Gregorian reform of 1582, more than four centuries of disenchantment came more or less to a close. Of course there would be future discontent, for the calendar in one form or another is an institution that will last as long as humanity itself; but the motives would no longer be those of the late middle ages, or of that period of Church reform whose historical title — the Reformation — should remind mere historians of the calendar to be modest. The calendar was never more than a straw in an increasingly turbulent wind. It is perhaps not impossible to draw one or two interesting conclusions as to the component forces of the greater Reform movement from the calendar's history, but this might well be thought a rather perverse way of approaching the larger, perfectly accessible problem. It is of some interest, even so, to ask what sort of people were our calendar reformers. In doing so we have to bear in mind a not uncommon historical difficulty: of many reformers we know virtually nothing, and if we make generalizations from the cases of scholars known independently for their works or deeds, notable or not, we are likely to produce a distorted picture. There is no escaping the fact, however, that the calendar occupied the thoughts of a sizeable number of scholars who would be judged important to the scientific movement on quite independent grounds. Consider the very diverse roles of Grosseteste, Sacrobosco, Campanus, Bacon, John of Murs, Geoffrey of Meaux, Pierre d'Ailly, Nicholas of Cusa, John of Gmunden, Regiomontanus, Paul of Middelburg, Copernicus, Reinhold, John Dee, and Christoph Clavius, fifteen scholars taken from my account whose selection for an intellectual history of western Europe would certainly not rest primarily on their contributions to the calendar debate. It would be a mistake to try to chart the growth of a scientific consciousness in Europe from that particular debate; there are better and more direct ways of doing this. From a scientific point of view the calendar debate is disappointing. I have tried to emphasize the eclecticism of the scholars I have discussed, an uncritical eclecticism, in fact. Even after the introduction of printing, and the dating of colophons, writers were often extremely vague about the chronological ordering of the texts on which they relied. Astronomical writers all too often reported a mixture of tradition (and calculation based on it) and genuine observation — a cynic might say in the ratio of a hundred to one — which their readers were often incapable of distinguishing. I have already cited John Dee as an excellent example of a man who had no excuse for his uncritical confusion of the one with the other.

From an astronomical and arithmetical point of view, that is to say, granted all the ecclesiastical and theological presuppositions, the calendar was a simple enough exercise in the invention of rules, rules that would harmonize incommensurable movements as closely as possible. It was an exercise well within the capabilities of innumerable clerics, and the fact that a large social group existed with competence in both the religious and the scientific aspects of the problem at issue makes it all the more surprising that they took so long to achieve success. Why were they not successful sooner? One answer has been given as soon as we have listed the ways in which specific attempts at reform were thwarted, one by one, by external circumstance. It is often said that institutional conservatism was at the root of successive failures, but the evidence does not support this view. (The picture changes as regards Protestant countries after the Gregorian reform, but that is not my theme.) Of course there were conservatives within the Church, who no doubt rejoiced when the experts could not agree among themselves. On the other hand there was, as we have seen, a considerable degree of papal sympathy with, and interest in, reform. Whenever we do have clear evidence as to the reasons for the abandonment of one plan or another, they usually have to do with the need to solve more momentous, or simply more urgent, political and religious problems.

It cannot be said too often that the calendar problem in the period under discussion was a church matter. Secular interest in structuring the calendar (as opposed to enjoying its holidays) was minimal. In any case, in the milieu I have been considering there was hardly a man who would have put the common law above the law of the Church. This much having been said, there is no doubt that different reformers had different motives. There was the astronomer who, having detected error, could not forbear to point it out, whether to prove his cleverness, to save his church from derision (and Bacon was afraid that even the rustic might laugh at the lunar calendar's faults), or simply out of a love for the truth. There is no reason why the three sorts of motive should not have been combined in one man, although the proportions clearly differed appreciably from case to case. It would not be wrong, for instance, to describe d'Ailly, Cusanus, and Paul of Middelburg as "careerists", for all their undoubted virtues, while Regiomontanus, whose short-lived career had much in common with theirs, surely had a purer concern for truth, at least of the textual and astronomical variety.

This introduces a question I have not touched upon in my all too cursory survey, namely the biographical element. It seems to me that a closer study of those most concerned with calendar reform would reveal a common character trait, a certain critical unease in their outlook on the Church — a body of which they were all loyal members. It is tautologous to say that they were not wholly conservative, but there is no *a priori* reason why, in a wider ecclesiastical context, they should not have turned out to be something of the sort. My impression, at least, is that as far as the evidence goes this was never the case. It would be foolish to pretend that one man can stand proxy for all, but since Robert Grosseteste in a very real sense set the stage for our four centuries of calendar history, I will take him as an example of one who had a deep concern with the need for a wider, political and spiritual, reform of the Church. He used to be presented by English historians as a radical leader in the movement towards the liberty of the English church, a very misleading view. On the contrary, he held to a very clear view of the Church as a tightly bound organism with a strongly hierarchical structure. It was precisely this view that enhanced his awareness of the disorder and corruption which he saw threatening it. He was no anti-papalist. He could at one and the same time deplore the exactions of the pope and appeal to the pope for support in the struggle to prevent secular interference in the ecclesiastical system. He went to Rome in 1250, when he was at least eighty years old, to protest a number of iniquities. In Sir Maurice Powicke's words:

> Pope Innocent IV sat there with his cardinals and members of his household to hear the most thorough and vehement attack that any great pope can ever have had to hear at the height of his power.[74]

Grosseteste's vitality was a rare quality. (His fourth and last work on the calendar, the *Computus minor*, was written when he was in his seventies, administering England's largest diocese.) Those who followed in his footsteps in the cause of calendar reform could not hope to share it; but I suspect that many of them, perhaps most, shared his belief that the Church was at the mercy of the imperfect human beings holding office within it, and that they, together with the institutions by which they cared for the souls in their charge, should be subordinated to this greater responsibility. They seem, in short, to have been men of a rather independent frame of mind, reformers in a wider sense.

REFERENCES

1. And when it comes to writing on their history we are most of us plagiarists, for here is a theme on which some of the Church's most erudite scholars have written. A comprehensive bibliography would occupy some hundreds of pages. I will single out one or two titles that cover my own particular topic in a useful way. The vocabulary of calendar and computus is generally unfamiliar, and can be found very clearly explained (although in connection with an early work) in W.E. van Wijk, *Le Nombre d'Or: Étude de chronologie technique, suivie du texte de la Massa Compoti d'Alexandre de Villedieu* (The Hague, 1936). An equally lucid but short monograph on the Gregorian reform by van Wijk is *De Gregoriaansche Kalender* (Maastricht, 1932). Two works on reform proposals in the late middle ages (1876) and "Gregorian" period (1881), both by F. Kaltenbrunner, are likely to remain standard for many years to come: "Die Vorgeschichte der gregorianischen Kalenderreform", *Sitzungsberichte der phil.-hist. Classe der kaiserlichen Akad. der Wissenschaft, Wien*, lxxxii (1876), 289-414; and "Beiträge zur Geschichte der Kalenderreform", *ibid.*, xcvii (1881), 7-54. I shall constantly refer to these as "Kaltenbrunner (1876)", and "Kaltenbrunner (1881)". Kaltenbrunner's ordering of his subjects is sometimes very misleading, especially in the early centuries, and he is occasionally over-enthusiastic (for example, about Master Conrad and Nicholas of Cusa) and repetitious, but he had a better command of his material than most of his contemporaries. His work is well supplemented on the sixteenth century by D. Marzi, "La questione della riforma del calendario nel 5° Concilio Lateranense", *Pubbl. del R. istituto di studi superiori pratici e di perfezionamento di Firenze, Sezione di filos. e filol.*, ii (no. 27) (1896), 1-263; and Marzi surveys then recent literature in his "Nuovi studi e ricerche ... secoli XV e XVI", *Atti del congresso internaz. di scienze storiche, Roma, 1903*, iii (1906), 637-50.

   My dogmatic statements about currently accepted astronomical parameters are based on the *Explanatory supplement to the astronomical ephemeris ... etc.* (London, 1961) or derived from data given there, without further reference.

   For a good short bibliography, including such classical authorities as Clavius, Petavius, and Scaliger, see van Wijk (1936), 135-41. Note that Marzi's bibliographical references are frequently unreliable.

2. Several dates for the equinoxes were in use in late antiquity and the early middle ages. The matter is somewhat complicated by the fact that the Babylonians left behind them a tradition of reckoning the "zodiacal signs" from points such that the vernal point came out at Aries 10 (system A) or Aries 8 (system B). Pliny (*Nat. hist.*, lib. xviii) places the Sun at the 8th degree of the appropriate signs at the beginnings of the seasons. This gave rise to confusion among medieval computists, although probably never serious; and has muddied certain historical discussions of the dates assigned to the vernal equinox. The literature is vast, and need not detain us here.

3. L. Baur did not include the *Compotus* in his edition of the philosophical writings of Grosseteste, but he commented extensively on it in *Die Philosophie des Robert Grosseteste* (Beiträge zur Gesch. der Phil. des Mittelalters, Bd. xviii, Heft 4-6), Münster i.W., 1917. See esp. pp. 46-33. There seem to be at least four works by Grosseteste relating to the calendar: the first to have been printed (Venice, 1518) was his *Compotus correctorius* (1215-19?). A *kalendarium* with associated canons was edited by A. Lindhagen (1916). For further details, see S. Harrison Thomson, *The Writings of Robert Grosseteste*, Cambridge, 1940.

4. I say "day divisions" rather than "midnight" since on some astronomical conventions the day is taken to begin at mid-day.

5. Kaltenbrunner (1876), 402.

6. "*Computus est scientia distinguendi tempus certa ratione...*" Bruges MS. 528, ff. 1r-6v.

7. For Grosseteste, see n. 3.

8. Sacrobosco's *Computus* was one of at least a dozen medieval treatises (cf. n. 6) beginning "*Computus est scientia...*" His was: "*Computus est scientia considerans tempora ex solis et lune motibus*" (see Thorndike and Kibre, col. 243). Many commentaries were written on it, and it was frequently printed in the sixteenth century: *De anni ratione, seu De computo ecclesiastico* (that issued with his *De sphera mundi*, Wittenberg, 1540 might be the *princeps*, although a Paris edition without date has been claimed for 1538). Even this is twenty years, however, after the Campanus *princeps* (see n. 9).

9. "Rogavit me unus ex hiis quibus contradicere nequeo..." (Thorndike and Kibre, col. 1365; printed with Sacrobosco's *De sphera*, Venice, 1518).

10 There are numerous editions of the *Speculum maius*, beginning with the seven volume edition of Strasburg, 1473-6; see that of Douai, 4 vols, 1624 (repr. Graz, 1964), vol. 1. lib. 15, *de formatione coelestium luminarium*. This whole enormous encyclopedia was written between c. 1244 and some time in the 1250s.

11. F.S. Benjamin, Jr. and G.J. Toomer, *Campanus of Novara and medieval planetary theory* (Madison, 1971), 7.

12. For comment on the reading of the text of the mandate (without the calendar interpretation) see L. Thorndike, *A history of magic and experimental science*, vol. ii (New York, 1923), 625. He settles on a reading which makes the pope ask for those "remedies you think should be applied in those matters which you recently intimated were of so great importance", this to be complied with "without delay as secretly as you can".

13. Ed. Brewer, 271-92.

14. Ed. Bridges, i. 281.

15. L. Baur, "Der Einfluss des Robert Grosseteste auf die wissenschaftliche Richtung des Roger Bacon", in A.G. Little, *Roger Bacon: Essays* (Oxford, 1914), 45.

16. Bacon admittedly groups Thābit with al-Battānī and others, who argued for $J = 106$, giving 131 to Asophus ('Abd al-Rahmān ibn 'Umar al-Sūfī). See Steele, ed., fasc. 6, 12-18.

17. For more information see my "The Alfonsine tables in England", in *PRISMATA - Festschrift für Willy Hartner*, ed. Y. Maeyama and W. Saltzer (Wiesbaden, 1977), 269-301

18. "Cum sit intentio ostendere falsitatem kalendarii nostri..." (Thorndike and Kibre, col. 342); expl.: "Explicit compotus novus phylozophycus compositus per fratrem Iohannem de S.". Probably South German. His radix for tables of the Moon: 21 March 1273 (the calendar being supposed corrected), fer. II, $6^h 25^m$, golden no. I. His equinox: 14 March 1273, 20^h (but correctly: 13 March, $2^h 43^m$ a.m.). His value for J: 120. (Compare Vincent of Beauvais!) See Kaltenbrunner (1876), 307. Whether rightly or wrongly I do not know, but Kaltenbrunner implies that 14 March meant 14 days *complete*, and that we should write 15 March, 8 p.m.

19. Peter of Dacia (Peter Nightingale) calculated his calendar for a 76 year period beginning 1292. It included the same features as that of William of Saint Cloud, such as the altitude of the sun at noon, and the time of the lunations to a quarter of an hour. It is known in more than fifty MSS and was printed (from one of them) in the *Bibliotheca Casinensis* iv (1880), 232-47. A critical edition by F. Saaby Pedersen is in preparation for the *Corpus Philosophorum Danicorum Medii Aevi*. Cf. O. Pedersen: *Petrus Philomena de Dacia*, Copenhague, 1976 (= *Cahiers de l'Institut du Moyen-Âge Grec et Latin*, No 19).

20. The *almanach* begins: "Cum intentio mea sit componere almanach..." (Thorndike and Kibre, col. 310) and the calendar "Testante Vegetio in libro suo de re militari antiquis temporibus..." (ibid., col., 1568).

21. For quotations from John of Murs and discussion of authorship, see Lynn Thorndike, *op. cit.*, iii (1934), 297-8. On the general problem, and further examples of conservatism, see the article referred to in n. 17.

22. For the text of the letters see E. Deprez, "Une tentative de réforme du calendrier sous Clement VI: Jean de Murs et la chronique de Jean de Venette", *École française de Rome, Mélanges d'archéologie et d'histoire*, xix (1889), 131-43. There is an excellent summary of John of Murs' work generally in the *Dictionary of scientific biography* (by Emmanuel Poulle), vii (1973), 128-33.

23. For MSS, and discussion of a longstanding confusion over the authorship of the document — was it John of Murs or John of Lignères? — see Thorndike, *ibid.*, iii (1934), 268-9.

24. The value for J comes explicitly in tract I, and for M in tract II, but some have mistakenly accepted $210^y\,260^d$ as their figure for M, drawn from the Alfonsine tables, rather than the correct $310^y\,260^d$ (310.71 years).

25. (Holcot) "Utrum stelle sint create..." (Thorndike and Kibre, col. 1674); (John de Thermis) "Ad honorem domini nostri..." and "Itaque me videar aliquid ex me..." (ibid., cols. 44 and 797). Kaltenbrunner (1876), 322, says that John was writing for Clement VI; but he was dead in 1354, and the MSS are explicit.

26. The tract by Nicephoros Gregoras (1295-1359) was included in his *History*, of which there are several editions in Greek and Latin. A partial translation into French by Louis Cousin was published in Paris in 1685.

27. For more details of the tables by Levi (1288-1344) see B.R. Goldstein, *The astronomical tables of Levi ben Gerson* (Hamden, Conn., 1974), *passim*, and for an expansion of these brief comments, *ibid.*, 27.

28. See my "Astrology and the fortunes of churches", *Centaurus*, xxiv (1980), 181-211, esp. 200-01.

29. To give only one of several possible examples, in his *Tractatus contra astronomos* he took long sections unacknowledged from Oresme's *De commensurabilitate.* See E. Grant, *Nicole Oresme and the kinematics of circular motion* (Madison, etc., 1971), 130-1, with references also to G.W. Coopland, who first realised the borrowings from Oresme both there and in two other tracts.

30. Three works by Pierre d'Ailly, with their references in Thorndike and Kibre, are: "Astronomice veritatis viam sequentes quam sapientes...", namely the *Concordantia* (col. 158); "Sanctissimo domino pape Johanni vicesimo tertio..." (col. 1372); and "Non modica diligentie cura...." (col. 921). Cf. C. v. d. Hardt, *Magnum Concilium Constantiense* (Frankfurt & Leipzig, 1679), ii, 72, and further references in Kaltenbrunner (1876), 328, n. 2. For general material on the cardinal, see *Lexikon für Theologie und Kirche* (Freiburg, 1963), viii, 330.

31. Kaltenbrunner (1876), 330, 334.

32. *Ibid.*, 333.

33. *Loc. cit.* (following v. d. Hardt).

34. His proof of the spurious nature of the Donation of Constantine and his arguments for its having been an eighth century forgery are justly famous.

35. *Historia gestorum generalis synodi Basiliensis* ed. Birk in *Monumenta conciliorum generalium*, ii (Vienna, 1873); see cap. xix, lib. viii, pp. 708 ff. Paraphrased by Kaltenbrunner (1876), 336-7.

36. Perhaps Hermann Zoestius, author of a tract on the calendar in MS. Melk K. 24, where he says he had written earlier, in 1432, on the subject. The advantage of omitting the seven days (which was not enough to put the equinox right) was that the dominical letters remained the same — a trifling advantage. Hermann noted four ways of dropping the days: by reducing all 31-day months to 30-day months, for one year; by dropping a day out of each of seven consecutive years; by dropping seven days from May 1437.

37. See his *Opera* (1565), 1155-67 and Thorndike and Kibre, cols. 53, 1536.

38. For John of Segovia's comments see Kaltenbrunner, 338, n. 1.

39. See the volume for 1435-41, pp. 347, 349-50.

40. Actually the entries are vacated, since they are repeated below, with the stipulation that the award be made before Whitsunday next. I hope they could agree on when Whitsunday was to be celebrated.

41. This occurs on the last of eight fly leaves (8r) prefacing what is a fine early (12-13 c.) astrological and astronomical collection. The statement is followed by what looks to me standard John Holbrook material (Cambridge based data; length of the year to sexagesimal fourteenths, etc.) very probably deriving from Richard Monk's tables in some measure, as when he gives the entry of the Sun into Aries at the Cambridge meridian for 1434 (March $11^{d}\,5^{h}\,20^{m}$; 14, 28, 19, 25!). See also the note at end of References.

42. See my "Chronology and the age of the world" in *History, cosmology, theology*, ed. W. Yourgrau (New York & London, 1978), 307-33. The tradition had of course much earlier roots.

43. It is hardly necessary to give full references to the tables, which begin on f. 14v and end on 21v. The Laud catalogue distinguishes three items, but rather arbitrarily, and I shall assume that these pages were meant to comprise a coherent whole, inconsistencies notwithstanding.

44. *Dictionary of scientific biography*, vii, 324b (art. by A.P. Youschkevitch and B.A. Rosenfeld).

45. See further the article by K. Ferrari d'Occhieppo in *Regiomontanus Studien* (ed. G. Hamann), *Oesterreichische Akad. der Wiss., phil.-hist. Klasse, Sitzungsberichte*, ccclxiv (1980).

46. *A history of magic and experimental science*, iv (New York & London, 1934), 561.

47. Bibl. Apostolica Vaticana, MS 3684, ff. 2r-8v.

48. H. De Jongh, *L'Ancienne faculté de théologie de Louvain au premier siècle de son existence* (1432-1540) (Louvain, 1911), 83-7.

49. *Sacrorum conciliorum nova et amplissima collectio* [etc.] (Florence, Venice, Paris, etc., 1759 onwards; with reprints etc.), suppl. vi (Lucca, 1852), 462.

50. For more details see Kaltenbrunner (1873), 375-86, who notes that Paul did not see all the consequences of his plans.

51. On Vienna especially see Kaltenbrunner (1873), 386-98.

52. Vol. i, pt. 2 (for 1513-14; enlarged ed. 1920), 1320 [21.07.1514]; vol. ii, pt. 1 (for 1515-16; 1864), 151 [1.06.1515], 647 [10.07.1516], 829 [8.12.1516].

53. Unless I remark to the contrary, I shall quote John Dee's views from his *A Playne Discourse and Humble Advise, for a Gratious Queen Elizabeth* [etc.], Bodleian Library, MS Ashmole 1789, pp. 3 ff. There is much ancillary material, which I shall not discuss in detail here; but note the petition to the Queen at p. 61 (she is to press for dropping eleven days among Christian kings, hoping that they will see sense — this of course was

after the Gregorian reform), and note the draft calendar for May 1583-December 1583, and letters to Dee, later in the MS. For a transcript without the tables filled in, and ending before the petition, see Ashmole 179, item vii. There is a fine transcript in Oxford, Corpus Christi College MC (C) 254, ff. 147v-161v, followed by several valuable documents, beginning with f. 161v: "To the Lordes of the Councell. The Lord Threasurers report of the consultation had and examination of the plaine and brief discourse made by John Dee for the Queenes Majestye, etc. 25º Martii 1582". (See also n. 67 below). We are told that Digges, Savile, and Chambers agreed in principle with Dee, but thought it too late, and that Britain should now go along with adjacent countries in dropping only *ten* days. They refer to a scheme drawn up by Dee for doing just this — which is his calendar of Ashmole 1789 (see above), of which there are two copies here (163v-176v). There follow excerpts from Grosseteste's *Computus* (176v-177r) and actual letters about the calendar to Dee from Walsingham (1582), as well as other transcripts. Much of this MS is in Dee's hand.

54. D. Marzi (1896 - see my n. 1), 174.

55. *Ibid.*, pp. 233-50 contains an edition by Marzi of a MS life of Paul of Middelburg written by Bernardino Baldi (1553-1617).

56. For this whole episode see D.J.K. O'Connell, "Copernicus and Calendar Reform", *Studia Copernicana* (Warsaw, 1975), xiii, 189-202, esp. pp. 196-7.

57. Thus E. Rosen, in the discussion appended to O'Connell's paper (see n. 56), says that Giglio accepted the length of the *year* given by the Alfonsine tables. See the following note.

58. The system of epacts devised by Giglio (Lilius, in its Latin form) is explained in van Wijk (1932), 25-9. He accepts Giglio's use of the Copernican figure for the length of the month, but I note that H.J. Felber, in a paper preceding O'Connell's, p. 187, says that the Lilian new moons were computed by the use of the old Alfonsine dates. I leave the question to my colleagues.

59. This hypothesis was proposed by Professor Noel Swerdlow: "The origin of the Gregorian civil calendar", *Journal for the history of Astronomy*, v (1974), 48-9 (as pointed out to me by Professor Bernard Goldstein). This very acute observation is lacking in historical force, at least as far as settling the question of who used which authorities. It suggests, first of all, that those concerned with the reform were not making a conscious compromise. (We know several examples of would-be reformers who advocated approximative rules in the interests of simplicity). The Gregorian rule could easily have been seen as a reasonable approximation to any or all of the "best" authorities, unrounded. But as Swerdlow shows, it could just as well have been seen as an exact rule, accepting any of the "best" authorities, suitably rounded. He opens our eyes to a historical possibility, without really venturing into historical territory. From a theoretical standpoint, indeed, he opens our eyes to more possibilities than he mentions. It may be very easily verified that (with our modern way of rounding, at least) *any* author who accepted a value for J lying between 130.99 and 135.76, when working to the limits of accuracy usually claimed (say two fifths of a second or better), would have rounded sexagesimally so as to give the Gregorian rule. This would have included, for instance, anyone working from the Toledan tables of solar motion (sidereal coordinates, thus needing correction for precession) with a vernal point moving temporarily (I assume he would have accepted trepidation, but he need not have used it to get this figure) at the rate of a degree in 72 years. But this is just an example of how to miscalculate history. Swerdlow had in the background to his argument one important historical fact, namely that Pitatus (1560) remarked that the intercalation of 97 days in 400 years was "consistent with the tropical year of the *Alphonsine tables* and with the mean tropical year of Copernicus and Reinhold". And the *need* for such information brings me back to the point I was making in the text.

60. Mansi, *op. cit.* (see my n. 49), 702-6; and Marzi (1896), 191-5.

61. *Ibid.*, 211.

62. Kaltenbrunner (1876), 386 ff.

63. *Ibid.*, 392.

64. Marzi (1896), 206-8.

65. *Ibid.*, where the document is printed as a frontispiece.

66. W.E. van Wijk (1932), 22, correcting a misunderstanding by Kaltenbrunner. Note that the President of the Gregorian Commission (Cardinal Sirleto) had been involved in the preparation of the Breviary.

67. See n. 53 above. There is some doubt about the date, which might be in error for 1583 (the New Year for purposes of civil dating began on 25 March).

68. *Calendar of State Papers, Domestic... Elizabeth, 1581-1590*, ed. R. Lemon (London, 1865), 107.

69. The numbers in parentheses are page references to MS Ashmole 1789. See n. 53 above.

70. For an illustration from this MS, and some comments on it, see R.T. Gunther, *Early science in Oxford*, vol. ii (Oxford, 1923), 52, pl. See, however, the following footnote.

71. The vital parts of MS Digby 178 seem to have been copied by some mid-fourteenth century Mertonian, possibly Bredon. There is what has been taken as his autograph (on the grounds, in particular, that it uses the first person singular) on f. 13r. Between ff. 11r and 13r are tables for the Sun between 1341 and 1344 (a full leap year cycle), as well as a table of lunar latitude. There is another copy of these pages, with the "ego Bredon" (!), in MS Digby 176, ff. 71-2, and there it is stated that the tables were *calculated and written by William Reed.*

72. See n. 53.

73. See n. 53.

74. *Robert Grosseteste, Scholar and Bishop*, ed. D.A. Callus (Oxford, 1955), xxxiii.

[*Note added in proof*: Essentially the same material as that referring to "R. M." in MS Ashmode 369 (referred to on page 91) is to be found in MS Gloucester Cathedral 21, f. 9r. This was pointed out to me by Mrs Hilary Carey. Sure enough, the manuscript contains Holbrook material. It belonged to John Argentine, chaplain to Henry V and Henry VI. See N.R. Ker, *Medieval manuscripts in British libraries* (Oxford, 1977), 952-5.]

III.

ASTRONOMICAL ASPECTS OF THE REFORM

ASTRONOMICAL ASPECTS OF THE CALENDAR REFORM

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In the Julian calendar 19 years equaled 6939.75 days, longer than the lunar Metonic cycle by 0.0616 days. This resulted in the calendric precession of new moon by almost 3¼ days in a thousand years. This shift, noted repeatedly in medieval Europe, was a cause of concern and, perhaps, a principal factor inducing attempts to reform the calendar. In fact, some reform projects were restricted to the amendment of the lunar cycle, without paying much attention to the correct length of the year.[1]

With the solar year we come to the central question of calendar astronomy. The determination of actual dates of equinoxes may appear a straightforward and direct operation. However, astronomers for centuries preceding the Gregorian reform had to account for evidence that the length of the tropical year was variable. Also, to define the solar year meant to define the relations between equatorial and ecliptic coordinates, in short the fundamental system of celestial coordinates including the equinoctial points. For several centuries before the Gregorian reform this was the most troublesome question in mathematical astronomy. It centered on the precession of the equinoxes, a phenomenon which in the geostatic astronomy was described as the motion of the eighth sphere, the sphere of the fixed stars. This motion, common to the lower spheres, affected directly the Sun's orbit and, consequently, the length of the tropical year. Conceptual inaccuracies and the lack of coherence of various competing explanations of this motion created most serious problems for setting up a scientifically based calendar.

This indeed is the point to be stressed, as on a purely quantitative level the whole question becomes much simpler and, in later Middle Ages, a purely numerical solution was possible. The length of the tropical year was accepted commonly as $365^d\, 5^h\, 49^m\, 16^s$ (365.24254^d), a value that is only 0.0034^d (30^s) too long in comparison with the actual value of 365.24220^d ($365^d\ 5^h\ 48^m\ 46^s$). The Julian year of 365.25^d was more than 11^m longer than this. An example of a practical numerical solution can be found in the project of the calendar reform formulated at the Council of Basel in 1435 and noted by Thomas of Czempiń (Strzempiński), the later bishop of Cracow.[2] That project called for the omission of the intercalary (366th) day once in 136 years and for a one-day forward shift of Golden Numbers every 272 years. All in all, this was a sound proposal; the actual error of lunar and solar periods would reach one day only in well over two millenia. However the astronomical foundations of the project were, indeed, very weak.

The dominant astronomical theory for over 200 years, since the early 14th century, was that contained implicitly in the Alfonsine Tables, the most universal tool of practical astronomy. On analysis, the tables themselves display a generally coherent Ptolemaic theory of planetary motions; the picture is much less satisfactory for the motion of the eighth sphere.

The tables combined two ancient models: one (Ptolemaic) of the uniform motion of the stellar sphere together with the ecliptic; and the other, of periodic oscillation ("trepidatio") of that sphere around two fixed points of the mean ecliptic of an outer sphere. The motions were related to the celestial equator which, within the geostatic cosmology, defined an absolutely fixed reference plane. The composition was thought necessary in view of the historical evidence, pointing to the changes in the length of the tropical year.[3] The geometrical equivalent of the tables is shown in Figure 1. The tables themselves contain the linear component, the forward motion of point Υ_9 ("equinox of the ninth sphere") with the velocity of $1°/136$ years and the trepidational motion of Υ_8 ("equinox of the eighth sphere") with an amplitude of 9°, producing the "aequatio accessus et recessus octavae sphaerae" $P\Upsilon_8$. The equation follows the formula $\sin P\Upsilon_8 = \sin 9° \sin \Theta$, which is in fact a strict solution of the spherical triangle $P\Upsilon_8\Upsilon_9$ with the right angle at P. Clearly the values computed from the tables do not correspond with the (only possible) geometrical interpretation. The actual equinoctial point, the intersection of the ecliptic with the equator at Υ, and the whole motion of the sphere is determined by the arc $\Upsilon\Upsilon_8$ and not, as in the tables, by the sum of two arcs $\Upsilon_9\Upsilon_{10} + \Upsilon_8 P$. The difference enters directly into the solar theory, as it changes the dates of the equinoxes by up to one day in a century. The most important defect was the ambiguity of the geometrical model, in which no "radix" position was given of the equinox of the ninth sphere (Υ_9), such as, for example,

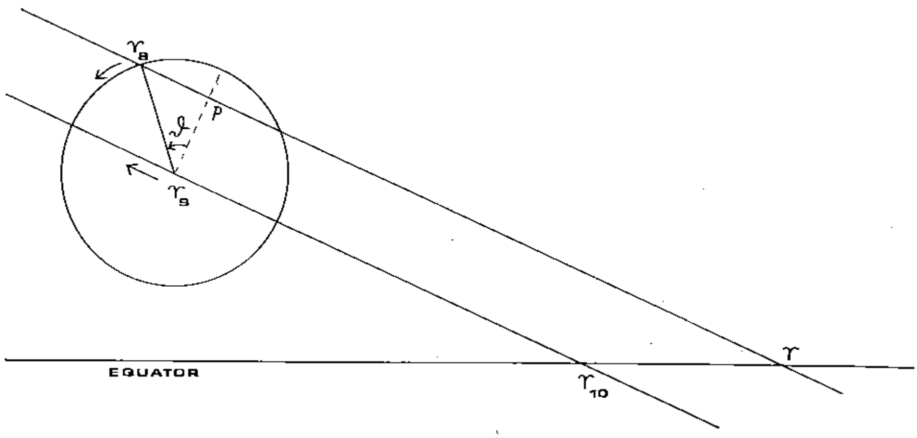

FIG. 1. The diagram represents the region around the intersection of the ecliptic with the equator at the Aries (vernal) equinoctial point. Analogous geometrical features occur at the opposite point of the celestial sphere, the Libra point.

the date at which it crossed the equator. Finally, changes in the equation of time should be noted, generated by the changing position of ♈ on the equator.[4]

This lack of coherence and the eclectic treatment of various co-existing theoretical models inserted itself into both astronomical textbooks and into astronomical computations, including the most direct effect of the motion of the eighth sphere, that of the changes of stellar coordinates (the longitudes of stars listed in a catalogue determine the equinox for its epoch). It was a common practice — well into the 16th century — to compute the positions of the stars, adding appropriate corrections (from Alfonsine Tables) to the coordinates of the Alfonsine star catalogue. The astronomical community of those times did not realise that to arrive at the stellar coordinates for a specific epoch a series of various procedures was involved beginning from the earliest historically attested source, the catalogue of Hipparchus. His star places were reduced by Ptolemy for 140 AD using a markedly too small rate of the motion of the eighth sphere (1°/100 years). The tenth century Islamic astronomer As-Sufi, misdating Ptolemy's catalogue by over 40 years, computed the difference of stellar longitudes with a different rate (1°/66 years). As-Sufi's catalogue was reduced with the same rate to the epoch of 1256 by the compilers of the Alfonsine star catalogue. In later European tradition this epoch was taken as 1252 AD. It is from that date that star places were computed with the Alfonsine Tables of the eighth sphere.

The defects of the Alfonsine theory and its possible reinterpretation became a principal subject of astronomy of the 15-16th centuries. It was treated at some length in the standard theoretical textbook of the times, the *Theoricae Novae Planetarum* of George Peurbach. Peurbach noted the difference between tabular and actual dates of equinoxes but the only change he proposed in the theory was to transfer the "equation" from Υ_8 P to Υ_9 H (Fig. 2). In early 16th century the theory of the eighth sphere was discussed with explicit reference to its importance for the postulated calendar reform, especially about the time of and after the Fifth Lateran Council.

Jacob Essler in 1508 [5] and Martin Biem of Olkusz in 1516 [6] computed the correction of the equinoxes missed by the Alfonsine Tables. Somewhat arbitrarily both authors defined the initial epoch (radix) for the linear motion of the eighth sphere, assuming the centre of the trepidational circle to cross the equator at the beginning of the Christian era, at noon of 31 December, 1 BC. It is only with such an additional condition that actual differences of equinox dates based on the geometry of the Alfonsine Tables as compared to the dates of the Tables themselves can be computed (Fig. 3).

The importance of the subject led even to violent, truly Renaissance style, polemics such as that between Albert Pighius of Paris and Marco Beneventano of Naples.[7] They argued for (Pighius) and against (Beneventano) the validity of the geometrical interpretation of Alfonsine Tables. Marco Beneventano noted again the difficulties arising from the undefined position of the trepidational circle (the "radix" position of Υ_9). Outside the

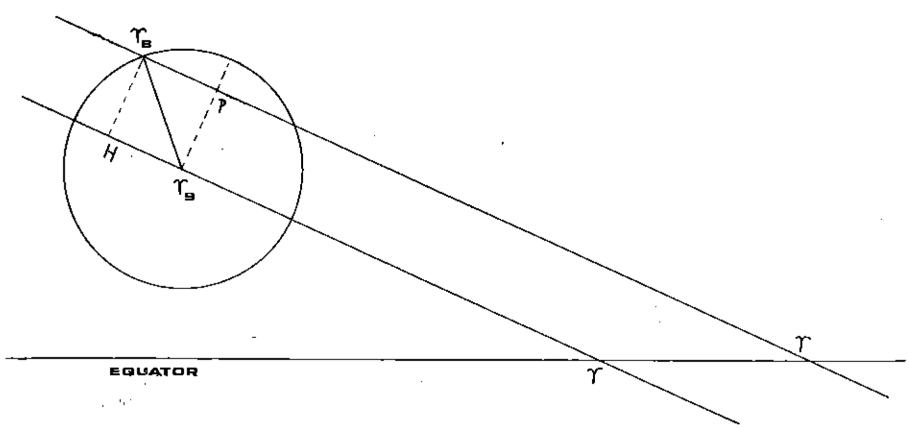

FIG. 2. Peuerbach's change to Figure 1 given in his Theoricae Novae Planetarum.

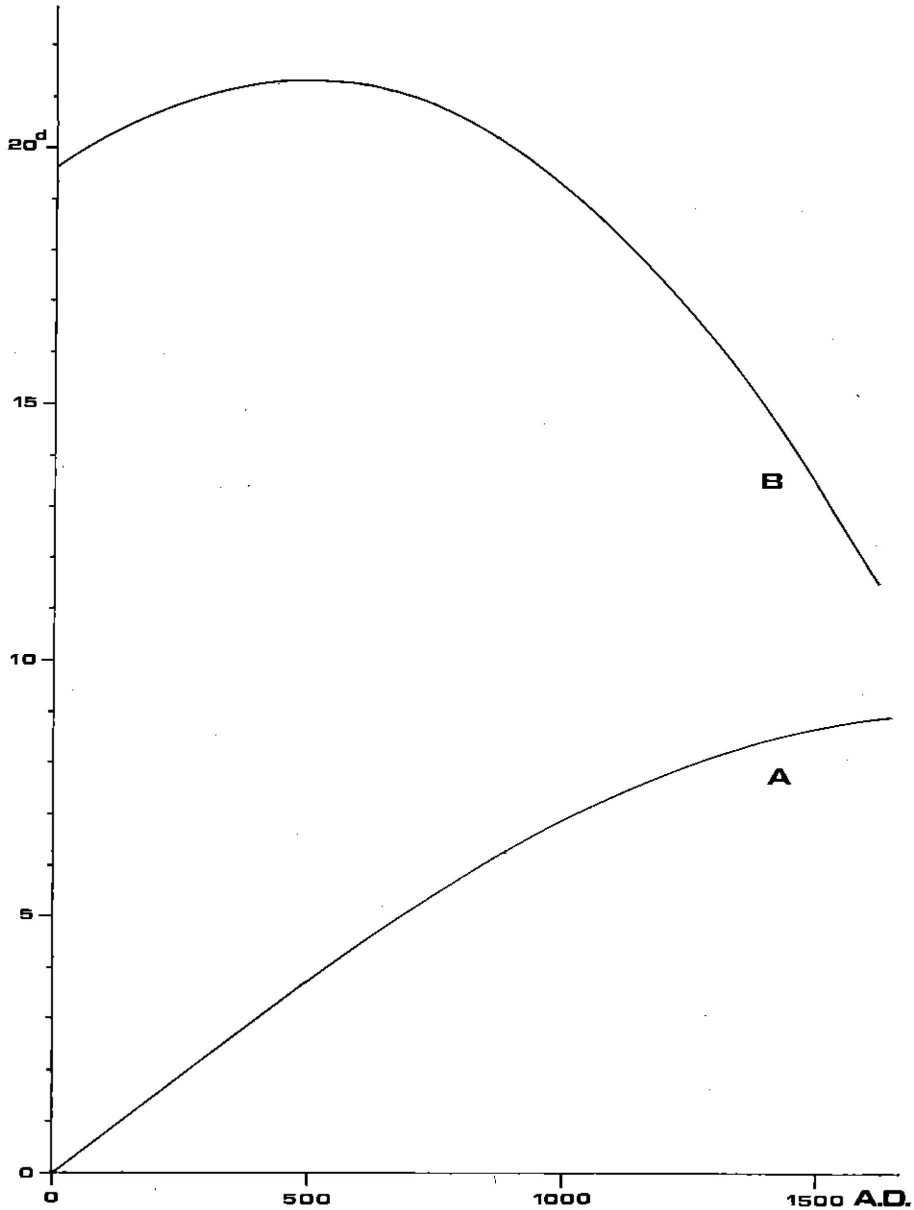

FIG. 3. Difference in days between actual and mean dates of the vernal equinox according to the algorithm of the Alfonsine Tables (A) and their geometrical interpretation (B).

mainstream of the discussion, isolated authors tried to revert to the simple theory of a linear motion of the stellar sphere.

The only further attempt to clarify the issue of the eighth sphere in its Alfonsine interpretation was the treatise by John Werner of Nuremberg, *De motu octavae sphaere* of 1522.[8] The substantial innovation introduced by Werner, rectifying to a large extent the difficulties of the Alfonsine theory, was to change the order of the spheres and, in this way, to stabilize the trepidational circle at the intersection of the "mean ecliptic" and the equator. In Werner's theory the stellar sphere had to move with uniform motion, the trepidation was provided for by three additional outer spheres. Werner's concepts did not find subsequent followers. This might have been partly due to its geometrical complexity but a more important factor seems to be the (1543) publication of Copernicus's *De revolutionibus.*

In the dedicatory preface to Pope Paul III Copernicus stressed the connection between the state of astronomy and the possibility of a calendar reform. Such a reform was impossible at the time of the Lateran Council for purely scientific reasons: "quod annorum et mensium magnitudines, atque Solis et Lunae motus nondum satis dimensi haberentur".[9] Clearly the second part of this quotation referred to the unsatisfactory state of the foundations of the mathematical astronomy. Copernicus attributed to the Lateran Council the stimulus which induced him to undertake detailed re-investigation of these problems.[10] As witness to this interest is the solar table, a device constructed by Copernicus to demonstrate the Sun's distance from the equinox, preserved in part at the Olsztyn castle.

Within the Copernican theory the stellar sphere became a motionless fundamental background of mathematical astronomy. The precession of celestial equator with equinoctial points along the fixed ecliptic explained the changes of stellar longitudes and the difference between the sidereal and tropical years.[11]

In its details the Copernican theory of precession is much more complex then this general picture. Separate mechanisms were introduced to represent the (non-linear) precession of the equinoxes and periodic changes of the obliquity of the ecliptic. A trepidational term ("anomaly of the equinoxes") with the period of 3434 Egyptian years was kept to account for changes in the rate of precession, as shown by ancient and early medieval observations.[12] However the importance of the Copernican theory of precession for our subject was of the very first order. By unequivocal definition of all elements in the system of celestial co-ordinates it eliminated the incoherence of the former doctrine. Numerical parameters could now be referred with formal precision to the geometrical reference frame. This is not to say that the subject of the variability of the solar year lost its topical character or that all disputes were closed. What mattered was that the professional standards were improved making astronomical expertise more exact.

To a large extent, this change was introduced in the astronomical practice of the later 16th century through the Prutenic Tables of E. Reinhold.[13] The tables of Reinhold, a critical revised and expanded version of the tables from *De revolutionibus*, displaced the Alfonsine (and related) tables as the standard working tool of the astronomical profession.[14] It was a relatively short-lived event; the Prutenics became passé at the end of the century, but they dominated the field just in the period of the final and successful reform of the calendar.

On the eve of that reform the discussion centered on the mean length rather than, as seventy years earlier, on the definition of the solar year. Thus Petrus Pitatus in his interesting project of a new calendar of 1560[15] argued for the (mean) Alfonsine value of the solar year, this being confirmed by determinations of recent astronomers like Abraham Zacuth, Nicholas Copernicus and Erasmus Rheinholdus. The (Alfonsine) trepidation of equinoxes should be disregarded as it does not influence the mean length of the year.[16]

The spokesman for the actual Gregorian reform, Christoph Clavius, investigated carefully the effect of the (Copernican) anomaly of the equinoxial points on the date of the equinox. Clavius' exposition of the Gregorian calendar, the *Romani calendarii explicatio*, contained a lengthy analysis of this effect, using Prutenic Tables and concluding that the adoption of the mean solar year could produce at most an error of one day in the actual equinox.

The same work contained a short synopsis of the history of the astronomical aspects of calendar reform, which may serve to summarize the subject of this paper: . . . ob irregularem motum octavae spherae (. . .) haec res plene cognosci non potest, hic multis saeculis elapsis, nihil certi nobis (. . .) reliquerunt. Unus post hominum memoriam Nicolaus Copernicus (. . .) ausus est solertia sane incredibili, adhibitis nobis hypothesibus (. . .) annum solarem ad certam, definitamque normam redigere (. . .).[17]

This brings us again to the role of astronomy in the long process of calendar discussion and calendar reform. Astronomers as such were neither the most interested nor the most active group initiating the reform. In scientific practice any calendar was simply a conventional tool necessary for linking past and contemporary observations. Hence familiarity with various historical calendars was a necessary condition for serious research. The Alfonsines began with a sizeable set of appropriate auxiliary tables for converting various eras and calendars to a uniform sexagesimal day-count. Exigencies in the life of the Church were a primary motivating factor in the new calendar projects. Once such a project was envisaged, a second stage followed at which the conformity of a new calendar scheme with the scientific doctrine of the times (and the validity of that doctrine) had to be investigated. Surely, the story of futile attempts at a reform in late Medieval times and of the final success in 1582 goes a long way to show that the results of these investigations were of much importance.

As a footnote, a somewhat academic, but surely legitimate, technical point might be raised, that of the zero meridian of the calendar. This is a point of minor practical importance, as the differences arising from referring the calendar tables to various longitudes are by and large obliterated through the use of mean motions and through the approximations due to counting individual periods in integral numbers of days. And yet, any set of astronomical ephemerides (and that includes the luni-solar calendar) are necessarily referred to, and valid at, a specific meridian. This question was not explicitely treated in past studies and projects of the calendar. For the Julian calendar the answer, if any at all, could only be given with a very rough approximation. Let us, however, discuss briefly the possible determination of the reference meridian implicit in the Gregorian calendar.

For the Moon the zero meridian was involved only in the onetime change of lunar epact caused by the three days shift of new moons. The determination of the discrepancy of actual and calendaric times of new moons is equivalent — in terms of fundamental astronomy — to the mean of a series of observations made by various authors in various places in Europe. Thus the reference longitude of the radix of the motion of the calendaric moon is in fact the mean value of longitudes of Latin European astronomical centers.

For the Sun's ephemerides one can rely on the explanatory text of Clavius.[18] To verify new calendar parameters Clavius computed the times of a series of equinoxes and of cardinal points of the Copernican anomaly of equinoxes, using tables of Reinhold and Magini.[19] Both these sets of tables relied on the fundamental system of mathematical astronomy determined by Copernicus at, and for, the meridian of Frombork, identified by Copernicus with the meridian of Cracow. The Prutenic Tables of Reinhold are in fact ameliorated Copernican tables reduced to a meridian $5^m = 1^\circ 15'$ east from Frombork (the meridian of Königsberg); the appropriate reduction for the tables of Magini is $45^m = 11^\circ 15'$ west from Frombork (meridian of Venice). The mean of the two values, $20^m = 5^\circ$ west of Frombork, may therefore be considered with some licence as the "Gregorian meridian".

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4. The theory generated also spurious changes in the obliquity of the ecliptic within the clearly impossible limits of $23.5^{\circ} \pm 9^{\circ}$.

5. I. Essler, "Speculum astrologorum..." (Maguntiae, 1508).

6. *Nova calendarii romani reformatio*, ed. by L.A. Birkenmajer (Kraków, 1918). Biem wrote, on behalf of the Cracow University, to the calendar commission of the Lateran Council.

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8. Cf. J. Dobrzycki, "John Werner's Theory of the motion of the eighth sphere", *Actes du XII^e Congrès International d'Histoire des Sciences* III A (Paris, 1971), 43-45, and "Teoria precesji", 29-32.

9. *De revolutionibus orbium coelestium libri VI* (Norimbergae, 1543), fol. IV v.

10. "Ex quo quidem tempore his accuratius observandis animum intendi, admonitus a praeclarissimo D. Paulo episcopo Semproniensi, qui tum isti negotio praeerat" (*De revolutionibus, loc cit.*).

11. Cf. K.P. Moesgaard, "The 1717 Egyptian years and the Copernican theory of precession", *Centaurus* XIII (1968), 120-138.

12. Incidentally in the new theory the trepidation term and its impact on the solar theory were greatly diminished with the tropical year changing within the limits of $\pm 11.8^{m}$ and the actual equinox differing from the mean by $1^{d}4^{h}$ at the most.

13. *Prutenicae Tabulae coelestium motuum* (Tubingae, 1551); cf. O. Gingerich, "The role of Erasmus Reinhold and the Prutenic Tables in the dissemination of Copernican theory", *Studia Copernicana*, VI (1973), 43-62, 123-125.

14. As noted before the heliocentric theory was not necessarily a precondition for the fundamental mathematical astronomy. In fact several authors have transformed Copernicus back to a geocentric form. I can name here A. Leoninus a Groenewoude, "Theoria motuum coelestium referens doctrinam Copernici ad mobilitatem Solis..." (Coloniae Agrippinae, 1583); A. Magini, "Theoricae novae coelestium orbium theoricae congruentes cum observationibus N. Copernici" (Venetiis, 1589).

15. "Compendium Petri Pitati Veronensis... super annua solaris atque lunaris quantitate... Romanique Calendarii instauratione..." (Veronae, 1650).

16. "Extat tamen certa aequandi anni ratio per restitutionem solis (...) per arcum orbis magni a polis eclipticae fixae (...) nullam statuendo differentiam quod sol sub mobili eccliptica in utranuis partem deferatur. Sed quoniam ecclesia in divinis mysteriis non tam stricte mathematicam certitudinem requirit, veluti astronomus in planetarum motibus accuratissime, quod fieri possit, observat, verum eadem, veris et inaequalibus neglectis, medios et aequales luminarum motus (quod et haebrei itidem a Mose et Noa citra, graeci quoque et latini patres fecerunt) observat". (*Compendium*, fol. 5 v).

