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THE PERIOD OF THE ECLIPSING BINARY RR CENTAURI (*)

D. J. K. O' CONNELL, S. J.
Accademico Pontificio Soprann.

SVMMARIVM — Adhibitis circa 3,000 observationibus, tempus periodicum eclipsium stellae duplicis RR Centauri exquiritur. Incrementum huius periodi praeteritis 50 annis demonstratur. Auctor determinat formulam parabolicam, qua tempora obscurationum praedicuntur.

RR Centauri was discovered in 1896 by A. W. ROBERTS [1]. ROBERTS made 739 visual observations in 1896-1899 [2] and over 300 in 1901 [3]. PINGSDORF made 522 visual observations in 1929-1931 [4]. VOÛTE [5] published a very good light curve based on 906 extra-focal photographic exposures, made in 1925 and 1926 and measured with a photometer. In Kukarkin and Parenago's Catalogue (1948) the period is noted as variable. It seemed worth while making an investigation of the period.

Estimates were made on 511 plates taken at Riverview Observatory between 1934 and 1950, 474 with the R and P cameras (Zeiss Astrotriplets) and 37 with the G (Grubb-Parsons-Ross) camera. VOÛTE's comparison stars were used, with the addition of H.D. 125015 (B9) and H.D. 123994 (F8), the magnitudes of which were determined from comparisons with VOÛTE's sequence.

Times were reduced to the Sun. A mean light curve was obtained from 367 estimates on plates taken from 1934 to 1939, using the period $0^{d}.6056906$, which was found to fit the Riverview observations of these years best. The observations for each year were plotted separately, except for those of 1940-49, which were combined into three groups. With the aid of the mean light

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curve, epochs of both minima were determined for each group of observations. These epochs are listed in the table. The two minima are listed in separate columns. Weights were assigned proportional, approximately, to the number of observations used for each minimum.

When mean epochs of minimum are used to investigate the period of an eclipsing binary, it is necessary that the observations on which they are based should not be spread over too long an interval, and that an epoch of minimum should be chosen midway in the series of observations. All the observations used here fulfil the first of these conditions. PINGSDORF's minimum occurs midway in his observations, as do those determined by the writer, but the minima published by ROBERTS and VOÛTE need to be revised in this respect.

ROBERTS' first observations of RR Centauri were made in 1896 [**1**]. He combined these observations with those he made in 1898 and 1899 to obtain an improved light curve and epoch of minimum [**2**] (the statement that the observations started in 1894 is evidently a misprint). The published epoch of minimum is on January 1, 1900. Indeed, in the same paper (p. 85), ROBERTS announced that he intended to reduce all epochs of maximum or minimum of variable stars to the first epoch occurring in 1900. Fortunately he gives the period ($0\overset{d}{.}605683$) that he sused for this reduction. Using this period, an epoch of minimum about the middle of his ohservations was obtained. This minimum is given in the table.

ROBERTS published another minimum, based on observations made in 1901 [**3**]. Again he reduced the epoch to January 1, 1900, using the period $0\overset{d}{.}605680$. With this period epochs of both minima were obtained midway in these observations.

VOÛTE's published minimum refers to the beginning of his observations. Using his period ($0\overset{d}{.}60567$), the epoch of minimum was transferred to the middle of his series of observations.

These published epochs of minimum refer to what I have called Minimum I. ROBERTS, in his third paper [**3**], and VOÛTE give the interval between the minima, so that epochs of Minimum II could be computed. They are given in the table.

Weights were assigned to these minima, as before, on the basis of the number of observations used. Double weight was given to the photographic observations.

