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On explaining everything

On Explaining Everything*

Sobre explicar todo

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Abstract

This work explores foundational issues related to many-worlds theories in Cosmology. It is argued that the metaphysical picture drawn by these theories arise from metaphysical assumptions made during their formulation—most of which are problematic. I elucidate the nature of these assumptions and examine their legitimacy. I conclude the metaphysical presuppositions responsible for the apparent reliability of many-worlds theories in Cosmology are unmotivated and unwarranted by evidence. On this basis, the questions many-worlds models in Cosmology attempt to solve turn out to be a non-starter because their presupposed metaphysical grounding is ill-founded.

Keywords: many-worlds theories - Cosmology - metaphysical assumptions - laws of physics - laws of nature - scientific explanation

Resumen

Este trabajo explora temas de fundamentos relacionados con las teorías de muchos mundos en la Cosmología. Se argumenta que el cuadro metafísico dibujado por estas teorías surge de los supuestos metafísicos hechos durante su formulación, la mayoría de los cuales son problemáticos. Elucidaré la naturaleza de estos supuestos y examinaré su legitimidad. Concluyo que las presuposiciones metafísicas responsables de la aparente fiabilidad de las teorías de muchos mundos en la cosmología no están motivadas y no están justificadas por la evidencia. Sobre esta base, las cuestiones que los modelos de muchos mundos en la cosmología intentan resolver resultan ser un fracaso porque su supuesto fundamento metafísico está mal fundado.

Palabras clave: teorías de muchos mundos - Cosmología - supuestos metafísicos - leyes de la física - leyes de la naturaleza - explicación científica

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> In our description of the space M of possible universes *m*, we must recognize that it is based on an assumed set of laws of behavior, either laws of physics or meta-laws that determine the laws of physics, which all *m* have in common. Without this, we have no basis for defining it.
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> Ellis et al. (2009), p. 6

> If we were to conceive the whole order of nature, we should find that there are many things that—by their nature—could not exist.
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> Baruch Spinoza (1677), p. 205

Introduction

§1. Scientific explanations seek to describe the unknown in terms of the known. In statistical mechanics for instance and in certain quantum mechanical frameworks an explanation of the material forms and relationships of the world is worked out in terms of particles, which by their turn are small-scale models of grosser objects. These models go a long way, but they reach a boundary beyond which they cannot pass. A wise man once wrote there are more things between heaven and earth than philosophy can dream but an even wiser man later claimed science is a philosophical enterprise in which representations of reality can be successfully conceived and patterns found in nature quantified—but profoundly different attitudes of the mind create profoundly different representations and quantifications. Different theories, in short. Thus "imagination is more important than knowledge" is good sloganeering. General Relativity Theory opened the gates for intellectual scrutiny of unequal sublime matters: measurement, inspection and understanding of the universe as a whole. This has no precedent in the history of Western Science since its inception by the minds of Galileo and Newton. And in undertaking this task the human mind is unable to resist the temptation of questioning orthodox thinking, of giving up to the seductiveness of Shakespeare's voice and start wondering whether or not there is more to reality than that which can be read from Einstein's equations and catalogued by astronomical observations. This prolegomenon may suggest that the idea that many universes (or worlds) exist (or might exist)—not as abstract entities but in a solid and concrete way as the world we live in—is somewhat new in the history of ideas. It is not. It has been, for instance, a commonplace topic in science fiction writing since this branch of literature became a thing. The difference lies in how *serious* the idea is taken: it is now a whole field in science, a very live subject in quantum cosmology and cosmic inflation models (Vilenkin 1983, Linde 1983, 1990, Weinberg 2000, Rees 2001). Perhaps the reader may then be misled into thinking *realist* modal discourse is a fairly recent thing. Again, it is not. Proponents of this view are active at least since the seventies, and from two very distinct areas. In Philosophy, the credit is due to David Lewis who, in his *Counterfactuals*, argues vividly in favor of this approach:

> I believe that there are possible worlds other than the one we happen to inhabit. [...] I emphatically do not identify possible worlds with respectable linguistic entities; I take them to be respectable entities in their own right. When I profess realism about possible worlds, I mean to be taken literally. Possible worlds are what they are, and not some other thing. If asked what sort of thing they are, I cannot give the sort of reply my questioner probably expects: that is, a proposal to reduce possible worlds to something else.
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> I can only ask him to admit that he knows what sort of thing the actual world is, and then explain that other worlds are more things of *that* sort, different not in kind but only to what goes on at them. Our actual world is only one world among others. (1973, pp. 84-85)

But metaphysicians and modal logicians are not the only ones to seek for answers to the problems that concern them in worlds (or universes, if you wish) forever hidden from their sight. Some physicists are serious in defending this view is robust and, even further, actually *mandatory* if we wish to interpret quantum mechanics in a coherent, realist way. Theoretical physicists DeWitt and Graham, in the preface to *The Many-Worlds Interpretation of Quantum Mechanics* (1973, p. v), state the following:

> Everett propounded a new interpretation of quantum mechanics that denies the existence of a separate classical realm and asserts that it makes sense to talk about a state vector for the entire universe. The state vector never collapses, and hence reality as a whole is rigorously deterministic. This reality, which is described jointly by the dynamical variables and the state vector is not the reality we customarily think of, but as a reality composed of many worlds. By virtue of the temporal development of the dynamical variables the state vector decomposes naturally and orthogonal vectors, reflecting a continual splitting of the universe into a multitude of mutually unobservable but equally real worlds.

