THE CONTRIBUTION OF THE INITIAL SINGULARITY TO THE LIFE PROCESSESS

Cristi STOICA[1]

holotronix@gmail.com

ABSTRACT. Life is a complex phenomenon, composed by many irreversible processes. Its existence is therefore conditioned by the second principle of thermodynamics, stipulating the increase of entropy. To explain this principle, Penrose (1979) proposes that in the Big-Bang the Weyl curvature vanishes.
At the level of singularities, the quantities from Einstein's equation become infinite. It is widely considered that mathematics and physics break down there. Surprisingly, recent mathematical explorations reveal that singularities from the standard black holes and from the FLRW Big-Bang model are mathematically tractable, and the equations of physics make sense again. Einstein's equation can be rewritten in a form which is equivalent to the original one, but also works at singularities.
In addition, any Big-Bang singularity of this type satisfies the Weyl curvature hypothesis of Penrose.
KEYWORDS: Entropy, life, Weyl curvature hypothesis, black holes, singularities, Big-Bang.

Life and entropy. Entropy

The very existence of life is strongly dependent on the second principle of thermodynamics. This principle states that the entropy of a closed system increases. Hence, the life processes are irreversible. But the fundamental equations of physics don't seem to prefer a particular direction of time.

The solution (Boltzmann) is that the entropy measures a kind of "disorder" of a system. The increase of entropy gains a statistical explanation, assuming that the initial state of the universe was sufficiently ordered.

Apparently, life's number one enemy is the increase of entropy: the degradation which affects in time the living organisms leads to illness, and eventually to death.

[1] Doctorand, Institutul de Matematică „Simion Stoilow" al Academiei Române.

But in the same time, without the law of entropy, life would be impossible.

The living organisms on Earth receive from the Sun energy, in a highly organized state. They gradually consume the energy, eventually returning it back to the environment in a less organized state. According to Penrose (2005, 2011), the solar light, composed by high energy photons, is absorbed by plants, which are subsequently eaten by herbivores, which in turn feed carnivores and humans. All these organisms return to the environment photons of lower frequencies.

Carefully chosen initial conditions (fine tuning)

The entropy increases because its value is smaller than the most probable value, which corresponds to thermal equilibrium. It is smaller now, because in the past was even smaller. Consequently, it appears that the most ordered state had to be at the initial moment, estimated (Penrose, 1979) at the incredibly tiny value $\frac{1}{10^{10^{123}}}$ (for comparison, the number of particles in the visible universe is of "only").

How could the initial conditions be so well chosen? Possible explanations may be:

- They were chosen by a supernatural, omniscient being (God).
- All possible initial conditions are realized in parallel universes, which form the Multiverse. The universe we perceive is, of course, one of the few which are favorable to our existence.
- There is a law of physics which imposed severe constraints on the Big-Bang, making it so special.

Big-Bang as a source of order

According to the theory of general relativity, matter is accompanied by the curvature of spacetime. The way spacetime is curved is described geometrically by the Riemann curvature tensor. The Riemann curvature tensor has two parts. One of the two parts (the Ricci part) depends on the way energy is distributed in spacetime. It manifests by shrinking the objects. The remaining part, the Weyl curvature, is at the origin of tides, and characterizes the non-uniformities of the gravitational field.

Searching for an explanation of the highly ordered state of the Big-Bang, Penrose states the Weyl curvature hypothesis, according to which the Weyl curvature vanishes at the Big-Bang.

Singularities. The problem of singularities

The theory of general relativity has two major problems:

1. It predicts the occurrence of singularities (Penrose, 1965; Hawking, 1966a; Hawking, 1966b; Hawking, 1967; Hawking & Penrose, 1970).

2. Any attempt to quantize gravity failed, because it is non-renormalizable (‘t Hooft & Veltman, 1974; Goro & Sagnotti, 1986).

In general, these problems are considered as an indication of the necessity to give up general relativity and replace it with a more radical approach (superstring theory, loop quantum gravity etc.).

