COMPLEXITY AND PREDICTIONS AT THE FUNDAMENTAL LEVEL OF SCIENTIFIC KNOWLEDGE

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1. THE BASIC POINTS

What is the experimental evidence for *Complexity* to *exist*, and for *predictions* to *exist*?

The experimental evidence for the *existence* of *Complexity is as follows*:

1) The <u>A</u>nderson-<u>F</u>eynman-<u>B</u>eethoven-type phenomena (AFB) i.e. phenomena whose laws and regularities ignore the existence of the Fundamental Laws of Nature from which they originate (see chapter 2);

2) The Sarajevo-type effects, i.e. <u>U</u>nexpected <u>E</u>vents of quasi irrelevant magnitude which produce <u>E</u>normous <u>C</u>onsequences (UEEC) (see chapter 3).

The experimental evidence for the *existence* of *predictions* consists of the very many results of reproducible scientific experiments.

For example the measurement of the anomalous magnetic moment, in symbols (g–2), of the electron (e):

$$(g\text{--}2)_e$$

which is theoretically computed at an extraordinary level of precision (few parts in ten billion parts) and is experimentally verified to be correct.

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Could the

$$(g\text{–}2)_e$$

be predicted before the discovery of the Maxwell equations and the exis-
tence of Quantum ElectroDynamics (QED)?

Predictions at the *fundamental level of scientific knowledge* depend on
UEEC events.

For example: it is the discovery of the laws governing electric, magnet-
ic and optical phenomena (all totally unpredicted) which produced the
mathematical structure called QED.

The mathematical structure was not invented before the innumerable
series of *UEEC events* in electricity, magnetism and optics which allowed
Maxwell to express 200 years of experimental discoveries in a set of 4 equations.

The mathematical formalism comes *after* a totally unexpected discov-
ery: an *UEEC event* which no one was able *to predict*.

In the whole of our knowledge predictions exist only in Science.

These predictions are the analytic continuation of what is already
known. The *greatest* steps in the *progress of Science* come from totally
unpredicted discoveries.

This is the reason why we need to perform experiments, as Galileo
Galilei realized, 400 years ago.

Today we have all the mathematics needed to describe the *Superworld*
but in order to know if the Superworld exists we need the experimentally
reproducible proof of its existence.

2. AFB PHENOMENA FROM BEETHOVEN TO THE SUPERWORLD

Let me now mention a few examples of AFB phenomena in Science.
Beethoven and the laws of acoustics.

Beethoven could compose superb masterpieces of music without any
knowledge of the laws governing acoustic phenomena. But these master-
pieces could not exist if the laws of acoustics were not there.

The living cell and QED.

To study the mechanisms governing a living cell, we do not need to
know the laws of electromagnetic phenomena whose advanced formulation
is called Quantum ElectroDynamic, QED.

All mechanisms needed for life are examples of purely electromagnetic
processes. If QED were not there Life could not exist.

Nuclear Physics and QCD.

Proton and neutron interactions appear as if a fundamental force of nature is at work: the nuclear force, with its rules and its regularities.

These interactions ignore that protons and neutrons are made with quarks and gluons.

Nuclear physics does not appear to care about the existence of QCD, although all phenomena occurring in nuclear physics have their roots in the interactions of quarks and gluons.

In other words, protons and neutrons behave like Beethoven: they interact and build up nuclear physics without 'knowing' the laws governing QCD. The most recent example of an Anderson-Feynman-Beethoven-type phenomenon: *the world could not care less about the existence of the Superworld*.

3. UEEC Events, from Galilei up to the Present Day

In figure 1 there is a sequence of UEEC events from Galilei to Fermi-Dirac and the 'strange particles'. In figures 2, 3, 4 from Fermi-Dirac to the construction of the Standard Model and in figure 5 a synthesis of the UEEC events in what we now call the Standard Model and Beyond (SM&B).

I	Galileo Galilei discovery of $F = mg$.
II	Newton discovery of $F = G \dfrac{m_1 \cdot m_2}{R_{12}^2}$
III	Maxwell discovers the unification of electricity, magnetism and optical phenomena, which allows him to conclude that light is a vibration of the EM field.
IV	Planck discovery of $h \neq 0$.
V	Lorentz discovers that space and time cannot be both real.
VI	Einstein discovers the existence of time-like and space-like worlds. Only in the time-like world, simultaneity does not change, with changing observer.
VII	Rutherford discovers the nucleus.
VIII	Hess discovers the cosmic rays.
IX	Dirac discovers his equation, which opens new horizons, including the existence of the antiworld.
X	Fermi discovers the weak forces.
XI	Fermi and Dirac discover the Fermi–Dirac statistics.
XII	The 'strange particles' are discovered in the Blackett Lab.

Figure 1. 'UEEC'. Totally Unexpected Discoveries. From Galilei to Fermi-Dirac and the 'Strange' Particles

FROM FERMI-DIRAC TO NOW

1927	P.A.M. DIRAC	$(i\partial\!\!\!/ + m)\,\psi = 0$	*The Physics of Virtual Processes is conceived*

ANTIPARTICLES   *ANTIMATTER*

e^+ ; $\bar{p},\ \bar{n},\ \bar{\Lambda},\ \bar{\Sigma}$ ..... $\bar{D}$; $^3H,\ ^3He$, ... ✳④

| 1932 | 1955-57 | | 1965 | 1978-1980-1988 |
|------|---------| |------|----------------|

(Anderson, Blackett, Occhialini)   *(CERN-Bologna)*

(Segrè) (Piccioni)   SPACE - AMS
                                                       1998 - 2004

1947	**SUBNUCLEAR PHYSICS is born**

$(2S_{1/2} - 2P_{1/2})$ *Shift* π–*Meson* (1st Family) quark V^0–*Particles* (2nd Family) quark
(Lamb, Retherford)   *(Lattes, Occhialini, Powell)*   *(Blackett, Rochester, Butler)*

Renormalization: 1947-71 $\pi \to \mu \to e$
Radiative Effects   P ≠
                                      $\pi^0 \to \gamma\gamma$ C ≠ $(\theta - \tau)$ puzzle
                                                                     1955

	1968	1968	✳④

Scale Breaking in (DIS) ◄ *(Scaling)* ► *(No Quarks)*   Flavour Mixing
All Quantities run with q^2:   & CP ≠   *Proliferation*
$\alpha_1(q^2); \alpha_2(q^2); \alpha_3(q^2)$ 1957 | LOY

