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Hypotheses in Cosmology

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On a first glance constructing hypotheses in cosmology works the same way as in terrestrial physics, physical cosmology being the science of the large scale structure of space–time, its matter content and its long term evolution. Let's throw a view on the Standard Hot Big Bang model from a methodological point of view.

The basic assumption of the customary approach includes the unity and uniqueness of the world, there is one well ordered world and cosmology contains the description of this order in it. The customary procedure is as follows. One differential equation, Einstein's law of gravitation, comprises a host of mathematical solutions, the majority of which has only a conceptual existence and enjoy the mathematician's interests for purely formal reasons.

Only a small subgroup of metrical structures, the so–called Friedman–Robertson–Walker–worlds, are considered to be worthwhile to represent the global structure of our physical space–time. The basic presupposition of relativistic cosmology, an insight already gained by Isaac Newton, was that gravity is the ruling force, that is responsible for the evolution and structure of the universe.

Obviously, for the time being, only the particular homogeneous and isotropic solutions of the differential equations of gravity could be regarded as offering an answer to the question how matter and radiation are organized and distributed at large scale.

Cosmological conjecturing however cannot be brought on the way in a purely empirical fashion – we cannot fathom the depths of space like cosmic explorers. Instead we have to anticipate some prior knowledge on the global structure of space–time, which might be validated subsequently. Since Hermann Bondi coined the term Copernican principle for the assumption that « the earth is not in a central specially favored position »[1], there have been many quarrels about the methodological status of this preliminary selection.

First of all, Einstein's theory of gravitation does not force this option, there are plenty of exact solutions of the field equations that do not comply with the Copernican principle. For instance, in 1990 José Senovilla, de la Universidad de Salamanca, found an inhomogeneous solution without singularities that might be a much

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1 [Bondi 1952].

more satisfactory description of the universe as a whole. It is an exact solution of the field equations with a perfect fluid source and a realistic equation of state [p =ρ/3]. The solution does not present any singularities either in the past or in the future. All the curvature invariants are regular over the whole space–time.[2]

On the other side there have been many attempts to test the global invariance of natural laws by indirect methods. The coincidence of redshifts deduced from 21 cm and resonance transitions in absorbing gas detected in front of four quasi stellar objects, results in stringent limits on the variation of the product of three physical constants both in space and time ($\alpha^2 g_p$ (m/M)) spatially uniform to an accuracy of parts in $1 : 10^4$ throughout the observable universe. [α=fine structure constant, g_p=gyro–magnetic ratio of the proton, m/M=the ratio of electron to proton masses.] A quantity as complex as g_p, which depends on strong interaction physics, uniform over most of space–time, even in causally disjoint region suggests that all physical laws are globally invariant.[3]

The Copernican Principle therefore counts as a preliminary hypothesis that does not defy any independent empirical testability. When this principle, however, is presupposed, expressing that there are no distinguished locations in the universe and that it is spherically symmetrical about any point, all asymptotically flat spaces like Schwarzschild or Reissner–Nordstrom–solutions are excluded because their spherical symmetry shows up only when observed from special locations.

As soon as we have decided to remain within the class of FLRW–type global solutions with constant spatial curvature and universal cosmic time parameter, establishing cosmological hypotheses follows the customary rules of methodology. The high symmetry of these space–times requires special idealization assumptions concerning the content of matter, what is usually called the *model object*. Within the terminology of Mario Bunge it is the conceptual object that constitutes a profile of its referent. Seen from a 'bird's eye view' we simplify the variety of galaxies as 'molecules'

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2 [Senovilla 1990], page 2219.

3 [Tubbs / Wolfe 1989], pages L105–L108.

of a gas. The internal structure of the element that represents cosmic matter is disregarded, in the same way as classical mechanics treats bulky planets as mass points, ignoring all properties with the only exception of inertial mass. The cosmic model–object only bares three independent characteristics : 4–velocity u^{α}, time dependent mass–energy density $\rho(t)$ and pressure $p(t)$. If necessary this brute simplification can be enlarged refining the model object with possible features of matter like shear, rotation or anisotropy–pressure. The already mentioned solution of Senovilla contains positive and negative shear in different directions. The simple fluid model–object representing cosmic matter, for the time being, is a fallible assumption and if it should be proved to be too simple it can be enriched with further detailed peculiarities. Up to now, except from Senovilla solution, it never proved necessary to transcend the condition of homogeneity. In any case it is a contingent feature of the special kind of universe we live in, that it allows such a simple description making life much more easy for cosmologists and corroborating an old philosophical intuition, namely the *uniformity of nature*.

