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BEFORE THE BIG BANG: A COSMOLOGICAL CODE

Was there a Big Bang at all, as most of the physicists seem to believe today? Is there a "0 time" at the "very beginning"? What is the origin of the Universe? Was there "something" *before* the Big Bang? Do these questions make sense? Is physics ready to answer them, even if only tentatively? Since there *was* a Big Bang – it was a "singularity". This unique event has been confirmed and stands on 3 major proofs generally accepted nowadays. It induces the existence of a very mysterious state of reality "before the Big Bang" that mathematicians call the "Initial Singularity". This singularity can be understood as the "ultimate source" at the origin of our Universe.

The article deals with the question: *what happens before the Big Bang, on the zero point marking the origine of everything*? The idea of the authors is that at zero, there is no real time. Instead, we find this new form of time, called imaginary time. The authors suggest that at zero scale, the observables (in other words the world where we live whose evolution is parametrized by real time) must be replaced by the underlying "cosmological information " whose evolution is not real but parametrized by imaginary time). This is because there exists a deep correspondence -a symmetry of duality- between physical theory (real time / energy) and topological field theory (imaginary time / information).

Keywords: Big Bang, time, space, world, cosmological code

Was there a Big Bang at all, as most of the physicists seem to believe today? Is there a "0 time" at the "very beginning"? What is the origin of the Universe? Was there "something" *before* the Big Bang? Do these questions make sense? Is physics ready to answer them, even if only tentatively? Since there *was* a Big Bang – it was a "singularity". This unique event has been confirmed and stands on 3 major proofs generally accepted nowadays. It induces the existence of a very mysterious state of reality "before the Big Bang" that mathematicians call the "Initial Singularity". This singularity can be understood as the "ultimate source" at the origin of our Universe.

In 2006, we have written in collaboration with Prof. Dr. Mića Jovanović a book published under the title "Before the Big Bang". During extensive discussions and exchanges of written notes with Prof. Dr. Jovanović, we realized how

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much a multi disciplinary approach could be useful to solve one of the most difficult problems concerning not only the origin of the Universe but also the origin of the Big Bang itself. In particular, Prof. Dr Jovanovic introduced us to some new intruments and tools in mathematics dealing with statistical analysis, a field where he is an expert. This was very topical considering that statistical mechanics is particularly appropriate to understand the equilibrium state of spacetime on the Big Bang limit and even "before".

I.

The Concise Encyclopedia of Mathematics[1] defines "singularity" as "a point in which an equation, surface, etc. blows up or becomes 'degenerate'. Physics encoutered singularities right after the very first attempts to "marry" the two revolutionary theories of the first decades of the XXth century: theory of relativity and quantum theory. Relativistic quantum field theory of light and matter, Quantum Electrodynamics, formulated by the physicists Dirac, Heisenberg and Pauli in the late 1920s, led to mathematical disaters – singular solutions. The nightmare returned the second time when in the 1960s-70s the mathematician Roger Penrose (and later also Hawking and Ellis) convincingly argued that singularities must be present in every space-time that comes as a reasonable solution of Einstein's equations of gravitation. Before the "singularity theorems" the existing cosmological models of the expanding universe had a singularity at the "beginning of time". But was there a hope that, perhaps, with some small adjustements we could build better models? Many tried, with no avail. The singularity theorems of Penrose, Hawking and Ellis put an end to the hopes that the problem can be cured without drastic changes in our understanding of the fundamental laws of the universe. We have tried to deal with this very speculative interrogation and that it is the subject of our research within the Megatrend Laboratory of Cosmology. But the "singularity hypotheses" is so transgressive, so speculative, that it was one of the reasons of a debate all over the world, known later as the "Bogdanoff Singularity". Another possible reason for the world discussion could be that, in our research, we stumbled upon something very important, some deeply guarded "secret" – the Holy Grail of Science.

