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GENESIS OF A PYTHAGOREAN UNIVERSE

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Abstract

A purely scientific approach to the problem of cosmogenesis ultimately requires derivation of the visible order from the totality of chaos, thus turning into the problem of *chaosogenesis*. The hypothesis of chaosogenesis is discussed and refuted on the scientific grounds of mathematical elegance, wide range, and high precision of fundamental laws of nature. Thus, the problem of cosmogenesis is proven to be unsolvable within the bounds of science. Scientific confirmation for the Platonic world of elegant mathematical forms structuring the physical world is stressed, and some consequences are pointed out. A two-way relation between Pythagoreanism and fundamental science is discussed.

The Fine Tuning Question

"There is now broad agreement among physicists and cosmologists", writes Paul Davis [1], "that the universe is in several respects 'fine-tuned' for life". Similarly, Stephen Hawking has noted:

> The laws of science, as we know them at present, contain many fundamental numbers, like the size of the electric charge of the electron [*fine structure constant*] and the ratio of the masses of the proton and the electron. ... The remarkable fact is that the values of these numbers seem to have been very finely adjusted to make possible the development of life.[2].

Another crucial point is articulated by Alexei Tsvelik [3]. As he points out, since

> the number of existing life-imposing conditions by far exceeds the number of constants, their fulfillment could not be achieved by fine tuning of these constants and required also the right choice of the fundamental principles of physical laws such as general covariance, gauge invariance etc.

The premise of the fine-tuned universe revived the old metaphysical problem of the source of order in the world as the problem of fine-tuning: who or what tuned the universe so fine? A pure scientific approach required finding an objective answer: not "somebody" but "something" as the cause of tuning.

Order From Chaos

It is thought that this "something" could be any combination of laws of nature provided by one or another general theory and chaotic factors; or, using the terms of platonic philosophy: any combination of forms and chaos. However, any theory used in that respect immediately leads to the question: why is this very theory structuring everything existent? Why doesn't some other theory instead? In other words, the use of any theory for this does not solve the problem of fine-tuning, but moves it to a higher level. The only way to solve this problem totally in the framework of science is to show a possibility of appearance of being from nothing, or *chaosogenesis*, the appearance of order from chaos. Indeed, theories, being specific forms, are limited entities, thus raising the question "why this theory and not other?". Chaos per se is limitless, a totality intrinsically undivided into "this" and "that", whose various manifestations differ from each other due only to the variety of doors that one or another theory opens for chaos to enter. Historically, the idea of chaosogenesis is very old, having been traced down to Hesiod and pre-Socratics, and it had been opposed by Pythagoreans and Platonics. For instance, Plotinus wrote: "Any attempt to derive order, reason,

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or the directing soul from the unordered motion of atoms or elements is absurd and impossible."[4] Not all of recent cosmologists share Plotinus' views on the chaosogenesis, so the idea is frequently pronounced. For instance, Max Tegmark has formulated the "Ultimate ensemble theory of everything", whose main motivation is clearly expressed [5]:

> If the TOE [*theory of everything*] exists and is one day discovered, then an embarrassing question remains, as emphasized by John Archibald Wheeler: Why these particular equations, not others? Could there really be a fundamental, unexplained ontological asymmetry built into the very heart of reality, splitting mathematical structures into two classes, those with and without physical existence? After all, a mathematical structure is not "created" and doesn't exist "somewhere". It just exists. As a way out of this philosophical conundrum, I have suggested that complete mathematical democracy holds: that mathematical existence and physical existence are equivalent, so that all mathematical structures have the same ontological status.