It was a long way for science to establish the truth that mathematical hypotheses on the world as a whole are feasible at all. Remember for instance that as late as in the end of the sixteenth century Giordano Bruno refuted the idea of continuous and regular motions of celestial bodies.[4] Bruno conceived of the heavenly bodies as animated beings in free movement and he insisted on the impossibility on constructing a harmonious picture of the universe within which one might do precise calculations. Bruno made a distinction which sounds very fashionable. He distinguished between the universe and the worlds. Cosmological hypotheses are legitimate within the range of our sensible perception. But the infinite universe which contains an infinite plurality of worlds, has neither dimension nor measure, neither form nor figure, it is no system at all.[5] In contradistinction to Bruno's astrobiology the founding fathers of modern astronomy Copernicus, Kepler, and Galileo held the conviction that the universe is a unitary system and that the cosmic geometry can be found in principle. As everyone knows the defenders

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4 [Bruno 1955].

5 [Michel 1962].

of the geometric approach and the conception of the order of the universe won the dispute, but one should not leave out of consideration that those three Renaissance-astronomers were finitists, convinced that the universe is a finite system of stars with the sun at its center.

It was Bruno who defended fervently the revolutionary cosmographical thesis, as Arthur Lovejoy has called it, the « assertion of the actual infinity of the physical universe in space and the infinity of the number of solar systems contained therein ».[6]

Up to now infinity remained a stumble stone of cosmological reasoning, Kepler was terribly frightened in front of spatial infinity : « we feel lost in that immensity to which limits and the center are denied ».[7] In an attempt to refute the doctrine of Brunian thought Kepler invented the first known kind of Olbers' argument. An infinite homogeneous space filled with brilliant stars would produce a bright night sky with a luminosity equal to the surface of the sun.[8]

Although cosmology was thought to be treated on the same methodological foot as terrestrial physics, even in classical time infinity showed up its conceptual ambiguity, when Newton discussed with Reverend Bentley the stability of a static universe of unlimited extension.

> « And much harder it is to suppose all the particles in an infinite space should be so accurately poised one among another as to stand still in a perfect equilibrium. For I reckon this as hard as to make not one needle only but an infinite number of them ... stand accurately poised upon their points. »[9]

Newton pondered that cosmological stability of an infinite system of stars attracting themselves by gravity could only be guaranteed by divine power. In the years to come the confidence in supernatural forces dwindled more and more and the problem of infinity remained unsolved until the advent of general relativity. Even

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6 [Lovejoy 1957], page 108.

7 [Kepler 1859], page 688.

8 [Kepler 1938–1959], pages 281–311.

9 [Newton 1961], page 238.

within the paragon of relativistic cosmology infinity shows up paradoxical traits, as the argument of Ellis and Brundrit to be delt with later on exhibits quite clearly. Above that, hypothetical reasoning within the realm of relativistic cosmology shows the well known feature of every day physics. Matter is represented by idealized models of a perfect fluid disregarding all local irregularities hidden in the complexities of galactic matter. Complexity is of no typical cosmological concern.

That cosmological hypotheses comply in many regards with customary methodology can be verified by the capacity to deliver novel predictive success, the most valuable kind of corroboration, we know of. The hot fireball stage of the early universe, some finite time interval ago, was indeed a *prediction* of general relativity, not made by Einstein himself but by the Russian mathematician Alexander Friedman, who discovered the class of non–stationary solutions. Einstein at that time favored a static universe and tried to suppress expansion by introducing the cosmological term into his field equations. In 1930, however, Eddington proved that the only really static solution of Einstein's field equations, the cylinder model of 1917, is unstable like Newton's universe, because the universal attractive nature of gravity is inconsistent with a static infinite universe. As Stephen Hawking claimed : « Newton could have predicted the expansion of the universe ».[10] In the same way it could be argued that Einstein could have predicted the non stationary character of space–time. Only after Eddington's discovery it turned out that dynamic change is the necessary property of relativistic space–time. The universe has to be expanding or contracting. At that time, however, Hubble's discovery of the cosmological redshift had changed the minds of astronomers and astrophysicists towards the non–static models, although the hypothesis of cosmic evolution had its break–through not until 1958, when Martin Ryle could show on account of his radio measurements, that there were too many faint sources standing at large distances compared with the brighter and closer ones.[11]

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[10] [Hawking 1987b], page 3.