17. Ch. Clavius, *Romani calendarii explicatio...* (Romae, 1603), 81.

18. Ch. Clavius, *op. cit.*, 80, 89-92, 97.

19. G.A. Magini, *Ephemerides coelestium motuum* (Venetiis, 1582).

COPERNICUS AND THE DETERMINATION OF THE LENGTH OF THE TROPICAL YEAR

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1. *Copernicus and the Reform of the Calendar*

Copernicus's contribution to the Gregorian Calendar Reform has been widely discussed and analysed.[1] In particular Edward Rosen, in his biography of Copernicus published in the appendix to the volume "Three Copernican Treatises", on the basis of existing documentation, delimits the role played by Copernicus at the time of the Fifth Lateran Council (1512-1517), during which attempts were made to gain a greater insight into the astronomical and chronological aspects of the calendar reform.

Despite the testimony of Galileo, who in the famous "Letter to the Grand Duchess"[2] stated that "Copernicus was called to Rome from the remote parts of Germany for the sake of this reform", it appears by now to be ascertained that Copernicus's role in this question was quite limited. It seems quite probable that following the letter addressed to Paul of Middelburg on 16 February, 1514 by Leo X in which the Pope expressly invited the eminent Dutch scholar to Rome to discuss the calendar, the same Paul of Middelburg asked for Copernicus's opinion on the matter. In fact, it has been ascertained that Copernicus answered this invitation with a letter, as results from the list of correspondence drawn up by Paul of Middelburg and attached to the report he sent to Leo X about the Calendar.[3]

On the other hand, we know nothing of the content of Copernicus' letter to Paul of Middelburg. It would however appear most probable that it concerned the determination of the length of the tropical year. Although this may not be considered the most important reason that moved Copernicus to conceive *De Revolutionibus*, it played a not secondary role in the evolution of the planetary theory as described by Copernicus in *Commentariolus*, presumably written between 1512 and 1514, up to the new formulation of the theory of the Sun's motion described in Book III of *De Revolutionibus*, terminated in the years 1524-25.

It, therefore, does not seem too presumptious to hold that the period from 1514 to 1516, during which problems connected with calendar reform were forcefully reproposed, coincides with one of the crucial periods in the development of Copernicus's planetary theory. In the years 1515 and 1516 Copernicus, as we shall point out later, carried out precise observations on the duration of the tropical year since he was convinced that a better knowledge of solar and lunar motion would be a decisive step toward calendar reform. In the preface to *De Revolutionibus*, written in 1542, he appears to insist on this concept when he states: "not long ago, under Leo X, when the reform of the ecclesiastical calendar was under discussion in the Lateran Council, no solution was found for the sole reason that the length of years and months and solar and lunar motion were not yet considered to be sufficiently well determined. Since that time, in fact, I have turned my attention to the observation of these phenomena, solicited in this by that eminent monsignor Paul (of Middelburg), bishop of Fossombrone who was presiding over those discussions." [4]

2. *Considerations on the Length of the Tropical Year in Copernicus*

As we know, the 1582 Gregorian calendar was still based not on the duration of the tropical year formulated by Copernicus, but on that derived from the Alfonsine Tables, sponsored by King Alfonso X of Castile, compiled in 1252 and printed for the first time in 1483. The fact that the new Calendar should not be regulated in conformity with Copernicus' treatise but according to the indications contained in the *Compendium* written by Luigi Lilio (also called Luigi Giglio or Aloisius Lilius) and published after his death in 1577, contributed to the poor reception accorded to Copernicus' results in measuring the length of the tropical year. It was, in fact, from the accurate analysis of the values of the length of the tropical year and of the equinoctial motion determined throughout the ages by the best astronomers, that Copernicus became convinced, erroneously, that the duration of the seasonal year was not constant and that uniform motion should be measured beginning from the stars and not by seasons. As is known, he attributed the observed variability of the tropical year to the irregular motion of the equinoxes.[5] At the sametime he determined, as we will show, the length of the tropical year with unusual accuracy. In Table 1 the length of the seasonal years (in days) determined from a given equinoctial day until a following corresponding equinoctial day in the spring or autumn are given according to different authors quoted by Copernicus in the *Commentariolus.*

The values of the length of the mean year adopted by Copernicus starting from measurements of the interval between successive equinoctial days is greater than that adopted in the Alfonsine Tables, equal to 365.2425 and obviously greater that the length now accepted for the tropical year (365.24220). In any case it appears to be one of the best of the determinations then available.

The determination of the length of the year starting from observations of the equinoctial days according to the method used by the ancients and by Copernicus himself is at any rate a rather imprecise method. To realize this it is enough to consider the fact that the length of the year deduced from Copernicus's measurements from the intervals between the spring and autumn equinoxes of the year 1515 [10] and between the autumn equinox of 1515 and the spring equinox of 1516,[11] is 364 days, 23 hours and 02 minutes. It is thus possible to hypothesize an average uncertainty in the length of the equinoctial days of from 6 to 12 hours and that is about 0.25 - 0.50 days/year. Undoubtedly a more appropriate method is the one based on stellar observations of the position of the spring equinox and that is, the one based on the determination of the precessional motion of the same equinox.

3. *The Length of the Tropical Year from the True Precession Measurement*

In *De Revolutionibus* Copernicus carried out an accurate analysis of the measurements of the position of the equinoctial point according

TABLE 1. — Length of the Tropical Year (in days) Attributed by Copernicus to Different Astronomers.[6]

Hipparchus	365.2500
Ptolemy [7]	$365.24\overline{66}$
Albategnius [7]	365.2403
Hispalensis [8]	365.2424
Copernicus [9]	$365.242\overline{7}$

to the ancients so as to determine the effects of precession and to study its periodic variation, wrongly attributed to the equinoxes. Copernicus himself, in 1515 [12] and 1525,[13] carried out stellar observations for the purpose of improving knowledge of mean equinoctial motion and he calculated the value of the mean precession in longitude to be $50'' 12''' 5'''' = 50''.2014$.[14]

On the basis of these data Rheticus computed the values of the true precession of the equinoxes referred to the first star of Aries (♈ Arietis) at certain times of observations.[15] Starting from these data Table 2 was reconstructed and the mean precession values referring to different intervals of time were calculated. Starting from these precession values we shall attempt to show that the value of the length of the year obtained with the values observed by Copernicus is exceptionally close to the value now accepted.

Utilizing the precessional values given in Table 2 it is easy to calculate the time required by the Sun to move from a vernal equinox round the elliptic back again to the next vernal equinox, that is, the length of the tropical year. The length of the sidereal year, the time required by the Sun to traverse the ecliptic as regards a fixed point, which appears in the ratio: (Sid. year)/360° = (Trop. year)/(360° − preces.), was well known in Copernicus' time. Copernicus himself gives the value of $365^d\, 6^h\, 9^m\, 40^s = 365.25671$ [17] for the length of the sidereal year and this is about 30 seconds greater than the value now used (365.25636). Using the value given by Copernicus for the length of the sidereal year we have the values of the length of the tropical year given in Table 3.

The values for the length of the tropical year deduced from the observations carried out by Copernicus in 1525 and referring to the observations made by Albategnius, the most authoritative of the Arab astronomers, are consistent with the values of precession and length of the sidereal year known to Copernicus.

TABLE 2. — Precessional Values Calculated for Different Time Intervals

Hipparchus-Timocharis	166 years	35''.8
Ptolemy-Hipparchus	264	35''.7
Albategnius-Ptolemy	742	55''.8
Arzachel-Albategnius	196	62''.1 [16]
Copernicus-Arzachel	449	46''.5 [16]
Copernicus-Albategnius	645	51''.3

TABLE 3. — Length of the Tropical Year (in days) Deduced from Precessional Values.

Hipparchus-Timocharis	365.24662
Ptolemy-Hipparchus	365.24665
Albategnius-Ptolemy	365.24098
Arzachel-Albategnius	365.23921
Copernicus-Arzachel	365.24360
Copernicus-Albategnius	365.24225

However, no one at that time made use of this value because of the opinion of the promotors of calendar reform regarding Copernicus planetary theory. One of the main promoters of the calendar reform, Ignazio Danti, who in 1576 had determined the epoch of the solstices with the sun-dial he had built in the church of St. Petronius in Bologna (since destroyed), still attributed to Copernicus in 1578 [18] the value of the length of the year of $365^d\,5^h\,55^m\,13^s = 365.2466$, which is obviously wrong and which, as can be seen from Table 1, is simply the value of the length of the year that Copernicus attributed to Ptolemy.

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5. *ibid.*, p. 409.
6. The values given are those reconstructed on the basis of the text supplied by N.M. Swerdlow, Proc. of the Amer. Phil. Soc., 117, 1973, pp. 423, 512.
7. In *De Revolutionibus* the values 365.2466 and 365.2405 are attributed to Ptolemy and Albategnius respectively (cfr. *De Rev.*, FB, p. 411).
8. Hispalensis has been correctly identified by A. Birkenmajer with Alfonso de Cordoba (Stromata Copernicana, Cracow 1924, p. 353). The length of the year mentioned by Alfonso de Cordoba is the same adopted in the Alfonsine Tables disregarding the fraction of minutes (cfr. *Comm., HR*, p. 78, n. 14, and E. Rosen, *Three Cop. treat.*, p. 66, n. 21.
9. Length of the tropical year adopted by Copernicus (*Narr. Pr.*, ER, p. 116 and 202).
10. The interval between the spring equinox and the autumn equinox in 1515 observed by Copernicus is $186^d\,2^h\,12^m$ (cfr. *De Rev.*, FB, p. 431).
11. The interval between the autumn and spring equinox is evaluated by Copernicus as being $178^d\,21^h\,24^m$ (cfr. *De Rev.*, FB, p. 431). Calculating this same interval on the basis of the epochs reported by Copernicus himself (cfr. *De Rev.*, FB, p. 412) one has however $178^d\,20^h\,50^m$.
12. *De Rev.*, FB, p. 373.
13. *ibid.*, p. 371.
14. *ibid.*, p. 415.
15. *Narr. Pr.*, ER, p. 116.
16. The precession values are derived from the value of $21^\circ\,33'$ for the true precession of the first star of Aries attributed to Arzachel and calculated by Neugebauer from the Tables of the *De Rev.*, cfr. *Narr. Pr.*, ER, p. 116, n. 30, and H. Hugonnard et al., *Intr. a l'Astr. de Coper.*, p. 105, n. 21.
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IV.

SOME PRINCIPAL PERSONAGES OF THE REFORM

CHRISTOPH CLAVIUS AND THE SCIENTIFIC SCENE IN ROME

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In September 1580 the congregation established by Pope Gregory XIII to reform the calendar presented him with a report entitled *Ratio corrigendi fastos confirmata, et nomine omnium, qui ad Calendarii Correctionem delecti sunt oblata SS.mo D.N. Gregorio XIII.*[1] The report outlined a number of requirements and methods which the entire congregation thought should be adopted for the construction of the new calendar, the principles of which may well have been drawn up in some detail already when the report was written.[2] We shall not here consider the contents of the *Ratio* but only draw attention to the fact alluded to in its title, viz. that among all the documents issued by the congregation this report alone revealed all the names of its members.

Among the nine signatures we find the names of three prominent prelates. The first is Cardinal Guglielmo Sirleto who was the prefect of the congregation and co-ordinator of its work. Next comes Bishop Vincenzo Lauri of Mondovì who was perhaps the co-ordinator of the group before Sirleto.[3] In the third place we find the name of the Patriarch Ignatius of Antioch. It is certain that the three of them were well acquainted with astronomy and we have direct evidence of this in the case of the Patriarch.[4] However, they must have been primarily selected as authorities on such matters as ecclesiastical chronology, liturgy, the history of the calendaric deliberation of the Councils, and rites of the Eastern and Western churches.[5]

The next group of three comprises one Leonardo Abel from Malta whose only role, as an expert in Arabic, seems to have been to act as a witness to the signatures of the Patriarch. In the Latin text the next member is called Seraphinus Olivarius Rotae Auditor Gallus; this reveals him as a French lawyer who was probably summoned to the congregation in view of the many legal implications of the reform for both Canon and Civil Law. A further signatory was the Spaniard Pedro Chacòn (or Ciaconius in the Latin texts) who was a highly erudite patristic scholar and church historian and as such able to assist the congregation with respect to the exact interpretation of conciliar and pontifical statements regarding the calendar in general and the movable feasts and the martyrology in particular.

Finally we find a group of three persons who formed the scientific section of the congregation. The first was Antonio Lilio, who was an astronomer in his own right, but acted mainly as a kind of scientific executor for his deceased brother Luigi Lilio, who had framed the principle upon which the reform was going to be founded. In consequence the only real experts in mathematics and astronomy among the members of the congregation were the two last signatories, Christoph Clavius and Ignazio Danti.

It is worth noticing that, with the exception of Lilio, all the members of the congregation belonged to the clergy, like numerous other scholars and scientists of the time all over Europe but particularly in Italy.[6] Furthermore, no member was a Roman by birth or particularly connected with the Roman cultural tradition. This is certainly true of Lilio and Danti among the scientists. The only exception seems to be Clavius who was a member of the Collegio Romano of the Society of Jesus. Consequently, it appears that the reform was not the natural result of a movement within the local, Roman tradition.[7] It was the product of an enterprise of the Catholic clergy, performed in a truly international and ecumenical spirit with participants from Italy, Spain, France, Germany, and the East. Nevertheless, it emanated from Rome and it is reasonable to assume that there were at least some links between the fathers of the reform and the local scientific scene. This scene was in some respects different from that which we find at the same time elsewhere in Italy, and particularly in the northern parts of the peninsula.

Sixteenth century Rome provided no public support for scientific or technical research. The particular economic system of the Papal State, as well as its still feudal nobility and to some extent also its geography, did not stimulate the emergence of a core of scientific experts working in public administration. There were no court or state mathematicians like Tartaglia in Venice, Galileo in Florence, Brahe in Denmark, or Kepler at the Imperial Court, who in the 16th and 17th centuries gained public support for their scientific activities, although a few cardinals and other princes extended their

FIG. 1. A portrait of Christoph Clavius by the artist Francisco Villamena (1606) from the *Archivum Romanum Societatis Iesu, Hist. Soc.* 149, f. 116. Courtesy of Rev. E. Lamalle, S.J.

patronage to technicians or scientists, imbued with the spirit of humanism, and also with an eye to having their estates looked after by competent servants. Neither did engineering problems such as hydraulics and draining lead to the development of such permanent offices ("uffici" or "magistrati") which elsewhere offered professional opportunities and social prestige to scientific experts.[8] The result was that at the time here considered Rome was possessed of only two institutions of learning where the mathematical sciences[9] were taught and transmitted more than they were extended or developed. These were the two chairs of mathematics in the University of Rome, called La Sapienza, and the university of the Jesuits, known as the Collegio Romano.

As far as La Sapienza is concerned we are rather badly informed about its mathematical curriculum, and not even the list of successive professors occupying the chair is complete.[10] It is certain, however, that there was no unbroken tradition of lectures in mathematics, which seem to have ceased altogether around the middle of the 16th century. From 1567 they became more regular,[11] although until 1602 they were still given *in diebus festis* or *in tempore vacationis* and thus relegated to a secondary position.[12] Throughout the 17th century they were classified as "extraordinary" and thus placed outside the principal or essential curriculum. The teaching was here, as in many other universities, of an elementary character compared with the scientific level of contemporary mathematics or astronomy. Algebra was overshadowed by geometry (usually limited to the first Books of Euclid's *Elements*) and in astronomy the ordinary text-book still was Sacrobosco's *Tractatus de sphaera* which now was completely obsolete in the light of recent developments.[13] Attendance at the lectures was poor, and the professors ranked well below their colleagues in such remunerative disciplines as law or medicine.[14] The number of publications in pure or applied mathematics was small, the narrow scope of the teaching of mathematics being no great stimulus to research.[15] However, this is not the whole picture since the mathematical disciplines were cultivated also outside the universities. Many of the numerous *case professe* of the religious orders organised their own schools for resident monks or friars with at least some mathematics on their programmes, as one can see from the many mathematical books and manuscripts which have found their way from these convents to the Biblioteca Nazionale.[16]

Among the better known mathematicians in La Sapienza was Antonio Maria Pazzi who was born in Reggio Emilia and educated as a physician.[17] He arrived in Rome at an unknown date before 1560 and became acquainted with the Jesuit mathematician Baldassarre Torres at the Collegio Romano.[18] He is best remembered for his researches into the mathematical manuscripts of the Vatican Library. Here he identified the copy of Diophantus' *Aritmetica* which was soon used by Bombelli,[19] and also the copy of Pappus' *Collectiones* which formed the basis of Commandino's printed edition. His own translations of this and other works have not survived.[20] This historical and philological approach to mathematics was even more conspicuous in one of his successors, Giovanni Battista Raimondi, born in Naples of a Cremonese family.[21] His teaching career in the university was short and obscure.[22] Leaving the university he entered into the service of Cardinal Aldobrandini [23] and from 1584 until his death in 1614 he acted as the first director of the famous *Stamperia Orientale Medicea* founded in Rome by Cardinal Ferdinando de' Medici. Here he published scientific and linguistic texts together with religious literature for the use of missionaries in the East, and he also instituted a search for codices containing both Greek and Arabic works. An important result of this activity was the recovery of Nasir-Ed-din's Arabic version of Apollonius' *Conica,* so that books V-VII for the first time became available to scholars.[24]

Whereas we know something of Roman mathematicians like Pazzi and Raimondi,[25] there is very little evidence of any astronomical activity at La Sapienza, or in educated Roman circles in general. A layman like Latino Orsini is more than a mere name,[26] but otherwise we are left with such conclusions which may be inferred from books transferred from convents to the National Library, from names mentioned in Clavius' correspondence,[27] and from the influx and spread of new ideas brought to Rome in the period 1560-1580 by scientists from elsewhere, like Cardano, Commandino, Benedetti, or Baldi whose influence was real, although it can be ascertained only indirectly and with great difficulty.[28] It can at least be said, however, that if there were competent astronomers in Rome,[29] no one among them had sufficient standing or competence so that the congregation would invite them to participate in its work. The only exception to this rule was the dominant figure of Christoph Clavius around whose chair in the Collegio Romano most of the Roman activity in astronomy slowly and gradually began to recover.

The Collegio Romano was founded in 1551, only eleven years after the Society of Jesus itself. It had a very modest and difficult start and only slowly conquered the eminent position it later occupied.[30] In 1553 a regular course of mathematics [31] was entrusted to the previously mentioned Baldassare Torres,[32] another physician who was born in Spain and had spent some years in Sicily before entering the Society. In Sicily he must be considered a pupil of Francesco Maurolico, and here he also became acquainted with the methods for teaching mathematics within the order which had been developed under J. Nadal in its College at Messina.[33] In Rome he published nothing, and one of his extant note books (Codex Barberini Lat. 304) reveals no scientific originality, referring only to astronomical literature before 1540 so that for instance Copernicus' work is conspicuously absent.[34] Such was the state of affairs when in 1555 the 18 year old Clavius entered the Society in Rome.[35] It clearly explains his statement to later friends like Baldi and Grienberger that he was self-taught in mathematics.[36] Nevertheless in 1563, when he was still in his third year of theology, he began teaching mathematics in the Collegio, Torres having resigned in 1560. Here he spent the remaining part of his life, except for a short spell in 1595-96 when he was stationed in Naples.[37]

In the academic history of the Jesuits the "School of Clavius" plays a conspicuous role in the light of an impressive number of scientists whom he formed or influenced. But looking back on Clavius' early years at the Collegio it is impossible to discern the existence of any such "school". None of his famous pupils actually met him until after 1590 (Grienberger and perhaps Biancani) or even after 1600 (van Maelcote, Gregorio de St. Vincentis, P. Lembo, P. Guldin, O. Grassi, J. Wremann, and others). No similar name can be mentioned from earlier years. This leads to the rather unexpected conclusion that for many years Clavius' teaching bore very little fruit in the form of students dedicating themselves to mathematics, and that his influence seems to have become felt at a point of time when he himself gave up teaching, i.e. on his return from Naples. In other words, Clavius had no "school" at the time when the Calendar Congregation was formed, and he did not enter it as the head of a brilliant crowd of young mathematicians who only exist in the imagination of later historians.

On the other hand things were moving at the Collegio during the years immediately preceding the reform. First, in 1581 Pope Gregory XIII gave university status to the College which now became known as the Gregorian University. It was provided with new, imposing buildings and books and astronomical instruments were donated on a scale contrasting sharply with the previous poverty and lack of equipment. This raised the status of the mathematical disciplines to the same level as other subjects taught by the Fathers, something which Clavius himself had repeatedly asked for in letters to the superiors of the order.[38] And finally another, and presumably earlier,[39] project of his materialised with the establishing of a particular "Academy of Mathematics" within the framework of the new university. It was these developments which led to the emergence of a "school" as a collective entity; after 1600 Galileo and others often referred to it as "i matematici del Collegio Romano" or even "gli accademici del padre Clavio". This made all the difference. For while Clavius in his "unfruitful" period had educated young members of the Society to go and teach elsewhere — and the rapidly expanding order was in great need of teachers — there was now a permanent institution with several members on the staff, forming together a scientific milieu able to attract first-rate scholars.[40] But this belonged to the future. When Clavius joined the team of calendar reformers he was still a more or less lone and isolated mathematical scholar in his college, teaching a subject of a rather low standing and at a secondary school level, and without the personal fame and prestige which marked his later years.

Clavius' industry and diligence as a teacher was overwhelmingly demonstrated by the impressive series of mathematical text-books which he produced over a period of almost forty years. They began with his *Elements of Euclid* (1574) which was not a simple translation but a huge collection of notes, commentaries and elucidations, followed by his *Epitome arithmeticae practicae* (1583), the commentary on Theodosius' *Sphaerics* (1586), the *Geometrica pratica* (1604) and the *Algebra* (1608). These manuals cover practically all mathematical fields and profoundly influenced mathematical teaching in the early 17th century both inside and outside the schools of the Society of Jesus, securing for Clavius a minor, but secure position in the history of mathematics. However, we shall not consider here this aspect of his scientific career but instead concentrate on his efforts in astronomy. Here he published less, but there is no doubt that he was as deeply interested in the astronomical as in the mathematical questions of his time.

Already in 1560 he made an observation of an eclipse of the Sun while he was still a young student at Coïmbra, describing it as total and noticing that the totality lasted as long as the time it takes to recite the *Miserere*. Another observation followed in 1567 in Rome when he saw what he took to be an annular solar eclipse. Both observations were published in Clavius' first printed work, the huge *Commentarius in Sphaeram Joannis de Sacro Bosco*, which appeared in 1570 and later went through six further editions. Curiously enough the former eclipse was here misdated to 1559, an error which was not corrected until the fifth edition appeared. Both observations gave rise to controversies, the first with Tycho Brahe and the second with Kepler who in 1604 denied that it could have been annular.[41]

The *Sphaera* of Sacrobosco had appeared in the 13th century as a brief manual of spherical astronomy with a few concluding pages on the motion of the Sun and the Moon. It had become firmly established in the university curriculum and had given rise to innumerable commentaries of which Clavius' work certainly was the most impressive. He provided it with a section on planetary theory (along traditional lines), while at the same time he announced his intention of writing a separate work on theoretical astronomy. This *Theoricae planetarum* would be a counterpart to the *Commentarius* and of great interest in a period when the great problems raised by Copernicus became more and more urgent, and it may well be that Clavius regarded this project as his principal effort in astronomy. However, it was set aside for other publications. In 1581 the *Gnomonica* (on sundials) appeared and was followed by the *Astrolabium* (1593). In 1603 appeared the *Romani Calendarii* (...) *explicatio* which explained and defended the principles of the Gregorian calendar at the same time as it secured Clavius' fame as one of the fathers of the reform. But still the *magnum opus* on the theory of the planets failed to materialise.[42] There were several reasons for this delay of a work which was eagerly awaited by Clavius' younger brothers in the Society. Thus writing in 1590 from Vienna Father Grienberger asked when the publication could be expected.[43] Five years later he realised that the work was held up by the new ideas published by Tycho Brahe in his *De mundi aetherei recentioribus phaenomenis* (1588).[44] This reason was confirmed in the same year (1595) in a letter from Clavius to the Bologna astronomer Magini in which he doubts whether Tycho will ever finish his observations, and also complains that the Danish astronomer is going to upset the whole of astronomy by his new "Tychonian" system of the world.[45]

Clavius' hesitation to publish on the subject of planetary theory is a testimony to his understanding of the necessity of a solid observational basis for theoretical constructions. In the *Commentarius* (1581) he had stated that theoretical models must agree with the observed phenomena, not only geometrically (i.e. in a qualitative way) but also *ad numeros*. And when Magini in 1589 published a book in which he tried to accommodate Copernicus' observations within a geocentric cosmology Clavius wrote him a letter, dated 1 January 1595, asking him to publish such observations of his own which were used in support of his theory — something which Magini failed to do.[46] Everything considered, it is reasonable to assume that Clavius was at least partially aware of the fact that progress in theoretical astronomy would imply a broader observational basis than that which was available to him. This basis was provided by Tycho, but it was the young Kepler and not the aged Clavius who was destined to harvest the fruit of the twenty years of observation on island of Hveen.

What must interest us here is the fact that Clavius was invited to join the calendar congregation at a time when he had published no theoretical work at all. This reveals the standing he had acquired in Rome on the basis of his mathematical work and his activity within the Collegio Romano. But it also raises the problem of what he would be able to contribute to the work of the commission. On this point the extant documentary sources are unfortunately not too illuminating, although some information can be gleaned from books or papers by Clavius himself and by Danti, the two best scientific experts of the Calendar Congregation. These comprise a number of notes and letters, and Clavius' *Apologia* (1585) against Mästlin and Vieta, and his *Explicatio* (1603), although all these works were published years after the reform, explaining and defending it, but not necessarily reflecting the actual course of the deliberations which led the congregation eventually to adopt one particular solution, just as they do not reveal the points on which Clavius may have changed his mind during the procedures. To this list must be added the successive seven editions of the *Commentarius*.

Let us first consider one of the fundamental problems on which the congregation had to make up its mind before any reform could be initiated. Should the reformed calendar be based on the true motions of the Sun and Moon, or on their mean motions? Tradition pointed to the latter possibility, since both the Julian, solar calendar, and the luni-solar ecclesiastical calendar were based on mean motions only, and, therefore, were independent of both planetary theory and cosmological hypotheses. But would it not be better to base time-reckoning on the true motions, that is on the actual, uneven motions of the mean Sun and the mean Moon? Perhaps an astronomer would think so.[47] At least that was what Clavius thought in the beginning. In a letter to Professor Moleto in Padua, dated as late as 24 October 1580, and thus three years after the publication of the *Compendium*, he confessed that "I should think that in order to restore and keep account of astronomy it would be rather important to adopt the true motion; but these gentlemen ⟨of the congregation⟩ do not understand this for several reasons".[48] Also Magini in Bologna held this view as it appears in his *Tabulae secundorum mobilium coelestium* (1585). But the majority of the congregation thought otherwise, deciding that also the reformed *computus ecclesiasticus* should be based on mean motions. There is ample evidence that Clavius came round to the same view. In his *Apologia* (1585) against Mästlin he also criticised Magini for his idea of determining the movable feasts by the true motions of the luminaries, inserting a long explanation of the reasons which had persuaded the congregation to adopt a traditional solution. This explanation was reprinted later in the *Explicatio*.[49]

The decision to use mean motions was a matter of principle. Another and much more difficult problem was which values of the mean motions one should adopt? That Clavius was interested in this question at an early age appears from a number of draft notes in his handwriting of which the earliest seems to be from 1571 (before he joined the congregation).[50] Here he examines the period relation 19 years = 235 synodic months upon which the ecclesiastical calendar was based. Clavius assumes that one synodic month =

$$29^{d}\, 12^{h}\, 48^{m}\, (3 + 1/20)^{S}$$

instead of the traditional (Ptolemaic) value of

$$29^{d}\, 12^{h}\, 44^{m}\, (3 + 1/3)^{S}$$

(and slightly closer to the modern value 29.530588). This enables him to calculate that 235 lunations fall about $1^{h}\, 28^{m}\, (3 + 1/4)^{S}$ short of the Alfonsine value of the year. This discrepancy amounts to one day in 311 years whereas the congregation later fixed it to one day in 312,5 years which is a little more removed from the true value. In the same codex in which this note is found Clavius added that as a result of this cumulative error the "ecclesiastical" lunations lagged almost 5 days behind the astronomical from the time of Dionysius Exiguus until his own day, so that "if the calendar is to be restored to its original state all golden numbers must be increased by five"; in consequence, the golden number one found on December 13 should be moved to December 9.

However, the length of the mean synodic month presented no serious problem[51] compared with the burning question of the length of the year. It was commonly accepted that the sidereal year (the period of the return of the Sun to the same fixed star) had a constant, or very nearly constant, value; this was one of the reasons why Copernicus had adopted a sidereal frame of reference for his astronomy. The problem was the tropical year as the period of the return of the Sun to the vernal equinoctial point on the ecliptic. Now it was an established fact that this point did move towards the west relative to the fixed stars, a motion called "precession" by Copernicus. In consequence, after one annual round towards the east the Sun would meet the equinoctial point before a complete sidereal year had elapsed. In other words, the tropical year must be somewhat shorter than the sidereal, and the difference must depend on the magnitude and character of the motion of precession. On this point the opinions of astronomers were divided.

Almost completely abandoned was the Ptolemaic linear theory, according to which there was a constant rate of precession of 1° per century. It had proved unable to account for observations made by Muslim astronomers in 9th century Bagdhad who, therefore, concluded that the rate of precession was variable. One theory (connected with the name of Thabit ben Qurra) assumed accordingly that the equinox performed a slow oscillatory motion or "trepidation" about a fixed mean position.[52] Another theory (implied in the Alfonsine tables) envisaged precession as a uniform drift of the equinox towards the west, superimposed by a periodic trepidation.[53] A variant of this idea was adopted by Copernicus, but with new numerical parameters and explained by the various motions of the earth within a heliocentric cosmology.[54]

Each one of these models led to a different theory of the tropical year. The linear precession of Ptolemy gave a constant value of the length of the year which was known to be wrong. This had become clear already to Muslim astronomers working from the 9th century onwards in Bagdhad and elsewhere, as the Patriarch Ignatius explained to the Pope in a letter (1579) and in a later report on the *Compendium* (12 March 1580) in which he maintained that the year had a constant, although non-Ptolemaic value.[55] On the other hand the trepidation theories all led to a variable year, the respective length of which depended upon the actual value of the varying rate of precession. Thus the situation might well seem confused from a purely mathematical point of view. It became even more complicated for epistemological reasons. The various theories of precession were not simply regarded as mathematical procedures for calculating stellar positions and the length of the year. They had to be given a physical interpretation in so far as any component of the precessional motion had to be ascribed to a uniform or "simple" rotation of a particular "sphere" within the upper regions of the universe. Thus the linear precession of Ptolemy implied the existence of a fixed equinox in a ninth sphere relative to which the eighth sphere containing the fixed stars could "precede". Thus precession was usually discussed in treatises like *On the motion of the Eighth Sphere* or similar titles. Since there were more components of motion in the trepidation theories the latter implied the existence of even more spheres. So the congregation might well have decided not to discuss competing astronomical theories since the very manner in which the problem of the length of the year was conceived made it difficult to avoid discussions of a cosmological nature regarding the number and configuration of the celestial spheres.[56]

We are not too well informed of how the Congregation's two astronomical experts, Danti[57] and Clavius, approached these problems. Danti in 1574 and 1575 had observed the vernal equinox in Florence using an armillary sphere placed in front of the church Santa Maria Novella (where it still is).[58] He derived a remarkably good value of the year of $365^d\,5^h\,48^m$ which was low enough, compared with the Ptolemaic value of $365^d\,5^h\,55^m$, to strengthen his belief that the year was variable. He seems to have adhered to an Alfonsine model of precession in order to account for this variation, although in his last publication, a book on the astrolabe (1578) he prudently wrote that it was still too early to give judgment on the great problem of the length of the year, mentioning, however, that also Copernicus and the Prutenic Tables assumed it to be variable.[59]

It is no easy task to investigate the development of Clavius' opinions on the problems of precession and the length of the year; but it seems rather certain that he did not agree with Danti, to whom, strangely enough, he never referred to by name,[60] on how best to account for the variation of the year, which he too assumed to be a fact. Thus in the Jubilee Year 1575 he constructed a celestial globe for the Collegio,[61] determining the stellar positions by using both Copernicus' catalogue of the fixed stars dating from 1525 and Copernicus' mean value of the actual rate of precession to calculate the increase of longitudes in the period 1525-1575.[62]

However, this use of Copernican data did not prevent Clavius from keeping an open mind when precession was discussed in the Congregation. He even brought to the knowledge of the members an unpublished essay written before 1550 by Ricciardo Cervini in which the author argued that there was no precession at all. Clavius had received the manuscript from Father Roberto Bellarmino who again had it from his cousin Erennio Cervini, a nephew of the author. It appears from three letters from the future Cardinal to Erennio Cervini that Clavius had discussed the problem with him at the Collegio, using his celestial globe to ascertain the position of a number of stars used by Ricciardo Cervini for his argument against precession.[63] But the principal source for Clavius' changing ideas on the theory of precession and its cosmological implication is the long series of editions of his *Commentarius* to Sacrobosco.[64]

In the first edition (1570) of this work Clavius was almost completely faithful to the Ptolemaic tradition. Although he explained the theories of trepidation, he did not comment upon them,[65] and the frequent references to Copernicus are mainly about the physical unacceptability of his new system of the world. This attitude had changed in a significant way at the time when the 1581 edition appeared, showing that Clavius had made a more profound study of Copernicus in the very years in which he was active in the Congregation.[66] Thus he now supplemented his previous account of trepidation with the remark that "But although it is necessary — as I truly think it is — to admit such a motion of the eighth sphere or something similar, because of phenomena or appearances soon to be mentioned, it is very uncertain if this should be done in the Alfonsine manner. This would seem to lead to much absurdity, as I shall show elsewhere".[67] A few pages later this was stated in an even more unambiguous way: "Not a few think that this motion is to be excluded altogether from the schools of the astronomers (...). For just as it seems certain that one must ascribe a trepidation or some similar motion to the eighth sphere because of the said phenomena, it is highly uncertain if it can be accounted for in the way in which astronomers explain it (...) since this explanation will result in many consequences which are seen to disagree with experience as I shall explain more fully in the theory of the eighth sphere".[68]

In the 1581 edition Clavius offered no real proof of the "absurdity" of the common theories, just as he never completed or published the work referred to in the passages just quoted. It can be said, however, that the reasons convincing him of the falsity of the usual hypotheses regarding trepidation were partly those already expressed by the Italian author Annibale Raimondo, whom Clavius knew.[69] In later editions of the *Commentarius* they were inserted in a paragraph entitled *De quadruplici motu octavae ex recentiorum astronomorum sententia*.[70] Here we shall briefly examine the theoretical contents of this text which enumerates some observational data which falsify predictions derived from the theory of trepidation, adding that the scholars working with King Alfonso did not provide their tables with *radices* (epochal values of variable parameters) which were sufficient to allow them to calculate the supposed motion; had they done this their theory would have proved to be in plain contradiction to the phenomena. This is enough to show that "this motion does not exist in nature, but is completely fictitious and a fabrication without any basis whatever".[71] But the text not only criticized the prevailing theory; it also clearly shows that Clavius had begun to adhere to the Copernican parameters with respect to this phenomenon. Thus he took over from the Polish astronomer all data of stellar longitudes and latitudes from the catalogue of the fixed stars, as well as the distance of the first star of Aries from the equinoctial point and the mean annual precession valid in recent years, using all this for his celestial globe as already mentioned. Also a number of short phrases or statements not found in the first edition testify to the fact that Clavius was now using Copernican data to correct or cast doubt upon the Ptolemaic-Alfonsine values which he himself had adhered to in 1570.[72]

Such novel features introduced in a manual which was completed at the time the Congregation was completing its work suggest that Clavius would have altered the theoretical framework of his book in such a way that it would accommodate the new data. But this was surprisingly not the case. The theoretical structure was left unchanged and was, therefore, in some cases unable to account for the new data and in other cases in plain contradiction to them.[73] This kind of compromise may well stem from rather casual circumstances. Asked to issue a new work that was rapidly becoming the standard astronomical manual of the time,[74] and being heavily burdened with the work of the Congregation, Clavius had to content himself with minor changes. Having been aware of the provisional value of this compromise and also of the criticism that might follow, Clavius would have done better if he had placed the new data in an appendix and explained the need for a new interpretative synthesis which could not yet be provided; this was what he did later in a similar situation.[75]

It was not until the fifth edition of the *Commentarius* (1606), judging from the editions that I have been able to examine, that Clavius offered a new theoretical scheme to account partially for the new data he had introduced 25 years earlier.[76] The relevant passage here began with the following words: "Since the motion of trepidation not only does not completely agree with, but rather utterly destroys and annihilates phenomena which have been observed at various times, the Prussian Nicolaus Copernicus — the illustrious restorer of astronomy in this our own century, whom all posterity will celebrate and admire with gratitude as another Ptolemy — has stated that one must think in a new way of the motion of the eighth sphere, having compared his own observations with those of both ancient and recent astronomers." Clavius then described the four Copernican motions of the earth, adding that "Although we willingly shall adopt and embrace this fourfold motion of the eighth sphere and the periods it was given by Copernicus, we must completely reject the way in which they are explained."

There follows a discussion of why the Copernican hypothesis must be rejected on physical grounds, and an alternative hypothesis is put forward with reference to Joannes Antonius Maginus, *vir doctissimus*, who had accepted the Copernican analysis of a number of phenomena but transferred to the heavenly spheres every motion which the Polish astronomer had ascribed to the earth and its axis. This entailed the consequence that above the eighth sphere there were not only two higher spheres (as usually assumed), but three, making a total of eleven rotating heavens in the whole universe.[77] In fact, in his *Novae coelestium orbium theoricae congruentes cum observationibus N. Copernici* (Venice, 1589) Magini had used the "optical equivalence" of astronomical theories asserted by Copernicus to transform the Copernican system into a sort of modified Ptolemaic system provided with Copernican parameters.[78] This had forced him to increase the traditional number of spheres, since he was unable to account for the changing obliquity of the ecliptic by means of the sphere already used for the motion of precession, as a consequence of his peripatetic belief — which Clavius shared — that a "simple" body like a celestial sphere can have only one "simple" motion.[79]

Why was Clavius only now at long last prepared to revise his cosmology in order to accommodate parameters which he had adopted 25 years earlier? Any answer to this question must be a reconstruction since his own papers are silent on this point. The new pattern of spheres proposed to Magini was probably already known to Clavius. Copernicus had criticized a similar idea in the beginning of the 16th century. Clavius was only now perhaps inclined to use it because he had seen it developed by an able calculator like Magini. However, the mechanism of precession in Magini's *Theoricae* was an *ad hoc* construction, an approximative, geometrical explanation of Copernican parameters, but unsupported by new data and not even rigorously consistent with older data. Clavius' letter to Magini mentioned above reveals how arbitrary the system of the Bologna astronomer could appear.

However, Clavius himself did not provide what he felt was lacking in Magini. In the *Commentarius* he presented the new scheme without any mathematical apparatus at all. Consequently, he did not show that a 12-sphere universe could account for the phenomena *ad numeros*, and the problem of whether a modified Ptolemaic system could accommodate the new data was left unsolved.

This indifference to the central question of the exactness of concepts and theories in a mathematician like Clavius seems to us perplexing and tends to lead us to a negative evaluation of his attitude to standards of exactness which were generally admitted in astronomy towards the end of the 16th century. But here one must first remember that the *Commentarius* was primarily a didactic manual from which he wished to keep calculations at a minimum and, secondly, that he had planned to review the whole problem in a research work — his *magnum opus* on the *Theoricae planetarum* which he frequently mentioned in his correspondence in terms which reveal that he was held up because of the inability of his modified Ptolemaic system to deal with the phenomena of the Sun, Moon, planets and precession *ad numeros*. The composition of the *Theoricae* and the great amount of time Clavius spent on it may serve as a typical example of the problems facing the astronomers of the Society of Jesus during these decisive years — problems which were becoming even more crucial and were soon to reach a culmination through the work of Kepler and Galileo.

Leaving astronomical theories on one side one must also ask what kind of observational work Clavius performed in order to test new astronomical data appearing since the time of Copernicus? For a historian of astronomy like Delambre the answer was easy: Clavius "n'était pas réellement astronome; il n'a fait aucune observation, aucune recherche théorique". This judgment is certainly unfair in comparing Clavius to typical astronomical calculators like Magini. If he was more a theoretical than a practical astronomer the same holds true for Copernicus. In fact, there are some observations on record in Clavius' writings, and the existence of others can be inferred from other sources. Leaving aside the special observations of anomalous events like the new stars of 1572 and 1604,[80] or Galileo's discoveries in his *Nuntius Sidereus*, the bulk of Clavius' known observations were, in one way or another, connected with solar and lunar periods, and with precession. The adjustment of Copernican longitudes of fixed stars to the epoch 1575 of the celestial globe almost certainly implied a number of observations; in fact, there are traces of them in books and documents connected with Clavius.[81] Furthermore, if his letters and other writings show no clear signs of qualified planetary observations it is evident that he paid special attention to eclipses, starting with the Coïmbra observation of 1560, which was mentioned above and presumably was the first clearly recorded observation of a total eclipse of the Sun. But his work on eclipses was prior to, or unconnected with his examination of solar and lunar periods and cycles during his membership of the congregation; also, it was of a qualitative nature although Clavius was aware of its implications, as when he asserted that the eclipse of 1560, being total, was enough to disprove Tycho Brahe's theory of the Moon.

Some general conclusions seem to emerge from this account of one of the founding fathers of the reform of the calendar. Considering the situation of astronomy between the *De revolutionibus orbium coelestium* and the publication of Kepler's laws no one can ignore the serious difficulties which hindered or prevented any precise determination of those cycles which were so essential for the calendar. In consequence, a mathematical scheme of the kind adopted by the Congregation must be regarded as a wise solution, precisely because it was largely independent of hypotheses concerning long term variations of the periods, and also independent of physical hypotheses regarding the mechanism which produced them. But this does not mean that the Gregorian Congregation adopted its solution out of mere fidelity towards the traditional *computus ecclesiasticus*. Nor does it imply that its members — or at least some of them — did not realise that a mechanism more intimately connected with astronomical events would, from a theoretical point of view, be superior to the one they adopted, although this can be documented only in the case of Clavius. On the contrary, such a mechanism was considered desirable, but owing to the state of astronomy at the time, it was also thought to increase the technical difficulties out of proportion to the relatively small increase in exactness it would produce. This judgment has proved to be correct until today, and this paper is no more than an attempt to discuss the facts and conditions, both conceptual and empirical, that persuaded the most interesting of the scientific figures in the congregation to make this judgment his own.

REFERENCES

In the References the name of an author followed by page numbers indicates the work listed under that authors name in the *Bibliography* which is given at the end of this Reference Section.

The following abbreviations are used:

APUG	Archive of the Pontifical Gregorian University, Rome.
ARSI	Archivum Romanum Societatis Iesu, Rome.
ASR	Archivio di Stato, Rome.
BAM	Biblioteca Ambrosiana, Milan.
BAR	Biblioteca Universitaria Alessandrina, Rome.
BCR	Biblioteca Casanatense, Rome.
BAV	Biblioteca Apostolica Vaticana, Rome.
BNF	Biblioteca Nazionale, Florence.
BNVE	Biblioteca Nazionale Centrale Vittorio Emanuele, Rome.

It is to be observed that *Codices Vat. lat.* 7045-7058 are only a part of those containing documents relating to the reform; others are BAV *Codices Vat. lat.* 5643, 6147, 6191, 6192, 6210, 6214, 6217, 6416, 6417, 7180, 7942; *Reginensis* 2020; *Barb. lat.* 272. These and codices in other libraries were studied in due time by such historians as Kaltenbrunner and Schmid and are not especially considered in this paper.

1. This report is dated "Romae, die festo exaltationis S.tae Crucis, 1580" (that is September 14). As far as I know, two copies of it exist; one in BAV, *Cod. Vat. lat.* 3685, 1-10; the other in BCR, ms. 649, 164r-167v. This latter manuscript also contains copies of some of the most important documents collected by the congregation's prefect, Cardinal Guglielmo Sirleto. After his death they were bound together in *Cod. Vat. lat.* 5645; this codex, later, was divided so to form *Codices Vat. lat.* 7045-7058.
2. In his paper, pages 217 to 220, A. Ziggelaar rightly argues that not every principle stated in the *Ratio* was followed in the new calendar.
3. The relation between the role of Lauro and Sirleto is not at all clear. It is sometimes supposed that, when Lauro went to Mondovì to take charge of his episcopal duties, the full direction of the work was transferred to Sirleto; nevertheless it is certain that Lauro attended the congregation's works. Two letters from Bellarmino (not yet cardinal) to his cousin Erennio Cervini, written in 1579 and 1580, show Lauro as still the coordinator of the congregation (Le Bachelet, pp. 109-110, 125-126). For Sirleto see Denzler.
4. As for Ignatius' writings concerning the reform see note 55, on him personally see Levi Della Vida.
5. The Church State congregations (either permanent, for government matters, or provisional) were usually presided over by someone in the high ranks of the clergy (by a cardinal as a rule). Also in 1700 a congregation created by pope Clement XI to review the Gregorian calendar was presided over by Cardinal Enrico Noris, a student very similar to Sirleto (Bolla; Wernicke). In the case of these two congregations, however, the choice was not only directed by this tradition, but it was also directed by the need that the reform should not only be technically good. It also had to follow traditions felt vital in the Church's history.
6. A possible interpretation (for which no clear proof exists) is that the Holy See, wishing to make it evident that the reform was an ecumenical enterprise having a religious ground, had it executed not by laymen but by members of the clergy.

7. We might add that, among the many Italian writings on the calendar's reform presented to the congregation, printed or circulated in manuscript form during the ten years 1572-1582, not one was published or written in Rome. The only exception is represented by Carlo Lauro, who in 1575 wrote, on request of the Pope, the *Calendarii temporum et Sanctarum Festivitatum restitutio, et correctio* (BAV, *Cod. Vat. lat.* 5643). Among others who took part in the discussion authors like A. Raimondo, A. Piccolomini, G.B. Benedetti lived in northern Italy (for a chronological list of publications on the subject see Riccardi, v. II, in the section "Cronologia matematica").

8. More exactly, this is true for those territories which already were part of the State in the Middle Ages (Lazio and part of Umbria), with Rome as their center. In the North, however, territories recently conquered by the State, and particularly those in Emilia and Romagna centered around Bologna, had their historical and economical traditions as well as their geography deeply connected with those of the Po basin. This helps to explain why in the XVIth century the University of Bologna had the best mathematical teaching in Italy, whilst in La Sapienza the situation was much poorer. This situation lasted in the central part of the State till the beginning of XVIIIth century (see Baldini, I), when public works pertaining to rivers, lakes, roads and boundary measures were still decided mostly by provisional congregations. As for the court mathematicians, in northern Italy they were not customarily the same persons who lectured in mathematics in State universities. For instance the Serenissima Repubblica di Venezia, having to answer Pope Gregory's request to judge the *Compendium* of 1577, did not give the charge to the well known G. Moleto, professor at Padua university, but to G. Zarlini, better known for his studies on music. Similarly, in Turin and Florence mathematicians of the Savoia and Medici families were hardly ever professors in the universities of those states. For the general conditions of the Pontifical State see Caravale-Caracciolo.

9. Clavius discussed at length the chief classifications of "mathematicae scientiae" in the introduction to his edition of Euclid's *Elements* (*Opera*, I, pp. 3-4: "In disciplinas mathematicas prolegomena").

10. University documents up to 1527 were all destroyed during the sack of Rome in that year. So the questions whether Copernicus taught astronomy (as Rheticus wrote) in the year 1500, and whether his lessons were taught in La Sapienza (see Bilinski for a recent affirmative answer) cannot be answered on documentary evidence. Carlo Cartari, secretary in the university in the years around 1680, wrote that among the XVIth century *Rotuli* (original roles with matters and lectors, year by year) there survived only those of the years 1539, 1542, 1548, 1549, 1552, 1561, 1563, 1567, 1576, 1582, 1587, 1592, 1593, 1594, 1595, 1599 (ASR, *Archivio Cartari-Febei*, 65, 181r-183v). These roles still exist (the original *Rotuli* in ASR, *Cimeli*, 13-26; a later copy in ASR, *Università di Roma*, 94, 1-30). The roles offer the only useful data for a didactic history of La Sapienza in that period. The historians (Carafa, Renazzi) used them, but not always correctly; so the following data are more often referred to archival documents than to those writers.

