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METEOROLOGY AND CLIMATE: PROBLEMS AND EXPECTATIONS

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ABSTRACT

The predictive power of differential non linear equations weakly coupled, in the description of elementary processes by far more rigorously known than those existing in Meteorology and Climatology where the differential equations are strongly coupled, is discussed in order to call attention on the claimed predictive power in the field of Meteorology and Climate change where problems must necessarily be by far more complex. Years of work and strong financial support are needed in order to improve the theoretical formulation of these problems and the corresponding experimental worldwide observations. This is necessary before anyone can claim that a scientific rigorous understanding has been achieved in mastering all Meteorology and Climate change problems of the past, present and future.

METEOROLOGY AND CLIMATE: PROBLEMS AND EXPECTATIONS

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INTRODUCTION

A key element in the problems of Meteorology and Climate change is the mathematics needed, which consist of a system of differential non linear equations strongly coupled.

My contribution to this Conference is directly related to my work in the field of the Fundamental Interactions. Here we attempt to make predictions, for example in the energy threshold where the existence of the Superworld should be and in the energy level where all phenomena should originate. These predictions are based on a system of three differential non linear equations weakly coupled.

If these predictions are true or false attracts the attention of few fellows interested in the Logic of Nature. They will not have consequences in everyday's life for the years to come.

On the contrary, the predictions concerning Meteorology and Climate change have enormous consequences and are in fact at the centre of everybody's attention world-wide.

In the **first part** of this paper I will present a review of the main results on Meteorology and Climate change presented at the Ettore Majorana Foundation and Centre for Scientific Culture in Erice during the past three years.

In the **second part** I will present my personal experience working with a mathematical structure by far more exact than the other structures needed in Meteorology and Climatology.

Despite the rigour intrinsic in our field we have a lot of problems in making predictions. The extrapolation of our difficulties to a field such as Meteorology and Climatology, which is by far less rigorous than the study of the Fundamental Interactions, brings me to the conclusion that predictions in Meteorology and Climate change must necessarily be taken with great caution. Much greater than our predictions.

The study of Complexity at the fundamental level of scientific knowledge brings us to the conclusions that we should avoid giving to the public the message that Science has mastered all Meteorology and Climate change problems of the past, present and future.

1 – FIRST PART

STATUS OF PREDICTIONS IN METEOROLOGY AND CLIMATE CHANGE AT THE EMFCSC DURING THE PAST THREE YEARS (2004-2005-2006)

The Mathematics of Meteorology and Climate change belongs to what is considered the Science of **Complexity**. A series of complex systems is shown in figure 1.

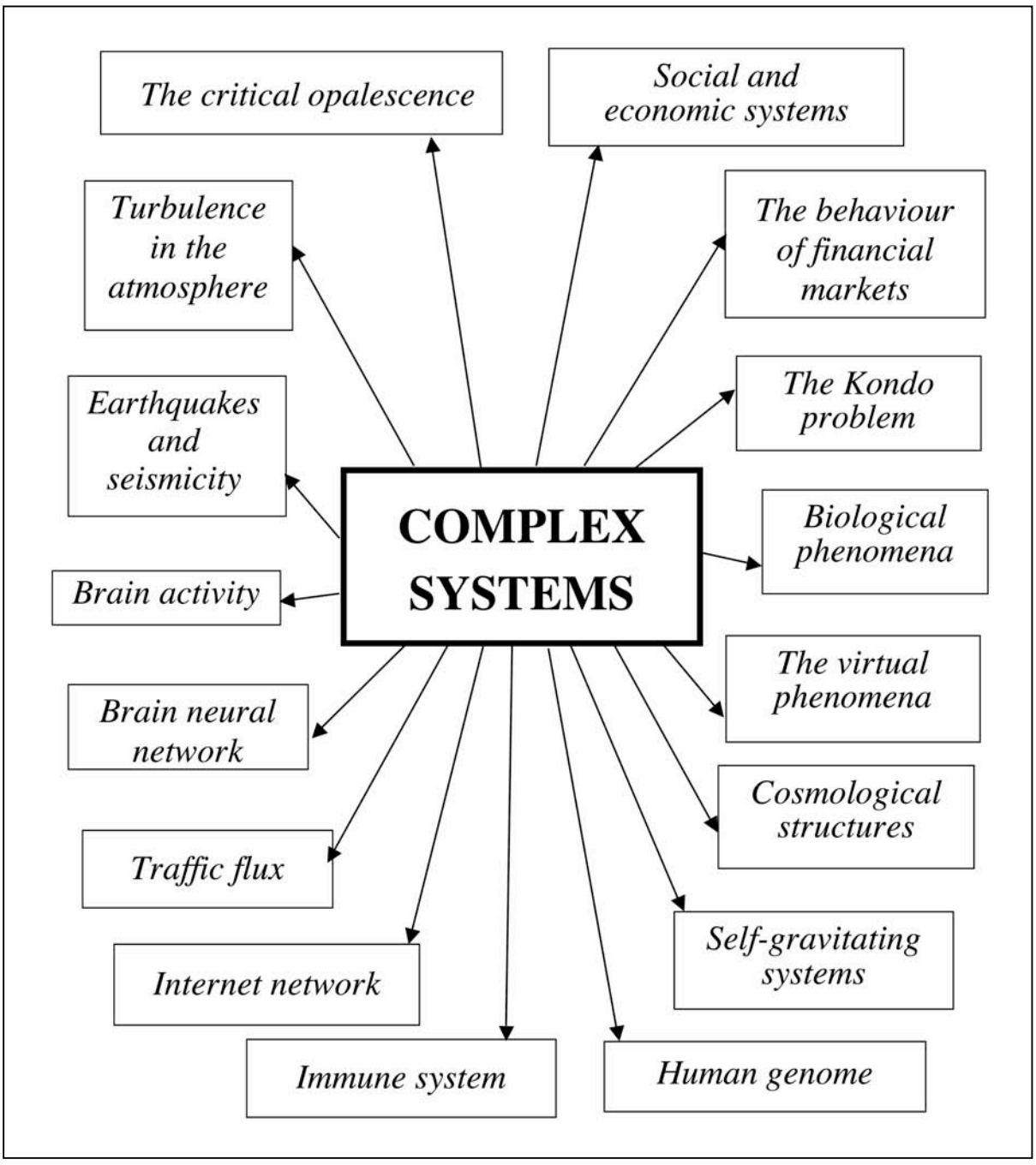


Figure 1

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.

SEVEN DEFINITIONS OF COMPLEXITY

People speak of 'Complexity' as a source of new insights in Meteorology, Climatology, Biology, Geology, Cosmology, Social Sciences and in all intellectual activities, including Physics, which look at the world through the lens of a standard analysis – illustrated in figure 7 of the Addendum – in terms of either Simplicity or Complexity.

But 'Complexity' is ill-defined, as shown by the existence of at least seven definitions of Complexity [1, 2].

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 means: UEEC event (see later).
- •• 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 – illustrated in figure 8 of the Addendum — in order to focus our attention on the key features needed to study our real world.

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 [3-6].

There is no question that nature shows structures which are considered complex on the basis of **AFB** and **UEEC** events (as shown in figure 2 from reference [1]). Let me specify the meaning of AFB and UEEC events. The Anderson-Feynman-Beethoven-type phenomena (AFB) are phenomena whose laws and regularities ignore the existence of the Fundamental Laws of Nature from which they originate. The Unexpected Events of quasi irrelevant magnitude which produce Enormous Consequences (UEEC) are also called Sarajevo-type effects.

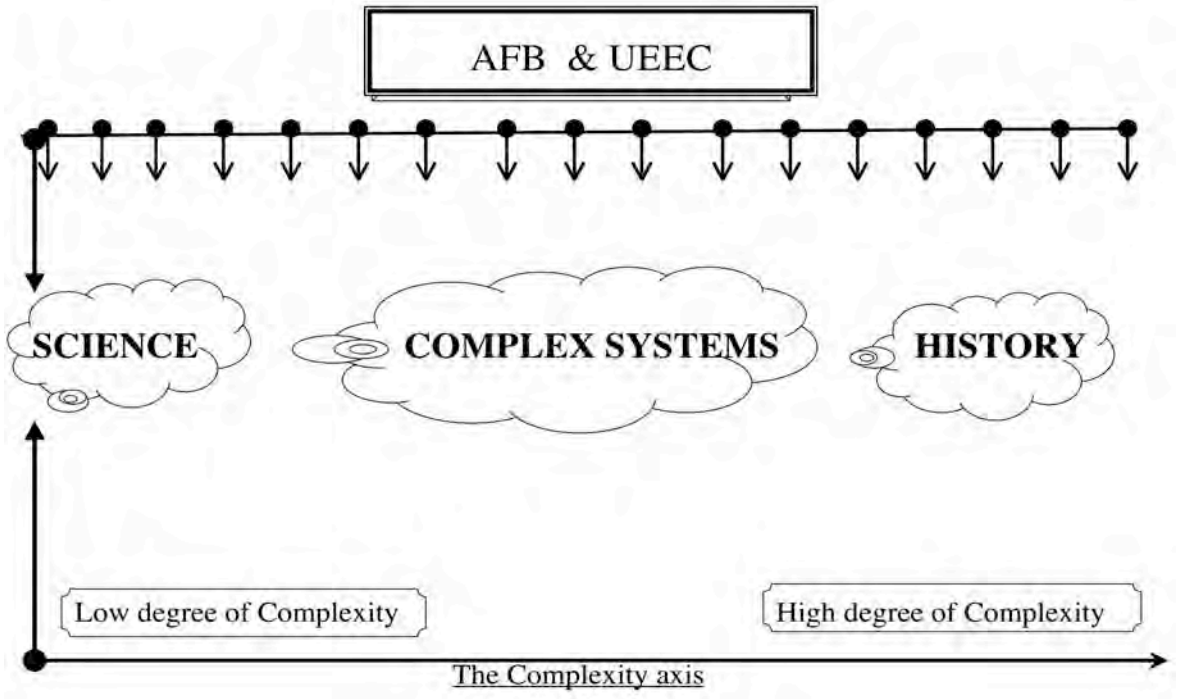


Figure 2

Let me discuss **AFB** and **UEEC** in Science. I first 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 masterpieces 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 was 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. The nuclear interactions ignore that protons and neutrons are made with quarks and gluons whose interactions obey the mathematics of Quantum ChromoDynamics (QCD).