Gauge Unification ⑤ª ✳ **1979-94**   Nuclear Forces   CP ≠
⑤ᵇ ✳ *and Gap*   R ≈ 1 Fermi   1964
                                                            Why m_π *so small?*
                      μ (2nd Family) lepton $(\eta-\eta')$ QCD (?)   CP ≠
                                                                                     T ≠
                                                                                      ?
②ª ✳ $(g-2)_\mu \equiv$ QED | 1960

②ᵇ ✳ $\tau_\mu \equiv$ G (Fermi) | 1961   *Statics*   *Dynamics*

②ᶜ ✳ **HL ≡ 3rd Family** | 1960-1975

                      $\Gamma(X^0 \to \gamma\gamma) \to$ *too small* $SU(3)_f$
③ᶜ ✳ | 1968 | $\Gamma(X^0 \to$ *all*$) \to$ *too high*
                      $m(X^0) \to$ *too high*   1980 *Effective Energy* ✳③ª

| 1976 | Instantons | *New intrinsic*   *Universality*
                                                        degree of freedom   *Features* ✳③ᵇ
| η'-Leading in gluon Jets | 1997 | ✳③ᶜ |
                                                           $SU(3)_c \equiv$ QCD   ✳④
                                                        Asymptotic freedom — Confinement
                                                        (1972-1974)   (1975)

THE STANDARD MODEL	≳ 20 Parameters

$SU(3)_c \otimes SU(2)_L \otimes U(1)_Y$	Repeated 3 times
QCD	QFD	QED	

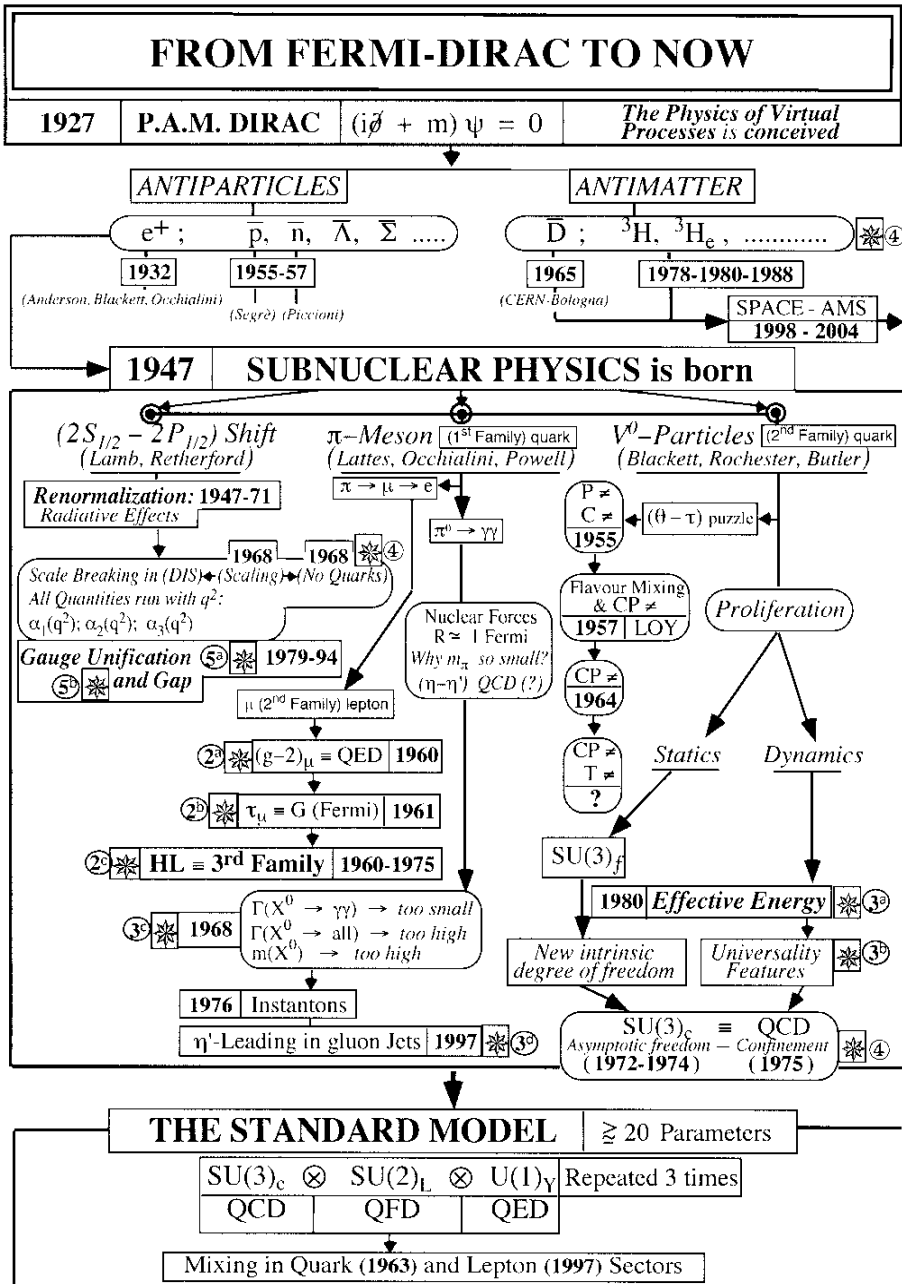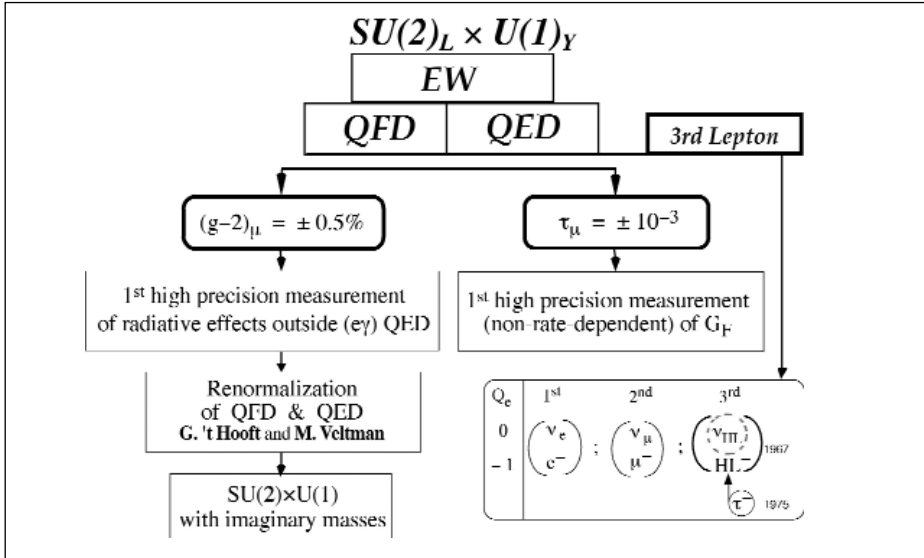| Mixing in Quark (**1963**) and Lepton (**1997**) Sectors |
|--|

Figure 2.