11. The *Rotuli* of the years 1587 and 1599 do not mention any lecture of mathematics (ASR, *Univ. di Roma*, 94, 21r-v, 31r-v). In the *Rotuli* of other years the professors are: 1567, A.M. Pazzi; 1576, G.B. Raimondi; 1582, "Io. Petrus Pomerius Hispanus"; 1592-1595, G. Marchesetti. I could not get any information about Pomerius (Pomarius in other university documents); he was teaching in La Sapienza from 1579 at least (ASR, *Archivio Cartari-Febei*, 65, 36v), so that Raimondi's career as a teacher lasted until that year at most. Some evidence has induced historians to think that sometime in the period 1585-1591 mathematics was also taught by Maurice Bressieu, a former professor in the Collège Royal and author of *Metrices astronomicae libri quatuor*, Parisiis 1581 (Poggendorff, I, 294).

12. One infers this from a request from Luca Valerio (who was later a member of the Accademia dei Lincei and Galilei's friend); in that year Valerio taught ethics and mathematics, and asked that his lectures be held at the same time as other lectures.

13. ASR, *Archivio Cartari-Febei*, 65, 30r-36v. At 36v it is written that "Mathematicus (leget) ... Sphaeram Sacriboscí, et Theoricas Planetarum ac Iudiciarum, ut permissum est a Sacrosancto Concilio Tridentino". This connexion between astronomy and astrology (opposed by Clavius) was strengthened by placing astronomical teaching in the faculty of arts and medicine, to which astrology seemed to be important. It continued in some Italian universities up to the XVIIth century. As for the almost entirely Euclidean connotation of mathematical programmes it survived in La Sapienza until the beginning of the XVIIIth century. In 1685 competitors to the chair of mathematics had to show their proficiency only by explaining some geometrical problems in the *Elements*.

14. In Rome, as in all of Italy, the earnings of a lecturer in mathematics were for a long time (till university reforms in the middle of the XVIIIth century) the lowest in the faculty of arts.

15. This may be observed by examining the different sections in Riccardi, v. II.

16. Many mathematicians who were members of religious orders (a majority in Italy until the end of the XVIIth century), even if they attended university courses and were in some relation with university professors, executed their mathematical training mostly in conventual schools and libraries. This is the case for such individuals as Danti, Castelli, Cavalieri, Coronelli, Rampinelli, Frisi.

17. Pazzi was teaching at least from 1567 (but his name is not in the 1563 role). He seems to have left Rome in 1575, going back to his native town, Reggio Emilia. Therefore, the occurrence of G.B. Raimondi's name in the role of 1576 may well mark the beginning of his teaching.

18. See notes 32, 34, 35.

19. Bombelli, *Algebra*, Bologna 1572, 2r. Here Bombelli wrote that Pazzi had translated Diophantus' text into Latin: His translation has been recognized by A. Agostini (p. 41) in the anonymous codex *Palatino* 625 in BNF. This contains a translation of some propositions from books I-V of Diophantus' *Arithmetics*, together with a commentary and new proofs.

20. Pazzi enumerated them in a letter of his, written from Rome in April 1568 to Marquis Gherardo Spini in Reggio Emilia (Venice, Biblioteca Marciana, ms. *Marc. lat.* IV, 38, 8r-12r; this letter was published in Tiraboschi, IV, 72-77). For Pazzi and his translations see also C. Frati - A. Segarizzi, 26-7; J. Morelli, 6-11; Kristeller, II, 206-7; Rose, 47, 146, 149 n. Pazzi published nothing, therefore, his name is not found in Riccardi. The only information about his teaching in La Sapienza is that in 1568 he was lecturing on book I of the *Elements* (Renazzi, II, p. 176). In view of the possible influence of his philological interests on Roman scientific circles the dispersal of his library, which he sold before going back to Reggio, is highly regretable. Only a catalogue of it remains in BAM, ms. D 422 (De Nolhac, p. 217 n.).

21. Raimondi was probably born in 1536 (Saltini, p. 263). Saltini is the most informative on Raimondi's life. Other writings are: Lunadori, 186-190; Arisi, III, 140; Bertolotti, 219-239; Levi Della Vida, 204, 230, 263-266; Rose, 146, 149 n, 244, 262; Bignami Odier, 52, 103, 106; Kristeller, II, 210-211.

22. He travelled in the Near East, where he learned perfectly Arabic and other languages, of which he was a life long student. The most important part, among his manuscripts in the Magliabechi collection of BNF, are projects for grammars and dictionaries (a

catalogue in Saltini, 297-308). He came back to Italy in 1575, settling down in Rome (in 1576 he was already lecturing in La Sapienza and also was Baldi's teacher in Arabic).

23. Cinzio Aldobrandini was a nephew to Pope Clement VIII, and a well known patron of artists and students among whom was Raimondi. During the academic year 1575-6 Raimondi lectured on "Bosco I.us" (namely book I of Sacrobosco's *Sphaera*) and "Theorica planetarum" (ASR, *Archivio Cartari-Febei*, 65, 31v). The same document shows that his teaching was highly appreciated: "D. Joannes Baptista Raimundus vere philosophus et in qua profitetur facultate vere pollens, nec nisi legitime impeditus intermittit lectiones." Lunadori (185) goes into some detail about Aldobrandini's circle of intellectuals and Raimondi's presence among them (Lunadori often visited this circle and was Raimondi's close friend). In his description Raimondi appears as a supporter of Platonism against Aristotelianism; so he was active in the debate between these two philosophies that seems to have had some importance in the Roman culture of those years: "Ma come egli vidde il Mondo tanto appassionato nella dottrina Peripatetica, rivolse l'animo alle Mattematiche, con applauso universale degli huomini dotti, da' quali è stato preconizzato Padre della Geometria" (p. 187). Other sources suggest that Raimondi defended Platonism in some inaugural addresses in La Sapienza. I have not been able to find these texts.

24. For the history of the manuscript of the *Conics* see Giovannozzi. A catalogue of the works Raimondi wished to print in the *Stamperia* was given by Labbè, 250-253. Some of them are scientific in character.

25. The interest of both were oriented more towards mathematics than astronomy, but from their university chair they lectured on Sacrobosco's *Sphaera*. Raimondi also wrote a paper on the correctness of the Gregorian date for Easter of the year 1598 (BNF, ms. *Magliabechiano*, cl. XXII, 9). Lunadori (187-188) informs us that Raimondi translated Euclid's *Data* and the whole text of the *Conics*, adding that he wrote commentaries to Pappus and to Archimedes' *Opera Omnia*. Among these works only the version of *Data* (BNF, ms. *N. Num.* II, 173) and the commentary to Pappus (but only to his book V: BNF, ms. *Magliabechiano*, cl. XI, 107) are extant. Lunadori also hints at an interesting bent in Raimondi's mathematical orientations which does not appear in his conserved writings: he highly valued "la scienza resolutiva delle Mattematiche, ch'è la perfettione, e il compimento di esse." This interest for analysis (which term is possibly used here to mean algebra) is rather uncommon in Italian mathematicians-philologists of that time; in some measure it associates Raimondi with Clavius.

26. He was the inventor of a geodetic instrument then illustrated by Danti (*Trattato del radio latino ... inventate dall'Ill.mo et Ecc.mo Signor Latino Orsini*, Roma 1583). Orsini worked as an engineer and expert in fortifications for the Church State (Almagià).

27. APUG, mss. 529 and 530. For an index of the letters see Phillips; rather strangely, none of them is prior to 1579.

28. Rose, 155, 188-193, 243. From 1571 onwards Cardano lived in Rome; he and Benedetti are listed by Baldi (who had Clavius and his circle as his source) among Clavius' scientific connections together with Commandino (Zaccagnini, 344). Less friendly were Clavius' relations with Raimondi, who wished to edit scientific manuscripts in the Medici collection and seems to have allowed no one, and surely not Clavius, to study them. So in the second edition (Rome, 1589) of his *Euclids Elementorum libri XV* the Jesuit wrote (pp. 6-7) that he had been informed that an arabic codex of the *Elements* offered in one of its theorems a proof of Euclid's postulate V; he had attempted to have it "ab eo, qui eum Euclidem arabicum possidet" (viz. Raimondi), but the answer had been negative, so he had decided to publish a proof of his own in the long *scholium* to prop. 28 of the first book. Yet Clavius' demonstration is almost identical with that given in Nasir Eddin's text published by Raimondi in 1594. So it was a

common opinion in Roman mathematical circles (it was also echoed by Luca Valerio) that the Jesuit had been informed at least on the logical structure of the proof given by the Arabian mathematician (which is considered in Heath, I, 208-210). Anyway, Clavius tried later to see another arabic codex of the Medici collection (probably Apollonius' *Conics*) applying directly to a Great Duke's officer, Belisario Vinta (well known in Galilei's biographies). But in his answer (19 October 1605; APUG, ms. 530, 57r) Vinta wrote "non si può ciò fare, fin che non si accomodino certe diffidenze con il sig. Gio. Battista Raimondi intorno all'assunto, ch'egli si era già preso di stampar quei libri, et altri pur Arabici."

29. Some names are found in "ex libris" of printed books or manuscripts in BNVE. Among these books are such works as the *Tabulae Prutenicae*, Copernicus' *De revolutionibus*, and various writings by Werner, Maestlin, Brahe and others.

30. Villoslada; Codina Mir.

31. See the few documents in Lukács, I.

32. Scaduto (II), p. 129, collects the existing information about him.

33. Scaduto (I) and (II); Codina Mir; Lukács, I (for documents on the college); Rose, 167-8, 196-8.

34. A summary research in the *Barberini* codexes of BAV did not find any which is recognizable as the first part of a notebook of which n. 304 is the second. No name of owner or writer is found on the codex, but its content makes the attribution certain. Torres' notes are various in character, being commentaries (to book VII of the *Elements*); translations (Archimedes, *De insidentibus aquae*, and Ptolemy, *De analemmate*); indexes of scientific books in some libraries, including those in the Collegio Romano (which appears to have been used also by external students like Commandino and Pazzi); some medical annotations; an ordered series of Torres' lessons in the Collegio in the years 1557 and 1558, when gnomonics and optics were treated.

35. It is unlikely that the two men met. Clavius was admitted to the Society by Loyola himself (in Rome in January or February 1555: *Monumenta Ignatiana*, IV, 2, Matriti 1918, 824; ARSI, *Rom.* 53, 60r). In the following autumn he was sent to the College of Coimbra (*Monumenta Ignatiana*, ibid.), where he studied rhetoric for two years and philosophy for two years, until the autumn, 1560: in August of that year he was still at Coimbra, where he could observe a total eclipse of the sun; in the following September he visited Montserrat (*Monumenta Ignatiana*, IV, 2, 866), and this visit happened most probably during Clavius' travel back to Rome, because in May, 1561 he was already in the Collegio Romano as a student in the third year of philosophy (C. Sommervogel, *Les Jésuites de Rome et de Vienne en MDLXI d'après un Catalogue rarissime de l'époque*, Bruxelles 1892, p. 25).

36. Zaccagnini, p. 335; Grienberger ("Ad lectorem"). These witnesses discredit the belief that in Coimbra Clavius listened to Pedro Nuñez's lessons; Grienberger's short narration has some interesting data on the genesis of mathematical interest in Clavius, whose teaching in the Collegio Romano probably began in 1563 (*Epistulae P. Hieronymi Nadal S.I. ab anno 1546 ad 1577*, II, Matriti 1899, p. 459). The growth of his interests and lectures may be followed through the citations that are so numerous in the various editions of his works, as well as in a few documents he wrote on methods and programmes for the chair of mathematics: Baldini (II); *Monumenta Paedagogica*, 471, 474. Another source is A. Possevino's *Bibliotheca selecta* (Rome, 1593), where book XV contains a bibliography on the mathematical sciences inspired by Clavius. Nevertheless two important features in his mathematical learning, namely his connection with Commandino and the other with Maurolico, may be traced back to the tradition started in the Collegio Romano by Baldassarre Torres.

37. See Villoslada. After those years, Clavius did not teach anymore, but was working in the Collegio as a *scriptor* (scholar exempted from academic duties) and head of the academy of mathematics. His chair was transferred to such collaborators of his as C. Grienberger and O. van Maelcote.

38. See note 36.

39. ARSI, *Studia*, 5c, 185r-187v: *Discursus P. Christophori Clavii de modo, et via, qua Societas Jesu ad maiorem Dei honorem, et animarum provectum augere hominum de se opinionem, omnemque Haereticorum in Literis aestimationem, qua illi multum nituntur, convellere brevissime, ac facillime possit.* This project suggested that some specialized academies (for mathematics, theology, philology) were formed in different colleges of the Society, where gifted persons could gather coming from every province of the Order; exempted from any other duty, they could constitute highly qualified groups of specialists. The text carries no date. As to members of the academy of mathematics, none is known prior to 1600. Yet Clavius began to gather it much before, because a report by Father L. Maselli to Provost E. Mercurian (written in August 1576) says that "in la mathematica il P. Clavio seguita la sua accademia che si fa dentro del collegio et si fa frutto" (Lukács, IV, 658).

40. Among those who learned mathematics under Clavius before 1580, two are worth remembering: a roman nobleman, Lorenzo Castellani, who later financed some editions of the master's works and wrote a defense of him against Viéte's criticisms; and Father João Delagado S.I., who later lectured on mathematics in College of Coimbra (Rodrigues, I, 1, 12-13; IV, 403-4).

41. The first observations of solar eclipses recorded in Clavius' writings were made in 1560 and 1567. They had an interesting role in that period's astronomical discussions and were introduced in the 1581 edition of *Commentarius* (see also *Opera*, III, 295). Clavius observed the first eclipse, which he described as total, in August 1560, when he was still in Coimbra but strangely enough he dated it in 1559, until the fifth edition of the book, when some objections by correspondents convinced him to change the year. The possibility of total eclipses was denied by Brahe and others. The Dane partly declared his doubts in his letter to Clavius (APUG, ms. 529, 65r-66v:, see Nordlind, I), and exposed them more clearly in his *Astronomiae instauratae progymnasmata* when stating his theory of the moon (but without mentioning Clavius' name or observations). This caused his theory to be criticized by Magini and Clavius (F. Tengnagel to Magini, 24 December 1602: Favaro, 258-260). But Clavius did not yet specify times and measures of his observation, so that Kepler, having defended him in *Ad Vitellionem Paralipomena* (Francofurti 1604, 285-307), wrote a letter to Father Ziegler to persuade Clavius to write "pleniorem aliquam narrationem, maxime circa illam Lusitanicam" (Ziegler to Clavius, 13 September 1606: APUG, ms. 530, 243r-244v). But all evidence seems to show that Clavius could not give any quantitative data, because he had observed that phenomenon with no instrument. There is a reference in a passage of an astronomical manuscript by I.R. Quietanus (*Restitutio universalis motuum coelestium in stellis fixis, Sole, Luna, et maxime Eclipsibus...*: BCR, ms. 1582), who was very familiar with Jesuit astronomers of the Collegio Romano during the years 1610-1620. Quietanus wrote (33v-34r) that Clavius' assistants (Grienberger and Güldin) had tod him that their master thought that the eclipse in 1560 "duraverit per tantum temporis spatium quo Miserere aliquis per modum officii divini recitare potuisset." Quietanus, judging that such a prayer could last about 90 pulse beats, calculated that the eclipse lasted one minute and 16 seconds. This measure, he thought, showed that Brahe's measure of the diameter of the moon was wrong. As for the eclipse of 1567, Kepler doubted (*Ad Vitellionem Paralipomena*, Francofurti 1604, p. 297) that it could be annular as Clavius had described it. His doubts were confirmed in *Nature*, 15

February 1877, page 342, where calculations were given showing that in Rome the eclipse had been almost total, so that an observer would perceive it as annular.

42. Clavius (*Opera*) made known his project concerning the *Theoricae* already in 1570: "Rationes autem, quibus haec omnia investigari possint, et examinari (distantias enim centrorum, et magnitudines semidiametrorum examinare per tempus hic non licuit, sed eas ex aliis auctoribus, ut scriptae sunt, accepimus) in nostris theoricis explicabuntur" (p. 495). In the following editions this phrase was kept, but Clavius added to it, as a provisional substitute for the coming book, a scheme of the Alphonsine theory of planetary motions. In summary, Clavius had been promising to publish that work throughout a period of forty years, but it never came to be. No part of it is extant.

43. APUG, ms. 529, 44r-45v.

44. *ibid.*, ms. 529, 84r-v; see also a letter of Clavius to G. Serrano (APUG, ms. 530, 140r-v).

45. Favaro, 214-216; see also Nordlind (I) and (II). Nevertheless, as Ziegler was to note (APUG, ms. 530, 244r-245v), Brahe's researches had an impact on Clavius' thought in so far as they showed more clearly than ever before that astronomical tradition was inadequate. Clavius became convinced of this, but he was not able to change radically his concepts. This is perhaps the best explanation of his failure to complete the *Theoricae*, which seems to have been conceived as a commentary to the *Almagest*. In 1600 Clavius gave some notice of the work to Magini, who asked him not to finish it until the "corretioni del moto solare del Signor Ticone" were published (APUG, ms. 530, 208r), and again in 1606 he wrote, something about it to Stalerio, another Jesuit, who answered praising "il disegno di V.S. di seguitare dopo l'*Algebra* l'incominciata fatica di Tolomeo: quale sarà accettissima almeno per havere il vero modo per investigare li moti delle stelle" (APUG, ms. 529, 188r-v).

46. Magini's book was *Novae coelestium orbium theoricae congruentes cum observationibus Nicolai Copernici*, Venetiis, ex officina Damiani Zenarii, 1589. A sketch of Magini's system was given by Delambre (509-512) and Favaro (66-73). Being a calculator more than a practical astronomer, Magini seems to have written his book without testing Copernicus' observational work. He did not satisfy the following request by Clavius: "V.S. faria una cosa fuora di modo utile e grata, se stampasse l'osservationi per le quali sono state composte le sue teoriche" (Clavius to Magini, 27-1-1595, in Favaro, 214-216).

47. As a matter of fact, all that could be derived with certainty from the best known measures of the tropical year (some had been recorded in book III of Copernicus' *De revolutionibus* and were listed later by Clavius) was that they fell within narrow limits. Their temporal succession did not show any obvious connection with a fixed rate of change in precession. Among the three existing models of precession: (1) Ptolemaic; (2) that of trepidation, in the different forms it was given from Thabit to Alfonso X to J. Werner; and (3) Copernican; only the second and the third accounted for a variation in the tropical year and provided periods, making it possible in principle to calculate any short term difference among years. A somewhat detailed study on mean and true changes produced by trepidation had been made by A. Pighius (*De aequinoctiorum solsticiorumque inventione* and *De ratione paschalis celebrationis*, both published in Paris in 1520) and by J. Werner (*De motu octavae sphaerae*, Nurnberg 1522). After them, P. Pitati considered those values as a possible basis to reform the Julian calendar (*Paschales atque Noviluviorum mensurni canones*, Venetiis 1537). He thought, however, that the greater exactness made possible by the use of true motions was not necessary for the reform. Pitati also recalled that, in collaboration with Paul of Middelburg, he observed the 1520 vernal equinox in Rome, and he listed two other observations of his own for the vernal equinoxes of the years 1535 and 1536. In another book (*Compendium... super annua solaris, atque lunaris anni quantitate*, Veronae 1560, p. 7),

he referred to another observation of the 1536 equinox made (possibly by Cardano) at Tübingen; only the first of these observations is listed by Riccioli, p. 10-12. On Pitati's works see Riccardi).

48. Clavius to Moleto: Rome 24 October 1580 (BAM, ms. *S 77 sup.*, 295r). Clavius' letter to Moleto seems to be an answer to the latter's position in his *De corrigendo Ecclesiastico Calendario* (published in appendix to the *Tabulae Gregorianae*, Venetiis 1580) in which (book I, ch. XIII) the choice of true motions was strongly advocated. A position similar to Moleto's was held by another influential mathematician, G.B. Benedetti, who expressed it in his judgement of the 1577 *Compendium novae rationis restituendi Calendarium* (BAV, *Vat. lat.* 5645, 148r; BCR, ms. 649; the text was also printed in Benedetti's *Diversarum speculationum liber*, Augustae Taurinorum 1585).

49. Clavius, *Opera*, V, 66, see also the letter of Magini to Clavius (APUG, ms. 530, 208r).

50. Since there are no letters of Clavius in APUG prior to 1579, information must be derived from drafts that were to become his *Computus Ecclesiasticus* (published first in Rome in 1597 and then in *Opera*, V, 561-596). These drafts were written at different times and thus show variations in his thought. The principal ones are the following: *Novilunia, seu coniunctiones Lunae cum Sole; Plenilunia, seu oppositiones Lunae cum Sole; ... quibus additur compendium perutile in computum ecclesiasticum* (BVNE, ms. *Fondo Gesuitico* 338; the codex has no author's name, but Clavius handwriting and style are recognizable; he was, moreover, alone in treating mathematical subjects in the Collegio Romano in 1571, on the title page of the codex); *Computus ecclesiasticus traditus a R.P. Clavio MDLXXV in Collegio Romano* (BAV, *Ott. lat.* 370); *Computus ecclesiasticus* (BAV, *Barb. lat.* 1849); *Calendarii correctio in quo consistat* (ARSI, *Opp. NN.* 42, 109r-116v; a later hand wrote on the title page: "edita et a P. Christophoro Clavio ... explicata viva voce anno 1852." The first text, *Novilunia*, is the only one written before Clavius became a member of the Calendar congregation and it is from that draft that I derive the discussion in the text.

51. The so called anomaly of the metonic cycle (namely the difference of 235 lunations with respect to 19 tropical years) was believed by reformers to be about one day every 312,5 years. So if the lunar period they chose had been slightly wrong (it was about 29,53055 days), a long time had to pass before difficulties could arise in the calendar.

52. See Carmody, Dreyer, Goldstein, Neugebauer.

53. See Goldstein.

54. See Swerdlow.

55. A copy of Ignatius' letter is found in Clavius' correspondence in APUG (ms. 530, 253r-255v); the Arabic text of his report may be seen in Florence, Bibl. Laurenziana, ms. Orientale 301, whereas two copies of a Latin translation made by L. Abel are in Arch. Seg. Vaticano, *Bolognetti* 315, 2r-58r, and in BNF, ms. *Magliabechiano* cl. XXII, 8. Patriarch Ignatius maintained that the idea of a variable tropical year was due to observational and instrumental errors, also adding that a whole series of near-eastern observations (708 A. D. to 1472) showed the length of the year to be constant. He alludes to these observations by listing, sometimes the authors, sometimes the places where they had been made. This series of observations does not seem to have been sufficiently researched in studies on Islamic astronomy.

56. Copernicus had already emphasized a link between astronomical problems and the reform of the calendar when he declined the offer to have a part in the reform, on the grounds that some essential astronomical points had still to be clarified.

57. No document pertaining to the congregation offers any detail on Danti's role in it, nor it is sure when his membership began. From 1577 to 1580, having left his chair in Bologna, he was working in applied hydraulics and cartography on the Pontifical Govern-

ment's behalf. In late 1579 or in 1580 he came to Rome, where he built the Tower of the Winds and directed works in the famous Vatican Galleria delle Carte Geografiche, where frescoes were painted representing all the Italian regions. In 1583 Gregory XIII rewarded him with the bishopric of Alatri, where he died in 1586. Danti, a Dominican friar, also met with some difficulties within his order. He is one of the most important figures for studies of the beginnings of Copernicanism in Italy (1560 to 1570). In that respect the almost complete dispersal of his manuscripts is very unfortunate. A few letters by him are preserved by libraries in Bologna, Florence, Milan, Modena. Existing studies on Danti are listed by M.L. Righini Bonelli; for the titles of his works see Riccardi and Almagià, p. 1-7.

58. I. Danti, *Primo volume dell'uso et fabbrica dell'Astrolabio et del Planisferio*, Firenze 1578, 319-320.

59. I. Danti, *ibid.*, 322.

60. As far as I known, Danti's name is never found in Clavius' works or letters. This is very strange if one recalls that he was one among the best known Italian astronomers, professor of mathematics in the important Bologna University and planner of astronomical instruments, greatly admired in the period, such as the unfinished gnomon in Florence's Santa Maria Novella, that in Bologna's San Petronio and, in the Vatican, the Tower of the Winds with its meridian line. The failure of Clavius to mention Danti is even stranger if one assumes, as was probably the case, that Danti's measures for the years 1574 and 1575 were used by the congregation to determine the equinox.

61. In 1581 (*Opera*, p. 182) Clavius accepted Copernicus' measure of the increase in stellar longitudes from Ptolemy's time instead of that given by Petrus Apianus. He also added: "Sed quoniam stellae paulatim ab occasu in ortum progrediuntur, addenda erunt hoc tempore plura minuta. Nam ab anno MDXXV usque ad annum Iubilei MDLXXV, quo Romae secundum hanc tabulam globum astronomicum quam correctissime construximus, stellae fixae fere progressae sunt Min. 26. Quare longitudinibus in praecedenti tabula repertis addendi erunt grad. 27 min. 47 ut verae longitudines inveniantur. Id quod nos in eo globo praestitimus". An increase of 26' in fifty years results from a mean annual precession of 31,2". Here Clavius seems to imply two facts: the first is that he had measured the longitudes of some stars, and the second is that he found those longitudes to agree with Copernicus' mean annual precession for the modern time. These facts cannot be properly discussed here. It is only to be noted that in BNVE the "Rari e Manoscritti" department has a valuable celestial globe by an unknown author, which comes from the Collegio Romano and is dated "Anno jubilei 1575". M. Fiorini p. 187-8) described it without attempting to trace its origin, and his description was followed by E.L. Stevenson (165-6). At a first examination the globe seems to be that remembered by Clavius and, in a different context, by Bellarmino. In one of his letters to Erennio Cervini (Le Bachelet, 107-108) Bellarmino wrote that Clavius believed to be "certa, o quasi certa" the idea of those who maintained "l'anni esser ineguali".

62. "Nomina et ordinem in tabula infra positam exposuimus iuxta observationes fere Nicolai Copernici. Mutatae enim iam reperiuntur omnium stellarum sedes, sive longitudines a temporibus Ptolemaei ad nostram usque aetatem, propter motum illum tardissimum, quo eas moveri diximus ab occidente in orientem" (*Commentarius*, 1581, 150).

63. Ricciardo Cervini was the father of Pope Marcellus II. Clavius discussed Cervini's ideas in the second edition of his *Commentarius* (1581, pp. 61-62) without revealing the author. See Bellarmine's letters to E. Cervini (published by Le Bachelet: 107-8, 109-110, 125-6). R. Cervini's essay appears to be lost, but some astronomical notes he wrote in a codex containing the Alfonsine tables (BCR, ms. 653) clearly state his ideas on precession. On Cervini's life and work see M. Palma.

64. For a list of editions and reprints see Sommervogel, *sub voce* "Clavius". The history of the text is, on the whole, very intricate, but it also gives the historian a key to Clavius' development as an astronomer in a period that was a crucial one. The importance of changes in the text was already clear to some contemporaries I.R. Ziegler S.J., who later was to edit Clavius' *Opera*, wrote to him: (Mainz, 17 July 1605) "Est et hoc quod ex R.V. sciscitor quid sentiat de Tychonis Brahe Astronomia instaurata. Suspicor R.V. nonnihil illius scriptis affici. Suspicionem movet quod viderim ultimam editionem sphaerae R.ae V.ae carere illis appendicibus, quibus in prioribus editionibus R.a V.a egerat de motu duplici nonae et decimae sphaerae: item de quantitate coelorum seu orbium." It seems that Clavius never answered this or other important questions in Ziegler's letters (APUG, ms. 530, 244r-245v). In another letter written in 1612, Ziegler complained: "iam quintam ad R.V. scribo epistulam, nec quidquam responsi accipio" (APUG, ms. 530, 252r).

65. *Commentarius* (1570), p. 78, 85-86.

66. In 1570 references to Copernicus were rather generic, so it is possible that they originated more from the *Tabulae Prutenicae* than from *De revolutionibus* itself, although the tables of the fixed stars were said to be derived "ex observationibus Nicolai Copernici." The problem of when and how Clavius studied Copernicus would require a paper in itself. Among BNVE copies of *De revolutionibus* (of both 1543 and 1566 editions) three were in the library of the Collegio Romano. One 1543 copy (cat. N. 201-39-I-26) has Clavius handwritten notes concerning the trigonometric part in book I; since these notes mention his edition of *Theodosii Tripolitae Sphaericorum libri III* (Romae 1586) they do not establish when Clavius firstly studied the book. The other two copies (1566 edition, cat. N. 7-2-E-23; 201-39-I-18) show no sign of having been used by Clavius (the first came to the college "ex dono B. Aloysii Gonzagae", that is after 1585); so they are interesting in another respect, having been censured in partial accordance with the 1616 anticopernican decree; on the contrary, Clavius' copy was not censured, and this may mean that it was not conserved in the general library (Bibliotheca secreta), or rather that it was used only by the mathematicians of the college.

67. *Commentarius* (1581), p. 56.

68. *Commentarius* (1581), p. 62-3.

69. Raimondo's *Discorso ... fatto sopra 'l moto della trepidatione dell'ottava Sfera* (written 1580) was published as an appendix to his *Trattato utilissimo ... del flusso e del riflusso del mare* (Venezia 1589). He also wrote about the new star of 1572 and the comet of 1577; his writings on the calendar as well as on other subjects are listed by Riccardi; see also Hellmann, 1 and 2.

70. *Opera*, III, p. 33-42. In this paragraph a history of theories of the motion of the eighth sphere, from Hipparchus to the Alphonsines, preceeds the description of inconsistencies between that theory and real phenomena.

71. *Opera*, III, 35.

72. Examples of such phrases are: "secundum Alphonsinos", "ut Ptolemaeus vult", "ut receptum est a communi astronomorum schola". They almost invariably denote that Clavius is convinced that a certain concept or measure is false, or at least uncertain.

73. In fact, if a geocentric interpretation of Copernicus' measures made it necessary to introduce another sphere, as Clavius did later, in 1581 the traditional number of spheres was preserved: "Statuimus ergo in universum esse undecim caelos, decem quidem secundum Astronomos mobiles, unum vero ex sententia Theologorum immobile prorsus" (p. 46). Clavius also added to his text a scheme (p. 448-467) summarizing planetary motions in an entirely Alphonsine way. This contrast of theoretical pattern and specific data is clear in Clavius' treatment of the obliquity of the ecliptic (p. 253): after enumerat-

ing the values it has been given from Ptolemy to J. Werner, he writes "Inter omnes autem praedictas maximas Solis declinationes communis schola Astronomorum retinet eam, quam Ioannes Regiom. summus astronomus observavit, nimirum grad. 23 min. 30. Quamvis admodum probabile sit, eam fortassis esse tantum grad. 23 min. 28, paulo amplius, qualem posuit Copernicus." So the Copernican measure is introduced as more reliable than others, but no inference is drawn from it as to the whole model, while it is obvious that the geometric structure of Copernican procession theory connects precession and variable obliquity and tries to show that other theories are not consistent with historical values for both phenomena (see Swerdlow).

74. It soon became the standard edition of *Sphaera*, which was the most used introduction to astronomy until the beginning of the XVIIth century (Thorndike; Johnson).

75. When reprinting the *Commentarius* to Sacrobosco's *Sphaera* in *Opera*, Clavius prefaced his catalogue of the fixed stars with a short notice on Brahe's observations and Galileo's telescopic discoveries (*Opera*, III, 74-5)). Having admitted that those new data were not consistent with the original Ptolemaic system he concluded: "Quae cum ita sint, videant Astronomi, quo pacto orbes coelestes constituendi sint, ut haec phenomena possint salvari (such being the state of things, astronomers have to consider which arrangement of heavenly spheres may save these phenomena)." Contemporaries like Kepler and the Jesuit G. Biancani, who taught mathematics at the Jesuit college in Parma, construed these words as being a cautious admission of the necessity of an entirely new cosmological hypothesis. Some other historians have also followed this opinion. No evidence in any of Clavius' later writings, however, shows that he renounced those physical tenets which had induced him to oppose Copernican ideas, nor did he ever favour Brahe's system. In 1616 C. Grienberger, his former assistant, had to decide if Biancani's *Cosmographia* was worth printing; in that work Clavius' passage was quoted in order to show the heliocentric point of view to be reasonable. In his judgement of the work Grienberger denied that Clavius' words conveyed such a meaning; to him the master simply meant a further adjustment in the Ptolemaic model (ARSI, *F.G.*, 655, 105r-121v).

76. See *Opera*, 33-42, the paragraph: "De quadruplici motu octavae sphaerae ex recentiorum astronomorum sententia". I could not examine the edition Lugduni 1593 and its reprints. The 1606 edition was entitled *Christophori Clavii Bambergensis, ex Societate Jesu, in Sphaeram Joannis de Sacro Bosco Commentarius, nunc quinto locupletatus. Accedit geometrica atque uberrima de crepusculis tractatio* (Romae, sumptibus Jo. Pauli Gallii, 1606); in this paper, however, the 1607 reprint has been used (Lugduni, Hug. a Porta), in which the paragraph is at pp. 65-79.

77. The whole subject is discussed by Clavius in a new paragraph (see note 76). In 1581 he had written: "Statuimus ergo, in universum esse undecim caelos, decem quidem secundum Astronomos mobiles, unum vero ex sententia Theologorum immobile"; the 1606 text has "duodecim" and "undecim" instead of "undecim" and "decem".

78. See Delambre, 241-242.

79. Magini's theory cannot be discussed here. The essential point in it is a geometric problem, namely to construct a geocentric system producing — to an observer on Earth's surface — a Copernican precession. The number of the spheres may be arbitrary, even if the least possible number is preferable for economic reasons. To construct such a system is surely possible (on the mathematical potentialities of geocentric systems see Hanson and Goldstein). A tentative explanation of the supposed variations of precession by the addition of a sphere was already current at the beginning of the XVI century, as Copernicus hinted at it in *De revolutionibus*, III, 1.

80. See Baldini (II).

81. In addition to those parts of *Commentarius* where longitudes of stars are discussed, an indirect proof is given perhaps by a copy of *De le stelle fisse libro uno* by the well known philosopher and astronomer A. Piccolomini (BNVE, cat. N. 14-33-L-18). The book is bound in a volume together with *Della sfera del mondo* (Venezia 1566) by the same Piccolomini. The volume was in the library of the Collegio Romano. In the tables of constellations the positions of several stars have been corrected by a handwriting that is probably Clavius'. No one else would have written corrections in a mathematical book of the library before about 1590-1600 and Piccolomini's book was most probably not studied very carefully after that period.

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ALOISIUS LILIUS AND THE "COMPENDIUM NOVAE RATIONIS RESTITUENDI KALENDARIUM"

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After more than eight hundred years of attempts to legislate a reform of the Julian calendar, a plan was approved by Pope Gregory XIII in a bull signed in Frascati, Italy on 24 February, 1582.[1] In the first paragraph of this papal decree the members of the pope's commission on calendar reform recount the care and discretion with which they had chosen the new plan, explaining that opinions of it were solicited from the most eminent scholars and heads of government: "A few years ago", the edict reads, "we sent this new plan for restoring the calendar contained in a little volume to the Christian princes and the more celebrated universities... ."[2] This "little volume" was the *Compendium novae rationis restituendi kalendarium* (*Compendium of the New Plan for Restoring the Calendar*), which contained a summary of the proposed reform, an elegant plan developed by a medical lecturer from Cirò in Calabria named Luigi Giglio, or also Lilio, who is frequently cited by his Latinized name Aloisius Lilius.[3]

In 1577 copies of the *Compendium* were circulated for review among astronomers and mathematicians at the universities of Paris, Vienna, Genoa, Salamanca, Alcalá, Louvain, and Cologne. The reviewers generally praised the proposal for its accuracy and convenience, but unfortunately Lilius never lived to see the adoption of his ingenious reform. Sometime after teaching medicine at the University of Perugia, he apparently returned to Cirò and, in 1576, was stricken ill and died there while in the employ of his lord Count Garafa. But Lilius may, in fact, have died in Rome; precious little is known with certainty about the man whom the most renowned member of the calendar commission, Christoph Clavius, hailed as the "primus auctor" of the new calendar.[4]

At the time of Lilius' death, his plan of reform was only in manuscript. The unprinted work, however, was posthumously presented to that commission of mathematicians and clergymen which Gregory XIII had installed in 1576 during the fourth year of his pontificate. While they deliberated upon an appropriate means of restoring the calendar, members of the commission state in the papal bull that "a book was brought to us by our beloved son Antonio Lilio, doctor of arts and medicine, which his brother Aloysius had formerly written...".[5]

Although by far the most important document in the history of the Gregorian reform, Lilius' treatise — the "book" alluded to in the papal bull — was never printed and the manuscript is evidently lost. The commission had originally intended to print Lilius' manuscript and distribute copies of it to the Catholic rulers and selected experts for their appraisal, but Pope Gregory was eager to get on with the reform and so the plan was sent out only in a synopsis based on Lilius' manuscript. This was the *Compendium*, and it is apparently the closest extant document to Lilius' original text.

The incomparable authority on the history of the reform, the nineteenth century Graz privatdocent Ferdinand Kaltenbrunner, noted in the last of his three exhaustive papers on the subject that Lilius' manuscript could not be found among the Vatican archives and that it had probably been deposited in an unknown location. He wrote:

> The codices which served me as sources only included writings which were sent to Gregory XIII, and, as one may well imagine, all is complete; at least there are no serious gaps noticeable — with one exception, and this is the writing of Aloisio Lilio which provided the impetus for the calendar work. It can not be found in the Vatican, and as I suppose, for the following reasons: it was naturally a working-object of the commission and probably moved into the hands of Clavius and Antonio Lilio after the publication of the calendar, because they had, as we will see later, yet to accomplish the task of preparing a complete explanation of the new calendar. This was initially delayed for not very clear reasons, but perhaps on account of the polemic in which Clavius got himself involved with Maestlin and Scaliger for about 21 years; Antonio Lilio had meanwhile died and perhaps already by that time his brother's work with his estate had drifted to a place

> now unknown to us. Perhaps it further remained in the hands of Clavius until, after his passing, it was together with the other internal documents and papers of the commission moved to a location likewise unknown to us.[6]

The whereabouts of Lilius's manuscript is apparently still unknown. If the work survives at all, its discovery would enable us to know precisely what Lilius had originally intended for the reform, since his plan had undergone some modification by Clavius and the commission. A somewhat less significant discovery, however, has been made. The original text of the *Compendium* has itself long been considered lost. Moreover, numerous authorities in the past century, including Kaltenbrunner, have concluded that the *Compendium* was never printed, that it was circulated for review in manuscript only, and that a printed version appeared much later in Christoph Clavius's *Romani calendarii a Gregorio XIII P. M. restituti explicatio*, the definitive treatise on the Gregorian calendar, commissioned by Gregory's fifth successor Clement VIII and published in 1603.[7]

Kaltenbrunner stated:

> This summary bears the title: "Compendium novae rationis restituendi Kalendarii" and probably it was also only sent out in manuscript, because I find nowhere a notice on its printing, and also only in this form is there any meaning as to why Clavius wrote in the forward to his "Explicatio" that he placed the compendium in the front of his work, "so that thereafter his (Lilius's) memory will be left for posterity, but most of all it is transferred to this place so that it will be visible to all, on whose behalf the commission made the corrections of the calendar".[8]

In October 1981, I undertook a search for the original *Compendium* in Italy, visiting a number of archives from Bologna to Rome. A printed copy of the treatise does, in fact, exist (in rather moldering condition) in the Biblioteca Nazionale Centrale in Florence.[9] Catalogued by title, the work is given as by an anonymous author. After having found this copy, I located two others which are also indexed by title in the main card catalogue of the Vatican Library.[10] Continuing my search, I discovered a copy in the Biblioteca Comunale degli Intronati di Siena which, with the exception of a few minor variants in orthography, is identical to the copy I examined in the National Library in Florence.[11]

Recently, Thomas B. Settle of the Polytechnic Institute of New York informed me that he had discovered a copy of the *Compendium* in the

Biblioteca Marucelliana in Florence in 1975 and, in addition, had found two copies in the Biblioteca Nazionale Centrale (where I have examined one), as well as a manuscript copy in Italian at the same library, the text of which very closely parallels the Latin copy.[12] There are thus at least seven extant copies of the *Compendium*, and it is not unreasonable to suppose that there are others.

None of the copies which I or Settle have examined exists as separate volumes; each is bound in a varying collection of other calendrical treatises published around the same time as the *Compendium*. The copy I examined in the National Library in Florence is the first work in a collection including, in order, the following treatises:

> *Ad Alexandrum Farnesium Cardinalem S. R. E. Vicecancellarium, Epitome Pauli Clarantis Interamnatis Nahartis in librum de Paschatis Chronologia eiusdem Auctoris.* (Venetiis, 1576).
>
> *Ad Principes Christianos, de Paschatis Chronologia Quaestiones XVII. Pauli Clarantis Interamnatis Nahartis.* (Perusiae, 1578).
>
> *De Romani Calendarii Nova Emendatione, ac paschalis solennitatis Reductione per R. P. F. Johannem Salon Valentinum Francisanae observantię professum, Nunc primum editum.* (Florentiae, 1576).

The copy I found in Siena is also included as the first work in a collection comprising three additional treatises, the second being Salon's *De Romani calendarii...*; the other two works are:

> *De Nova Ecclesiastici Calendarii, pro legitimo Paschalis celebrationis tempore, restituendi forma, Libellulus, Alexandri Picolominei, Archiepiscopi Patrensis, & in Archiepiscopatus Senensi Coadiutoris; ad D. Francisum Medicem, Hetruriae Magnum Ducem Secundum.* (Senis, 1578).
>
> *Sỳnopsis de Restitutione calendarii, Aucthore Francisco Iunctino Florentino,... Alenconiorum Ducis, & c.* (Lugdini, 1579).

Each of these short works is a commentary on Lilius's plan; the treatises of Salon, Clarante, and Piccolomini also contain proposals of their own. These authors were not in complete agreement with all that Lilius proposed. Piccolomini, for instance, took objection to the so-called Lilian epacts for computing the date of Easter, recommending an alternative scheme which still employed the epact, that is, the lunar phase expressed as the number of whole days elapsed since new Moon on 1 January of a given year. Salon and Clarante also addressed the technical aspects of the reform, making

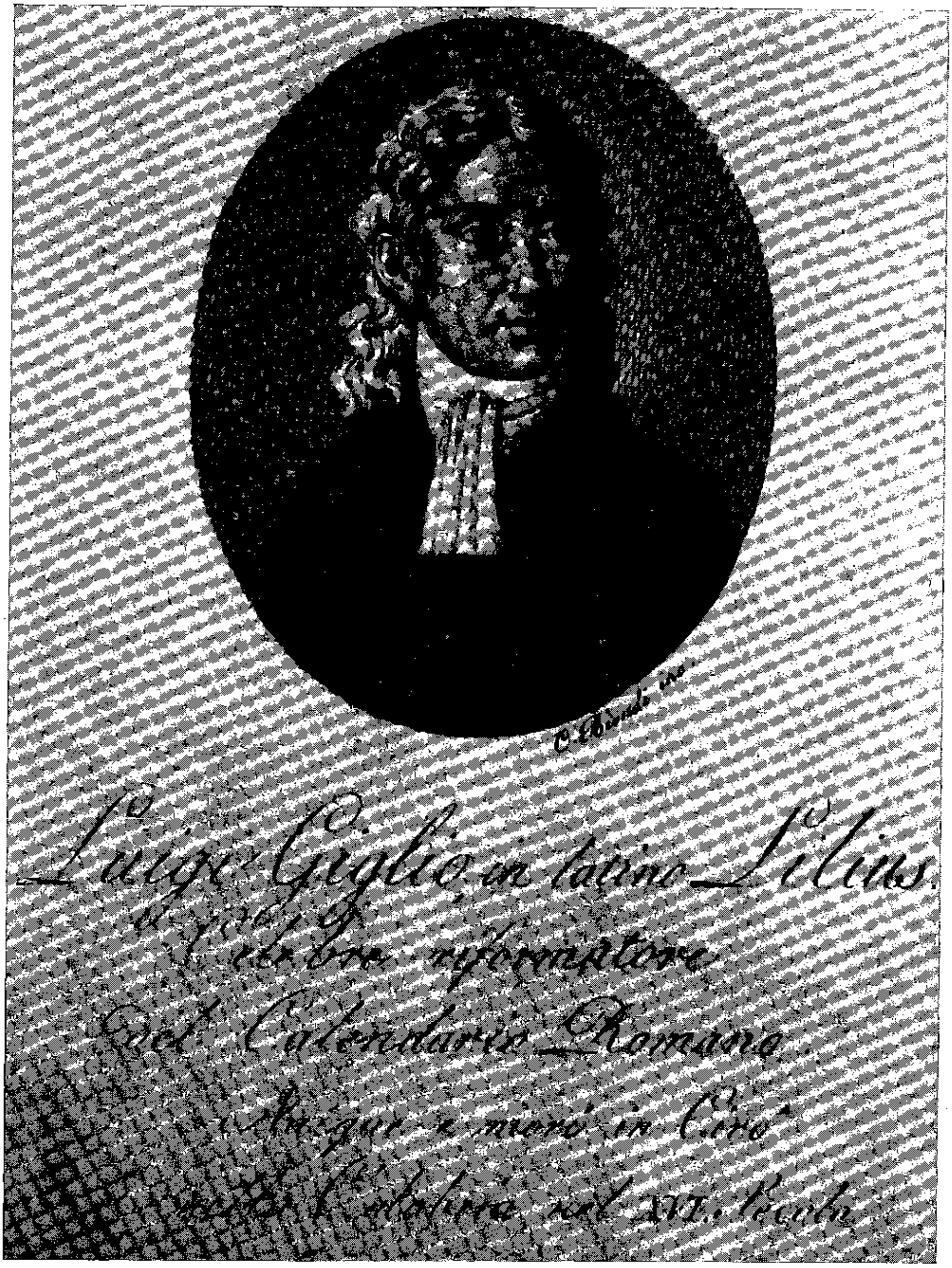


FIG. 1. Aloisius Lilius, an engraving by C. Biendi reproduced in Nicola Gervasi,s *Biografia degli Uomini illustri del Regno di Napoli,* Tome VI (Naples, 1819). Photograph by Giovanna De Vita, courtesy of the Biblioteca Nazionale di Napoli.

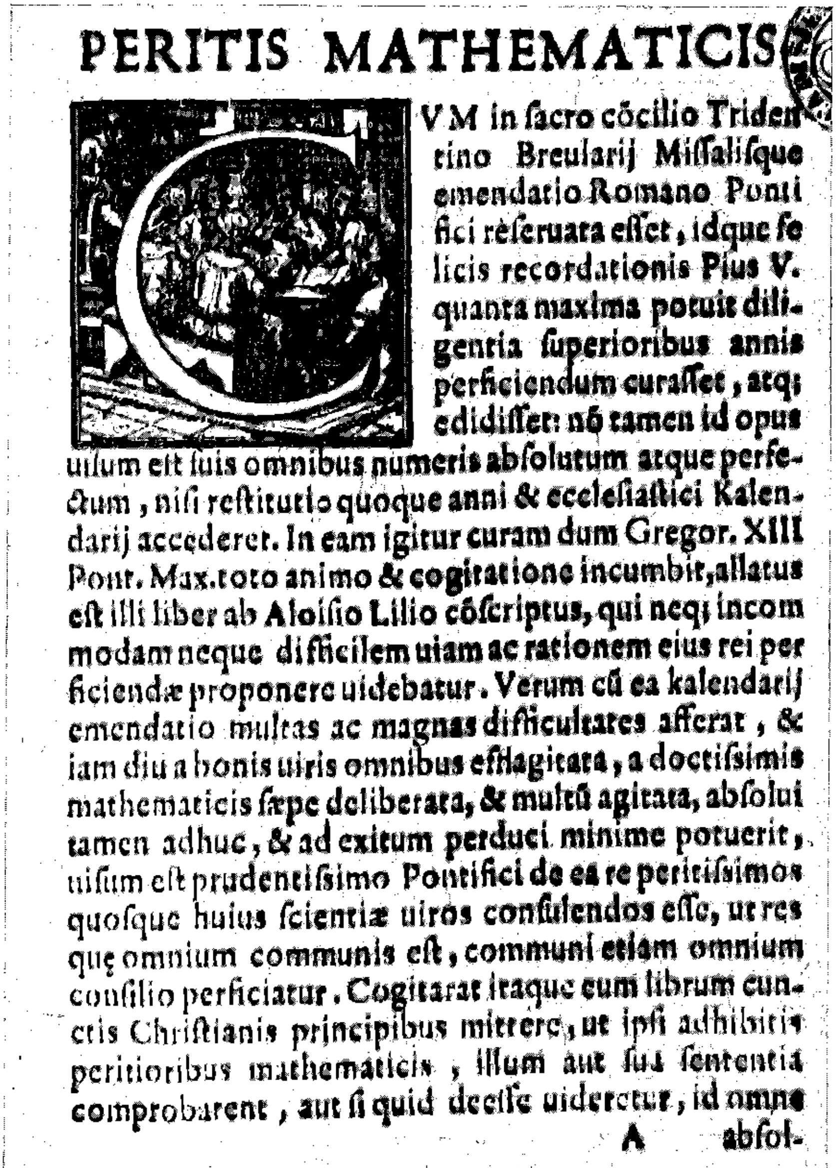
certain suggestions for improvement but also quite liberally praising Lilius. In discussing the intercalary rules which Lilius proposed, Salon extols him as a "most excellent Physician and by no means ordinary Mathematician".[13]

The *Compendium* was printed in Rome in 1577 by the heirs of the renowned publisher Antonio Blado who, incidentally, had been the first to issue Machiavelli's *Il Principe*. From 1546 until his death, Blado served as official printer to the papal court. His sons inherited the firm and later issued some important judicial discources of Gregory XIII.

