Eight assumptions of modern physics which are not fundamental

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Abstract

This essay considers eight basic physical assumptions which are not fundamental: (**i**) spacetime as the arena for physics, (**ii**) unitarity of the dynamics, (**iii**) microscopic time-reversibility, (**iv**) the need for black hole thermodynamics, (**v**) state vectors as the general description of quantum states, (**vi**) general relativity as a field theory, (**vii**) dark matter as real matter, (**viii**) and cosmological homogeneity. This selection ranges from micro-physics to cosmology, but is not exhaustive.

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1 Introduction

From ancients times, the idea that the most basic aspects of nature are already known is a recurrent one. Consider Laplace's famous words:

> «*An intellect which at a certain moment would know all forces that set nature in motion, and all positions of all items of which nature is composed, if this intellect were also vast enough to submit these data to analysis, it would embrace in a single formula the movements of the greatest bodies of the universe and those of the tiniest atom; for such an intellect nothing would be uncertain and the future just like the past would be present before its eyes.*»

Laplace, thus, envisaged a combination of Newtonian gravitation and mechanics as a theory of everything. Of course, all the revolutionary scientific developments made after 1814 have shown how wrong he was!

But the temptation to believe that the most basic aspects of nature are already known remains among many physicists. Only three decades ago, Stephen Hawking famously declared that a theory of everything was on the near horizon. He was not alone, with Steven Weinberg publishing his bestselling book «*Dreams Of A Final Theory: The Search for The Fundamental Laws of Nature*» and, in more recent years, with string theorists such as Edward Witten selling string theory as our best candidate for a theory of everything [1, 2].

Are the most basic aspects of nature considered in established theories such as general relativity or quantum field theory? Are the basic physical assumptions of speculative theories such as string theory really fundamental? As shown in the next sections both questions are answered with a sonorous «*NO*»: many of our basic physical assumptions are not fundamental.

2 Spacetime is not fundamental

The ordinary concept of relativistic spacetime $(t, \mathbf{x})$ emerges as a crude approximation to an underlying $3N$-dimensional Liouville space $(\{\mathbf{x}\}^N; \tau)$ with a fundamental concept of time τ as the invariant evolution parameter that synchronizes, *implicitly*, the many-body correlations in the universe.

The idea of a more general concept of time, beyond spacetime, is being considered by physicists such as Matej Pavsic in their generalization of string and M-theories [3]. For instance, Pavsic generalizes the Dirac, Nambu & Goto action of the strings by adding an *explicit* invariant evolution parameter to the ordinary spacetime coordinates. However, he is not using a fundamental concept of time τ as the mentioned above.

3 Unitarity is not fundamental

The immense majority of physicists believe that the evolution of our universe is unitary. We consider a more general non-unitary evolution that eliminates traditional difficulties such as the measurement problem in quantum mechanics. This century-old problem of physics is as follows: at the one hand, the SCHRÖDINGER equation describes the unitary evolution U of an isolated quantum system; at the other, this equation cannot describe the non-unitary evolution during a measurement process.

Our solution to this problem considers a more general kind of non-unitary evolutions Ω, with unitarity recovered as an approximation $\Omega \approx U$. This extension explains, in a natural way, why the SCHRÖDINGER equation describes the evolution of a quantum system only under special circumstances. Effectively, if we retain terms up to quadratic order in the interacting quantum Liouvillian and ignore higher order corrections, further approximate the surrounds of the system by an equilibrium environment, trace out the very fast degrees of motion in a typical system's time scale, and take the limit of ultra-short correlation time, we can obtain the generalized SCHRÖDINGER equation [4]

$$\mathrm{d}|\psi\rangle = -i\hat{H}|\psi\rangle \mathrm{d}t + \sum_k \left(\langle \hat{L}_k^\dagger \rangle \hat{L}_k - \frac{1}{2}\hat{L}_k^\dagger \hat{L}_k - \frac{1}{2}|\langle \hat{L}_k \rangle|^2 \right) |\psi\rangle \mathrm{d}t + \sum_k \left(\hat{L}_k - \langle \hat{L}_k \rangle \right) |\psi\rangle \mathrm{d}\xi_k,$$

with the ordinary SCHRÖDINGER equation of quantum mechanics recovered when the LINDBLAD operators are set to zero $\hat{L}_k = \hat{L}_k^\dagger = 0$.