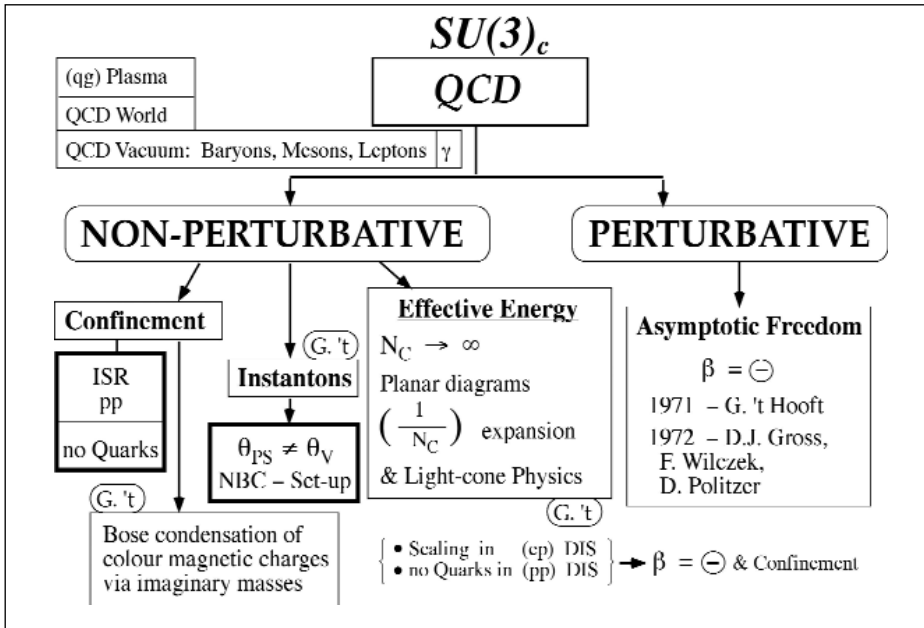Figure 3. Details from figure 2, concerning $SU(2)_L$ and $U(1)_Y$.

Figure 4. Details from figure 2, concerning $SU(3)_c$.

SM&B

THE STANDARD MODEL AND BEYOND

①   RGEs $(\alpha_i \, (i \equiv 1, 2, 3); \; m_j \, (j \equiv q, \, l, \, G, \, H)): \; f(k^2)$.
-   GUT $(\alpha_{GUT} \cong 1/24)$ &   GAP $(10^{16} - 10^{18})$ GeV.
-   SUSY (to stabilize $m_F/m_P \cong 10^{-17}$).
-   RQST (to quantize Gravity).

②   Gauge Principle (hidden and expanded dimensions).
—   How a Fundamental Force is generated: SU(3); SU(2); U(1) and Gravity.

③   The Physics of Imaginary Masses: SSB.
—   The Imaginary Mass in SU(2)×U(1) produces masses ($m_{W^\pm}$; m_{Z^0}; m_q; m_l), including $m_\gamma = 0$.
—   The Imaginary Mass in SU(5)⇒SU(3)×SU(2)×U(1) or in any higher (not containing U(1)) Symmetry Group ⇒ SU(3)×SU(2)×U(1) produces Monopoles.
—   The Imaginary Mass in SU(3)$_c$ generates Confinement.

④   Flavour Mixings & CP ≠ , T ≠ .
—   No need for it but it is there.

⑤   Anomalies & Instantons.
—   Basic Features of all Non-Abelian Forces.

Note:					
q	≡	quark and squark;	m_F	≡	Fermi mass scale;
l	≡	lepton and slepton;	m_P	≡	Planck mass scale;
G	≡	Gauge boson and Gaugino;	k	≡	quadrimomentum;
H	≡	Higgs and Shiggs;	C	≡	Charge Conjugation;
RGEs	≡	Renormalization Group Equations;	P	≡	Parity;
GUT	≡	Grand Unified Theory;	T	≡	Time Reversal;
SUSY	≡	Supersymmetry;	≠	≡	Breakdown of Symmetry Operators.
RQST	≡	Relativistic Quantum String Theory;			
SSB	≡	Spontaneous Symmetry Breaking.			

The five basic steps in our understanding of nature. ① The renormalization group equations (RGEs) imply that the gauge couplings (α_i) and the masses (m_j) all run with k^2. It is this running which allows GUT, suggests SUSY and produces the need for a non point-like description (RQST) of physics processes, thus opening the way to quantize gravity. ② All forces originate in the same way: the gauge principle. ③ Imaginary masses play a central role in describing nature. ④ The mass-eigenstates are mixed when the Fermi forces come in. ⑤ The Abelian force QED has lost its role of being the guide for all fundamental forces. The non-Abelian gauge forces dominate and have features which are not present in QED.

Figure 5.

A few cases (seven) where I have been directly involved are summarised in figure 6.

Each UEEC event is coupled with a *despite,* in order to emphasize the reason why the event is unexpected.

UEEC EVENTS
IN THE CONSTRUCTION OF THE
SM&B = MY PERSONAL EXPERIENCE

① *The 3rd lepton,* another **one ν_{HL}** (now called ν_τ)
   despite the abundance of neutrinos: ν_e and ν_μ.

② *Antimatter*
   despite S-matrix and C, P, CP, T breakings.

③ *Nucleon Time-like EM structure*
   despite S-matrix.

④ *No quarks in violent (pp) collisions*
   despite scaling.

⑤ *Meson mixings*
   $0_V \neq 0_{PS} : (51°) \neq (10°) \neq 0$ **despite** $SU(3)_{uds}$.

⑥ *Effective energy:* the QCD-light
   despite QCD.

⑦ *The running of α_1 α_2 α_3 versus energy at* **a point E_{GU}.**
   (1979) *(1991)* **despite** straight line convergence.
   [EGM]

Figure 6.

The SM&B is the greatest synthesis of all time in the study of the fundamental phenomena governing the Universe in all its structures.