[11] [Ryle / Clarke 1958], page 289.

It is seldom remarked that even the second great corroboration of the hot Big Bang–model was originally foreseen and can therefore be counted as novel predictive success.

Ralph Alpher and Robert Herman inferred in their analysis of the origin and distribution of elements, that the primordial fireball should have left a remnant, a radiation observable even at the present. In 1948 they calculated what temperature conditions would be necessary to yield the currently observed distribution of elements. They concluded that a faint glow measuring only 50 Centigrade about absolute zero should be found everywhere throughout the universe.[12]

Penzias and Wilson stumbled upon this isotropic radiation just by chance and not led by the theoretical predictions of Alpher and Herman, but other astrophysicists like Jim Peebles and Robert Dicke could easily trace back this feeble radiation without localizable source to a cosmological origin.

Even the third cornerstone of our Big Bang–model, the particular abundances of hydrogen deuterium and helium, has been anticipated by George Gamow in 1946[13], thereby verifying the ancient metaphysical speculations on deep intrinsic connections of microcosm with macrocosm. If the cosmic microwave background can be regarded as a direct evidence of the stage of development of the universe when it was only 300.000 years old, then the universal abundance of helium to the amount of 25% is an indirect evidence of the history up to the first second. An immediate witness of the cosmological origin of helium would be the discovery of the Neutrino background, the temperature of which has been estimated up to 1,9 K.

Ultimately the long awaited fulfillment of a prediction came to the fore. George Smoot and his coworkers could identify by means of the COBE satellite of the NASA the wrinkles in the cosmic background necessary as primordial germs of galaxy formation.[14] Whereas the first COBE results reported in January 1990 could not detect any irregularities in the temperature larger than one part in

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[12] [Ralph / Robert 1948], pages 774–775.

[13] [Gamow 1946, pages 572–573.

[14] [Smoot et al. 1992], pages L1–L6. [Cohen 1992], page 420.

10000, the measurements announced in April 25, 1992, were between ten and a hundred times more precise than the measurements from 1990. These newly refined COBE measurements showed irregularities in the background radiation as large as about one part in 100.000, just what astrophysicists thought they would find. In the meantime the measurements of COBE's Differential Microwave Radiometer (DMR) have been cross-checked several times, giving strong suggestions that the temperature fluctuations in the cosmic background radiation must be the traces of the forerunners of today's universe clusters of galaxies in our universe.

As far as well. Up to this point cosmological hypothesis show up the customary feature with that tricky interplay between theory and experience meticulously investigated by philosophers of science.

But following the Big Bang–model backwards in time and leaving out for the moment such subtleties as the inflationary scenario, we reach epistemologically shaky ground. The model leads head on to a space–time singularity, that means we encounter in the finite proper time of a cosmic observer infinite density of energy and temperature, pressure, and gravitational tidal forces. The singularity acts as an absolute zero of time and space with infinite curvature establishing a boundary beyond which no physical entity can exist. Within customary physical semantics it is usual to regard any prediction that a physical parameter goes to infinity as not representing any state of affairs of reality, therefore most physicists think of the geodesic incompleteness as a failure or break down of the model, the main reason being that an infinite value of a parameter cannot be put to test in a laboratory.

But besides the lack of testability, there is another perspective from which we may look at the singularity. Roger Penrose has pointed out, that taking singularities more seriously, in philosophical terms more in an ontological vein, could pave the way for solving a bundle of physical and conceptual problems.[15]

Penrose proposed the hypothesis concerning the past singularity that the Weyl curvature vanishes there and showed that thereby the origin of the second law of thermodynamics can be explained. As far as we can observe, the Big Bang singularity was a

[15] [Penrose 1987], page 17.

very special one. This specialty can be accounted for, if we demand that the Weyl curvature is zero at any past singularity what means that the gravitational degrees of freedom have not mixed up with the matter.