Published as a quarto volume, the *Compendium* consists of only twelve unnumbered leaves (twenty-four pages), of which the first and last are blank. The date and place of publication is given at the bottom of the last printed page: "Romae. Apud haeredes Antonij Bladij Impressores Camerales Anno. M. D. LXXVII". In the center of this page, after the conclusion of the text, a short paragraph is appended prohibiting "under penalty of excommunication" the selling or reprinting of the book. This interdiction is given by Cardinal Guglielmo Sirleto, the Calabrian president of the papal commission on calendar reform, who assumed the chair in 1577 after Tommaso Giglio, Bishop of Sora, was obliged to step down after having presided for only a short while.

Since the commission had collectively decided in favor of Lilius' plan, the *Compendium* was apparently to be regarded as a collaborative work, because its author is nowhere cited in the treatise. The work is commonly referred to as "Lilius' compendium",[14] even contemporaries of Lilius referred to it as such. Alessandro Piccolomini, an acquaintance of Lilius' brother, Antonio, repeatedly alluded to it as Lilius' book, remarking, for instance, on faults perceived "in secŭdo capite compendii Aloysii Lilij".[15] But no part of the *Compendium* was actually written by Lilius; the author of the treatise was one of the senior members of the calendar commission, a Spanish mathematician named Pedro Chacon.[16] Like many members of the commission, little is known about him. He is listed on the commission's final report to the pope as simply "Petrus Ciaconus. Hispanus".[17] He had been appointed to the commission when Bishop Giglio was its president, and so was probably the longest-serving member.

Although the *Compendium* was sent to both princes and savants, Chacon addresses only the scientific audience, beginning "Peritis Mathematicis: ". The initial letter, "C", is illuminated with a charming woodcut showing the pope presiding over members of his commission. As an introduction, Chacon recalls the labors of Pius V at the Council of Trent in reforming the Breviary and Missal. It was on the death of Pius V in



PERITIS MATHEMATICIS

CVM in sacro cõcilio Tridentino Breuiarij Missalisque emendatio Romano Pontifici reseruata esset, idque felicis recordationis Pius V. quanta maxima potuit diligentia superioribus annis perficiendum curasset, atq; edidisset: nõ tamen id opus uisum est suis omnibus numeris absolutum atque perfectum, nisi restitutio quoque anni & ecclesiastici Kalendarij accederet. In eam igitur curam dum Gregor. XIII Pont. Max. toto animo & cogitatione incumbit, allatus est illi liber ab Aloisio Lilio cõscriptus, qui neq; incommodam neque difficilem uiam ac rationem eius rei perficiendæ proponere uidebatur. Verum cũ ea kalendarij emendatio multas ac magnas difficultates afferat, & iam diu a bonis uiris omnibus efflagitata, a doctissimis mathematicis sæpe deliberata, & multũ agitata, absolui tamen adhuc, & ad exitum perduci minime potuerit, uisum est prudentissimo Pontifici de ea re peritissimos quosque huius scientiæ uiros consulendos esse, ut res quę omnium communis est, communi etiam omnium consilio perficiatur. Cogitarat itaque eum librum cunctis Christianis principibus mittere, ut ipsi adhibitis peritioribus mathematicis, illum aut sua sententia comprobarent, aut si quid deesse uideretur, id omne

A absol-

FIG. 2. Page [1] of the *Compendium* addressing the "learned mathematicians" to whom the treatise was sent in 1577 for review of Lilius's calendar reform. The illuminated "C" shows Pope Gregory XIII presiding over several members of his calendar commission. The page is from the copy of the *Compendium* in the Biblioteca Comunale degli Intronati di Siena. Photograph by Gordon Moyer.

1572 that Ugo Boncompagni, a former professor of law at the University of Bologna, became Pope Gregory XIII.[18] As a cardinal, he had served as a prominent juror at the Council of Trent, and so after assuming the papacy he at once began to occupy himself with the still unresolved issue of correcting the calendar. Chacon explains: "So while Pope Gregory XIII devoted himself with all his heart and mind to the solution of that problem, a book was brought to him written by Aloisio Lilio which seemed to propose a neither inconvenient nor difficult method for bringing an end to the matter." [19] A similar account was later given in the papal bull "Inter gravissimas" of 24 February, 1582.[20]

In this first paragraph, Chacon remarks that Pope Gregory had at first decided to submit Lilius' treatise in its original and unabridged form to the Catholic sovereigns. "He had thought to send that book to all the Christian princes", Chacon explains, "in order that they would, after consulting the more expert mathematicians, either approve of it or, if they should find any fault, would rectify it completely and perfectly, and at the same time in order that, by chance, some more appropriate method was to be found somewhere, which he himself might rather follow." "But", Chacon continues, "with the book not yet in print, this would have been troublesome and difficult, and perhaps less necessary for the learned astrologers to whom this plan had to be submitted. He deemed it to be sufficient, therefore, to mention briefly only the main points in which the matter at issue is contained, and to leave out all other things." [21]

Despite Chacon's admission that Lilius's book was "not yet in print", the manuscript apparently never *did* get into print. Although the Pope had granted Antonio Lilio, in recompense for his "care and solicitude" in effecting a reform, the exclusive rights to publish the work on the calendar for a period of ten years, this privilege, which had been conferred in a bull of 3 April, 1583,[22] was later rescinded, probably as a result of Antonio's delay in getting anything into print. He had been given the enormous authority of printing explanations and other material relevant to the reform all over Europe. The task perhaps proved too great for one man. Gregory XIII eventually granted a general *imprimatur* with the order that copies of the new calendar conform in all respects to the original.

Perhaps Antonio Lilio had planned to publish his brother's manuscript, or at least include parts of it in a future explication. Plans had been underway to publish a complete rationale of the calendar to have been entitled *Liber novae rationis restituendi kalendarii Romani,* but this work also never appeared.[23] As a host of indignant scholars rose up against the reform, efforts shifted from merely explaining the calendar to staunchly defending it. Apparently what was to have been this definitive elucidation became instead Clavius' 800 page defense of the calendar, the *Explicatio*, in which a good many arguments are repeated verbatim from his *Novi calendarii Romani apologia, aduersus Michaelem Maestlinum*.[24] It was left to the Jesuit astronomer to explain the Gregorian calendar to the Christian world and, in particular, to justify the reform in the face of scurrilous attacks from its mostly Protestant opponents. All of Clavius's six treatises on the calendar were collected and republished in 1612 in Tome V of his *Opera mathematica*.[25] The *Compendium* is reprinted, as part of the *Explicatio*, in this volume, with various scholia accompanying its text, but nothing pertinent to Lilius's manuscript has been added.

Unless the manuscript of Lilius is discovered, it will never be fully known what he had actually planned. In a concluding remark in the *Compendium*, Chacon simply states: "He [Lilius] adds several other things which serve a fuller explanation and proof of the value of the method he has devised, but it does not seem necessary to mention these things now." [26]

Chacon presents only the essential features of Lilius's plan; he does not dwell at length on the reasons for things. Kaltenbrunner thus decried the *Compendium* as "der überhaupt sehr durftige Auszug",[27] but this remark is certainly presumptuous since there is no longer an original text by which to compare the *Compendium*. Chacon's summary of Lilius's manuscript proved, in fact, a sufficient précis by which the reviewers were able to formulate their opinions of the plan.

Lilius's proposal encompasses both the civil and ecclesiastical elements of the calendar; the *Compendium* includes both his system for stabilizing the drift of the date of the vernal equinox and his method for properly reckoning the date of Easter. Beginning on the second page, Chacon explains that in order for the Paschal Feast to be celebrated on the proper date, which is computed in accordance with the rule established by the Church Fathers at the Council of Nicaea, the date of the vernal equinox, which had been slowly regressing through the calendar, would have to first be stabilized. He briefly reviews the familiar rule for determining the date of Easter which was set forth at the First Christian Council of Nicaea in A.D. 325. The Council had proposed that Easter should be observed on the first Sunday after the fourteenth day of the Moon (approximately the full Moon) which occurs on or next after the vernal equinox, which at the time of the Council was assumed to be fixed at 21 March.[28] This unhandy rule was designed to avoid any coincidence of the dates of Passover and

Easter — the early church had been much concerned with distinguishing Christianity from Judaism.

Since the mean length of the Julian year was slightly longer than the length of the tropical year, the vernal equinox fell increasingly earlier than 21 March, eventually causing great confusion in the reckoning of Easter. By the time of the Gregorian correction, the Paschal Feast was actually being celebrated approximately ten days too late.[29] Chacon declares: "The equinox has not easily kept its place, but abandoning its position and continually wandering backward at an uncertain rate it has already reached the fifth or indeed the sixth day before the Ides of March [11 or 10 March]." [30] He adds decidedly: "And how great a confusion this will cause in all things, but especially in ecclesiastical affairs, has been set forth by many earlier writers, and is now also meticulously and copiously dwelled upon this author [Lilius]." [31] Chacon then points out that the Golden Number ("aureo numero"), the number of the year in the 19-year Metonic cycle by which the dates of new and full Moons were ascertained, can no longer be used to derive the date of the Paschal Full Moon, since the date of the vernal equinox grows evermore erroneous. He warns: "And darkly like a serpent this ill shall extend itself more and more each day, unless at some time a cure is necessarily applied." [32] In regard to this pernicious drift of the equinoctial date, he remarks: "To this problem, however, the author of the little book promises a remedy, and indeed an everlasting one." [33]

To halt the drift of the equinoctial date, Lilius proposed that three intercalary days out of every 400 years be omitted. It is stated: "For all time to come, he drew up an intercalary plan such that, from here on, not all century years which are now by custom intercalary are to be intercalary, but every first three are to be common and only the fourth is to be intercalary, so that in the years 1700, 1800, and 1900 no day will be intercalated, but in the year 2000 a day will be intercalated in the usual and accustomed manner." [34] Omitting the leap days that would normally have been added in these centurial years reduces the number of intercalary days from 100 in 400 Julian years to 97 in 400 Gregorian years, affording the calendar year a mean length of $365^{97}/400^{d}$ or $365^{d}.2425$. Since the length of the tropical year in 1582 was approximately $365^{d}.24222$,[35] the discrepancy between the tropical year and the calendar year under Lilius' plan was only a little more than 24 seconds. The Gregorian year, (which at the time of its inception was often referred to as the Lilian year),[36] was consequently in much closer agreement with the mean Sun than the Julian year of $365^d.25$.

According to Chacon, Lilius based his intercalary plan on the length of the Alfonsine year,[37] that is, the value of the tropical year given in the *Alfonsine Tables*, which was first published in 1252 under Alfonso X of Castile and remained the standard planetary tables until the middle of the sixteenth century when it was superseded by the *Prutenic Tables* of Erasmus Reinhold.[38] The length of the Alfonsine tropical year is not given in the *Compendium*, but Clavius quotes the value as $365^d\,5^h\,49^m\,16^s$ $(=365^d.2425463)$.[39] This value is approximately $10^m\,44^s$ $(= 0^d.0074537)$ shorter than the mean length of the Julian year. Lilius assumed that the Alfonsine year was approximately equal to the tropical year, and so estimated that the Julian calendar deviated from the mean Sun at the rate of about one day every 134 years. Therefore, based on the value of the tropical year given in the *Alfonsine Tables*, it would be necessary to extracalate one day every 134 years or three days every 402 years. However, perhaps because of the uncertainty of the value of the tropical year, Lilius simply rounded-off the omission to three days every 400 years.

It is not exactly known how Lilius derived an intercalation of 97 days in 400 years.[40] In his *Explicatio*, Clavius cites the measurements of the tropical year given by Copernicus in his *De revolutionibus orbium coelestium*, as well as the value given in the *Alfonsine Tables*.[41] A fallacious acceptance of the theory of trepidation led Copernicus to postulate a maximum and minimum value of the tropical year; the mean of these two measurements, however, is just slightly greater than the Alfonsine year, whereas Reinhold's value is only slightly smaller. Although Lilius used the Alfonsine value on which to base his intercalation of 97 days in 400 years, it would have actually made no difference which of these values he employed — all three differ from one another by less than a second. Each value, however, is about four seconds greater than the mean length of the Gregorian year. Chacon offers no explanation of Lilius's reasoning; he merely states: "For he himself proposes the length of the Alfonsine year, because it is an average of the various measurements and therefore less subject to error... ."[42]

Next, Chacon deals with Lilius's plan for restoring the date of the vernal equinox to 21 March where it had purportedly fallen at the time of the Council of Nicaea nearly 1300 years earlier. Two plans are presented. It is suggested that the 10-day displacement of the vernal equinox be rectified by either suppressing each intercalary day in a period of 40 years beginning in 1584 or by simply dropping 10 days all at once in 1582 from "the month in which it will seem most fit".[43] The commission later adopted the plan of omitting the days all at once from the month of October. In reply to Michael Maestlin, Clavius explained that there was nothing mysterious in the choice of month; October simply contained the fewest religious observances and was therefore the least disruptive for the Church.[44]

The last half of the *Compendium* concerns the restoration of the date of Easter, which the papal commission clearly regarded as the most important aspect of the reform. The new intercalary plan which provided a much closer agreement between the length of the calendar year and tropical year was instituted not so much for its own necessity, but as a prerequisite to ensuring an accurate reckoning of the date of Easter which, by rule, is dependent upon a fixed date of the vernal equinox.

To facilitate the calculation of the date of the Paschal Full Moon, Lilius developed a system based on the cycle of epacts. On six pages in the middle of the *Compendium*, a set of tables are included for each month in the year (two months to a table) on which are designated the approximate dates of all the new Moons of any given year.[45] The number of the epact of the year in question is listed within these tables next to each date on which a new Moon occurs. The epact of the given year is obtained from an auxiliary table entitled *Tabula Epactarum expansa.* The epact of the year is found on this table at the intersection of the row containing the Golden Number of the given year and the column containing the so-called Letter of Martyrology.[46] The Golden Number can be calculated by a simple formula: add one to the given year and divide the sum by 19; the remainder is the Golden Number for that year. Vertical tables in the margins of the text are used to find the Letter of Martyrology of the given year. Chacon remarks: "We have subjoined these tables, as well as others, which this book's author calls 'tables of the times'." [47]

Lilius' Table of Epacts was altered on several occasions by the commission; we owe its present form to minor adjustments [48] made by Clavius so as to better balance the lunar cycle with the civil calendar. The entire cycle now repeats in a period of 7000 years.

Chacon concludes the summary of Lilius's plan, declaring, "This, then, is what that author argues." [49] He then implores the experts to whom the *Compendium* would be sent to carefully consider the proposal: "Come on, therefore, you Mathematicians, you who engage yourselves in the contemplation and understanding of celestial matters, devote yourselves with all your mind and care to this common cause, and after diligently meditating upon and considering these things, either approve of what Lilius proposed, or, if you know something better, be so good to inform us about it in all sincerity." [50]

The *Compendium* was apparently quickly forgotten after its limited publication in 1577. At least since Kaltenbrunner's paper of 1877,[51] scholars have consistently overlooked the original copy; even A. G. Kästner a century earlier cited only the copy reprinted by Clavius.[52] Soon after the publication of Kaltenbrunner's series, a repetent at the University of Tübingen, Josef Schmid, published another series of three articles on the reform.[53] Together, the papers of Schmid and Kaltenbrunner comprise the most extensive treatment of the history of the Gregorian calendar, but Schmid also fails to cite an original copy of the treatise.

For at least a century, not a single authority [54] on the history of the Gregorian reform seems to have realized that the *Compendium* was published by the papal commission in 1577 and circulated throughout Europe in printed form. Many, too, have claimed that the only extant version of the treatise is that given by Clavius in his *Explicatio.* Scholars have evidently followed Kaltenbrunner in concluding that a printed *Compendium* never existed, and further presuming that the original draft is lost. However, the original printed *Compendium* apparently did not escape the attention of the noted cataloguer Pietro Riccardi. In his *Biblioteca matematica Italiana*,[55] Riccardi correctly identifies the *Compendium* as a separately printed work. He describes the treatise as consisting of twelve unnumbered leaves with signatures A_2 to C.[56] But since Riccardi's catalogue had a very limited printing, it is not so surprising that later writers have missed his apparently firsthand citation.

If Lilius had not died six years before the introduction of the calendar reform, his manuscript would perhaps have been printed. Even if the commission had still decided to send the reviewers a synopsis of his proposal, he, and not Chacon, would most likely have written it. In any case, we would almost certainly have a more complete and definite knowledge of the basis of the Gregorian reform. Perhaps, too, more would be known about Lilius himself, whom Clavius considered "a man most entitled to immortality, who was the principal author of such an excellent correction...".[57]

REFERENCES

1. "*Inter gravissimas*" in *Kalendarium Gregorianum perpetuum* (Rome, 1583), [A1]-A5. The papal bull was first published in Rome on 1 March, 1582. The *Kalendarium Gregorianum perpetuum*, which included a copy of the bull, was first issued in Rome in 1582 as the Church's official publication of the reform. It was later reprinted in Clavius, *op. cit.* (ref. 4) and *op. cit.* (ref. 25), 13-52, see pp. 13-15. The vituperative critic of the Gregorian calendar, François Viète, also reprinted the treatise, with the bull, in his *Opera mathematica* (Leiden, 1646; repr. Hildesheim, 1970), see pp. 505-8.
2. *Ibid.*, [A1].
3. There are many variants of his name. His Latinized name was often given as Aloysius Lilius. He was also known as Aloisio Baldassare. Lilius has often been confused with the scholar Lilio Gregorio Ghiraldi (1479-1552), cf. *Encyclopaedia Britannica*, iv (9th edn, Chicago, 1894), s.v. "Calendar", by W.S.B. Woolhouse and T. Galloway, 671. On Aloisius Lilius see Gordon Moyer, "Luigi Lilio and the Gregorian reform of the calendar", *Sky and telescope*, lxiv (1982), 418-19; and Raffaele Nicastri, *Cirò, patria del riformatore del calendario* (Catanzaro, 1920), 98-111.
4. Christoph Clavius, *Romani calendarii a Gregorio XIII P. M. restituti explicatio* (Rome, 1603), Epistola ad lectorem.
5. *Op. cit.* (ref. 1), [A1].
6. F. Kaltenbrunner, "Beiträge zur Geschichte der Gregorianischen Kalenderreform", *Sitzungsberichte der kaiserlichen Akademie der Wissenschaften, Philosophisch-historische Classe*, xcvii (1880), 7-54, pp. 10-11.
7. Clavius, *op. cit.* (ref. 4), repr. in *op. cit.* (ref. 25), v. 3-12.
8. F. Kaltenbrunner, "Die Polemik über die Gregorianische Kalenderreform", *Sitzungsberichte der kaiserlichen Akademie der Wissenschaften, Philosophisch-historische Classe*, lxxxvii (1887), 485-586, p. 490; F. Kaltenbrunner, *Die Polemik über die Gregorianische Kalenderreform* [repr. *ibid.*] (Vienna, 1877), 8.
9. Shelfmark 12.6.59.
10. Racc. I., IV.963, int. 4; S. Offizio, 318, (1).
11. For example, on the first page of the Siena copy the pope's name is abbreviated "Gregor. XIII", whereas in the copy examined in Florence it appears "Gregorius XIII". The word "curam" in the sentence alluding to Gregory XIII has been shortened to "curã" to allow space for the pope's unabbreviated name.
12. Fondo Nazionale: II.IV.263 [old fondo: Magliabechiana XIX, no. 83].
13. Juan Salon, *De Romani calendarii nova emendatione, ac paschalis solennitatis reductione per R. P. F. Johannem Salon Valentinum Francisanae observantię professum, nunc primum editum* (Florence, 1576), 16.
14. Several leading reference works mistakenly ascribe authorship of the *Compedium* to Lilius: *The new century Italian Renaissance encyclopedia*, ed. Catherine B. Avery (New York, 1972), s.v. "Lilio or Giglio, Luigi", 557-8; Ilan Rachum, *The Renaissance: an illustrated encyclopedia* (New York, 1979) s.v. "Lilio, Luigi (c. 1510-76)", 299. I incorrectly cited Lilius as the author in *Scientific American*, ccxlvi (1982), 110.
15. Alessandro Piccolomini, *De nova ecclesiastici calendarii, pro legitimo paschails celebrationis tempore, restituendi forma, libellus, Alexandri Picolominei, Archiepiscopi Patrensis, & in Archiepiscopatus Senensi coadiutoris; ad D. Francisum Medicem, hetruriae magnum ducem secundum* (Siena, 1578), 103.

16. Chacon is identified as the author in a letter from Vincenzo Lauro, another Calabrian on the commission, to Guglielmo Sirleto, 31 May, 1581. Lauro, who was in Turin, sent the letter to Sirleto in Rome. *Bibl. Vat., Cod. Vat. lat.* 6194, 67-68, see 67r. I owe this reference to Rev. August Ziggelaar, S.J.
17. *Bibl. Vat., Cod. Vat. lat.* 3685; repr. in Kaltenbrunner, *op. cit.* (ref. 6), 48-54, p. 54.
18. On Gregory XIII, see Ludwig Freiherrn von Pastor, *Geschichte der Päpste im Zeitalter der Catholischen Reformation und Restauration*, ix (Freiburg im Breisgau, 1958), chap. 4.
19. *Compendium novae rationis restituendi kalendarium* (Rome, 1577), [1].
20. *Op. cit.* (ref. 1), [A1].
21. *Op. cit.* (ref. 19), [1]-[2].
22. Reprinted in Giulio Aromolo, *Papi, Astronomi, Epatte: Luigi Giglio* (Naples, 1963), 91-92.
23. Kaltenbrunner, *op. cit.* (ref. 6), 47.
24. Christoph Clavius, *Novi calendarii Romani apologia, aduersus Michaelem Maestlinum Gaeppingensem, in Tubingensi academia mathematicum, tribus libris explicata* (Rome, 1588).
25. Christoph Clavius, *Opera mathematica*, 5 vols. (Mainz, 1611-1612).
26. *Op. cit.* (ref. 19), [16].
27. Kaltenbrunner, *op. cit.* (ref. 6), 13.
28. In A.D. 325, the vernal equinox actually occurred on the evening of 20 March.
29. Reckoned from A.D. 325, the deviation of the Julian calendar from the mean Sun in 1582 was approximately 9.7 days (baesd on S. Newcomb's value of the tropical year, see ref. 35).
30. *Op. cit.* (ref. 19), [2].
31. *Ibid.*, [3].
32. *Ibid.*
33. *Ibid.*, [4].
34. *Ibid.*
35. Based on Simon Newcomb's expression for the length of the tropical year at epoch 1900 January 0, Greenwich Mean Noon (i.e. 1899 December 31, 12^h UT):
$$365^d.24219879 - 0^d.00000614\ T,$$
where T is the time from that epoch "reckoned in terms of the Julian century, or 36525 days as the unit". See Simon Newcomb, *Tables of the motion of the Earth on its axis and around the Sun* (Washington, D.C., 1898), 9-10, p. 9.
36. For example, Joseph Scaliger uses "anni Liliani" in his criticism of the Gregorian reform which he appended to his commentary of the *Canon pascalis* of Hippolytus (Leiden, 1595), 34-78. David Origanus in his *Ephemerides novae motuum coelestium Brandenburgicae, ab anno 1595 ad annum 1630 productae* (Frankfurt am Main, 1599) gives the Golden Number, cycle of Indiction, etc. in both the Julian and "Lilian" calendars for the year 1601, as well as for other years.
37. Salon also claims that Lilius followed the length of the Alfonsine year in constructing his intercalary plan; he states: "Aloisius Lilius Medicus exellentiss. & Mathematicus haud vulgaris Alfonsum Regem in anni quantitate imitatus; Cyclum magnum 400. annorum excogitauit, in quibus 400 annis dimitterentur tres bissexti, ita quod unius bissexti omissio 133 annis responderet". Salon, *op. cit.* (ref. 13), 16.
38. E. Reinhold, *Prutenicae tabulae coelestium motuum* (Tübingen, 1551).

39. Clavius, *op. cit.* (ref. 4), repr. in *op. cit.* (ref. 25), v. 65. Clavius writes: "Annus autem Solaris verus, quem Tropicum vocant, tantus non est, sed aliquot horae minutis minor, cōpletēs secūdū Tabulas Alphōsi Hispaniae Regis dies 365. & horas tantū 5. min. 49. sec., 16. quae quidē anni magnitudo media quadammodo est inter maximam, & miniā anni magnitudinē". Clavius repeats verbatim from his apology to Maestlin, *op. cit.* (ref. 24), 21.

40. Petrus Pitatus of Verona proposed a mathematically identical plan in his *Compendium... super annua solaris, atque lunaris anni quantitate,... calendarij instauratione,...* (Verona, 1560), 4v-5. He would, however, have begun the omission of the bissextile day in 1600, so that 1600, 1700, and 1800 would have been common years and 1900 would have been an intercalary year. An important unanswered question is whether Lilius borrowed from Pitatus.

41. Clavius, *op. cit.* (ref. 4), repr. in *op. cit.* (ref. 25), v, 70.

42. *Op. cit.* (ref. 19), [4]. "Proponit enim sibi anni Alfonsini mensuram, quę inter uarias media est, atque ideo errori minus obnoxia...".

43. *Ibid.*

44. Clavius, *op. cit.* (ref. 24), 22.

45. New Moons reckoned by the cycle of epacts often deviate from the astronomical new Moons by one or two days.

46. A term commonly used to refer to the simple alphabetical scheme used in designating lines of epacts within the tables. Chacon merely refers to it as "literam".

47. *Op. cit.* (ref. 19), [13].

48. For an explanation of the Table of Epacts and Clavius's adjustments see Alexander Philip, *The calendar: its history, structure and improvement* (Cambridge, 1921), chap. 15, 61-82. See also J. Mayr, "Das Kunstwerk des Lilius", *Astronomische Nachrichten*, ccxlvii (1933), 429-44.

49. *Op. cit.* (ref. 19), [17].

50. *Ibid.*

51. Kaltenbrunner, *op. cit.* (ref. 8).

52. Abraham Gotthelf Kästner, *Geschichte der Mathematik*, ii (Göttingen, 1797; repr. Hildesheim, 1970), 475. The title of the *Compendium* as given by Clavius (see ref. 7) is *Compendium novae rationis restituendi Calendarium à Gregorio XIII. Pontifice Maximo ad Principes Christianos, et celeberrimas quasq. Academias missum anno Domini 1577.*

53. J. Schmid, "Die der Reform vorausgehenden und unmittelbar folgenden wissenschaftlichen Arbeiten", *Historisches Jahrbuch der Görres-Gesellschaft*, iii (1882), 388-415; "Verhandlungen über die Annahme der Reform durch die orientalischen Kirchen", *ibid.*, 543-95; and "Nachträge", *ibid.*, v (1884), 52-87.

54. For example, I.G. Hagen, S.J., published a comprehensive account of the reform, but was apparently unaware that the *Compendium* was printed twenty-six years before it appeared in Clavius' *Explicatio*. He only mentions that the *Compendium* was "printed by Clavius". See I.G. Hagen, "Die Gregorianische Kalenderreform", *Stimmen aus Maria-Laach*, lxxxvii (1914), 41-51, p. 48. The Leiden scholar W.E. van Wijk in his *De Gregoriaansche kalender: een technisch-tijdrekenkundige studie* (Maastricht, 1932), 24, states that Lilius' work "in the adaptation of Ciaccone [Chacon], was sent out to the princes of Christendom and to each of the renowned universities, probably as a manuscript. It was later printed among other things for the Explicatio of Clavius." J. de Kort, S.J., in his "Astronomical appreciation of the Gregorian calendar", *Ricerche astronomiche*, ii (1949), 109-16, p. 109, n. 1 cites the *Compendium* only in Clavius. Lastly, Noel Swerdlow in his "The origin of the Gregorian civil calendar", *Journal for*

the history of astronomy, v (1974), 48-49, p. 48, mistakenly states that "neither the treatise nor Lilius' original work on the calendar was ever printed, and both have apparently been lost." In citing the *Compendium* in J.C. Houzeau and A. Lancaster, *Bibliographie générale de l'astronomie*, i, part 2 (Brussels, 1889), p. 1458, § 13759, which lists it as a rare quarto volume by "L. Lilius" published in Rome in 1577, Swerdlow concludes, "There is, to my knowledge, no such edition. It is, however, not impossible that the *Compendium* survives still undiscovered in manuscript." See *ibid.*, 49, n. 2.

55. P. Riccardi, *Biblioteca matematica Italiana*, i (Milan, 1952), col. 41.

56. *Ibid.* Riccardi may have examined the copy I have found in the Biblioteca Nazionale Centrale in Florence, which contains the signature "C". The copy I discovered in the Biblioteca Comunale degli Intronati di Siena is without this signature.

57. See ref. 4.

THE VATICAN TOWER OF THE WINDS AND THE CALENDAR REFORM

JUAN CASANOVAS S.J., Specola Vaticana

Introduction

In the years previous to the reform of the calendar, Pope Gregory XIII ordered his palace architect Ottaviano Mascherino to build what is now called the Galleria delle Carte Geografiche in the Western side of the Corridoio del Belvedere.[1] Its name derives from its forty large geographical wall paintings, which were done under the direction of the Dominican Father Ignazio Danti. He had been called to Rome in 1580, from his professorship of mathematics at the University of Bologna. A man of great activity, he had acquired a well deserved reputation both as a cosmographer and as an artist. He had drawn the geographical charts of the cloakroom of the Grand Duke Cosimo I de' Medici in Florence, and also a wall map in Perugia. His work done in Rome, now part of the Vatican Museum, constitutes a monument to the Italian cosmography of the XVI century.

At the Northern side of that gallery Ottavio Mascherino also built a tower 73 m high. Since it was built between 1578 and 1580 before Danti came to Rome, most probably Mascherino did not forsee its future use. As an extension of the Gallery, the tower was given also to Ignazio Danti for decoration.

The Tower of the Winds and the Danti's Anemoscope

The plan proposed by Danti was to install one of his anemoscopes which he had successfully built in Florence and Bologna, and to decorate the interior with wall paintings. The winds and their respective qualities were to provide the themes for his pictorial compositions. The name "Tower of the Winds", of course, tells us clearly what the artist's principal intention was. In his treatise on anemography,[2] printed while he was still in Bologna, Danti has as the frontispiece a drawing of the octogonal tower and of the anemoscope that Andronikos of Kyrrhos built in Athens about the year 50 B.C. and he refers explicitly to it in the prologue.

The Vatican anemoscope consisted in a weathervane on the roof which, through a mechanism of iron rods and gears, pointed an arrow to the corresponding wind direction on the ceiling of the main room of the tower. Danti left to the Vatican Library a manuscript[3] which contains a treatise on the winds, their various names in different languages, their characteristics, etc., and also a description of the anemoscope, accompanied by drawings of the mechanism he used. Besides this, the manuscript contains an authoritative interpretation of the wall paintings and decorations which adorn the main room of the tower. See a study by Stein for their complete description.[4] Unfortunately by the end of the XVIII century the anemoscope, rusted and useless, had already been removed.[5] Only the arrow in the interior survives. The restoration of the whole tower and of the wall paintings has just recently been completed.[6]

The anemoscope, however, has practically been forgotten by tradition, which has named the main room not after the anemoscope but after the meridian line on the floor, also a work of Danti. Tradition also claims that astronomical observations were made there for the determination of the duration of the tropical year and that the effective ten-day drift of the equinox from the 21 March was observed there; these would thus have been measurements made for the reform of the calendar decreed by Pope Gregory XIII in 1582. In this connection, it is often maintained that this work constitutes the beginning of the Vatican Observatory or Specola Vaticana. We intend to discuss in this paper to what extent these assertions are true.

The Tower of the Winds and Early Astronomical Observations

There are many documents which attest to this tradition. We present the following of special significance. Pope Clement XI, in an encyclical letter addressed to various European universities in 1703, wrote:[7]

> « The large instruments for observing the sun which Gregory XIII ordered built by mathematicians of his time, especially by Fr. Ignazio

> Danti in Rome, Florence and Bologna... those instruments big and perfect, show with evidence that the equinox coincides with provisions of the Gregorian reform... ».

At the end of the XVIII century, the tower was used by Mons. Filippo Gilio, who installed meteorological and geophysical instruments and did astronomical observations for about 20 years. During this time a lapidary inscription was placed on the tower:[8]

> « Pius VII having embellished and enlarged the observing tower in which the meetings of famous mathematicians for the Gregorian calendar took place... ».

Finally, in 1890 when Pope Leo XIII signed the "motu proprio" founding the actual Specola Vaticana it is explicitly stated:[9]

> « With how much diligence, constancy and liberality Gregory XIII carried out the business (of calendar reform) can be ascertained from faithful historical monuments. In the part of the Vatican buildings which seemed more suitable for it, he ordered constructed an observing tower, which he equiped with the instruments of his time large and accurate, and where the learned men who were given the task of restoring the calendar met. The tower still remains and within is the meridian line made by Ignazio Danti, as well as the round marble table placed across the line on which there are skillfully engraved marks which, when struck by a beam of sun light coming from above, show that there was need for emendation of the old time reckoning and that the reform is in accordance with natural course of things ».

The tower was built in about 1580, but the paintings and the instruments (the anemoscope and the meridian) were not finished until 1582. In order to settle once and for all the question about the astronomical observations supposedly done there in connection with the reform of the calendar, it may suffice to remark that the "Compendium" of the new calendar which except for minor details was formally later approved had already been sent to the universities and European governments for examination in 1577. That year is well before the workmen started the construction of the tower, and, when in 1580 the pontifical commission for the calendar reform presented its final report, Danti and his painters were just beginning their work. If any such astronomical observations were make there they came too late. Furthermore it is clear that no new astronomical observations were required for the new calendar, since the available astronomical tables of that time already provided enough data.

As a matter of fact Ignazio Danti arrived in Rome early in 1580 and joined the pontifical commission for the reform of the calendar only in the final stages of its work.

However, even though the meridian in the Tower of the Winds was not actually used for the preparation of the Gregorian calendar, it is perhaps true that Ignazio Danti wanted to reproduce in Rome the meridian or gnomon he had developed in Florence and in Bologna, with the explicit intention of measuring the length of the tropical year and determining the equinox, as a contribution to the reordering the calendar.

Ignazio Danti's Astronomical Instruments in Florence and Bologna

Ignazio Danti was born in Perugia in 1536.[10] He learned astronomy and cosmography at Rome. In his preface to the Sphaera of J. de Sacrobosco, translated into Italian by his grandfather, he relates how he received lessons from his father and his aunt.[11] He joined the Dominican order early, having been allowed to pursue his favorite studies.

Danti was called to Florence perhaps as early as 1562, and appointed by the Grand Duke Cosimo I de' Medici as a cosmographer. He probably had been presented to the court by his brother Vincenzo, who was working there as sculptor. He was soon commissioned to ornament the Grand Duke's "cloakroom" with the geographical charts still to be admired in Florence.[12] In all his pictorial projects, Danti was not the actual painter, but had overall responsibility and was credited with the original drawings and the disposition of the maps. Danti further increased his fame by making a big geographical globe and an astrolabe. In 1571 his residence was moved to the Grand Duke's palace, and provision was made for him to teach mathematics, the position later on given to Galileo.

Danti's activity was divided between teaching and writing books. From that time come his famous publications like his "Trattato dell'uso et della fabbrica dell'astrolabio" (Firenze 1569), to which he added in his second edition of 1578 a description of old astronomical instruments. In 1573 he published Euclid's Optics, translated from Greek into Italian with commentaries, and also a translation of Proclus' "Sphaera".

Those were the years when many projects for a calendar reform were being publicized and Ignazio Danti decided to get Cosimo interested in them and in providing funds for the construction of instruments for measuring some parameters of the year. His first attemps were modest. In 1572 at the façade of the church of Santa Maria Novella he constructed a reproduction of a "plinth" with which he determined the obliquity of the ecliptic.[13, 14] Later in 1574 he installed in the façade of the same church a bronze equatorial ring in order to determine the equinox.[15] The plinth and the equatorial ring can still be seen in their original places, with an inscription giving the date of installation and describing the observations made with them.

He must have soon realized that the accuracy to be obtained with such instruments could not be of much help in a precise determination of the tropical year. Their popular impact, however, must have been great, since Danti used to gather his students and the young noblemen at Santa Maria Novella for the observation of the equinox.

A more serious project developed in his mind. At the Florentine cathedral of Santa Maria dei Fiori around 1460, Paolo Toscanella used Brunelleschi's dome as a huge gnomon. Instead of using the shade of a pole or of an obelisk, he let the sun shine through a hole in the lantern of the dome which was at a height of 80 m. At the summer solstice the spot of light on the floor of the church was indicated with marks on a marble slab. A full description of this gnomen has been given by Ximenes.[16] It seems that the summer solstice was observed regularly also in order to check the stability of the dome, and each observation was registered. Danti realized that the summer solstice is not the best for the determination of the length of the year, and, since the enormous height of the dome impeded the observation of the equinoxes, he decided to move back to Santa Maria Novella, where he built two gnomons, the first made of an entrance hole in the façade and the second much higher up in the transept of the church.[17] However, Danti had no opportunity to make good use of those gnomons. For reasons not clear to his biographers, in 1575, after the death of his protector Cosimo I, his successor Francesco ordered him to leave Tuscany within twenty-four hours.[18]

Fortunately for Danti, he was appointed professor of mathematics at the University of Bologna the next year in September. His teaching is summarized in his "Le scienze matematiche ridotte in tavole" (Bologna, 1577).[19] He immediately built a new gnomon at the church of San Petronio, since in his manual for the use of his gnomon [20] he mentions an observation made with it already in 1576 during the winter solstice. Nothing remains of this early gnomon in San Petronio. The hole for the sunbeam was made in a temporary wall, later taken down. Riccioli in his "Astronomia Reformata" [21] gives a description of this early gnomon, later replaced by the monumental one built by Giovanni Domenico Cassini. As Riccioli states, the orientation of the church and the unfavorable arrangements of the columns did not allow Danti to draw a line on the floor parallel to the meridian, but rather at an angle to it. Ignazio Danti left a printed sheet, a sort of a manual on how to use the gnomon. Among other things he gives a short note on the calendar and the need to know accurately the duration of the tropical year. It is interesting that Danti refers to the Copernican statement of the inequality of tropical years, and he says that the measurements done with the large gnomon could help discover the truth in the dispute between the Alfonsines and the Prutenics. Danti adjoins a list of possible observations which could be done with the gnomon, like, for instance, the measurement of the solar and lunar diameters, the motion of the apogee, etc. A full program is proposed, which was performed later by Cassini.[22]

In these gnomons, built by Danti and inspired by the gnomon of Toscanella, it is evident that use is made of the principle of the "camera obscura". A remarkable gain in accuracy is obtained in comparison to the ones which use the shade of an obelisk. In his small treatise on Hipparchus' Diopter,[23] Danti refers explicitly to Reinhold,[24] who in his comments to the "Theoreticae Planetarum" proposed observing eclipses from inside a dark room by letting the light rays of the sun or the moon pass through a hole on the wall and form an image on a screen. Furthermore, in his commentaries on his translation into Italian of Euclid's Optics,[25] Danti explains with profusion how to get an inverted image of an external object on to a screen inside a dark room, illustrating his treatment with drawings. He even presents a method to right the image using mirrors. In this same commentary, Danti refers to the story about someone who tried to make the spot of light in the Toscanella's gnomon smaller by making the entrance hole smaller, with the result that the spot looked larger. This could be interpreted, as a better definition of the sun's image giving the feeling of its being larger. Also a square hole had been tried with the more surprising result of the same elliptical spot. However, the name of Giambattista della Porta, who a few years earlier had described the use of the "camera obscura" in his book "Magia Naturalis" [26] is not found in Danti's writings. Probably he knew about it, but the experiments with Toscanella's gnomon just mentioned and particularly his explicit reference to Reinhold suggest a development independent from della Porta, at least as regards to his gnomons.

As for their intended use, Danti never had the opportunity to obtain a value of the tropical year better and more secure than that given by contemporary astronomical tables. Good observations repeated during many consecutive years were required for that. He never had the opportunity of making those. He left Florence before his big gnomon was finished, and only one observation of a winter solstice done at San Petronio is recorded. The same can be said of the gnomon built in the Tower of the Winds in the Vatican.

Danti's Gnomon in the Tower of the Winds

In 1577 Danti visited his home town Perugia, and was asked to survey the county, which he did in twenty days. Afterwards at the governor's palace he painted on the wall a map incorporating all his measurements, drawings of towns and any information he had gathered in his field survey. The governor of the Pontifical States visiting Perugia was so impressed with Danti's work that he proposed him for the commission of surveying the Pontifical States, which he did during 1578 and 1579.[27] Afterwards he was called to Rome to take charge of the decoration of the Galleria del Belvedere, where he put into the wall paintings not only information about the Pontifical States which he himself had surveyed but he also included information about the rest of Italy.

Danti was appointed Pontifical Cosmographer and a member of the commission which at the time was already examining the responses to the "Compendium" sent to Rome and preparing the final report. Therefore, Danti from 1580 to the end of 1582 had to prepare the drawings for the forty large maps the painters were executing in the Galleria del Belvedere. A part of this project was, of course, the decoration of the tower which Mascherino had built as an extension of the Galleria. He built his anemometer for the tower, as we have seen, and also his gnomon, which is of a reduced height of only 5.19 m. It was checked for accuracy by Calandrelli in 1842 [28] and later by Stein [29] who confirmed a deviation of the meridian line by an angle of 1.2° and an error of 7.5 cm in the marking of the equinox, corresponding to an anticipation of the vernal equinox by one day.

As was said before, Danti never had the opportunity of scientifically exploiting his gnomons. The same happened with the gnomon in the Tower of the Winds. It was finished in 1582, but in 1583 Danti was appointed bishop of Alatri, about 100 km south of Rome, and he died there in 1586.

Any possible determinations of the length of the tropical year supposedly done with Danti's gnomon for the reform of the calendar would have come too late. Nevertheless, considering the great reputation and popularity of Ignazio Danti after the execution of his much admired geographical charts in the Corridoio del Belvedere, his previous work in Florence and his professorship in Bologna, it is conceivable that some observations of the equinox took place at the Tower in the presence of church dignataries, perhaps even of Pope Gregory himself. The need for a reform of the calendar could then be dramatically shown. The magnificent wall paintings with allegories about the various winds, and his anemometer would have been added motives for a visit to the tower.

After Danti left Rome, the tower was used for various purposes, even for the accomodation of special guests to the Vatican. Astronomical observations were done at the end of the XVIII century when Mons. Filippo Gilio was engaged in meteorological and astronomical research there for about twenty years.[30] His new meridian and a sundial can still be seen. After this short period of scientific activity, the tower was again used alternately to accommodate offices and guests until 1890 when Pope Leo XIII founded the actual Specola Vaticana. For about 15 years various instruments were installed there, until the Specola moved to the Vatican Gardens occupying the Leonine tower, now the offices of the Vatican Radio. Finally in 1932 the transfer of the Specola Vaticana to Castel Gandolfo was begun.

Conclusion

The Tower of the Winds has remained a monument of the years of the calendar reform. Whether Ignazio Danti intended to place a gnomon and a meridian line there, as a memorial of the great achievement of Pope Gregory XIII in carrying out what many of his predecessors were not able to do, is not clear. As a matter of fact all the paintings and decorations in what is now called the "meridian room" refer to the winds and the weather, but none to astronomy and to the calendar reform. But tradition has forgotten the anemometer and spoken of the Tower of the Winds as the early Vatican astronomical observatory.

The gnomons as developed by Ignazio Danti, that is making use of the "camera obscura" effect, became very popular in Italy for astronomical observing. It will suffice to mention the work of Cassini in Bologna. Later they were used mainly for the accurate determination of the sun's transit across the local meridian infact. The name meridian was introduced at that time. In early literature only the name "gnomon" is found, indicating its intended use for astronomical observations.

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V.

THE DECREE OF 1582

THE PAPAL BULL OF 1582 PROMULGATING A REFORM OF THE CALENDAR

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Introduction

Between the 4th and 15th of October, 1582 Pope Gregory XIII introduced the new calendar by the apostolic letter *Inter gravissimas*, dated 24 February, 1582. In this paper I would like to address the following questions concerning this letter. What authority had this letter? Who had constructed the new calendar? What were the contents of the calendar reform? How was it promulgated and published? How should we evaluate it in a religious and ecumenical perspective?

The Authority behind the Decree

The decree of 1582 was issued with papal authority. It is written in the form of an apostolic letter or papal bull, as an ecclesiastical law.

The Pope under whose authority the calendar reform was instituted, was Gregory XIII (1502-1585). Born in Bologna in 1502 of a noble family, Ugo Buoncompagni studied law and became lecturer and judge in his native town. In 1539 he moved to Rome and among other tasks he was sent to the Council of Trent both in 1549 and during its last year 1562-1563. He was ordained a priest and became bishop of Veste; on 12 March, 1565 he was elected Cardinal and sent to Spain as *legatus a latere.* In 1572 he was elected Pope. Pope Gregory was 75 years old when he sent to all Catholic princes his proposal for the reform of the calendar, the *Compendium novae rationis restituendi Kalendarium*, (Compendium of a

New Way of Restoring the Calendar) in 1577. When in 1582 he signed the apostolic letter *Inter gravissimas* he was 80 years old but still in the best of health. Pope Gregory was so happy for the achievement of his calendar reform and so grateful to God that ever since that date he had the Litanies said every day in his palace with the assistance of all employees.[1]

From the very start of the apostolic letter Pope Gregory appeals to the authority of the Council of Trent. The first words "Inter gravissimas" mean "among the most serious" and the first sentence reads:

> Among the most serious tasks, last perhaps but not least of those which in our pastoral duty we must attend to, is to complete with the help of God what the Council of Trent has reserved to the Apostolic See.

At the last session of the Council of Trent, on 4 December, 1563 the last decree left it to the Pope to finish and publish what had been prepared by the Fathers of the Council for the reform of the Mass book and the breviary because time had run out for them.[2] Pope Pius IV could not fulfill this task before his death in 1566, but his successor the holy Pope Pius V († 1572) promulgated a reformed breviary in 1568 [3] and a reformed Roman Mass book in 1570. The breviary incorporated also a provisional calendar reform. The calendar's indications of the new moons were moved by four days back to the time when the moon was really in conjunction with the sun. New discrepancies were to be prevented by an additional leap day every 300 years, from 1800 onwards. This awkward reform seems to have had little effect. Ten years later, in 1578, Pietro Galesino published in Milan a new martyrology on the authority of Pope Gregory XIII. It followed the old, traditional calculation of the new moon's age. Juan Salón criticized the corrected cycle.[4] In 1579 Giuntini [5] referred briefly to this measure of Pope Pius V.

The Commission for the Reform of the Calendar

The decree of the Council does not say a word on calendar reform but only speaks of a reform of the Mass book and the breviary, so the calendar reform undertaken by the Pope can only be said to be implied by the decree of the Council. According to the letter of the decree Pope Pius V executed the decree in his reform of the Mass book and breviary. But as the *Compendium* says: The work of Pope Pius V was not entirely complete and perfect, as long as the year and the calendar of

CALENDARIVM GREGORIANVM PERPETVVM.

Orbi Christiano vniuerso à GREGORIO XIII. P. M. propositum. Anno M. D. LXXXII.

GREGORIVS EPISCOPVS

SERVVS SERVORVM DEI

AD PERPETVAM REI MEMORIAM.