Everett himself writes in his long PhD thesis:

> It is [...] improper to attribute any less validity or 'reality' to any element of a superposition than any other element, due to [the] ever present possibility of obtaining interference effects between the elements, all elements of the superposition must be regarding as simultaneously existing ([1956] 1973, p. 150).[1]

Although these suggestions may appear, in some respects, very straightforward and mundane, they are actually very delicate. A host of enabling assumptions are required for the many-worlds thesis to stand a chance of being true, in any model you like—assumptions which, deprived of any empirical support, find their roots in the philosophical literature. Centuries ago David Hume coined the following slogan: the impossible, says he, can be neither believed nor conceived.[2] Before him Gottfried W. Leibniz—an imperialistic apostle of Christian dogmas—insisted that, among all possible worlds, only the best one—ours—obtained. Why? Very simple, say the fanciers of simple formulas: The Book of Nature is to God a very special book and He would write no other story but the best possible one. We no longer follow Leibniz and his predecessors and heirs in appealing to Theology to support or undermine the scientific conjectures we craft. The ghost of Hume, however, is still alive and kicking. It haunts the road of counterfactual reasoning—a road empiricists with deep-seated tendencies toward realism like to take. Philosopher of science Ian Hacking—whose authority in probability theory everyone is agreed—jokes (1987, p. 133) that buying one model of many-worlds seems to help develop a taste for others. Perhaps this explains why our theoretical scruples about conceivability evidence are routinely ignored. Perhaps not. The following questions seem to me in this context however mandatory, given how exquisitely the many-worlds hypothesis is, in Cosmology,[3] connected to a complex of issues in Mathematics, Physics, Philosophy of Science and Metaphysics:

1) Is the thesis according to which more than one possible world (or universe, if you wish) exist (in the same way as our own; same laws holding) *consistent*[4]?
2) If (1) is to be answered affirmatively, how can we find out the facts of the matter?[5]

§2. *Aim of this paper and a brief note on procedure.* This work undertakes a systematic philosophical exploration and analysis of the latent assumptions responsible for the apparent reliability of many-worlds models in Cosmology. These assumptions are the following:

Proposition 1. The Laws of Physics are the same everywhere in our Universe (world);[6] *ergo* there exists some sort of necessity attached to them (they are 'physically necessary').

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[1] In the particular interesting case of Schrödinger's cat , for instance, the 'radioactive atom + cat' state can be written as

$$|\Psi\rangle = a_1|\text{atom undecayed}\rangle|\text{cat alive}\rangle + a_2|\text{atom decayed}\rangle|\text{dead cat}\rangle.$$

Everett's theory reads $|\Psi\rangle$ as describing two different, independent worlds: one in which the atom did not decay and the cat is alive and another in which the atom decayed and the cat has ceased to be. In this case the states $|\text{cat alive}\rangle$ and $|\text{dead cat}\rangle$ can be seen as two states in orthogonal subspaces that partition the Hilbert space of the cat, for instance, H_{alive} and H_{dead}. See Bub (1997), Chap. VIII.

[2] "It is [...] an established maxim of metaphysics, that whatever the mind clearly conceives, includes the idea of possible existence; in other words, that nothing we imagine is absolutely impossible" (Hume 1968, p. 32).

[3] The term 'multiverse' is widely used in the literature to refer to the many-worlds hypothesis in Cosmology. Personally, I like the sound of 'many-worlds' better. My apologies to the multiverse enthusiasts. Earman (1987) also uses the terminology I employ here.

[4] A set of propositions X (X = {a, b, c,..., n}) is consistent if and only if there exists a way to assign truth-values to all the terms in order to make all propositions of X true. That is to say all propositions of X must be true under the same truth conditions. If X does not fulfill this requirement, X is inconsistent.

[5] Similar questions were asked by Skirms (1975) to discuss a different subject.

Proposition 2. The values of the constants and free parameters of our theories, as the initial conditions which obtained in our Universe, could have been different. They are contingent aspects of Nature (Susskind 2006, Barrow & Tipler 1986, Wheeler 1977, Carter 1973, Carr & Rees 1979, Dyson 1979, Dirac 1937).