It has to be noted, that purely by itself, without any forms involved, chaos cannot produce anything. Tegmark's model is not an exclusion from this rule: it assumes that all possible worlds are based on mathematical structures, such as groups, algebras, fields and other formal systems. It also assumes that there is a way for these structures to show themselves as phenomena, and to be observed both as mathematical and physical objects. Chaos comes in his model as a totality of all mathematical structures, thus having the same ontological status. What makes Tegmark's model very special, is its minimal involvement of forms, which is why we are equating his model of "mathematical democracy" with chaosogenesis. A possibility for the structure of the fundamental laws of nature to be accidental was expressed by several leading scientists, e. g. by Andrei Linde (see a citation below) and Steven Weinberg [6]:

> …we have to keep in mind the possibility that what we now call the laws of nature and the constants of nature are accidental features of the big bang in which we happen to find ourselves, though constrained (as is the distance of the Earth from the Sun) by the requirement that they have to be in a range that allows the appearance of beings that can ask why they are what they are.

The Darwinian theory of evolution is widely believed to explain the birth of order from chaos. To follow its line of thought, the universe is considered a member of a huge or infinite ensemble of universes, one generated by the other, with daughter universes mostly inheriting the logical structure of the mother ones, adding some mutations on top of it [7,8]. After the heredity and variation of the multiplying logical structures is settled, the third Darwinian principle, selection, can be introduced as well. This role is played by the so called weak anthropic principle, or WAP [9], pointing out that only those universes can be observed where observers can appear, which selects a narrow class of fine-tuned universes as it is noted in Weinberg's quotation above. Thus, though our universe is thought of in this Darwinian approach as ultimately generated by chaos, its fine tuning apparently receives a scientific explanation as a result of a Darwinian chaosogenesis. Although in the infinite megaverse, only a tiny portion of universes is fine-tuned for life and consciousness, the probability for any observer to see the universe as fine-tuned is one hundred percent. Nothing seemingly contradicts the assumption that our universe is a random representative of WAP-selected subset of Tegmark's multiverse, but is that really so? Does the universe indeed have no clear signature undoubtedly excluding any possibility of its genesis from this chaotic totality of all possible mathematical structures? Is the concept of chaosogenesis refutable by any thinkable observation, i. e. is it a scientific hypothesis? Apparently, it is not considered as such by some leading experts. For instance, Brian Green clearly says that [10]:

> I draw the line at ideas that have no possibility of being confronted meaningfully by experiment or observation, not because of human frailty or technological hurdles, but because of the proposals' inherent nature. Of

> the multiverses we've considered, only the full-blown version of the Ultimate Multiverse falls into this netherland. If absolutely every possible universe is included, then no matter what we measure or observe, the Ultimate Multiverse [*i.e. Tegmark's one*] will nod and embrace our result.

Contrary to B. Green, we are showing below that Tegmark's hypothesis is not only able to disagree with, but actually runs counter to certain observations, so it fails, and fails as a scientific theory.

A Cosmic Observer

"Observers" in WAP are not normally specified; it is not taken into account what it is namely they do observe. We suppose that to be qualified as "observers" they at least have to be conscious, as it is also reasonable to assume that conscious creatures observe their immediate space of life support and have access to at least empirical knowledge about it. However, this sort of knowledge has nothing to do with theoretical knowledge of big cosmos; the first by no means entails the second. Let us fix this point of an important distinction, a distinction between those *simple, minimal, empirical observers* and *cosmic observers*, who are discovering theories of big cosmos, seeing their universe both at extremely large and extremely small scales, far exceeding the scale of immediate life support. To become cosmic observers, minimal ones must live in a very specific world among the populated worlds. Namely, their universe has to be theoretically comprehensible on a big cosmic scale; the world has to be *theoretizable*, so to say. In other words, the possibility for observers to be not simple but cosmic requires that their universe must have a very special logical structure: it has to be described by elegant laws covering many orders of magnitude of their parameters. Contemporary humanity is indeed a cosmic observer: for today, our scale of scientific cognition is described by an enormous dimensionless parameter $\sim 10^{45}$: that big is the ratio of the sizes of largest object of physics, the universe, $\sim 10^{26}$m, to the smallest ones, the top quark and the Higgs boson, corresponding to $\sim 10^{-19}$m.