INTER grauissimas Pastoralis officij nostri curas, ea postrema non est, vt quæ à sacro Tridentino Concilio Sedi Apostolicæ reseruata sunt, illa ad finem optatum, Deo adiutore perducantur. Sane eiusdem Concilij Patres, cum ad reliquam cogitationem Breuiarij quoque curam adiungerent, tempore tamen exclusi rem totam ex ipsius Concilij decreto ad auctoritatem & iudicium Romani Pontificis retulerunt. Duo autem Breuiario præcipue continentur; quorum vnum preces, laudesque diuinas festis, profestisque diebus persoluendas complectitur, alterum pertinet ad annuos Paschæ, festorumque ex eo pendentium recursus, Solis, & Lunæ motu metiendos: Atque illud quidem felicis recordationis Pius V prædecessor noster absoluendum curauit, atque edidit. Hoc vero, quod nimirum exigit legitimam Calendarij restitutionem, iamdiu à Romanis Pontificibus prædecessoribus nostris, & sæpius tentatum est, verum absolui, & ad exitum perduci ad hoc vsque tempus non potuit, quod rationes emendandi Calendarij, quæ à cælestium motuum peritis proponebantur, propter magnas, & fere inextricabiles difficultates, quas huiusmodi emendatio semper habuit, neque perennes erant, neque antiquos Ecclesiasticos ritus incolumes (quod in primis hac in re curandum erat) seruabant. Dum itaque nos quoque credita nobis, licet indignis, à Deo dispensatione freti, in hac cogitatione, curaque versaremur, allatus est nobis liber à dilecto filio Antonio Lilio artium, & medicinæ doctore, quem quondam Aloysius eius germanus frater conscripserat, in quo per nouum quendam Epactarum Cyclum ab eo excogitatum, & ad certam ipsius aurei numeri normam directum, atque ad quamcunque anni solaris magnitudinem accommodatum, omnia, quæ in Calendario collapsa sunt, constanti ratione, & seculis omnibus duratura, sic restitui posse ostendit, vt Calendarium ipsum nulli vnquam mutationi in posterum expositum esse videatur. Nouam hanc restituendi Calendarij rationem exiguo volumine comprehensam ad Christianos Principes, celebrioresque vniuersitates paucos ante annos misimus, vt res, quæ omnium communis est, communi etiam omnium consilio perficeretur; illi cum, quæ maxime optabamus, concordes respondissent, eorum nos omnium consensione adducti, viros ad Calendarij emendationem adhibuimus in alma Vrbe harum rerum peritissimos, quos longe ante ex primarijs Christiani orbis nationibus delegeramus: Ii cum multum temporis, & diligentiæ ad eam lucubrationem adhibuissent, & Cyclos tam veterum, quam recentiorum vndique conquisitos, ac diligentissime perpensos inter se contulissent, suo, & doctorum hominum, qui de ea rescripserunt, iudicio hunc præ cæteris elegerunt Epactarum Cyclum, cui nonnulla etiam adiecerunt, quæ ex accurata circumspectione visa sunt ad Calendarij perfectionem maxime pertinere.

FIG. 1. The first page of the decree *Inter Gravissimas* as it appears in Tome V of the *Opera Mathematicorum* of Christoph Clavius. Courtesy of the Library of the Jesuit Curia, Rome.

the Church were not corrected. So the successor to Pope Pius V, Gregory XIII, had to assume that the task imposed by the Council had yet to be fulfilled. And certainly, the call for reform put forth both in previous Councils and at other occasions included the request for a correction of the calendar. So Pope Gregory knew that he was supported by a strong and long consensus within Western Christianity when he started work on the reform of the calendar.

To this purpose he nominated a commission, called *congregatio* according to Roman usage. The date of its origin is not known. Christoph Clavius, one of the most assiduous members of the commission, said in 1603 that for a period of ten years the commission held meetings in Rome under the authority of the Pope.[6] In 1585 some members of the commission addressed themselves to the Pope while its president Cardinal Sirleto was ill. That same year both Pope Gregory and Sirleto died. We may take this as the end of the activity of the commission.[7] Thus it would have originated in 1575. However, if we take 1582 as the final year, then the commission would have originated about 1572. Indeed, the protonotarius Spetianus said in 1581 that Cardinal Sirleto had occupied himself with the problem for ten years.[8] In the *Explicatio* [9] Clavius said that no better way of correcting the calendar than the Gregorian reform had occurred to any of those who had collaborated in it, not even after a long research during about ten years.[10]

The Spanish Franciscan Juan Salón, published in 1576 a book on *The Emendation of the Roman Calendar and the Determination of the Pascal Solemnity*.[11] In the preface he urges the Pope and the cardinals to act because the intentions of the Council of Trent were not yet carried out. He then mentions his intervention with the Bishop of Sora, president of the "Congregation on the Determination of the Mobile Feasts" (*Congregationis Super Reductionem Festorum Mobilium*); this intervention took place in the year before, in the jubilee year 1575. In August 1576 Giovanni Padovani published in Italian a work on the "Reform of the Year".[12] In the dedication to Agostino Valerio, Bishop of Verona, he requests him to give notice of this book to the Holy Father "who for many reasons which will be given hereafter has to apply all diligence in making this reform soon". In 1577 Padovani published a booklet on Computus [13] and in the dedication to Bishop Valerio he mentions that the Pope is said to have undertaken the reform. But he has also heard that it proceeds very slowly because the very learned consultors could not agree on the fundamentals;

everyone attacked the opinion of the others and defended his own, so no hope existed for a mature result.

What proposals did the commission have at its disposal from which to choose? In addition to several proposals prior to the Council of Trent some new ones had arisen.

In 1576 Juan Salón published his proposal in the book mentioned above. He wished to change the vernal equinox to 24 or 25, not 21 March. After each cycle of 124 years the golden number would be adjusted to the anticipated equinox and at times also to the anticipated new moons. He has also described this proposal in manuscripts.[14] Also in Salón's hand are two other handwritten proposals.[15] The first one was written in 1577 [16] at the order of Cardinal Sirleto, who was then president of the commission.[17] The second manuscript is based on mean motions of the moon and proposes that a leap day be omitted every 100 or 104 years and that the golden number then be corrected.[18] Finally, Salón refers to his book in a short, handwritten memorial [19] proposing that a leap day be omitted every 124 years.

"From the beginning of his pontificate" Pope Gregory XIII, urged on by Cardinal Benedict Lamellini, had commissioned Tommaso Gigli to have another book on the correction of the Roman calendar and the mobile feasts evaluated by experts mathematicians in Rome.[20] Tommaso Gigli, Bishop of Sora, from Calabria, was the Pope's treasurer. The book in question was composed by Luigi Giglio, physician and mathematician. Giulio Aromolo [21] has written the biography of this doctor from Calabria who was to become the primary author of the calendar reform. Luigi Giglio, or Aluise Baldassar Lilio, was born in Cirò in Calabria about 1510 in a family of modest means. He studied medicine and also astronomy in Naples;[22] he settled in Verona [23] and died in 1576. Although he was alive at the time his proposal was presented in Rome, it does not seem that he made the presentation. His brother Antonio, also a physician and astronomer, promoted his cause. In 1575 Bishop Tommaso Gigli asked Salón to give his opinion on the proposal of Giglio. Salón says that initially he was well disposed towards the invention of Giglio but changed his mind when others made objections.[24] Giglio had proposed a cycle of epacts. The epact of the year is the age of the moon at the start of the year. The term *epact* had been in use before Giglio; his invention was the insertion of epacts in the perpetual calendar in combination with the table of epacts and the table of adjustments, as will be explained later. Salón rejected the epact cycle for three reasons: 1) it would not last long unless it were frequently adjusted; 2) it is hardly intelligible for the more simple-minded who make up the large majority of clerics;[25] 3) merely because of its novelty it will not please. In the same year, 1575, the learned Archbishop of Patras, Alessandro Piccolomini, came to Rome [26] and he had several discussions with Antonio Giglio, the brother of Luigi, as well as with his collaborators in the composition of the proposal. Piccolomini also read Giglio's book at the suggestion of Tommaso Gigli, the president of the commission, but he did so quickly. Although Antonio Gigli explained and defended his brother's proposal in friendly conversations, Piccolomini was not convinced, or rather he admitted that he did not grasp well Giglio's epact cycle and so he also concluded that it was too difficult for clerics.[27]

Another expert consulted by Tommaso Gigli was Giovanni Carlo Ottavio Lauro, a scientist in Rome. He kept Giglio's work for three months and used it in preparing his own proposal for the reform. In the meantime mathematicians and other experts, gathered under the presidency of Tommaso Gigli, had repeatedly testified their approval of Giglio's work, even when the president urged them to write down the very smallest defects in this proposal. On the other hand they rejected Lauro's work as incorrect and useless. Once again for "many months" Lauro kept Giglio's book under pretext of correcting the errors. The result was again submitted to the judgement of the experts and found to be an incorrect and misunderstood application of Giglio's inventions. On the contrary the experts maintained that the proposal of Giglio was the best of all, even the best possible.

At this moment the experts lost their patience and addressed themselves directly to the Pope; they asked that the reform be expedited notwithstanding the "chimeras" of Lauro, whom they mention, under the name of Giovanni Carlo, as an astrologer (*astrologo giuditiario*). The copy of this memorial in the Vatican Library [28] has no date or signature. The handwriting might be that of Christoph Clavius, Jesuit and professor of mathematics at the Collegio Romano; the spirit is certainly his. On 30 July, 1575 Lauro was paid for his work on the calendar reform.[29] Lauro's manuscript, composed in 1575, is preserved at the Vatican Library.[30] It avoided mentioning epacts and kept to golden numbers, but instead of one perpetual calendar (with epacts) Lauro constructed a table with virtually thirty calendars — that is, thirty different distributions of golden numbers over the days of the year instead of the old calendar with only one distribution of golden numbers. It is in principle a viable solution. The disadvantages are the abandonment of the perpetual calendar and the lack of a clear derivation of the distribution of golden numbers; the user has to take them from Lauro's table without sufficient explanation of how the golden numbers change every century. Later, in his explanation of the Gregorian reform, Clavius rejected a solution without epacts because using thirty calendars would be too cumbersome.[31] Giovanni Battista Gabio, Professor of Greek at the Pontifical University, La Sapienza, was also asked to give his opinion on Giglio's proposal. Gabio praised it but found that the booklet of Lauro should not be rejected.[32] Gabio had honoured Lauro with a Greek poem of six lines in his booklet on the calendar reform.[33]

The above discussion proves that the proposal of the brothers Giglio reached the commission in 1575, shortly before the death of Luigi Giglio in 1576, and that, although it was received with doubts and some resistance,[34] in some way it triggered serious work on the reform. As to the resistance to the proposal of the brothers Giglio we have more evidence in another memorial addressed to the Pope. It warns that the calendar to be sent out to the princes has not been approved by mathematicians in Rome, as the Pope has been told, but by the authors and other interested persons. It asks for a closer examination with the intervention of Cardinal Sirleto and Monsignore Seraffino (= Séraphim Olivier) and disinterested theologians and mathematicians.[35] Indeed, at some moment Cardinal Guglielmo Sirleto replaced Tommaso Gigli as president of the commission. As of 1577, there is noted on all documents on the calendar reform addressed to the Pope: "al card.le Sirleto".[36] The promotion of Gigli to the bishopric of Piacenza, on 12 November, 1576 [37] may indicate the approximate date of the change of presidents. As late as 9 September, 1577 Gigli wrote from Piacenza to Sirleto to ask if the reform plan by Giovanni Carlo had been printed with some points corrected.[38] Gigli died in 1578.

It was the able leadership of Sirleto, and not primarily the presentation of Luigi Giglio's project by his brother Antonio, that rescued the commission, if indeed it was Sirleto who definitely decided to accept Giglio's proposal after the hesitations of his predecessor. Guglielmo Sirleto (1514-1585), born in Guardavalle near Stilo in Calabria, was nominated Cardinal by Pope Pius IV in 1565.[39] He was a great scholar, and particularly a hellenist. He had been a serious candidate at the conclaves which elected Pius V and Gregory XIII. He had taken an active part in the reform of the Roman breviary and missal under Pope Pius V.[40] Other members of the commission cannot be identified at this first stage but several of them may be on the list of members which we will find in 1580, and a few will be identified as members as early as 1577.

Finally the invention of Luigi Giglio triumphed over all objections and rivals. On 5 January, 1578 [41] Pope Gregory sent it out to the scientific world in the form of a compendium. The author of the compendium is a theologian from Toledo, Pedro Chacón (1526/7-1581), in Italy called Pietro Ciaconio,[42] clearly at that time already a member of the commission. He died on 26 October, 1581.[43] There are some thoughts for the covering letter to the Roman Emperor [44] from the hand of Cardinal Sirleto. The final letter has been printed [45] and is dated 11 January, 1578.

When Christoph Clavius, the Jesuit professor of mathematics at the Collegio Romano, a German from Bamberg in Bavaria, speaks about the preparation of the compendium in his *Explicatio*, published in 1603, he says "we", indicating that he worked on the commission as early as 1577.[46] Clavius was certainly a hearty supporter of the invention of Luigi Giglio, whom he recognizes as the principal author of the Gregorian reform.[47]

> We owe much gratitude and praise to Luigi Giglio who contrived such an ingenious Cycle of Epacts which, inserted in the calendar, always shows the new moon and so can be easily adapted to any length of the year, if only at the right moments the due adjustment is applied.

The Compendium of 1577

The *Compendium* addresses itself to "peritis mathematicis", expert mathematicians, and was sent to them through the "Christian princes" and the universities. Among these Christian princes were reckoned only Roman Catholic princes; at least, there is no trace of the *Compendium* having been received by other Christian, not Roman Catholic princes. It was sent as a printed booklet of twenty pages in quarto.[48] The text has been faithfully reprinted in Christoph Clavius' *Romani Calendarii... Explicatio*, Rome 1603 and Mainz 1612, with the exception of the severe prohibition by the Pope, formulated by Cardinal Sirleto, to reprint the *Compendium.* According to the preface the book of Luigi Giglio had been offered to the Pope but not yet printed; however, for mathematicians the compendium would suffice.

The substance of the proposal by Giglio is that it is no longer the golden number which determines the Easter date but the epact of the year. This is the age of the moon at the beginning of the year and also the number of days left in the preceding year after the last completed lunation. This number was, up to then, adequately and uniquely determined by the golden number. For example when the golden number was 7, the epact of the year was always XIV and this, together with the Sunday letter, fixes the date of Easter. However, in the course of time the golden number had become unreliable as an indicator of the epact. When the golden number was 7, for example, the epact of the year was, in reality, not XIV but XVIII in the days of Pope Gregory. Therefore Giglio took the step of breaking the unequivocal link between epacts and golden numbers. To a given golden number may hereafter, in the course of the centuries, be joined any epact, any of the thirty possible epacts; therefore Giglio composed a table, the expanded table of epacts with the 19 golden numbers on top and underneath thirty rows of possible epacts to each golden number. See Table I on pages 212-213, the one finally adopted by the commission. This is the essence of Giglio's proposal. Its immediate consequence is that in the perpetual calendar to each date is assigned not a golden number but an epact. If the epact of the year is V, then all dates of the year with epact V will be days of new moon.

The next question is to determine which of the thirty rows is to be used. Each row is given a letter as an indicator. At the end of every new century we may have to shift to another row. Once this shift has been determined, a list of centuries can be made up with a letter assigned to each century which indicates the row valid for that century.

The series of epacts has to be changed almost each century because Giglio applied both the solar and the lunar adjustment at the end of centuries. For the solar adjustment this had been proposed in 1564 by Pietro Pitati of Verona. Giglio accepts the Alphonsine figure for the length of the year: 365 days, 5 hours, 49 minutes and 16 seconds, which is 1/134 of a day less than one Julian year (365¼ days). Now 1/134 $\cong$ 3/400 so in 400 years the equinox will be anticipated 3 days. To correct for this, Giglio, following Pitati, proposed to leave out the leap day for centennial years not divisible by 400. This measure disturbs the Metonic cycle, so that the moon will be one day late every time the leap day is left out; the epact of the next year will be one less than normal, so we have to shift to the next following row of epacts. In his *Explicatio* Clavius calls this a postponement (*postpositio*) of the moon.[49] The opposite happens when a similar arrangement is applied for the adjustment to the motion of the moon. After one Metonic cycle of 19 years the moon anticipates its phases 1 hour 27.5 minutes or one day in 312.7 years which makes 8 days in 2500 (+ 1.6) years. Giglio corrects this by increasing the epacts by one unit every 300 years and the last time (eighth) after 400 years.

Finally, one has to correct, once for all, for the error accumulated since the Council of Nicaea up to 1580, whereby the equinox had moved from 21 March to 11 March and the moon had been anticipated by four days. This is done by leaving out ten days and jumping to the right row of epacts. The ten days could be left out all at once or [50] one could omit leap years for a period of 40 years. The first alternative is said to have been proposed by Nicholas of Cusa and Herman Zoest at the Council of Basel.[51]

Some Comments on the Compendium

Through the nuncios the Holy See transmitted the *Compendium* to the princes and universities. The experts returned their comments to their universities and princes, the princes sent them on to the Pope with their own declaration. The Secretary of State, Tolomeo Gallio, Cardinal de Como, passed them on to Cardinal Sirleto.[52] Kaltenbrunner described each of these comments individually in his third paper on the calendar reform and Schmid supplemented this.[53] However, some reactions deserving special mention have been found after their pioneering work.

Most surprising is the scorn of Kaltenbrunner for the judgement given by the mathematician of the Duke of Savoy, Giovanni Battista Benedetti: "He is so submissive that it appears he cannot judge other than with complete affirmation." [54] Evidently, Kaltenbrunner failed to recognize Benedetti as one of the greatest scientists of his age. Indeed, Kaltenbrunner had only seen the letter by Duke Emanuel Philibert, dated 31 May, 1578,[55] which is a covering letter to the comments by Benedetti. The opinion of Benedetti himself is preserved in another place [56] and dated 1 April, 1578. Benedetti prefers the Easter date to be fixed according to the true motions of sun and moon rather than by cycles. He finds that the Prutenic tables are sufficiently exact for this purpose. Furthermore not ten days, not even 14, but 21 days should be left out in order to make the first day of January the winter solstice. The lengths of the months are to be adjusted so that they coincide with the presence of the sun in each of the twelve zodiacal signs. Surely, these time intervals change their lengths in the course of time because of the motion of the perihelion of the earth, but Benedetti assures us that only after 24,000 years will an adjustment be

TABLE I. - EXPANDED

Years		Golden Numbers 3	4	5	6	7	8	9	10	11
Julian	P	*	XI	XXII	III	XIIII	XXV	VI	XVII	XXVIII
	N	XXIX	X	XXI	II	XIII	XXIIII	V	XVI	XXVII
	M	XXVIII	IX	XX	I	XII	XXIII	IIII	XV	XXVI
	H	XXVII	VIII	XIX	*	XI	XXII	III	XIIII	XXV
	G	XXVI	VII	XVIII	XXIX	X	XXI	II	XIII	XXIIII
	F	XXV	VI	XVII	XXVIII	IX	XX	I	XII	XXIII
	E	XXIIII	V	XVI	XXVII	VIII	XIX	*	XI	XXII
1582-1699	D	XXIII	IIII	XV	XXVI	VII	XVIII	XXIX	X	XXI
1700-1899	C	XXII	III	XIIII	XXV	VI	XVII	XXVIII	IX	XX
1900-2199	B	XXI	II	XIII	XXIIII	V	XVI	XXVII	VIII	XIX
2200-2299, 2400-2499	A	XX	I	XII	XXIII	IIII	XV	XXVI	VII	XVIII
2300-2399, 2500-2599	u	XIX	*	XI	XXII	III	XIIII	XXV	VI	XVII
	t	XVIII	XXIX	X	XXI	II	XIII	XXIIII	V	XVI
	s	XVII	XXVIII	IX	XX	I	XII	XXIII	IIII	XV
	r	XVI	XXVII	VIII	XIX	*	XI	XXII	III	XIIII
	q	XV	XXVI	VII	XVIII	XXIX	X	XXI	II	XIII
	p	XIIII	XXV	VI	XVII	XXVIII	IX	XX	I	XII
	n	XIII	XXIIII	V	XVI	XXVII	VIII	XIX	*	XI
	m	XII	XXIII	IIII	XV	XXVI	VII	XVIII	XXIX	X
	l	XI	XXII	III	XIIII	XXV	VI	XVII	XXVIII	IX
	k	X	XXI	II	XIII	XXIIII	V	XVI	XXVII	VIII
	i	IX	XX	I	XII	XXIII	IIII	XV	XXVI	VII
	h	VIII	XIX	*	XI	XXII	III	XIIII	XXV	VI
	g	VII	XVIII	XXIX	X	XXI	II	XIII	XXIIII	V
	f	VI	XVII	XXVIII	IX	XX	I	XII	XXIII	IIII
	e	V	XVI	XXVII	VIII	XIX	*	XI	XXII	III
	d	IIII	XV	XXVI	VII	XVIII	XXIX	X	XXI	II
	c	III	XIIII	XXV	VI	XVII	XXVIII	IX	XX	I
	b	II	XIII	XXIIII	V	XVI	XXVII	VIII	XIX	*
6600-	a	I	XII	XXIII	IIII	XV	XXVI	VII	XVIII	XXIX

* From Clavius, *Explicatio* 1612, pp. 110-111.

TABLE OF EPACTS *

12	13	14	15	16	17	18	19	1	2
IX	XX	I	XII	XXIII	IIII	XV	XXVI	VIII	XIX
VIII	XIX	*	XI	XXII	III	XIIII	25	VII	XVIII
VII	XVIII	XXIX	X	XXI	II	XIII	XXIIII	VI	XVII
VI	XVII	XXVIII	IX	XX	I	XII	XXIII	V	XVI
V	XVI	XXVII	VIII	XIX	*	XI	XXII	IV	XV
IIII	XV	XXVI	VII	XVIII	XXIX	X	XXI	III	XIIII
III	XIIII	25	VI	XVII	XXVIII	IX	XX	II	XIII
II	XIII	XXIIII	V	XVI	XXVII	VIII	XIX	I	XII
I	XII	XXIII	IV	XV	XXVI	VII	XVIII	*	XI
*	XI	XXII	III	XIIII	25	VI	XVII	XXIX	X
XXIX	X	XXI	II	XIII	XXIIII	V	XVI	XXVIII	IX
XXVIII	IX	XX	I	XII	XXIII	IIII	XV	XXVII	VIII
XXVII	VIII	XIX	*	XI	XXII	III	XIIII	XXVI	VII
XXVI	VII	XVIII	XXIX	X	XXI	II	XIII	XXV	VI
25	VI	XVII	XXVIII	IX	XX	I	XII	XXIIII	V
XXIIII	V	XVI	XXVII	VIII	XIX	*	XI	XXIII	IIII
XXIII	IV	XV	XXVI	VII	XVIII	XXIX	X	XXII	III
XXII	III	XIV	25	VI	XVII	XXVIII	IX	XXI	II
XXI	II	XIII	XXIIII	V	XVI	XXVII	VIII	XX	I
XX	I	XII	XXIII	IV	XV	XXVI	VII	XIX	*
XIX	*	XI	XXII	III	XIIII	25	VI	XVIII	XXIX
XVIII	XXIX	X	XXI	II	XIII	XXIIII	V	XVII	XXVIII
XVII	XXVIII	IX	XX	I	XII	XXIII	IIII	XVI	XXVII
XVI	XXVII	VIII	XIX	*	XI	XXII	III	XV	XXVI
XV	XXVI	VII	XVIII	XXIX	X	XXI	II	XIIII	XXV
XIIII	25	VI	XVII	XXVIII	IX	XX	I	XIII	XXIIII
XIII	XXIIII	V	XVI	XXVII	VIII	XIX	*	XII	XXIII
XII	XXIII	IIII	XV	XXVI	VII	XVIII	XXIX	XI	XXII
XI	XXII	III	XIIII	25	VI	XVII	XXVIII	X	XXI
X	XXI	II	XIII	XXIIII	V	XVI	XXVII	IX	XX

necessary. The proposal is not only interesting and original but also very rational because, by eliminating all reference to the moon, it makes the year entirely solar. (It had also been the intention with the Julian calendar to let the year begin at winter solstice.) But, of course, this proposal was too radical for the commission which scrupulously, but also wisely, kept to tradition as far as possible, without introducing unnecessary innovations.

Kaltenbrunner was right in his assumption that the publications on the calendar by Rastelli and by Giuntini in 1579 were occasioned by the *Compendium*.[57] In his dedication to Giacomo Boncompagni, scientist at Perugia, Rastelli recalls that during a visit to Rome he heard from members of the commission about the planned reform; he thinks that it is so complicated that it will not last long. Rastelli hopes that Giacomo Boncompagni will present his proposal to the Pope. Having stated several alternatives, Rastelli mentions the possibility of leaving out eleven days after 4 October, 1579 because then there are no feasts of saints. He prefers, however, that the equinox be changed to 24 or 25 March, as most commentators do, but he is unique in his final preference for the alternative method of leaving out leap days during 56 years. That is all that the little book of 72 pages deals with.[58]

Francesco Giuntini is the author of the *Synopsis de Restitutione Calendarii.* He was a doctor of theology and attached as a theologian to the household of Prince François Valet, brother of the King of France and Duke of Alençon. He states that in 1580 the equinox should fall on 10 March and Giuntini calculates from this the length of the year as 365 days, 5 hours, 47 minutes and 21.6 seconds, accepting 25 March as the date for the equinox at the beginning of the Julian calendar. From this rather low value for the length of the year results an anticipation of the equinox by one day every 114 years. Giuntini proposes that the equinox be moved to 24 March by leaving out 14 days so that one does not violate the order of Sunday letters or the solar cycle. Giuntini ignores the proposal of a perpetual calendar because he keeps to the plan of Pope Pius V of adjusting the cycle of golden numbers after every 304 years.[59]

The Senate of Venice asked the astronomer of the University of Padua, Giuseppe Moleto, to respond to the *Compendium.* Moleto would have the equinox moved to 25 March where it was in the years when Julius Caesar and Jesus Christ lived.[60] Moleto found the proposal inadequate, even in contrast with astronomical rules, though in perfect accord with those of the computists.[61] As many experts in astronomy, he found it necessary to follow the true motions of sun and moon instead of mean motions which are only human inventions.[62]

The reaction of Paolo Clarante is rather spontaneous, at least not official. He published in 1578 at Perugia *Ad Principes Christianos, De Paschatis Chronologia Quaestiones XVII*, 17 queries on the chronology of Easter, addressed to all Christian rulers. It is, for the most part, an alternative to the *Compendium*. The copy in the Vatican Library [63] begins with a handwritten letter to the Pope reminding him that the author many months before through Cardinal Sirleto had given notice to the Pope that he, Clarante, had reviewed the *Compendium* and that the Pope wished to have this critique sent to him anonymously, as a private matter.[64] Now the author requests the Pope to "embrace" his calendar, about which Cardinal Farnese had spoken to the Pope, and to have it sent to the kings. The name of Cardinal Sirleto is also on the backside of the book, in the same handwriting. One month later Clarante urged the acceptance of his proposal in a handwritten memorandum addressed to the Pope.[65]

The eagerness of the commentators to have their thoughts published in print is astonishing. Piccolomini revealed the motive for this in the following respectful terms:[66]

> I was not motivated by the fear that my writings would be altogether lost, as some in similar circumstances might perhaps fear because their writings must ultimately be sent to Rome where they are subjected to the judgement of people who themselves wrote about the same matters; they, both authors and critics would have to pronounce a verdict on their own cause; one might, therefore, fear that condemnation would be assured beforehand especially since one who resides in Rome may catch the ear of influential persons and thus by constantly urging persuade them. As I have said, from such fears and preoccupations I am altogether free; because I think that the scholarship of those who have carefully dealt with or are dealing with this matter in Rome is combined with the highest intellectual integrity.

The Criticism by Patriarch Ignatius

Finally, there is one thorough criticism to the *Compendium* which has never been well described in the history of the calendar reform. At the end of 1577 or in the first days of 1578 a person arrived in Rome who said that he was the ex-patriarch of Antioch, of the Syrian Jacobite Church (of the Nestorian confession). He sought reconciliation with God and with the Apostolic See. He was accompanied by just one servant and held a recommendation by the Patriarch of Aquileia.[67] Was he a fake? Provisionally lodging was assigned to him and he proved to be sincere. When he became a patriarch, in 1557, he had chosen the name Ignatius; his original name was Na'amatallah. On 28 March, 1576 he abdicated and from Venice he travelled to Rome.[68] On 30 January, 1578 Pope Gregory received him in audience.

In Syria and on his journey he had impressed others by his knowledge of medicine and mathematics. In the correspondence of the Jesuit Christoph Clavius, preserved at the Gregorian University in Rome, are a few sheets [69] with the following comments of Ignatius to the *Compendium*, which had been interpreted for him: (1) the anticipation of the equinox cannot be as much as one day in 134 years because at the time of the Council of Nicaea it was on 21 or 20 March and it had not yet gone back to 10 March; (2) from many observations in the East one concludes that the sun anticipates one day in 132 years; (3) the idea of leaving out ten leap days during 40 years should be rejected; (4) adjustments at the turn of the centuries is too irregular; (5) the moon gains one day, not in 304, but in 276 years; (6) the 14th day of the lunation, according to the calculation of the *Compendium* by mean motions, differs sometimes two to four days from the true motion so that we would sometimes celebrate Easter with and sometimes before the Jews; (7) for the same reason Easter may sometimes be celebrated a month late. Finally, the Patriarch promised to present within a very few days the result of the research in his books, according to the commission by his Holiness. Indeed, in Florence at the Laurentiana a manuscript of Ignatius is preserved [70] in the Arabic language, written in Karšuni characters. Leonardo Abel, from Malta, confessor and translator for Arabians in Rome,[71] translated it. The translation is in the Vatican Archives and is dated Rome, 12 March, 1580.[72] Again, Ignatius refers to the order given to him by the Pope.[73] To a series of authorities, among them the Holy Pope Victor and Saint Ambrose in his letter to the bishops of Emilia on the celebration of Easter,[74] Ignatius adds others which the author of the proposed calendar had not noticed: *Didascalia*, chapter 23; the acts of the Council of Nicaea (The Pasch of Christ has to be the Sunday following immediately after the "Phase" of the Jews); canon 103 of the book of Iellesat. According to Ignatius it is not the conjunction of sun and moon which marks the beginning of the month but the day when the moon becomes visible minus 24 hours and this according to the horizon of

Jerusalem and as calculated by mean motions.[75] Thus the 14th day will be full moon but the *Compendium* makes full moon fall on the 16th day. The *Compendium* believes that the mean motion of the sun is irregular and hence the length of the year variable. But this has to be attributed to the instruments of observation. A long series of observations in the East, from 708 to 1472, establish that the length of the year is 365 days, 5 hours, 48 minutes, 53 5/12 seconds. There is however a motion of the apogee of the sun but this amounts only to 4 degrees during one revolution of the equinoctial point, which takes 25,550 years.[76] In 1570 the equinox reached 11 March; at the time of the Council of Nicaea it was on 21 and 20 March; Ignatius calculates that it then retrogrades one day in 132 years,[77] although the length of the year that he found previously leads to 126 years. Ignatius follows the Persian idea of keeping pace with the loss of one day in 132 years by delaying every eighth leap year so that not the 32nd but the 33rd year is a leap year.[78] Having done this four times we have gained one day in $4 \times 33 = 132$ years and we avoid extreme variations in the date of the equinox. On f. 22r Ignatius reveals the "greatest error" of the *Compendium*: "that it has not understood the first day of the month of the Jews." It counts the 14th day from noon, whereas the day of the Jews begins at sunset. Also, if conjunction takes place shortly before sunset, the next day will invariably be the first day of the month. It thus results that the month always begins more than one day too early in the *Compendium*. If we also take the anomaly of the moon's motion and the longitude difference between Rome and Jerusalem into account, the real full moon may occur up to five days later than calculated. Summarizing[79] Ignatius repeats that the *Compendium* makes the lunation begin one day too early and from noon, as astronomers do, but not as the Jews do. Ignatius joins a few tables to find Sunday letters according to several assumptions and he also adds thirty tables to find the new moons according to the opinion of the Holy Fathers and that of the *Compendium*.

The Report of the Commission

In his *Explicatio* Clavius asserts that the reform agrees completely with those rules of the Christians in the East which Patriarch Ignatius showed the commission in Rome,[80] in particular that Easter may be celebrated immediately after the 14th day of the lunation. Ignatius is among the members who signed the report of the commission dated 14 September,

1580. The President is Cardinal Sirleto; Ignatius signed in Arabic and in Chaldean. Leonardo Abel interpreted his signature. The other members are: Vincenzo di Lauro, from Tropea in Calabria, Bishop of Mondovì, from 1566-1587 († 1592); Séraphim Olivier (1538-1609), Frenchman from Lyon (born of an Italian mother), and auditor of the Rota; he became a cardinal in 1604; the German Jesuit, Christoph Clavius; the Spanish theologian, Pedro Chacón; Doctor Antonio Giglio; the Dominican professor of mathematics, Ignazio Danti. According to Schmid also Giovanni Battista Gabio, poet, professor of Greek at La Sapienza, was a member of the commission.[81] In any case he translated the final text of the calendar reform into Greek.

The original text of the report is preserved in the Vatican Library.[82] It was edited by F. Kaltenbrunner,[83] and this edition was copied by Gaspare Stanislao Ferrari, Jesuit professor at the Pontifical Gregorian University.[84] It had been, however, printed as early as 1703.[85] First of all, the commission declares that, although the Church can move the celebration of Easter to another time, civil life does not require this change. It is, therefore, preferable that the Council of Nicaea and the norms of the Fathers be followed. But how? The only consensus, if any, emerging from the enquiry about the *Compendium*, would seem to be that it had to be rejected. But already on 17 March, 1580 the commission had decided to fix the equinox at 21 March,[86] which Giglio had judged to be more according to the dignity of the Church (thus in the *Compendium*). In spite of much criticism the commission reported that all scientists who had been asked, had approved the epact cycle of Giglio, that is to say, all who had understood it, and apart from a few who would force the Church to follow the most difficult and cumbersome methods of astronomers.[87] Clavius himself had within the commission favoured the use of true motion;[88] but he thereafter, defended the decision of the commission most loyally. The commission definitely accepted the epact cycle of Giglio as the only one which yields a perpetual calendar. It agreed on a few guide-lines, called "hypotheses": If full moon occurs after six p.m., it is assigned to the next day. At new moon however, there is no need of so much precision. This seems to be the result of all the criticism by Ignatius. The equinox was set at 21 March because then nothing had to be changed in Mass books and breviaries. (This fulfilled a wish of the King of Spain.) The ten days should be left out in October 1581, the year of correction.

1581 did not become the year of correction. From the University of Louvain Adriaan van Zeelst (Adrianus Zeelstius) had sent a comment on the *Compendium* dated 12 February, 1579.[89] It was sent to Rome by a delegate of the Pope, then in Cologne, Giovanni-Battista Castagna, Archbishop of Rossano, on 8 May, 1579.[90] van Zeelst praised the invention of Giglio but found it impractical and accessible only to experts. He promised an alternative of his own invention. The commission entertained great hopes for this invention. In a provisional version of the report of the commission in 1580 van Zeelst was called a German who praised the cycle of epacts and had promised to produce a better cycle within a year.[91] At the end of September, 1580 the University of Louvain received from Rome an enquiry about the work of van Zeelst on the calendar reform. The completed work of van Zeelst was then sent to Rome,[92] dated 1581. The author admitted that much was unintelligible to him. Giglio had set the epact of each year, the difference between solar and lunar year, to 11 days. van Zeelst came forth with the exact amount in hours, minutes, seconds and parts of seconds. An expert in the commission, the handwriting seems to be that of Clavius, wrote a criticism of the comments of van Zeelst.[93] The conclusion was that nothing prevented the realization of the reform which had been studied for so long a time in Rome under the presidency of the Bishop of Mondovì. This shows that Vincenzo di Lauro presided over the meetings as long as he was in Rome.[94] Sirleto must then have been a more remote leader. On 15 September, 1580 Vincenzo became nuncio in Turin.[95] On 13 January, 1581 he wrote to thank Cardinal Sirleto for the wise resolutions taken by the commission.[96] On 31 May, 1581 [97] he wrote to Sirleto that he agreed with him about the discourse of van Zeelst which he had studied; he regretted that this had delayed the correction of the calendar to 1582.

But by now time had run out for the commission and probably for the Pope himself who was very eager to bring the matter to a final conclusion. In the same letter, just mentioned, Lauro declines the offer to prepare the bull and proposes Pedro Chacón. Chacón did prepare the text but Lauro had to contribute as well and sent his work together with an explanation of the calendar on 20 October, 1581 from Turin to Sirleto.[98] Chacón died on 26 October, 1581. On 11 February, 1582 Sirleto sent Antonio Giglio to Mondragone, the villa outside Rome where the Pope preferred to stay whenever he could, and there the Pope signed the bull on 24 February, 1582.[99] The table at which the Pope signed the document, is still shown at Mondragone. The handwritten text of the bull is in the bullarium of the Vatican Archives.[100] On 1 March the text was published at the doors of Saint Peter's Basilica, at the chancellary in Rome, the building annex to the Basilica San Lorenzo in Damaso, located on what is today the Corso Vittorio Emanuele II, and at the Campo dei Fiori. It was printed together with the new perpetual calendar and the essentials of the new system and copies were dispatched to all Catholic countries through the mediation of the nuncios. As a reward to Antonio Giglio and to avoid uncontrolled reprinting of the calendar the Pope issued on 3 April, 1582 a brief prohibiting any publication of the calendar without the approval of Giglio. Giglio from his side promised together with the printer to provide plenty of copies in due time. Soon the nuncios received a few copies to be handed over to princes, bishops and other personalities together with a promise of cases full of books soon to be sent. However, these cases were so much delayed that scarcity of calendars became an obstacle in carrying out the reform.[101] The Pope withdrew the privilege of Giglio on 20 November, 1582.[102]

Contents of the Final Reform

Substantially the new calendar follows the proposal in the *Compendium* so that Clavius in his *Explicatio* could recognize Luigi Giglio as the primary author of the reform. The essence of the new calendar is the cycle of epacts, as shown in Table I, pages 212-213, and this is taken over wholeheartedly by the commission. Three leap days are to be left out in 400 years according to the Alfonsine length of the year which is a mean of the varying lengths of the year according to Copernicus. The cyclic dates of new and full moons were adjusted to the Prutenic tables so Clavius could say that the reform followed the Prutenic or Copernican tables.[103] However, all epacts have been made one unit less.[104] This may perhaps be seen as a response to the criticism of Ignatius that the *Compendium* took the conjunctions of the sun and moon for visible new moons. However, nowhere in the calendar nor in the *Explicatio* of Clavius is this distinction made. Perhaps the commission did not wish to take sides in a controversy.[105] Clavius gives as a reason [106] the need to avoid that Easter should be celebrated too early. Indeed, errors cannot be completely avoided because artificial cycles cannot represent exactly the real motions of sun and moon with their anomalies. The reform preferred, therefore, to place the new and full moons too late rather than too early because it would be a lesser error to celebrate Easter in the second month after the equinox than in the last month before the equinox or even to celebrate Easter on the same date as the Jews, that is on the fourteenth day of the moon instead of the day thereafter. But perhaps the commission had made its choice by a somewhat experimental method. It may have calculated full moons according to the available astronomical tables and chosen its epacts such that a minimum of errors results. In fact, Clavius defends the epacts of the calendar by showing that any other choice would make the errors more frequent. We can check it also by comparing the Easter date for the years 2000 to 2500 with the dates for full moon, calculated by Professor T. Lederle.[107] It can be seen that a shift of the epacts by one day, whether forwards or backwards, increases the errors. In the following table P-Q means the number of weeks that (the Gregorian) Easter precedes the Easter date according to modern calculations of the dates for the real equinox and the real full moon. The top row lists the number of Easter dates between 2000 and 2500 where the different cases apply when the epacts of Giglio and the *Compendium* are used; next the numbers for the actual Gregorian calendar; finally the numbers for the case when the epacts are decreased by even one more unit.

P-Q	−5	−4	−1	+1	+3	+4
Giglio Compendium	1	1	88	0	3	14
Gregorian	1	1	26	9 (2)	0	17
− 1	0	4	4	45 (34)	0	13

In parentheses are the numbers which result when we keep to the principle that new moon after six in the evening is attributed to the following day. This principle, announced by the commission in its report of 14 September, 1580, I have not seen respected neither by the Gregorian calendar nor by Professor Lederle, but we see that it reduces the errors. It is obvious that the least errors occur when new moon is assumed to take place exactly when it becomes visible, one or two days after conjunction; so perhaps the criticism of Ignatius was accepted in practice, though never overtly. Nowadays we are able to compare the Gregorian calendar with accurate predictions of the true motions of the moon. Clavius made a comparison but had to be guided by the mean motions of the moon, the only ones which he could predict sufficiently. The saying that Gregorian cycles follow the mean motion of sun and moon is however misleading, as Clavius points out in his explanation of the calendar. For in the case of the equinox the motion of the real sun is combined with the mean precession of the equinoxes. The real motion of the sun in the course of each year is irregular enough (the eccentricity of the orbit of the earth is large enough) to make the arrival of the real sun to the equinoctial point several days different from the date of the arrival of the mean sun at the same point. Thus astronomers in the days of Pope Gregory were aware that spring plus summer in the northern hemisphere lasts a week longer than autumn plus winter.

Another difference between the proposal of Giglio and the rules of the Gregorian calendar is in the method of producing hollow months, that is months of 29 days. Giglio had leapt over either the 29th or the first day of a lunation in the perpetual calendar to make lunations of 29 instead of 30 days. The commission changed this so that either the 24th or the 26th day of the lunation was left out. The basis for this change is the place of these epacts in the perpetual calendar. Epacts XXIX and XXX occur on 1 April and 31 March; epact XXV and 25 are placed at 4 or 5 April. Thus, just as in the old calendar, hollow months are produced by jumping a day on 6 April, which is the right date, if one wishes to be certain that all or nearly all paschal lunations are hollow. So the purpose of this change was to keep to tradition as closely as possible. As Clavius states it in his *Explicatio*:[108]

> It was preferable to choose the two epacts, XXV and XXIV, for the lunar adjustment because in this way the lunations according to the cycle of 30 epacts, and particularly (and more importantly) the 30 Easter lunations, coincide better with the lunations of the golden numbers of the Council of Nicaea, the decrees and decisions of which we have retained, as far as was possible and reasonable. For we see that the lunar adjustment was made by the golden numbers nearly at the same places at which it is made in the new calendar by the epacts XXV and XXIV.
>
> Moreover, just as in that cycle of the golden numbers all 19 Easter lunations contain only 29 days . . . , thus also in the new cycle of epacts . . . all 30 Easter lunations contain each 29 days, except two lunations. . . .

On the other hand in the *Compendium* according to Giglio seven Easter lunations numbered 30 days.[109] Epact XXV is placed at 5 April, together with epact XXIV. But sometimes both these epacts are in use within one Metonic cycle. For example, for 1981 the epact was XXIV; only 11 years later, in 1992, it should be XXV. So twice within one

Metonic cycle six new moons, those of the hollow months, should fall on the same dates. This is unacceptable because it would mean that the moon's phases return to the same dates before the cycle is completed. Giglio invented the means of preventing this. Analogously, in the actual perpetual calendar, at the side of the epact XXVI, is written another number, 25, in Arabic numerals. Usually this number 25 is ignored. However, the epact of 1992 will not be XXV but 25; this means that the new moons of 1992 fall on the dates with epact 25. There is no risk that in another year within the same cycle new moons will fall on the epact XXVI because this epact XXVI is not used in a Metonic cycle when both XXV and XXIV are in use. For the sake of clarity the number 25 is placed also next to XXV in the months of 30 days to indicate where all the new moons fall in years like 1992 which have the epact 25. By similar reasoning the explanation applies to the epacts XX.19 at 31 December. The Arabic figure applies only to the rare case when the golden number 19 and epact XIX coincide. This happened in 1595 and five times in the seventeenth century. See Kaltenbrunner [110] for a fuller explanation.

Tradition was a key concept for the reform, a tradition which was sanctified by the practice of the Church from the times of the Apostles of Jesus and particularly by the authority of the Council of Nicaea, the first Ecumenical Council convoked in 325 by the Emperor Constantine. No calendar rules were laid down at the Council other than that all Orthodox Christians were to celebrate Easter on the same day. Nor was it an offense when Christians happened to celebrate Easter on the same day as the Jews, but this should not be taken as a rule. The rule accepted was that Easter should be celebrated on the Sunday following the fourteenth day of the first lunation, that is the first lunation of which the evening of the fourteenth day falls after the vernal equinox, which was fixed on 21 March, where it was in the days of Nicaea. In addition to simple respect for Nicaea, the main reason for the commission to keep to this date was so as not to disturb the order of feasts whose dates were set some time after 325, and thus with 21 March for the equinox. Consequently, ten days had to be left out in order to change the equinox from 11 to 21 March. The cycle of Sunday letters received one single discontinuity when it was decided that the ten days should be left out after Thursday 4 October, to be followed by Friday 15 October. Why in October? Clavius explains [111] that we should suspect nothing more mysterious in this choice than that there are fewer feasts of saints in October. The feast of S. Francis of Assisi was saved because it is celebrated on 4 October. It is true that February, March and April also contain few feasts of saints but they covered the seasons of Septuagesima, Lent and Easter which should not be disturbed, unless necessary.

The papal bull and Clavius [112] both emphasize that the new calendar is perpetual. This has been misunderstood, as if no adjustment should ever become necessary. The true meaning is that the calendar is perpetual, because the figures placed at each date refer to the epacts and not to golden numbers. The golden numbers of the years are fixed and cannot be changed because they result immediately from dividing the number of the year by 19. But for the epacts of the year one can select any of 30 possible combinations with the golden number and, therefore, the figures in the new calendar have never to be changed because they refer to these epacts. The system of combining epacts with golden numbers, the expanded table of epacts, is perpetual. All adjustments and changes are made in the table of adjustments which assigns to each century a letter referring to some row of the *Expanded Table of Epacts.*

The Martyrology [113]

On 4 November, 1581 Vincenzo di Lauro informed the Secretary of State, Cardinal de Como, that he had dispatched the projects by Pedro Chacón and himself for the papal bull and for the explanation of the calendar. He added that it would be necessary to publish the new martyrology simultaneously with the new calendar. He had proposed the formulation: "Calendarium, ad quod etiam accommodata est ratio martyrologii." [114] The final text has:

> ... Calendarium immensa Dei erga Ecclesiam suam benignitate iam correctum atque absolutum hoc nostro decreto probamus, et Romae una cum Martyrologio imprimi, impressumque divulgari iussimus.

The martyrology is the list of saints who are commemorated on a certain day and in former times it was read every day during the liturgical morning office (hora prima). It needed a reform, partly because the list of saints and the statements about them had to be changed, but also because the reading begins with the announcement of the age of the moon that day.

Through the offices of Cardinal Sirleto, Juan Salón had received from the Pope the task of reforming the martyrology. In 1578 Salón delivered to the Pope an example [115] for the months January and February.[116] Salón claimed to have followed Paul of Middelburg for the moon cycles and in his covering letter [117] he showed by a few examples how exactly his new moons coincided with the astronomical new moons, conjunction of sun and moon. All this work had to be done again after the acceptance of the new epacts to make them agree with these. For this reason and perhaps others Salón never finished his task, completing his martyrology only up until 8 July.[118]

In its report dated 14 September, 1580 the commission expresses the intention to finish soon the calculation of all the new moons for the martyrology. Before 6 December of the same year Cesare Baronio (1538-1607), Oratorian, Church historian, received the task of reforming the martyrology in cooperation with Sirleto, Curzio Franco, a canon, and others. Kaltenbrunner did not know of any new martyrology before 1586. However, the new martyrology was indeed published together with the new calendar. In 1582 the martyrology from 15 October on of that year was published.[119] In 1583 the complete martyrology was issued with detailed explanations of what in the Roman Martyrology belongs to the announcement of the moon. It is completely in the style of Clavius' explanation of the calendar and was taken over literally in newer editions of the martyrology, the latest being that of 1956. The newer editions also contain an Apostolic Constitution of Pope Gregory on this new martyrology. It is dated 14 January, 1584 and thus had not been inserted in the two first editions of 1583. These editions contained too many errors so Sorleto had a corrected edition prepared;[120] it appeared in 1586 in Rome under the title: *Martyrologium... cum notationibus Caesaris Baronii Sorani.*[121]

The Explanation of the New Calendar

Despite all efforts to keep to tradition the reform was a novelty in its method of calculating Easter. Therefore, the books on the calendar contained not only the bull *Inter gravissimas* and the perpetual calendar with the list of epacts and the table for the adjustment of the epacts, these being the essentials of the new calendar, but also a short explanation. Several times one is referred for further information to a book on the new way of restoring the calendar. The task of preparing this book was given to Antonio Giglio.[122] In 1585 Giglio finally announced that after much work and toil it was finished.[123] It was never published. Pope Gregory died on 10 April, 1585, Sirleto on 6 October of the same year and Giglio himself most probably before 1595.[124]

On 20 October, 1581 Vincenzo di Lauro had sent his explanation of the new calendar to Cardinal Sirleto.[125] A short and clear explanation of the reform is found in the Vatican Library.[126] Schmid [127] attributed it to Pedro Chacón or Vincenzo di Lauro. It seems to be the one sent by di Lauro. Another copy is among the manuscripts of Christoph Clavius [128] and has a few corrections (in Clavius' hand?).