Some years ago, our own "mémoire" written for a Master's Degree in theoretical physics was on the subject of Big Bang and the future evolution of the universe as described by a rather original variation of the Friedmann-Lamaître cosmological model of the expanding universe. This model presents us with a very mysterious problem: the "initial singularity" in the past. The eminent Princeton physicist John Wheeler (the one who invented the word « black hole » and contributed during the fifties to the construction of the first American hydrogen

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[1] Weinstein Eric W.: *CRC Concise Encyclopedia of Mathematics*, CRC Press 1999.

bomb) commented with others on this problem as follows: "No problem of cosmology digs more deepely into the foundations of physics than the question of what 'preceded' the « big bang » , the 'initial state' of infinite (or near infinite) density, pressure and temperature. And, unfortunately, no problem is further from solution in 1973."[2] Thirty years later the solution was still far away. Indeed, this important and difficult question of the "origin of the Universe" is the main theme of our two Phd thesis and scientific publications. And the question of the "initial singularity" is, as we well understood it, the major "tour de force" of our interests and research in theoretical physics.

In fact, a part of our Ph.D. thesis was on the subject of quantum groups and quantum field theory, particularly on the subject of thermal equilibrium states of quantum systems. Technically these states are required to satisfy the so called KMS (for the names of three physicists, Kubo, Martin and Schwinger) condition. Again, we proposed that the KMS condition should be imposed on the early state of the universe. As we were well acquainted with the highly specialized mathematical machinery that is involved in studying properties of equilibrium states using algebraic tools, we thought that we should be able to develop our ideas and to clarify them.

Our own experience is that discussing with various experts in quantum groups and quantum field theories was quite rewarding. We enjoyed their questions, their ways of answering our questions, the challenging atmosphere of these discussions, with many different subjects from different domains unexpectedly brought in. Our own thinking was stimulated, the depth of our own understanding and mastering of our own domain of expertise was challenged.

II.

Here we would like to make some comments on the fundamental questions of physics. When discussing the problems of the "initial singularity" or the "Zero Point", it is necessary to dig deeper than usual and to question the very foundations of physics. Currently physicists believe that there are four fundamental forces in the Universe. Gravitation and electromagnetism are two of them, acting on large scales. Of course, to understand the behaviour of these forces in the "infinitly small" (in the quantum domain) physicists are trying to "quantize" them. So, when it became clear that it was necessary to quantize electromagnetic fields, even more abstract mathematics had to be called upon in order to handle the problem. That led, in the 1960's, to the more abstract and more general algebraic formulation of quantum statistical mechanics and of quantum field theory, mainly by Rudolph Haag, Daniel Kastler, David Ruelle, Huzihiro

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[2] Misner, C. W., Thorne K. S., Wheeler, J. A.: *Gravitation*, Freeman and Co, New York 1973, §28.3.

Araki and others. At the same time it became more and more clear that the original incompatibility between the geometry based theory of gravitation and the algebra based quantum mechanics persists, and even gets stronger, with the discoveries of infrared and ultraviolet divergences in quantum field theory on one hand, and that of black holes and other singularities in general theory of relativity on the other hand. In the search for a more satisfactory, unified description, two different pathways have been proposed. First of all, following the old ideas of the physicists Kaluza and Klein, an attempt to unify electromagnetism and gravity via the use of additional, "invisible", space-time dimensions has been revisited and applied to non-Abelian gauge theories. As far back as 1921, Theodor Kaluza described a unification of gravity and electromagnetism by adding just one "extra" space dimension. In 1981 the mathematical physicist Edward Witten published his seminal paper[3], where he revived the older ideas, with a hope that in more than four space-time dimensions, field theories would be less divergent and more "tamable." As we wrote elsewhere, Witten's paper was extremely interesting, and it took us several years, first at CERN and then at University of Bourgogne, to develop a mathematical formalism that would allow formulating within the framework of quantum groups theory some of Witten's calculations and conjectures. In 2001, we publiched a paper summarizing the results of our joint research.[4]

Later on, "hyperdimensional physics" was extended to include supersymmetry and string theories – always with the hope that these new additions to the formal structure of field theories would cure the theory from dreadful inconsistencies and infinities.

III.

Today, after so many lost hopes and unfruitful attempts, it seems that changes of a much deeper nature are needed, and that these changes have to deal with the very nature of quantum theory. Important formal developments in the direction of the unification of quantum theory and gravity are due to the famous mathematician Alain Connes and his pioneer work on non-commutative geometry. In 1993 Robert Coquereaux, together with another mathematical physicist, Michel Dubois-Violette, organized the First Caribbean Spring School of Mathematics and Theoretical Physics in Saint-François, Guadeloupe.[5] It is there that the

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[3] Witten, E.: "Search for a realistic Kaluza-Klein theory", *Nucl. Phys*, B186, 1981, 412.