The Condition of Elegance

This condition of *theoretizability* apparently is extraneous to the selective anthropic principle, that is, theoretizability seems unnecessary for the universes to be populated by conscious creatures or to be observed. Indeed, the latter condition is essentially local; it requires something like a life-friendly planet inside a huge universe. The former condition, though, is global; it requires the laws of nature to be elegant at a big cosmic scale, a scale by far exceeding that of the life on the planet. Generally, local conditions do not entail global consequences, and since theoretizability is a specific functional requirement detached from WAP selection, we have to conclude that it is highly unlikely for an observed universe to be theoretizable. Since we know, after Isaac Newton, that our universe is theoretizable, chaosogenesis theory is apparently refuted by that. However, this refutation leaves a possibility to object. Its core statement, that theoretizability is a specific requirement *detached* from the anthropic condition for universes "to be observed" can be questioned. How can we be sure that theoretizability is logically independent from WAP? It would not be independent, if WAP did not allow for our theoretizable laws of nature any visible modifications even at extremes of very large and very small scales, modifications that might exclude the appearance of conscious beings for one or another reason. The very concept of a fine-tuned universe is suggesting to us that sort of an idea concerning the fundamental constants, and so, we may ask: what if the same is true concerning the very structure of the laws of nature? Although it is hard to believe that moderate modification of, say, General Relativity at the distances exceeding the solar system, can dramatically reduce the possibility of consciousness on our planet, there may be a chance that it cannot be excluded. This very argument for the strong relation between the weak anthropic principle and theoretizability was recently suggested by A. Linde [11]:

> ... the inflationary multiverse consists of myriads of 'universes' with all possible laws of physics and mathematics operating in each of

them. We can only live in those universes where the laws of physics allow our existence, which requires making reliable predictions.

Let's accept this arguable hypothesis to its maximal extent, and suppose, contrary to our previous assumption, that somehow WAP does not allow significant deviations of the laws of nature locally compatible with conscious beings from the globally theoretizable form. Then, the question is: which deviations from the existing laws are allowed by the anthropic principle? If the world is generated by pure chaos, all imaginable additional terms to the life-selected ones are coming into play; the amplitude or width of the resulted deviation is limited by the anthropic principle, but functional behavior of the deviation is arbitrary. We have some estimations about the allowed deviation in the context of fine-tuning as relative variations of the fundamental constants compatible with WAP, and the most stringent of them are at the order of 0.1%. Since we are considering here the problem of functional accuracy, the enormously stringent requirements on some constants, like the initial conditions at the big bang [12], do not reduce the amplitude of these functional variations. Thus, working on the Linde argument, we may roughly estimate the sensitivity of the anthropic selection to the relative functional variations of the fundamental laws to not be finer than 0.1% [9] or so. Were the laws of nature be generated by a random choice from Tegmark's multiverse, , they would be expressed by irregular functions possibly following elegant ones within a relative width of ~0.1% or more. In this respect, it does not matter whether chaos reveals itself through arbitrary functions or arbitrary mathematical structures; with Tegmark's "mathematical democracy" functional representatives of the two families are indistinguishable, and are dominated by extremely complicated, practically irregular functions. The elegant formulas might be approximations to the real irregular fundamental laws with that accuracy, but not better. We know though, that the real accuracy of our fundamental theories is not only better than required by WAP, but many orders of magnitude better; they are absolutely precise on that scale. Indeed, the General Relativity test with a double neutron star PSR 1913+16 showed an unprecedented agreement between theory and observation at the level of 10^{-14}. Another impressive demonstration of that extremely high precision relates to the Quantum Electrodynamics: the theoretically predicted value of an electron's magnetic moment is confirmed by measurements with the accuracy ~10^{-11}; see e. g. Ref. [12]. These fantastic precisions, achieved due to theoretical and experimental breakthroughs, show that beautiful mathematical forms discovered by physics as fundamental laws of nature cannot be random. Indeed, a random coincidence only in a single case of the aforementioned General Relativity measurement has the probability as low as ~ $10^{-14}/10^{-3} = 10^{-11}$. Taking into account all the measurements of this sort together, each one refuting chaosogenesis with probability very close to one, refutes this hypothesis absolutely.