However, systematic research of singularities indicates the possibility that these problems are not that intractable as claimed. Moreover, the new results seem to lead to a confirmation of the Weyl curvature hypothesis.

Benign singularities and malign singularities

The fundamental geometric object in general relativity is the metric tensor g_{ab}, which determines the distances and time intervals. In an orthonormal frame, the metric tensor has the matrix following form:

In a general frame it has a more general form – that of a symmetric matrix. The values of the elements in this matrix vary from point to point, and can be calculated from Einstein’s equation.

$$g = \begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Under general hypotheses, Einstein’s equation leads to singularities.

In our approach, we can say that there are two main types of singularities:

1. *malign*, with the property that one or more elements in the matrix representing the metric tend to infinity $g_{ab} \to \infty$.

2. *benign*, with the property that the values g_{ab} are continuous and stay finite, but $\det g \to 0$.

Benign singularities are not free of problems. When defining the Riemann curvature, and the covariant derivatives, one needs to use the inverse of the metric, g^{-1}. But when $\det g \to 0$, these values become infinite.

Yet, for a large class of singularities, these infinities can be avoided, by avoiding the use of the inverse of the metric in the definition of the geometric objects. This way, the quantities necessary to general relativity can be constructed for this kind of singularities too (Stoica, 2011a; Stoica, 2011b; Stoica, 2011c).

Einstein's equation

$$G_{ab} + \Lambda g_{ab} = \kappa T_{ab}$$

can be written in the equivalent form

$$G_{ab} \det g + \Lambda g_{ab} \det g = \kappa T_{ab} \det g$$

which works for benign singularities in which the involved quantities remain finite and continuous.

Benign singularities in cosmology

An example is the singularity from the cosmological model of Friedmann-Lemaître-Robertson-Walker. Without modifying general relativity, it is shown that the Big-Bang singularity from this model is characterized by quantities which remain finite and continuous (Stoica, 2011i; Stoica, 2012a).

Malign singularities

However, the black hole singularities are, at least at first sight, malign. For example, for the Reissner-Nordström metric

$$ds^2 = -\left(1 - \frac{2m}{r} + \frac{q^2}{r^2}\right)dt^2 + \left(1 - \frac{2m}{r} + \frac{q^2}{r^2}\right)^{-1} dr^2$$
$$+ r^2 d\sigma^2,$$

which describes the stationary black holes electrically charged with charge q and mass m, the metric component $g_{tt} \to \infty$. Yet, this problem depends on the coordinates employed. A coordinate transformation of the form

$$\begin{cases} t = \tau\rho^T \\ r = \rho^S \end{cases}$$

changes the metric into

$$ds^2 = -\Delta\rho^{2T-2S-2}\left(\rho d\tau + T\tau d\rho\right)^2 + \frac{S^2}{\Delta}\rho^{4S-2}d\rho^2$$
$$+\rho^{2S}d\sigma^2.$$

For $T > S \geq 1$, the singularity turns out to be benign (Stoica, 2012f).

For the other stationary black holes, Schwarzschild (Stoica, 2011e), and Kerr-Newman (Stoica, 2011g), we can find such coordinates too. Moreover, they are compatible with the causal structure (Stoica, 2011h; Stoica, 2011d). This means that the evolution equations are not obstructed by these singularities, and the information is not loss.

The main problem associated to singularities, the *information loss paradox* (Hawking, 1973, Hawking, 1976), doesn't take place in this case.

Quantum gravity. Quantization

Quantum field theory is, along with general relativity, the most successful theory from fundamental physics. Its success is based on techniques which are considered by most mathematically dubious, involving infinities which are canceled by introducing other infinities (renormalization). Even though these techniques become clearer from mathematical viewpoint, there are still many problems.

The main problem seems to be solved with the discovery of the renormalization group. The decisive step was made with the proof that the Standard Model is renormalizable ('t Hooft & Veltman, 1972, 't Hooft, 1973), by using the method of *dimensional reduction*. This method consists in making calculations as if the number of dimensions were $4-\varepsilon$ instead of 4, followed by taking the limit $\varepsilon \to 0$.