[4] Bogdanov Grichka, Bogdanov Igor: *Class. Quantum Grav*, 18, 2001, 4341,

[5] Coquereaux R. *et al.* (ed.): "Infinite Dimensional Geometry, Non Commutative Geometry, Operator Algebras, Fundamental Interactions," World Scientific, Singapore 1995. It is there that Daniel Kastler delivered his 'Lectures on Alain Connes' Non Commutative Geometry and Applications to Fundamental Interactions. [This is doubled]

mathematical phsyicist Daniel Kastler delivered his "Lectures on Alain Connes' Non Commutative Geometry and Applications to Fundamental Interactions." Years later, our own lectures were devoted to "Topics in Quantum Dynamics", where we described new avenues in the very foundations of quantum theory, the avenue that we think can lead to the escape from the dead end, escape from the "quantum trap."[6]

Many physicists agree that the new theory, the one that can really change the paradigm, must be "sufficiently crazy" - otherwise it would have been already discovered. As we wrote in our books, our "working hypothesis" is that our approach might help in changing something in theoretical physics.

Which category does our work belong to? Are our theories falsifiable? We must admit that we do not belong to any standard category. We developed our original methods of research by applying sophisticated algebraic methods to physical problems.

In particular, as we already observed, we made the proposal to use the KMS condition for the description of a (pre) space-time state of the Universe. It is important to note that before we started to promote such an approach, nobody realised that this idea applies *de facto* to the pre-spacetime description. Indeed, one of the main properties of the very definition of a KMS state on a von Neumann algebra is that the metric becomes "complex", splitting the time into a real component and an imaginary component. Therefore, if Nature is described by a KMS state at a certain "instant of time" - this state will be subject to "quantum fluctuations": as we have shown in some of our papers, the KMS condition predicts that the time flow would be somehow *fluctuating*. The evolution of every quantum system, including the Universe, is not always peaceful. There are "quantum jumps", there are "events", there are "catastrophes". To mathematically describe such jumps and events within the standard, even advanced, formalism of quantum theory, as described in textbooks, is impossible. It is necessary to make a full use of the operator algebras, of dynamical semigroups - the mathematical formalism of open quantum systems, and of random processes. One needs to be able to dynamically describe "phase transitions" and breakdowns of a symmetry, such as when water vapour condenses into fluid, and fluid freezes into snow or ice. Change of space-time signature, as described on a global or on a local scale, in the deep past of the Universe, are of this type. Such a change can be dynamically possible only when the Universe is "open".[7] In order to deal with

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[6] For additional information cf., "EEQT - a Way Out of the Quantum Trap", published in: Breuer, H.-P., Petruccione, F. (eds.): *Open Systems and Measurement in Relativistic Quantum Theory*, Lecture Notes in Physics, Springer-Verlag 1999 (with Ph. Blanchard)

[7] EEQT has been developed precisely for this purpose. A short recent review of EEQT can be found in: Bonifacio Rodolfo (ed.): "How events come into being: eeqt, particle tracks, quantum chaos, and tunneling time", *Mysteries, Puzzles and Paradoxes in Quantum Mechanics*, American Institute of Physics, Woodbury, NY 1999 [AIP Conference Proceedings, no. 461] ; J. Mod. Opt. 47 (2000), 2247-2263 (with Ph. Blanchard and A. Ruschhaupt). The

the necessary extension of the conceptual and mathematical framework to solve these problems, our minds must be open to new ideas.

IV.

There are many ways to look at the Universe around us and one of them may turn out to be much more useful in making further progress than others. The eminent physicist John Wheeler, who was one of the last collaborators of Einstein and recently died being almost a hundred years old, is a good example of a thinker who has been looking at the Universe in many different ways. As a youth, he once touched a 11,000-volt power line, just to *see what it would feel like.* Indeed, one of his disciples, Kenneth Ford wrote: *The same John Wheeler who calculated how an excited uranium nucleus wiggles its way toward fission has also dared to ask "How come existence?"*

It is very interesting to notice that Wheeler had successively three different ways to see reality during his life. First, several decades ago, he began by saying "everything is particles". Indeed, everything we observe may be viewed as a gigantic amount of particles -electrons, positrons and others- that behave in certain ways and that interact with each other according to certain rules. If you adopt this viewpoint, the only task is to understand the rules how these particles move and interact with each other.