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. Here is the most recent example of Anderson-Feynman-Beethoven-type phenomenon: **the world could not care less about the existence of the Superworld** [1].

Concerning **UEEC** in Science these are reported in the Addendum with a series of six figures, not inserted directly here for simplicity. They are relevant in order to give the detailed proof about the existence of Complexity at the fundamental level of scientific knowledge. This is needed since in chapter 2 the problems of predictions at the fundamental level of scientific knowledge are discussed. The **UEEC** events reported in figure 10 go from Galilei to Fermi-Dirac and the 'strange particles'. The **UEEC** events in figures 11, 12 and 13 go from Fermi-Dirac to the construction of the Standard Model; in figure 14 there is a synthesis of **UEEC** events in what we now call the Standard Model and Beyond (**SM&B**). In figure 15 there is a set of **UEEC** events where I have been personally involved.

The public at large is convinced that the science of Meteorology and Climatology has understood everything about the past, the present and the future. Science, instead, has been repeating that we still have a long way to go before we reach that goal. What Science was able to achieve was to establish the mathematical basis needed in order to describe what happens inside that 10 Km wide band of air circling the solid and liquid surfaces of our globe.

The father of this mathematical structure was the great John von Neumann. The mathematics involved is a system of strongly coupled, non-linear differential equations, where the solution can only be arrived at by a series of numerical approximations. In these approximations you need to introduce a number of free parameters. Von Neumann was always warning his young

collaborators about the use of these free parameters by saying: If you allow me four free parameters I can build a mathematical model that describes exactly everything that an elephant can do. If you allow me a fifth free parameter, the model I build will forecast that the elephant will fly.

The mathematical models for Meteorology and Climate change have a lot more than five free parameters. There are a minimum of two for each volcano. And then those necessary to describe the dynamic properties of the air strip that surrounds this sun's satellite, with all the interactions between atmosphere, ocean, winds, maritime currents and greenhouse gases. There are also the free parameters for the particles of dust, soot and other substances being constantly injected in the atmosphere, without the possibility of an accurate check of their characteristics, whether in terms of quantity or quality. These 'dust' particles play an important role in the thermodynamics of the atmosphere.

In the models that are being considered, we would need to know the variation with time of these particles injected in the atmosphere, including aerosols, for which it would be important to know what was happening in the past, before we had specific measuring instrumentation and therefore know little or nothing of. But there is another unsolved problem in the models being used. To produce meteorological variation phenomena, the only way is to introduce them ad hoc. This method is called 'forcing'. This 'forcing' is the base argument to arrive at the conclusion that it is the human activities which produce meteorological variations.

In the past, history has taught us that phenomena of strong variation occurred, which resulted in the transformation of magnificent expanses of green land – such as for Greenland – into vast expanses of ice, and luxuriant extensions of vegetal life into deserts, such as the Sahara today. If we ever come up with a mathematical structure capable of describing the past of the solid and liquid surfaces of earth, and only then, it will be possible to confirm what is being advocated today by the 2500 scientists of the Intergovernmental Panel for Climatic Changes (IPCC)[1].

[1] This panel was established in 1988 by Professor G.O.P. Obasi, DG of the WMO (World Meteorological Organization), following the Erice Seminars (1985, 1986, 1987) where the Planetary Emergencies were discussed. The original purpose of the panel was to put under the control of the highly qualified Erice scientific community the problems of Meteo and Climate. During the first period of the panel activities there was a close collaboration. Now the dimension of the IPCC has reached a level not expected by us when we started it. An interesting reconstruction of these events has been reported at this Conference by Dr L.M. Michaud.

The reason being that, for this, the present mathematical models are far from being satisfactory. The public at large wishes to know if it is true that human activities are creating a huge perturbation of the Climate characteristics of our globe. To answer this question, the United Nations instituted a permanent committee composed of 2500 scientists from the world over, the IPCC quoted above, which has been at work for the last few years and has led the public to believe – as said before – that Science has understood all about Climate. If that was true, climatologically, the destiny of our planet should be free of uncertainties and under the rigorous control of Science. But it's not this way.

When von Neumann, half a century ago, started it all, the mathematical models describing the Climate were two-dimensional. It was the brilliant collaborator of von Neumann, the very young Tsung Dao Lee [7], Fermi's favourite pupil and a Nobel Laureate, who introduced the 'third dimension' in the mathematics of Climate. Without this third dimension, 'turbulence', the fundamental property of all models, could not exist.

The Father of 'turbulence' [7] participated in the Erice Seminars dedicated to the mathematical models used by the ICCP and found them wanting. We're talking here of mathematical models whose results have consequences costing billions of dollars and involve the responsibility of all the governments in the world. It is necessary to bring these basic themes back to the scientific laboratories where they belong, taking them away from the hands of those who use them to satisfy ambitions that have nothing to do with scientific truth. The public at large wishes to know what conclusions, based on scientific rigour, can result from the analysis of the measurements already taken.

There is a need to do more work, with a lot more rigour, to better the models being used. In fact, on the basis of what has been done until now, **it is not possible to exclude that the observed phenomena may have natural causes**. **It may be that man has little or nothing to do with it.** Not only do we need to improve the 'mathematics' of the models but it is also necessary to improve the measuring devices and their sensitivity. A mathematical model cannot improve the quality of the data it is fed for the computation of the atmospheric evolution.

This is why NASA sent out, in 2006 (28 April), two satellites, Cloud-Sat and Calypso. These satellites allow the study of the clouds and thus will effectively contribute to the improvement of meteorological models. This is the

proof that the criticism expressed during the Erice Seminars [8, 9, 10] was then, and still is today, of great value.

The two satellites will provide repeated measurements of the cloud layers and thus allow for the design of more realistic models. It is as if man had succeeded in transporting himself inside the clouds and was able to carefully study all the details. The cloud characteristics are very important in order to allow a comparison between model forecasts and experimental data.

The Spirit of Erice, which characterizes the Erice Seminars, is the one who brought the focus on the status of health of our planet. Its problems are real, but no cure can be expected from the alarmism and the announcement of imminent catastrophes, such as the one which forecasted, 30 years ago, the end of all marine life in the Mediterranean.

All that was discussed above is related to Meteorology, and to what happens inside that layer of air that surrounds us in brief intervals of time: days, weeks, months and maybe a few years. In fact, John von Neumann had discovered, half a century ago, that the longer the interval of time and the worst would be the forecast.

Today's limits are for 2 weeks, beyond which it is not possible to come up with scientifically credible forecasts. How do we fare with Climate? Here we have to distinguish between Meteorology and Climatology. Meteorological variations imply brief durations. Climatological variations imply long durations. Brief durations are quantified in weeks. For the long duration we are talking not of decades but of centuries. Meteorology is dominated by the meteorological motor in which the effect of human activities represents a maximum level of 10%. The rest depends from natural phenomena: the energy sent by our sun, what happens in the depths of our planet, volcanoes injecting enormous quantities of substances in the atmosphere and enormous quantities of lava oozing out from the cracks and fault lines in the bottom of oceans creating strong perturbations in the ocean dynamics, the liquid layer of earth's surface.

And this is why the Scandinavian countries went from an extreme Climate to the moderate one they have today, while Greenland, as said before, from being a 'green land' became that expanse of ice. So far, we have considered effects dominated by the meteorological motor powered by the following sources: the sun, the structural characteristics of the earth crust and the planet core, lava and burning iron.

There are however phenomena that cannot be explained by the effect of our Sun or Earth. The explanation has to entail phenomena with a long variation cycle, measured in million of years. And thus enters into consideration cosmic Climatology, which depends on the position of the earth relative to the galactic arms. In the galactic arms, the intensity of cosmic rays can be tenfold that measured outside the arms. Cosmic rays consist mainly of those particles that are the electrically-charged and weighty 'ashes' of the Big Bang, called protons. These ashes contribute to half of our body weight. We ourselves, and anything related however remotely to our world, cannot exist without protons.

When a proton enters our atmosphere, it acts as a nucleus of condensation for water vapour and thus contributes to cloud formation. If we were to observe our Earth from a satellite, we would see that light coming from the sun is reflected off the clouds. Light means energy and heat. If, instead of penetrating our atmosphere, this energy and heat are reflected back into cosmic space, the temperature of the atmosphere decreases. The more protons impact our atmosphere the more clouds will be created and the lower the temperature of the atmosphere will be.

To enter one of the Galactic 'arms' means exposing earth to an intense flux of cosmic rays. This would generate an ice age. In the galactic zones outside the 'arms', the flux of cosmic rays decreases and earth would experience periods of torrid Climate. When earth finds itself in the zone of maximum cosmic rays flux, the polar caps become huge and extend down to the lower latitudes. Oslo and St Petersburg were part of the Northern polar cap **140 million years ago**. The Northern polar cap, **280 million years ago**, covered Europe reaching Suez; it reached Lhasa in India and Houston in North America. Going back to **420 million years ago**, the ice age saw the polar caps extending to latitudes of 50^{o}: in the Northern hemisphere, it meant that Prague and Vancouver were part of the polar cap. These ice ages correspond to the periods during which earth was exposed to maximum fluxes of cosmic rays.