Notice that we have derived this generalized SCHRÖDINGER equation after applying a set of approximations to an underlying non-unitary evolution. However, this generalized SCHRÖDINGER equation is enough for solving several interesting puzzles of quantum mechanics. For instance, this equation eliminates the famous SCHRÖDINGER-cat paradox. A cat is not described by the ordinary SCHRÖDINGER equation of quantum mechanics because the LINDBLAD operators are not zero; as a consequence, the cat cannot be in macroscopic superposition of a live-cat and a dead-cat.

The derivation of unitarity as an approximation to a more general non-unitary evolution also allows the abandonment of the old philosophical concept of determinism and fully embraces the observed probabilistic nature of our universe.

4 Time reversibility is not fundamental

There is a belief that the irreversibility that we observe in nature is due to our ignorance and that time-reversibility is a fundamental symmetry of nature. From BOLTZMANN, many physicists have tried hard to derive macroscopic irreversibility from microscopic time-reversible equations. The problem is on the details; when we check the supposed 'derivations', we find that the final irreversible equations are incompatible with the initial reversible ones and that no derivation was given of the irreversible equations from the reversible ones. This is the famous paradox of the arrow of time.

What is the solution to the long-standing theoretical puzzles and paradoxes associated to the arrow of time? The solution is the abandon of the time-symmetry assumption. The macroscopic irreversible equations can now be derived from microscopic irreversible equations. And what is the origin of the time asymmetry of our universe? The existence of bifurcation points in the LIOUVILLE space. Of course, reversibility is obtained in the special case when there are no bifurcations.

It is interesting to notice the relation of the new bifurcation theory to the last theory of the Brussels-Austin School [5]. This School is also looking for the microscopic origin of irreversibility, but their approach is different. They consider a kind of large quantum systems with POINCARÉ resonances, demonstrate that those large systems exist outside the HILBERT space and, next, they study a rigged HILBERT space extension of quantum mechanics with time-asymmetry built in. Ignoring technical difficulties related to the precise mathematical nature of the extension and to the treatment of the resonances, the School obtains two possible semigroup evolutions: one of them is compatible with the second law of thermodynamics, whereas the other is not. The School then selects the semigroup compatible with the observations.

Apart from considering a more general kind of systems, the new bifurcation theory selects the correct semigroup in the Brussels-Austin theory without any appeal to the macroscopic second law. How can this be achieved? It happens that the POINCARÉ resonances are time-symmetric because irreversibility is not present at the energetic level; this is the reason why the School obtains two different semigroups related by a time-inversion. However, bifurcations are oriented in time and remove the ambiguity in the Brussels-Austin theory.

5 Black hole thermodynamics is unfounded

Black hole thermodynamics is a supposed extension of ordinary thermodynamics needed to deal with the behavior of matter in the presence of black holes [6]:

> «*Even in classical general relativity, there is a serious difficulty with the ordinary second law of thermodynamics when a black hole is present, as originally emphasized by J.A. Wheeler: One can simply take some ordinary matter and drop it into a black hole, where, according to classical general relativity, it will disappear into a spacetime singularity. In this process, one loses the entropy initially present in the matter, and no compensating gain of ordinary entropy occurs, so the total entropy, S, of matter in the universe decreases. One could attempt to salvage the ordinary second law by invoking the bookkeeping rule that one must continue to count the entropy of matter dropped into a black hole as still contributing to the total entropy of the universe. However, the second law would then have the status of being observationally unverifiable* [...] *the ordinary second law will fail when matter is dropped into a black hole.*»

This is incorrect. For an isolated system, the second law of thermodynamics predicts that the entropy S of the system never decreases with time $\Delta S \geq 0$, but this is no longer true for open systems.

