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1 There are several flavours of the *Cosmological Principle*, such as the *Copernican*, the *Perfect* and the *Weak Anthrophic* and *Strong Anthropic* ones. Would you like to stress the differences and the most important assumptions underlying each one?

1.1 Perfect Cosmological Principle

Before discovery of cosmic background radiation (CBR) thanks to Penzias and Wilson, 1965, (e.g., Barrow & Tipler, 1986, pg.368) two opposite alternatives were possible regarding cosmological evolution. One was related to the *Perfect Cosmological Principle*, that is: *The Universe is, on average, the same everywhere, in all directions and at all times.* On this Principle, Bondi, Gold, Hoyle and Narlikar (1948, 1963-'64; see, Barrow & Tipler, 1986, pg.421 and references therein) grounded their *steady -state theory* of cosmic description. To cure the problem of lack of constant density due to the discovery by Hubble (1929) that the universe expands with time, they were available to assume that the creation of only one hydrogen atom/liter each $5 \cdot 10^{11}$ years had resolved the problem (Bondi, 1961). In Hoyle's words (1948) :*" Using continuous creation of matter, we shall attempt to obtain, within the framework of the general theory of relativity, but without introducing a cosmical constant, a universe satisfying the wide cosmological principle* [i.e., the perfect one]*that shows the required expansion properties".* The other alternative was that the universe did not be characterized by the monotony imposed by the Perfect Cosmological Principle but, on the contrary, by a high level of variety and fantasy owing to the continuous change of density and temperature. Penzias's and Wilson's discovery proved that it was in this second way that expansion occurs. Indeed, perfect cosmological behavior was ruled out by the perfect black- body energy distribution of CBR which told us that matter and radiation were in thermodynamic equilibrium in the remote past even if they are not now. At present cosmological density (of about 3 $protons/m^3$) one photon actually needs more than the universe age to interact with an electron. The conclusion was that density must have changed relentlessly during cosmic evolution and its temperature as well. A fantastic scenario appeared in the history of the universe marked by a sequence of different physical phenomena, exactly the opposite of the Perfect Cosmological Principle's depiction. The latter subtracted to the universe all the inventiveness and fantasy, relegating its story to a flat picture albeit obeying our mental needs of *Ockham's Razor Principle.* [1]

1.2 Cosmological Principle

In the meantime, the large surveys (e.g., that of 157,320 galaxies using the Anglo Australian Telescope (e.g., Peacock et al., 2001), the other which contains around 10^6 galaxies collected in Shane's & Wirtanen's catalogue (Combes et al., 1995, pg. 293) and the APM survey with over two million galaxies (e.g., Longair 1998)) began to map the universe structure on the large scale. At the end of 1989, the Cosmic Background Explorer (COBE) was launched. It measured the black-body temperature of the CBR ($\sim 3K$) and revealed its very small fluctuations (of the order of 10^{-5}) at the universe age of about 300,000 years after the Big-Bang (Coles & Lucchin, 1995). So the texture of the young and old universe appeared to be characterized by a high degree of *homogeneity* and *isotropy* ratified in the *Cosmological Principle*: *On the large scale (greater than 200 Megaparsec) the universe is, at a good extent, homogeneous and isotropic at any one time.* To describe the cosmological evolution one then needs to set up a metric for the space-time which takes into account this Principle. From the point of view of a physical observer, it means that each

[1] Proposed by William of Ockham in the fourteenth century: *Pluralitas non est ponenda sine neccesitate*, which translates as: *entities should not be multiplied unnecessarily.*

hyper-surface which describes the universe in a four-dimensional space has to appear to him at all times to be *homogeneous* and *isotropic* and to be the same even if the observer changes. In other words, the Cosmological Principle implies the *Copernican Principle* (e.g., Peacock, 1999) that is: *We are not priviliged observers of the universe.* In turn, if we find that distant galaxies are heading away from us in all directions, that does not mean that we have the privilege of being at the fixed centre of an expanding universe, but rather that the nature of cosmic expansion is such that the recession of distant galaxies is what would be observed by any other observer located in any other point in the universe (see, Jones et al. 2003). The immediate consequence is: a distant galaxy has to move away in all directions because there is not a special one, but all directions means no direction at all, i.e., *it is the reference frame which expands.*