In the last half billion years, earth has lost, four times, its polar caps: no ice at the North Pole and none at the South Pole. And, four times, the polar caps were reconstituted. Man did not exist then, only the so-called cosmic rays, discovered by mankind in the early twentieth century. The last cosmic ice age started 50 million years ago when we entered into one of the galaxy arms. The flux of cosmic rays reached its peak nearly 30 million years ago. We are now in

the process of moving away from the arm and, therefore, the evolution of the Climate of cosmic origin will – for a few million years to come – be towards higher temperatures.

2 – SECOND PART
COMPLEXITY AND PREDICTIONS AT THE FUNDAMENTAL LEVEL

I now discuss a personal experience in making predictions [11] using a system of 3 differential nonlinear equations weakly coupled; the mathematic basis is the 'renormalization group equations', RGEs [12].

These equations allow to describe how the gauge couplings (α_1 α_2 α_3) of the three fundamental forces change with energy. It is this change which allows the Fundamental Forces of Nature to converge towards a unique origin. The system of three coupled differential non linear equations mentioned above is:

$$\mu \frac{d\alpha_i}{d\mu} = \frac{b_i}{2\pi} \alpha_i^2 + \sum_j \frac{bij}{8\pi^2} \alpha_j \alpha_i^2 , \quad (1)$$

with i, j = 1, 2, 3 and α_1 α_2 α_3 being the so called 'gauge' couplings of the Fundamental Forces of Nature: electromagnetic, weak and strong subnuclear, respectively.

The lines in figure 2 are the result of calculations executed with a supercomputer using the mathematics of equation (1). This system of coupled non-linear differential equations describes the Superworld, from the maximum level of energy (Planck scale) to our world at the minimum of energy.

The results reported in figure 2 are the most exact use of the RGEs for the running of the three gauge couplings α_1 α_2 α_3 [13]. The unification of all forces and the threshold, where to find the first particle of the Superworld, with its problems are reported in figures 2 and 3 respectively.

During more than ten years (from 1979 to 1991), the 'prediction' of the energy threshold for the existence of the superworld was based on the running of the gauge couplings (α_1 α_2 α_3). No one had realized that this energy threshold was strongly dependent on the 'running' of the masses. This is now called: the EGM effect (from the initials of Evolution of Gaugino Masses).

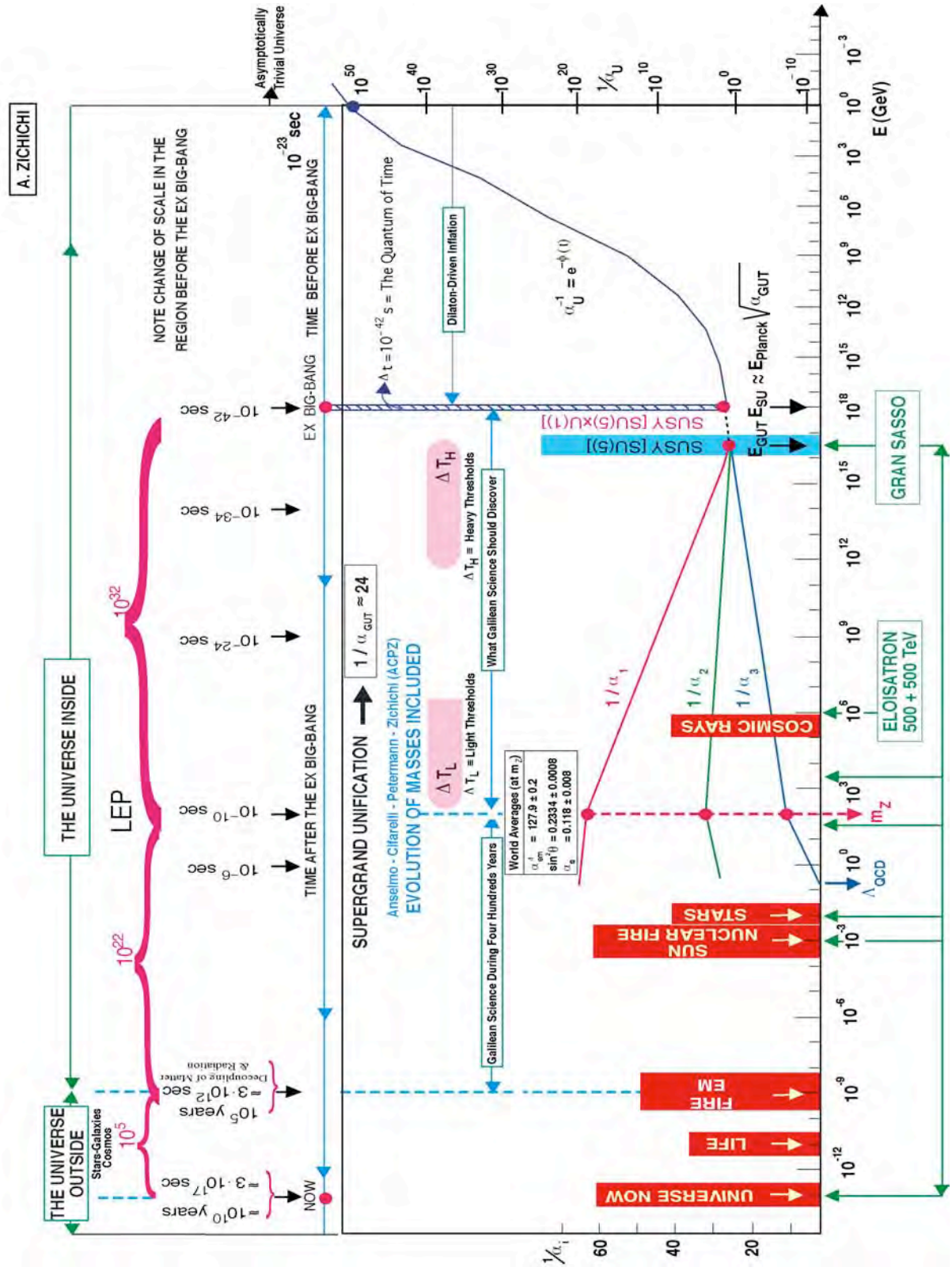


Figure 2

To ‘predict’ the energy threshold using only the ‘running’ of the gauge couplings (α_1 α_2 α_3) corresponds to neglecting nearly three orders of magnitude

in the energy threshold for the discovery of the first particle (the lightest) of the Superworld [11], as illustrated in figure 3.

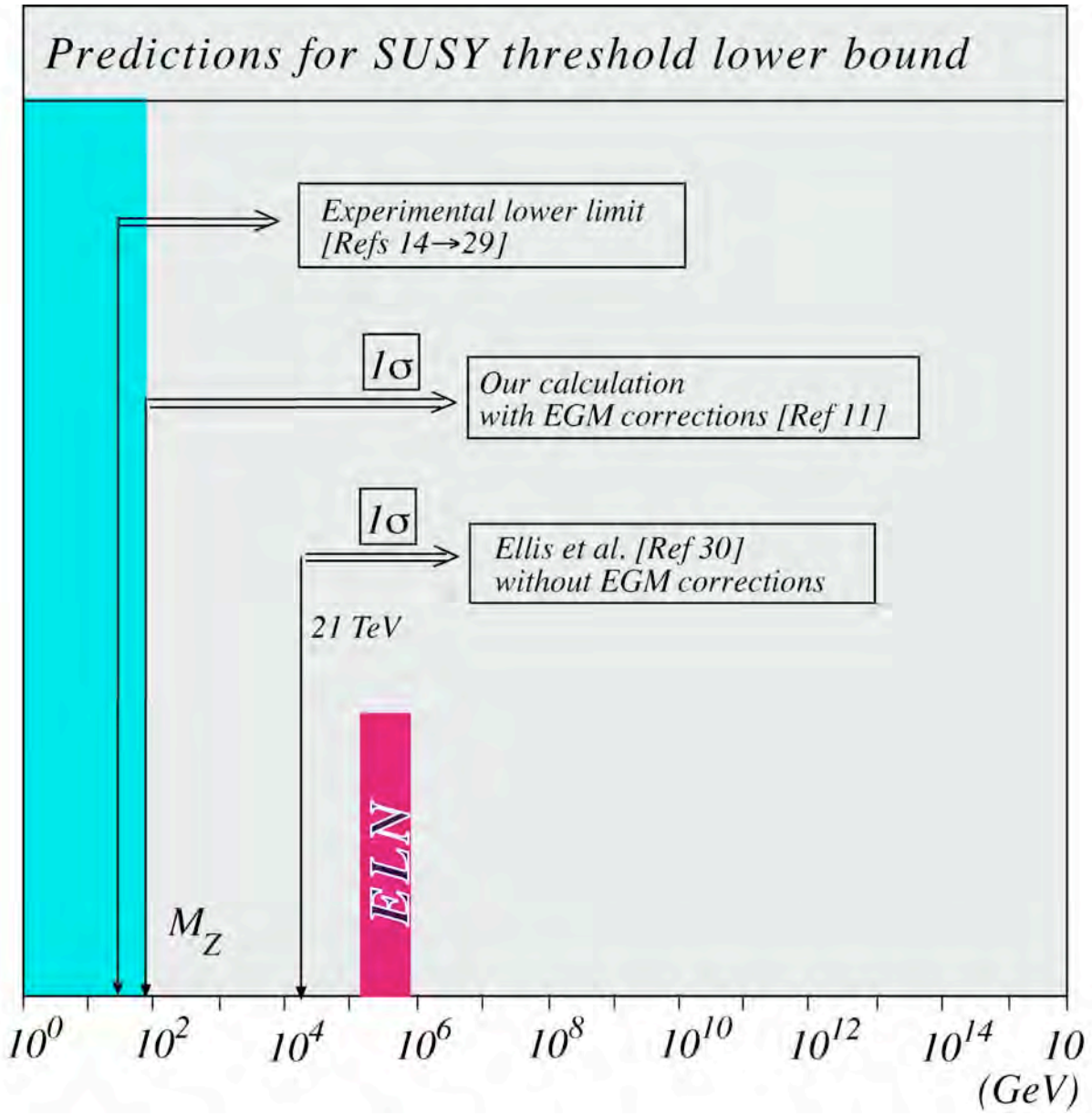


Figure 3

In figure 4 we show how many important properties (at least five, reported in figure 4) of the physics to be described had been neglected by some authors (AdBF), whose claim was **to 'predict'** the energy scale at which the first particle of the Superworld would be discovered.

