

The background of the cover is a dark blue field filled with numerous small, out-of-focus orange and yellow circular spots, resembling distant galaxies or cells. Three larger, more detailed circular structures are prominently featured in the foreground. Each of these structures has a bright orange-yellow core with a complex, swirling internal pattern, surrounded by a translucent blue, irregularly shaped outer shell.

*The Structure of Space-time
and the Emergence of Complex
Life*

*connections between life and the
expanding universe*

The Structure of Space-time and the Emergence of Complex Life

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Abstract. This article is a continuation of the work started in 2016 by Serpa and Steiner on the structure of space-time. The original theory proposes an alternative to the idea of direct quantization of gravity through a semi-classical evolutionary model, now associated with an entropic principle applied to the accelerated expansion of the universe. This principle relates the emergence of intelligent life to an expectation value of the expansion rate of space-time. The theory is consistent with general relativity and observational cosmology at its current stage of technological development, making a test program plausible in the relatively near future.

Key words: space-time, gravity, entropy, general relativity.

Resumo. Este artigo é uma continuação do trabalho iniciado por Serpa e Steiner em 2016 sobre a estrutura do espaço-tempo. A teoria original propõe uma alternativa à ideia de quantização direta da gravidade por meio de um modelo evolutivo semiclássico, agora associado a um princípio entrópico aplicado à expansão acelerada do universo. Este princípio relaciona o surgimento de vida inteligente a um valor de espera da taxa de expansão do espaço-tempo. A teoria é consistente com a relatividade geral e com a cosmologia observacional em seu estágio atual de desenvolvimento tecnológico, tornando plausível um programa de teste em futuro relativamente próximo.

Palavras-chave: espaço-tempo, gravidade, entropia, relatividade geral.

Introit

The end of the nineties brought discoveries that marked the beginning of a long revolutionary phase in the sciences. Three discoveries

were really decisive: the accelerated expansion of the universe, the exoplanets as common facts in the universe, and the cooperation between trees and all the individuals of a vegetation cover through the soil. Regarding the latter, in 1997 it was possible to prove the existence of a super-fast way of collaboration within the world of vegetables, a vast tangle of structural filaments of fungi constituting a natural network known as the "mycelial network". This via allows exchanges of carbon, phosphorus and nitrogen between distant individuals. Not only that, but apparently plants use the network for communication. Since about 90% of terrestrial plants maintain a symbiotic relationship with fungi, the so-called "mycorrhiza", and that in several situations plants seem to cooperate in combating invasive species through the release of toxic substances, it is concluded that Darwinian competition for resources does not always prevail. Although we still don't understand exactly how collaboration and nutrient exchange occurs through the mycelial network, its existence undeniably brings us closer to a more holistic understanding of both the telluric systems and the universe.

Bearing in mind the implication of space-time dynamics in the structure of all existing things, the thesis I defend is based on the belief that the arising of the building blocks of life is associated with variations in the rate of accelerated expansion of the universe and in the related inhomogeneous evolution of entropy. To support this belief, there are strong indications of the inhomogeneity of the universe, something that in a sense points to a diversity of entropic conditions relevant to the study of the emergence of life. The existence of inhomogeneities suggests a fertile ground for discussions about how biology would be affected by different environments, since there are traces of inhomogeneity even in the rate of accelerated expansion of space-time. Faced with such a reality, biology and physics naturally tend to come together through astrobiology and cosmology.

My particular interest in inhomogeneous cosmologies began during 2006 with what can be summarized from a letter of William Stoeger addressed to Marcelo B. Ribeiro, who kindly sent me a copy [29]. At the time, the main motivation was to be able to simulate the effects of the supposed dark energy through an inhomogeneous cosmology.

There are different inhomogeneous cosmologies. What became known as Lemaître-Tolman-Bondi (LTB) cosmology is a general model defined by the geometry

$$ds^2 = -dt^2 + \frac{[R'(t, r)]^2}{W^2(r)} dr^2 + R^2(t, r) d\Omega^2, \quad (1)$$

where $W(r)$ is a function associated with the curvature of $t = \text{const.}$ Let $M(r)$ be the mass contained in the radius r , so that

$$M(r) = 4\pi \int_0^r dr \rho(t, r) \frac{R'(t, r)}{W(r)} R^2(t, r).$$

As the theory I adopt does not consider particles, the referred mass is just a coupling constant between neighbouring regions of expanding space-time. Thus,

$$\frac{dM}{dr} = 4\pi \rho(t, r) \frac{R' R^2}{W(r)},$$

where

$$\rho(t, r) = \frac{M' W(r)}{4\pi R' R^2}$$

is the proper density. From Einstein's field equation, Stoeger sets the "Friedman-like" equation

$$\dot{R}^2 = W^2 - 1 + \frac{1}{3} \Lambda R^2 + \frac{2}{R} G(r),$$

where

$$G(r) = \int_0^r M'(r) W(r) dr,$$

from which

$$4\pi \rho(t, r) = \frac{G'(r)}{R^2(t, r) R'(t, r)}.$$

As Stoeger highlighted, we have in short a 3-parameter model depending on the choice of $G(r)$, $W(r)$ and Λ . Here is not the place to discuss the various approaches already made to the problem of this choice. For now, I just want to point out that a possible way is to associate the parameterization with some thermodynamic constraints such as the entropy density of space-time.

There is a thought of Don Lincoln's that sounds like a maxim to me, and, whenever appropriate, I like to repeat it: "Thermodynamics means energy, and disequilibrium means 'not equal', or different. [...] Differences in energy allow energy to flow and make the kinds of changes that allow life to exist"[17]. For me, thinking about energy immediately leads to thinking about entropy, and I imagine Lincoln thinks the same way. Energy flow implies entropy flow. So once there is flow, there must be difference. Even if one wants to adopt a homogeneous model of the universe at large scale, it is the inhomogeneity at smaller scales that enable the conditions for life to emerge and flourish. For this reason we need at least bubbles where

LTB or similar geometries are valid, in such a way that significant differences in the continuum occur. On the other hand, we can also think of bubbles of decelerated entropy (but always advancing) in interaction with neighbouring regions of accelerated entropy, aiming at border exchanges. Over time, this last approach became my main focus, as my goal is to arrive at a sub-Planckian model of the structure of space-time in continuous expansion, connecting it to the configuration of the most elementary conditions for life to exist.

Preliminaires

*Two possibilities exist: either we are alone in the Universe
or we are not. Both are equally terrifying.*

Arthur C. Clarke

In the late 1990s we find that the universe is expanding at an accelerated rate, perhaps at the expense of an obscure repulsion factor called "dark-energy". We do not know exactly what this supposed dark-energy is, but, assuming an entropy density intrinsic to the expansion, perhaps it is exactly the energy inherent in the expansion process, a fundamental component of the basic nature of space-time.