Consider a monocomponent open system that transports matter to the surroundings adiabatically and in absence of chemical reactions; the correct expression for the second law is [7]

$$\Delta S - \left[\left(\frac{S}{N} \right) \Delta N \right] \geq 0.$$

Now the entropy S of the open system can increase, decrease, or remain constant in function of the mass flow term enclosed in brackets. Contrary to a common confusion, the decreasing of entropy S in an open system is perfectly compatible with the second law of thermodynamics. Moreover, the second law continues being observationally verifiable in open systems, with all the known observations up to the date –including laboratory experiments– being in complete agreement with the predictions done by the thermodynamics of open systems [7].

We must accept that claims such as «*the ordinary second law will fail when matter is dropped into a black hole*» [6] must be traced to the insistence of general relativists such as ROBERT M. WALD to apply the expression of the second law for isolated systems, $\Delta S \geq 0$, to systems which are not isolated!

It is interesting that the mass flow term $(S/N)\Delta N$ is proportional to the area $\mathbf{A}$ separating the matter from the black hole. Precisely an entropic term proportional to the area of the black hole is postulated in black hole physics [6], but this is completely misleading for the following reasons.

First, the presence of an entropic term proportional to area is not related to the exotic nature of black holes, but this term is a mere consequence of the thermodynamics of open systems.

Second, the mass flow term $(S/N)\Delta N$ is not minus the total variation in the black hole entropy. The total variation, ΔS_{BH}, would contain a production term due to dissipative processes within the black hole. WALD, as many others, confounds ΔS_{BH} with the entropy transferred between the black hole and the matter outside $\Delta_e S_{BH} = -(S/N)\Delta N$

$$\Delta S + \Delta_e S_{BH} \geq 0.$$

Third, since $\Delta_e S_{BH}$ is not a production of entropy, but a flow term, it can be positive, negative or zero. By confounding such elementary aspects of the second law, general relativists are obligated to claim that the evaporation of a black hole via emission of radiation is not a dissipative process [8]! Moreover, general relativists said us, for decades, that one of the fundamental laws of black hole physics was the law of increasing of area $\Delta \mathbf{A} \geq 0$; although this could not be true and they now accept that their area law is violated during evaporation [6]. From the perspective of the thermodynamics of open systems, $\Delta_e S_{BH} \propto \Delta \mathbf{A} < 0$ for a radiating heat process is a perfectly valid and even a naturally waited result.

There are lots of misconceptions regarding black holes, but I have focused here only on the so-called thermodynamics of black holes, which is an unfounded field full of mistaken claims.

6 Quantum state vectors are not fundamental

As any non-introductory textbook on quantum mechanics explains, the original wavefunctions $\psi(t, \mathbf{x})$ introduced by SCHRÖDINGER are replaced by DIRAC kets $|\psi(t)\rangle$. DIRAC kets are vectors living in a HILBERT space.

It is broadly believed that DIRAC kets provide a fundamental description of the quantum state of any system and by this reason they are named «*state vectors*». Quantum field theory, string theory, and its recent generalizations [3] are formulated in terms of state vectors, but this is, once again, an approximation.

Effectively, due to the presence of quantum correlations, an electron in a macromolecule is not described by a $|\psi(t)\rangle$; a heat bath at thermodynamic equilibrium is not described by a $|\psi(t)\rangle$ due to thermal effects, and so on. Why then quantum field theory and string theory still rely on DIRAC kets?

There is an easy answer: both quantum field theory and string theory are based on a pure scattering approach. Particles (or strings) are supposed to be initially so separated than can be considered to be non-interacting, in which case both correlations and thermal effects vanish and the S-matrix is well-defined. The scattering approach is excellent at accelerator physics experiments such as those made recently at the LHC, but it fails miserably if you want to study the dynamics of a particle in a reaction vessel or in a living cell. For example, you cannot assume that an electron in a transfer reaction is infinitely separated from the other particles in a reaction vessel; and this is the reason why scattering theory is of very little help in chemical reaction dynamics in condensed phases.