1.3 Modern Cosmology and center of the universe

After the conclusion of the Great Debate, which occurred at the National Academy of Sciences in Washinton, April of 1920, (e.g., Mihalas and Binney, 1968, Chapter I and references therein) between H. Shapley and H.D. Curtis, the sequence of shifts related to the center of universe arrived at its end. This center had been moved from Earth to Sun by Copernicus (1543) and Galileo (1609). After them, at the end of the eighteenth century, W.Herschel concluded that the Sun lay roughly at the center of his first Milky Way map, and until Kapteyn's universe (e.g. Kapteyn, 1922) the heliocentric position was strongly sustained. It was H.Shapley who discovered the Sun's off-center of about 15 kiloparsecs (between 1915-1919) using globular cluster distribution in galactic longitude. But the *the last act of the Copernican revolution* was the conclusion of the Great Debate: neither the Earth, nor the Sun, nor even our Galaxy was special. Modern Cosmology will very soon conclude that the center of the universe does not exist. This result since the beginning of the 20^{th}

century has had and nowadays continues to have an enormous impact on the cultural level. If the Life site inside the universe texture was without any relevance, the Life itself appeared to be like mould on a lost planet in the universe's immensity. Man and his Life are absolutely marginal in the cosmical context, to such a point that, according to the Copernican Principle, the human view point itself is not of any importance because each observer located anywhere in the universe would see the universe in the same way. On one side, Man, by accepting this tremendous humiliation, has been able to construct cosmological models actually based on the Copernican Principle, which on the other side have brought again to the scene the connection between Cosmos and Life.

1.4 The Large Numbers Puzzle

The story began in 1923 with A.Eddington, who suggested that the large total number of protons inside the universe's horizon, $N \simeq 10^{80}$, might play a part in determining some fundamental constants of Nature (Barrow & Tipler, Chapter 4, 1986). There are indeed some Large Numbers coincidences: e.g., the *coupling constant of the gravitational force* is, in dimensionless units:

$$\alpha_G = Gm_N^2/\hbar c \simeq 10^{-39}$$

where m_N is nucleon mass, G, gravitational constant and, $\hbar$, Planck's constant/2π. α_G turns out to be about $N^{-1/2}$. Moreover the ratio of electric force between proton and electron to their gravitational force is:

$$N_1 = e^2/Gm_pm_e \simeq 10^{39}$$

that is about $N^{1/2}$ (m_p, m_e proton and electron mass, respectively). Even the ratio between the age of universe, t_o, and the light crossing time of the classical electron radius, r_e, is of the same order of magnitude:

$$N_3 = \frac{t_o}{r_e/c} \simeq 6 \cdot 10^{39};\ c = light\ speed.$$

Since 1937 P.Dirac took into account very seriously these coincidences, concluding that gravity must weaken at increasing cosmic time. To understand the deep meaning of these kinds of apparently strange speculations we have to look back at what we know now by means of modern cosmological models. The large numbers relationships showed indeed that there was a mysterious connection between the *macro-cosmos* and the *micro-cosmos* as now has been proved. The increasing of microscopic complexity at the beginning of universe (let us think, for example, of the *recombination epoch* when the atoms form) occurred indeed in order to allow for the formation of large scale structures, which in turn would allow microscopic complexity growth to continue by the nuclear synthesis inside stars formed as *sub-units* of these structures. One appears related to the other in an extraordinarily beautiful link. To these interesting speculations in the 1930s one should add the relationship underlined by Dicke in 1961 between universe age and the time requested to form carbon, necessary to Life, inside the stars, which again was another macro-micro cosmos link.