It would be difficult to understand the emergence of life without considering this basic nature. The rarity of life, and more specifically of intelligent life, may be associated with the expansion rate of the universe and the entropy density intrinsic to the expansion, in such a way that, assuming the rate is not isotropic, only in regions with a average rate similar to that of the vicinity of the Milky Way in a very remote past could support complex life capable of evolving to the level of intelligence life.

If dark-energy is really the factor that accelerates expansion, there is nothing more reasonable than imagining the entropy trail it leaves everywhere. In my work I will talk much more about entropy than energy itself simply for the sake of language adaptation, as entropy tells us more about the self-wear and tear of the universe and its self-regulating mechanisms that allow for spontaneous creation of complexity¹. From here, the need for considerable changes in our ways of furthering knowledge is already perceived. To satisfy such a need, it would be useless to proclaim a new physics avoiding

¹ On this alleged primacy of entropy, it is worth reproducing Carroll: "[...]el origen de todas las diferencias importantes entre el pasado y el futuro se puede trazar hasta un único principio fundamental, la Segunda Ley de la termodinámica. Esto implica que nuestra capacidad para recordar el pasado pero no el futuro debe poder ser explicada, en última instancia, en función de la entropía, y en particular recurriendo a la hipótesis del pasado según la cual el universo primigenio se encontraba en un estado de muy baja entropía." [7]

the standard ideas of physics, ending up using the same terminology from standard physics, such as "energy" and "field". It's not even a new language, but, as Bohm said, "a new way of using the existing language – the *rheomodo* (flowing mode)" [2]. We can draw inspiration from Wittgenstein's dictum also quoted by England, "...the borders of my language are the borders of my world." [10].

Our linguistic forms of expression often get in the way of accurately identifying the meaning we want to give to concepts and ideas. For example, in modern Western languages, the verb expresses time, placing it on clocks outside of things themselves. However, some primitive languages express time in the very movement of things, and not in verbs. This is the case of the Tupi language, for which past is «pûera» and future is «rama», hence «Ybirárama» (the seedling, that is, the future tree), and Ybirápûera» (the stump, the tree that is gone). Similarly, time is in gravity itself and in space, with entropy indissolubly embedded in.

An obstacle to discussing the subject in this unconventional way is that we place ourselves as observers of space-time, as beings external to it. In fact, we are also expanding space-time, even though it is unlikely that we will ever be able to detect our own expansion since we can assume that we are invariant to scale changes. Ultimately, everything is fundamentally space-time, and truly thinkable as such from the point of view of relativistic cosmology. In this way, the fragmentation of reality is a mere artifice of human understanding, an *a priori* action of human intelligence, its way of describing the world. In fact, we have a shelf of fragmented representations, each of which has its applicability limits, but few perspectives on a consistent description of what would be the fundamental constitution of the universe.

Present work establishes some essential premises to conduct a consistent investigation that can substantiate the association between the emergence of intelligent life and the natural dynamics of space-time. It is important to make clear that it is not part of the implicit study program to discuss ideas of great unification, nor to move towards a quantization theory of gravity.



The corpuscular way of thinking gravity

We are always looking for particles simply because "particle" is the appropriate construct for studying a world of objects that break into as many pieces as we want. However, when one thinks of a universe in continuous expansion, when one understands that space-time is not a mere receptacle to be filled by another substance, but the very "substance" of everything, then corpuscular language – or any other based on individualized "packets" – does not survive as way of expression of the ultimate essences. Certainly, a program to unify all interactions is something interesting, but I think that people read far more into it that it deserves, firstly because, given the current scenario of obstacles, we do not know whether such a program will be feasible and, secondly, because unification can take place on a much deeper level, far below what our most sophisticated experiments can show.

This ultimate level is made, I am convinced, of a space-time woof which not only permeates everything that exists but constitutes "everything that exists". My thesis is that the building blocks of what we might call "organic life" could only form under certain conditions set in this expanding fundamental woof. To discuss how we can link the conditions of the universe for the emergence of complex life it is necessary to be very careful not to make mistakes using nice physics words and meaningless vagaries. First, we need to understand why it is so important to consider the differences between gravity and other forces in order to lay the groundwork for the theory at hand.

The controversy on the fourth interaction: a real paramount problem?

One surprising thing is that, despite the suggestion of a quantized gravitational field is completely counterintuitive, there is still a strong belief that gravity quantizes, ignoring that gravitational field, as described by general relativity, is not of the same nature as the other fields (this insistence to quantize gravity seems to be provoked by an irresistible impulse of analogy that compels us to deal with gravitational interaction as we deal with other interactions; in addition, much of this motivation in astrophysical cosmology comes from the fact that we ignore the physics inside a black-hole, something we assume is dominated by quantum mechanics, but which may well be further on the most competent intellectual resources). That belief proceeds more viscerally from Lagrangian field theory, in use of which if we want to introduce a gauge symmetry – precisely a supersymmetry – between bosons and fermions, this will only be

feasible if the space-time is curved, that is, in presence of gravity; this is the foundation of supergravity, the theory that assumes the existence of a partnership between a boson and a fermion of gravity – called respectively graviton and gravitino –, a key hypothesis for the implementation of gauge symmetry. By the way, in ($N = 1$) supergravity, bosons and fermions always occur in pairs, which are irreducible representations of the corresponding supersymmetric algebra [20].

Thinking in terms of laboratory apparatuses, we may say the starting problem is that gravity is extraordinarily weak and, although it seems to act as a force in common sense, it is much more than this, since gravitational field is the deformation of the shape of space-time itself. Furthermore, gravity is manifested by effects that are the result of a long cumulative process over time. While quantum theories zoomed-in on something as small as neutrinos and quarks, and may treat space as a flat background for measuring how far particles interact, putting time as an external counter and ignoring the curvature of space-time, the effects of gravity only become evident at the very zoomed-out levels of massive bodies like planets, stars, black-holes and so on, objects resulting from an age-old cosmic evolution. At this scale, time demonstrates its physical reality as an evolutionary variable, playing a clear creative role.

All of these features characterizes widely divergent contexts. In consequence, an enormous amount of failed attempts to quantize gravity have accumulated since the 1930s in view of serious theoretical and experimental drawbacks that were arising and adding to, obviously because 1) there is no concrete empirical evidence of the quantum emissary of the gravitational interaction (graviton), even less of its supersymmetric partner (gravitino), and 2) the formalism of quantum field theory is intended to describe specific empirical contexts by which it is justified; apropos, renormalization stops running when the hypothetical gravitons enter the game, generating a great math-mess from an endless feedback-loop of spacetime warping - creation of gravitons - spacetime warping again. To apply quantum field theory under such "reentrant" conditions would be forcing gravity to behave in a way that fits an empirical context completely outside of its reality. Even loop quantum gravity, whilst interesting and theoretically innovative, resent a hard lack of testable predictions. At least for now, I think we waste time trying to paint gravity with conventional quantum hues, hunting gravitons and gravitinos perhaps as exotic elements very difficult to detect (instead, we can work on a supersymmetric semiclassical theory of gravitation via adS space-time glued to Minkowskian space-time).