A fundamental description of the quantum state of any system is given by a state operator in a LIOUVILLE space: $\hat{\sigma} = \hat{\sigma}(\{\hat{\mathbf{x}}\}^N; \tau)$. State vectors can be obtained as an approximation when the state operator is pure $\hat{\sigma}^2 = \hat{\sigma}$.

7 General relativity is not an ordinary field theory

It is broadly believed that general relativity –a geometric theory– is fully equivalent to the field theory of a massless, self-interacting, spin-2 field. This belief is reinforced by statements in many textbooks. However, as shown recently [9], general relativity (GR) is not equivalent to a field theory of gravity (FTG). The usual claims of equivalence are based in several misconceptions such as the confusion between the general relativistic metric $g_{\mu\nu}^{\mathrm{GR}}$ with the effective metric $g_{\mu\nu}^{\mathrm{FTG}}$ associated to the gravitons of the field theory.

General relativity can be obtained as an approximation from a field theory of gravity [9], somehow as geometric optics can be derived from physical optics. The approximations involved in the geometrization of gravity are two: (**i**) the neglect of $T_{grav}^{\mu\nu}$ and $T_{int}^{\mu\nu}$ in the field-theoretic tensor $\Theta^{\mu\nu}$ [10] and (**ii**) the approximation of the effective metric by the curved spacetime metric $g_{\mu\nu}^{\mathrm{FTG}} \approx g_{\mu\nu}^{\mathrm{GR}}$, ignoring higher-order graviton corrections.

A detailed analysis [9] shows that the five-decades-long failure to obtain a consistent theory of quantum gravity is closely related to the attempt to quantize general relativity without understanding the fundamental differences between geometric and field-theoretic expressions.

8 Dark matter is a fictitious distribution of mass

Vast amounts of data clearly demonstrate discrepancies between the observed dynamics, in large astronomical systems, and the predicted dynamics by Newtonian gravity and general relativity. The appearance of these discrepancies has two possible explanations: either these systems contain large quantities of a new kind of unseen matter –the Dark Matter (DM)– or the gravitational law has to be modified at this scale –as in MOdified Newtonian Dynamics (MOND)–.

This dichotomy is not entirely new in the history of physics. Astronomers already attributed to a new kind of unseen matter the discrepancies between the Newtonian predictions for the motion of Mercury and its observed motion. A new planet was supposed to exist orbiting near the Sun. The confidence on the universal validity of Newtonian gravitational theory was so high that, in the words of the historians RICHARD BAUM & WILLIAM SHEEHAN, to «*the people of the late 19th century, Vulcan was real. It was a planet. It had theoretical credibility and had actually been seen. Even textbooks accorded it a chapter*» [11].

The first discovery of Vulcan was announced on 2 January 1860 during a meeting of the *Académie des Sciences* in Paris. Several re-discoveries and confirmations were done in posterior decades, somehow as discoveries of the hypothetical DM are announced in our days [11]. All of us know now that Vulcan does not exist and that the motion of Mercury includes gravitational effects which cannot be accounted by Newtonian gravity because this theory was based in a set of non-fundamental assumptions.

In a striking parallelism with the Vulcan case, the hypothetical DM has never been directly detected despite much experimental and observational effort during several decades [11]. During the preparation of this work Xenon100 has reported another null detection of any sign of the existence of the hypothetical DM in previously unexplored parameter space.

The problem here is that general relativity is based in a set of basic assumptions which are not fundamental. Recent research [11] shows that the anomalies can be explained by an extended theory of gravity –characterized by a new kind of nonlocal gravitational potentials $h_{\mu\nu}(R(t))$–. The abandon of the mentioned set of basic assumptions allows us to obtain the relation $a_0 \approx (1/2)cH_0$ between the MILGROM acceleration a_0 and the HUBBLE parameter H_0. Notice that this is a fundamental result which cannot be obtained even in relativistic MOND theories such as TeVeS [11].

The cited research also shows how the generalized equation of motion can be cast into ordinary form, when a fictitious distribution of DM, M_{DM}, is added to the real mass M. From our definition of DM, we obtain the main properties traditionally attributed to M_{DM} through *indirect* observations, in excellent agreement with the DM literature [11].