1.5 Anthropic Principle

Yet it was B. Carter (1974) who for the first time pointed out that the key to previous links was Life. It is due to him that we have the first formulation of the so called Anthropic Principle (AP):" *what we can expect to observe must be restricted by the conditions necessary for our presence as observers"* (Carter, 1974, pg.291). Barrow & Tipler (1986) took up again Carter's idea by reformulating the Anthropic Principle in two ways, in the Weak form (WAP) as follows:*"the observed values of all physical and cosmological quantities are not equally probable but they take on values* *restricted by the requirement that there exist sites where carbon-based life can evolve and by the requirement that the universe be old enough for it to have already done so".* In the Strong form (SAP) it is as follows:*" the universe must have those properties which allow life to develop within it at some stage in its history.* What is the relevance of these two formulations? They open the door to a large spectrum of interpretations. I think many controversies arise from the different meanings people assign to the same steatments. It seems to me that the most important thing lies in this: *for the first time a physical connection between histories of the universe and Life is clearly enunciated.* To ground these Principles, a very long chain of physical phenomena was collected by Barrow and Tipler (1986) with the impressive *fine tunings* Life requests in order to appear. We will refer to them when we will answer to the second question (par.2).

We wish first of all to underline the deep difference between WAP and SAP. It shoud be noted that the WAP formulation changes into the SAP one essentially by substituting *can* by *must.* That means the *possibility* of Life development in the WAP version becomes *necessity* in the SAP one. That implies the existence of a methaphysical finality in the whole cosmological evolution. A methaphysical component appears indeed in the SAP formulation. On the contrary, when we analyze the different characteristics of some cosmos evolutionary phases or the chemical-physical properties of some substances involved in the processes of Life building up, we do not pass over the Science domain. Indeed we simply consider Life itself as a complex phenomenon, looking at it as a function of many parameters and testing how sensitive it is to a small variation of one of its variables. Nevertheless, taking into account the probability of the *monstrous sequence*[2] (Hoyle, 1959) of compatible and independent events of which Life needs,

[2] *"I do not belive that any scientist who examined the evidence would fail to draw the inference that the laws of nuclear physics have been deliberately designed with regard to the consequences they produce inside the stars. If this is so, then my apparently random quirks have become part of a deep-laid scheme. If not then we are back again at a monstrous sequence of accidents."*

it is manifest how *the probability of Life not appearing is great.* But *we are* ! Then the question arises: *why?*. In my opinion it is important to be as precise as possible about the limit between the two domains, that of Science and that of all which lies above the Science. We can refer to the latter as Methaphysics (following the original meaning related to the order of Aristotle's works, *metà tà fusiká*, i.e., *all that is beyond the Physics*) or Trascendence which are used as synonyms in this context. The problem of Science-Trascendence relationship goes back to the origin of modern Science thanks to Galileo. Even if the debate is outside the aim of this contribution, let me stress which are in my opinion some of main lines of the problem in order to locate WAP and SAP correctly. Science refers to the domain of quantity, of corporeity; Methaphysics refers to the domain of what lies beyond them. The two methodologies are completely different (see, Dallaporta, 1997). The two domains develop along two orthogonal axes: the horizontal one, Science, the vertical one, Trascendence. Then, inside the Science domain are soundly located the questions of the incredible fine tuning connections between Cosmos and Life which WAP underlines. On the contrary, when we wish to add to the *whys* the possible answers to them as SAP claims, we are going beyond Science. But I think the requests WAP asks us to answer are so strong and so unavoidable that it is wrongfully considered weak. Then hereafter we will reformulate WAP as follows: *the collection of facts which connect the factors (see, par.2)- constraining the main features of cosmos and its evolution- with Life, by which it is possible to infer how strongly the Life phenomenon is depending on these factors.* We refer to it as WRAP.

2 What is the interplay between the present cosmological scenarios and the development of Life?

To answer this question, we have first to stress the principal factors which constrain the main features of the universe. Briefly we can group them into the three following sectors (see, Dallaporta

& Secco, 1993):

-A) the values of the main constants in Fundamental Physics.