Proposition 3. A choice between different contingent possibilities has somehow happened; *the fundamental issue is what underlies this choice.* Two possible explanations present themselves. Hypothesis 1: Cosmic Coincidence (either by (1a) creation *ex nihilo* (Vilenkin 1982, Swinburne 1991)[7] or by (1b) a self-referential or self-sustaining universe (Dicke and Peebles 1979, Hawking 1987, Gott & Li 1997)). Hypothesis 2: Many universes (or worlds).

Proposition 4. All proposals are mutually exclusive. The second hypothesis fits the facts better than the first.

Proposition 5. The Laws of Physics must be the same in all possible universes (worlds), if they exist (Ellis 2009, Rees 2007, Smolin 1997, Barrow & Tipler 1986, Lewis 1973).

For the reader's convenience, the many-worlds hypothesis in Cosmology is sketched in an appendix to this paper.[8] The questions (1) and (2) posed above are answered by an assessment of the extent with which the set of propositions 1-5 stands up to philosophical scrutiny. It is asked: Specified the conditions—logical and empirical—which 1-5 must satisfy, do they all meet them simultaneously? Do they resist rigorous conceptualization? So, with the stage thus set, we shall begin at the beginning—and that means a survey through a microcosm of conceptual problems that still reverberate through modern-day discussions in Metaphysics.

Part I: The challenges of defining metaphysical structure: possibility space and conceivability evidence

§3. Essential to the discussion of these questions is an appreciation of the proper point of departure for modal inquiries concerning the actual. See, the idea that some of the things that are true about the world are true of necessity is a venerable old one. Other things about the world are merely contingently true, it is thought. Next, we find ourselves enrolled on the task of distinguishing necessity into its various kinds. The things whose contrary would violate the laws of logic are logically necessary. Anything compatible with these laws is logically contingent[9]. Problems, of course, abound in attempts of finding a principled way of distinguishing logical truths from all others (but they need not detain us). Some propositions are said to be not logically necessary—they are *metaphysically* necessary[10]. Under this heading fall Kant's postulates that every event has a cause, and that in any change the object's substance remains intact (for instance). The same label also applies to the necessary but synthetic truths of arithmetic and Euclidean geometry, I guess. More contemporary philosophers—the most prominent of which is Kripke, if my knowledge is correct—say that genuine identity statements, singular or not, are due the same metaphysical ranking. We are, after this survey, left with both logical and metaphysical contingent statements and, among these, there still exist some to which are ascribed a more restrict, immediate, concrete kind of necessity. These are assertions taken to be *physically* necessary. But what is the nature of these? Well, these truths are identified with all the things required and entailed by the so-identified "genuine laws of nature". These truths, note, are not only the case: they *must be the case*. They are a matter of physical necessity. There exist, of course, propositions which are true and which state facts about nature which are only contingent. Both (a) they and (b) their contradictories are consistent

6 Isotropy everywhere. See Walker (1944), Ehlers (1993) and Ellis (1971).
7 Vilenkin develops a cosmological theory. Swinburne argues for the existence of God along these lines.
8 The reader not acquainted with the many-worlds thesis in Cosmology may wish to consult the appendix first and then return to Part I.
9 I refer to classical logic, of course.
10 Here I follow Sklar (1990).

with the laws of nature. Although they state what the facts are, it is held, they say what is but could have been different (as far as the constraints of that we have called 'physical necessity' are concerned).

It sure makes a nice sound when we say certain phenomena are such and such as a matter of physical necessity. This concept is just too obscure and slippery, however. Presumably, it refers to all and only that is constrained by the true laws of nature. But again: what are these? They are of course true generalizations, but not all generalizations are laws (Ayer 2000, Earman 1986, Carroll 1990). The substantial question is to find a principled way of delimiting the generalizations that are 'truly' laws of nature from those which are just 'contingent' generalizations. One could resort to the picturesque system of David Lewis, and argue that laws of nature are those laws that hold on all possible worlds (Swoyer 1982). But if we define possible worlds as the worlds in which the laws of nature hold and define laws of nature as the generalizations which hold in all possible worlds, what concrete knowledge do we gain?[11] One could shift strategies and think there might be syntactical means for discriminating true generalizations from mere contingent ones, such as 'excluding reference to particular things' or appealing to 'natural kinds' or 'natural property' predicates, ascribing physical necessity to 'genuine natural kinds' or 'intrinsic properties' (Lewis 1983, Shoemaker 1998). These maneuvers are unfruitful, however. There are as many plausible, non-question begging means of discriminating natural from non-natural kinds as there exist to distinguish 'accidental' generalizations from 'true', 'legitimate' laws of nature.