In order to attempt giving such a prediction, there are at least five important properties to be taken into account, as reported in the last five columns (6–10) of figure 4. This is very instructive in order to realize the danger

of making ‘predictions’, even when the mathematics is more accurate that the one used for Meteorology and Climatology ‘predictions’; and even if in our case there are no dozens of ‘free’ parameters, but fundamental quantities carefully measured in our laboratories.

●	①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩
Authors	*Input data*	*Errors*	*EC*	M_{SUSY}	*CC*	*UC*	ΔT_L	M_X	ΔT_H	*EGM*
ACPZ [11, 13, 31→35]	WA	± 2 σ	all possible solutions (24)	Yes	physical	Yes	Yes	Yes	Yes	Yes

Authors	*Input data*	*Errors*	*EC*	M_{SUSY}	*CC*	*UC*	ΔT_L	M_X	ΔT_H	*EGM*
AdBF [36]	only one experiment	± 1 σ	only one solution	Yes	Geometrical	No	No	No	No	No

① *WA* ≡ *World Average*
② *Errors* ≡ *Uncertainty taken from all data (World Average) or from a single experiment*
③ *EC* ≡ *Evolution of Couplings*
④ M_{SUSY} ≡ *Mass Scale assumed to represent the Supersymmetry Scale breaking*
⑤ *CC* ≡ *Convergence of Couplings*
⑥ *UC* ≡ *Unification of Couplings above* E_{GUT}
⑦ ΔT_L ≡ *Low Energy threshold*
⑧ M_X ≡ *Mass Scale at the breaking of the Grand Unified Theory to the SU(3)xSU(2)xU(1)*
⑨ ΔT_H ≡ *High Energy threshold*
⑩ *EGM* ≡ *Evolution of Gaugino Masses*

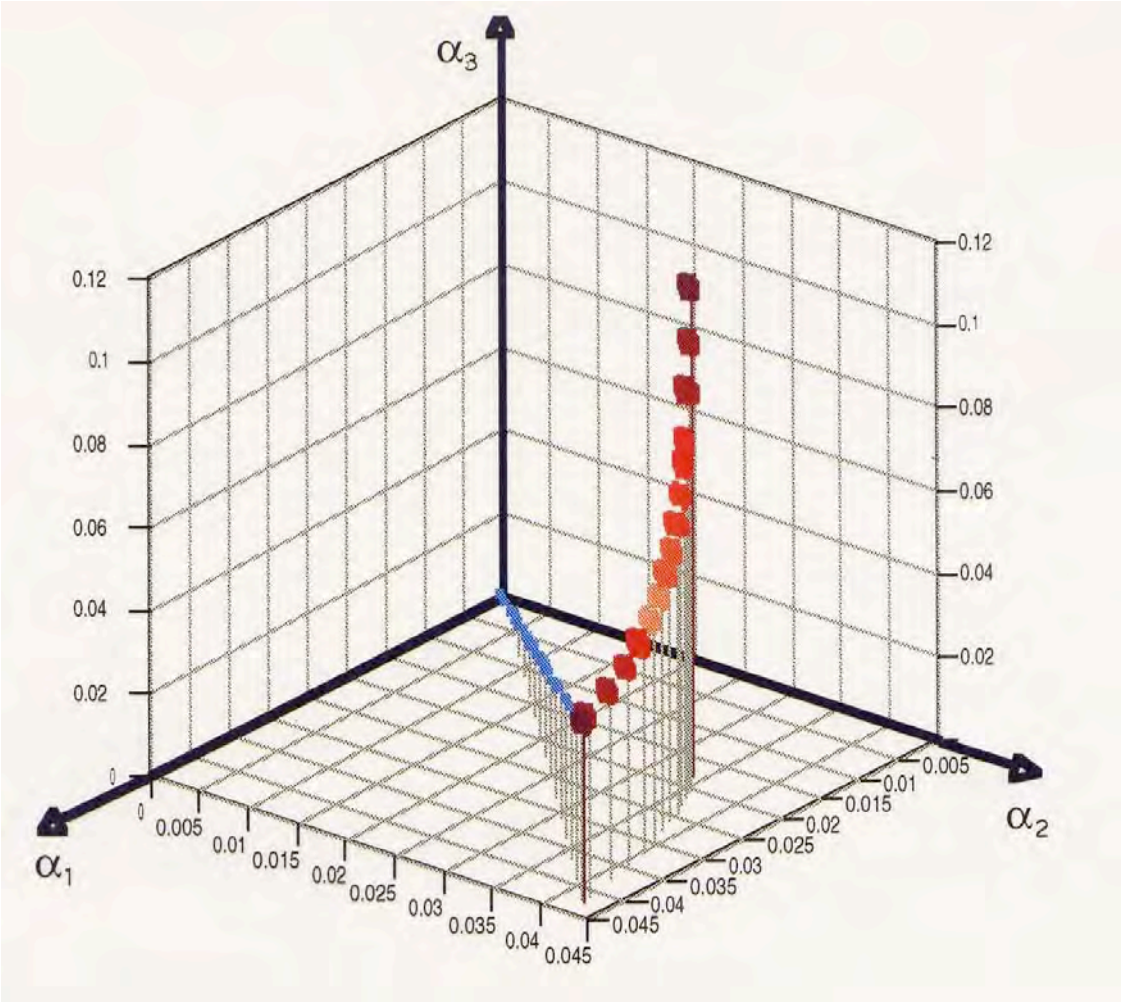
Figure 4

In figure 5, we show a different way of reporting the results obtained using the same (1) mathematical structure (RGEs). The three axis are the gauge couplings α_1 α_2 α_3 and the other details are given in the figure caption.

After we have published these results [31], the (α_1 α_2 α_3) graph has been given the name of ‘action space’.

In this space the ‘straight’ line should be the one which would naively be considered the ‘platonic’ way of ‘predicting’ the changes of α_1 α_2 α_3 in order to have them meet at the same point E_{GUT} (the last in the graph).

Despite the 'Platonic' Simplicity would indicate the series of points making up the straight line as the platonic ideally simple solution, the real solution is the sequence of points which totally deviate from the straight line.



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 value of the gauge coupling α_3 is taken at the Z^0-mass: $\alpha_3 (M_Z) = 0.118 \pm 0.008$; the other input is the ratio of weak and electromagnetic couplings also measured at the Z^0-mass value: $\sin^2 \theta_W (M_Z) = 0.2334 \pm 0.0008$.

Figure 5

Finally, in figure 6 we give a simplified version of our analysis whose 'predictions' are relevant for the projects being implemented, for example the new CERN collider LHC and the project for the most powerful collider in the world (ELN) at (500+500) TeV.