-B) The global properties of the universe and its history.

-C) The space dimensionality.

Related to each sector, a huge collection of relationships proposed by many authors (e.g.,Barrow & Tipler, 1986; Dallaporta & Secco, 1993; Rees, 2002; Barrow, 2003; Gingerich, 2007) may prove the interplay between the present cosmological scenarios and the development of Life. To keep it short we will take into account only few exemplifications for the sectors A) and B). To understand how special is the spatial dimensionality equal 3 of our universe, we invite the reader to refer at the references cited above.

2.1 A) The values of the main constants in Fundamental Physics

We will refer only to the coupling constant values of the four forces. At the very early phases after the Big-Bang there are no doubts that the universe was the highest energy laboratory of particle Physics. Even if the reliability of the physical phenomena is decreasing, going back toward singularity, the electro-weak unification proved at about 100 GeV at Ginevra CERN, allow us to take seriously into account the other possible unification as depicted by the grand unified theory (GUT) at the time of about $\sim 10^{-35} sec$. At this time, when the energy density of the universe had to be about $10^{15} GeV$, according to GUT the three forces: the strong and the electro-weak could be unified. The spontaneous breaking of the high level symmetry corresponding to this unified force, due to the universe's expansion allows the strong force to separate from the electro-weak by assuming a coupling constant which now is equal to: $\alpha_S \simeq 15$. At about $\simeq 10^{-11} sec$ the electro-weak symmetry breaks too and the corresponding unified force splits into the electromagnetic force (with a typical coupling constant value of, $\alpha \simeq 1/137$) and into the weak one (with a typical coupling constant of, $\alpha_W \simeq 10^{-5}$). These values with which the forces detached one from the other are crucial in the primordial nucleosynthesis epoch ($\simeq 200 sec$). Indeed if α_S increases only by 0.3%, dineutron binds and with, $\Delta\alpha_S/\alpha_S$, increasing by 3.4% the diproton is bound too. But if, $\Delta\alpha_S/\alpha_S$, decreases less than 9%, the deuterium nucleus fails to be bound (Davies,1972 in Barrow & Tipler, Chapter 5, 1986). These little changes might have catastrophic consequences for Life. For example, if the deuteron was unbound, the consequences for the nucleosynthesis of elements necessary for development of Biology are strong because *a key link in the chain of nucleosynthesis would be removed* (Barrow & Tipler, Chapter 5, 1986).If, on the contrary, the strong interaction was a little stronger, the diproton stable bound state would have the consequence that *all the hydrogen in the universe would have been burnt to* ^2He *(diproton) during the ealy stages of the Big Bang and no hydrogen compounds or long-lived stable stars would exist today* (Barrow & Tipler, Chapter 5, 1986). Indeed the reactions to form ^4He would find a channel about 10^{18} times faster in comparison with those without diproton formation. The hydrogen reserve would have been quickly consumed without allowing, e.g., the water formation. Moreover the stability of a nucleus of a mass number A and atomic number Z hinges on a fine link between the strengths of electromagnetic and strong forces as follows:

$$\frac{Z^2}{A} \leq 49(\frac{\alpha_S}{10^{-1}})^2(\frac{1/137}{\alpha})$$

Thus, if the electromagnetic interaction were stronger (increased α*) or a stronger interaction a little weaker (decreased* α_S*), or both, then biologically essential nuclei like carbon would not exist in Nature* (Barrow & Tipler, Chapter 5, 1986).

These are only very few exemplifications of a huge collection given in the cited book.