The disagreement regarding the fundamentals of the concept of laws of nature could hardly be more chaotic. Earman (2004) complains philosophical debates about laws take away the impression of scholasticism, divorced from real physics. French & McKenzie (2012) highlight the lack of engagement between science and metaphysics and say that current metaphysics seem 'reduced to a domain of fantasy ontologies' and 'baroque possibilities.' Their excellent analysis of current theorizing about the modalities attached to laws show how well-supported are Earman's complaints (2004, section 4). Ladyman & Ross (2007, p. 24) argue that "contemporary metaphysics has [...] become almost entirely a priori" and attempts to apply it to modern physics have proved to be in general disastrous. See: the current perspective in the field is that

> Metaphysics is about the most explanatory basic necessities and possibilities. Metaphysics is about what could be and what must be. Except incidentally, *metaphysics is not about explanatory ultimate aspects of reality that are actual* (Conee & Sider 2005, p. 203, italics mine).

This state of affairs astonishes me. Are we not concerned with what is there in the world? And what is it like? Is it not correct to say that all truths about the world are taken to be grounded on a basis built by science—truths that, I hasten to add, are the basic concern of metaphysics? I fail to understand how some contemporary metaphysicians craft scientifically-independent, empirically-detached systems and still hope to meaningfully reconstrue the metaphysical features manifest in the actual world—the only world we know of and have access to and which is the ultimate purpose of our intellectual efforts to understand. And yet, conversely, the manifold ways in which underdetermination keeps re-arising as a problem for the natural sciences is a clear symptom of the dangers that emerge when the (by our immediate awareness) inferred natural world is treated as a given. How to represent the various states of nature within our theories, states whose correlations are supposedly given by 'laws', is no trivial matter. After all, how can we express a general correlation amongst states and choose the best expressive mathematical language to do the job until we know what the states are—until we have a minimal understanding of how nature is supposed to be like in order that our theoretical representatives adequately describe it, explain it? Physics alone, divorced from ontology, cannot settle the important questions regarding what there is. The philosopher's presence is requested in Neurath's boat—the scientist has been sailing alone for long enough.

The pressure to philosophize is particularly strong in the case under study in this paper because the metaphysical content of many-worlds models clearly springs from the metaphysical assumptions that

[11] We shall see the difficulties one starts to drown in when relying on such a notion later on in this piece.

were made during their formulation. These assumptions are neither trivial nor unproblematic. One major presupposition is the understanding that the set of possible worlds is to be constrained solely by our conceivability capacities. Something's being possible to some thinking person or other uncovers, it is held, paradigmatic cases of existence. This assumption follows from the joined arguments of David Hume, philosopher, already cited, and Murray Gell-Mann, physicist.

The former claimed, as we have seen, that 'conceivability entails possibility'. The latter informed us that possibility confines the necessity of existence. Possibility *entails* actualization. In other words,

(i) anything we can imagine is possible and
(ii) all things not forbidden are compulsory.[12]

Ergo all we can imagine happens—and happens necessarily. We can imagine the parameters of our theories, the constants and initial conditions—all that we lack theoretical resources to explain—having different values. Therefore it is possible that they do. Therefore they do. In other universes—universes suggested by possible-world-semantics attached to a 'governing', realist account of laws.

The aforementioned physically disinterested approach to metaphysics had its backreaction in scientific practice. Too busy fitting facts to equations, physicists seldom stop to think about the real implications of the fundamental laws of the models they work on, whether the route from theory to reality—our epistemic access to the world—is as straightforward as a sense of 'miraculous agreement with the data' may lead one to embrace naive scientific realism. Of course, there is good reason to pay a good deal of attention to 'laws of nature': it is these generalizations which yield the scientific resources needed for the prediction and explanation of phenomena within the scope of a theory. Relations among universals are presuppositions for induction and confirmation. How is then the concept of 'law of nature' still so poorly understood, given its importance? Is this concept the kind of 'cab conveniently dismissed when we reach a pious destination' on which Schopenhauer threw scorn?

I have no new solutions to offer regarding the 'law of nature' conceptual malaise neither I think we can profit with this discussion here, but I want the reader to come to grips with what is at stake in many-worlds building and to look at the metaphysical fog that surrounds it with a vision unclouded by philosophical consideration. So let us move forward by assuming for the sake of the argument the notions of 'law of nature' and 'physical necessity' are objective, coherent ones and let us face the so-called 'explanatory problem of the contingency of the constants, free parameters and initial conditions' head-on. My situation is the following. *If* the problem with applying modal methods of reasoning to the intuition that the laws of our most well-confirmed theories remain fixed under 'counterfactual