Gravitational clumping is then a consequence of growing Weyl curvature. Penrose's hypothesis which is thought to be incorporated in a theory of quantum gravity later on allows to deduce the thermodynamic behavior of our world according to the second law, thereby providing an explanation of the arrow of time. Above that Penrose cherishes founded hopes that the idea of taking the singularity seriously will give an answer to the most startling riddle of the interpretation of quantum mechanics, the reduction of the state vector. This recalcitrant puzzle of the collapse of the wave function involves a time asymmetric transition, that may be covered quite well by such a geometry–induced entropy increasing process.

If Penrose is right, a cosmological hypothesis pertaining to the initial singularity covers two conceptual mysteries of natural philosophy with one stroke, the enigma of the origin of time and the riddle of the collapse of the wave function.

Around the initial singularity and the existence of an absolute zero of time a host of metaphysical and theological conjectures entwined because it is believed by certain authors that the singularity is the event that marks the boundary between the natural and the supernatural part of reality.

Some theologians like William Lane Craig have argued that the singularity of the standard Big Bang model can be interpreted pretty well as lending « tangible support to the theistic doctrine of *creatio ex nihilo* ».[16] On the contrary, this philosophers of science like Adolf Grünbaum emphasized the unfeasibility of this interpretation, because that model of Riemannian geometry, though featuring a finite age of the cosmic time, is devoid of a first instant and is thus temporally unbounded in the past.

The psychological root of the creationist interpretation of the initial singularity might be seen in the seductive inference from the metaphor of the Big Bang, which smacks like a first event although

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[16] [Craig 1994], pages 217–224.

being the lowest upper bound of the time axis. In this respect the cosmological Big Bang hypothesis is of course counterintuitive and far away of our common sense experiences. We are accustomed to set our experience in a frame in which there is an infinite causal past of every event.

Today there are alternatives to the Big Bang–hypothesis even within then realm of general relativity – taking the cosmological constant $\lambda \neq 0$, there is ample space for a model that lacks a singularity and is in accord with Lucretius,' genetic principle : *Nullam rem ex nihilo gigni divinitus umquam.*[17]

Lucretius does not demand this principle as a purely dogmatic knowledge claim, but exposes a sufficient reason : *Nam si de nihilo fierent, ex omnibus rebus omne genus nasci posset, nil semine egeret.* In other words, absolute emergence of matter from nought is a case of methodological corruption, a slippery slope ; breaking the lawfulness of reality opens the door for more violations and in the last resort an arbitrary object could pop out of nothingness, without the need of earlier states of any real system.

Therefore : *principiis obsta.*

Here we encounter the genuine motivation for modern astrophysicists to engender novel cosmological hypotheses that are in accord with Lucretius,' principle.

One main reason for Einstein to renounce with the cosmological term was simplicity [*logische Ökonomie*], but even Steven Weinberg remarked recently that economy and parsimony may easily lead us astray. If not forbidden by any fundamental principle of symmetry it is a rule that every complication of a theory that *can* occur *will* occur. Therefore it *is* a cosmological hypothesis that $\lambda = 0$ and in consequence we need a vindication why it takes that special value.

At any rate λ is a genuine part of the field equations and there is no a–priori knowledge of that fundamental constant vanishing.

One of the open questions of the cosmological term is the semantical interpretation of λ. If it is part of the geometry of space–

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[17] [Lukretius 1981], I.150.

time [left side of field equation] it plays the role of a curvature, if part of the matter content it may be counted as a density ρ with a corresponding [negative] pressure [$p = -\rho c^2$]. Within the realm of quantum field theory λ takes over the semantics of an energy–density of the vacuum

$$[\ \varepsilon_V = \rho_V c^2].$$

It is capturing to note that in 1920 in a lecture on the « New Ether of Relativity » Einstein anticipated that entity as a substance that does not bare any mechanical or kinematical properties but codetermines physical events in an essential way.[18]