2.2 B) The global properties of universe and its history

2.2.1 Growth of complexity

There is an impressive trend in the whole history of the universe beginning from the very early phases at which the high level symmetries break. For example, when the Higgs mechanism is at work, the electro-weak force differentiates into weak and electromagnetic ones by distinguishing between, $W^{\pm}$, and, Z_o, massive mediator bosons for the first and the massless photons for the second. The universe's aim appears to differentiate, to articulate itself by increasing its complexity or, in other words, to grow its microscopic thermodynamical information [3], I, without violating the second thermodynamic Principle, that is increasing in the meantime its total entropy. The same paradigm appears to be followed as well at the *recombination epoch* when atoms form. After this time, the large structures form by enriching the universe with extraordinarily beautiful complexity on the macroscopic scale too. It appears as if a *large carving was in progress.* But all this is exactly what the end- product, Life, needs. Indeed Life requests a very high level of structuration, of differentation, of local thermodynamical information. The universe indeed appears in some sense bend to these needs.

2.2.2 The fine tuned expansion

Before the introduction of inflation mechanism thanks to Guth (1981) (e.g., Coles & Lucchin, 1995), one of the problems to be solved in modern cosmology was the *flatness problem.* It appeared very strange indeed that in whichever universe we were (*open*, *critical* or *closed*) the corresponding model describing it had the same limit of the parameter density Ω when time goes toward

[3] According to Layzer (1976), $I = S_{max} - S$ where S_{max} means the maximum value the entropy of a system may have as soon as the constraints on it, which fix its entropy value to S, are relaxed.

singularity [4]. Actually all the models not only had to tend to the critical one, i.e., with $\Omega = 1$, but in a way surprisingly tuned: e.g., at the Planck epoch, $t_P \simeq 10^{-43} sec$, an open universe had to have: $\Omega(t_P) = 1 - 10^{-62}$, and a closed one, $\Omega(t_P) = 1 + 10^{-62}$. Moreover at the present age, t_o, i.e., after about $14 \cdot 10^9$ years the density parameter has not to be much different from 1. The acceptable models indeed have to be characterized by a density parameter inside these limitations: $0.03 < \Omega(t_o) < 2$. It means the universe has now to differ from a critical one of less than a factor 100, when its density variation along the whole evolution is of 123 orders of magnitude. The Ω constraints are not trivial because they are strictly related to the age of universe and to the possibility to form structures. Actually, whithout this small shift which tunes the expansion the universe had collapsed very soon or expanded so fast that neither stars neither galaxies might form. In both cases the Life *had not the necessary conditions to develop itself.* The inflation seems to take care of this very peculiar initial condition of universe even if the previous fine tuning problem transfers into the not completely resolved inflationary modulation (see, Coles & Lucchin, 1995, Chapter 7). Moreover most of the inflationary models does predict an almost flat universe that is a very special value of $\Omega_o = \Omega(t_o) \simeq 1$. But dynamical estimates about ordinary and dark matter amount yield typical value of $\Omega(t_o) \simeq 0.3$. In 1998 the analysis of the distant-redshift relationship using high redshift Type Ia supernovae, has led to the discovery that the universe expansion from about the time of Sun's birth ($z \simeq 0.5$) is accelerating (Riess et al., 1998). According to this extraordinary scientific new the dominant contribution to the present-day energy budget is a component called *dark energy. Dark* because we ignore its origin and because its equation of state is [5]: $p = wc^2\rho$, with $w < -1/3$ that is an ingredient with an *anti-gravitational character.* The most straightforward candi-

[4] Ω is the ratio of matter and energy density to the value of the same quantities for the critical universe. Open universe corresponds to $\Omega < 1$, critical to $\Omega = 1$, closed to $\Omega > 1$.

[5] The relation between pressure, p, and energy density, ρ; c is the light speed.