Some formal aspects

We are all tired of knowing the severe problems entailed by the imposition of quantization on gravity (after twenty years, the main considerations of Butterfield and Isham [4] are still valid, so that the reader can easily access them for verification), so I will be very specific about what seems to me relevant to the theory I advocate. From my point of view, of all the essential theoretical obstacles posed, the one that stands out the most refers to the proposition of an expectation value replacing the original right-hand side of Einstein's equation,

$$G_{\mu\nu} = 8\pi\hat{T}_{\mu\nu},$$

in a way that

$$G_{\mu\nu} = 8\pi \langle \psi | \hat{T}_{\mu\nu} | \psi \rangle,$$

or, more precisely,

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} \langle \psi | \hat{T}_{\mu\nu} | \psi \rangle,$$

with the cosmological constant term added into the energy-momentum tensor to include the contribution of the "vacuum energy". The objection that arises, also pointed out by Carlip [5] and Kiefer [14], is clearly transmitted by the following question: could it be possible that a sudden change in the right-hand side of Einstein's equation due to the wave function collapse was consistent with the conservation of the left-hand side? This is not a trivial question, and depending on the answer, if any, there will be need to rethink the way the universe works as we understand it today.

Thus, we are in a quandary. Einstein's theory is increasingly solid, withstanding the most rigorous tests even on the millimeter scale, while gravity quantization proposals do not minimally offer a viable experimental program; also, for general relativity, the conception of a pulverized world is neither relevant nor consistent². So, either we give up insisting on a quantized structure of gravitation, turning our eyes to more critical problems referring the Standard Model – trying to explain the asymptotic behavior of vacuum space-times with a cosmological constant, the evidence of dark matter and the baryon asymmetry –, or we persevere in a conundrum with no prospects for

² Some authors speak of quantum gravity, quantum space-time, gravitational waves and also quantum black-holes at the same time, coming to something like "quantization of geometric quantities", which leads us, *prima facie*, to think about the quantization of the metric itself. This last outcome leaves us on a moving ground as there is nothing more opposed to General Relativity than a fragmentation of geometry. Paraphrasing Butterfield and Isham [4], the expression "quantized metric" is portentous and hides obscure conceptual challenges when talking together about "quantum gravity".

solution, keeping alive the chimerical ideal of unification. Even if we could get at least one primitive proto-model of quantum gravity compatible with general relativity and at the same time with Lagrangian field theory, I imagine that the number of problems which would remain unsolved would not be worth the effort; we would probably be getting ourselves into a bigger mess.

Currently, I am forced to believe that gravity does not require direct quantization, but rather points to an entropic approach related to the expansion/contraction of space-time. Gravity is, therefore, an entity strongly associated with the expectation value of the expansion (or contraction) rate of space-time, and not with direct metric quantization.

Is it possible to apply some sort of supersymmetry to gravity while preserving General Relativity?

As might be expected, the numerous existing works on supersymmetry and supergravity maintain the conventional basic approach of the atomized emissaries of the fourth interaction and their supersymmetric partners [1][6][11][18][21][31]. Human beings are very devoted to their first ideas which, although functioning precariously, always carry, so to speak, "the benefit of the doubt". These ideas in physics are often tied to forms that characterize objects of thought based on analogies with concrete objects in the outside world. While this brings some comfort in face of seemingly endless uncertainties, it reaches a point where it becomes impossible to move forward without the contradiction of a heterodox alternative. As Bunge pointed out, "[...] *la forma no es una propiedad universal ni originaria. Así pues, los electrones y las familias no tienen forma.*" [3]. The purpose of this section is to deconstruct some notions that can interfere with the understanding of the theory in focus. This deconstruction of the forms – the result of a neo-critical vision adopted over several years – is necessary in order to understand how the concept of space-time is introduced in the theory.

Symmetry is a concept that is easily assimilated by the way it is presented in multiple examples in nature. Furthermore, due to its strong natural appeal, it is possible to extend it to abstract domains, in such a way that entire theories are built on the basis of symmetries, being considered understood if we know those symmetries well. Therefore, it is fully plausible to interpret gravitons and gravitinos as entities representing a symmetry between certain "meta-fields" associated with gravity. In truth, it is a symmetry of the gravitational field itself, described by elements that are not real quanta in the sense of introducing a gauge symmetry.

So, all we have are representations, which should never be confused with reality. Meta-fields are neither more nor less real than the fields we know. Starting from the general principle that the symmetries of nature are what really matters, gravitons and gravitinos compose a translation of an inherent general symmetry between expansions and contractions of the unique space-time woof, making a kind of tapestry in this woof. This approach has been published in full in my article *Thesaurus Theoriis Circa Gravitatis et Cætera* [23], from which I took the liberty of transcribing a small part with some adjustments.

Using the language thus modified, we can think about developing heuristic models of how the gravitational field behaves in extreme situations, or rather, maintaining the consistency of the proposed approach, how space-time is configured in the vicinity of massive objects. By hypothesis, we can imagine two space-times glued together, one being an adS region (an adS black-hole, for instance), the other a Minkowskian region (the external space-time), the first dominated by gravitino's meta-field, the second by graviton's meta-field, both constituting a symmetry demarcated by a dividing event horizon physically characterized as a special field connection. Except for a type of "tunneling", the adS process represented by gravitinos is converted to the representation of gravitons at the boundary between the two space-times where the mass associated to gravitino's meta-field is absorbed by the horizon field letting only a "filtered" process without mass – the graviton meta-field – passing through (for this reason, the horizon field was called «filtrino»).

When it comes to gravity, it would be convenient to consider the possibility of non-local actions, since gravity is manifested by very long-term cumulative processes. The reluctance to embrace non-locality at the heart of the search for a new way of using language to construct realist theories can be a barrier to the advancement of cosmology. So, applying field formalism we may consider a phenomenological Lagrangian density exhibiting a time-integral and something like a «border gauge» field mass-coupled to gravitino's meta-field³,

³ A «border gauge» is a diffeomorphism implemented from a boundary between two space-times through which mass concession occurs. As the question is to describe the influence of the past on a local situation, it would seem contradictory to covariantize the theory (anyway, it's good to remember that there are no local diffeomorphism-invariant observables in general relativity). So I set out from an integration imposed on the Lagrangian, reversing the approach and making that a transformation rule could arise from the Lagrange equation itself. Although the disregard of inheritance factors is in part consequence of an exaggeration of simplification, non-locality phobia in quantum field theory is very related with the fear to lose Lorentz and gauge invariance, both well preserved with local variables.