If λ is regarded as a new fundamental constant of nature like c, or G, and we base our cosmological considerations on the complete field equations, the space of solutions widens enormously. Models with $\lambda > 0$ and a spherical metric are expanding all the time, they exhibit a turning point of weakening expansion which allows to count with a higher age of the universe as hitherto conceded. Here we encounter an advantage in case that time for galaxy formation should prove to be too short within the standard model with $\lambda = 0$. If $\lambda \neq 0$ is included as a valuable hypothesis, this has to be consistent with the remaining astronomical knowledge. Current estimations allow to conclude that λ is very small, in the order of 10^{-56}cm^{-2}. That value will not influence local celestial phenomena although it may solve cosmological conundrums. Empirical methods to measure the value of a positive λ are the gravitational lens effect and the so–called Lyα–forest in connection with the matter distribution of voids, walls, and strings. Meticulous evaluations of the Lyα–forest by Wolfgang Priester and his coworkers of the Bonn-group revealed a value of $\lambda = 3{,}77\ h_0 2\ 10^{-52}\text{m}^{-2}$ ($h_0 = H_0/(100\ \text{km/(s·Mpc)})$).

The Bonn–group therefore favors strongly a Big Bounce model instead of a Big Bang–model, that is to say a universe that is infinitely old in regard to its space–time but not with respect to its matter content. Matter will be generated in a phase transition from quantum vacuum by an intense interaction of the extremely rapidly varying space–time curvature with that vacuum, although the universe never

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18 [Einstein 1920].

reaches the terrible density of the Planck domain. The model always remains 17 orders of magnitudes below the Planck density and therefore it stays all the time within the domain of the applicability of relativity and quantum field theory.

I mentioned the Big Bounce model in order to indicate that there is real heuristic power in the old genetic principle of Lucretius and working within its realm might engender more successful hypotheses than without it.

However, neither the finite Big Bang model with a time interval of inflation, nor the infinite Big Bounce model with phase transition triggered by the bounce, answers all the desired questions that can be asked meaningfully by an intelligent inhabitant of that universe. Already Georges Lemaître closed his famous paper of 1927 with the words « Il restait à se rendre compte de la cause de l'expansion de l'univers »[19] and up to now the situation has not changed principally.

From a philosophical point of view it is highly fascinating to judge whether those urgent questions can be answered at all on logical reasons. Since early times it has been the task of physical cosmology to reduce the contingent traits of phenomena to nomological structures. Our attempts of mapping accidental features of physical reality on a conceptual model customarily yield two issues : an ensemble of local laws represented differential equations and a set of initial and boundary conditions characterizing the state of the system at a certain time. Many philosophers of science claimed that science is bound to inquire into local laws only, whereas scientists themselves including Einstein have fervently pursued the ambitious aim of a complete knowledge of nature. Recently Stephen Hawking underlined, that cosmological hypotheses need not exclude the accidental traits of our universe. « I think that the initial conditions of the Universe are as suitable a subject for scientific study and theory as are the local physical laws ». We shall not have a complete theory until we can do no more than merely say « Things are as they are because the were as they were ».[20]

In a certain sense his own cosmological hypothesis elaborated with James Hartle may be regarded as a conceptual structure that

19 [Lemaître 1927], page 59.

20 [Hawking 1980], page 3.

fulfills the demand. That is, it defies any question on the origin of the boundary conditions and the coming into existence of the universe. Within that eternal Parmenidean world without temporal structure it is simply meaningless to ask, how the universe emerged and how it will come to an end, « one should just say : THE UNIVERSE IS ».[21] At the moment nobody knows whether the speculative hypothesis of imaginary time and the no boundary conditions lead to testable consequences that can be confronted with astrophysical observations. However, the model is instructive for those sceptical philosophers who understand their profession only in providing doubts on far reaching discoveries of science.

We meet another type of completeness casting a glance on superstring approach which today is the favorite candidate for a unitary theory of all particle interactions. Incompleteness pertains to the host of adjustable parameters, as particle masses and coupling constants, fixing the strength of the different forces. The progress in our understanding the accidentals of the universe that provides superstring can be demonstrated by the fact that it contains a natural place for gravity. In the conceptual scheme of superstring a consistent singularity free theory of gravity is necessarily involved, as Steven Weinberg recently remarked.[22] Reduction of contingent elements can be exemplified in considering the role of gravity within the pattern of nature : Newton's inverse square law was forced by observation, but at his time nobody could give sufficient reasons why gravity should diminish with r^{-2} rather than within any other exponent. Only when Newton's law turned out to be a limiting case for weak gravitational fields, in Einstein's theory of gravitation an explanation came to the fore, *why* gravity is ruled by an inverse square law. But even the stronger Einsteinian theory describing gravity as the space–time curvature, provides no reason, *why* matter should curve space–time at all. Only within the ultimate step towards superstring unification we got for the first time an answer to the question *why* gravity is by logical necessity a part of nature.