The basic achievements of the SM&B have been obtained via UEEC events; moreover the SM&B could not care less about the existence of Pla-

tonic Simplicity. An example is shown in figure 7 where the straight line (small dots) would be the Platonic simple solution towards the Unification of all Fundamental Forces. But the effective unification is expected to be along the sequence of points (the big ones) calculated using the Renormalization Group Equations (RGEs).
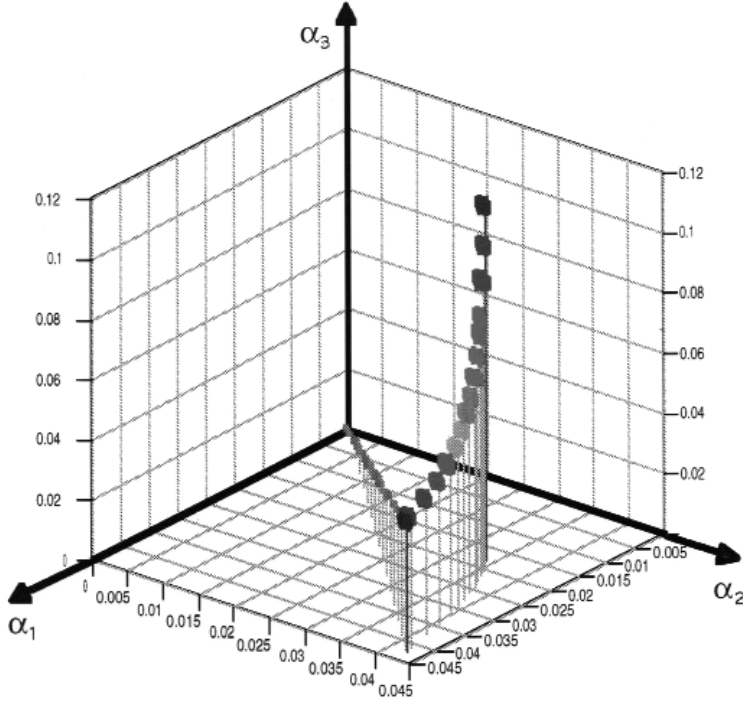

Figure 7. The points have a sequence of 100 GeV in energy. The last point where the 'ideal' platonic straight line intercepts the theoretical prediction is at the energy of the Grand Unification. This corresponds to $E_{GU} = 10^{16.2}$ GeV. Other detailed information on the theoretical inputs: the number of fermionic families, N_F, is 3; the number of Higgs particles, N_H, is 2. The input values of the gauge couplings at the Z^0-mass is $\alpha_3(M_Z) = 0.118 \pm 0.008$; the other input is the ratio of weak and electromagnetic couplings also measured at the Z^0-mass value: $\sin^2 \Theta_W(M_Z) = 0.2334 \pm 0.0008$.

Platonic Simplicity is violated at every corner in the process of construction of the SM [1].

These violations are the proof that Complexity exists at the fundamental level of scientific knowledge where we have proved that AFB phenomena and UEEC events are present.

The conclusion is that Complexity exists at the elementary level. In fact, starting from Platonic Simplicity, the SM&B needs a series of 'ad hoc' inputs [1].

4. Seven Definitions of Complexity

People speak of 'Complexity' as a source of new insights in physics, biology, geology, cosmology, social sciences and in all intellectual activities which look at the world through the lens of a standard analysis in terms of either Simplicity or Complexity. But 'Complexity' is ill-defined, as shown by the existence of at least seven definitions of Complexity.

Definition Number 1

Complexity is a property of systems that are somewhere in between a completely random and a completely regular state, often described by a highly non linear set of equations but sometimes not describable by equations at all.

Definition Number 2

Bad ones:
  1) Chaos.
  2) The need for lengthy calculations.
  3) The need for many distinct variables.
Better ones:
  4) Unexpected difficulty when attempting to describe something in a precisely formulated theory.
  5) What is left over after all systematic approaches failed.
But it could also be that: Complexity is an excuse for sloppy thinking.

Definition Number 3

The Complexity of a theory (problem) is the minimum amount of computer time and storage required to simulate (solve) it to a specified level of precision.

Definition Number 4

If we admit that biological or linguistic evolution, or financial dynamics are complex phenomena, then their typical dynamics is somehow between strong chaos (i.e. positive Lyapunov exponents) and simple orbits (i.e. negative Lyapunov exponents). In other words, Complexity (or at least some form of it) is deeply related to the edge of chaos (i.e. vanishing maximal Lyapunov exponent). Since the edge of chaos appears to be related paradigmatically to an entropy index 'q' different from unity, there must be some deep connection between Complexity and generalized entropies such as 'S_q'.

Definition Number 5

From the mathematical point of view:
- A problem can be polinomial, which means that it is not to hard to predict surprises.
- A problem can be NP or NP-complete, which represent different degrees of difficulty in predicting surprises.
- • Surprises mean: UEEC event.
- • That degree of difficulty can be associated with the level of Complexity.

Definition Number 6

A system is 'complex' when it is no longer useful to describe it in terms of its fundamental constituents.

Definition Number 7

The simplest definition of Complexity: '*Complexity is the opposite of Simplicity*'. This is why we have studied the platonic Standard Model and its extension to the platonic Superworld.

These seven definitions of Complexity must be compared with the whole of our knowledge in order to focus our attention on the key features needed to study our real world.

5. COMPLEXITY EXISTS AT ALL SCALES

The Logic of Nature allows the existence of a large variety of structures with their regularities and laws which appear to be independent from the basic constituents of Nature and fundamental laws which govern their interactions.