such as

$$\mathcal{L} = M^2 |g\rangle \langle \tilde{G} | \partial_\tau \langle \tilde{G} | \int |g\rangle d\tau + 1/3 M^2 \langle \tilde{G} \rangle^3 + i \tilde{r} \partial_\tau \tilde{r}, \quad (2)$$

where the kets mean that fields are represented with the aid of a math structure called «gravitor». Gravitors are dual «column-objects» generated from the group $S(\gamma_\eta)$ given by the 2×2 matrices γ_η

$$\begin{aligned} & \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}, \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}, \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}, \begin{pmatrix} 0 & -1 \\ -1 & 0 \end{pmatrix}; \\ & \begin{pmatrix} 0 & i \\ -i & 0 \end{pmatrix}, \begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix}, \begin{pmatrix} i & 0 \\ 0 & i \end{pmatrix}, \begin{pmatrix} -i & 0 \\ 0 & -i \end{pmatrix}; \\ & \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}, \begin{pmatrix} -1 & 0 \\ 0 & -1 \end{pmatrix}, \begin{pmatrix} 0 & i \\ i & 0 \end{pmatrix}, \begin{pmatrix} 0 & -i \\ -i & 0 \end{pmatrix}; \\ & \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}, \begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix}, \begin{pmatrix} i & 0 \\ 0 & -i \end{pmatrix}, \begin{pmatrix} -i & 0 \\ 0 & i \end{pmatrix}. \end{aligned}$$

The above referred dual column-objects form the group $\mathcal{U}$ of the gravitors with elements $(\pm \mathbf{1}_2, \gamma_\eta)$ and $(\pm \mathbf{i}_2, \gamma_\eta)$. From $\mathcal{U}$ we are interested in the subgroup $\mathcal{U}'$ of the gravitors that can represent Wick-rotations from one another under the adS Clifford subalgebra $\mathbb{C}_{3,2}^{(\gamma_\mu)}$, so that we have in gravitorial theory a duality symmetry

$$\begin{pmatrix} \mathbf{i}_2 \\ \gamma_\mu \end{pmatrix} \rightarrow \begin{pmatrix} \gamma_{11}^- & \gamma_{12}^- \\ \gamma_{21}^- & \gamma_{22}^- \end{pmatrix} \begin{pmatrix} \mathbf{i}_2 \\ \gamma_\mu \end{pmatrix} \quad (3)$$

for the gravitino representation, where γ_{ab}^- is the inverse matrix of γ_{ab} , or,

$$\begin{pmatrix} \mathbf{1}_2 \\ \gamma_\nu \end{pmatrix} \rightarrow \begin{pmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{pmatrix} \begin{pmatrix} \mathbf{1}_2 \\ \gamma_\nu \end{pmatrix} \quad (4)$$

for the graviton representation. The meta-fields were defined as follows:

1. $\langle G |$ and $|g\rangle$ as coordinates of the whole system, related to graviton and gravitino representations, respectively;
2. $\langle \tilde{G} |$ as the gravitor inscription of the mass retained at the adS zone with M^2 appearing due to this inscription and its coupling to other fields;
3. $\tilde{r}$ as an auxiliary non-coupled field defined at the junction between the two space-times.

The generators of the graviton subgroup are

$$\begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & 1 \\ 1 & 0 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 0 & -i \\ i & 0 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ 1 & 0 \\ 0 & -1 \end{bmatrix}, \begin{bmatrix} 1 & 0 \\ 0 & 1 \\ i & 0 \\ 0 & i \end{bmatrix}.$$

These generators constitute extra dimensions of the theory and must absolutely not be associated with sensible dimensions.

As previously described, the time integral applied denote strong interference of system's history on local field inhomogeneities. A Lagrangian model that includes a time integral on the gravitino meta-field as described above, I called «paleogravity». I implemented this way because it is expected that light gravitino processes with mass $\lesssim \mathbf{O}(10)eV$ may contribute appreciably to the total matter of the universe, affecting structure formation since early epochs to the present days [21]. I suppose the states of graviton are «mirrored» in states of gravitino, always in pairs, beneath adS Clifford algebra⁴.

Lastly, paleogravity is not a quantum representation but a meta-framework created on a symmetry to produce a non-local image of gravity. Through this *construto* it is possible to associate meta-fields with polarizations of gravitational waves – Riemannian metric fluctuation modes over a classical space-time background – in accordance with the forms of $\langle G |$ and $| g \rangle$ (one must remember that as the universe expands, each graviton mode – with its constant wave vector $\hat{k}$ – is associated with the physical wave vector $k/a(t)$ that redshifts according to the expansion). Perhaps gravity can never be treated quantumly, being gravitons and gravitinos only names that symbolize its intrinsic symmetry. This epistemological emptying can cause a feeling of vacuity of everything – the world and the things that seem to fill it. However, on the contrary, this apparent emptying clears up reality, revealing the first condition of evolution. For, looking from the side of cosmology, symmetries like the one discussed above represent initial steps towards the emergence of complexity.



⁴ The generators of supersymmetry are elements of the adS Clifford Algebra $C_{3,2}$ and, at the same time, elements of the orthogonal group $\mathbb{O}(3,2)$ that represent Wick-rotations when acting on gravitons. The reasons by which I applied an adS Clifford algebra for supergravity with gravitino affors is that 1) Clifford algebras usually furnishes spinorial representations of rotation groups and 2) supergravity does not exist without adS space [20].

The expanding geodesic element

Having moved away from the corpuscular image of gravity, reducing its hypotheticals quanta to no more than names of particular processes described by means of a very special symmetry, we are in a position to advance towards the main ideas about the cosmology behind the emergence of complex life. The reader should be aware that a great number of *ad hoc* "speculative" basic assumptions seems to be typical in most published papers in modern theoretical physics literature aimed at disentangling the fundamental features of the physics at ultra-short distances, in face of the complete absence of a feasible experimental program. Therefore, the following theory is no exception to this reality. Nevertheless, it is important to emphasize that the main aspect which distinguishes present theory from other tentative theories quantizing gravity is that the microphysical foundation considered lies in the introduction of differentials on sub-Planckian intervals. As we will see, these intervals are really just views of the space-time whole.

In the early work on the structure of space-time [22], we write the expectation value measure of the rate in which the invariant geodesic element expands/contracts with a correlation function in the form

$$\langle 0 | g_{\mu\nu} d\langle x - \varepsilon \rangle_\mu d\langle x - \varepsilon \rangle_\nu | 0 \rangle = \Omega^2 \left\{ - [1 - C(u)] du^2 \right\}, \quad (5)$$

to be valid at ultra-short (sub-Planckian) distances, where u is an evolutionary time function that corresponds to $1/H$ (H is the effective Hubble parameter) for time coordinate equal to 0 and to 0 for time coordinate equal to ∞ , and $C(u)$ is defined from some retarded Green's function (for more details, see reference). The theory was first applied in the context of the so-called "G-closure", now generalized to any expanding geodesic element. This work provoked a long and productive debate before it was published, and I am grateful to Professor Ilya Petrov from Bulgaria for his welcome.