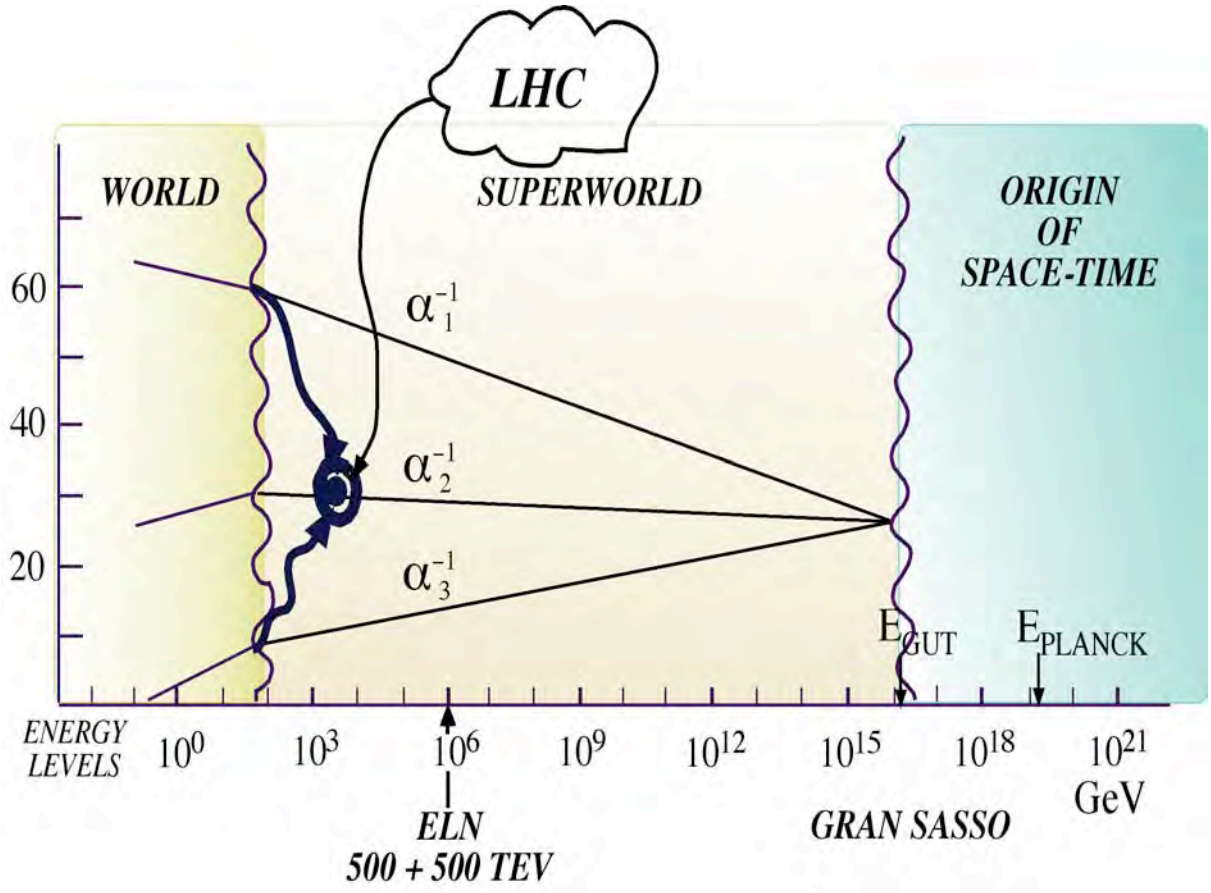


Figure 6

Our attempts to make 'predictions' do not attract the attention of people in the street since they deal with problems like the origin of space-time, as shown in figure 6.

The point I would like to call everybody's attention is that we have problems in making predictions [37] on the energy threshold for the existence of the superworld and other properties of the real world despite the mathematical structure we use is more powerful and accurate that the one used by Meteorology and Climate change model builders. Their ability to make 'predictions' should be weakened by far more than it is in our case.

3 – CONCLUSION

During the past three years (2004-2005-2006) at the Erice International Seminars for the study of Planetary Emergencies, the status and the predictions in the field of Meteorology and Climate change have been discussed by eminent specialists. The details of what I have reported in the first part of this paper can be found in the proceedings of the above quoted Seminars [8, 9, 10].

In the second part of my report, the Science of Complexity and the problems of predictions at the fundamental level of scientific knowledge have been discussed.

The conclusion is that years of work and strong financial support are needed in order to improve the theoretical formulation of the problems and the corresponding experimental worldwide observations. The two NASA satellites Cloud-Sat and Calypso an the associated projects are an example of what is needed before anyone can claim that a scientific rigorous understanding has been achieved in mastering all Meteorology and Climate change problems of the past, present and future.

ACKNOWLEDGEMENTS

I would like to thank my colleague and friend André Peterman (co-autor of the RGEs), the specialists and the multidisciplinary scientists (listed in the following pages) who participated in our Sessions on Meteorology and Climate change at the International Seminars on Planetary Emergencies in Erice, during the years 2004, 2005 and 2006 [8, 9, 10].

The number/s in parenthesis indicate the International Seminar/s to which the fellows contributed.

Professor Pradeep Aggarwal (8)	International Atomic Energy Agency Vienna, Austria
Professor Amir I. Ajami (8)	International Agriculture Programs University of Arizona Tucson, AZ, USA
Dr. Hussain Saleh Al-Shahristani (8)	University of Surrey Guilford, UK

Dr. Natasha Andronova (9)	Department of Atmospheric Sciences University of Illinois Urbana, IL, USA
Dr. Giuseppe Tito Aronica (9, 10)	Department of Civil Engineering University of Messina Messina, Italy
Dr. Scott Atran (8, 9)	Institut Jean Nicod, CNRS Paris, France *and* University of Michigan Ann Arbor, MI, USA
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Dr. Vladimir B. Britkov (8, 9, 10)	Information Systems Laboratory Institute for Systems Analysis Moscow, Russia
Professor Herbert Budka (8, 9)	Institute of Neurology University of Vienna Vienna, Austria
Dr. Robert Budnitz (9)	Energy & Environment Directorate Lawrence Livermore National Laboratory Livermore, CA, USA
Colonel Christian Bühlmann (10)	Research & Development HQ Planification Services Military Federal Department Bern, Switzerland
Dr. Franco Buonaguro (8, 9, 10)	Istituto Nazionale dei Tumori "Fondazione G. Pascale" Napoli, Italy
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Professor Massimo V. Civita (9)	Applied Hydrogeology Polytechnic of Turin Turin, Italy
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Dr. Richard Hoskins (10)	International Atomic Energy Agency Vienna, Austria
Dr. Kembra Howdeshell (10)	Reproductive Toxicology Division NHEERL, ORD, EPA North Carolina, USA

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Dr. Rolf K. Jenny (8)	Global Commission on International Migration Geneva, Switzerland
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Dr. Charles McCombie (10)	Arius Association Baden, Switzerland
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4 – ADDENDUM
THE SCIENCE OF COMPLEXITY AT THE FUNDAMENTAL LEVEL OF SCIENTIFIC KNOWLEDGE

In this Addendum I try to report a synthesis of the main steps in the study of Complexity at the fundamental level of scientific knowledge.

In figure 7 it is shown the general trend which considers Science the result of the rigorous logic needed, thanks to mathematics, to make 'predictions'. These predictions are possible because of reductionism in the study of the real world where Simplicity is to be searched in order to find out the correct way to solve a problem.

On the opposite side there is History, which needs a holistic approach with the whole of our knowledge being involved and this is why History is considered to be the asymptotic limit of Complexity.

The general trend has so far been to identify Science and History as the extreme limits of Simplicity and Complexity, respectively. The present status is drastically different, as shown in Figure 9. After 400 years of the reductionism it could be that we need to consider Holism as the basic structure of Science. We are not going back to the pre-scientific holistic approach. The rigorous knowledge we have achieved thanks to Science remains valid. It is the understanding of Holism that needs Science even if the final result could be that Science is NP complete, as shown in figure 9. In other words the great steps in Science are all UEEC events. But when such an unexpected event comes in, we need the reductionistic approach in terms of mathematical rigour and of reproducible experiments to make predictions.

Let us go back to History and Science as the two extreme limits of Complexity and Simplicity. 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’ [38].

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 that the force F acting on a stone is proportional to the acceleration by gravity (g) and not to the speed, as believed during more than two thousand years: 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 appear 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. The **UEEC** events reported in figure 10 go from Galilei to Fermi-Dirac and the ‘strange particles’. The **UEEC** events in figures 11, 12 and 13 go from Fermi-Dirac to the construction of the Standard Model; in figure 14 there is a synthesis of **UEEC** events in what we now call the Standard Model and Beyond (**SM&B**). A few cases (seven) where I have been directly involved are summarised in figure 15. Here each **UEEC** event is coupled with a **despite**, in order to emphasize the reason why the event is totally unexpected.

The **SM&B** is the greatest synthesis of all times 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 Platonic Simplicity. An example is shown in figure 16 (reported in the second part of this paper on page 17 as figure 5) where the straight line (small dots) would be the Platonic simple solution towards the Unification of all Fundamental Forces. But the effective unification is ‘predicted’ to be along the sequence of points (the big ones) calculated using the mathematical structure (1) of three differential non linear equations weakly coupled.

This set of figures (10 – 16) is the proof that predictions in Science are possible only when an UEEC has been understood in terms of a rigorous

mathematical description based on the reductionistic approach. But the most remarkable feature of Science are the UEEC events. If this is true in the most rigorous way of studying the real world, this must also be true when we depart from what should be the asymptotic limit of Simplicity. The straightforward consequence is that – no matter what will be the predictions in Meteorology and Climate change – the best one is that Meteorology and Climatology are expected to be dominated by UEEC events.