But, without these laws it would be impossible to have the real world which is in front of us and of which we are part of. A series of complex systems is shown in figure 8.
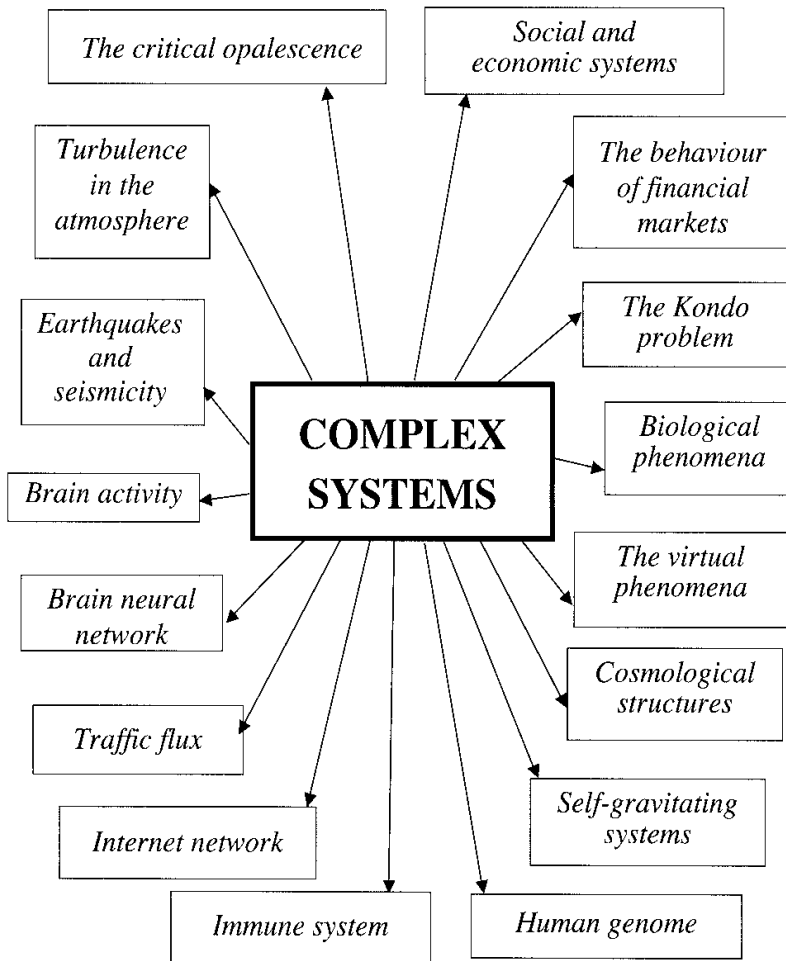
Figure 8.

As you can see, we go from traffic flux, to the internet network, to earthquakes and seismicity, to social and economic systems, to the behaviour of financial markets, to the study of cosmological structures, and so on.

There is no question that nature shows structures which are considered complex on the basis of AFB and UEEC events (as shown in figure 9).
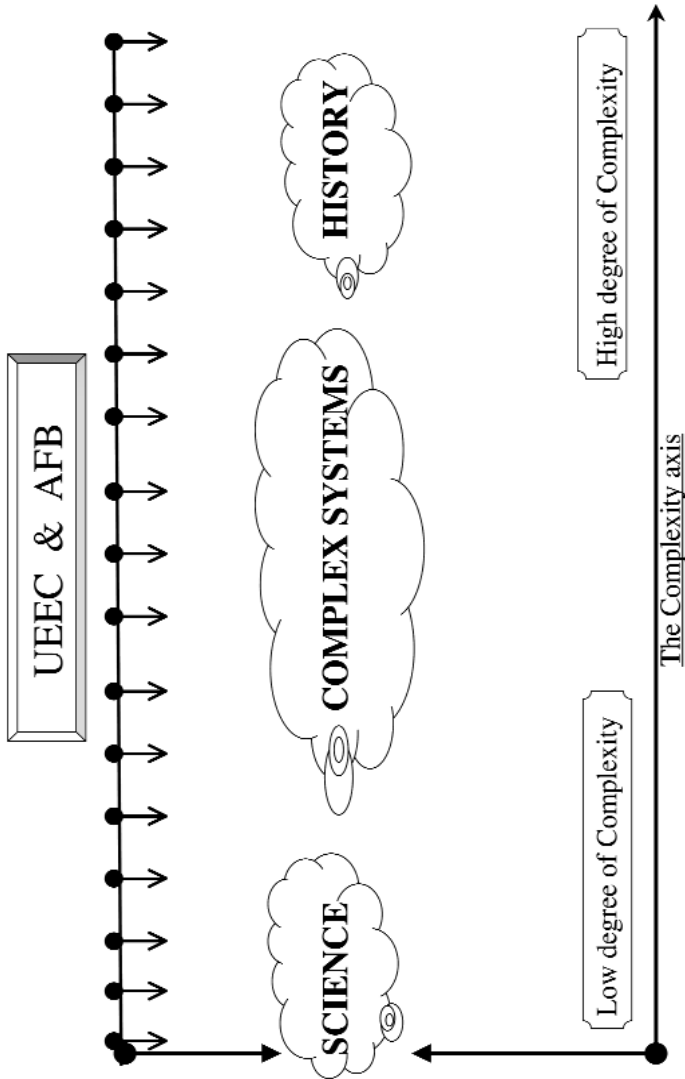
Figure 9.

The only certainty about Complexity is the existence of the experimentally observable effects: UEEC & AFB. These effects exist at all scales, and therefore Complexity exists at all scales, as illustrated in figure 9.

6. SCIENCE, FROM PLANCK TO COMPLEXITY

Four centuries of Galilean research work based on Reductionism, i.e. on the identification of the simplest elements in the study of Nature, has allowed us to get the greatest achievement of Science, i.e. the so called *Standard Model* and its extension (SM&B), illustrated before in figure 5.

This extension predicts GUT (the Grand Unification Theory), the existence of the Superworld and the resolution of the quantum-gravity problem via the powerful theoretical structure of RQST (Relativistic Quantum String Theory). All these developments started thirty years ago when a great scientific novelty came; all experimental discoveries obtained with our powerful accelerators were to be considered only matters of extremely low energy.

The scale of energy on which to direct the attention to understand the Logic that rules the world, from the tiniest structures to the galactic ones, had to be shifted at a much higher level: to the mass-energy named after Planck, E_{Planck}, something like seventeen powers of ten above the Fermi scale, E_{Fermi} , that already seemed to be an extremely high level of energy.
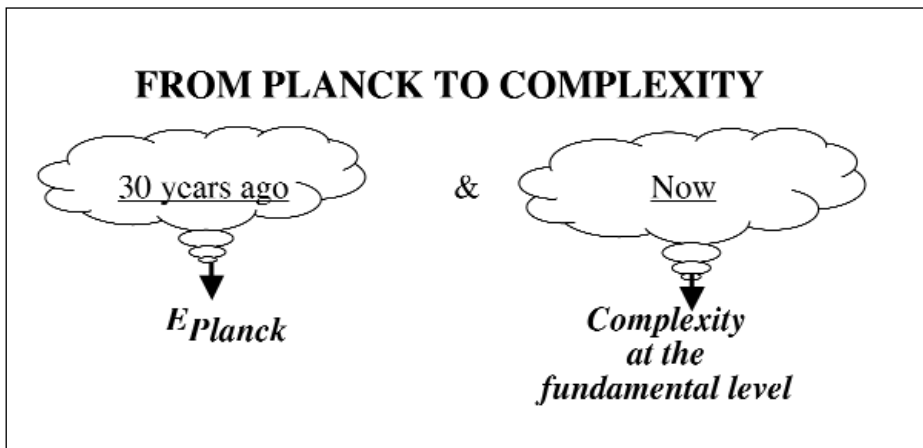
Figure 10.