[12] Known in the particle physics community as the 'Totalitarian Principle' (Gell-Mann 1956), it is a well-established physical principle in the path integral formulation of quantum mechanics. Simply put, the idea is the following: quantum mechanics, as we know, is all about amplitudes. The amplitude of a physical process such as "the particle starts at position x at time t_1 and stops at position y at time t_2" is known in quantum field theory as the *propagator*. This propagator depends on the trajectory that a particle takes in getting from, say, A to B. There exist many possible paths, in principle. Within the framework of classical physics, the algorithm for solving this problem is to (a) write down a Lagrangian L; (b) plug L into the Euler-Lagrange equation to find the equations of motion and (c) solve the equations. The trajectory calculated will be that which minimizes the action

$$S = \int_{tA}^{tB} dt\, L[q(t)].$$

In quantum mechanics, quantum fluctuations allowed by the uncertainty principle make things less straightforward. Richard Feynman suggested (Lancaster & Blundell 2014) that in getting from A to B the particle takes *every single possible trajectory*: it goes forward and backward in time, zig-zagging, looping, whatever. In any direction at any speed. To get the quantum amplitude Feynman then stated that each trajectory contributes a complex factor of $e^{-iS/h}$, where S is the action describing that trajectory, and then in order to find the amplitudes one must just sum over the contributions. And that's it. 'The particle does whatever it pleases' is here the underlying premise. In other words, 'all things possible happen' in particle trajectories. It is interesting to notice in this context how the human mind craves for uniformity in Nature. When a general principle is identified in Science, the mind accustomed to its operation tends to imagine it typical of the workings of the whole Nature, to widen its field of application and, in the absence of any immediate constraint, to postulate its universal validity. Allow me to give you one concrete example. Father of inflationary cosmology Alan Guth, when explaining chaotic inflation, likes to say without ado '*anything* that can happen will happen, and it will happen infinitely many times'. No further explanation of *why* is that the case, or how can be verified that such *is* in fact the case. It is just assumed to hold. The 'all possible worlds exist' reasoning seems to go along the same lines—it is a 'kind of reasoning' now common in physics which can be understood as an extrapolation of Feynman's path integral methodology to calculate quantum mechanical amplitudes. To explore this idea of course requires a paper of its own.

perturbations' were that we could not prove, or explain, their reliability, then maybe, *maybe* we could live with that. The method yields what we need: a many-worlds (universes) theory able to explain the (supposed)[13] worrisome contingency of the parameters and constants of our theories. That is not the problem, though. The problem is that the intuition is dubious and the methods, unreliable. It is of course true that for any putative 'law-like generalization' involving certain parameters and constants our imaginative capacities can yield a possible world where the laws are exemplified but the parameters and constants are not. These imaginings, however, are idle, and for a very simple reason. In view of the good sense of asking, 'Is Hume's move from conceivability to possibility a legitimate one?' a short search reveals that the proper answer to this question is a loud 'No!'

Take, for instance, classical electrodynamics. You may think you can dream up a possible world in which the electric and magnetic fields do not work in accordance with Maxwell's laws, but *if Maxwell's equations really express laws*, if *that* is the case, then the world you dreamed up is but a dream and a bad dream at that (Earman 1986, p. 98). The **E** and **B** fields of your dreams can be electric and magnetic

[13] Some perspective can be gained if we place the issue in historical context. In his *Principles of Nature and of Grace Founded on Reason* (1714), German philosopher Gottfried W. Leibniz posed a problem which is now known in metaphysics as the 'Primordial Existential Question' (PEQ): 'Why is there something contingent at all, rather than nothing contingent?' He justified (?) the query carefully on the grounds of
(a) his Principle of Sufficient Reason (PSR), and
(b) an a priori argument from simplicity for the presupposition of the Null Possibility Hypothesis (that is, the ontological thesis which states that, in the absence of external cause, the natural state of affairs is one which contains nothing contingent at all (see Parfit 1998 for a detailed discussion of this thesis)).
Note that the Null Possibility presupposition is clearly ingrained in PEQ:

> 7. Up till now we have spoken as physicists merely; we must now rise to metaphysics, making use of a great principle, commonly but little employed, which holds that nothing takes place without sufficient reason, that is to say that nothing happens without its being possible for one who has enough knowledge of things to have reason sufficient to determine why it is thus and not otherwise. This principle having been laid down, the first question we are entitled to ask will be: Why is there something, rather than nothing? For 'nothing' [the Null World] is simpler and easier than something. Further supposing that things must exist, it must be possible to give a reason why they must exist as they do and not otherwise.
> 8. Now this sufficient reason of the existence of the universe cannot be found in the series of contingent things, that is to say, of bodies and of their representation in souls [...] Thus the sufficient reason, which needs no further reason, must be outside this series of contingent things, and must lie in a substance which is the cause of this series, or which is a necessary being, bearing the reason of its existence within itself; otherwise we should still not have a sufficient reason, with which we could stop. And this final reason of things is called God.