Although in recent times many unified theories with breathtaking conceptual novelties are exposed to competition on the

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21 [Hawking 1987a] 651.

22 [Weinberg 1987], page 15.

common market of ideas, there remained considerable doubt concerning the possible explanation of a bundle of accidental features of our universe that have been named *fine tuning*.

Our universe looks as if it were especially fine tuned for life to occur within it. Setting aside for a moment possible explanative hypotheses, the fact of fine tuning simply cannot be denied. The term is not to be misused in the sense, that there must be a divine Fine Tuner [*ordenador cósmico*] or any other abstract teleological principle which commands that the universe should have these life-sustaining properties. The talk of fine tuning only means that small changes in the universe's basic features would have made origin, evolution and maintenance of life impossible. John Barrow and Frank Tipler showed up in their monumental work the overwhelming variety of necessary conditions to be met by the universe in order to produce intelligent observers. Only to mention the smoothness of the region that came out of the Big Bang, the flatness of expansion, the exact value of inflation, the near cancellation of the cosmological constant, the exact values of the coupling constant of the four interactions, the ratio of the particle masses, the slight excess of matter over antimatter ($1 : 3 \times 10^9$), all these particularities constitute weighty evidence for a fine tuning that neither can be denied nor explained by first physical principles, at most at the moment.

Facing the uncontroversial fact of fine tuning three main cosmological hypotheses have been invoked in order to tackle with this piece of recalcitrant data. The most ancient conjecture is that of a Purposive Designer, who deliberately adopted the boundary and initial conditions in order to create organic life forms. This type of teleological hypothesis, which goes back to Cicero[23], has been heavily attacked by David Hume[24], who pointed out the inconclusive character of the design analogy. Furthermore, the analogy does not provide an argument for a divine Creator, but at most points to a kind of supernatural architect. Above that, a terrestrial constructor needs preexisting material to build a house, he does not create anything from naught. And what is more, we cannot prove that only

23 [Cicero 1961].

24 [Hume 1947].

one architect did the whole designing, we may as well claim e.g. a gang of four transcendent beings each of which is responsible for one interaction. Recently J. J. C. Smart criticized the hypothesis of the cosmic engineer pointing out that « if God planned the universe, then there must be as much complexity in the plan as in the universe itself, and as much complexity in God's ability to *make* the plan ».[25] Therefore the hypothesis of a cosmic watchmaker to apply William Paley's famous example only postpones the desired explanation. It is, as Antony Flew uses to say, like ordering a taxi and leaving it when not further needed. So there is no explanatory power in the theistic teleological hypothesis, although it seems to contain some attracting force even to outstanding scientists. Recently Paul Davies revived that sort of thinking, comparing the whole network of physical laws to a set of rules of a game of chess. In a paper he published in *Conocer* with the seductive title « Como funciona la mente de dio » he drew a comparison between the fine tuned laws of the universe and a cosmic game of chess [*ajedrez cósmico*]. If the rules of chess were totally arbitrary, we would get a boring chaotic game. In reality the rules have been fixed *in order* to provide a complex and interesting structure. According to Davies our universe possesses a perfectly designed system of laws in which that multifarious variety of complex systems is really possible. But Davies' analogy of the cosmic game of chess is only one more example of the old fallacy of William Paley's watchmaker. From a logical point of view the argument is inconclusive as it deduces that nature needs a designer in the same way as a watch that has been found crossing a heath needs the watchmaker. Of course, explaining higher complexity is a greater challenge to scientific ingenuity and it might be that the fine tuning will resist to our curiosity for a long time to come, but nevertheless this does not justify the applications of unsound types of argumentation.

On of the most speculative conjectures has been brought forward by John Leslie, he calls it *extreme axiarchism* (ἀξία = value). In this approach God is identified with an abstract principle, he is no longer a personal entity as in Christian theism. Leslie goes back to the neoplatonic tradition in claiming that value tends to come into existence. According to Leslie the axiarchic principle is *creative*,

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[25] [Smart 1989], page 167.

values having an intrinsic tendency to realize themselves. When we say something ought to be the case, we feel asserting that a certain state of affairs should occur.