Dimensional reduction in renormalization

Many of the problems accompanying renormalization vanish if one assumes that at very small distances (the *ultraviolet limit*) the number of dimensions really is smaller than 4, in general 2 (Thirring, 1958; Lipatov, 1988; Lipatov, 1989; Lipatov, 1991; Verlinde & Verlinde, 1993; Aref'eva, 1994).

A possibility is to consider that at small scale space really loses some of its dimensions, from topological viewpoint. Thus, the coupling constant can have a finite limit at very high energies too

(Shirkov, 2010; Fiziev, 2010; Fiziev & Shirkov, 2011; Fiziev & Shirkov, 2012; Shirkov, 2011).

Moreover, the dimension $D = 2$ would also solve the problem of quantum gravity (Carlip, 1995; Carlip et al., 2009; Carlip, 2010).

The methods of renormalization group suggest a solution for quantum gravity, even in the absence of renormalizability. If Weinberg's suggestion (Weinberg, 1979) is correct, and there are evidences supporting it (Reuter & Saueressig, 2002; Litim, 2004; Niedermaier, 2007; Hamber & Williams, 2005; Reuter & Saueressig, 2007; Codello et al., 2009), then this implies a dimensional reduction at small scales to $D = 2$ (Kawai et al., 1996; Litim, 2006).

Another approach of dimensional reduction is the *fractal spacetime approach* (Calcagni, 2010b; Calcagni, 2010a).

It follows that many problems of renormalizability, including quantization of gravity, seem to vanish if the number of dimensions would reduce to a smaller value. The question is what is the cause of this mysterious dimensional reduction?

Benign singularities and dimensional reduction

In addition to the properties which allow the eliminations of the problems which we though accompany the singularities, the benign singularities have a byproduct: they imply a *dimensional reduction* (Stoica, 2012d).

First, $\det g = 0$ means that the distance along one or more directions becomes 0. Moreover, at those points, the fields involved don't depend on the dimensions which reduce to 0.

Hence, dimensional reduction is geometric in nature, and it occurs spontaneously in the case of benign singularities, although spacetime continues to have, from topological viewpoint, 4 dimensions.

In addition, if we consider a charged particle described by the Reissner-Nordström solution, at the singularity the geometric dimension becomes 2, and the electromagnetic field remains finite even at the singularity (Stoica, 2012f).

The Weyl curvature hypothesis

One consequence of the dimensional reduction taking place at singularities is that the Weyl curvature vanishes. A Big-Bang singularity of this type automatically satisfies the Weyl curvature hypothesis (Stoica, 2012c).

We reiterate the question from the beginning of this paper: "Why are the initial conditions so well chosen?" It seems that now we have an answer:

• They were chosen by a supernatural, omniscient being (God);

• All possible initial conditions are realized in parallel universes, which form the Multiverse. The universe we perceive is, of course, one of the few which are favorable to our existence;

• There is a law of physics which imposed severe constraints on the Big-Bang, making it so special.

Conclusions

The theory of singularities presented here

– Allows the extension of the evolution equations beyond the singularities. This includes

• The Big-Bang singularity in the Friedmann-Lemaître-Robertson-Walker model (Stoica, 2011i; Stoica, 2012a).

• More general Big-Bangs, which are not required to be homogeneous and isotropic (Stoica, 2012c).

• The singularities of the stationary black holes (Stoica, 2011e; Stoica, 2012f; Stoica, 2011g; Stoica, 2011d; Stoica, 2011h).

• Other types of singularities.

– It allows us to avoid Hawking's information paradox, being compatible with global hyperbolicity (Stoica, 2011d; Stoica, 2011h).

– Shows that the dimension is automatically reduced, offering by this a foundation for quantum gravity (Stoica, 2012d).

– The Big-Bang singularities automatically satisfy the Weyl curvature hypothesis, providing thus an explanation for the second law of thermodynamics (Stoica, 2012c).

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