Thus Leibniz is telling us here that (a) the existence of something contingent is not to be expected at all and (b) its actual existence cries out for explanation in terms of a non-contingent sufficient reason (which he articulates in his Section 8). Leibniz's ontological imperatives set the stage for the 'fundamentalist query' which pervades science and which is deeply ingrained in cosmology and particle physics: the Holy Grail of 'a Theory of Everything'; incorporating gravitation, space-time structure, and weak, strong and electromagnetic interactions in a single mathematical scheme. Explanatory dreams include the unification of all branches of science and the calculation of all parameters and constants of Nature from first principles (Barrow & Tipler 1986; Leslie 1978; Smolin 1997). Underlying this programme, note, is the idea that, de jure, *there should be nothing contingent*. If contingency obtains, then (a) there ought to be a reason for it and (b) this reason can be expressed in causal terminology. We could challenge Leibniz and his scions with a counter-question: Why should there be nothing contingent at all, rather than something contingent? and watch them get lost in unwarranted apriorism; but PSR dies hard. Indeed Albert Einstein famously written in his late years (1949, p. 63) the following prophetic-like words:

> I would like to state a theorem which at present cannot be based upon anything more than upon a faith in the simplicity, i.e., intelligibility, of nature: there are no arbitrary constants [...] that is to say, nature is so constituted that it is possible logically to lay down such strongly determined laws that within these laws only rationally completely determined constants occur [...].

On such grounds, I ask: what motivates scientists and philosophers not only to know how contingent certain aspects of the world are, but also to *want things not to be contingent*, building thus theories crafted to satisfy such desire? The Standard Model of Particle Physics is undermined with theoretical puzzles and arbitrary parameters (Redhead 1996) but it nonetheless stands as the undefeated world-champion of accuracy. Nobel-prize winner physicist Steven Weinberg seems to endorse Einstein's faith regarding the ontological structure of Nature when he asserts that

> [The Standard Model] describes everything we see in the laboratory. Aside from leaving gravity out, it is a complete theory of what we see in nature. But it's not an entirely satisfactory theory, because it has a number of arbitrary elements [...] If you ask, 'Why are those numbers what they are? Why, for example, is the top quark, which is the heaviest known elementary particle, something like 300,000 times heavier than the electron?' The answer is, 'We don't know. That's what fits experiment.' That is not a very satisfactory picture. (NOVA Interview, 2003)

If the world is less contingent, it is felt, then less remains to be explained. It is not just the desire to reduce intellectual labor which is at work here, though. Leibniz's voice echoes loud. The thing is, the greater the contingency, the less we know why things are a certain way rather than another. Many-worlds models in Cosmology can be seen as an attempt to justify the contingency within our theories which cannot be explained away by any other means but, it is felt, cries out for explanation.

fields as your imagining wishes, but they are conterfeits, for all that's worth. We would not have the faintest idea on how to start speculating about their physical properties. A compensatory dynamics would have to be sorted out. Would the new equations yield wave-like solutions? A constant value for the speed of light? And so on. Maxwell's equations are the very essence of electromagnetism. Altering them may lead the whole framework into bankruptcy. And if were these counterfeit electrodynamic theories proposed, in light of which criteria would they be evaluated?

A many-worlds theorist may agree to this, but object that he does not think the laws vary freely: the constants and free parameters do. That is just what I want to question. There exist some aspects of physics that cast doubt on claims of this sort: again in classical electrodynamics, global solutions to the Maxwell-Lorentz equations for spherically symmetric charge distributions, well-defined on all of Minkowski space and with zero initial velocities and positions (and for which the fluid density rapidly dilutes as *r*, the Euclidean coordinate, goes to infinity) can be shown, without much difficulty, simply not to exist (see Frisch 2004). Only *local* solutions, specified on an open set $\{t_1 < t < t_2, r_1 < r < r_2\}$, can be found, meaning that there exists a time $t_{max} < \infty$ such that any solutions with these initial conditions can be defined only for $|t| \leq t_{max}$ (see Parrot 1987, Chap. 5, Sec. 3 for detailed discussion and proof).[14] Conclusion, there can be no electrodynamically possible worlds on which these initial conditions hold—and yet zero initial positions and velocities are amongst the 'infinitely many possible' values in the possible world framework! We are, in this context, faced with the problem of understanding why are certain initial conditions 'allowed' and others 'forbidden'. May there be more 'law-likeness' in the initial conditions, in the particulars of the world at a given time, than we are willing to admit? May a little searching persuade us that the question many-worlds models are trying to answer is misconceived?

More examples can be drawn. Indeed we find in the thesis of philosopher of physics Lawrence Sklar, already cited, confirmation of this idea, in somewhat different form. In his "How Free Are Initial Conditions?" (1990), he teaches us the following:

> The usual formation of the special theory of relativity will contain a characterization of the spacetime as the standard Minkowski spacetime. This might be derived from some postulation of a relativity principle, especially concerning the velocity of light as constant and isotropic in all inertial frames [...] The nonexistence of causal signals propagating 'outside the light-cone' is taken as an empirical fact essential to the theory.
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> But, of course, the postulation of light as limiting causal signal is independent, logically, of the postulation of the Minkowski spacetime structure itself. So it becomes amusing to ask what a theory would look like in which did exist superluminal causal signs, the 'tachyons' of such great notoriety [...] the real problem with tolerating tachyons is the possibility they generate of causal paradox, that is of characterizations of state of affairs in some spacelike hypersurface that leads to the conclusion that *that very state of affairs could not exist*. How this occurs is easy to see. Let a faster-than-light signal propagate from a given event. Then there will be, on the basis of the usual relativistic stipulations for the determination of simultaneity for events at a distance from one another, some observer (some inertial reference frame that is) relative to which the tachyonic signal will be determined to be propagating from its origin event to distant events earlier in time, relative to the chosen frame, than that origin event. This must be so since in Miskowski spacetime any event outside the light cones of a given event will be in every time order (to the past of, simultaneous with and future with respect to) the given event for some inertial observer or other. Since the trajectory events of the tachyon are outside the light cone of the origin event, they must describe causal propagation into the past of the origin event for at least some inertial observers.
>
> But if causal signals of arbitrarily high velocity are permitted, then there will be some causal sign propagable from the reception of the tachyonic signal at event *o'* that causally influences what goes on at the origin event, *o*. For relative to some observer *o'* is before *o* and can serve as an origin of a causal signal propagated forward in time to *o* relative to the new observer. The net result is that postulating tachyons in conjunction with retaining Minkowski spacetime results in the possibility of the notorious closed causal loops in spacetime (pp. 553-554, italics mine).

[14] I chose not to tire the reader with the plodding definition-theorem-proof-corollary-definition process here (which for the case in point would be a rather long one).

The price one pays for allowing tachyons to exist is the dramatic effect of breaking down the metaphysics of causality: states of the world on a given spacetime hypersurface are granted to causally influence their own occurrence/condition/properties by means of such causal loops (I shoot myself before pulling the trigger that launches the bullet, for instance). This result is heavily freighted with consequences of both epistemological and metaphysical flavor. How is it related with our initial idea that Nature hinders our desires to choose parameters and initial conditions as freely as we like? Let us look at Professor Sklar's exposition more closely and see if more insight into the intuitions behind it can be gained. The speed of light *c* plays a major role in all physics due to the fact that it is the limiting speed v_{lim} for all local relative motion, as shown by the laws of standard relativistic physics for transformations of velocity derived from the Lorentz group. It is, in other words, a universal speed, invariant under velocity addition:

$$\forall v,\ v_{\text{lim}} + v \longrightarrow v_{\text{lim}}.$$

No physical object or information-carrying signal can exceed it. v_{lim} is Nature's means of defining causality. All physics, as far as we know, is Lorentz invariant and the peculiarity of the universal speed—the 'constant'[15] speed of light *c*—is characterized solely by the fact of its Lorentz invariance (a critical requirement of the Lorentz transformations is the invariance of the speed of light. This fact is used in the derivation of the Lorentz group and in the transformations themselves. It helped Einstein to find an answer to the question, 'How can we determine of two spatially separated events if they occur or not at the same time?'). But the objection against asking, 'Why is the speed of light 'constant'?' is grounded on the fact that no principled answer can be found. Declarations of 'impossibility by fiat' of trans-luminal propagation lack explanatory power, it is thought. The universal speed is understood as a sheer *contingent* feature of Nature.

Backward-causation, causal loops in spacetime that allow events to bootstrap themselves into existence, Gödelian time-travel and other faster-than-light related paradoxes are widely discussed because they are cute and their elucidation require the sort of apparatus that are stock-in-trade in philosophy[16]. It has been pointed out in the literature however that one need not hold to the posit of the universality of v_{lim} in order to have a well-behaved, 'physically possible' theory in which spacetime is Minkowski spacetime *if consistency constraints are satisfied*—meaning if Nature chooses the initial conditions of its collection of systems wisely and not promiscuously (Earman 1995, Sklar 2002). But note that one cannot keep one's cake and eat it too: either the speed-limit *c* must go up in the hierarchy of physical explanations and confine 'physical necessity' or, if the laws of nature do happen to allow causal propagation outside the light cone or/and spacetime has such a structure that closed causal loops are allowed, then some initial conditions are excluded from the set of possibility in a way that is generated by physical principles.

Hence if we aim to verify the crucial claim that all possible worlds obtain we have inferential knowledge which enables us to conclude that, relative to assumed laws, some values of parameters and initial conditions are impossible. They do not just 'happen to be' distributed in our world. Their *peculiarity* does not seem to follow from any law of nature or known physical principle, and we do not know how to explain them. They seem to be constraints we must however assume nature imposes if we are to explain important features of the universe we find ourselves in and if we are to keep our theories self-consistent. Many-worlds theories are couched in the terminology of the 'physical necessity' of laws

[15] Meaningful variations of the constants of Nature refer to dimensionless constants; only dimensionless constants have invariant significance under unit change. The speed of light is *not* one of them: its value can be changed at will by means of changing the coordinates or units used (rescale of time units or spatial distances). In the international standard for time units, its value is 299792458 meters per second; it can be, however, set without loss of generality to unity by means of proper unit change. That is actually a standard procedure in Physics since it simplifies calculations. It is important to keep in mind, however, that this does not mean the *physics* of the speed of light has changed: different metrics do not represent different physical speeds of light (see Ellis 2008, for an interesting discussion of the implications of varying the speed of light to the whole of Physics).