In a recent work [25] the idea of small reservoirs of thermal energy, first modelled as particles in de Broglie's relativistic thermodynamics, was represented by small intervals of time in a time-like geodesic (of course, the idea of a time reservoir is not at all intuitive but is in the core of the theory). Having in mind the rate of change of the entropy, and the fact that entropy has the same direction as the time arrow, we write a Lagrange functional as

$$\mathfrak{L} = \delta Q_{int} \dot{f}(H) + f(H) \frac{\delta Q_{ext}}{\tau_{ref}}, \quad (6)$$

where τ_{ref} is the characteristic transition time interval of the system, called "reference time", and $f(H)$ is a generalized coordinate given

by the Heaviside function of the time interval

$$f(H) = (\tau - \tau_0)H(\tau - \tau_0), \dot{f}(H) = H(\tau - \tau_0),$$

which can be translated into Macaulay *kets* as

$$(\tau - \tau_0) H(\tau - \tau_0) = \langle \tau - \tau_0 \rangle^1,$$

with

$$H(\tau - \tau_0) = \frac{d}{d\tau} \langle \tau - \tau_0 \rangle^1 = \langle \tau - \tau_0 \rangle^0.$$

So, alternatively, we may write for the first Lagrangian form

$$\mathfrak{L}_1 = \delta Q_{int} \langle \tau - \tau_0 \rangle^0 + \langle \tau - \tau_0 \rangle^1 \frac{\delta Q_{ext}}{\tau_{ref}}. \quad (7)$$

Combining the two notations, for a time-like geodesic we have

$$\begin{aligned} \langle 0 | g_{44} d\langle x - \varepsilon \rangle_4 d\langle x - \varepsilon \rangle_4 | 0 \rangle &= \Omega^2 \left\{ -[1 - C(u)] du^2 \right\}; \\ \langle 0 | g_{44} d\langle \tau - \tau_0 \rangle^1 d\langle \tau - \tau_0 \rangle^1 | 0 \rangle &= \Omega^2 \left\{ -[1 - C(u)] du^2 \right\}. \end{aligned} \quad (8)$$

The entropy balance between the internal and external environments referred to the interval $\langle \tau - \tau_0 \rangle^1$ is given by

$$\frac{\delta Q_{ext}}{T} = \frac{\tau_{ref}}{\beta} \frac{\delta \dot{Q}_{int}}{T}, \quad (9)$$

where $\beta = \left\{ 1, \frac{1}{2}, \frac{1}{3}, \dots, \frac{1}{n} \right\}$, and τ_{ref} is the characteristic transition time interval of the system, called "reference time" [25]. We can read this expression as a relationship between the variation of each heat transfer interaction $\dot{Q}_{int}$ which crosses a border of a temperature system T (that is, the variation of the entropy interaction $\dot{Q}_{int}/T$) with the entropy flux from the external environment across that border.

Now, we can define an entropy-density pseudo-vector⁵,

$$\mathfrak{A}^4 = \wp_0 \frac{d\langle \tau - \tau_0 \rangle^1}{ds} \sqrt{-g}, \quad (10)$$

where $\wp_0$ is the proper entropy-density within the time interval $\langle \tau - \tau_0 \rangle^1$.

With

$$\frac{d\langle \tau - \tau_0 \rangle^1}{ds} = \frac{1}{\sqrt{g_{44}}}$$

⁵ In fact, the term pseudo-vector translates the fact that an entropy density is not, properly speaking, a vector in the usual physical sense.

and

$$X_4 = \langle \tau - \tau_0 \rangle^1,$$

$$g_{44} = (-g) (\wp_0 \mathfrak{A}_4)^2,$$

the expectation value of the expanding/contracting rate will be

$$\langle 0 | (-g) (\wp_0 \mathfrak{A}_4)^2 dX_4 dX_4 | 0 \rangle = \Omega^2 \left\{ -[1 - C(u)] du^2 \right\}. \quad (11)$$

Still, in a flat space-time the energy density is deduced as

$$\left\{ \frac{H\sqrt{3}}{\sqrt{8\pi G(1-C(u))}} \left[1 - \frac{1}{2} \frac{u}{1+A(u)} \frac{dA(u)}{du} \right] \right\}^2 = \rho_{\langle \tau - \tau_0 \rangle^1} [22], \quad (12)$$

Given the energy density, the expectation value of the rate at which the invariant element evolves only in time mode in a locally flat background is described by

$$\langle 0 | (-g) (\wp_0 \mathfrak{A}_4)^2 dX_4 dX_4 | 0 \rangle = \Omega^2 \left\{ -[1 - C(u)] du^2 \right\} =$$

$$- \left[\frac{3}{8\pi G u^2 \rho_{\langle \tau - \tau_0 \rangle^1}} \left(1 - \frac{1}{2} \frac{u}{1+A(u)} \frac{dA(u)}{du} \right)^2 \right] du^2, \quad (13)$$

since

$$\frac{3H^2}{8\pi G \rho_{\langle \tau - \tau_0 \rangle^1}} \left[1 - \frac{1}{2} \frac{u}{1+A(u)} \frac{dA(u)}{du} \right]^2 = 1 - C(u) [22].$$

Improving the semi-classical structure we may write a consistent relation between the expectation value of the rate and the expectation value of the energy density, so that

$$\langle 0 | (-g) (\wp_0 \mathfrak{A}_4)^2 dX_4 dX_4 | 0 \rangle =$$

$$- \left[\frac{3}{8\pi G u^2 \langle 0 | \rho_{\langle \tau - \tau_0 \rangle^1} | 0 \rangle} \left(1 - \frac{1}{2} \frac{u}{1+A(u)} \frac{dA(u)}{du} \right)^2 \right] du^2, \quad (14)$$

or

$$\langle 0 | (-g) (\wp_0 \mathfrak{A}_4)^2 dX_4 dX_4 | 0 \rangle =$$

$$-g_{\mu\nu} \left[\frac{3}{8\pi G u^2 \langle 0 | \rho_{\langle \tau - \tau_0 \rangle^1} | 0 \rangle g_{\mu\nu}} \left(1 - \frac{1}{2} \frac{u}{1+A(u)} \frac{dA(u)}{du} \right)^2 \right] du^2. \quad (15)$$

Therefore, sudden changes in the right-hand side are consistent with sudden changes in the left-hand side. Before someone just think this theory is based on a perturbative implementation and objects that as a whole perturbative quantum gravity is inconsistent at quantum

level due to the infinite number of non-renormalizable ultraviolet divergences, I remember with Woodard that this is in principle a non-perturbative approach since $A(u)$ and $C(u)$ can be evaluated non-perturbatively [34].