In 1583 Franciscus Flussas Candalla [129] wrote a booklet on the *Restoration of the Equinox*. It criticizes the Gregorian reform defending the change of the equinox to 25 March. By order of the Holy Father Clavius answered it and Sirleto sent the response of Clavius to Flussas with a covering letter dated 29 August, 1583.[130] We have the replies of Flussas [131] and his covering letter to Sirleto [132] dated Castelnau de Médoc, near Bordeaux, 2 February, 1584.[133]

In the end, all the burden of defending and explaining the calendar turned upon Clavius. After having already written several defenses of the Pope's calendar, Clavius, as the only survivor of the commission, was charged by Pope Clement VIII with the task of writing the explanation of the calendar. He published it in 1603, and it is the standard work on the Gregorian calendar. The manuscript is preserved.[134]

How Was the Calendar Promulgated and Published?

The reform was most easily accomplished in Italy, in Spain and in Portugal. As an example we have the circular letter which the Bishop of Iesi, Gabrielle de Monte, sent out in his diocese.[135] He ordered the jump from 4 to 15 October and added the calendar of the feasts for these days to his letter. He mentioned also the new epacts as if they needed no explanation. On 26 May the Secretary of State, the Cardinal of Como, sent the calendar in twelve copies to Cardinal Luigi Madruzzo, Legate of the Holy See at the Diet in Augsburg.[136] On 28 May the new calendar was sent to the nuncio of Savoy, Vincenzo di Lauro. By 12 June he had delivered copies to the Duke and to the Archbishop of Turin and the reform was to be accomplished on 4 October.[137] Alberto Bolognetti, nuncio in Poland, had not yet received the twelve copies of the calendar on 26 July, 1582.[138]

The *Calendar* was translated into Italian by Reverend Bartholomeo Dionigi da Fano. The translation was published in Venice in the very year 1582. Two copies are at the National Library in Rome, one of them belonged once to the Collegio Romano of the Jesuits. Apart from a few misprints it is a true rendering in Italian of the *Calendar* with its canons, preceded by the canon on the year of correction. The translation of the bull *Inter gravissimas* is followed by the decision on the printing of the Calendar in favour of Antonio Giglio, called Gilio in the translation.

The Decree of 1582 and Other Churches

Kaltenbrunner describes the calendar reform of Pope Gregory as another bone of contention cast into the Protestant world.[139] One might, however, see the reform in a quite different way. The Pope presented his bull in 1582 as an implementation of the decrees of the Council of Trent and thus as an act of the Counter Reformation, but he did so with the desire to meet the justified claims of the reformers. As part of a genuine reform in an important area of the Church's life, the decree of 1582 is an ecumenical act. On the other hand, as an implementation of the Council of Trent and set within the framework of the liturgy of the Roman Church, revised by Pope Pius V, the decree addresses itself only to those who accepted all this, that means, only to Roman Catholics. The Pope could not effectively impose an important measure on other Christians who did not recognize his supreme authority. In fact, in Rome the opinion was once voiced that it would be unworthy of the Pope to ask non-Catholics for their opinion.[140] Among all the authors writing on the proposed reform only one calls attention to the Christians of the Reformation. Bishop Hugolino Martelli of Glandèves pleaded energetically for a return to 25 March as date for the equinox, since, as he proposed, this was the date for the equinox at the time of the Gospel accounts and that Jesus would have, according to Martelli, been born on 25 December. Another of his arguments was that Christians of the Reformation would be more willing to accept a date referred to the Gospel than a date referred to tradition, to the Council of Nicaea. It was, however, too evident that Martelli had to supplement by much eloquence what was lacking in the rigour of his arguments, so no official notice was taken of his books.

The decree of 1582 recalls that a compendium of the planned reform had been sent to the "Christian rulers" and we know that it was sent in 1577 only to Catholic princes. Kaltenbrunner[141] reproached the Pope that his reform had no regard for the Reformation. But the Pope could rightly expect that his Calendar reform would be received as a part of that general reform of the Church which was sought after with such diligence by the

Protestants that it caused a breach in Christianity. In fact, in the bull of 1582 the Pope mentioned especially Emperor Rudolph II and urged him to carry out the reform. The Emperor had many Protestant subjects and among them powerful princes. The Pope, knowing how strained the position of the Emperor was and realizing that he needed support, believed, perhaps, that the passage in the bull would strengthen the Emperor in his execution of the reform. Kaltenbrunner finds it a serious mistake of the Pope that he did not propose the calendar at the diet of Augsburg in 1582.[142] How could Pope Gregory have done so? It belonged to the Emperor to propose reforms at the Diet. The Pope had done all that he could.[143] Although the bull did not carry a threat of excommunication, it was issued under the full authority of the Pope and concerned the important matter of the celebration among Christians of the greatest feast of the Church, the Resurrection.

The reaction of the Oriental Churches to the proposed Calendar reform was first registered in Venice by Giuseppe Zarlino (1519-1590), the famous director of the choir at St. Mark's and author of books on music and other subjects. In 1578 he delivered his report on the *Compendium* to the nuncio of the Pope in Venice. Less than a month later Zarlino addressed himself again to the nuncio in a letter of moving concern for relations with the Orientals. Zarlino had met a Greek who had heard that the Pope planned to fix Easter on a certain day in March or April. He feared great scandal and damage to the relations between the Churches and prayed God to forbid it. Zarlino reassured him that the Pope only wished to reduce the vernal equinox to a fixed day. They agreed that it would be worst of all if one Church celebrated the Passion of our Lord while the other at the same time celebrated his Resurrection, and that could happen even in the same house because there was "an infinity of" mixed marriages.[144] The problem must have been discussed in the commission. The letter was among its acts. J. Schmid mentioned it among the papers which Antonio Giglio borrowed, only he could not recognize the name Zarlino.[145] In the first drafts of the report of the commission, before the final text of 14 September, 1580, the plan was seriously discussed of delaying the reform in order to invite representatives of the Patriarchs of Constantinople, Antioch and Alexandria to the commission. Patriarch Ignatius supported this plan. But would the Orientals accept a reform? It was thought best to invite Patriarch Ignatius and a Greek bishop from Venice to the commission. Both had then to be informed accurately on the reform.[146] We have seen that Ignatius signed the report of the commission on 14 September

1580 and his comments on the *Compendium* show that he was informed at the latest during March 1580. On 28 April, 1580 Cardinal Sirleto and Vincenzo di Lauro had considered "the cycles which the Orientals use"[147] and when the Dalmatian Pietro Cedolini was in secret relations with the Patriarch of Constantinople from October 1580 to April 1581 he explained the calendar reform but the Patriarch answered no to the Doge Nicolò de Ponte.[148] On 17 April, 1581 a Greek colonel from Candia, Antonio Eudemonjani, wrote from Venice to the Pope. He proposed negotiations with the four Oriental patriarchs in order to avoid differences between Greeks and Latins in places where they were mixed.[149] A further delay threatened the reform. Much work had been done and everything was ready. The Pope was approaching his eightieth year, a formidable age. On 17 June, 1581 Clavius wrote to Vincenzo di Lauro. He had discussed the matter with the president of the commission, Cardinal Sirleto, and they agreed that they would finalize the reform in any case. Thus had Vincenzo di Lauro also decided while he was present in Rome, Clavius wrote.[150] This must have been the result of the discussions mentioned above, and it agrees with the fact that the final report of 14 September, 1580 did not mention discussions with the Orientals. Although the commission did not oppose negotiations, it insisted on pursuing the reform without delay and thus not waiting for the consent of the Orientals. Thus the Pope proceeded. He signed the bull on 24 February before he had come to any agreement with the Patriarch Jeremiah but subsequently he negotiated with him. This subsequent dealing between the Pope and the Patriarch is discussed in the paper by Hoskin in this volume. We might only add that the desire to correct the offense caused by not proposing the *Compendium* to the Greeks occasioned the edition in Greek of the decree *Inter gravissimas* with the calendar and its rules in Rome in 1583. It also contained the tables and rules of Giambattista di Zanti for the application of the reform to the Calendar of Greek feasts.[151]

The personality and the role of Patriarch Ignatius of Antioch may be the clue to another edition in Rome of the same texts in Karšuni, that is in Arabic with Syrian characters. J. Schmid speaks about the efforts of Ignatius to persuade the Jacobite Churches of Antioch and of Alexandria to accept the Gregorian Calendar.[152] Schmid assumes that the Jesuits, Giambattista Eliano and Giovanni Bruno, in their mission of 1582 to Syria had a mandate in this respect. However, in a letter dated 3 March, 1581 Clavius assures Eliano that "the patriarch" had already accepted the calendar. When Leonardo Abel, the interpreter of Ignatius in Rome, arrived in Syria in 1583 with some copies of the Chaldean version of the calendar, the Patriarch of Antioch refused to accept the calendar unless all other nations did so, because he was afraid of the Turks.[153] Also for the Patriarch of the Nestorian Chaldeans Abel delivered some Chaldean versions of the calendar. In Alexandria Eliano had to rewrite the text in Arabian characters so that the Copts could read it.[154] Giovanni Battista di Zanti, professor of astronomy in Bologna,[155] who composed the rules for the application of the calendar reform to the calendar of the Greek Churches,[156] published in 1583, by order of the Pope, tables for the Syrians, in Arabic, printed in Syrian characters.[157]

There is also an edition of the Gregorian calendar in Armenian, Rome 1584. One copy exists in the Vatican Library[158] and one in the National Library in Rome.[159] The manuscript is in the Vatican Library and the translator is the Armenian Marcus Antonius Abagarius.[160] A colony of Armenians in Galicia in Poland, subjects of Patriarch Jeremiah, addressed themselves to him on behalf of the calendar;[161] in 1583 the Roman Catholic Archbishop of Lemberg dealt with them on the same subject. During the mission to Syria mentioned above Leonardo Abel delivered a copy of this version to the Patriarch of Armenia, Cacciadore in Sis.[162]

An Evaluation

The Gregorian reform of the calendar has often been praised for its high scientific standard. Such an authority in astronomy as Delambre found the Gregorian calendar better than its own authors had supposed. Delambre regrets only that the Church did not take the decision to have Easter on a fixed Sunday.[163]

However, Giglio, Clavius and finally Pope Gregory chose the scientifically most difficult path out of respect for tradition. The authors of the Gregorian reform declared repeatedly that they preferred to keep to the rules of celebrating Easter derived from the Israelite religion and the Christian history of salvation and that they did not wish to break with any traditions but on the contrary to return to the exact, original intentions of the Fathers of the Council of Nicaea. Their achievement in science and in Church politics is fundamentally a great act of religion, one of respect for tradition in the Church.

The Gregorian calendar is first of all a reform, part of the vast and much required reform of the whole Church. It is also part of the Catholic Counter-reform, understood as encountering the equitable demands of the

Protestants. If Pope Gregory had made use of his acknowledged power to set Easter on a fixed Sunday, thereby abandoning old Christian and biblical traditions, what would have been the reactions from Protestant regions in Europe? While we cannot answer this question, we know how negative their reaction was on the most moderate, considerate measure which the Roman authors did take.

The bull *Inter gravissimas* was issued late, only half a year before the execution of the reform. A calendar reform has to be promulgated at the latest in the calendar year preceding the year of the reform. We have seen the reason for the delay but we understand also the impatience of Clavius and other members of the commission. Vittorio Peri is quite indignant about the behaviour of Clavius in the affair concerning the Greeks. He contrasts Clavius' attitude to the generous minds of Pope Gregory and Cardinal Sirleto.[164] However, Clavius did not write that *he* wished to press the reform through before negotiations with the Orientals. He says: *We*, Sirleto and I, agreed, and he appeals to a previous decision by di Lauro. Not Clavius, but Sirleto was president of the commission; not Clavius, but Pope Gregory signed the bull on 24 February, 1582 before Rome had sent a representative to Constantinople. The Pope and Sirleto are the responsible parties. It is true that both Pope Gregory and Sirleto opened their minds with regard to Christians of the East after they had assured the execution of the reform. But the same holds for Clavius. Already in his letter of 3 March, 1581 he wrote to Giambattista Eliano:[165]

> About the calendar, which is already finished, you should not be anxious, because the Pope plans to let two very able men come from there, and the patriarch has also subscribed to our calendar and admitted that it is very good. I hope that it will soon be published, because the Pope is quite eager.

This letter, predating the one to Vincenzo di Lauro, is of a quite different tone. In the letter to Lauro Clavius had to defend the reform; in the letter here quoted he wanted to encourage a brother-in-religion for a very delicate and difficult expedition. In 1583 Clavius defended the change of the equinox to 21, and not to 25, March because the alternative would cause much disturbance "to all Christians but most of all to Greeks and Orientals"[166] and in his *Explicatio* Clavius gave similar reasons and regards for "all the Greek Churches which are numerous and which above all have to be taken into consideration".[167] Indeed, the Greeks were upset when they heard the rumour that the equinox would be reduced to 25 March and became satisfied when they learned that it would be changed to 21 March.[168]

Clavius also told how Patriarch Ignatius of Antioch appeared at the meeting of the commission with books from the East and it was verified that the measures planned by the commission were in full agreement with these texts.[169] If in the letter to Lauro Clavius shows himself more upset than usual, it is a natural reaction because Clavius had done much tedious work of lengthy and accurate calculations. But above all we should remember gratefully that citizens of Venice, where the Christian West and East met most intimately, took the initiative of proposing negotiations with the East; indeed, the first one seems to have been an Orthodox layman.

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15. *Ibid.*, 6214, 1-17; 6217, 48-59.
16. *Ibid.*, 6214, 7v.
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23. Giovanni Battista Riccioli S.J., *Chronologiae Reformatae Tomus Primus* (Bologna, 1659), Book I, ch. 28, p. 73: Aloysius et Antonius Lilius Veronenses.
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25. To counter-balance this opinion one might allege the position of the faculty of theology in Paris on the *Compendium*, sent out in 1577. Ferdinand Kaltenbrunner, "Beiträge zur Geschichte der Gregorianischen Kalenderreform", *Sitzungsberichte der phil.-hist. Classe der Kaiserlichen Akademie der Wissenschaften*, XCVII (Heft 1) (Vienna, 1880), 38, recapitulates the lengthy rejection of the plan by these theologians in these terms: astronomers are contemptible, dangerous and ignorant people.
26. Alessandro Piccolomini, *De Nova Ecclesiastici Calendarii, pro legitimo Paschalis celebrationis tempore, restituendi forma, Libellus* (Siena, 1578), 70.
27. *Ibid.*, 70-72.
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42. Bibl. Vat., *Cod. Vat. lat.* 6194, 67r. A. Oliver in: *Lexicon für Theologie und Kirche*, vol. II (Freiburg im Breisgau, 1958), col. 1000. A. Orive, *CHACÓN, Pedro*, in *Diccionario de Historia Eclesiastica de España*, vol. II (Madrid, 1972), 673. Pedro Chacón is not to be confounded with his contemporary Alonso Chacón, Dominican and author of historical works.
43. According to his epitaph, now in S. Maria di Monserrato: Vincenzo Forcella, *Iscrizioni delle chiese e d'altri edificii di Roma del secolo XI fino ai giorni nostri*, vol. III (Roma, 1873), 238.
44. Bibl. Vat., *Cod. Vat. lat.* 7093, 432r; 6214, 129 and 130; 6417, 17-24.
45. August Theiner, *Annales Ecclesiastici*, vol. II (Rome, 1856), § 90, p. 578.
46. Clavius, *op. cit.* (ref. 6), ch. 11 § 5 and ch. 13 § 18.
47. *Ibid.*, ch. 13 § 20, p. 167.
48. Gordon Moyer, "The Gregorian Calendar", *Scientific American* CCXLVI (May 1982) 108, 110, has found some copies in Italy. The copy preserved in the Vatican Library is catalogued Racc. I.IV.963, int. 4, among Miscellanea Calendarij Gregoriani. Biblioteca Nazionale in Rome has another one. However, these are all copies of the *Compendium*, not of the book of Luigi Giglio.

49. Clavius, *op. cit.* (ref. 6) ch. 12 § 9, pp. 147-149.

50. Following the proposal by Bartholomeus Caligarius in 1548, according to Josef Schmid, "Zur Geschichte der Gregorianischen Kalenderreform. III. Nachträge", *Historisches Jahrbuch der Görres-Gesellshaft*, V (1) (München, 1884), 54-55.

51. Francesco Giuntini, *op. cit.* (ref. 5), 8.

52. E.g. Bibl. Vat., *Cod. Vat. lat.* 6193, 345; copy in: Bibl. Vat., *Cod. Barb. lat.* 5741, 35. The *Cod. Vat. lat.* 5645 contains the original letters of the rulers and academies together with some of the commentaries by their experts; the index of the codex lists also other commentaries with a reference to the codices in which they are contained. Among the correspondence of Christoph Clavius in the Archives of the Gregorian University (AUG) we find copies of both the answer of the Emperor Rudolph II and of his letter to the Pope, both mentioned by the Secretary of State, in cod. 530, 20 and 96.

53. Schmid, *op. cit.* (ref. 7), 393-405.

54. Kaltenbrunner, *op. cit.* (ref. 25), 29.

55. Bibl. Vat., *Cod. Vat. lat.* 5645, 11.

56. Bibl. Vat., *Cod. Vat. lat.* 5645, 148-150; printed in *Cod. Vat. lat.* 10493, 138, as noted on *Cod. Vat. lat.* 5645, 148, but I have not found the printed text.

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58. See also Schmid, *op. cit.* (ref. 50), 67 ref. 1.

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60. Giuseppe Moleto, *De Corrigendo Ecclesiastico Calendario* (Venice, 1580), 13r, 16r.

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73. *Ibid.*, 3v.
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117. Bibl. Vat., *Cod. Reg. lat.* 373, 18-19.

118. Bibl. Vat., *Cod. Vat. lat.* 6214, 103-128, 101-102.

119. It was probably not composed by Antonio Giglio; cf. Denzler, *op. cit.* (ref. 34), 114. But it contains the privilege of Giglio to be mentioned in this paper.

120. Cf. Bibl., *Cod. Vat. lat.* 6147, 15-16; the letter is probably written by Curzio Franco because it comes from Naples.

121. Kaltenbrunner, *op. cit.* (ref. 25), 21.

122. Schmid, *op. cit.* (ref. 7), 408-411.

123. Bibl. Vat., *Cod. Vat. lat.* 6417, 58.

124. Schmid, *op. cit.* (ref. 7), 411; cf. Bibl.. Vat., *Cod. Vat. lat.* 5645, 1.

125. Bibl. Vat., *Cod. Vat. lat.* 6194, 174.

126. *Ibid.*, 6214, 30.

127. Schmid, *op. cit.* (ref. 50), 73.

128. *AUG* (ref. 52), 529, 286-288.

129. This "Flussas" is a Frenchman; cf. Schmid, *op. cit.* (ref. 50), 75. François de Foix (1512-1594) was Count of Candalle and Bishop of Aire. Philippe Tamizey de Larroque, "Notes et documents inédits pour servir à la biographie de Christophe et de François de Foix-Candalle, evêques d'Aire". Abstract from *Revue de Gascogne* (Paris, 1877).

130. Bibl. Vat., *Cod. Vat. lat.* 7093, 346.

131. Bibl. Vat., *Cod. Vat. lat.* 6217, 60-69.

132. Bibl. Vat., *Cod. Vat. lat.* 8102, 1-4. Denzler, *op. cit.* (ref. 34), 108 seems to have misunderstood the situation.

133. Bibl. Vat., *Cod. Reg. lat.* 2023, 279-280, a further criticism of the reform was made by Giovanni Vincenzo (?) Della Porta in Naples, who respectfully expressed the opinion that Giglio was not very lettered.

134. *AUG* (ref. 52), cod. 774.

135. Bibl. Vat., *Cod. Vat. lat.* 10727, 73.

136. *Nuntiaturberichte aus Deutschland*, vol. II (ref. 90), pp. 421-3.

137. Bibl. Vat., *Cod. Vat. lat.* 6417, 27.

138. *Monumenta Poloniae Vaticana*, vol. V (ref. 101), 411, 425.

139. Kaltenbrunner, *op. cit.* (ref. 110), 486.

140. Bibl. Vat., *Cod. Vat. lat.* 6417, 14r.

141. Kaltenbrunner, *op. cit.* (ref. 110), 494.

142. *Ibid.*, 503.

143. Cf. *Nuntianturberichte aus Deutschland*, vol. II (ref. 90), 423. The Vatican Archives contain in *Archivio dell'Arce* 5506, Arm. XV, n. 4, 1627 on ff. 340-341 in print the constitution of the Pope for those who "for various obstacles" did not start the new calendar in October 1582. It is also in print in *Secr. Brev.* 53, 231-232. The manuscript is there on f. 228r. The essentials of the constitution are drafted on f. 229r and f. 233r. The constitution is dated 7 November, 1582. Cf. also the note on *Secr. Brev.* 53, 235v, dated 11 November, 1582. It orders a jump from Sunday 10 to Monday 21 February, 1583. The same codex AA 5506 contains on f. 329 in print the calendar from Sunday to Ash Wednesday. The constitution has been printed in the *Kalendarium Gregorianum Perpetuum* published in Douai in 1583. The original edition of the new calendar had already detailed indications for how to introduce the calendar in October 1583 or following years. These indications were originally destined for those in India and America who did not receive the news on the reform in due time.

144. Bibl. Vat., *Cod. Vat. lat.* 7057, 58-59, copy.

145. Schmid, *op. cit.* (ref. 7), 509; *op. cit.* (ref. 71), 546.

146. Bibl. Vat., *Cod. Vat. lat.* 6214, 71-72; 45-46.

147. Vittorio Peri, *Due Date. Un'unica Pasqua. Le origini della moderna Disparità Liturgica in una Trattativa Ecumenica tra Roma e Costantinopoli (1582-1584)*. Con appendice di documenti (Milan, 1967), 24.

148. Vittorio Peri, "La Data della Pasqua. Segno d'Unità e Occasione di Scandalo". *Vita e Pensiero*, XLVIII (9) (1965), 674-675.

149. Bibl. Vat., *Cod. Vat. lat.* 6415, 33-34.

150. *Ibid.*, 6417, 49.

151. *Ibid.*, 67, 69-92.

152. Schmid, *op. cit.* (ref. 71), 586-588.

153. *Ibid.*, 589-591.
154. Letter of 11 April, 1584; Bibl. Vat., *Cod. Vat. loc.* 6210, 83r; 6417, 66.
155. Bibl. Vat., *Cod. Vat. lat.* 6214, 18r.
156. *Ibid.*, 55-61.
157. Bibl. Vat., N. VII, 16.
158. Racc. gen. Orient. IV, 597.
159. 55.9.K.32.
160. According to Schmid, *op. cit.* (ref. 71), 585 in *cod. Angelicus* A 6, 18.
161. Schmid, *op. cit.* (ref. 71), 563.
162. *Ibid.*, 591.
163. Jean-Baptiste Joseph Delambre, *Histoire de l'Astronomie Moderne*, vol. I (Paris, 1821), pp. 2, 12, 58.
164. Peri, *op. cit.* (ref. 148), 673-674; *op. cit.* (ref. 147), 149-151.
165. ARSI (*Historical Archives of the Society of Jesus in Rome*) *Gall.* 95, II, 122r.
166. Bibl. Vat., *Cod. Vat. lat.* 6217, 60v.
167. Clavius, *op. cit.* (ref. 6), ch. 3 § 1, p. 65.
168. Bibl. Vat., *Cod. Vat. lat.* 6194, 414v, 463v.
169. Clavius, *op. cit.* (ref. 6), ch. 1, towards the end of § 7, p. 61.

VI.

RECEPTION OF THE REFORM

THE REACTION OF ASTRONOMERS TO THE GREGORIAN CALENDAR

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This paper has a bearing not only on the history of chronology in particular, but on the history of science in general. The reaction of astronomers to the calendar reform provides us with a very good example of the general problems involved in such an undertaking, especially those deriving from the practical needs of society. Furthermore, we can see clearly how external non-scientific factors influenced scientists when their opinions were sought.

The Gregorian calendar reform has been studied by such authors as Kaltenbrunner,[1] Schmidt,[2] and Stiewe,[3] to mention only the most important. I will restrict myself here to a few of the topics which, although touched upon in the literature, have never been clearly expressed. Not many astronomers reacted to the reform in anything like a critical way, and when they did so, we find that their objective criticisms were often colored by personal reasons arising from their different religious and metaphysical positions. Consequently the reaction of astronomers was not uniform. With few exceptions, none had an entirely negative reaction. One clear exception was that of mathematicians in Prague who refused to help the bishop change the calendar of feasts. There were those who opposed the reform for personal reasons or on general principles like the theologians Lucas Osiander (1534-1604) and Jacobus Heerbrand (1521-1600), and the astronomers Michael Maestlin (1550-1631) and Tobias Moller (2nd half 16th c.); but there were also supporters who, nevertheless, presented suggestions for changes.

Maestlin was the only astronomer to protest on general principles; other critics like Justus Scaliger (1540-1609), Georgius Germanus (2nd half 16th c.), Sethus Calvisius (1553-1617), and Franciscus Viëta (1540-1603), accepted the principle of reestablishing the calendar according to the traditions of the Council of Nicaea, but they submitted alternatives and corrections. Those in favour of the reform included Protestants like Bartholomaeus Scultetus (1510-1614), Tycho Brahe (1546-1601), and Johannes Kepler (1571-1630), as well as Jesuits such as Christoph Clavius (1537-1612), Paulus Guldin (1577-1643), and Dionysius Petavius (1583-1652).

To understand the reactions of astronomers we shall consider in turn the mentality of the astronomers, the arguments they propose and the circumstances under which their critique was expressed. Although the existing literature touches on these questions, they have never been treated separately and in detail. To understand the mentality of the various astronomers, we have to take into account their relationship to the "magisterium ecclesiae", the liturgy, and the Christian faith itself. Of particular importance is the different relationship of Protestant and Catholic astronomers to the "Magisterium ecclesiae". Maestlin's statements in his work, "Ausführlicher Bericht von dem allgemeinen Kalender",[4] an opinion addressed to the Pfalzgraf bei Rhein, are eloquent examples. According to him the Pope had no right to institute a calendar reform, and he did so only with a view to gaining power. The Pope was even a heretic. Maestlin argued that by calling the calendar a "Calendarium perpetuum" the Pope and the authors of the *Canones*[5] showed their disbelief in the Last Judgement which he himself thought would happen soon, thus providing a theological argument against the necessity for a calendar reform. But in his book *Elenchus Calendarii Gregoriani*,[6] Sethius Calvisius refuted this argument by stating that for the same reason it would be unnecessary to build any more houses in the future.

Totally different, of course, was the reaction of those critics with Catholic sentiments. Viëta, who submitted an alternative plan in his *Relatio calendarii*,[7] believed that the true intentions of the Pope were not really fulfilled by this reform and that Clavius was responsible for the errors. Georgius Germanus, however, who called himself a Catholic in his *Computus ecclesiasticus*[8] opposed the reform, criticizing Clavius, and he sent his paper to the Protestant mathematician, David Origanus (1558-1628) for examination, thus indicating that he hoped to unify the Catholic and Protestant opinions.

Such hope was also expressed by two other astronomers who were moderate critics of the Gregorian reform. The Catholic Jacobus Cuno in his *Theses de calendario Juliano*[9] proposed a compromise between the old and the new calendar, as did the Protestant Sethus Calvisius. Also conciliatory was the rebuttal to Maestlin's opinion which the Protestant representatives of the "Pfalzgräfliche Schule" at Neustadt a.d. Hardt[10] had composed for the Pfalzgraf.

The different attitudes of Protestants and Catholics towards the "Magisterium ecclesiae" become evident from the connection between the calendar reform on one side and liturgy and faith on the other. Luther in his tract "Von den Konziliis und Kirchen"[11] contested the very connection and Maestlin agreed with him. An anonymous opinion addressed to the Bavarian sovereigns affirmed the necessity of the reform, but required that the Protestants accept the new calendar only from the emperor. Maestlin is, however, the only astronomer to use this position clearly as a motive for his rejection of the entire reform, although the Lutheran preacher (not an astronomer), Jacobus Heerbrand, a representative at the Council of Trent, did likewise. Heerbrand, professor at the University of Tübingen, presented his objections in the *Disputatio de Adiaphoris et Calendario Gregoriano*.[12] He is even more strident than Maestlin. For Heerbrand the Pope was the Anti-Christ, who "putavisse posse mutare tempora". Essentially he put the question of whether the calendar reform is really an "Adiaphoron" and he concluded that it was not indifferent to one's faith whether it was accepted or not. Thus, its acceptance is not allowed even if the Emperor gives the order to do so. On the other side the *Confessio Augustana* maintained that the Easter rule was not an article of Faith.[13]

From the opposite point of view, in his work, *Explicatio ad Calendarium Gregorianum*, Clavius admits that the Pope has the right to declare Easter an immovable feast. Paul of Middleburg (Paulus de Middelenburgo), the chairman of the calendar commission of Leo X, had likewise stated this opinion in the fourteenth book of his *Paulina*.[14] For Rome the reform was primarily, but not exclusively, a religious concern. The bull, *Inter Gravissimas*, referred to the Council of Trent which had explicitly charged the Pope to reform only the breviary and the missal.[15] The result was a small calendar reform in 1568 together with the new breviary. The full reform of the calendar occurred only after the completion of the new Martyrology, an indication of the Church's thinking concerning the connection of the liturgy and the calendar, a connection which has a long tradition beginning with an early pre-Nicaean Easter sermon by Hippolytus of Rome († 235), who connected the Easter events with the cosmos. To

Hippolytus we owe our early Easter cycle and Scaliger commented on him in 1595 in the same work where he states his alternative to the Gregorian reform.[16] Shortly before, in 1551, the cycle of Hippolytus had been recovered in Rome.[17] Hippolytus, when speaking of the cross, says that it is the fulcrum of the universe, the point where all comes to rest. In regard to the death of the Lord we find that nearly the entire cosmos had collapsed and dissolved during the anguish of the passion.[18] An eclipse was believed to be a supernatural event and a sign of the extinguishing of the φῶς τὸ ἀληθινόν,[19] a tradition which we find again in the late medieval commentary on the "Sphaera" by Sacrobosco, which was the primer of astronomy for all priests up to the seventeenth century.[20] This treatise ends with a citation from the "Breviarium Romanum" which remained valid until 1971: "Aut Deus naturae patitur aut machina mundi dissolvetur".[21] The Church Fathers at the Council of Nicaea adopted, it appears, the same convention as Hippolytus when they fixed the Easter date to the first Sunday after the full moon which occurs after the vernal equinox. But because no Canon exists to prove this we have to rely on traditions and indirect sources.

One's view of the relationship between science and faith influenced attitudes towards calendar reform. For example, a scholar of the Thomist schools deriving from Albert the Great would think differently on these matters than a student of Latin Avveroism. For instance, the prevailing view at the University of Paris was that the reform should not be put into the hands of astronomers lest they should decide to replace ecclesiastical cycles with astronomical calculations. The Roman Curia was, indeed, wary of depending on astronomers because of such opinions as those of Galileo, who considered that astronomers were justified in their interpretations of Sacred Scripture in so far as astronomical topics were concerned.[22]

We now turn to the arguments proposed by various astronomers as to who should author the reform, how it was to be carried out and its consequences. Following the Council of Nicaea it was the Emperor Constantine who promulgated the encyclical which is preserved in the *Vita Constantini* by Eusebius.[23] Luther in his tract *Von den Konzilis* refers to this encyclical and appears to argue that the wordly sovereigns should be responsible for the calendar reform.[24] He thus initiated what was to become a traditional attitude for astronomers from the Protestant tradition. At the beginning of the Imperial Circular of 4/14 September 1583 it was noted that the new calendar had been established on the basis of the expert opinions and reflections of the court mathematicians employed by Christian sovereigns and rulers and with the previous knowledge of the emperor. Furthermore, it was acknowledged that uniformity in time calculation was necessary for commerce and traffic throughout the empire. The edict did not refer to the cycle of Church feasts or other ecclesiastical aspects of the calendar. The Elector of Saxony stated that time calculations were the emperor's task and, together with the Elector of Mainz, he claimed that in such matters the pope should present his opinions to a council and that consultations should be had so that any reform would proceed with unison among the various parties involved.

As to the precise details of the reform, there were various alternatives proposed to the one that was officially promulgated by Gregory XIII. Viëta was severely criticized for publishing a calendar with his own modifications but attaching a copy of the official papal bull *Inter Gravissimas*, thus giving the impression that his was an official version of the calendar. His modifications concerned the calculation of the epacts, the manner in which the intercalation days were inserted between the hollow and full months and the date for the beginning of the year. The astronomer Calvisius also criticized the calculation of the epacts. Georgius Germanus attempted to devise a calendar so that Easter would never occur before the date fixed by the Prutenic tables and so that the vernal equinox would not occur before March 21. Although he avoided some of the difficulties met by Clavius, his calendar was not on the whole as manageable as the one ultimately adopted. Scaliger contested the rule for leap years because it permitted the vernal equinox to occur other than on March 21.[25] Although his method matched the celestial movements better it did not possess the convenience of the one adopted. In his *Alterum Examen*[26] Maestlin criticized the whole method of calculating the cycle of epacts since he claimed it would create as many errors as the calendar it purported to reform. He assumed that the Prutenic tables, already discarded by Tycho Brahe, were used in the reform. Nevertheless, he himself used the Prutenic tables to argue that the leap year rule of the calendar reformers would place the vernal equinox at the time of the Council of Nicaea on March 20 instead of on March 21. For this he was justly reproached by the Jesuit Possevinus (1534-1611). The reformers had, as a matter of fact, also used the Alfonsine tables.

On the other hand, Maestlin's strong desire that strict astronomical methods be applied in the reform was based upon a quite justified concern for the civil effects, such as trade and commerce, which a reform of the calendar entailed. It was in this spirit of responding to the necessities of civil society that Schulin published a calendar with both the old and the new style reckoning but, in so doing, he had to defend himself against reproaches for not allowing the new calendar to stand on its own even at the risk of creating confusion.[27] Well founded intentions, however, can go too far. Some Protestant intellectuals went so far as to claim that the papal edict was against nature. For instance, in the anonymous *Bawrenklag uber des Romischen Papstes Gregorii XIII newen Calendar* it was stated that farmers no longer know when to till the ground and the birds are uncertain as to when they should sing and when they should fly away. The argument of Maestlin and Osiander that the pope had stolen ten days from the farmers' life is found in a copy of a proclamation in which a Bohemian priest tried to explain the loss of ten days to his faithful. On their part those of a Catholic tendency also went to absurdities such as the claim that a nut tree, in response to the papal promulgation of the calendar, blossomed ten days in advance in Gorizia, Italy.[28]

At the request of Count Palatine Ludwig Philip, Paulus Fabricius prepared for the emperor a criticism of Maestlin's work whereby he accuses Maestlin of inconsistencies on several points and recommends that he should have reserved his criticism for the strictly scientific questions associated with the calculation of the cycles.[29] However, Fabricius' criticism was suppressed by the imperial court which was seeking conciliation between the various factions.

The first printed defense of the calendar, published in Mainz in 1585, is by the Jesuit Johannes Busaeus (1540-1587).[30] Some of his main arguments, directed against Heerbrand are: Constantine initiated but did not execute the rule for determining the date of Easter; it is a practical matter that the pope should carry out the reform since neither the Protestant sects nor the German sovereigns agree among themselves and, furthermore, the world is larger than the German empire; the new calendar is not substantially but only accidentally different from the old and the difference pertains to mathematics and not to theology. Another defense of the calendar reform was given by Johannes Rasch of Munich[31] but his arguments, directed mostly against Maestlin, are not very convincing. The Jesuit Possevinus also refuted Maestlin and announced the forthcoming reply of Clavius.[32] In his *Apologia* to Maestlin[33] Clavius explained why the use of mean motions was adopted, the principal reason being that no tables giving exact true positions with time existed. He argued, furthermore, that local longitude differences would cause discrepancies and thus the traditional desire, since the Council of Nicaea, that all Christians celebrate Easter on the same day could not be realized except by the use of mean motions. Clavius also showed that in any reasonable calendar the variation of the date of Easter, namely that it could be celebrated at the beginning or at the end of the first full moon of spring, could not be avoided. In 1606 Clavius wrote a work against the criticism of Scaliger showing that his suggested method of intercalation was not practicable.[34] Scaliger later responded to Clavius in a personally offensive way.[35] Although Clavius advanced further objective arguments,[36] the discussions had by now reached the level of personal vituperation.

We would now like to discuss the ways in which consultations and eventually the promulgation of the calendar took place. Bishop Hugelinus Martellus († 1593) in two treatises argues that the Church hierarchy was to be respected in matters of the calendar[37] and, like Josephus Zarlinus,[38] he proposed that dates be fixed according to the vernal equinox and the celebration of Easter at the time of the Council of Nicea. This was also the thesis of Floridus Plieningerus but his his arguments were based mostly on a kind of mystical experience.[39]

It is undoubtedly true that many difficulties could have been avoided had agreements been sought more diligently with the civil authorities and with the Protestants. However, the *Compendium* of Lilius was not sent for evaluation to the Protestant sovereigns and the universities.[40] Furthermore the new calendar was not presented at the Diet of Ausburg called by Rudolph II in 1582, as attested to by the archduke Ferdinand of Tyrol. When the calendar was promulgated with the issuance of the bull, *Inter Gravissimas*, the *Canones* and an example of the calendar for the last quarter of 1582, there were complaints that it was not available enough. For instance, the Elector of Brandenburg said that he could not introduce the calendar at the time requested because the issues printed in Rome were not available. The mathematician, Martin Chemnitius (1522-1586) regrets that he cannot comment on the reform because he has received only fragmentary information from Danzig, Posen and Munich.[41] A further difficulty arose from the fact that the official explanation of the calendar, *Liber novae rationis restituendo Calendarii*, promised in the *Canones* never appeared. Infact it was only twelve years later that a substitute for it in the form of the Clavius[42] was issued. Although the *Explicatio* contains much material reflecting Clavius' personal arguments with various critics, it is an official document of the Church issued with the authority of the Pope and containing all of the principal documents of the reform: the Bull, *Inter Gravissimas*; the *Canones*; an example of the calendar for October-December 1582; and the *Compendium* of Lilio.

Some mathematicians, feeling that not enough scientific rigor had been applied to the calendar reform, made other attempts of their own. Paulus Fabricius, an expert of the emperor on calendar matters, composed a calendar in 1583 proposing that it be gradually introduced by issuing it alongside the old calendar until 1600.[43] Theodorus Graminaeus, an astronomer, lawyer and theologian at the University of Cologne, wrote in 1583 his *Exhortatio de exequenda Calendarii correctione* [44] and in 1595 an article entitled *Supputatio Ecclesiastica* [45] appeared, written by the personal physician of the bishop of Würzburg, Adrianus Romanus (1561-1615), later court mathematician for the king of Poland. The reactions of individual astronomers to the promulgation of the calendar ranged from the ridiculous mercenary interests of a Tobias Moller to the interesting debates of Kepler and Brahe. Moller complained that he had not received the compensation he requested for having proposed a new calendar to the Diet at Augsburg in 1582 and he refused to list his arguments against the Gregorian Calendar for fear that they would be plagiarized and he would suffer financial loss.[46]

Both Tycho Brahe and Johannes Kepler were imperial mathematicians and Protestants and these factors undoubtedly placed some constraints on their expressing opinions on the calendar. Brahe responded positively to the Gregorian reform and from the very beginning used the new calendar to date his correspondence and his observations. We have two letters from him in which he states that there are no problems with the new calendar except that it is difficult for the Protestants to accept that it was authored in Rome.[47] Kepler expresses the opinion that the Gregorian Calendar is the best of those which had been constructed.[48] He left a posthumous article which presents his arguments in the form of a dialogue between a Protestant chancellor, a Catholic preacher and an expert mathematician. His summary sentence is of some interest: "Easter", said he, "is a feast and not a planet. You do not determine it to days, hours, minutes and seconds." [49] In 1613 at the Diet of Regensburg Kepler unsuccessfully argued that the Gregorian Calendar be adopted, stating that it did not involve the acceptance of a papal bull but only the result of the work of astronomers and mathematicians. But the Protestant sovereigns did not begin to yield in their resistance to the Gregorian calendar until 1699, when the astronomer, Erhard Weigel (1625-1699), a teacher of Leibniz, suggested replacing the tables of Clavius with the Rudolphine tables of Kepler, which were first printed in 1617.[50] Nonetheless, in the century or so following the promulgation of the Gregorian calendar there were a number of publications by astronomers supporting it.[51] In 1703, one hundred years after Pope Clement VIII's declaration on the calendar,[52] Francesco Bianchini (1662-1729), secretary of the Church's calendar commission and former librarian of Pope Alexander VIII, pronounced a final official statement on behalf of the Roman Curia.[53] Still in the subsequent years, up until 1775, the controversy continued concerning the determination of the date of Easter. Infact, a calendar issued in February 1700, based upon an astronomically exact determination of the date of Easter, placed the Protestant celebration of Easter one week earlier than the Catholic celebration in the years 1724 and 1744. The last differences were finally abolished by decree of the German Emperor and of the King of Prussia, Frederick II.

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THE RECEPTION OF THE CALENDAR BY OTHER CHURCHES

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Today we look back four hundred years to the Gregorian reform from a world in which the calendar is accepted without question by countries where Christianity has little influence. The calendar has proved itself a tidy and effective way of keeping the dates of the year closely in step with the seasons, a secular issue in which religion has no part. It is easy, therefore, for us to forget the religious motives behind the reform, the exceptionally intense religious conflict that formed the historical context of the reform, and the religious attitudes that influenced and often determined the acceptance or otherwise of the reform.

The minor modification in the pattern of future leap years might perhaps have won increasing acceptance in Europe without undue difficulty, especially if circumstances had made possible its introduction by secular rather than religious authority. But the restoration of the spring equinox to 21 March, its date at the Council of Nicaea, was undertaken *for religious reasons only.* There was an argument that, if any restoration was called for, it should be to the date of the equinox at the time of Christ; and, more importantly, that the restoration should be achieved painlessly, through the omission of 29 February in the scheduled leap years for the next four decades, rather than by the brutal excision of part of October 1582. More upsetting still to the Christian conscience was the new procedure for calculating Easter, which the Papacy was unilaterally adopting: one procedure among many possible, a procedure whose results deviated at times from the astronomical Moon, and one that involved setting aside the prescriptions thought to come from the Council of Nicaea and the abandonment of the agreement among Christians that had taken so many centuries to achieve. Christendom would have found such changes hard to swallow even in the most favourable context. In fact, the reform was imposed by a Bull that was often thought — but erroneously — to include the threat of excommunication, a Bull issued 32 short years after the death of Luther, when bitterness against the Papacy was greater than ever before or since.

The Reception in England

In the circumstances, the sympathetic attitude to the reform on the part of the secular authorities in England, discussed in the following paper, is remarkable and does credit to those involved — for had not the Queen, Elizabeth I, herself been excommunicated by an earlier pope in just such a Bull? The reform was referred to the mathematician John Dee for assessment, and his favourable verdict passed for comment to the astronomer Thomas Digges Henry Savile, scholar and patron of the sciences, and a Mr Chambers.[1] This committee of three endorsed Dee's response, and so in a letter dated 18 March 1582 (that is, 28 March 1583 by Catholic reckoning, for the new year began in England on 25 March rather than 1 January), Sir Francis Walsingham referred the matter to the Archbishop of Canterbury. The Archbishop was invited to confer with any bishops within easy reach "and thereupon return your opinion what you think of the same, and whether it be meet to be passed as it is set down, which it may please you to doe with all convenient speed, for that it is meant the said callendar shall be published by proclamation before the first of May next".[2] A mere eleven days later, on 29 March 1583 by English reckoning, the poor archbishop received a 'hastener' from Walsingham that left him in no doubt that he was expected to respond quickly and favourably: ". . . her majesty doth now find some fault that [she] doth yet hear nothing of the reports thereof that she looked to have received your grace".[3] The civil authorities could hardly have done more to press for conformity with Rome, but they had reckoned without the antipathy of churchmen to anything emanating from the Pope. On 4 April the archbishop replied in a letter of his own accompanied by comments from other bishops and from a "godly learned in the mathematicalls". In a masterly use of delaying tactics, they declared they could not consent to the change

> before mature and deliberate consultation had, nott only with our principall assemblie of the clergie and convocation of this realme, but also with other reformed Churches which profess the same religion as we doe, without whose consent if we should herein proceed we should

> offer juste occasion of schisme, and so by allowinge, though not openly yet indirectly, the Pope's dewyse and the [Tridentine] counsayle, [cause] some to swerve from all other Churches of our profession...[4]

We see how the archbishop escaped from the royal pressure on him as an individual by insisting on consultations so widespread that months if not years must elapse before a decision could be reached. And, more generally, he makes what was to be a repeated objection, that by accepting the change England would be submitting to the Pope's decree and by implication, to the general authority of the Pope and of the recent Council.

The accompanying documents amplify this point. What was done by the General Council at Nicaea can be undone only by another general conuncil, one in which — unlike Trent — all churches take part. And, "seeing all the reformed Churches in Europe for the most part doe hold affirme and preach that the Bishop of Rome is Antichrist, therefore we may not communicate with him in any thing as receaved from him, according to the Apostle, 2 Co. 6".[5]

Other documents urge that a change is pointless. Merchants agree that "they may use their trafficke as well without that alteration as with it".[6] Indeed, those merchants who "have occasion to traffik with the north and north-east parts (who have not receaved this alteration)" would be "driven to use the old kalendar still".[7] In any case, since the end of the world is not far off, the calendar will not have time to get much worse than it is, so "we doe think that the Pope might very well have spared his labour in this matter".[8] In any case, a nation that managed to live for nearly three months in every twelve in a different *year* from their Continental neighbours could easily cope with a difference of ten days. To this the "godly learned in the mathematicalls" adds that Lilius himself admits that occasionally his system of Easter epacts will mean that Easter will not be the next Sunday after the astronomical Full Moon, which is against the Council of Nicaea.[9] But the fundamental objection, reiterated in many different forms, is that England cannot accept the change, even if desirable on its own merits, *because* it has been imposed elsewhere by the Pope, who is repeatedly identified with Antichrist: "We should seem to some, not duly considering the cause of the alteration, nor well staid in religion, that we doe it for fear of the Pope's curse and excommunication, because he doth command it under payne of excommunication to be observed by all men".[10]

No doubt it was the procedural obstacle that was the principal element in the defeat of the Queen's attempt to have the reform introduced into England, and for another 170 years England was to be ten (or, after 1700, eleven) days ahead of the Continental calendar and to begin each year on 25 March. (The English are slow to change: to this very day the tax year ends on 5 April, which is 25 March adjusted to the Gregorian calendar.) A proposal in 1645 to adopt the New Style of dating came to nothing,[11] and eventually in 1699 the Archbishop of Canterbury revived the question with the veteran Puritan mathematician, John Wallis. Wallis published his response in *Philosophical transactions*,[12] and we find the arguments against reform have changed little since the time of John Dee. One should not hurry to make changes lest the new state "will be attended with greater Mischief, than the present Inconvenience".[13] If Pope Gregory was unhappy with the timing of Easter, he should have changed the Easter reckoning and left the civil year alone: now we have two calendars in use where formerly there was only one "and which now can never be remedied; unless all Nations should, at once, agree upon one; which is not to be supposed".[14] True, most Catholic countries use the reformed calendar.