Then later, Wheeler used to say "everything is fields". Electromagnetic and other kinds of fields can also support disturbances - excitations that only "look" like particles. Even though the correct description of reality in terms of fields is equivalent to the description in terms of particles - we can't really say whether particles are real and fields are an illusion or the other way around - there undoubtedly exists a significant psychological difference between these two ways of looking at reality. Insights that are obvious in one language can be very difficult in an other language and vice versa.

Finally nowadays, John Wheeler states that "everything is information". In 1969, in a famous lecture entitled "It from Bit", he said: *It from bit symbolizes the idea that every item of the physical world has at the bottom -at a very deep bottom, in most circumstances- an immaterial source and explanation.* Indeed, if we think about ourselves as objects in a gigantic computer game that follows a certain computer program, if you wish, we will also be able to predict what will happen as long as we understand the possible forms of information and the rules of the game properly.

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need for "events" in quantum theory was also discussed by Haag in R.: "Objects, Events and Localization", published in: Blanchard Ph., Jadczyk A. (eds.): *Quantum Future; From Volta and Como to Present and Beyond*, Proceedings of the Xth Max Born Symposium, Przesieka, Poland, 24-27 September 1997, Springer, Berlin/Heidelberg/New York 1999 (Lecture Notes in Physics 517).

Once again, this approach may be fully equivalent to the previous ways of looking at reality. Nevertheless, the psychological difference between these three viewpoints is large, especially at the beginning, before we learn how to calculate. It may be much easier to realize a particular subtlety if one follows the right approach. Each of the approaches encourages people to think about a different kind of new ideas, too. For example, the picture of everything as information has led Wheeler to the following concept.

V.

All of us should be happy that our world is equipped with time. Without time, everything would be boring and stagnant. Problems couldn't be fixed and nothing else could happen either. One couldn't hope that the future is going to be brighter than the present. As Wheeler said, "time is what prevents everything from happening all at once".

Many new developments in string theory have shown that space is an emergent concept. What does it mean? It means that the primordial form of existence doesn't require any space. Instead, it is based on different kinds of information that don't have a simple geometrical interpretation. Space emerges out of other concepts as long as these concepts conspire so that space becomes possible and large enough to be worth a discussion. We have talked about T-duality, mirror symmetry, and holography – three examples of situations in which even the number of dimensions of space itself and their qualitative shape depend on the way how we look at these situations.

However, if the Universe ever started from nothing, it is not just space but also time that had to be born. Einstein's special theory of relativity, in fact, requires that space and time are inseparable. According to this famous and well-established theory written down in 1905, everything that can be said about space can be said about time, too.

So it should be natural to expect that time is also an emergent and approximate concept. However, it is surprisingly much less understood how time can be emergent and what should be the fundamental entities that are able to conspire so that time suddenly begins its existence. Science is normally supposed to predict the future out of the known facts about the past. Scientific reasoning is analogous to a rope that connects its two endpoints. If we want to understand the origin of time, we must clearly break the secrets of ropes that have one endpoint only. This endpoint, the future, is the familiar physical reality in the future. However, the other endpoint in the past has to be replaced by a non-physical reality and a more general type of information, something that Wheeler has conceived "at the bottom" of spacetime, on the Initial Singlarity, and that we call the "cosmological code".

What kind of information is this cosmological code and how do we decode it to learn about our world? Is it analogous to the DNA code of animals in any way? It is easy to imagine that this cosmological code will be based on one of the following concepts: imaginary time, non-commutative time, topological quantum field theory, or the wave function of the Universe. As we have mentioned in some of our papers, a complex time is the time whose value is not a point on a one-dimensional real line. Instead, it is a point in a two-dimensional complex plane. While we are used to time that is real, it might be necessary to learn how to deal with imaginary time and perhaps complex time if we want to understand the birth of the Cosmos.

Also, we are used to various quantities that are simple functions of time. The position of a neutron as well as currency exchange rates depend on time. This also means that if you multiply these quantities by time, it doesn't matter how you order the factors: they are ordinary numbers, after all. This assumption could also be incorrect near the Big Bang. Quantities such as the density of energy could very well refuse to be functions of time. The order of the factors could matter. Time could become non-commutative.

As we have explained, topological quantum field theory doesn't care about the details of the shape of objects and small wiggles: it only cares about their qualitative characteristics such as the number of holes. This basic property of topological quantum field theory could become very useful or even essential in the context of the Big Bang, as we have repeatedly argued, because small variations of time shouldn't have any physical impact if time is required to be tiny anyway.