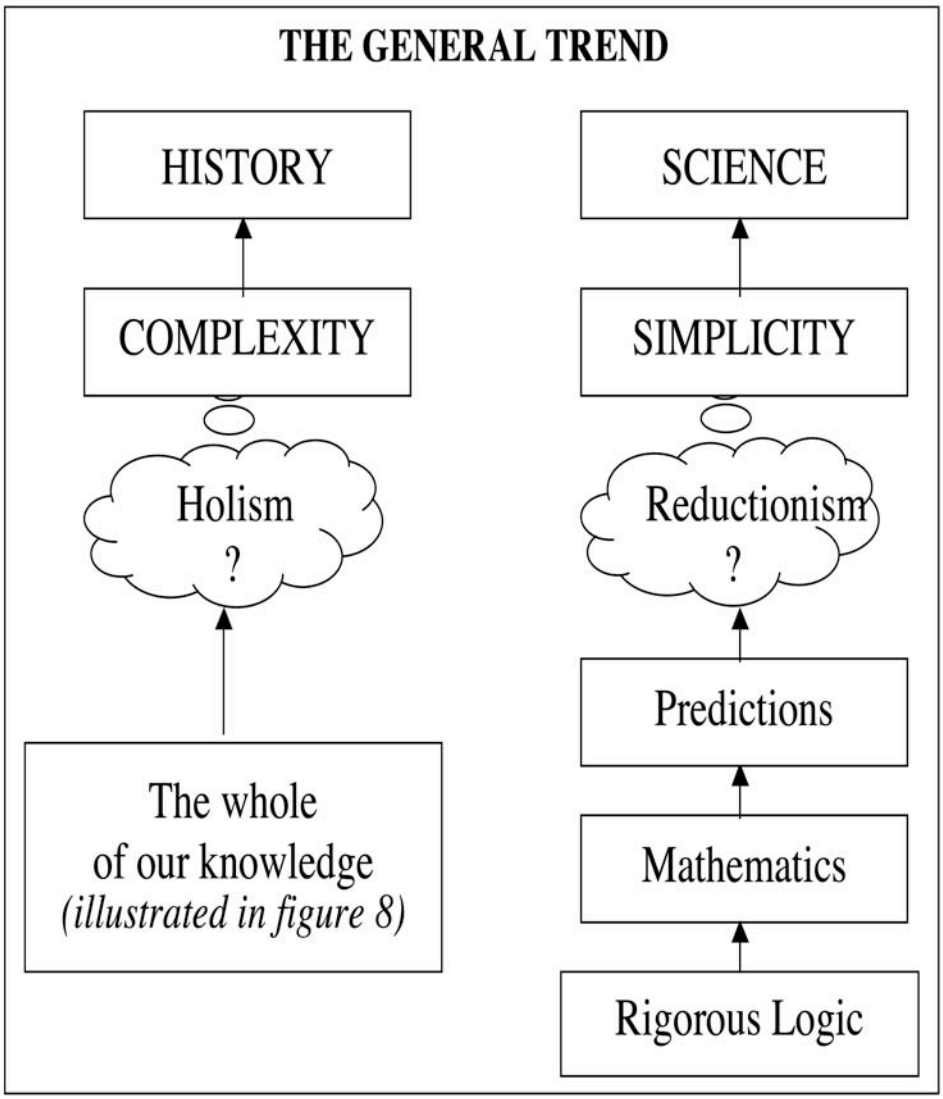


Figure 7

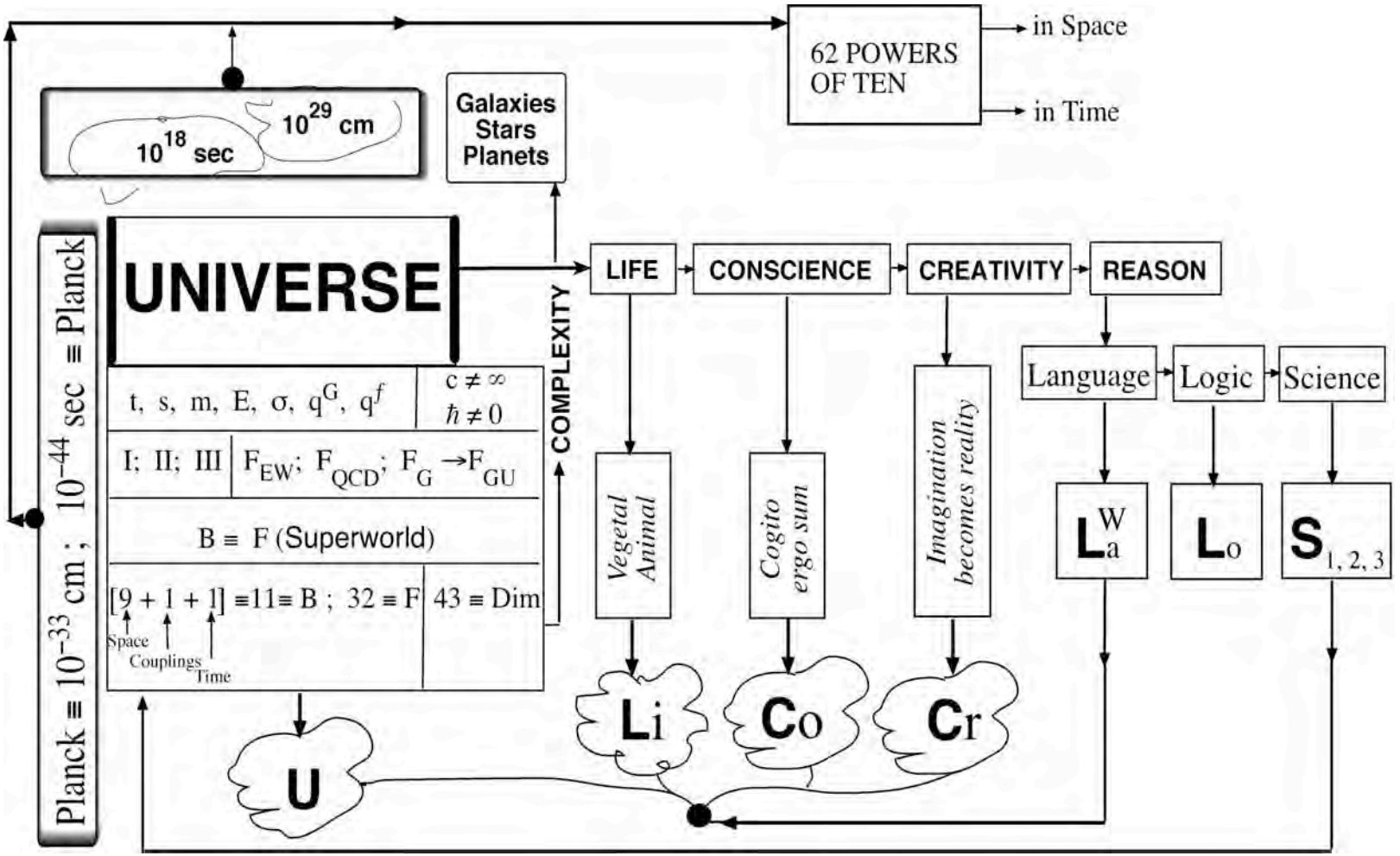


Figure 8

THE WHOLE OF OUR KNOWLEDGE

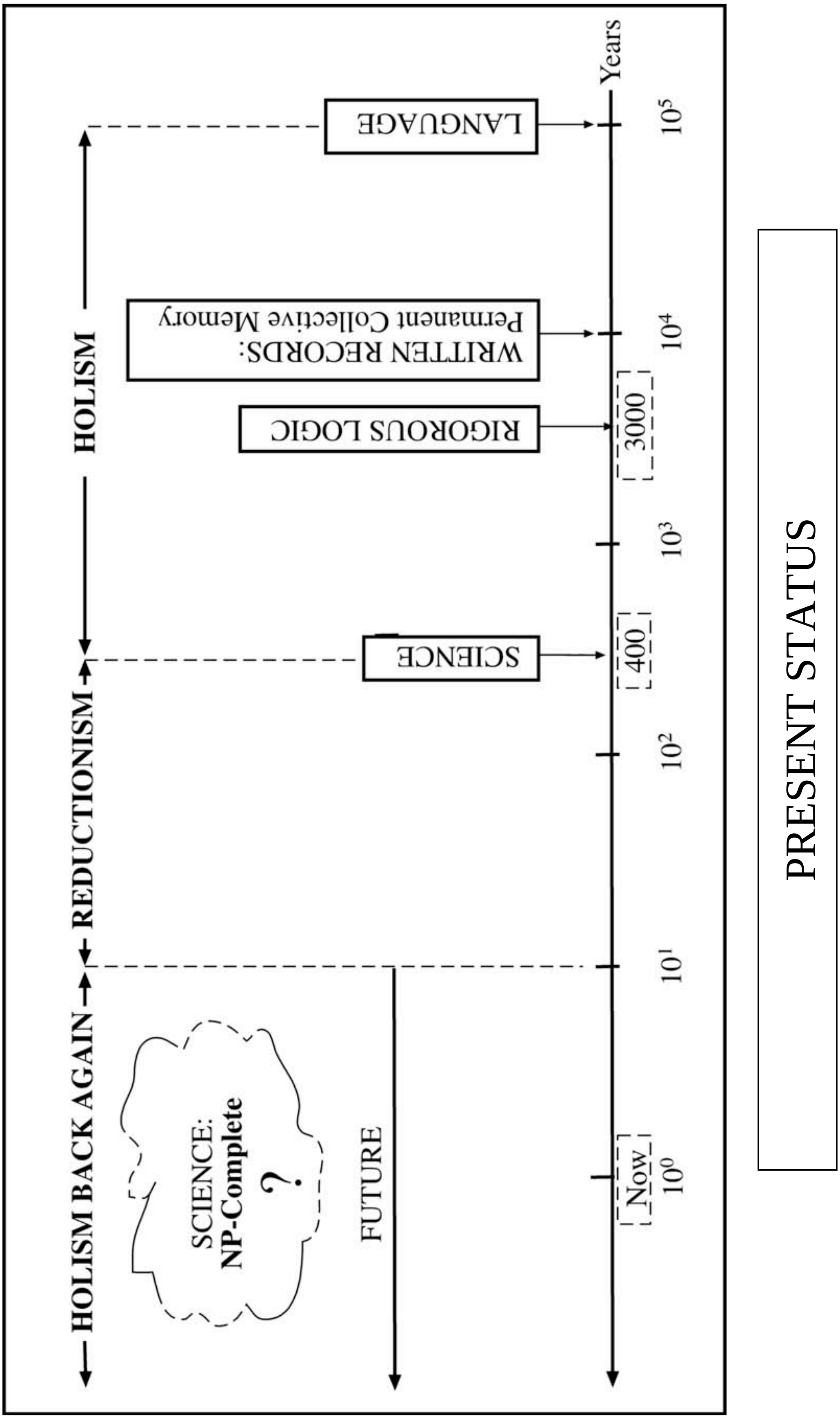

PRESENT STATUS
HOLISM BACK AGAIN
REDUCTIONISM
HOLISM
SCIENCE:
NP-Complete
?
FUTURE
SCIENCE
RIGOROUS LOGIC
WRITTEN RECORDS:
Permanent Collective Memory
LANGUAGE
Now
10^0
10^1
10^2
400
10^3
3000
10^4
10^5
Years

Figure 9

TABLE 1

'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 Arbour (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?