9 Universe is not homogeneous

The standard cosmological model is currently the accepted model for all interpretations of observed astrophysical data. The first basic element of this model is EINSTEIN's Cosmological Principle. The Cosmological Principle assumes that the universe is spatially homogeneous and isotropic on large scales [12]. Homogeneity of the matter distribution plays a central role in the expanding universe model, because homogeneity implies that the recession velocity is proportional to distance. This means that the linear velocity-distance relation, identified with the observed HUBBLE law, is only valid at scales where the matter distribution can be considered on average uniform. In fact, cosmologists such as PHILLIP JAMES EDWIN PEEBLES claim that «*the connection between homogeneity and Hubble's law was the first success of the expanding world model*» [12].

This deep link generates a problem in cosmology with the recent discovery of a fractal galaxy distribution within the scales of about 200 Mpc. In fact, according to modern observations, the linear Hubble law is well established starting from scales of about 1 Mpc, which are highly inhomogeneous.

Although this recent empirical fact presents a profound challenge to the standard cosmological model, it can be explained in recent models where the HUBBLE's law can be obtained even for highly inhomogeneous distributions of matter.

Summarizing, this essay considers eight basic physical assumptions which are not fundamental: (**i**) spacetime as the arena for physics, (**ii**) unitarity of the dynamics, (**iii**) microscopic time-reversibility, (**iv**) the need for black hole thermodynamics, (**v**) state vectors as the general description of quantum states, (**vi**) general relativity as a field theory, (**vii**) dark matter as real matter, (**viii**) and cosmological homogeneity. This selection ranges from micro-physics to cosmology, but is not exhaustive. There are more assumptions of modern physics which are not fundamental, but I could not discuss all them here by the nine-page size restriction for this contest.

References and notes

[1] The Universe on a String **2002:** *Astronomy Magazine, June, 42–47*. WITTEN, EDWARD.

[2] Although the original string theory was superseded by superstring theory, after by brane theory and, recently, by M-theory; string theorists continue to use the term «*string theory*» by marketing purposes.

[3] The Landscape of Theoretical Physics: A Global View; From Point Particles to the Brane World and Beyond, in Search of a Unifying Principle **2006:** *arXiv:gr-qc/0610061v2*. PAVSIC, MATEJ.

[4] Generalized stochastic Schrödinger equations for state vector collapse **2001:** *J. Phys. A: Math. Gen. 34(23), 4797–4809*. ADLER, STEPHEN L.; BRUN, TODD A.

[5] The Liouville Space Extension of Quantum Mechanics **1997:** *Adv. Chem. Phys. 99, 1–120*. PETROSKY, T.; PRIGOGINE, I.

[6] The Thermodynamics of Black Holes **2001:** *Living Rev. Relativity 4(6), 2012 February 16 (access): http://www.livingreviews.org/lrr-2001-6*. WALD, ROBERT M.

[7] Non-Redundant and Natural Variables Definition of Heat Valid for Open Systems **2012:** *viXra:1111.0024*. GONZÁLEZ ÁLVAREZ, JUAN RAMÓN.

[8] WALD writes that an «*isolated black hole will radiate away*» [6] but this is incorrect, because an isolated system cannot, by definition, radiate anything.

[9] General relativity as geometrical approximation to a field theory of gravity **2012:** *viXra:1203.0042*. GONZÁLEZ ÁLVAREZ, JUAN RAMÓN.

[10] Stress-Energy Tensor Beyond the Belinfante and Rosenfeld Formula **2012:** *viXra:1207.0002*. GONZÁLEZ ÁLVAREZ, JUAN RAMÓN.

[11] Modified Newtonian Dynamics and Dark Matter from a generalized gravitational theory **2011:** *viXra:1112.0075*. GONZÁLEZ ÁLVAREZ, JUAN RAMÓN.

[12] Conceptual problems of fractal cosmology **2000:** *Astronomical & Astrophysical Transactions: The Journal of the Eurasian Astronomical Society 19(3–4),417–435*. BARYSHEV, YU. V.