Also, in the original 2016 work, we still used expressions like "quantum of space-time" for lack of better names, and because the main focus was mathematical rather than linguistic. For now I think it's more interesting to name «*quainton*» (from "quaint", unusual, out of the way, singular, exotic) the interval $\langle \tau - \tau_0 \rangle^1$, in such a way that

$$\lim_{\tau_0 \rightarrow \tau} \langle \tau - \tau_0 \rangle^1 \leq \sqrt{\frac{G\hbar}{c^5}}.$$

So when we set an expectation value for the rate of expansion of the *quainton* element, it characterizes an aspect of the real world – the cosmic woof in running expansion – and not a state of ignorance. What is remarkable about this model is that the sub-Planckian sizes are in charge of the *quainton* and not directly of the metric tensor.

There are no parts, only the whole

In a line of universe, each X_4 geodesic interval (*quainton*) can contain different entropy densities, such that, below a given mid-cut point, there will be an expansion expectation value associated with an average entropy density, just as above that mid-cut point there will be a shrinkage expectation value also associated with a particular mean density. If the difference between the expectation values, say "expansion"- "contraction", is positive there will be expansion, otherwise there will be contraction. Curiously, going against the fragmentation of reality, the tools I used were nothing less than singularity functions! Despite the apparent paradox, the idea is quite simple: to establish "visions" of reality on a sub-Planckian scale and not di"visions".

At this scale, space, time and energy/entropy are the same thing; there is no empty energy space and no empty entropy time. Arbitrary intervals X_4 are not fragments of reality, but, in approximation to a Bohmian understanding, visions of reality that are not parts of the whole, but the whole itself taken from certain "points of view". What goes on in one interval is happening at all intervals. Imagine a very large succession of screens showing different viewing angles of an ornamental aquarium differing from one another by arcs of angles as small as you wish. What is observed on any screen with respect to fish movements corresponds to what all other screens transmit. So it is a line of universe, an infinite succession of "screens" X_4 that transmit "images" of the same entropy slightly different from their

line neighbours (in this case, the different "angles" are replaced by different entropy densities). Obviously, our "screens" do not display fish images, but conflicting contractions and expansions. We thus have a structure of geodesic lines that does not differ at all from the structure of the space-time continuum; this allows us to use them as abstractions without loss of generality with respect to the totality. That way, talking about the part and the whole is talking about one and the same thing. The parcelling of nature is just an artefact of our fragmentary perception, which certainly has nothing to do with the essential structure of the cosmos.



Life and entropy

In 1981, Hoyle and Wickramasinghe [12] pointed to a high improbability of the characteristics manifested by the known organisms, and, therefore, of their origins (the fact is that, whatever the reasons, the evidence so far does not alter this improbability). As early as 1993, Kauffman, on the contrary, held that life is not improbable, but an emergent collective property expected from complex systems [13]. I think that, in fact, life is an expected outcome from a given complex configuration. What seems to be very rare is the set of cosmological conditions that favor such a situation and the formation of the building blocks of life, that is, a certain rate of expansion at the point that, during an age, the space-time is entropically propitious to deploy a tapestry of spontaneous and creative thresholds. This subject cannot be treated as of isolated perspectives, requiring the convergence of several approaches taken from physics, biology, astrophysical cosmology and chemistry. Some interesting and instructive discussions can be found in [32] and [33].

Beyond traditional discussion

In the entropic model I proposed, entropy is a quantity that never decreases; its evolution takes place by accelerated or decelerated advance, following the arrow of time [25]. Let me observe *en passant* that confusion accumulates as the uses of the concept of entropy in thermodynamics and in information theory are mixed from a dangerously excessive analogy (unlike energy, information is something

that is created, existing in greater quantities as the universe expands). Dyson [9] made this mixture, although disputable, at least in the strict sense of showing what is quantitatively necessary for the permanence of a civilization.

As described in reference [4], a «Sentient Agglomerate» is a civilization culturally similar to humanity. The concept was treated within the scope of an essay on Fermi's Paradox, and aims to establish a general understanding of what we may call "intelligence". It was Dyson [9] who first addressed, in a milestone work later resumed by Krauss [15], the emergence of an intelligent society from the point of view of the entropy rate involved considering the magnitude of the material resources required for its maintenance. According to Dyson in his «scaling law», there is a quantity $\mathcal{Q}$ which measures the rate of entropy production in an individual per unit of subjective time. For him, entropy was measured in information units or bits, that is, a number expressing the complexity of an individual act of awareness, or the amount of information that must be processed to keep the individual alive long enough to do it. A human being is equivalent to a rate $\mathcal{Q}$ of 10^{23} bits, considering each moment of consciousness lasting about a second. So, a Sentient Agglomerate (SA) as the human species has $\mathcal{Q} = 10^{33}$ bits. This number gives the order of magnitude of the material resources needed to sustain the SA as a whole. Also, Dyson states that an individual (or a SA) with a given $\mathcal{Q}$ and temperature T must dissipate heat at a minimum rate as

$$\mathbf{m} = \mathbf{k}f\mathcal{Q}T^2,$$

where $\mathbf{m}$ is the metabolic rate measured in ergs per second, $\mathbf{k}$ is Boltzmann's constant, and f is a coefficient assumed equal to $(300deg\ sec)^{-1}$.

To maintain the rate of entropy production, that is, an energy availability compatible with the permanence of the SA, it is necessary that the universe is in a state of accelerated expansion favourable not only to the production of elements in general, but also to the formation of the fundamental building blocks of life. A very sharp space-time dispersion could result in a density of matter far below what is needed for atoms and molecules to constitute complex structures. At the other extreme, in a denser space-time, with galaxies and stars closer together, we can deduce that accidents like gamma ray bursts would be much more lethal to any emerging life form, sweeping planets with deadly radiation. Both extremes are tracers of something much more fundamental referring to the intrinsic movement of space-time.

Degrees of freedom and emergence

A very common misconception is to directly associate the increase in the number of degrees of freedom with the increase in complexity, or, so to speak, with the growth in the chances of occurrence of increasingly complex systems. Surely, complexity demands degrees of freedom, but, although necessary, such a demand alone is not sufficient; there is no observational support for an off-Earth increasingly high complexity, since our best instruments do not show any evidence to confirm it. The absence of observational evidence, especially of intelligent life, was well discussed in the references [8] and [24].

In fact, the level of complexity depends on the amount of degrees of freedom available and auspicious conditions for the degrees of freedom to interact and configure gravitational condensation, organized atomic and molecular structures, and biochemical syntheses. So, there must be some accelerated rate of expansion with the adequate level of entropy acceleration for the emergence of high complexity, but in a fleeting phase, very short-lived compared to the age of the universe. From here we understand that extremely low entropy states do not encourage complexity as one might mistakenly think, and we can conclude that there is a creative facet of entropy.