This consideration shows, by the way, that cosmological chaosogenesis is a scientific hypothesis since it is falsified by observations. Note that the idea of the multiverse was at least partly motivated by the wish to find a pure scientific explanation to the fact of the fine-tuned universe: if our universe is the only one, its fine-tuning does not suggest any other reasonable explanation but an act of purposeful creation. For a single universe, its fine-tuning is too stringent for a purely scientific explanation, but the idea of multiverse chaosogenesis, suggested as an attempt to explain fine tuning within bounds of science, is refuted by the opposite reason: the estimated WAP limitations on fine-tuning aren't anywhere fine enough to explain the experimental confirmations of the extreme precision of the elegant forms as fundamental laws.

A Pythagorean Universe

After having announced the "complete mathematical democracy" at the beginning of his article, later on Tegmark notices that "our physical laws appear relatively simple". At this point, to be consistent with reality, he gives up the proclaimed "mathematical democracy" in favor of an aristocracy of simple mathematical forms as an attempt to suppress the "weight" of universes with more

complicated laws. After this quiet overturn, his multiverse now has almost nothing to do with chaos; instead, it is generated by some source of elegant mathematical forms. As a result, "the embarrassing question" about the source of this ontological inequality of the mathematical forms remains as it was. This contradiction of Tegmark's "democratic" intention with his "aristocratic" practice was noted by Alex Vilenkin [13]:

> Tegmark's proposal, however, faces a formidable problem. The number of mathematical structures increases with increasing complexity, suggesting that "typical" structures should be horrendously large and cumbersome. This seems to be in conflict with the simplicity and beauty of the theories describing our world.

Since the laws of the universe are not picked randomly, they can only be purposefully chosen. Our universe is special not only because it is populated by living and conscious beings but also because it is theoretizable by means of elegant mathematical forms, both rather simple in presentation and extremely rich in consequences. To allow life and consciousness, the mathematical structure of laws can not be too simple, so as to be able to generate rich families of material structures. From another side, the laws have to be simple enough to be discoverable for the appearing conscious beings. The steps of that fundamental stairway can not be too high either; too trivial, and the laws are fruitless; too complicated, and they are incomprehensible. To satisfy both conditions, the laws must be just right. Such a special universe deserves a proper term, and we do not see a better choice than to call it *Cosmos or* to qualify it as *Pythagorean*, in honor of the first prophet of theoretical cognition, who coined such important words as "cosmos" (order), "philosophy" (love of wisdom), and "theory" (contemplation).

Since chaosogenesis, being limited only by the anthropic principle, is the only option for a completely scientific solution of the problem of cosmogenesis, it has to be concluded that the problem of cosmogenesis cannot be solved within the framework of science. Any scientific approach to that would require a specific set of axioms, consistent not only with the anthropic principle, but with elegant mathematical forms truly underlying our world. The question about embedment of one instead of another specific theory as a logical structure of the universe cannot be scientifically answered.

Starting with Pythagoras, it was a matter of faith for sparse groups of few people and lonely individuals that "fundamental laws of nature are described by beautiful equations", as put P.A.M. Dirac. Theoretical science was initiated and nurtured by this very faith, this "cosmic religious feeling" (A. Einstein), which inspired scientific cognition for twenty five centuries. Without any exaggeration, all great theories, from Copernicus, Galilei, and Newton, to Einstein and Dirac happened as guesses on the grounds of some fundamentally simple ideas like symmetry, conservation, or equivalence. The noted forty-five orders of magnitude of scientific cognition, with more than ten digits of precision reached in some experimental verifications , allow to conclude about a scientific confirmation of what was considered a matter of faith for two and a half millennia: now it is a matter of fact that the universe is indeed Pythagorean. In other words, the existence of the Platonic world of elegant mathematical forms structuring the physical world is scientifically confirmed, and the accuracy of this confirmation is many orders of magnitude better than that of any specific statement of physics.