date to produce it is a positive *cosmological constant* Λ with an equation of state parameter $w = -1$. Immediatly a fine-tuning problem again arises. A cosmological constant Λ seems to have caused the inflationary accelerated expansion at the GUT epoch if its energy density was: $\rho_\Lambda \simeq (10^{15} GeV)^4$ (in natural units). At the present the energy density to obtain $\Omega_{\Lambda o} \simeq 0.7$ (so that $\Omega_o = \Omega_o(matter) + \Omega_{\Lambda o} \simeq 1$) has to be $\rho_{\Lambda o} \simeq 10^{-47} GeV^4$. It means that the dark energy density (in g/cm^3, referring to Planck scale) had to be decreased of about 123 orders of magnitude. The mistery is *why* it had now to become so small but with the right amount in order that the total budget of *ordinary matter+dark matter+dark energy* yields properly $\Omega_o \simeq 1$. An interesting answer is given by Rees (2002) who includes as one of possible solutions for Λ mistery that *"its tuning... may be a fundamental request for our existence"*. Actually an higher value of Λ before or after galaxy formation would cause catastrophic consequences by preventing or destroying their formation owing to its repulsion effect against that of gravitational condensation. Such kind of universe *would be sterile.*

2.2.3 Carbon and Oxygen nucleosynthesis

Let us remember at least another of the many incredible bottlenecks through which the universe's evolutive story passes in order to produce the large amount of carbon that Life needs. That appears when nucleosynthesis inside the first generation of stars transforms three helium nuclei into one of carbon as follows: $3^4He \rightarrow ^{12}C$. At first two helium nuclei collide producing the nucleus of ^8Be. But this nucleus is unstable and would decade in $\simeq 10^{-7} sec$ unless it captures a third helium nucleus in order to change into ^{12}C. But this chain at the reaction temperature of about $10^8 K$ would not produce enough carbon for Life unless the last reaction was resonant, that means there would exist a level of ^{12}C nucleus about equal to the intrinsic energy of the two nuclei $^8Be + ^4He$ plus the mean typical kinetic energy of collision at $10^8 K$, so that the reaction rate would increase strongly . The resonance level indeed exists and it corresponds to $7.6549MeV$ as Hoyle predicted since 1954. This resonance channel was soon verified by Fowler in the laboratory (e.g., Reeves, 1991, pg.61; Ortolan & Secco, 1996). This is also a good example of the prediction capability the WRAP indeed has owing to its nature of a real physical principle.

It should be noted that the next reaction of carbon burning by which oxygen is produced has also to be tuned but in the opposite way. Indeed the following reaction: $^{12}C +^4 He \rightarrow^{16} O + \gamma$ has not to be resonant. If it does, all the carbon would be transformed into oxygen. Luckily it does not even if there is a resonant level for the oxygen nucleus but at a little bit too low energy, $7.1187MeV$. So comparable quantities of carbon and oxygen are produced to make the CO molecule a common one. As consequence the formaldehyde H_2CO is the association of two of the most common molecules (H_2 and CO) in the universe so that:

$$(H_2CO)_n \rightarrow \; sugars\ and\ carbohydrates$$

are easily built up (Hoyle, 1991). In turn the carbon and oxygen energy nuclear levels are strictly depending on the values α and α_S properly have. If α would vary more than 4% or α_S more than 0.4% the carbon or oxygen production will change of a factor in the range $30 - 1000$ (Barrow, 2002).

3 Conclusions

From this brief glance at the cosmology we may conclude that the universe appears to be built up in an extraordinary way. It does not look like a chaotic muddle of things but as something of which intelligibility continues to excite in us as in Einstein [6] some time ago deep surprise. We feel as we were in front of a

[6] It was Einstein who asked the question, *Why is the world comprehensible?* He could say only: *The eternal mystery of the world is its comprehensibility* (see, Einstein, ed. 1978).

great cathedral about which science allows us to understand the constructive ingredients but nothing about its ultimate meaning. The question is: *"What is the key to trying to understand it?.* My answer is: Beauty. Cosmos structure is permeated by Beauty. But Beauty is an *indecipherable cipher* which does not enter into the scientific domain. Nevertheless, it is the key to reading the whole Reality (Dallaporta, 1997). According to all the great traditional Religions, it tell us something related to an inner tension to offer, to a gratuitous gift, which is a distinguishing feature of Love. Then the universe and Life inside the universe appear by this light to be a benevolent, completely free offer. The deepest secret inside the cosmos turns out then not to be Life but Life as Gift.

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