Anisotropy as a realistic hypothesis

The universe is getting bigger and not simply expanding from us but accelerating outward. As the universe expands and ages the coalescence of gravitationally bound systems increases the entropy of matter and radiation. I had said several times that time plus entropy has a creative character as the universe expands. But there is a frequent confusion to be cleared up: the fact that the number of possible states increases over time and with expansion – creating opportunities for complexity to emerge – does not mean that entropy decreases; on the contrary, the more the universe expands and matter becomes less dense – with more dispersed energy –, the lesser the chances of high levels of complexity. In other words, the increase in entropy makes the emergence of intelligence less viable. The accelerating expansion of the universe is consistent with accelerating entropy, while local contractions of space-time referring to massive objects are compatible with decelerating entropy. Therefore, it makes sense to think that only a certain average rate of expansion – corresponding to a certain average acceleration of entropy – would make the emergence of complex life viable. For some reason we may never know, it seems to go this way.

Considering that at the instant of the Big-Bang the universe was in a state of very low entropy, it is natural to assume that life cannot happen either at a lower entropy extreme or at a very high level. In other words, the Goldilocks time era cannot happen either too soon or too late. Thinking in this way, it is logical to conjecture that if the acceptable entropy range for the emergence of life is relatively narrow, even more so will be the acceptable range for complex life, and even narrower will be the acceptable range for intelligent life. Since the increase in entropy accompanies the accelerated expansion of the universe, it makes sense to accurately investigate the possible anisotropy of the acceleration to establish the extent to which we can expect signs of extraterrestrial intelligence in the future.

Meticulous work by Migkas and colleagues deepens the question about the common assumption of isotropy of the late Universe and consequently of the X-ray galaxy cluster scaling relations [19]. This important work is a natural outcome due to many studies reporting deviations from isotropy when using various cosmological probes. Although a definitive conclusion has yet to be made, the fact is that considering an isotropic universe has been a convenient approximation given the observational limitations and the great difficulty of dealing with Einstein's equations in full.

Migkas and his team tested the anisotropy of the $L_X - T$ scaling relation between the X-ray luminosity (L_X) and the ICM gas temperature (T) of galaxy clusters, mapping the expansion rate in terms of the Hubble parameter, as shown in Figure 1 bellow, kindly conceded by the author (purple hues denoting slower rate; orange/yellow hues denoting faster rate). As equation (15) gives an expectation value for the expansion rate also based in Hubble parameter, this observational study will be of great interest for our theory.

The scale factor and the Hubble parameter

To proceed the next step of the research, we may consider some early results. As a first approximation, from equation (15), calculations showed that function $A(u)$, near the Big-Bang, must satisfy

$$\int \frac{dA(u)}{1 + A(u)} = 2 \ln u + k, \quad (16)$$

from which integration by parts furnishes

$$\frac{A(u)}{1 + A(u)} + \int \frac{A(u)}{(1 + A(u))^2} dA(u) = 2 \ln u + k, \quad (17)$$

with the immediate solution

$$A(u) = e^{2 \ln u + k - 1} - 1, \quad (18)$$

where k is a constant of scenario [22]. To deduce an equality for k – regardless of the extreme conditions in the vicinity of the Big-Bang – we can accept it in a bolt as a repercussion of the scale factor and the Hubble parameter by means of a relation between

$$\frac{dX_4}{du} = -\Omega\sqrt{1 - C(u)}$$

and

$$R_{(X_4)} = \Omega\sqrt{1 + A(u)},$$

that is,

$$\frac{1}{\left(R_{(X_4)}\right)^2} \left(\frac{dX_4}{du}\right)^2 = \frac{1 - C(u)}{1 + A(u)}. \quad (19)$$

Assuming $\Omega = 1/Hu$, we get

$$\begin{aligned} \frac{1 + A(u)}{\left(R_{(X_4)}\right)^2} \frac{1 - C(u)}{H^2 u^2} &= 1 - C(u); \\ A(u) &= \left(R_{(X_4)}\right)^2 H^2 u^2 - 1. \end{aligned} \quad (20)$$

Combining this result with solution (18), it comes

$$\begin{aligned} \ln \left(R_{(X_4)} Hu\right)^2 &= 2 \ln u + k - 1; \\ k - 1 &= 2 \ln \left(R_{(X_4)} Hu\right) - 2 \ln u; \\ k - 1 &= 2 \ln \frac{R_{(X_4)} Hu}{u}; \\ k - 1 &= 2 \ln R_{(X_4)} H. \end{aligned} \quad (21)$$

Lastly we deduce from

$$k - 1 = \ln \left[\frac{1 + A(u)}{u^2} \right],$$

that

$$\begin{aligned} \ln R_{(X_4)}^2 H^2 &= \ln \left[\frac{1 + A(u)}{u^2} \right]; \\ R_{(X_4)}^2 H^2 &= \frac{1 + A(u)}{u^2}. \end{aligned} \quad (22)$$

The value of k directly impacts the correlation function and therefore the expectation value of the expansion rate defined by equation (15). From equation (21), based on current estimates of H , it is possible to



elaborate a comparative simulation of different expansion scenarios.

Now, expressions (9) and (15) presuppose the Second Law in the form postulated by Tolman for a volume element $\delta\mathcal{V}_0$ [30]

$$\frac{\partial \mathfrak{A}^4}{\partial X_4} \delta\mathcal{V}_0 \geq \frac{\delta Q_{\text{ext}}}{T}.$$

Applying the integration on the four-dimensional volume, we have

$$\int \int \int \int \frac{\partial \mathfrak{A}^4}{\partial X_4} \delta\mathcal{V}_0 \geq 0,$$

and so, using (10), we open the sum on the temporal part

$$\iiint \wp_0 \frac{dX_4}{ds} \sqrt{-g} dx_1 dx_2 dx_3 \Big|_{X_4}^{X'_4} \geq 0,$$

and get, for $\sqrt{-g} dx_1 dx_2 dx_3 = d\mathcal{V}_0 ds$,

$$\int \wp_0 d\mathcal{V}_0 \Big|_{X_4}^{X'_4} \geq 0, \quad (23)$$

which is an expression for the entropy of the whole system. It is important to note that the general meaning of $\delta Q = T dS$ comes from the process boundaries and not directly from the entropic process itself. This expression is nothing more than an equilibrium relation, and in general relativity we can satisfy this relation, for instance, having in mind the energy flux across the area of some local Rindler horizon.

Some additional final comments

As already stated, biology cannot do without physics to broaden its understanding of life, just as it cannot ignore two fundamental processes of complex systems: adaptation and feedback. Therefore, the expansion rate implied must favour primarily these two processes for biological evolution to occur. In the same way that Earth's gravity regulates the functioning of our organisms – in addition to all anthropic engineering – so does the rate of expansion in terms of adaptive interaction conditions between systems and their environments.