MINIMA OF RR CENTAURI

Epoch	Minimum I					Minimum II					Observer	Years
	J. D. hel.	Wt.	O—C Unit $0^d_.001$			J. D. hel.	Wt.	O—C Unit $0^d_.001$				
			(1)	(2)	(3)			(1)	(2)	(3)		
	2400000 +					2400000 +						
− 16608	14171.887	10	+ 64	0	(+ 86)						Roberts (2)	1896–99
− 14382	15520.137	3	+ 48	0	(+ 73)	15520.440	3	+ 48	0	(+ 73)	» (3)	1901
416	24483.055	20	− 2	− 2	0	24483.358	20	− 2	− 2	0	Voûte (5)	1925–26
3189	26162.636	10	+ 6	+ 4	+ 2						Pingsdorf (4)	1929–31
5577	27609.025	2	+ 12	+ 5	+ 1	27609.327	2	+ 11	+ 4	0	O'Connell	1934
6125	27940.943	3	+ 13	+ 4	0	27941.246	2	+ 13	+ 4	0	»	1935
6769	28331.007	2	+ 13	+ 2	− 1	28331.310	2	+ 13	+ 2	− 1	»	1936
7337	28675.043	2	+ 19	+ 6	+ 3	28675.343	2	+ 16	+ 3	0	»	1937
7933	29036.028	2	+ 14	− 1	− 4	29036.334	2	+ 17	+ 2	− 1	»	1938
8582	29429.125	1	+ 19	+ 2	− 1	29429.430	1	+ 21	+ 4	+ 1	»	1939
9803	30168.676	1	+ 25	+ 3	+ 1	30168.976	1	+ 22	0	− 1	»	1940–42
11920	31450.926	1	+ 33	0	+ 2	31451.226	1	+ 30	− 3	− 1	»	1943–46
14093	32767.091	1	+ 38	− 8	− 1	32767.391	1	+ 35	− 11	− 4	»	1947–49
15247	33466.064	1	+ 47	− 7	+ 3	33466.367	1	+ 47	− 7	+ 3	»	1950

Despite the comparatively long interval between ROBERTS' observations and VOÛTE's, it seems certain that no error has been made in estimating the number of epochs elapsed, and that there has been no confusion between Minimum I and Minimum II.

The run of the residuals of the times of minima from a linear formula shows definitely that the period has increased during the half century covered by the observations.

A least squares solution, using all the minima in the table, gave the following result, with the corresponding probable errors:

$$[1] \quad \text{Minimum I} = \text{J.D.hel. } 2424231.0910 + 0^{d}.60568807\,E + 2^{d}.31 \times 10^{-10} E^2$$
$$\pm .0006 \quad \pm .00000006 \qquad \pm .06 \quad (\text{p. e.})$$

Probable error for unit weight $= \pm 0^{d}.0045$.

For Minimum II zero epoch is half a period later.

The residuals, $(O-C)_2$, from this formula (and from the corresponding one for Minimum II) are given in the table.

The residuals, $(O-C)_1$, from the linear formula:

$$[2] \qquad \text{Minimum I} = \text{J. D. hel. } 2424231.0910 + 0^{d}.60568807\,E$$

(and from the corresponding formula for Minimum II) are also given in the table. These residuals are plotted in Figure A, where circles denote Minimum I, and crosses Minimum II. The curve in Figure A is the parabola:

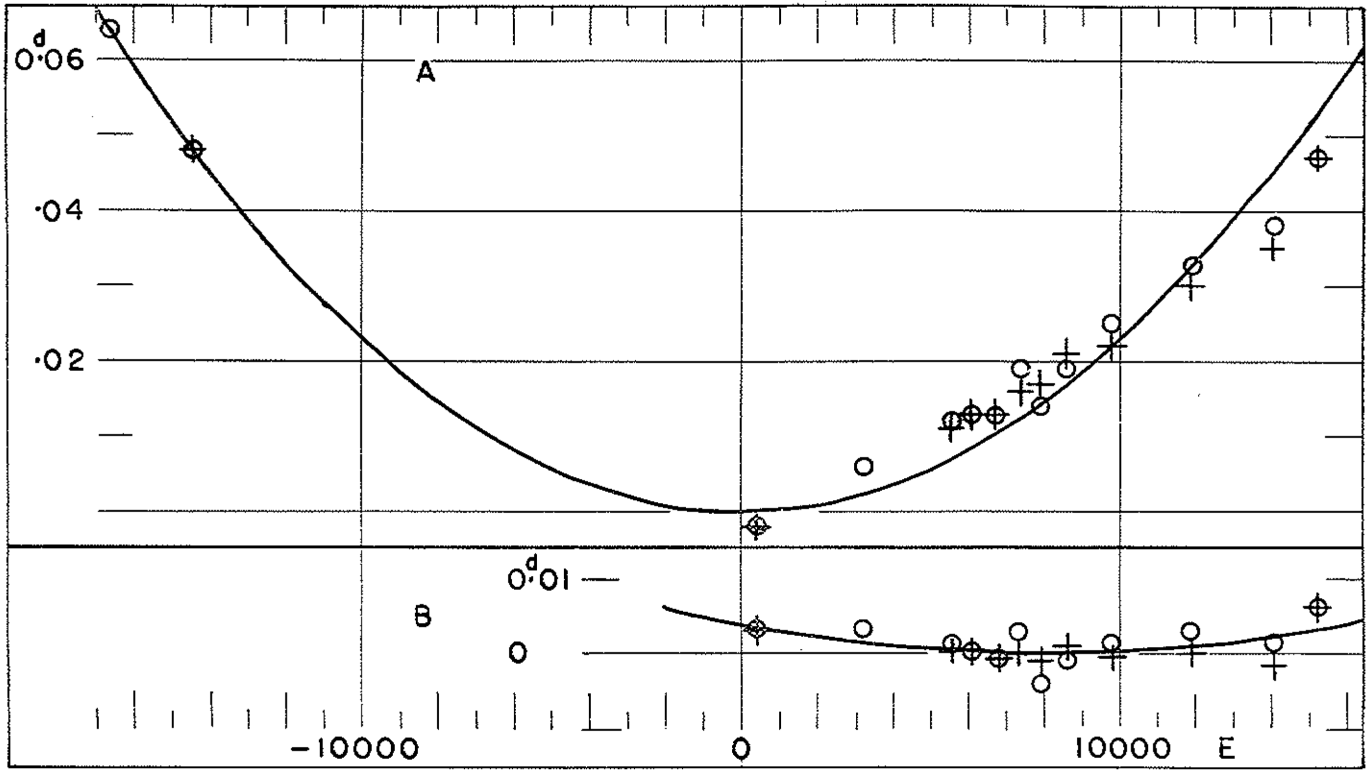
$$O-C = 2^{d}.31 \times 10^{-10} E^2 \; .$$