‘UEEC’
TOTALLY UNEXPECTED DISCOVERIES
FROM GALILEI TO FERMI-DIRAC AND THE ‘STRANGE’ PARTICLES

I	Galileo Galilei discovery of $F = mg$.
II	Newton discovery of $F = G\frac{m_1 \cdot m_2}{R_{12}^2}$
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 10

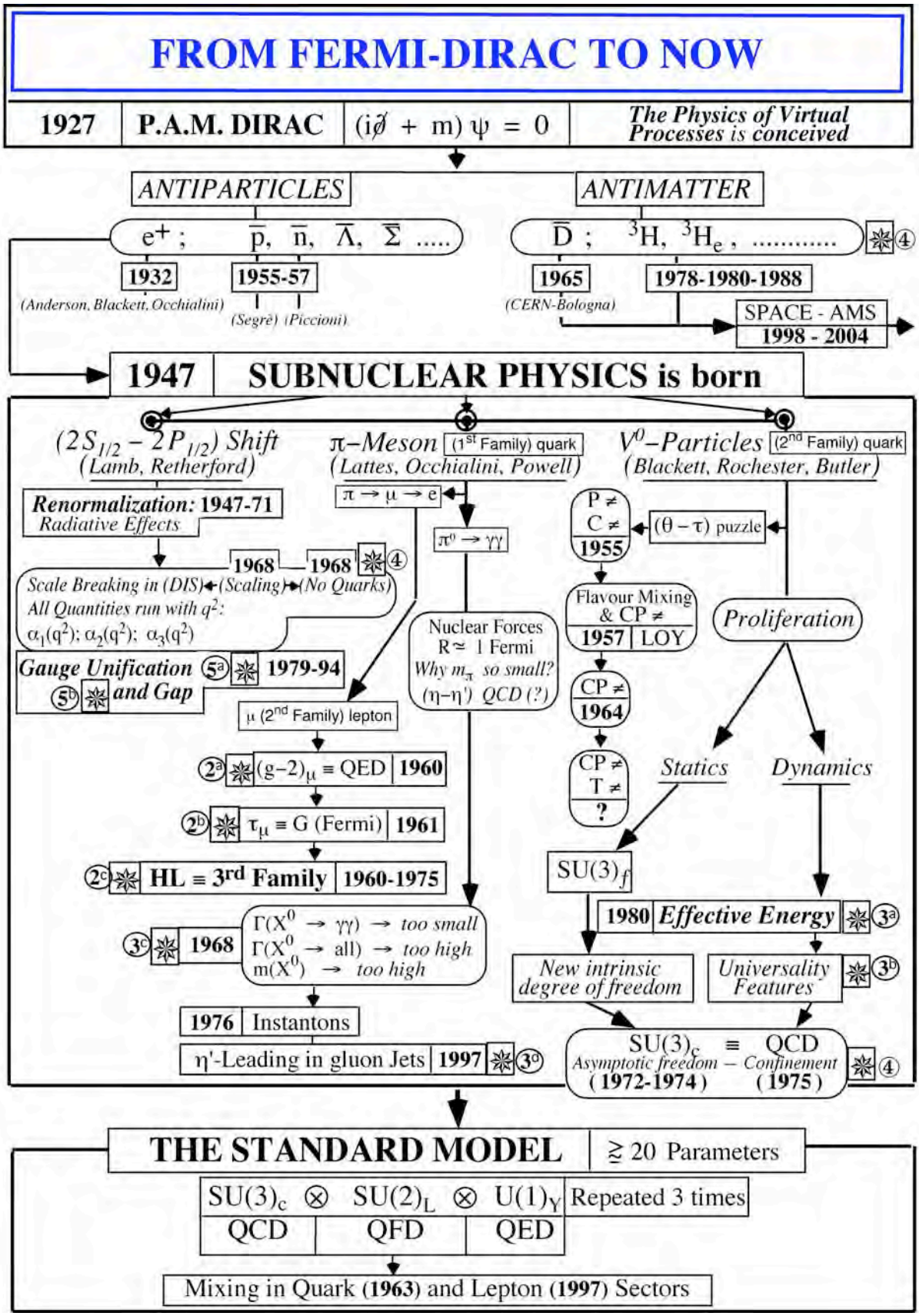

FROM FERMI-DIRAC TO NOW
1927
P.A.M. DIRAC
(iγ∂ + m) ψ = 0
The Physics of Virtual Processes is conceived
ANTIPARTICLES
ANTIMATTER
e+ ; p̄, n̄, Λ̄, Σ̄ .....
D̄ ; 3H, 3He , ...
1932
(Anderson, Blackett, Occhialini)
1955-57
(Segrè) (Piccioni)
1965
(CERN-Bologna)
1978-1980-1988
SPACE - AMS
1998 - 2004
1947
SUBNUCLEAR PHYSICS is born
(2S1/2 − 2P1/2) Shift
(Lamb, Retherford)
π−Meson (1st Family) quark
(Lattes, Occhialini, Powell)
V0−Particles (2nd Family) quark
(Blackett, Rochester, Butler)
Renormalization: 1947-71
Radiative Effects
π → μ → e
π0 → γγ
P ≠ C ≠ 1955
(θ − τ) puzzle
1968
1968
Scale Breaking in (DIS) ← (Scaling) → (No Quarks)
All Quantities run with q2:
α1(q2); α2(q2); α3(q2)
Flavour Mixing & CP ≠ 1957 LOY
Proliferation
Gauge Unification and Gap
1979-94
Nuclear Forces
R ≃ 1 Fermi
Why mπ so small?
(η−η') QCD (?)
CP ≠ 1964
μ (2nd Family) lepton
CP ≠ T ≠ ?
Statics
Dynamics
(g−2)μ ≡ QED 1960
τμ ≡ G (Fermi) 1961
HL ≡ 3rd Family 1960-1975
SU(3)f
1980 Effective Energy
Γ(X0 → γγ) → too small
Γ(X0 → all) → too high
m(X0) → too high
1968
New intrinsic degree of freedom
Universality Features
1976 Instantons
η'-Leading in gluon Jets 1997
SU(3)c ≡ QCD
Asymptotic freedom — Confinement
(1972-1974) (1975)
THE STANDARD MODEL
≳ 20 Parameters
SU(3)c ⊗ SU(2)L ⊗ U(1)Y
Repeated 3 times
QCD
QFD
QED
Mixing in Quark (1963) and Lepton (1997) Sectors

Figure 11

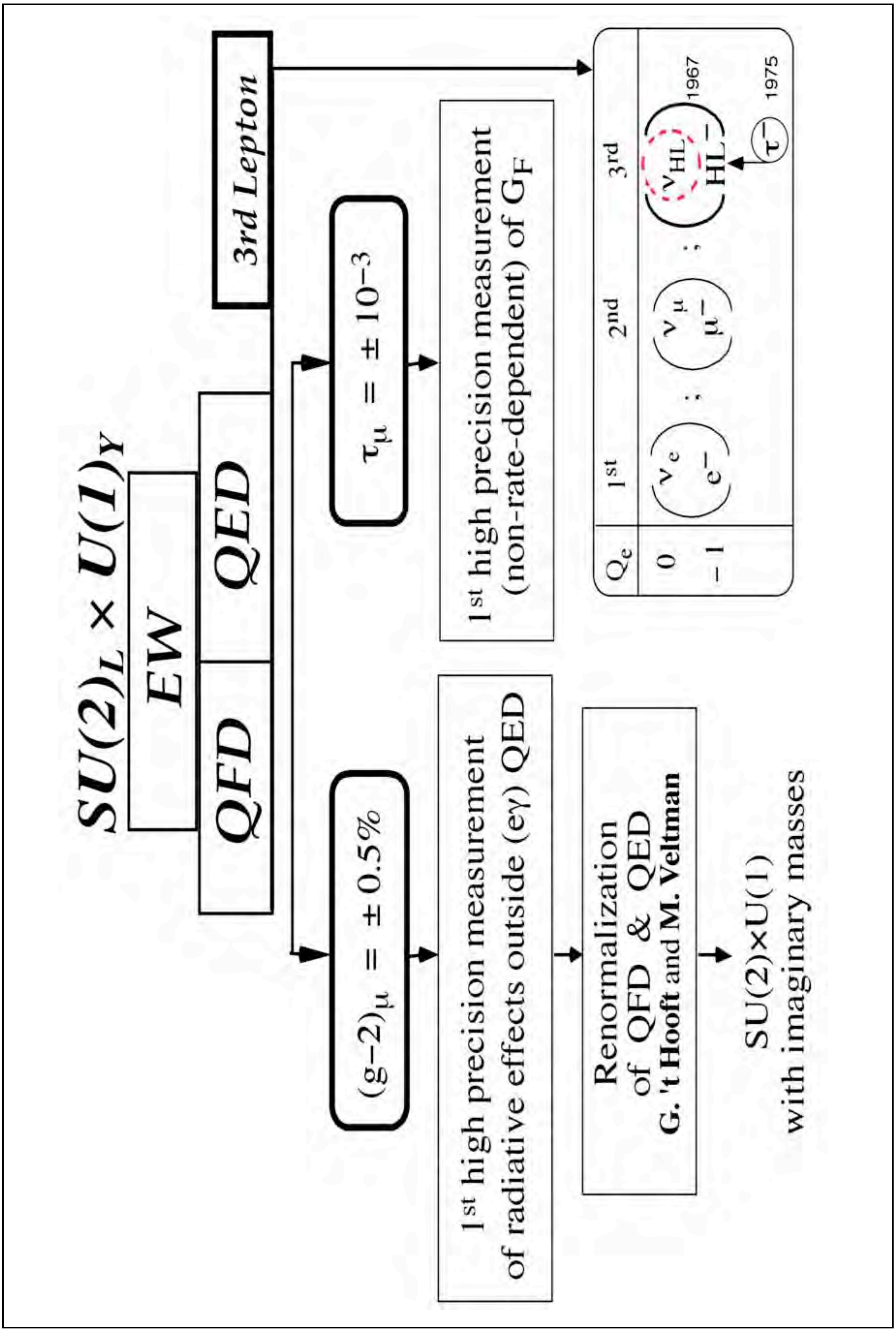


Figure 12: Details from figure 11, concerning $SU(2)_L$ and $U(1)_Y$.