Now, after thirty years, comes the novelty of our time, illustrated in figure 10: Complexity exists at the fundamental level [1]. In fact, AFB and UEEC events exist at all scales, as reported in chapter 5.

This result is corroborated by the mathematical structure (the only one) that is in a position of describing all that happens at the Planck scale: the Relativistic Quantum String Theory (RQST).

This mathematical structure produces innumerable minima of energy, named *Landscape*.

The theoretical discovery of the *Landscape* (Leonard Susskind) [2], has been followed by another formidable discovery in mathematical physics: the most rigorous model of RQST (Raphael Bousso and Joseph Polchinski) is NP-complete (Michael R. Douglas and Frederik Denef) [3].

This discovery corroborates all that we have put in evidence during the last five years [4-7]: *Complexity exists at the fundamental level* [1].

We do not know what will be the final outcome of String Theory.

What we do know is that: '*The world appears to be complex at every scale. Therefore we must expect a continued series of surprises that we cannot easily predict*'.

7. The Two Asymptotic Limits: History and Science

The real world seems characterized by two basic features, which are one on the opposite side of the other: *Simplicity* and *Complexity*.

It is generally accepted that *Simplicity* is the outcome of *Reductionism*, while *Complexity* is the result of *Holism*.

The most celebrated example of *Simplicity* is *Science* while the most celebrated example of *Complexity* is *History*.

Talking about asymptotic limits, the general trend is to consider *History* as the asymptotic limit of *Holism* and of *Complexity*; *Science* as the asymptotic limit of *Reductionism* and of *Simplicity*, as illustrated in figure 11.

The Logic of Nature allows the existence of Science (the asymptotic limit of Simplicity) and of History (the asymptotic limit of Complexity), which share a property, common to both of them.

It is interesting to define Science and History in terms of this property, probably the only one that they share; i.e. Evolution.

– Science is the Evolution of our Basic Understanding of the laws governing the world in its Structure ≡ EBUS.
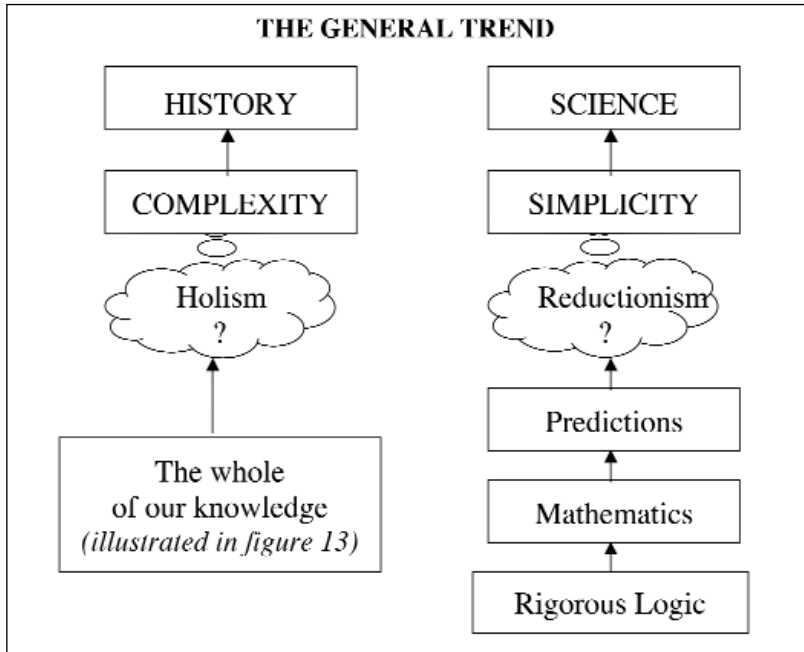– History is the Evolution of the World in its Real Life ≡ EWRL.

Figure 11.

In Table 1 we compare these two supposedly asymptotic limits – History and Science – on the basis of 'What if?'; a condition elaborated by the specialists in what is now known as 'virtual history' [8].

On the basis of 'What if?' these specialists conclude that the world would not be as it is, if one, or few, or any number of 'What if?' had not been as History tells us. This is not the case for Science. The world would have exactly the same laws and regularities, whether Galileo Galilei or somebody else had discovered

$$F = mg,$$

and so on for all the other scientific discoveries.

It is in the consequences of 'What if?' that the two asymptotic limits of Simplicity and Complexity seem to diverge, despite the fact that the sequence of 'What if?' in Science belongs to the 'totally unexpected events' (UEEC) exactly like the others listed in the column of History.

'WHAT IF ?'			
	In History ■ EWRL		**In Science ■ EBUS**
I	What if Julius Caesar had been assassinated many years before?	*I*	What if Galileo Galilei had not discovered that $F = mg$?
II	What if Napoleon had not been born?	*II*	What if Newton had not discovered that $$F = G \frac{m_1 \cdot m_2}{R_{12}^2}$$?
III	What if America had been discovered few centuries later?	*III*	What if Maxwell had not discovered the unification of electricity, magnetism and optical phenomena, which allowed him to conclude that light is a vibration of the EM field?
IV	What if Louis XVI had been able to win against the 'Storming of the Bastille'?	*IV*	What if Planck had not discovered that $$h \neq 0 ?$$
V	What if the 1908 Tunguska Comet had fallen somewhere in Europe instead of Tunguska in Siberia?	*V*	What if Lorentz had not discovered that space and time cannot be both real?
VI	What if the killer of the Austrian Archduke Francisco Ferdinand had been arrested the day before the Sarajevo event?	*VI*	What if Einstein had not discovered the existence of time-like and space-like real worlds? Only in the time-like world, simultaneity does not change, with changing observer.
VII	What if Lenin had been killed during his travelling through Germany?	*VII*	What if Rutherford had not discovered the nucleus?
VIII	What if Hitler had not been appointed Chancellor by the President of the Republic of Weimar Paul von Hindenburg?	*VIII*	What if Hess had not discovered the cosmic rays?
IX	What if the first nuclear weapon had been built either by Japan before Pearl Harbour (1941) or by Hitler in 1942 or by Stalin in 1943?	*IX*	What if Dirac had not discovered his equation, which opens new horizons, including the existence of the antiworld?
X	What if Nazi Germany had defeated the Soviet Union?	*X*	What if Fermi had not discovered the weak forces?
XI	What if Karol Wojtyla had not been elected Pope, thus becoming John Paul II?	*XI*	What if Fermi and Dirac had not discovered the Fermi–Dirac statistics?
XII	What if the USSR had not collapsed?	*XII*	What if the 'strange particles' had not been discovered in the Blackett Lab?