> But your Grace knows very well, that the Church of *England* had (long before this pretended Correction) Renounced the *Pope's Supremacy*; and (that being supposed) there is no pretence for the Pope of *Rome*'s imposing a Law on the Church and Kingdom of *England*, to change our Ecclesiastical and Civil year; more than in Us, for that in *Rome*... And really, though it may not yet appear and be owned above board; and, those who now press for an alteration, be not aware of it, and be far from any Popish design, I cannot but think there is, at bottom, a latent Popish interest, which (under other specious pretences) sets it on foot; in order to obtain (in practice) a kind of tacit submission to the Pope's Supremacy, or owning his Authority. And though they be so wise as to say nothing of it at present (for the Bait is designed to Hide the hook till the Fish be caught), they will please themselves to have gain'd *de facto*, what in words we disclaim.[15]

Wallis has nothing good to say about the new calendar. The first thing astronomers do, he says, unfairly, is to find the Julian date for an event. "And consequently how unreasonable it is for us to exchange our better Julian Year for one that is so much worse." [16] Instead it is the Papists who should change back again. And if one is to embark on calendar reform, it would be logical to alter the numbering of the years *anno domini* so as to count them from the true birth of Christ.[17] "And there is no Inducement for our changing our Better Year, for a Worse, but only in compliance with the Pope's pretended *Supremacy*, not only over all Churches and Kingdoms, but even the Celestial Motions." [18]

At long last, by the middle of the eighteenth century, England prepared to end her calendrical isolation by adopting the Gregorian dating and beginning the year on 1 January (as even neighbouring Scotland had done ever since 1600). In preparing the way for this change, the Earl of Macclesfield also urged the adoption of the Gregorian rule for Easter:

> For tho' I am aware, that their Method of finding the Time of *Easter* is not quite exact, but is liable to some Errors; yet I apprehend, that all other practicable Methods of doing it would be so too: And if they were more free from Error, they would probably be more intricate, and harder to be understood by Numbers of People...: And it is of no small Importance, that a Matter of so general a Concern, as the Method of finding *Easter* is, should be within the Reach of the Generality of Mankind, at least as far as the Nature of the thing will admit.[19]

In October 1752, by Act of Parliament, eleven days were omitted from the English calendar, thus bringing Christmas suddenly closer and upsetting ordinary folk. Sermons had to be preached to reconcile them to the change, one of them by the Rev. Peirson Lloyd, who addressed his flock on the theme "The New Style the True Style". Lloyd pointed out the long-term absurdity of the old ways, as a consequence of which "in Process of Time, the two Festivals of *Christmas* and *Easter* would have been observed on one and the same Day".[20] The old objection, that by adopting a popish reform one would seem to accept popish authority, had been removed by the passage of the years: "If the Correction of the Calendar had been then introduced here, when we had but just shaken off his [the Pope's] grievous Yoke, and when other Countries, owing the Jurisdiction of the Church of *Rome*, had received the same under the Direction and by Authority of the Pope, it might have given a Handle to inculcate the Doctrine of his Infallibility, since he could correct the Calendar, and made People less inclined to receive the Changes in Religion carried on in opposition to his Authority and Influence."[21] But after so many years, the morbid hatred of Rome was no longer a decisive obstacle to reform.

The Reception in Protestant Lands

The obstacles hastily and effectively thrown up in England by Elizabeth's bishops to frustrate her wish to implement the Gregorian reform had been expressed in language moderate by the standards of the time. In Protestant Germany language of far greater violence was to be heard, though the arguments were at root the same. From the many works published let me pick as my example the *Disputatio de adiaphoris, et calendario Gregoriano* by James Heerbrand, published in Tübingen in 1584. Heerbrand was born in 1521, and had been professor of theology at Tübingen since 1557. For him, Gregory the calendar-maker, "Gregorius Calendarifex",[22] is repeatedly "Romanum Antichristum",[23] and the calendar is a Trojan horse.[24] "In Bulla sua", he says of Gregory, "rugit Leo infernalis".[25] The Bull's reference to "the authority given to us from the Lord" he amends to "from the Devil".[26] "We do not recognise this Lycurgus (or rather Draco, whose laws were said to be written in blood); we do not recognise this legislator, this calendar-maker, just as we do not hear the shepherd of the flock of the Lord, but a howling wolf." [27] In an impressive display of sustained invective, he says of the unfortunate Pope: "All his loathsome and abominable errors, his sacriligious and idol-worshipping practices, his vicious, perverse and impious dogmas that are condemned by the word of God, the decrees vomitted up from the letter casket of his belly, the torrent of evils, these little by little he will once more insert into our churches, he will newly plant his tyrannical yoke on our necks...", and so on.[28] The calendar is an extension of the Council of Trent, its purpose is religious rather than civil, it is the yoke of the Roman tyrant and Antichrist.[29]

And what is Heerbrand's audience to do in the face of these evils? "Discharging the office of faithful shepherds, the slobbering wolf that threatens your flock you keep at a distance from the sheep pens and the flock, in your barking you are not guard dogs without a voice, you deny him and drive him away." [30] "Stand firm in that liberty of yours, and fight for it as befits strong athletes and soldiers of Christ." [31]

This was not the atmosphere in which to conduct a dispassionate assessment of the merits of the reform, and it is not surprising that, as explained in the following paper, the reformed calendar was not adopted in Germany until 1700, and even then Easter was to be calculated from the Rudolphine Tables rather than from the epacts. But this attempt to make Easter conform to astronomical reality only proved the wisdom of the artificial epacts: for in addition to creating divergencies among Christians over the date of the celebration, the Rudolphine Tables were in some years sufficiently in error to result in an Easter that conflicted with astronomical reality; and so, in 1775, Germany too adopted the Gregorian Easter.

The Reception in Orthodox Lands

Fraught though the years of the reform were for Western Christendom, the situation in the East was still more dangerous and uncertain. Protestant theologians from Tübingen hoped to find a reforming ally in the Patriarch of Constantinople, and copies of a Protestant catechism in Greek had been sent to that city.[32] The Papacy looked to the Patriarch for a common front against the reform. The Orthodox churches were divided among themselves and morale among both clergy and laity was at a low ebb. And in Constantinople the Patriarch had to contend with hostile and brutal Turkish rulers made all the more nervous by the recent setback at Lepanto. The situation was redeemed in part by the exceptional calibre of the Patriarch himself, Jeremiah II Tranos. Clearly the acceptance of the new calendar by the Patriarch would be a major step towards the implementation of the reform, and it was advisable that the reform be not introduced without prior discussions with the Patriarch and other Orthodox leaders.

The matter had to be handled with extreme delicacy: other Orthodox leaders displayed a crude hostility to Rome, and the Turks were nervous and highly sensitive to anything that smacked of a moral alliance against them on the part of Greek and Latin Christendom. The approach was therefore made to the Patriarch under cover of a delegation sent to Constantinople in the late spring of 1582 by the city of Venice (which had trading links with Constantinople) to attend a Moslem ceremony for the son of the Turkish emperor. A layman, Livio Cellini, went as one of the party of twelve, and the day after their arrival on 27 May 1582 he was received by the Patriarch to whom he gave a book, probably the Compendium, that set out the arguments for reform. The response of the Patriarch and his colleagues was cautious but not hostile; Cellini explained that, far from abandoning Nicaea, the Latins wished to fulfil more adequately the intentions of the Fathers of the Council.

In the following weeks the Patriarch found occasion to explain to Cellini the practical difficulties he faced in winning over to such a reform a church presently in a low state of morale. He himself was clearly sympathetic, but Jeremiah's sympathy was severely jolted when a copy of the Bull arrived from Rome revealing that the Papacy had already gone ahead with a unilateral imposition of the Reform. Even then the Patriarch's nobility of character overcame his irritation, but the same was not true of other Orthodox leaders, and a Synod held in Constantinople in November condemned the changes in harsh terms: the reform was against tradition, the Scriptures, the councils, and the Fathers; undertaken for inadequate reasons, it showed the vanity of the Papacy. Jeremiah had no option but to conceal his true sympathies and endorse the stance taken by the Synod.

In great secrecy, two more laymen were sent early in 1583 to Constantinople, and cloak-and-dagger discussions with the Patriarch occupied most of the summer. They were convinced that Jeremiah was for the reform; but the Patriarch did not have the monarchical authority of the Papacy. To secure adoption of the reform, he had to carry with him the other Orthodox patriarchs, and this he feared he could not do. Nevertheless the laymen returned to Italy delighted with the apparent success of their mission, and confident that the reform would be introduced in the East and that this would encourage closer relations between East and West. Alas, in February 1584 the Turks, alarmed at rumours reaching them, moved decisively against the Patriarch and his flock. Churches were closed, the Patriarch arrested and threatened with death, and a collaborator substituted in his place. In the event the Patriarch was exiled to Rhodes, and was not restored to his see until the end of 1589. There were renewed efforts from Rome to establish contact, but the opportunity had been lost, and a Synod held in Constantinople in 1593 took the opportunity definitively to condemn the reform.

In the present century, efforts have been made among the Orthodox to resolve the confusion that exists among their various churches. As things are, some follow the Julian calendar and the old calculations for Easter, some follow the Gregorian rule, and others follow a mixture of the two.[33] The number of autonomous or semi-autonomous churches makes agreement on any change difficult, and there is more hope of the adoption of a compromise ecclesiastical calendar than of the straightforward acceptance of the Gregorian reform. Provided what is done is equally acceptable to the principal Protestant churches, there seems no reason why the Papacy should not be open to such a compromise if as a result all Christians can celebrate their principal feast together.

Conclusion

The churches of a revealed religion are naturally resistant to change even in a theologically peripheral area, and most human beings prefer the familiar. It is therefore not surprising that the Gregorian reform was so widely opposed. Yet, as we have seen, the driving force behind the opposition was always dislike and even hatred of the Papacy. But the lesson to be learned from the ordeal of the Patriarch Jeremiah is that without monarchial power such as the Papacy possessed and was willing to use, no such reform could have been successfully introduced in the Europe of the sixteenth century, and perhaps for centuries thereafter. The Papacy was hated for the exercise of power; but there was no other way.

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THE CIVIL RECEPTION OF THE GREGORIAN CALENDAR

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In the present symposium the civil acceptance and the ecclesiastical reaction to the Gregorian calendar have been somewhat arbitrarily divided. In the 16th century, however, church and state were so entwined that the distinction is, at least for the early period, to some degree artificial. In the first instance, the civil acceptance of the new system was determined by the religious affiliation of the respective rulers.

Reception in Roman Catholic Countries of Continental Europe

In the Roman Catholic countries and their colonies the transfer to the Gregorian calendar generally took place as planned in 1582. In practice this meant that Italy, Spain, Portugal and Poland adopted the new dates in October.[1] Poland then included Lithuania and Latvia, and in the latter area the calendar reform was vigorously resisted as part of the political turmoil of that period. Later, when these areas became separate from Poland, they reverted to the Julian calendar until the present century. As for the Latin American colonies, rather specialized research would be required to learn how soon the new calendar took effect.[2]

In France the bishopric of Strasbourg moved first, in November, and the rest of the country followed in December after an edict from Henry III. Belgium and the Catholic States of the Netherlands likewise switched from the Julian to Gregorian calendars at the end of 1582. Ginzel's *Handbuch der mathematischen und technischen Chronologie*, one of the principal authorities on these matters, says that December 22 became January 1 in Flanders and the southern provinces of Belgium, which suggests that Christmas was omitted in 1582. This is confirmed by a letter from Thomas Stokes, an English merchant in Bruges, to Sir Francis Walsingham, the English Secretary of State; Stokes wrote that "Yesterday by proclamation from the Court, and proclaimed here in this town, 'that yesterday' was appointed to be New Year's Day and to be the first of January; so they have lost Christmas Day here for this year. — Bruges, the 23 December 1582, '*stillo anglea*'; and here they write the 2 January 1583." [3]

The transalpine Catholic regions adopted the reform in an extremely patchwork manner. Some parts of Austria moved to the new calendar in October of 1583, and others two months later, in December of that year. The town of Augsburg accepted the Gregorian calendar in February of 1583, but Bavaria as a whole waited until October. Würzburg, Münster, and Mainz all moved to the new system in November, but each dropped a different set of ten days. The Catholic portions of Switzerland changed to the Gregorian scheme on January 12/22 of 1584, which means that some cantons were split in their usage for over a century. Bohemia, Moravia, and the parliament in Prague under the Emperor Rudolph II also adopted the reform for the Catholics in January of 1584.[4]

Reception in Protestant Countries of Continental Europe

The Protestant regions of Germany were bitterly opposed to the new calendar. Michael Maestlin, the astronomy professor at Tübingen University, led the opposition on technical grounds and even edited a book of sermons against it. Although his student, Johannes Kepler, did not have such strong objections, he nevertheless retained the Julian system for his own ephemerides and the *Tabulae Rudolphinae*. Protestant Germany and Denmark held out against the Gregorian calendar until the very end of the 17th century. By then the Danish astronomer Ole Roemer helped persuade the king of Denmark on the virtues of calendar reform by a series of six arguments which were no doubt typical at this time. They were:

1. to seek agreement with other nations with respect to time reckoning seems better and more fruitful — however wrong the other nations might be — than to use a local, although accurate method, that nobody else will adopt;

2. all the errors inherent in the new system will appear only in ten or twenty thousand years, and are even then in dispute, whereas the errors of the old style are obvious without dispute after one or two centuries;

3. the only hope of reaching an agreement with the ensuing beneficial results is that the minority follows the majority, and particularly now when the majority is right;

4. the political considerations of our reformed churches are no longer the same as they were a hundred years ago when *pontifices* tried to presume upon Christendom by forcing this correction through; and the example of the Dutch proves that a reformed nation can seek a convenient solution of this question without any [bad] consequences;

5. everything points to the conclusion that the new style must sooner or later be adopted by the reformed, and perhaps it is already in preparation. If this is done by the Germans, or the English, or by both, we must needs follow them, whereas now we can publicly appear as their predecessors;

6. the time for such a change will be more convenient anno 1700 than at only other time during the next century.[5]

In Germany G. W. Leibnitz advocated the change. A face-saving move became possible in the work of the Jena astronomer Erhard Weigel, who proposed an "improved calendar", which matched the Gregorian scheme with respect to the dates; but which used astronomical reckoning according to Kepler's *Rudolphine Tables* rather than the cyclical system for establishing the Paschal full moon.[6] Germany finally abandoned the Julian pattern in February of 1700, as established by the Diet of Regensburg, and Denmark also made the change then. This was a critical time, because in the Gregorian reckoning 1700 was not a leap year, and hence the two systems moved out of phase by 11 days in March of that year. The capitulation of the remaining German principalities was apparently too much for the northern Swiss cantons — Basel, Bern, Geneva, Schaffhausen, Zurich, etc. — and they abandoned the Julian calendar at the beginning of 1701. Likewise, the Protestant States in the Netherlands changed at this time. The differences between the Gregorian and the "improved calendar" adopted in these Protestant lands became apparent in 1704 when the date of Easter by the cyclical calculation fell on March 23 and by the astronomical calculation on April 20. Again in 1724 the dates fell differently, a week apart. This situation was not straightened out until the time of Frederick the Great in 1775.

Meanwhile, in Sweden the situation became even more complicated. First, they omitted the leap day in 1700, thereby keeping their calendar ten days out of phase with the Gregorian system but now one day out of phase with the Julian system.[7] Apparently they also adopted the astronomical calculation of Easter, thus placing Swedish Easter on a date different from that of everyone else. The Swedes went back to the Julian dates in 1712 by adding an extra leap day, February 30, but retaining the astronomical calculation of Easter. Finally in 1753, a year after England at last became enlightened, Sweden adopted the Gregorian calendar, becoming the last country of Western Europe so to do.

Reception in England

The story of calendar reform in England is unusually long and well-documented. After decades of resistance, a turning point came quickly on 25 February 1750 (that is, 1751), when Lord Chesterfield introduced into the House of Lords a bill entitled "An Act for Regulating the Commencement of the Year [which was then observed in Britain on March 25], and for Correcting the Calendar now in Use." One secondary effect of this event was to generate an interest in England in the history of calendar reform, and I have found in the Houghton Library at Harvard a contemporary manuscript account by one Samuel Reynardson,[8] whom I have otherwise been unable to identify. I shall mention some of his remarks, not because he is necessarily an impeccable authority, but because they show an educated view of the matter some two centuries ago.

Reynardson quotes from the 17th-century antiquarian Robert Plot (1640-1696) who had observed "that whatever was done in this matter must in great measure be imputed to *Friar Bacon*, their whole reformation scarcely differing from his, except in the circumstance of the equinoxes, and solstices, which the Pope reduced to the places which it was supposed they held in the time of the council of Nicea, which Bacon would have brought to their places at a much more eminent Epoch, viz. at the time of the birth of Christ... being a time of much higher value and more to be esteemed by Christians than the Nicean council; in whatever else they have exceeded Bacon, in this they fell greatly short of his reformation."

Reynardson next points out that at the same time the calendar reformation was under consideration in Rome, John Dee had written a treatise on the same subject for Queen Elizabeth.[9] Of great importance to Dee were the observations bearing on the length of the year, and for me it was particularly interesting to see how he worked out his treatise with one of his two copies of Copernicus' *De revolutionibus* at his side, studying precisely the same parts of Book III that interested the technically-inclined continental astronomers during the same decades. Dee also consulted the

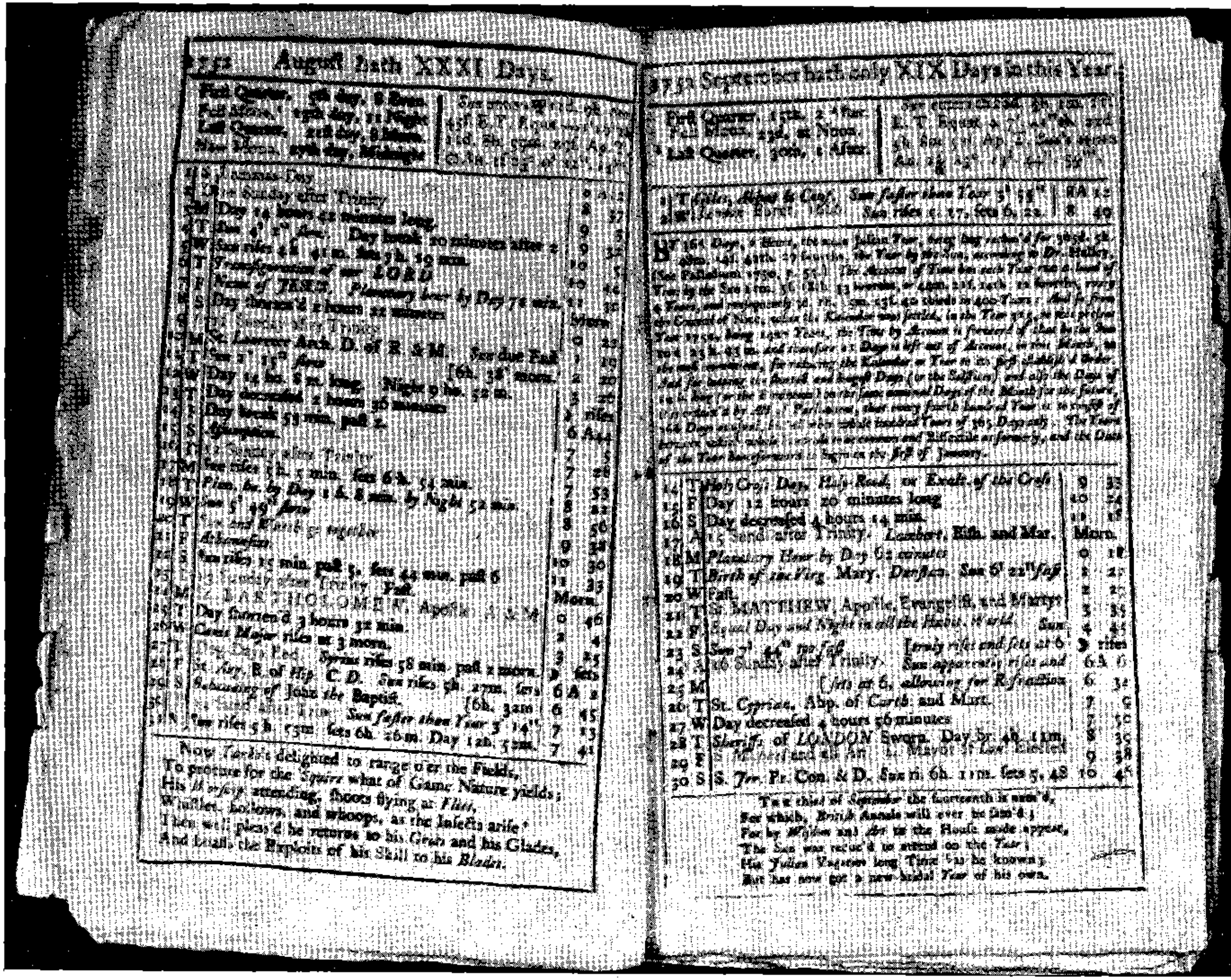


FIG. 1. Pages illustrating an English Calendar from *The Ladies Diary: or, the Women's Almanack for the Year of Our Lord, 1752.* Courtesy of O. Gingerich.

Basel 1551 edition of Ptolemy, and he referred to Reinhold's *Prutenicae tabulae.* Not until 32 pages into his somewhat rambling treatise does he get to more specific comments on calendar reform. Like Bacon, Dee preferred to rectify the calendar to the time of Christ rather than to the Council of Nicea, which required 11 rather than 10 days to be dropped. Near the end of his manuscript, in a petition to the queen, he wrote, "Yet, at the least, that therewithal, her Majestie will *Protect* her knowledg [sic] and assertion that *The true Reformation of tyme cheiflie to be now used of all Christians, is by abatinge of Eleven daies out of the Kalendar, Referred, and reformed to the tyme of Christ*", and he added that he hoped this would prick the consciences of the other Christian princes. However, according to the account of Lord Burghley, the chief administrator for Queen Elizabeth, Dee ultimately advised the Queen to follow the Gregorian scheme rather than go in non-conformity to the rest of the world, only announcing the truth of the matter "hoping that the truth will draw the Romanists and other parts of Christendom to take out of their calendar hereafter the same odd day." According to Reynardson, Dee also proposed to eliminate the ten days in a less traumatic way, taking three from May, one from June, and three each from July and August, thereby changing no festival days. (But see page 102 ff. for what Dee actually proposed to do.)

Lord Burghley sent Dee's treatise to Thomas Digges, Henry Savile, and a Mr. Chambers for review.[10] In March of 1581-1582 these mathematicians reported favorably, agreeing that while it would have been better to eliminate 11 days, it was desirable to stay in accord with the other countries. Sir Francis Walsingham, the secretary of state, then requested the aging Archbishop of Canterbury to consult with several other bishops and to give an opinion on the matter. Early in April the Archbishop responded that the bishops wished to take no action until they had an opportunity to consult with their own clergy and with the other Protestant churches. Suffice it to say, the favorable opinion of the mathematicians and the civil advisors were insufficient to overcome the deep resistance of the ecclesiastical authorities in England.

Reynardson remarks further that "The correction of Style was again proposed about the year 1750 by the *Earl of Macclesfield*, and countenanced and promoted by *Lord Chesterfield*; when many objections were raised thereto and many inconveniences expected to arise therefrom: But so much care and circumspection was employed in setting the Bill, which past into a law the year following; as fully to answer the views of those who promoted it."

George Parker, the second Earl of Macclesfield, had erected his own fine observatory at Shirburn Castle, and was long a member of the Royal Society, becoming its president in 1752. He was well connected with the circle of Newtonians and a close friend of James Bradley, the Astronomer Royal. In 1750 Lord Macclesfield presented a paper to the Royal Society on the solar and lunar year, which must have catalyzed the sentiments for calendar reform in England. Nevertheless, he was very circumspect about the matter, saying only that "If therefore this Nation should ever judge it proper to correct the Civil Year, and to make it conformable to that of the *Gregorians*, it would surely be advisable to correct the Time of the Celebration of the Feast of *Easter* likewise, and to bring it to the same Day upon which it is kept and solemnized by the Inhabitants of the greatest Part of Europe, that is, by those who follow the *Gregorian* Account." [11]

Philip Stanhope, the second Earl of Chesterfield, was a cosmopolitan man, now perhaps best known for the long series of letters to his son, and it is in these letters that we find a charming vignette on the passage of the calendar reform bill in Parliament. He wrote: "I acquainted you in a former letter, that I had brought a bill into the House of Lords for correcting and reforming our present calendar... It was notorious, that the Julian calendar was erroneous, and had overcharged the solar year with eleven days. Pope Gregory the Thirteenth corrected this error; his reformed calendar was immediately received by all the Catholic powers of Europe, and afterward adopted by all the Protestant ones, except Russia, Sweden, and England. It was not, in my opinion, very honorable for England to remain in a gross and avowed error, especially in such company; the inconveniency of it was likewise felt by all those who had foreign correspondences, whether political or mercantile. I determined, therefore, to attempt the reformation; I consulted the best lawyers and the most skillful astronomers, and we cooked up a bill for that purpose. But then my difficulty began: I was to bring in this bill, which was necessarily composed of law jargon and astronomical calculations, to both of which I am an utter stranger. However, it was absolutely necessary to make the House of Lords think that I knew something of the matter; and also to make them believe that they knew something of it themselves, which they do not... I gave them, therefore, only an historical account of calendars, from the Egyptian down to the Gregorian, amusing them now and then with little episodes; but I was particularly attentive to the choice of my words, to the harmony and roundness of my periods, to my elocution, to my action. Lord Macclesfield, who had the greatest share in forming the bill, and who is one of the greatest mathematicians and astronomers in Europe, spoke afterward with infinite knowledge, and all clearness that so intricate a matter would admit of: but as his words, his periods, and his utterance, were not near so good as mine, the preference was most unanimously, though most unjustly, given to me." [12]

A fortnight later Chesterfield again mentioned his speech in a letter to his son, writing "whatever applause it may have met with here, the whole, I can assure you, is owing to the words and to the delivery; for, between you and me, Lord Macclesfield's speech was, in truth, worth a thousand of mine. It will soon be printed, and I will send it to you." [13] Indeed, Lord Macclesfield's address was printed and Chesterfield's was not, so we have no way of making an independent judgement. In any event, the bill appears to have passed routinely through its three readings and to an affirmative vote on March 27, and a final vote on May 22 after being returned from the House of Commons. To the bill was appended a sample calendar with festivals and scripture lessons assigned, not for the defective year to follow, 1752, but for a regular year.[14]

The bill provided that the English calendar be brought into line with the Gregorian by dropping the days from September 2 to September 14, 1752. The bill met with a mixture of militant Protestantism and resentment of change, and "Give us back our Eleven Days" became a campaign slogan (nicely preserved in one of Hogarth's election paintings and engravings).[15] Nevertheless, the change seems to have gone painlessly both in Britain and in its overseas colonies. Benjamin Franklin's *Poor Richard's Almanac*, published in Quaker Philadelphia, noted that the "Yearly Meeting of the People called Quakers, held in London" had urged compliance,[16] and the introduction of the New style apparently passed without incident in America.

The French Calendar of Reason

It may not be amiss to mention that the next stage in the story of calendar reform was something that appears in retrospect as a comical step backwards from the universal acceptance of the Gregorian calendar. The French revolutionaries, in their anti-clerical zeal, adopted the "calendar of reason" on 5 October, 1793. In a system somewhat reminiscent of ancient Egypt, they established a year of twelve months, each with three weeks of ten days each, plus five or six epagomenal days.[17] These latter days were named the "sans-culottides" after those citizens who manned the barricades wearing common trousers rather than the aristocratic knee breeches. The day from midnight to midnight was divided into ten hours, and a hundredth part of an hour became a decimal minute. The calendar began retroactively on the autumnal equinox in 1792, and the months were renamed beginning then with

(Autumn)	Vendémaire	Brumaire	Frimaire
(Winter)	Nivôse	Pluviôse	Ventôse
(Spring)	Germinal	Floréal	Prairial
(Summer)	Messidor	Thermidor	Fructidor

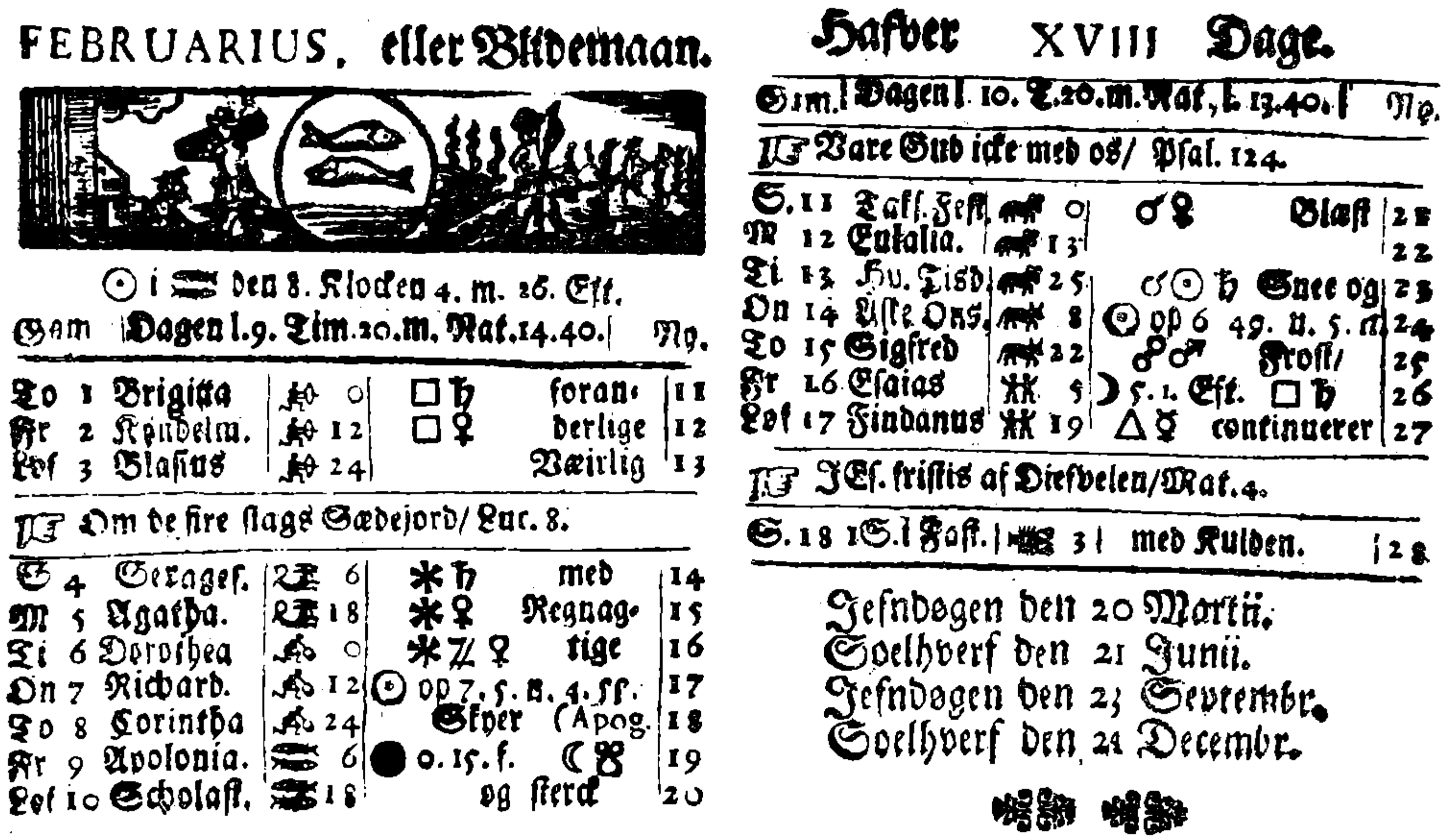
All of these radical revisions and novel nomenclature inspired a certain amount of ridicule, and English wit devised the following parody[18]

Autumn	→	wheezy, sneezy, freezy
Winter	→	slippy, drippy, nippy
Spring	→	showery, flowery, bowery
Summer	→	hoppy, croppy, poppy

Needless to say, the scheme met with considerable resistance, especially the idea of observing a day of rest only every tenth day. In 1801 Napoleon Bonaparte concluded an agreement with the Pope to reinstitute the observance of Sunday and several of the Christian festivals including Easter and Christmas.[19] On 15 Fructidor XIII (that is, on 2 September, 1805) the Senate appointed a committee to report on the calendar. This report, from Laplace, conceded that the French Revolutionary Calendar was too tightly linked to the historical and geographical details of France to win universal acceptance. As a consequence, France had the unique opportunity to adopt the Gregorian calendar a second time, going over on 11 Nivose XIV, that is, on the first of January in 1806.

Reception Elsewhere

The civil acceptance of the Gregorian calendar in the rest of the world had to await the 20th century, except for Alaska, which switched following the purchase by the United States from Russia in 1867, and for



FEBRUARIUS, eller Blidemaan.

☉ i ♒ den 8. Klocken 4. m. 26. Eft.

Gam | Dagen l. 9. Tim. 20. m. Nat. 14. 40. | Nq.

To 1 Brigitta	♐ 0	□ ♄	foran-	11
Fr 2 Kyndelm.	♐ 12	□ ♀	derlige	12
Lof 3 Blasius	♐ 24		Væirlig	13

☞ Om de fire slags Sædejord/ Luc. 8.

S 4 Geraget.	♑ 6	✱ ♄	med	14
M 5 Agatha.	♑ 18	✱ ♀	Regnag-	15
Ti 6 Dorothea	♒ 0	✱ ♃ ♀	tige	16
On 7 Richard.	♒ 12	☉ op 7. f. 8. 4. ff.		17
To 8 Corintha	♒ 24	Skyer	(Apog.	18
Fr 9 Apolonia.	♓ 6	● o. 15. f.	☾ ☊	19
Lof 10 Scholast.	♓ 18	og sterck		20

Hafver XVIII Dage.

Sim. | Dagen l. 10. T. 20. m. Nat, l. 13. 40. | Nq.

☞ Vare Gud icke med os/ Psal. 124.

S. 11 Faſt. Feſt.	♈ 0	♂ ♀	Blast	21
M 12 Eulalia.	♈ 13			22
Ti 13 Hu. Tisd.	♈ 25	☌ ☉ ♄	Snee og	23
On 14 Aske Ons.	♉ 8	☉ op 6 49. u. 5. m.		24
To 15 Sigfred	♉ 22	☍ ♂	Frost/	25
Fr 16 Esaias	♊ 5	☽ f. 1. Eft.	□ ♄	26
Lof 17 Findanus	♊ 19	△ ☿	continuerer	27

☞ JEſ. friſtis af Dieſvelen/ Mat. 4.

S. 18 1 S. i Faſt. | ♋ 3 | med Kulden. | 28

Jefndøgen den 20 Martii.
Soelhverf den 21 Junii.
Jefndøgen den 23 Septembr.
Soelhverf den 24 Decembr.

Fig. 2. The introduction of the Gregorain Calendar in Denmark in A.D. 1700 is illustrated by this reproduction of two pages of the official calendar in which the month of February has 18 days only.

Japan, which accepted the system on 1 January, 1873, the same year that Christianity was legalized there. This was presumably a direct consequence of the European mission of Prince Iwakura Tomoni and 50 leading government officials in 1871. The calendar was introduced into China by Sun Yat Sen in 1912, but not until 1929 did it officially replace the Chinese calendar.[20] The new calendar replaced the traditional lunar calendar, which, however, still persists for private affairs such as the celebration of birthdays. The seven-day week, known in China from Western influences for nearly a millennium, replaced the (roughly) ten-day lunar week.

The general disruption associated with the First World War brought the Gregorian calendar to Eastern Europe, including Bulgaria, Lithuania, Latvia, Estonia, Russia, Yugoslavia, and Romania. There had, nevertheless, been a considerable history of calendar reform movements in Russia already in the nineteenth century. According to Ginzel, the first proposal in Russia was made by an official, N. Otrjeschkow, in 1829, but rejected at a higher level.[21] Further attempts in 1837 and again two decades later also failed. In 1863 the Dorpat astronomer H. J. Mädler publicized a scheme to have an omitted leap day every 128 years, but he apparently had no proposal to handle the discrepancy between the two systems, which by then amounted to 12 days. In 1900 the discrepancy advanced to 13 days, and this would have been a logical opportunity for a change. In fact, in 1889 at a general assembly of the Russian astronomical association, Mädler's proposal was temporarily abandoned because it improved the accuracy of the Gregorian calendar by only one day in 4000 years. However, a joint committee of the Russian government, the Eastern Orthodox synod, and the astronomers decided that Mädler's scheme should have been adopted for the time of Christ's birth, so that 15 leap days would have been skipped by 1920, that is, 15 times 128 years, so that as of 1920 the proposed improved Russian calendar would then differ by two days in the other sense from the Gregorian calendar. Thus it was apparently decided to have a calendar reform in 1920 rather than 1900, but the hope that the other nations might also adopt such a change proved without foundation. Consequently, as one of the first acts of the Bolshevik government in 1918, Russia adopted the Gregorian calendar, this time in anticlerical defiance of the Eastern Orthodox Church.

Calendar reform came last to Greece, a few years after the disruptions of the First World War.[22] The Greek adoption followed a congress of the Eastern Orthodox Church in Constantinople in May, 1923, and it is fascinating to learn that their calendar improves upon the year length of the Gregorian scheme, so that leap years will include 2000, 2400, (as in the Gregorian calendar), but also 2900 and 3300 instead of 2800 and 3200; thus the dominions of the Eastern Orthodox Church will differ by a day from the rest of the world in the 29th century A.D., provided tendentious civilizations can last that long!

Although other calendars (such as the Jewish and Islamic ones) have continued in use, and although occasional attempts at calendar reform have gained some notoriety, since 1924 the entire world has been united in the secular use of the Gregorian calendar dates.

REFERENCES

1. The principal reference on the civil acceptance of the Gregorian calendar is F.K. Ginzel, *Handbuch der mathematischen und technischen Chronologie* (Leipzig, 1914), Band III, Kapitel XIV, Sektion 255, 266-279. See also W.E. Wijk, *De Gregoriaansche Kalendar* (Maastricht, 1932).
2. As an example I cite the following information supplied to me by Rev. Charles E. O'Neill, S.J., Director of the Jesuit Historical Institute in Rome. It was possible to get word from Spain to America in two months (leaving aside all question of port and transmission from port to interior of colony); hence, it was physically possible to have the Spanish American colonies change the calendar in October of 1582. However here is what actually occurred in the case of Perù: King from Aranjuéz, 14 III 1583, gave order for Perù. Letter of Father José de Acosta, Lima, 20 V 1584, to Fr. Gen. Claudio Aquaviva, states that the changeover in Perù is set for October of 1584.
3. A.J. Butler (ed.), *Calendar of State Papers, Foreign Series, of the Reign of Elizabeth* (London, 1909), xvi, no. 527, 516-517; I wish to thank John North for pointing out this reference.
4. See Appended Note by K. Fischer at the end of this paper.
5. Translated from the Danish original in Peder Horrebow, *Opera mathematico-physica*, II, Copenhagen 1740-41.
6. Ginzel, *op. cit.*, 272-274.
7. *Ibid.*, 275-276.
8. Houghton Library, Harvard University, under "Macclesfield", call number EC7 M1327 751 sb (1751). The volume includes a 1751 offprint of Lord Macclesfield's speech to the Royal Society (see note 9), a printed copy of Macclesfield's speech in the House of Lords given by him to Reynardson, and a copy of the Act itself (see note 15).
9. Dee's treatise exists in a holograph copy at the Bodleian in Oxford, ms. Ashmole 1789,3; Prof. John Heilbron intends to edit it for publication, and I am indebted to him for the opportunity to examine a copy of it. There is also another copy at the Bodleian, ms. Ashmole 179.6.
10. *The Gentleman's Magazine*, xxxvi (1851), 451-459; I wish to thank M. Feingold for this and related references.
11. *Philosophical Transactions*, xlvi (1750), 417-434; see also *The Earl of Macclesfield's Speech in the House of Peers on Monday the 18th Day of March 1750* [i.e. 1751], privately printed, London 1751.
12. Second Earl of Chesterfield, *Letters to His Son* (New York, 1901), Letter CXXXV, (March 18, O.S. 1751), 393-394.
13. *Ibid., Letter CVXXXVII* (April 7, O.S. 1751), 402.
14. F.W. Torrington (ed.), *House of Lords Sessional Papers*, Session 1747-48 to 1753 (Dobbs Ferry, N.Y., 1977). This version leaves all the critical dates blank; the final version, known to me only through an offprint, begins on p. 571.
15. Hogarth's depiction is best known through the engraving "An Election Entertainment, Plate I"; the original oil is in Sir John Soane's Museum in London.
16. V. Sanford, *Mathematics Teacher*, xlv (1952), 338.
17. Ginzel, *op. cit.*, Kapitel XVI, Sektion 264, 328-334.

18. P.W. Wilson, *Romance of the Calendar* (New York, 1937), p. 154.
19. Ginzel, *op. cit.*, 332-333.
20. "14 C, The Gregorian Calendar", 412-418, in *Explanatory Supplement to The Astronomical Ephemeris and The American Ephemeris and Nautical Almanac* (London, 1961).
21. Ginzel, *op. cit.*, Kapitel XVI, Sektion 268, 355-358.
22. M. Milankovich, "Das Ende des julianischen Kalendars und der neue Kalendar der orientalischen Kirchen", *Astronomische Nachrichten, CCXX* (1942) 379-384.

APPENDED NOTE: ON THE CALENDAR REFORM IN BOHEMIA AND MORAVIA

KARL FISCHER, Karlsruhe, Federal Republic of Germany

The Archbishop of Prague Martin Medek [1] introduced the Gregorian calendar in Bohemia on 22 October, 1582 by the "Publicatio novi Calendarii" which was published in "Monasterio Toeplensi" and addressed to the Catholic clergy. The edict was published by the celebrated Prague printer George Nigrinus as a one page issue in a folio form and thousands of copies were nailed to the church doors. Only two copies survived until the second World War. One copy was found at the Strahovian library, "Regiae canoniae Strahoviensis", the other one at the library of my former observatory in Prague-Podoli.[2] Neither of them exist any longer. According to the edict the 15th should follow the 4th of October 1582. Still, until the beginning of the 18th century the calendars were printed in the old as well well as in the new form, as it was necessary to make oneself understood to the neighbouring German Protestant countries.

An article about the introduction of the Gregorian calendar in Bohemia was cited in the Chronicle of the Bohemian Brothers.[3] It was a rather sceptical report of the 1582 edict of the archbishop.[4] We read about the opposition in 1584 of the Bohemian Brothers and that the Easter holidays were separately celebrated by the Catholics and Protestants.[5]

The Gregorian calendar was officially established by the imperial edict of 1 October, 1583 and came into force by the decree of the Bohemian assembly in such a way that 18 January, 1584 should follow the 7th day of January. It is uncertain as to when Easter was actually celebrated in Bohemia and how far the "Publicatio" of the Archbishop was followed. However, some of the aristocracy who boycotted the calendar reform in their landed properties were fined in 1584.[6] The old calendars, which were edited by John Stráněnský [7] and Wenceslas Zelotinus de Formoso Monte [8] were confiscated in the middle of December 1584, and their printers were arrested. Furthermore a warrant existed on Peter Codicillus de Tulechowa,[9] who, as the only Protestant, had accepted the Gregorian calendar and procured for himself an imperial privilege for calendar printing. He even omitted the anniversary of the feast-day of John Hus, the reformist of the Bohemian Brothers. Some satirical poems about the affair came into existence.

I should like to mention another annal, since lost, which I was able to consult: the *Chronicle of the Town Prossnitz*.[10] In the entry for 30 June, 1586 the introduction of the Gregorian calendar in Moravia was described. The Moravian Estates declined the Rudolphian edict at their assembly on 7 January, 1584 on the grounds that it was edited without the prior consent of the Moravian Estates. They did not accept the Gregorian reform until the next assembly on 8 June, 1584 and under the condition that the 15th should follow the 4th day in October.

The reform was received in the Bohemian and Moravian towns in the same way as in Alsatia. There was chaos in both countries until the battle on the White Mountain.[11] The Protestant villages continued to live according to the German Protestant example, the old calendar.[12] It was not possible to realise the reform, for example, in the mostly Protestant German district of Eger until 1606.[13]

The Gregorian reform was remembered by a saga in Moravia, which was included in a public record available at the state archive of Troppau/ Opava.[14] The main actor of the saga was an inkeeper and crossbow-marksman Bartholomaeus of Jamnitz and it took place at the estate of Thas and Ludwig Meseritsch von Lomnitz in the village Palowitz.[15] The saga was motivated by the victory of the good over the bad, of a priest over a devil.[16]

REFERENCES

1. Medek, Martin, the Archbishop of Prague, born in 1538 in Möglitz, died on 2 February, 1590 in Prague. He studied at the Jesuit School of Olmütz, was made a Member and Great Master of the Bohemian Cross Order in 1580. Rudolph II appointed him archbishop in January 1581; his ordination was in October 1581.

2. The copy of the Strahovian Library, opus 23 of a collective volume of one-page issues without signature was designated as "Codex Dobřensky" after the first owner, the Bohemian humanist Jacob Hans Wenzel Dobřensky of Schwarzbruck de Nigro Ponte (born 1623, died in Prague on 3 March 1697). The Strahovian copy had fragments of a renaissence pattern on its lower border with an inscription "Typis Georgii Nigrini" in contrast to my own copy. These one-page issues were nailed to the doors of all Catholic churches. Some non-catalogued copies might still be available in some town archives.

3. The former archives of the Bohemian Brothers in Herrnhut/Ochranow in Lausitz, near Bautzen, deposited in the Saxon Regional Archive of Dresden had secret church sources not ordinarily available to the public. *The Chronicle of the Bohemian Brothers* comprises about 30 volumes each, written partly in Czech and partly in German.

4. *Chronicle of the Bohemian Brothers*, xiii, 225.

5. *Ibid.*, xiii, 378.

6. *Ibid.*, xiii, 378.

7. Johannes Stráněnsky born in Potschatek, secretary of Lord Neuhaus, later a businessman, died in Potschatek in 1585. He was a Protestant, Czech humanist writer. His small calendars with prophecies were published by various printers in Prague. None is known exist.

8. Wenzel Zelotin (or Zelotyn) von Schöneberg de Formoso Monte z Krásné Hory, born about 1532, M.A., Prague, 1561, Professor of Mathematics and Astronomy at the Prague University from 1574 till 1585. Provost of the Protestant "Collegium of St. Wenzel" from 1584, died in Prague on 17 May, 1585. He was editor of large calendars, an activity which belonged to the duties of the "Astronomus publicus".

9. Peter Codicill von Tulechowa, born in Seltschan, on 24 February, 1533, M.A. Prague, 1560, Professor of Greek and Mathematics at the University from 1561 to 1589, the rector from 1582, died in Prague on 29 October, 1589. He was editor of a small calendar.

10. *The Chronicle of the Town Prossnitz*, leatherbound, damaged by moisture, contains about 300 pages describing the events from 1580 until the beginning of the 18th century, in German. It has been missing since 1965.

11. "White Mountain" is the hill near Prague where there took place the battle of 8 November, 1618, in which the Protestant rebellious Bohemian and Moravian assemblies were defeated by the Hapsburgs.

12. All the Bohemian and Moravian Protestants saw their ideal in the Wittenbergian and other German Protestant universities before the "White Mountain Battle". This fact contributed to the Germanization of both countries. In contrast the Jesuits adjusted to the Czech element and supported Latin.

13. Anonymous, "Three hundredth anniversary of the calendar", *Student News Prague*, iii (1883), 93.

14. A file of about 300 loose pages by a anonymous author, marked by a sign of a circle with a cross and the notice "manu propria". A collection of Silesian and North-Moravian fairytales, legends, descriptions of traditional costumes and customs from the middle of the 19th century, in German. Missing since 1965.

15. Jamnitz, a village in the southwest of Moravia, near the Austrian border. The overlord was Meseritsch of Lomnitz. Ludwig who was cited in the saga cannot be identified. In the neighbourhood was the little village Palowitz. It is strange that this South-Moravian legend got into this Silesian- and North-Moravian collection.

16. *Weekly News of Troppau*, vii (1878), 388-400.

VII.

POSTLUDE

CONTEMPORARY DISCUSSIONS ON THE REFORM OF THE CALENDAR

FRANÇOIS RUSSO, S.J., Paris, France

Foreword

As a result of the conciseness that modern literary practice demands (which was by no means the case in the seventeenth century), the title of this contribution makes no mention of the period covered, and this may lead the reader to expect a wider treatment than will in fact be provided. Clarification on two aspects is therefore called for. First, by "contemporary" we understand a period extending from the 1830s (for a reason that will be given below) to the Second Vatican Council; more exactly, to 1963, the date of a document that we shall discuss. For since that date, there has been no sign of discussions or declarations on the reform of the calendar. It is true that the most interesting section of this history is that following the Second World War, for it was then that there was an increasing and concentrated discussion of the proposed Universal Calendar, as we shall see in what follows. All the same, as this proposal is met with already in the nineteenth century, we have thought it right to devote space, however little, to the earlier period that extends from the 1830s to the Second World War.

As to the area covered in our discussion, although our title might imply that we would cover every aspect of the reform of the calendar, we shall in fact restrict ourselves in three ways:

(i) we shall not discuss the date of Easter; still less shall we discuss religious aspects of the reform of the calendar deriving from non-Christian religious bodies. We are concerned only with the civil calendar that corresponds in astronomical terms to a solar calendar to which the motion and phases of the Moon are irrelevant;

(ii) we shall not discuss the reception of the Gregorian Calendar, which is the subject of other papers at this conference;

(iii) we shall not discuss a great many proposals which were put forward, in the past two centuries, only to be shown not to be feasible. We confine ourselves to the history of the one calendar which in the last analysis was considered seriously, even if in the end it was not adopted — a calendar which for simplicity we shall term the Universal Calendar, using the general term in this specific sense. Nevertheless we shall make space for a brief mention of the calendar of thirteen months of 28 days which was mooted in the period following the Second World War.