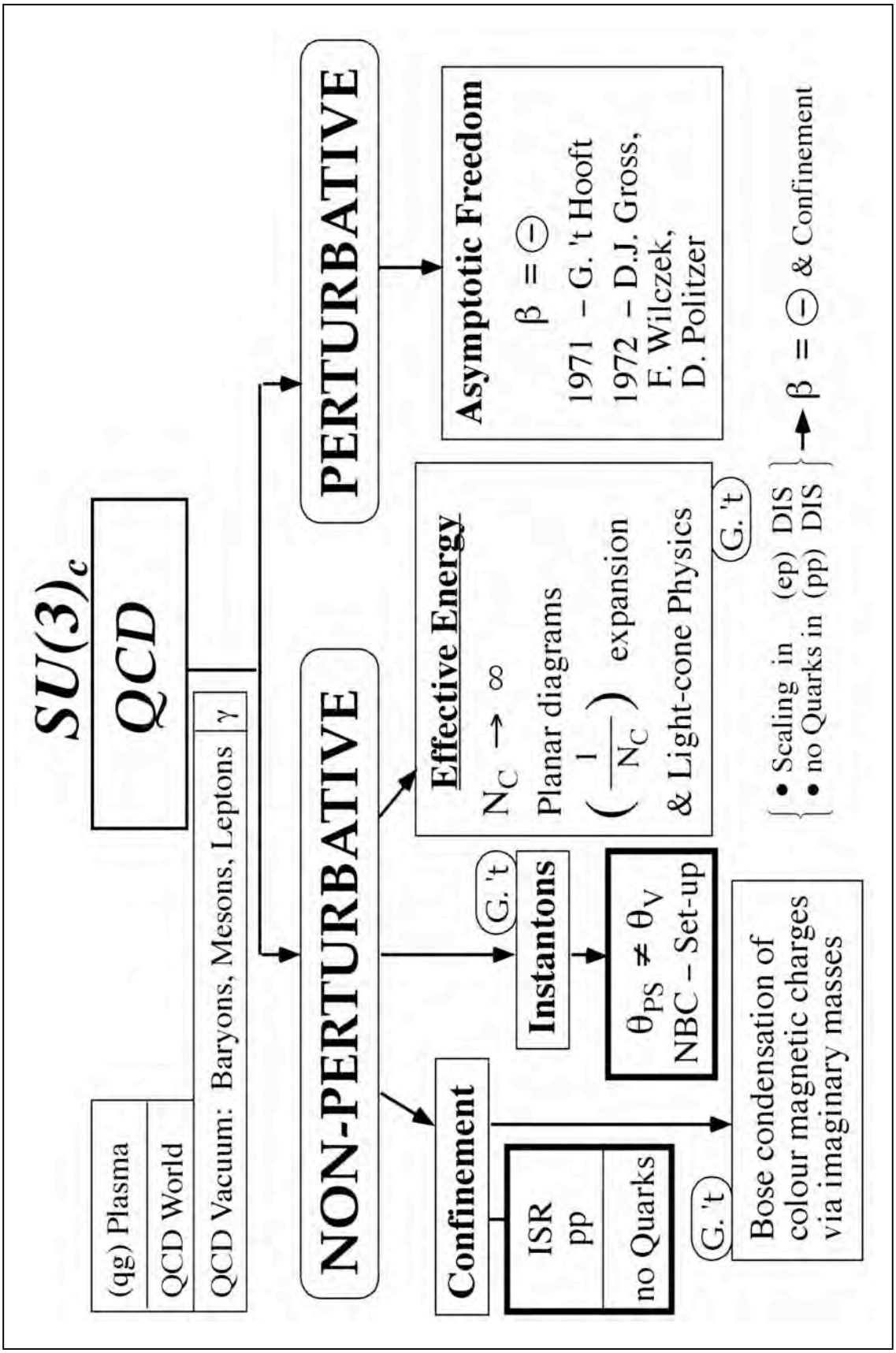


Figure 13: Details from figure 11, concerning $SU(3)_c$.

SM&B

THE STANDARD MODEL AND BEYOND

① RGEs (α_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 Symmetry Group (not containing U(1)) ⇒ 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; l ≡ lepton and slepton; G ≡ Gauge boson and Gaugino; H ≡ Higgs and Shiggs; RGEs ≡ Renormalization Group Equations; GUT ≡ Grand Unified Theory; SUSY ≡ Supersymmetry; RQST ≡ Relativistic Quantum String Theory; SSB ≡ Spontaneous Symmetry Breaking.
m_F ≡ Fermi mass scale; m_P ≡ Planck mass scale; k ≡ quadrimomentum; C ≡ Charge Conjugation; P ≡ Parity; T ≡ Time Reversal; ≠ ≡ Breakdown of Symmetry Operators.

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 14

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

① ***The 3rd lepton*** with his own neutrino, 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.

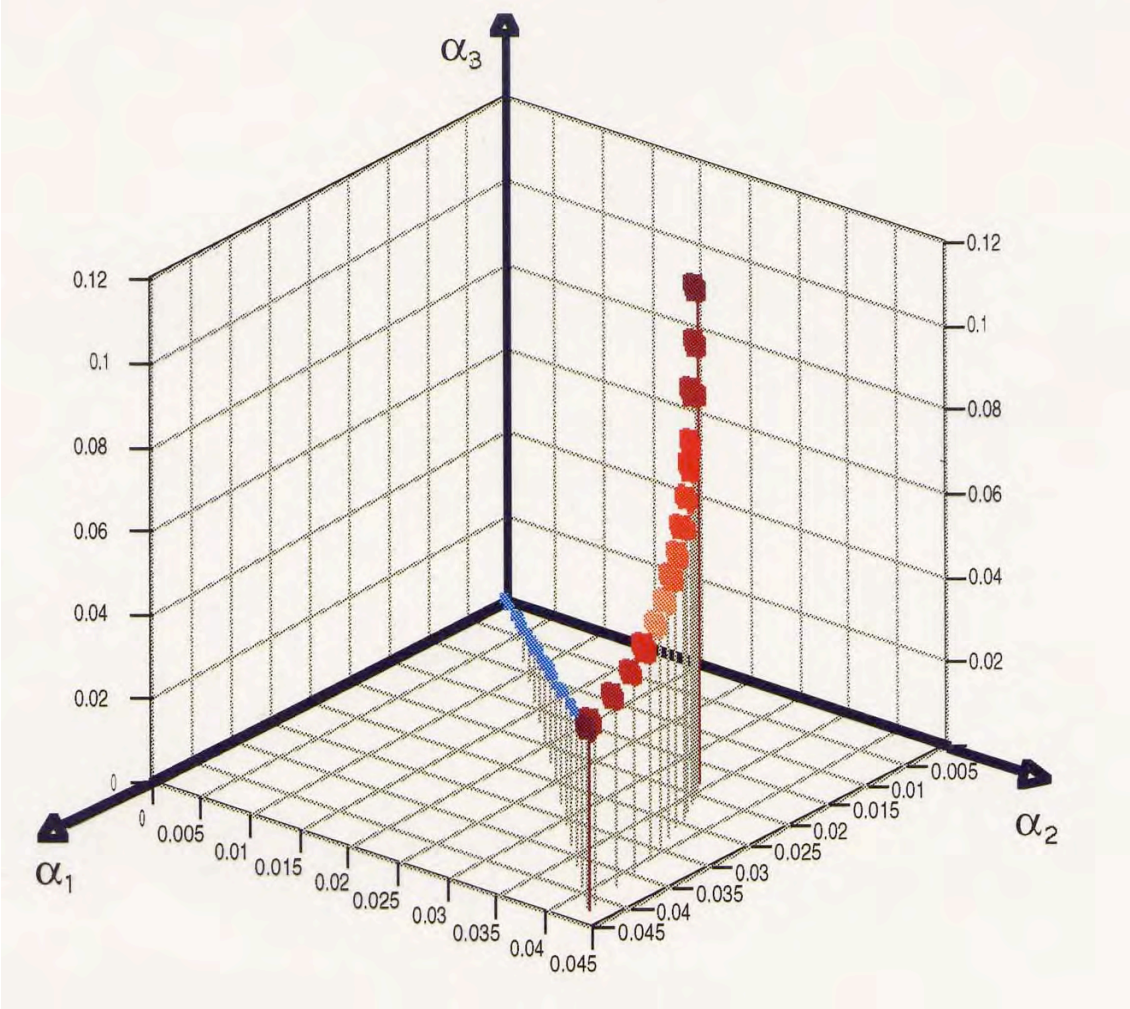
⑤ ***Meson mixings***
$\theta_V \neq \theta_{PS}$ **:** $(51^o) \neq (10^o) \neq 0$ **despite** $SU(3)_{uds}$.

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

⑦ ***The running*** *of* $\alpha_1\ \alpha_2\ \alpha_3$ *versus* ***energy*** *at* **a point** E_{GU}.
(1979) (1991) **despite** straight line convergence.

EGM

Figure 15



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 value of the gauge coupling α_3 is taken at the Z^0-mass: $\alpha_3 (M_Z) = 0.118 \pm 0.008$; the other input is the ratio of weak and electromagnetic couplings also measured at the Z^0-mass value: $\sin^2 \theta_W (M_Z) = 0.2334 \pm 0.0008$.

Figure 16 (the same of figure 5, reported on page 17)

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