Although Leslie's approach can be counted as a step toward a more naturalistic explanation of the accidental features of our universe, its platonic ontology of values contradicts every scientific result from neurology. From this source we know quite well that values are produced by the emotive centers of the limbic system of our brain, therefore values are states of a complex system of neurons hooked up in a complicated way. Values are not free floating entities like sharks in the ocean and cannot be thought as causally active agents over and above their existence within neural networks.

Some philosophers might be tempted to argue that fine tuning is not really in need for explanation. The parameter values and the constants of nature must have some values or other, why not the life sustaining ones that we are so fortunate to observe? For those who doubt that fine tuning of life really does stand in special need of explanation by any hypothesis whatever, John Leslie invented a charming story, in order to point out that even in every day life we seek explanation if rare mysterious events occur.

> « An old arch collapses exactly when you pass through. You congratulate yourself on a narrow escape from purely accidental death – until you notice your rival in love tiptoeing from the scene. »[26]

Surely, it may be solely a coincidence, but only after having fathomed the case sufficiently, you will come to the conclusion that your rival did not have a finger in the affair and did intervene in the stability of the arch.

As far as I know, no philosopher has really defended that the fact of fine tuning is something not to take care of. Besides the two metaphysical hypotheses already mentioned, we encounter two scientific conjectures the rivalry of which has not been decided.

Steven Weinberg strongly defends that all the coincidences and casual boundary conditions should be computed from first principles, and in the long run, when a strong theory of quantum gravity will be

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26 [Leslie 1989], page 10.

available, these contingencies will be deduced from the laws of physics. But at the moment this is nothing but a promissory hypothesis. Therefore cosmologists have reanimated a hypothesis from the metaphysical limbo of conjectures, namely the hypothesis of the plurality of worlds.

In the history of philosophy it was primarily Giordano Bruno who defended fervently the many worlds hypothesis, arguing mainly from the principle of plenitude. Bruno claimed that it corresponds to the dignity and the infinite power of God to create all possible entities. It is like claiming that everything that can occur within the reach of his allmightyness will occur. Bruno however upheld a clear distinction between the universe and the worlds. A set of worlds is not in itself a system, an ordered ensemble that baring a structure that can be explored by science.

Already in Renaissance time Bruno's metaphysical thesis was a bold conjecture refused by the majority of working astronomers. Copernicus, Kepler and Galileo, beyond the differences of their world view, upheld the uniqueness and the unity of the universe as a system that is held together by geometric structure as an expression of divine order. There is a striking similarity in the argumentation of today's protagonists of many worlds hypotheses. Obviously the unfathomable will of God does not matter any longer, but the principle of plenitude shows up in a new clothing. One of the hardest defenders of a hypothesis of plurality is Dennis William Sciama, who argues « that all logically possible universes exist in an ensemble of disjoint universes. An intelligent observer would automatically find himself in an universe, whose properties are compatible with his own development ».[27]

The main reason for this hypothesis, extremely prodigious at a first glimpse, is that it diminishes without doubt our astonishment on the fine tuned properties. Although the ensemble hypothesis is not a causal explanation, it is no longer surprising that one world has the fortunate qualities to engender life within the span of its development. Sciama's reasoning is typically Brunian. In order to escape critiques from ontological parsimony he turns Ockham's Razor upside down.

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[27] [Sciama 1993], page 107.

> « On the conventional view of a unique universe we have to assume that it was *decided* that all but one of the logically possible universes should not exist. ... My own view is that we should invoke a few constraints on reality as is compatible with observation. »[28]

That is to say, Sciama advocates to take Ockham's Razor as the principle of parsimony concerning restrictions of ontology. The paragon of such an argumentation can be found in elementary particle physics, where we expect, that any reaction as e.g. processes of decay will occur if not suppressed by any symmetry principle or conservation law, that is to say, here we believe that everything, which is not forbidden, is compulsory.