Table 1.

8. CONCLUSIONS

We have proved that AFB and UEEC – which are at the origin of Complexity, with its consequences permeating all our existence, from molecular biology to life in all its innumerable forms up to our own, including History – do exist at the fundamental level [4-7] and [1].

It turns out that Complexity in the real world exists, no matter the mass-energy and space-time scales considered.

Therefore the only possible prediction is that:
  – *Totally Unexpected Effects* should *show up*.
  – *Effects*, which are impossible to be predicted on the basis of *present knowledge*.

We should be prepared with powerful experimental instruments, technologically at the frontier of our knowledge, to discover Totally Unexpected Events in all laboratories, the world over (including CERN in Europe and Gran Sasso in Italy).

The mathematical descriptions, and therefore the predictions come after an UEEC event, never before.

Recall:

  –   The *discoveries in Electricity, Magnetism* and *Optics* (UEEC).
  –   *Radioactivity* (UEEC).
  –   The *Cosmic Rays* (UEEC).
  –   The *Weak Forces* (UEEC).
  –   The *Strange Particles* (UEEC).
  –   The *3 Columns* (UEEC).
  –   The *origin of the Fundamental Forces* (UEEC).

The present status of Science is reported in figure 12.

It could be that Science will be mathematically proved to be 'NP-complete'. This is the big question for the immediate future [9].

It is therefore instructive to see how Science fits in the whole of our knowledge as reported in figure 13.
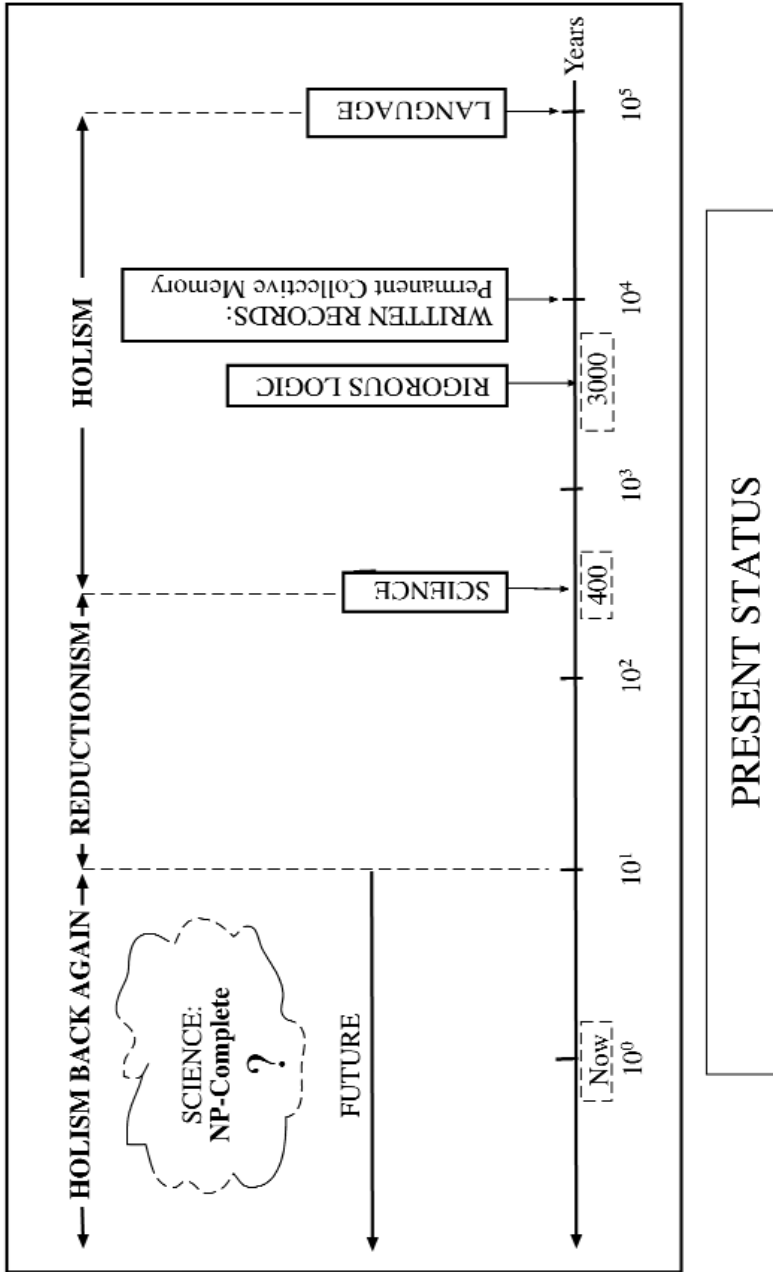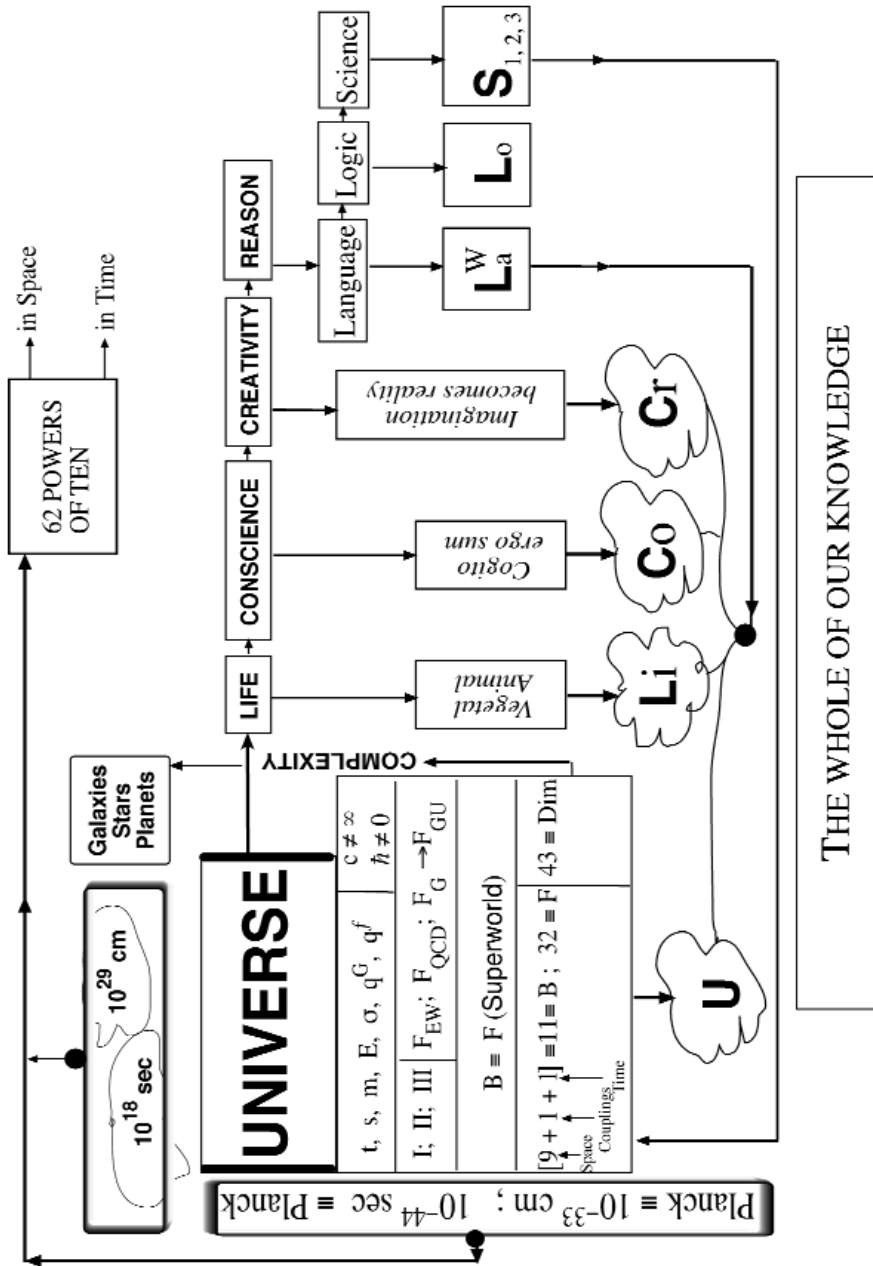
Figure 12.