We must, however, show that these restrictions are legitimate, that they do not falsify the history of the calendar. It seems to us that from this point of view only (i) could be objected to, for in effect this restriction forces us to make an abstraction from the real and concrete history of the calendar, in that during the modern period the question of the civil calendar based on the Sun and that of the date of Easter based on the Moon are interconnected. The same applies to Judaism and other non-Christian religious bodies. But this abstraction seems to us justified because logically these two questions are distinct, except in that, obviously, the choice of the date of Easter involves consideration of the solar calendar, chiefly as regards the dates of Sundays and that of the spring equinox.

Our way of proceeding seems to us not only legitimate but actually helpful in clarifying this complex history — provided of course that the real history that has this complexity, with these often unwarranted interconnections, is not neglected. Nor must we overlook the fact that opposition to proposed reforms of the calendar often has its source in religious issues, especially where non-Christian religions are concerned; this is because the break in the weekly sequence resulting from the Universal Calendar (which we discuss below) has attracted attention, as it continues to do so today, being seen as harmful to religious traditions and especially to the Christian churches and to Judaism.

Unsatisfactory Features of the Gregorian Calendar

The inequality of the divisions of the year. The divisions of the year — the month, the quarter, the half-year — are of unequal length. The month contains from 28 to 31 days; in the quarters the numbers of days are respectively 90 (91 in a leap year), 91, 92 and 92; and as a result the first half of the year has either two or three fewer days than the second. Consequently the numbers of weeks in the quarters and half-years are likewise unequal.

The unequal length of the months, quarters and half-years is a source of confusion and uncertainty in economic matters, such as the arrangement of statistics and the computations and figures relating to commercial operations and transportation; and similarly with the calculations according to which salaries, interest, insurance, pensions, prices and rents are determined by the month or quarter or half-year, for these periods are not simple fractions of the complete year. Finally, neither the quarters nor half-years contain an exact number of weeks.

The changes in the days of the week. The calendar of the days of the week is not fixed; instead it changes every year, for the year contains 52 weeks plus either one day or two. Hence, if the first day of one year is a Sunday, that of the next year will be a Monday (or a Tuesday if the former was a leap year). Were it not for the extra days in the leap year, the calendar would have just seven different forms, corresponding to the seven days of the week by which the year can begin. However, because of the extra day in leap years, the calendar reproduces itself exactly only every 28 years. As a result, in a given year the day of the month falls on a different day of the week to that in the previous year. Therefore:

(i) The dates of periodic events cannot be fixed with precision. One such date can be fixed in two ways, either by the day of the month (15 August, say), or by the day of the week within the month (the third Tuesday of October). With the present Gregorian calendar, neither method is exact and determined. Again, if a periodical event is assigned to a given day of the month, this day may sometimes be a Sunday or some other feast day. As a result the authorities must every year decide the particular cases, such as the beginning of law terms, the opening of Parliament, days of feasts, markets, administrative assemblies, the change of summer time, and so on.

If a given day (the first Monday of the month, for example) is decided upon for these events, other problems arise because of the fact that the corresponding date of the month is forever changing from one month to the next and from one year to the next, whereas if the calendar were fixed, the dates for these events could be decided once and for all. They would fall on the same days of the month and the same days of the week each year.

(ii) The position of the week within the quarter changes each year:

the weekdays fall within the division of the year in a different way each year, leading to complications in the preparation of accounts, statistics, etc.

It was to avoid these difficulties that the Universal Calendar was proposed.

The Universal Calendar

The calendar to which the name Universal Calendar has been given divides the solar year into twelve months and these have the same names as in the Gregorian calendar. The chief difference between the two calendars lies in the redistribution of the numbers of days among the months. These months, four of which have 30 days and eight 31, are arranged in four successive groups, each making up a quarter of the year. Each quarter comprises three months, one of 31 days followed by two of 30 days, making 91 days in all. Furthermore, *the first day of the first month of each quarter is a Sunday*; all the quarters have therefore exactly thirteen complete weeks and have the same overall configuration, and so they are now identical. Each quarter can therefore be thought of as a cyclic unity which repeats itself.

The four quarters of the year contain 364 days in all. But the solar year has 365 days, 6 hours and some minutes. In order that the calendar shall match the seasonal year defined by the movement of the Earth around the Sun, an extra day is added at the end of December, the "year's end day". It could be considered as 31 December, but it would not be included in the cycle of days of the week. Likewise, to settle the problem caused by the six extra hours, leap years are reckoned as in the Gregorian calendar, the only difference being that the extra day is similarly inserted at the end of June. This second extra day, which is no longer counted among the days of the week, corresponds to 31 June and occurs in leap years, which are calculated according to the Gregorian rules.

The differences between the new calendar and the Gregorian fall under two headings: (i) As regards the distribution of the days among the months, there are in all six changes of which five are intended to make the quarters equal and identical: two months are lengthened, namely February (by two days, or by one day in leap years) and April (by one day); three months, March, May and August, are shortened (by one day); the extra day in leap years is changed from 29 February to 31 June; and each month has exactly 26 working days in addition to the Sundays.

(ii) As regards the relations between the cycle of the week and the days of the month, a fixed rule is established for the whole of the year, and this is indeed the chief object of the reform. Because neither 365 nor 366 is divisible by 7, the number of days in a complete week, an artificial device is unavoidable: the introduction of extra days. This is the chief novelty of the proposal, but it has the result that the sequence of weekdays is broken.

From the practical point of view, the adoption of the new calendar in a year that began with a Sunday would ensure the continuity between the two calendars. The years 1950 and 1956 would have fulfilled this condition.

It would be possible to modify the new calendar in certain ways without destroying its basic character. The *beginning of the year* could more naturally begin with the winter solstice, 22 December, which is when the day is the shortest (this had been included in earlier schemes); and the extra days that occur each year and additionally in leap years ought certainly to fall between two quarters, but it is easy to think of other ways in which this could be done.

The chief difference between the Universal Calendar and the Gregorian is to be found in the *intercalary days*, the "blank" days, that are not days of the week. They break the continuity of the days of the week, once in normal years and twice in leap years.

Features of the Gregorian Calendar Which Are Retained in the Universal Calendar

One must be clear that the substitution of the Universal Calendar for the Gregorian makes no essential difference to the reform of the Julian calendar effected by Gregory XIII. This reform, intended to establish for all time a perpetual "civil" calendar, involved (as we have seen above) the suppression of ten days in October 1582 and the removal of three of the Julian leap years every four centuries; this ensured that the spring equinox will always fall about 21 March and that the tropical and the calendar years will keep in step. None of this is changed in the Universal Calendar.

True, improvements in astronomical observations have shown that the Gregorian year exceeds the tropical year by 3×10^{-4} days. In ten thousand years, therefore, the Gregorian calendar will have three days too many and the equinox will fall on 18 March. But it has very sensibly been held that a "perpetuity" of a century or two is quite adequate and that there is therefore no need to take into account the tiny difference between the Gregorian and the tropical years. On this point likewise the Universal Calendar does not depart from the Gregorian.

Further, the Universal Calendar keeps the same number of months, namely twelve; and likewise the length of a month is (February excepted) either 30 or 31 days in both calendars. Lastly, the number of days in the week is retained at seven. All these are customs, both civil and religious, that one would hesitate to alter; and it is because they broke this rule that various proposed reforms found no favour.

First Moves Towards a Reform of the Gregorian Calendar Before the First World War

From the numerous discussions and proposals for the reform of the calendar during this period, we shall, as explained in the Foreword, limit ourselves to those involving the Universal Calendar and, furthermore, to the most notable of these.

(i) The Rev. Mastrofini of Rome in 1834 put forward the first plan for a calendar that differed only in minor ways from the Universal Calendar. The leap-year day was left as 29 February or was placed in between the third and fourth year.

(ii) We shall mention — because of the notoriety of its author — the plan put forward in 1849 by Auguste Comte, which differed from the proposal for a Universal Calendar, but which was based fundamentally on the same concept, even though it departed further from the Gregorian calendar. In this plan the year is divided into thirteen months of 28 days with a "blank" day each year and two in leap years, these being put at the end of the year. As regards the relationship between months and weeks, the uniformity is greater than in the Universal Calendar in that each month contains exactly four weeks. But the creation of a thirteenth month did too much violence to the traditions of the Gregorian calendar for this plan to be adopted, even though it was revived after the Second World War.

(iii) In 1884 Camille Flammarion, the distinguished astronomer who was especially noted for his popularisation of the subject, opened the pages of his journal, *l'Astronomie*, to a discussion of the problem. The survey of the proposals put forward advocated a calendar that differed from the Universal Calendar only in minor details — the leap-year day was also placed at the end of the year, and the year began with the winter solstice.

(iv) In Rome itself the proposal of the Rev. Mastrofini in 1834 was discussed in several articles in the periodical *Ephemerides liturgicae*, which, if not an official publication of the Holy See, was very much "authorised".

(v) In 1900, in the *Journal d'horlogerie* of Geneva, a plan of M. Grosclaude revived the proposal of the Rev. Mastrofini.

(vi) In 1913 the journal *Ephemerides liturgicae*, mentioned above, took the view that the Church, while not taking the initiative herself, was in a position to accept a reform along the lines proposed by the Rev. Mastrofini. But this proposal was not acceptable to the numerous advocates of the scheme of Auguste Comte mentioned above, for a year of thirteen months of 28 days plus intercalary days. All the same, the Permanent International Committee of the Chambers of Commerce, and their congresses held in 1910, 1912, 1914 and 1921, took the view that this latter plan would be more difficult to impose than the Universal Calendar.

The Period Following the First World War

From its inception in the aftermath of the First World War, the League of Nations was involved in the reform of the calendar. In its turn the United Nations was similarly involved from its inception in 1947. But these inter-governmental initiatives were conducted in close cooperation with a number of non-governmental parties, notably the Holy See, the International Astronomical Union, and other major international bodies with social or economic aims.

(i) 1923: The consultative and technical commission of the League of Nations and its special commission. At its fifth session in Geneva, 29 August - 1 September 1923, the consultative and technical commission of the League of Nations took the view that a reform of the Gregorian calendar through the introduction of a more rational way of arranging the months and their lengths would be of great benefit to public life, to the economy, and to international relations, and therefore set up a "Special Committee for the Reform of the Calendar". Of the six members, three were nominated by the commission and one each by the Holy See, the Ecumenical Patriarch of Constantinople, and the Archbishop of Canterbury. The Committee was instructed to develop the proposals formulated by the International Astronomical Union at its General Assembly in 1922, in the light of the recommendations made by the International Chamber of Commerce at its Congress in London in June 1922.

The conclusions of the International Astronomical Union favoured a Universal Calendar though with the beginning of the civil year moved to 22 December to coincide with the winter solstice. In addition, a subordinate division by periods of 14 and 28 days was not ruled out (cf. the proposals of Auguste Comte).

The Committee of the League of Nations consulted with governments, major bodies, and individual men of science and religion. A substantial majority were in favour of a Universal Calendar, but a notable minority followed Comte in favouring a year of thirteen months of 28 days. As a result the Commitee's conclusions, published in 1927, were restrained. They refrained from coming down in favour of either solution. Instead they confined themselves simply to expressing the hope that the eventual reform of the calendar would be preceeded by careful preparation at the social level to enlist the support of public opinion without which no reform could be carried through.

(ii) 1931: The fourth general conference of communications and transport. In preparation for this conference a commission was set up which met in June 1931 to analyse, organise and complete the very extensive documentation collected by the Special Committee. (We should note that in 1930 the "World Calendar Association" was founded under the presidency of Miss Elisabeth Achelis. The Association was very active, thanks to the influence of its president and the publication of *Journal of calendar reform*.)

At this conference, which took place in October 1931, representatives were present from eighty-four nations and numerous civil and religious groups. In addition to differences over the question of Easter which are not here our concern, the conference noted a quite sharp division between members who favoured the Universal Calendar of twelve months and those who favoured the thirteen months of twenty-eight days. The conference therefore had to content itself with declaring: "the state of opinion seems to show that the time is not ripe for proceeding with a reform of the calendar".

(iii) 1935: The attitude of the Holy See in 1935. In response to a Memorandum addressed to the Holy See in June 1935 in the name of major groups in favour of reform, a reply was made that the Holy See was keeping a constant watch on the matter; it considers that the question of the date of Easter is bound up with the general question of reform; and, before taking up a position, the Holy See is most anxious that those who advocate different methods of reform should reach unanimity — or, failing this, that a substantial majority should be in favour of a particular system.

(iv) 1937: Council of the League of Nations. At its meeting in January 1937, the Council of the League of Nations considered a proposal from the Chilean delegation in favour of the Universal Calendar. The League of Nations referred the matter for examination to the Technical and Consultative Commission for Communications and Transport which, in the aftermath of its meeting in 1931, had been canvassing the opinions of governments. The result was that there was not at all a majority in favor of the proposal. In fact the Council of the League of Nations decided not to proceed further with this question, although it was made clear that this did not imply that the question might not be revived and reassessed when the time was ripe.

(v) 1947: The United Nations: The Economic and Social Council. At the fourth session of this Council, in March 1947, Peru put forward a resolution in favour of the Universal Calendar. After an extended discussion which revealed substantial differences of opinion, the Council decided to adjourn the examination of the question to the next session and requested the Secretary of the U.N. to bring together all the useful and relevant documents on the subject and to communicate for the benefit of the member states of the U.N. the text of the proposal from Peru. We mention in particular two documents of this session: "The Universal Calendar, Comment of the Secretary General" (E/465, 14 July 1947), and "Universal Calendar, a list of the documents relating to the reform of the calendar" (E/465, Add. 17 July 1947).

(vi) 1954: The Article by Father O'Connell. Father O'Connell, SJ, the director of the Vatican Observatory, published a long article in *Osservatore Romano* of 28-29 June, 1954 on the occasion of a proposal from India (see below). We reproduce the passages of this article that relate to the reform of the civil calendar. "As for the attitude of the Church to proposals for the reform of the calendar, there are some who think that she must oppose any attempt to achieve such a modification. This is in fact not really the case. It is our opinion that the Church has no reason to oppose a change in the calendar currently in use. Given a general wish for reform, motivated by serious concern for the economic and social life of human beings, the Church should not neglect to consider the question, subject of course to certain conditions which she herself cannot disregard. Intimately linked with the actual proposal for reform of the calendar is the question of the determination of the date of Easter. The promoters of the "Universal Calendar" say that they have no wish to become involved in this question. They fully accept that this matter is for the ecclesiastical authorities."

(vii) 1953-54: Communication of the Permanent Representative of India at the United Nations to its Secretary General. This communication, dated 28 October, 1953, consisted of the proposal to adopt the Universal Calendar as from 1 January, 1956 (document E/4.628). The proposal was accompanied by a note setting out the advantages of such a reform, much as we have described above.

This proposal was discussed for the first time at the 16th session of the Economic and Social Council, 30 November-1 December, 1953, and adjourned until the 18th session of the Council held in June-July, 1954. In addition to representatives of the member nations, there were representatives of a number of civil and religious organisations, notably the World Calendar Association. The Holy See, however, was not represented. No conclusion was reached. (The archives of the Information Centre of International Catholic Organisations in Geneva) possesses a private summary of the discussion of 1953 and 1954. Its account of the article of Fr. O'Connell takes him to task for claiming that the Universal Calendar found general support.) But the Secretary General of the Council, by unanimous resolution, was instructed to forward the proposal from India (with minor changes but substantially unaltered) "and all other relevant documents to the governments both of member nations of the United Nations and to those of non-members, requesting them to examine the question and give their opinion towards the beginning of 1955", the Council intending "to resume their study of this question at their 19th session after receipt of the replies of the various governments".

(viii) 1955: A document of the Economic and Social Council dated 22 March, 1955 (E/2.701) recalled the resolution of the 18th session of the Council and announced that some twenty replies from governments had been received up to 21 March, 1955. We have no information about the discussion on the calendar which formed item 21 of the second part of the 19th session of the Council. It seems that the question was abandoned.

Whatever the truth of this, so far as we know the United Nations has done nothing on the matter since.

(ix) 1963: The Document of the Second Vatican Council. In the Constitution "On the Sacred Liturgy" (4 December, 1963), an appendix entitled "Declaration of the Second Vatican Council on the reform of the calendar" contains the following passage on the civil aspect of the reform of the Gregorian Calendar: "The sacred Council declares that it is not opposed to proposals intended to introduce a perpetual calendar into civil society. But among the various systems which have been mooted for establishing a perpetual calendar and introducing it into civil society, the Church raises no objection provided that the week of seven days with Sunday is preserved and safeguarded, without intercalating any day outside of the week, so that the succession of weeks is preserved intact — unless very serious reasons are forthcoming, of which the Holy See will be the judge."

Conclusion

During the last nearly thirty years, neither intergovernmental organisations, nor governments themselves, nor religious authorities of the various confessions, nor public opinion, have taken any further interest in the proposal for a Universal Calendar, notwithstanding the unquestioned benefits it would bring to social and economic life. Furthermore, this issue seems to remain completely separate from the question of the date of Easter (which we have not discussed here); a question which likewise seems for the present to arouse no interest.

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A GLOSSARY OF TECHNICAL TERMS

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(Words in *italics* refer to separate entries)

accessus et recessus
: see *trepidation.*

A.D. (= anno Domini = "in the year of the Lord")
: The number of the current year according to the Christian era.

adiectio lunaris
: see *epactae.*

adiectio solis
: see *dies concurrentes.*

age of the moon
: the number of days elapsed since the preceding *new moon.*

Alexandrian calendar
: The old Egyptian calendar as modified by the Julian reform which made every fourth year a leap year with six *epagomenal* days.

almanac
: a list or calendar of dated events throughout a particular year, or a succession of years, such as the names of the days, the dates of liturgical feasts, the phases of the moon, etc.

Annunciation
: This feast was originally celebrated in Alexandria on May 20. In fourth century it was translated to March 25, the date of the old Roman *equinox*; - see *stylus.*

annus bissextilis (= a "bissextile", or *leap year*)

In the *Julian* and *Gregorian calendars* a *calendar year* of 366 days.

annus Diocletiani

The number of the current year according to the Diocletian *era*.

annus mundi (= "the year of the world")

The number of the current year reckoned from the *era* of the Creation.

annus Passionis (= "the year of the suffering", i.e. of Jesus)

The year in which the crucifixion took place; by Victorius of Aquitaine assumed to be the year of the consulate of the two Gemini (A.D. 28).

apogee

The point on the orbit of the sun, moon or a planet where it has its maximum distance from the earth.

Argumenta Dionysii

A set of mathematical procedures for determining calendaric parameters of a given year such as the *golden number*, the *epact*, the *indiction*, etc., described by Dionysius Exiguus in his *De titulis paschalis Aegyptiorum*.

Aries

Originally one of the constellations of the *zodiac*. Later the first of the twelve *signs* of the *ecliptic* into which the sun enters at the vernal *equinox*.

Ash Wednesday

A *movable feast* marking the beginning of *Lent* and celebrated on the Wednesday falling 40 days before *Palm Sunday*.

A.U.C. (= *ab Urbis conditae* = "from the foundation of the city")

The number of the year according to the *era* of the old Roman calendar. The foundation of the city of Rome was placed in 753 B.C. by Dionisyius Exiguus.

aureus numerus (= "golden number")

The number of the current year inside the 19 year lunar, or *Metonic cycle*. According to the *Argumenta Dionysii* it is found as the remainder when the A.D. is increased by one and divided by 19, the remainder zero being replaced by 19. The term itself is of medieval origin.

B.C. (= "before Christ")

The denotation of the number of a year before the beginning of the Christian *era.*

bissextile year

see *leap year.*

calendar

a list of the days of the year arranged month by month and provided with columns of information of events occurring on a particular day of a particular year, such as immovable or movable feasts, phases of the moon, the number and name of the day, etc. - See *almanac, perpetual calendar.*

calendar month

A period comprising an integer number of days by which the year is divided into twelve roughly equal parts. - See *full* and *hollow month, Nisan, Thoth, Roman months.*

Calendar of Reason

see *Revolutionary Calendar.*

calendar year

A year comprising an integer number of days on which a particular calendar system is based. See *lunar year, solar year, Egyptian year, year.*

calendaric precession

A somewhat misleading expression, meaning either (1) the gradual shift of the date of the vernal *equinox* which in the *Julian calendar* occurs one day earlier for every 130 years or so because of the discrepancy between the Julian and the *tropical year*, or (2) the fact that in about 308 years the *lunations* occur one day earlier than calculated by the imperfect *Metonic cycle.*

Christian era

see *era.*

chronology

The science of time reckoning in general, but often understood as historical chronology, or the art of determining the precise times of events in the past.

circulus

A term sometimes used instead of *cyclus*.

Circumcision

An immovable feast celebrated on January 1st in commemoration of the circumcision of Jesus. - See *stylus*.

cisiojanus

A mnemonic device of the later Middle Ages by which each day of the month was correlated to and thus denoted by a particular syllable of a Latin hexameter. Several such systems were used.

civil calendar

A calendar used for civil, as distinct from religious or ecclesiastical, purposes in society and usually promulgated by the secular authorities.

clavis terminorum

A number depending on the *aureus numerus* and thus characteristic of the year. Added to the invariable *sedes clavium* - dates it produces the *termini* of five of the movable feasts.

computus

The medieval term for the science of time reckoning.

concurrentes septimanae

see *dies concurrentes*.

conjunction

Two celestial bodies are in conjunction when they have the same *longitude* relative to the *ecliptic*. - See *new moon*.

consuetudo Bononiensis

A system of denoting the days of the month during the first half of which they were numbered forwards from one to fifteen whereas in the second half of the month they were counted backwards from the first day of the following month.

cursus paschalis

see *Easter canon.*

cyclus (= "cycle")

A period of time during which something — e.g. the sun or moon, or the day of the week — returns to the same absolute or relative position. - See *cyclus solaris, Metonic cycle, period relation.*

cyclus decemnovennalis

see *Metonic cycle.*

cyclus magnus paschae, or *paschalis* (= "the great Easter cycle")

A period of 532 years within which the dates of Easter Day form a pattern which repeats itself in the following cycle, as first discovered by Victorius of Aquitaine.

cyclus lunaris (= "lunar cycle")

see *Metonic cycle.*

cyclus paschalis

see *Easter canon.*

cyclus solaris (= "solar cycle")

A period of 28 *Julian years* after the passage of which the same day of the week will again occur on the same date of the year.

Cypriac Canon

An *Easter canon* introduced in A.D. 243 in Rome, based on the *era* of the Creation and wrongly ascribed to St. Cyprian.

Cyrillic Canon

An *Easter canon* composed of five 19 year cycles and covering the years A.D. 437 - 531, presented to the Emperor Theodosius II by Bishop Cyrillus of Alexandria.

day, beginning of

In *lunar calendars* the day was usually supposed to begin at sunset. In other calendars it began at sunrise or, in some systems, at noon or at midnight.

decan

A period of ten days three of which formed one month of 30 days in the Old *Egyptian* and *Alexandrian calendars*.

Dies Cinerum

see *Ash Wednesday*.

dies concurrentes (= "concurrentes")

A *ferial* number indicating the day of the week on a certain date, usually March 24; also called *adiectio solis* or *epactae solis*.

Dies Dominica (= "the Day of the Lord")

The usual name for the first day of the week in the early Church, giving rise to the terms Domenica, Domingo, and Dimanche in Italian, Spanish and French respectively.

dies feriales

see *feria*.

dies mensis (= "the day of the month")

The day of the month numbered according to a definite, but arbitrary, system of numeration. In the Roman calendar the days were counted forwards to one of three particular dates called *kalendae*, *nonae* and *idus*. Later a consecutive numeration became common. - See *consuetudo Bononiensis*.

Dies Solis

The Day of the Sun, or the first day of the *planetary week*, giving rise to terms like Sunday and Sonntag in the vernacular.

Diocletian Era

see *era*.

dominical letter

see *litterae dominicales*.

draconitic month

A period with a mean value of 27 days 5 hours 5 minutes, during which the moon completes a revolution relative to one of its nodes, i.e. points of intersection between the *ecliptic* and the lunar orbit. It is relevant to the theory of eclipses.

Easter

In the Christian Church an annual, movable feast commemorating the Passion, Death and Resurrection of Christ. - Cf. *Pascha, Passover.*

Easter canon

A table, rule, or procedure by which the date of *Easter Day* can be found for a number of consecutive years. - See *Cyrillic, Cypriac, Hippolytian Canon, Laterculus, Supputatio Romana.*

Easter controversy

A controversy in the Early Church between the *quartodecimans* who celebrated Easter according to the rules of the Jewish *Passover*, commemorating the Passion on *Nisan* xiv/xv and the Resurrection two days later, while their opponents insisted on celebrating the Resurrection on a Sunday and the Passion two days earlier. In 325 the Council of Nicaea decided in favour of the latter practice.

Easter Day

In A.D. 325 the Council of Nicaea decided that Easter Day, commemorating the Resurrection, should be celebrated on the first Sunday after the *Easter Moon*, unless this date coincided with the Jewish *Passover*, in which case the following Sunday was adopted.

Easter limits

The first and last day of the year on which Easter Day can fall. In the Alexandrian Church these limits were March 22 and April 25, whereas the Roman Church used March 19 and April 22. With Dionysius Exiguus the Alexandrian dates were adopted in the West.

Easter Moon

Originally the *full moon* occurring on the xiv of the Jewish month *Nisan*; later the first full moon after the vernal *equinox*, as determined by the *mean motions* of the sun and moon.

ecclesiastical calendar

The essentially lunar calendar by which the Christian Church regulates its *movable feasts.*

ecliptic

a great circle on the celestial sphere along which the sun seems to complete its annual revolution from west to east among the fixed stars. It forms an angle of ca. 23½° (called the *obliquity of the ecliptic*) with the celestial equator.

Egyptian Calendar

The old Egyptian calendar had a year of 365 days divided into twelve equal months of 30 days, plus five *epagomenal* days at the end of the twelfth month. - See *Thoth, sothis period.*

Egyptian year

A calendar year of 365 days without intercalated, or leap years.

embolismic

A day inserted in a month in order to improve its agreement with the phases of the moon is called embolismic. In the same way an embolismic month is inserted in a lunar year in order to make it agree better with the course of the seasons. - See *intercalary, intercalation.*

enneakaidekaëteris

A Greek term (sometimes used in medieval Latin) for a period of 11 *tropical years* supposed to equal 136 *synodic months.* - See *hendecadas, Metonic cycle, period relation.*

epactae (= "epact")

An integer number denoting the *age of the moon* on a certain date, usually January 1st, by which the date of the Easter moon can be determined.

epactae solis

see *Dies concurrentes.*

epagomenal days

Days which are "foreign" to the series of days numbered in a particular calendar; in particular the five days between the end of the twelfth and the beginning of the first month in the old *Egyptian calendar.*

ephemeris

a table listing the dates on which a certain celestial phenomenon occurs, or a list of positions of a celestial body with regular intervals of time.

Epiphany

An immovable feast celebrated on January 6th in commemoration of the revelation of Jesus to the three Kings from the East.

equator

the celestial equator is the great circle dividing the heavenly sphere into a northern and a southern hemisphere. It intersects the *ecliptic* in the two *equinoctial points*.

equinoctial points

The points of intersection between the *ecliptic* and the *equator*. The vernal equinoctial point is where the sun moves from the southern to the northern part of the heavens in its annual motion along the ecliptic; it is sometimes called the "first point of Aries". The autumnal equinoctial point is where the sun crosses the equator in the direction from north to south.

equinox

The point of time when the sun passes through one of the *equinoctial points* and the day and the night are nearly equally long. The vernal equinox is the time of the passage of the vernal equinoctial point when the sun enters the sign of *Aries* and spring begins. In the Alexandrian calendar this was supposed to happen on March 21, at least around the time of the Council of Nicaea. The old Roman calendar distinguished between the entrance of the sun in Aries and the vernal equinox, placing the latter on March 25. - See *Aries, calendaric precession, Easter moon*.

era

a particular year from which the following succession of years is counted. In antiquity it was customary to use a local era starting with the accession of the ruling king or prince. Among more general eras can be mentioned:

1) the Roman era, reckoned from the foundation of the city of Rome, placed by Dionysius Exiguus in 753 B.C.;

2) the era of Diocletian, called by Christians the era of the martyrs, beginning in A.D. 284;

3) the Christian era, or the era of the Incarnation, beginning with the year when Christ was born, or 753 A.U.C. according to Dionysius Exiguus;

4) the era of the Creation, reckoned from the beginning of the world according to Old Testament chronology, which gave no consistent results.

feria

A feast day in the old Roman calendar. In Latin Christian calendars the ordinary days of the week (apart from Sunday) were called *dies feriales* and numbered from 2 (Monday) to 7 (Saturday).

full month

A *calendar month* of 30 days.

full moon

A full moon occurs when the moon is in *opposition* to the sun, usually on the xiv day of the *lunar month* (when the *age of the moon* is 14 days). - See *Easter moon.*

gnomonics

The science of sundials.

golden number

see *aureus numerus.*

Goldstine number

A consecutive numbering of new and full moons introduced in H.H. Goldstine, *New and Full Moons 1001 B.C. to A.D. 1651*, Philadelphia, 1973.

Gregorian calendar

A modification of the *Julian calendar* promulgated 24 February, 1582 by Pope Gregory XIII in the apostolic letter *Inter gravissimas.* It decreased the number of leap years by three in every period of 400 years, changing years like A.D. 1700, 1800, 1900, 2100 ... not divisible by 400 into ordinary years.

Gregorian year

The average length of the year of the Gregorian calendar, equal to $365 + 1/4 - 3/400$ day, or 365.2425 days.

Hebrew Calendar

Essentially a lunar calendar with a year composed of six *hollow* and six *full months*, totalling 354 days. In order to adjust it to the seasons and keeping the first month, or *Nisan*, in place in the spring, an extra or embolismic month was occasionally intercalated between years by a decree from the Sanhedrin in Jerusalem.

hendecadas

A medieval Latin form of the Greek *enneakaidekaëteris.*

Hexaëmeron

A literary genre describing the creation of the world in six days according to *Genesis I.*

Hippolytic Canon

The earliest extant Roman *Easter canon,* calculated by St. Hippolytus and engraved on the base of his statue in Rome. It comprised seven cycles of 16 years each, covering the period A.D. 222-334.

hollow month

A *calendar month* of 29 days.

hour

The subdivision of the day into hours and smaller units of time is of no calendaric importance as such. In ancient and medieval times ordinary hours were "unequal" or "seasonal", the time from sunrise to sunset being divided into twelve "hours of the day", and the time from sunset to sunrise into twelve "hours of the night". The division of the whole day into 24 equal parts was known, but only used in astronomy until they were adopted for everyday use in the centuries following the invention of the mechanical clock (shortly before A.D. 1300).

idus

In the *Roman calendar* the 15th of March, May, July and October, and the 13th of the other months.

immovable feast

An ecclesiastical feast celebrated on a fixed date of the year, such as the commemoration of a martyr or saint, and also feasts like *Christmas,* the *Circumcision, Epiphany* and the *Annunciation.*

Indictio (= "indiction")

The indiction is the number of the current year within the old Roman indiction cycle of 15 years. It has no astronomical importance and seems to be of fiscal origin. According to the *Argumenta Dionysii* the indiction is found as the remainder when the number of the year according to the Christian era is increased by 3 and divided by 15 (the remainder zero being replaced by 15). The indiction was changed on September 1 in the East, but on December 25 (or January 1) in the West.

intercalation

The insertion of an extra so-called *embolismic* or *intercalary* day or month into a calendar at a suitable place of the year in order to adjust it to the course of the sun or the moon. - See also *epagomenal, leap year.*

Invocavit

The usual name in the Latin liturgical calendar of the first Sunday in *Lent*, i.e. the Sunday after *Ash Wednesday.*

Julian Calendar

A calendar introduced in 46 B.C. by a decree from Julius Caesar. It gave the Roman months the lengths thay still have, and instituted a *leap year* every fourth year. It remained in use until the introduction of the *Gregorian calendar.*

Julian date

A consecutive numbering of dates within the *Julian period.*

Julian period

A period of $28 \times 19 \times 15 = 7980$ years beginning in 4713 B.C. as defined by J.J. Scaliger in 1583 by combining the 28 year *cyclus solaris* with the 19 year *Metonic cycle* and the 15 year *indiction cycle.*

Julian year

The average length of the year in the Julian Calendar, equal to 365.25 days.

kalendae

the first day of each month in the Roman calendar.

Laterculus

An *Easter canon* for the years A.D. 213-312 by the Roman scholar Augustalis and based on a period relation assuming that 84 years are equal to 1039 months. It introduced the *epactae* of the years and had a *saltus lunae* with intervals of 14 years.

leap year

A calendar year of 366 days obtained by intercalating one leap day in a year of 365 days between February 23 and February 24 = *sextilis kalendae Martias*, whence the name *annus bissextilis*, or bissextile year for a leap year.

Lent

In the ecclesiastical year a movable period (of fasting) of 40 days beginning on *Ash Wednesday* and ending on *Palm Sunday*. - See *Invocavit*.

litterae calendarum

The first seven letters of the alphabet as correlated to the days of the year so than 1 January is denoted by A, 2 January by B, and so on. In leap years the letter F was given to both the leap day and to 24 February so that 1 March, always got the letter D. Throughout the year all the days with the same letter would fall on the same day of the week.

litterae dominicales (= "dominical" or "Sunday letters")

The *littera dominicalis* (l.d.) of a particular year is the *littera calendarum* (l.c.) of the first Sunday in January and, in consequence, of all the Sundays of the year. It moves one letter backwards from one year to the next. A leap year had one l.d. referring to Sundays before and another to Sundays after the leap day. Thus the l.c. will return to the same position in the calendar after the 28 year *cyclus solaris* and can be used as an indicator of the place of the year within this cycle.

litterae lunares (= "lunar letters")

The first twenty letters of the alphabet provided with dots in such a way that 59 different symbols are formed. They were arranged by Bede in a table of 19 columns (one for each year of the *Metonic cycle*) of 59 lines, by means of which the *age of the moon* can be found on each day of the first two months of any year of the lunar cycle so that the dates of the *lunations* can be determined.

litterae paschales (= "Easter letters")

Continuing Bede's table of *litterae lunares* throughout March and April, the letters for the 35 possible Easter dates were called *litterae paschales*.

litterae punctatae

Usually the same as *litterae paschales*.

litterae signorum

A series of 14 letters used by Bede to describe the motion of the moon relative to the twelve signs of the *zodiac*.

locus saltus

The date on which the *saltus lunae* is placed in a particular calendar system.

longitude

An astronomical coordinate measured from west to east along the *ecliptic* from the vernal equinoctial point (the first point of Aries) and used to characterize the position of e.g. the sun and the moon at a given point of time. - See *conjunction*, *opposition*.

luminary

The sun and the moon are called luminaries in contradistinction to the other planets.

luna (= "moon")

This term is sometimes used to denote the day of the month in a *lunar calendar*. *Luna xiv* is here the date of the full moon.

lunar calendar

A calendar based on the month as the fundamental chronological unit of time. - See e.g. *Hebrew Calendar*, *Ecclesiastical Calendar*.

lunar cycle

See *Metonic cycle*.

lunar year

the year of a *lunar calendar*, usually comprising six *full* and six *hollow months*, giving a total of 354 days, with an occasional *intercalary* day inserted to increase the agreement between the lunar year and the phases of the moon.

lunation

Usually the date of the *new moon*, or the period between successive new moons (see *synodic month*). Sometimes also used of the date of the *full moon*.

luni-solar calendar

A lunar calendar in which the *lunar year* from time to time (according to a variable or fixed scheme) is provided with an *intercalary* month in order to prevent the seasons from wandering through the year.

martyrology

a calendar or list of dates on which individual martyrs or saints are commemorated, always on fixed dates in the civil calendar.

mean moon

An abstract point moving along the *ecliptic* with a constant angular velocity equal to the mean velocity of the moon.

mean motion

the regular and uniform motion of the *mean sun*, resp. the *mean moon*, as distinct from the irregular true motions of the *luminaries*. Calendaric periods are based on the mean motions.

mean sun

An abstract point moving along the *ecliptic* with a constant angular velocity equal to the mean velocity of the sun. (In modern astronomy the mean sun moves on the *equator*).

meridian

a vertical plane, or a horizontal line, from north to south through a particular geographical locality. True noon is the time of the day when the sun crosses the meridian. On different meridians the same event — e.g. the *Easter Moon* — will occur at different times of the day, and earlier in the east than in the west. In some years this may influence the date of Easter so that the ecclesiastical calendar has to be referred to a standard meridian in order to avoid confusion.

Mesore

The twelfth month of the year in the *Egyptian* and *Alexandrian calendars*.

Metonic cycle

A span of 19 years based on a period relation assuming that 19 *solar* *years* are equal to 235 *synodic months*. It was used as the framework of the *luni-solar calendars* in the East, and also as the basis of the Alexandrian *Easter canons* of Anatolius, Cyrillus and others. In the West it was introduced by Victorius and was later adopted as the *cyclus lunaris* on which the Easter calculation was founded. Its approximative character led to a slowly increasing discrepancy between the calculated and the actual dates of the *lunations*, sometimes known as the *calendaric precession of the moon*. The Metonic cycle was often construed as a combination of the *octaëteris* and the *enneakaidekaëteris*.

millenium

A period of one thousand years. Seven such periods were supposed by some of the Fathers to comprise the whole duration of the world from Creation to the final Day of Judgment (milleniarism).

month

A unit of time defined by a complete revolution of the moon around the heavens relative to a particular point such as the sun, the vernal equinoctial point, or a node of the lunar orbit. - See *draconitic, synodic, tropical month, calendar month.*

movable feast

an ecclesiastical feast commemorated on different dates in different years. The principal movable feast is *Easter* from the date of which the dates of the others derive, such as *Lent, Palm Sunday,* the *Ascension* with the *Rogation* days, and *Pentecost*. - See *termini.*

new moon

One of the phases of the moon. In astronomy the new moon is the actual (but invisible) *conjunction* of the sun and moon. In lunar calendars, and in ordinary language, the new moon is the first visibility — also called *primatio* or *incensio* — of the lunar crescent in the evening just after sunset; this marks the beginning of the new lunar month.

New Year's Day

see *stylus.*

Nisan

the first month of the lunar year of the *Hebrew calendar*, placed in the spring at a time announced by the Sanhedrin in Jerusalem. The Paschal Moon fell on *Nisan* xiv.

nonae

In the *Roman calendar* the 7th day of March, May, July and October, but the 5th day of the other months.

nundinae

According to old Roman usage the *dies nundinarum*, or market days, were held every ninth day. As such they were abolished by Constantine.

obliquity of the ecliptic

see *ecliptic*.

octaëteris

A Greek term for a period of eight solar years assumed to equal 99 *synodic months*. It was presumably used for the (now lost) Easter canon of Demetrius. - See *Metonic cycle, ogdoadas*.

octava dies (= "the eighth day")

The eighth day after an ecclesiastical feast, and as such often used for denoting a day of the month.

ogdoadas

Medieval Latin form of *octaëteris*.

opposition

Two celestial bodies are in opposition when they occupy diametrically opposite points of the heavens so that their *longitudes* differ by 180°. A *full moon* occurs when the moons is in opposition to the sun.

Palm Sunday

The Sunday before Easter.

Pascha

A term denoting either the Christian *Easter* or the Jewish *Passover*.

Passover

A Jewish spring festival commemorating the exodus of Israel from Egypt and celebrated on the night of *Nisan* xiv.

Pentecost

A movable feast celebrated on the Sunday falling seven weeks after Easter Day in commemoration of the descent of the Holy Spirit.

period relation

A relation stating that n *solar years* equal m *synodic months* where n and m are integers. Several more or less approximate period relations were known to ancient Babylonian and Greek astronomers and used for time reckoning and calendar systems. - See *enneakaidekaëteris*, *Hippolytic cycle*, *Metonic cycle*, *octaëteris*, etc.

perpetual calendar

A calendar by which the movable feasts of any given year can be determined from the calculated *golden number* of the year. It can be made by providing the dates in a Julian calendar with *litterae calendarum* for each day of the year, and dates of *lunations* (marked by *golden numbers*) for a complete 19 year lunar (Metonic) cycle. If a Gregorian calendar is used the golden numbers are replaced by the Gregorian epacts.

Phamenoth

The seventh month of the *Egyptian* and *Alexandrian calendar.*

planetary week

an astrological version of the ordinary seven day *week* in which each day was named after its "governing" planet. It originated in the Orient but spread to the Greek, Roman and Germanic world, where local gods replaced the planets as "governors".

precession of the equinoxes

The slow motion of the *equinoctial points* towards the west relative to the fixed stars, causing the *sidereal* and the *tropical year* to have different lengths. In Antiquity and the Middle Ages precession was construed as a motion of the eighth celestial sphere (containing all the fixed stars) towards the east relative to the equinoctial point. - See *trepidation*, *tropical year.*

primacio

see *new moon.*

quartodecimans

see *Easter controversy.*

radix

The value of an astronomical variable parameter at a definite point of time, or epoch.

regulares paschae

Numbers which denote the difference in days between March 24 and the date of the *Easter moon.* Added to the *dies concurrentes* they give a sum indicating the weekday of the Easter moon.

regulares solares

Numbers which added to the *dies concurrentes* produce the *ferial* numbers of the first day of each month throughout the year. Also called *regulares mensium* or *regulares feriales.*

Revolutionary Calendar

A calendar introduced in 1793 by the French Revolutionaries. It reckoned the years from an *era* defined as the autumnal *equinox* 1792, dividing them into twelve months of 30 days with five or six *epagomenal* days at the end. Each month was divided into three "weeks" of ten days. It was abolished as of 1 January, 1806.

Rogation days

The three days preceding the *Ascension.*

Roman Calendar

The old calendar of the Roman Republic was a *lunar calendar* with ten named or numbered months from March to December, a gap in winter (later filled with the months of January and February) and occasionally an *intercalary* month of 22 or 23 days inserted between February 23 and 24. In 46 B.C. it was replaced by the *Julian Calendar.*

Sabbath

The seventh and last day of the Jewish week. In the Latin liturgy the name is usually retained instead of Saturday, or *feria 7ª*.

saltus lunae

the artificial or deliberate increase of the *age of the moon* by one day, made in a particular year of a calendaric cycle in order to adjust it to the actual *lunations*. - See *locus saltus*, *Laterculus*, *Supputatio Romana*.

Saros period

A period of 223 *synodic months*, approximately equal to 242 *draconitic months* and therefore a fairly good eclipse period.

sedes clavium

Five fixed days of the year used in medieval computistic science, viz. January 7 (for Septuagesima), January 28 (for Quadragesima), March 11 (for the Easter moon), April 15 (for the Rogation days) and April 29 (for Pentecost). If the *clavis terminorum* of the year is added to one of these dates, the *terminus* of the feast in question is obtained. - See *clavis terminorum*, *termini*.

sidereal year

The period in which the sun completes a revolution relative to the same fixed star. It has a length of 365 days 6 hours 9 minutes.

sign

The *ecliptic* was usually divided into twelve signs, each covering an interval of 30° and named after a zodiacal constellation which once coincided with the sign, but since has moved out of it because of the *precession*.

solar cycle

see *cyclus solaris*.

solar year

The period in which the sun completes a revolution from west to east on the heavenly sphere. It is either a *sidereal year*, or a *tropical year*.

solstice

One of the two days of the year on which the sun reaches its greatest distance from the celestial equator. The summer solstice marks the longest, and the winter solstice the shortest day of the year.

Sothis period

A period of 1461 years during which the new year's day (*Thoth* 1st) of the old Egyptian calendar moved backwards through the seasons to its original position because of the excess of the *tropical year* over the *Egyptian year.*

Sphere, the eighth

In ancient and medieval cosmology the outermost, spherical shell of the finite universe in which the fixed stars were located. - See *precession.*

stylus (= "style")

The "style" of the year was indicated by the date on which the new year began according to a particular calendaric convention. In the middle ages several styles were used, such as the

1) *stylus Nativitatis* with New Year's Day on Christmas Day (also called *stylus Curiae Romanae*);

2) *stylus communis,* or *stylus Circumcisionis,* with the new year beginning on January 1st;

3) *stylus Annunciationis,* or *Incarnationis* with March 25 as New Year's Day;

4) less common was the *stylus Paschalis* with a year beginning either on Good Friday or Easter Day.

Sunday

The first day of the week. - See *dies Dominica, dies solis.*

Supputatio Romana (= The "Roman Reckoning")

A Roman *Easter canon* inaugurated in A.D. 312 and based on a *period relation* assuming 84 years to be equal to 1039 months. - See also *Laterculus.*

synodic month

The period of a complete revolution of the moon relative to the sun, and thus also the period of the lunar phases, e.g. the time from one new moon to the next following. It varies around a mean value of 29 days 12 hours 44 minutes 3 seconds which was well known to both Babylonian and Alexandrian astronomers.

terminus

A limiting date for one of the movable feasts. The *terminus paschalis* is the date of the *Easter Moon.* It varies with a 19 year period from March 21 to April 18. Its date can be found by adding the *clavis* *terminorum* of the year to the *clavis paschalis* (= March 11). In the same way the *termini* of other feasts are found by adding the *clavis terminorum* to the *sedis clavium* (sometimes also called *clavis*) of the feast. For example, the *clavis Pentecostes* is April 29. A year with the *golden number* 10 has the *clavis terminorum* 17 as seen in a table of correspondance. Adding 17 to April 29 we get May 16, and the following Sunday is Pentecost.

Theophilic Canon

An *Easter Canon* based on the *Metonic cycle* and covering 100 years from A.D. 380 onwards, presented by Bishop Theophilus of Alexandria to the Emperor Theodosius I in Rome.

Thoth

The first month of the *Egyptian* and *Alexandrian calendars.*

tithis

An artificial unit of time, equal to 1/30 of a *synodic month,* and used by the ancient Babylonian astronomers.

trepidation

Most medieval astronomers (including Copernicus) described precession as an *accessus et recessus,* or oscillatory movement, of the *eighth sphere* around a mean position, sometimes adding to this *trepidatio* of the *equinoctial points* a linear motion proportional to time. In both cases the result would be a variation of the difference between the *tropical* and the *sidereal year.*

tropical year

The period of a complete revolution of the sun from west to east on the heavenly sphere, relative to the vernal *equinoctial point.* Its value is 365 days 5 hours 49 minutes. It is shorter than the *sidereal year* because of the *precession* of the equinoxes. Since medieval astronomers conceived the precession as a *trepidation* the difference was thought to vary in time. This erroneous view presented an obstacle to the reform of the calendar.

true motion

see *mean motion.*

Universal Calendar

The possibility of a Universal Calendar acceptable to all nations has often been discussed, also by the United Nations, but without being realised. Most proposals envisage a more rational subdivision of the year than that of the *Gregorian calendar* just as it has been recommended to abolish the *movable feasts* by placing them on fixed dates. The wish to keep an unbroken succession of *weeks* is an obstacle to such efforts.

vernal equinox

see *equinox.*

Victorian cycle

see *cyclus magnus paschalis.*

vigilia

the day before an ecclesiastical feast.

week

A period of Jewish origin, comprising seven consecutive days denoted by individual names or *ferial* numbers. Without having any astronomical significance the week has been of great importance for time reckoning as the only calendaric period which has survived all calendar reforms without interruption. - See *feria, Sabbath, Sunday, litterae calendarum, planetary week, Universal Calendar.*

Xanthicus

The sixth month in the ancient Macedonian calendar.

year

A word with several different meanings. - See *calendar year, lunar year, sidereal year, solar year, tropical year.*

zodiac

A series of twelve constellations called Aries, Taurus, . . . Pisces, situated along the *ecliptic* the *signs* of which are named after them. Because of the *precession* a zodiacal constellation no longer coincides with the sign bearing its name.

CLOSING REMARKS

The time has come when we must part and, once again on behalf of the Academy, I want to thank all of you for coming here and for contributing with your papers and discussions to the considerable success of this conference. We can all agree, I am sure, that the conference has lived up to Father Coyne's expectations that it should not only be a commemoration of events of 400 years ago, but that it should be concerned with new ideas on the history of calendar reform both before and after the edict of Pope Gregory.

The conference has also been, I believe, a happy reminder of the links which exist between the worlds of scholarship, of human affairs and of ecclesiastical concerns. The Holy Father in his memorable Address yesterday expressed it beautifully when he spoke of the harmony between the rhythms of the Universe, of human existence in society and of the life of the Church.

The organizing committee for this conference has done extremely well and you will all agree with me on congratulating them on their choice of speakers. Professor Pedersen will pay tribute to all those responsible for the success of the meeting. However, I am sure that you will allow me to express my special thanks to the indefatigable Father Coyne who managed to organize the conference in every detail having only just come back from a hard session at the Assembly of the International Astronomical Union in Greece and in spite of it all maintaining his cheerful demeanour throughout. Our gratitude is also extended to Father Martin F. McCarthy, S.J. and Dr. M.T. Brück who assisted Father Coyne in the running of this conference.

Again, thank you all, and with this I formally close this conference.

H.A. Brück