Finally, the wave function of the Universe, an idea pioneered by Stephen Hawking and James Hartle, could determine the priviliged initial conditions for the Universe or its "cosmological code". How does their idea work? Imagine that at some moment of time, the Universe has a finite volume and qualitatively looks like the surface of a four-dimensional ball *i.e.* the so-called three-dimensional sphere. Such a shape is analogous to the two-dimensional surface of Earth but includes one additional dimension. Our task is to calculate the probabilities of various wiggles and various values of fields defined on the sphere: we want to calculate the probabilities that the details of the Universe look in one way or another.

Hartle and Hawking propose a possible answer. They use Feynman's approach to quantum mechanics. If you remember, Feynman has figured out that probabilities of various events in quantum mechanics can be obtained as a sum of a certain quantity over all possible histories that respect the correct initial conditions and one of the interesting final conditions whose probability we want to compute. What kind of histories do Hartle and Hawking choose if they don't know what the initial conditions should be?

They sum over all possible ways how the interior of the Earth, if we use the metaphor, can be filled with fields and particles. The radial direction *i.e.* the distance from the center of Earth plays the role of time. But much like in our approach, it is actually an *imaginary time* – one that is indistinguishable from space. Moreover, the center of Earth plays no privileged role in this calculation. By allowing the time to be imaginary at the very beginning, we avoid the initial singularity. Indeed, one can show that all points inside the Earth are pretty much equally important and nothing special occurs near the center. Hartle and Hawking can prove that the wave function that determines what happens on the surface satisfies the right equation derived from the general theory of relativity, the so-called Wheeler-deWitt equation. They can also approximately calculate how the Universe looks like but so far it is not quite clear whether one can obtain a more accurate result that agrees with some observed and so far unexplained features of the Cosmos.

In our model of the young Universe, the imaginary time plays an analogous role. As a matter of fact, we have constantly repeated the same question: "*what happens before the Big Bang, on the zero point marking the origine of everything*"? As we have seen in our books, our idea is that at zero, there is no real time. Instead, we find this new form of time, called imaginary time. We suggest that at zero scale, the observables (in other words the world where we live whose evolution is parametrized by real time) must be replaced by the underlying "cosmological information " whose evolution is not real but parametrized by imaginary time). This is because there exists a deep correspondence -a symmetry of duality- between physical theory (real time / energy) and topological field theory (imaginary time / information).

If this article will help, even a little bit, in this direction, it may then fulfill its task.

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PRE VELIKOG PRASKA: KOSMOLOŠKI KÔD

Sažetak

Da li je uopšte bilo Velikog praska, kao što većina fizičara, čini se, veruje danas? Da li postoji „nulto vreme“ na „samom početku“? Odakle potiče univerzum? Da li je postojalo „nešto“ *pre* Velikog praska? Da li ova pitanja imaju smisla? Da li je fizika spremna da odgovori na njih, čak iako samo privremeno? Pošto Veliki prasak *jeste* postojao, to je „jedinstvenost“. Ovaj jedinstveni događaj potvrđen je i zasniva se na tri glavna dokaza koji su opšteprihvaćeni danas. On podstiče postojanje veoma misterioznog stanja realnosti „pre Velikog praska“ koje matematičari nazivaju „inicijalna jedinstvenost“. Ova jedinstvenost može se shvatiti kao „krajnji izvor“ porekla našeg kosmosa.

Rad se bavi pitanjem: *Šta se dogodilo pre Velikog praska, u nultoj tački, stvarajući poreklo svega?* Ideja autora je da u nuli ne postoji realno vreme. Umesto toga, pronalazimo ovaj novi oblik vremena koji se naziva imaginarno vreme. Autori ističu da na nuli opazivi svet (drugim rečima svet u kome živimo i čija se evolucija meri parametrima realnog vremena) mora biti zamenjen „kosmološkom informacijom“ u osnovi (čija evolucija nije realna, već se meri parametrima imaginarnog vremena). To je zato što postoji veliko poklapanje – simetrija dualnosti – između fizičke teorije (realno vreme / energija) i topološke teorije polja (imaginarno vreme / informacija).

Ključne reči: Veliki prasak, vreme, prostor, svet, kosmološki kôd