The first counterargument to such a hypothesis of ontological prodigality is that the other universes cannot be known *directly*. Nevertheless today methodology has been liberated from the early restrictions of the verification theory of meaning. At present time, we are quite content with a weaker kind of testability. For corroboration it is sufficient to provide good reasons for suspecting the existence of a chunk of physical reality. We never will be aware of a neutrino or graviton by perceiving a flash of light on our retina. The customary procedure in claiming the presence of an invisible system, be it in astrophysics or in the domain of elementary particle physics, can only be the following type : To believe in the existence of an entity, e.g. a black hole in Cygnus X–1, is the best available hypothesis among the set of competing conjectures. From a methodological point of view I cannot see any difficulty in adopting the existence of more than one world, if this conjecture is really the best one available in the concurrence of hypotheses.

There are however intriguing problems concerning the very concept of an « other world » itself. It is now usual as did Giordano Bruno to distinguish between that entity which comprises everything that exists, the capital U–Universe, on the one hand and the small u–universe or worlds on the other. However, it is everything but an easy task to discern what counts as another world. What are the criteria of demarcation in discerning that object of concern?

One might think that *absence of causal contact* would suffice, but as it is well known, there are within the realm of standard FRW–

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[28] [Sciama 1993].

models those of infinite extension even in their initial moment, e.g. Einstein–de Sitter–spacetime [$R \sim t^{2/3}$]. On account of the horizon structure of these spacetimes each of the infinite models do really cover an unlimited number of local regions without causal contact. A particle horizon sets the limits to what distance light could have traversed since the initial singularity.

Unless obtruding an unusual exotic global connection topology a world within a non–compact space–time contains infinite many galaxies, the majority of which never will have causal contact.

G.F.R. Ellis and G. B. Brundrit could prove that solely under the assumption that there are finite possible life forms and that there exists not vanishing probability that life will occur at all every simple and complex system including that big animals like man have infinitely many twins.[29]

So if lack of causal connection were a necessary and sufficient criterion of another world, already the standard model would comprise spatio–temporal regions that count as « worlds » different from ours.

There is another way of producing different worlds by varying the character of the physical laws, governing those worlds. This is clearly the sense Sciama has in mind, when he claims that « all logically possible universes exist in an ensemble of disjoint universes ». Examples of other worlds in this sense are not ruled by quantum mechanics or relativity theory or thermodynamics, but by some nonlinear quantum law, by a gravitational theory with time varying gravitational constant or by a second law of thermodynamics in which entropy steadily goes down.

Each of these different worlds would be ruled by its own fundamental set of laws or by its unitary theory and certainly it would be worthwhile to look for them, if these laws are compatible with the existence of intelligent life. This way of world making could only be excluded, if one day a theoretician would establish a proof that only one type of universe were possible, a conjecture ushered by Geoffrey Chew and recently reanimated by Steven Weinberg.

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29 [Brundrit / Ellis], pages 37–41.

There might be a third manner in which a meaningful talk of a plurality of worlds might be established, namely if there is a sequence of cosmic cycles, many oscillations of expansion and contraction in which matter is squeezed by some quantum reprocessing. Although there is a type of causal chain in the whole sequence of worlds, they would be disconnected on account of the anniquilation of information from the earlier states of the chain. In a sense, the earlier mentioned model of Big Bounce can be regarded as an example of a series of cosmic states simply to be named « worlds ».

Currently, the most popular way of talking of many worlds emerged within the inflationary scenario. Andrej Linde has given plausible reasons that the fundamental physical entity is a chaotic active quantum vacuum, existing from eternity to eternity, worlds being small self–reinforcing fluctuation processes within the embedding quantum domain. In this perspective the void is the primary ontological substance, material worlds are secondary but nevertheless permanent occurrences in the logical space of possibilities. The inflationary universe, as Linde puts it, « is the only lunch at which all possible dishes are available ». In any case there are several different ways of establishing an ensemble of many worlds, the conceptual content in the method of counting strongly depending on the pertinent theory. My impression is that many worlds cosmology is on shaky ground. Facing this ambiguity in the procedure of world making, it is to be hoped that one day cosmological hypotheses will lead back to a comprehensive theory of the largest physical system, in which only one world is needed, and our knowledge of it could be accounted for within this unique domain of reality. But in that case, as argue the defenders of the many world idea, we might have to renounce with an explanation of the fine tuned anthropic condition, because nobody could give the very reason why the unique possible world is precisely the fine tuned one. Maybe this will be the ultimate enigma of cosmology, but nevertheless even if this may be the case, we will never know it, our hopes being based on the most fundamental of all philosophical hypotheses that riddles do not exist.

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