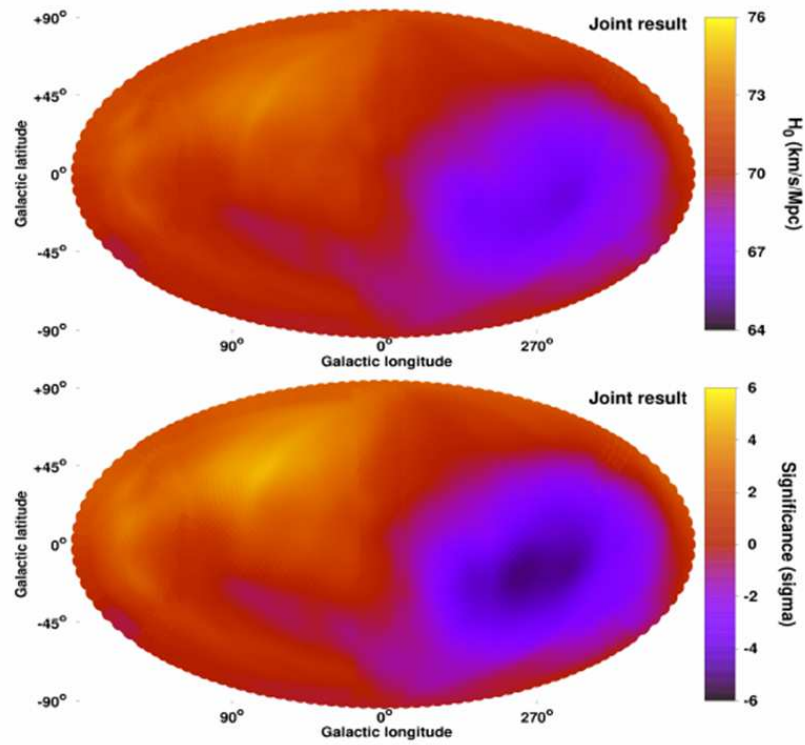


Fig. 1: H_0 anisotropy map as derived from the combined data analysis (courtesy of K. Migkas, *Astronomy & Astrophysics*, 2021).

Thus, all the structures and transformations described in biology, such as the large folder-chain organic molecules and cell division, only take place under very particular conditions of space-time expansion and entropy advancement described with the aid of a peculiar construct, the *quainton* (I see that some of England's interesting propositions would find physical and mathematical support here!). The dawning of life is part of the evolution of the universe, and cannot be taken as an independent natural deployment whose complete understanding, if one day possible, would never be exhausted by a single discipline. Certainly, the discovery of life beyond Earth would help to shed light on the questions and propositions I raise, as well as the certainty of its absence.

At this moment, the philosophy mediation is pivotal. Little by little it seems that we are rediscovering the place of philosophy alongside the sciences. There is still nonsense about its role as a way to create wanderings or to acquire merely lucubrate knowledge away from reality, when in fact it is the only tool we have to assume a critical position of refinement and logical verification of the ideas,

hypotheses and theories we build. Thanks to philosophy, we overthrow inappropriate metaphors and verify if what science claims to be observational really is. In face of so much scientific mediocrity seen in this world of profit and power, it is comforting to read a chapter by Harvey Leff devoted to the language and philosophy of thermodynamics [16], one more voice seeking to undo the mess of the traditional teaching of the heat science.



The explained formalism and its semantic aspects form the essential representation of the structure of space-time, foundation for evolutionary theorizations in the field of biology and for the understanding of the rarity of life as we know it. This paper will be followed by another formal study establishing the axioms of the theory, thus completing the cycle of five publications started in 2016 [22], passing through the articles of 2019 [24], 2020 [25] and 2021 [27] to which present work is linked. It will not be easy to arouse empathy on the part of biologists, since among them there is little affinity with physics, and, as everything has indicated, with the philosophy of science, despite the clearly recognized philosophical efforts of minds such as those of Joseph Henry Woodger – theoretical biologist who sought to make the biological sciences more rigorous and empirical –, Ashley Montagu – great anthropologist to whom we owe the fundamental critique of race as a biological concept –, Stuart Kaufman – whose contribution as a theoretical biologist in complex systems represents a decisive milestone in this field –, and Ilya Prigogine – a physical chemist who explored thermodynamics from the point of view of irreversibility discussed in his theory of dissipative structures, a seminal work for the deepening of studies on complex systems and advanced biology. However, astrobiology opens concrete perspectives for a relatively rapid change in this scenario. In any case, like it or not, physics and philosophy lead us to understand that the way of entropy is the natural way of the evolution of the universe. It advances irreversibly with time and with the accelerating expansion of the universe as in an uncontrollable drag. It would be illogical to imagine that there could be a random and "smooth" reversal of a process originated in an event of the proportions of the Big-Bang.

Conclusion

An investigation like the one I propose demands time, collaboration and information, starting with a more accurate determination of the current value of the Hubble parameter. I recognize the program is ambitious. However, I don't intend to give answers to everything, but we must agree that if we want to seek greater understanding of how our universe works, we need to risk new lanes.

Let's face it, although the discovery of any form of life in another planetary system is a fact that will have a huge impact on our worldview, only the existence of intelligent life – capable of conscious, independent thought and communication – is truly relevant to us. Hereupon, the question that really matters is: are there other space-time regions endowed with a rate of expansion consistent with the expected rate of entropy production of a SA? Present model in *quainton* physics associated with the research on the behavior of faint $L_X - T$ regions may be useful to answer this question. Here, the prospects for some preliminary calculations are opened, including an expectation value of the cosmic entropy acceleration. In addition, I think that the experience accumulated so far should lead us to a more humble attitude towards reality, valuing not only the opportunity to be alive but also the wonderful world that shelters us. It may not be a pleasant idea that we are a unique species, and that we are alone in the universe. However, even the movie entertainment industry has been dealing with this hypothesis in several science fiction films. In particular, I believe that the intelligent aliens shall be ourselves, our descendants in colonies in the solar system, and perhaps, in the distant future, on the nearest Earth-like exoplanets. Even in our solar system this shall require an incredible technological advance in all areas [26]. In any case, one thing is certain: if there is intelligent life outside Earth, it is a very rare phenomenon and so precious that it is probably very well safeguarded from external contacts by insurmountable natural constraints.

What we already know has been well summarized by Howard A. Smith:

"The development of intelligent life appears to require more than just planetary suitability [...]. There will be no civilization if a star is too large or too small, if a planet's orbit or obliquity is wrong, if its size or chemical composition is unsuited, if its surface is ill equipped, if its geologic and meteoritic history is too inauspicious, if the powerful chemistry needed to generate the first life forms is too intricate or too slow, if evolution from proteins to intelligence is too often aborted or directed into sterile tangents, or if civilizations

die off easily." [28]

Add to this a critical condition of a much more essential nature: the correct rate of accelerated expansion of the universe.



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