Figure 13.

Let me point out that Science is the consequence of us being the only form of living matter endowed with Reason, from where the sequence of Language–Logic–Science has originated [10]. The time-sequence of Language–Logic–Science is shown in figure 14.
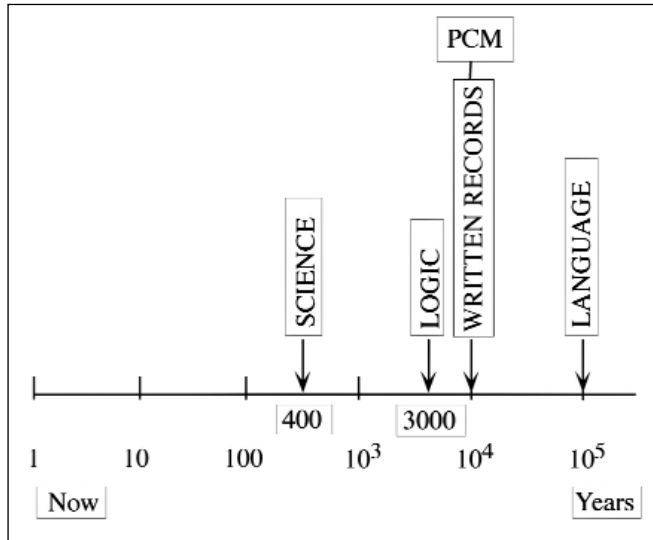
Figure 14. The Time-Sequence of Language – Logic – Science.

How can we interpret the fact that the greatest achievements of Science have always been originated by totally unexpected events? *Why? Answer*: Because the fellow who created the world is smarter than all of us, including scientists, mathematicians, philosophers.

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– 43th Course of the International School of Subnuclear Physics, Erice (Italy), September 2005, '*Complexity at the Elementary Level*'.

– Italian Physics Society (SIF) XCI Annual National Congress, University of Catania (Italy), September 2005, '*Complexity at the Elementary Level*'.

– Desy, Hamburg, November 2005, '*Complexity at the Fundamental Level*'.

– 44th Course of the International School of Subnuclear Physics, Erice (Italy), September 2006, '*Complexity at the Fundamental Level*'.

[5]   *The Logic of Nature and Complexity*
      A. Zichichi

presented at:

–   Pontificia Academia Scientiarum, The Vatican, Rome (Italy), November 2002, '*Scientific Culture and the Ten Statements of John Paul II*'; '*Elements of Rigour in the Theory of Evolution*'.

–   The joint Session of:
      6th Course of the International School of Biological Magnetic Resonance; Erice (Italy), July 2003, '*Language Logic and Science*'.

–   2nd Workshop on Science and Religion of the Advanced School of History of Physics; Erice (Italy), July 2003, '*Language Logic and Science*'.

–   10th Workshop of the International School of Liquid Crystals; Erice (Italy), July 2003, '*Language Logic and Science*'.

–   International School on Complexity, 1st Workshop on Minimal Life, Erice (Italy), December 2004, '*Evolution and Complexity at the Elementary Level*'.

[6]   *Complexity and New Physics*
      A. Zichichi

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–   INFN-Alice Meeting, University of Catania (Italy), January 2005, '*Complexity at the Elementary Level*'.

–   INFN Eloisatron Project 'The 1st Physics ALICE Week', Erice (Italy), December 2005, '*Complexity and New Physics with ALICE*'.

–   50th Anniversary of INFN Bologna - ALICE Week, Bologna (Italy), June 2006, '*Complexity at the Fundamental Level*'.

[7]   *Complexity and Planetary Emergencies*
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–   27th Sessions of the International Seminars on Planetary Emergencies, Erice (Italy), August 2002, '*Language, Logic and Science*'.

–   28th Sessions of the International Seminars on Planetary Emergencies, Erice (Italy), August 2003, '*Language Logic and Science, Evolution and Planetary Emergencies*'.

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[8] *Virtual History: Alternatives and Counterfactuals*
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[9] *The Logic of Nature, Complexity and New Physics: From Quark-Gluon Plasma to Superstrings, Quantum Gravity and Beyond*
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[10] *Language, Logic and Science*
     A. Zichichi, proceedings of the 26th Session of the International Seminar on Nuclear War and Planetary Emergencies, Erice 18-26 August 2002 (World Scientific, 2003).

The References [4-7] refer to the various occasions where I have presented papers on highly specialized topics and discussed the connection of these topics with Complexity. The title on the upper part refers to the connection with Complexity while the specialized topic is reported in the detailed references.