After two and a half millennia since its birth, fundamental science reached a grade of maturity allowing for a dual confirmation of its faith: the Pythagorean faith is confirmed as prophecy coming true and as a good tree that brings forth good fruit.

Three Worlds, Two Totalities

Pythagorean forms of the discovered laws of nature tell us that the ultimate goal of fundamental physics, the theory of everything, either contains a significant Pythagorean core, or, what is more reasonable to assume, is totally Pythagorean. This Pythagorean core has to be powerful enough to generate a sufficiently rich set of Pythagorean laws, as we observe, but

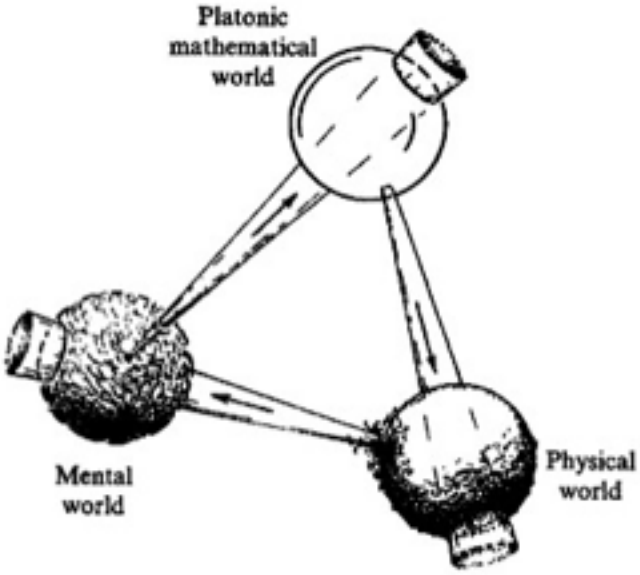
whatever this theory of everything is, it cannot be the ultimate answer to the question about the order of being, because this theory is special due to there being other forms, and so, like any other, it does not constitute a totality. In fact, there are only two explanatory principles, opposites of each other, which are totalities: chaos and Mind.

According to the above, the logical structure of the universe, being an elegant mathematical form, cannot be influenced by chaos at all. Thus, we do not have any other choice than to assign it to Mind. Chaos can still participate in the physical world as indeterminism, by means of uncertainty left by the laws of nature. A. Vilenkin prefers to formulate this apparently inevitable conclusion about the cosmic Mind as a question [13]:

> … the laws should be "there" even prior to the universe itself. Does this mean that the laws are not mere descriptions of reality and can have an independent existence of their own? In the absence of space, time, and matter, what tablets could they be written upon? The laws are expressed in the form of mathematical equations. If the medium of mathematics is the mind, does this mean that mind should predate the universe?

The very idea of observation, being so far associated with material objects only, is enriched now by an even more fundamental meaning of the platonic observation, i. e. observation of elements of the Platonic world structuring the material world. Cosmic observation is possible only due to a combined vision of both worlds: the discoveries of cosmological, geological, and biological evolutions became possible only after breakthroughs in the fundamental physics.

Roger Penrose suggested the idea and the image of "Three Worlds, Three Mysteries" [7]. The three worlds, physical, Platonic, and mental, differ time-wise. The Platonic world does not have any age at all, so it is atemporal. The material world is temporal; its age, counted from the border of all observations, the big bang, is calculated at 13.798 ± 0.037 billion years (note the precision!). The age of humanity as cosmic observers is extremely short on that scale. Although the history of many scientific discoveries is known minutely, although we cannot observe anything closer than ourselves, the genesis of the cosmic observer remains no less mysterious to us than the genesis of material and Platonic worlds.



R. Penrose, "Three Worlds, Three Mysteries" [7].

Wonder of Pythagorean harmony of the fundamental laws of nature and continuing demonstrations of human ability to discover them so remotely from our own natural scale leads now more than ever before to deep questions about the three mysteries, whose entanglement and coherence are revealing the underlying Unity, the ultimate transcendental Source of everything existent, including ourselves, the growing cosmic observers.

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