Although it follows definitely from this result that the period of RR Centauri has increased considerably since ROBERTS' observations, it is not certain that the rate of change has been uniform. A comparatively abrupt increase of period, some time between 1901 and 1925, would be consistent with the data given here.

The interval from 1925 to 1950 is well covered by observations. In order to see whether the period has increased during this interval, a least squares solution was made using all the minima in the table, except those of ROBERTS. The following result, with the corresponding probable errors, was obtained:

$$[3] \quad \text{Minimum I} = \text{J.D.hel. } 2429036.0321 + 0^{d}.60569121\,E + 0^{d}.62 \times 10^{-10} E^2$$
$$\pm .0004 \quad \pm .00000007 \qquad \pm .12 \quad (\text{p. e.})$$

Probable error for unit weight $= \pm 0^{d}.0019$.



Period of RR Centauri. Abscissae are epochs of minimum. Ordinates are residuals, O − C, in decimals of a day, — (A) from the linear formula (2); (B) from the linear part of formula (3). Circles denote Minimum I, crosses Minimum II. The curves are parabolas: $O - C = 2^{d}.31 \times 10^{-10}E^{2}$ (figure A); $O - C = 0^{d}.62 \times 10^{-10}E^{2}$ (figure B).

The residuals from this formula, and from the corresponding formula for Minimum II, are given in the table, $(O-C)_3$. The residuals from the linear part of formula [3] are plotted in Figure B. The curve in Figure B is the parabola:

$$O - C = 0^d\!.62 \times 10^{-10} E^2 \ .$$

Using the same data (i.e. excluding ROBERTS' minima) another least squares solution was made, assuming a constant period from 1925 to 1950. The following result was obtained:

$$[4] \quad \text{Minimum I} = \text{J. D. hel. } 2429036.0333 + 0^d\!.60569096\, E$$
$$\pm .0004 \quad \pm .00000008 \ (\text{p. e.})$$

Probable error for unit weight $= \pm\, 0^d\!.0025$.

It appears from these results that the period has increased during the interval, 1925-50, covered by these observations. The rate of increase, however, was much less than the average rate of increase from 1896 to 1925.

From the residuals for the two minima it can be safely concluded that the minima are evenly spaced, in agreement with the results found by ROBERTS and VOÛTE.

The writer's mean light curve shows Minimum I to be $0^m\!.01$ deeper than Minimum II. ROBERTS also found Minimum to be slightly the deeper, whereas VOÛTE found no such difference. No difference in brightness was found between the two maxima.

It does not seem worth while to publish the Riverview mean light curve, which is not as accurate as the very good curve published by VOÛTE. In any case, as the binary is a bright one, it will doubtless be ohserved photoelectrically.

The elements given in formula [3] should give adequate predictions of times of minima for several years to come.

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