[16] Extremely interesting discussion and thought experiment on the "backwards causation malaise" are those put forward by Albert Einstein. I direct the reader to his "Über das Relativitätsprinzip und die aus demselben gezogenen Folgerungen" (On the Relativity Principle and the Conclusions Drawn from It), *Jahrbuch der Radioaktivität und Elektronik* 4 (1907): 411-462.

of nature and 'merely *de facto*' parameters and initial conditions but if we take the line of reasoning far enough we see that the fundamental premise cannot be made concrete nor plausible: we can easily find examples that do not fit this picture in any easy way. We can cook up worlds with a lone proton, or with a huge gravitational constant, or with a negative cosmological constant, or in which light travels at infinite speed—but these are not worlds in which the actual laws hold.

Part II: The empiricist constraints

§4. It was once thought to be a necessary truth that space was Euclidean, but with the development of non-Euclidean geometry and the overwhelming empirical corroboration of general relativity theory it became obvious that such a statement holds a contingent status—actually, that it is false. We can ask on such grounds whether the notion of necessity is coherent, and whether it has any important application. Are there *any* necessary truths of nature? If so, what makes them so? What is their basis? How can we know them? I have so far focused on the supposed 'contingency' of the free parameters and initial conditions of our theories which presumably would allow one to build counterfeit worlds in which different values of those obtain. It is thought that they are just 'contingently connected' to fixed, universal, *necessary* laws. I have attempted to show this view is problematic and hence the modal theories that depend on them equally so. The physical constraints are tighter than generally thought, and are required by the assumed laws themselves. Now I suggest we turn the philosophical attention to the status of necessity which is ascribed to the supposedly irresistible commands of the laws of nature. This view has been mainstream within scientific practice and philosophy since at least Newton and Descartes (Ayer 1959, Giere 1999), and I think it is, in simple, straightforward empiricist fashion, not warranted by the facts.

I begin with an epistemological question. How can we know that a certain statement, say, S, is necessarily true? Most of us can be, perhaps, satisfied with the following answer: S will be a candidate for being a necessary truth when it is, as far as we know, true, and we cannot conceive how it could have been different. World-builders (philosophers of modality and physicists) like the following definition: something is impossible when it is true in no possible world; and something is possible when it is true in at least one possible world. A necessary truth is true in all possible worlds. A contingent statement is true in at least one but not all possible worlds; the contingent statement is a contingent *truth* when it is true in the actual world. Necessary truths are invariant across all possible worlds, contingent truths across only some (Nozick 2001, p. 148). By this token we can notice without effort the 'laws' of our theories do not satisfy the definition, and for a very simple reason. The abstract laws of our most well-confirmed theories, or what have passed for them, are *ceteris paribus* laws; they are considerably removed to the world to which they are supposed to apply (Cartwright 2000). Take, for instance, Newton's famous inverse-square law. It is irrelevant to cases where there are nuclear or electric forces at work. One cannot even solve (exactly) the equations of motion for a *three-body* gravitational system! Now look at the room you are at. How many bodies are there in it, interacting? Newton's equations do not successfully bear the burden of describing the gravitational attraction between the bodies in your room. Neither they do for any complex, real-world system. The laws of physics cannot be universal truths for they are neither universal, nor true.

I am a realist and an empiricist and I think generalizations of law must be tested in the way other propositions are, that is, by the examination of actual instances. If propositions of fundamental laws of nature are propositions which state what invariably happens we face immediate difficulties because most physical situations are brought under any law of physics only by distortion; whereas such situations can be in many cases described fairly well by concepts and equations from more phenomenological, circumstantial laws. In *How the Laws of Physics Lie* Nancy Cartwright has built an extremely strong case against fundamentalism regarding the so-called 'laws of nature': "if the evidence is taken seriously", she writes,

> they must be judged false [...] if the fundamental laws of nature are true, they should give a correct account of what happens when they are applied to specific circumstances. But they do not. If we follow out their consequences, we generally find that the fundamental laws go wrong; they are put right by the judicious corrections of the applied physicist or the research engineer (1983, pp. 12-13).

She puts forth examples from classical mechanics, statistical mechanics and quantum theory (1983, 1989) which show quite conclusively the strict falsity of abstract laws. Other philosophers such as Michael Scriven (1961), Ronald Giere (1988, 1999) argue in favor or the same view; even Armstrong (1983, pp. 6-7) and Earman (1986, pp. 80-81) admit the strict falsity of the traditional examples of fundamental laws of nature. Of course the empirical generalizations we call laws of nature have great explanatory power, of course they help us make fast, fruitful and promising progress on the physical problems that concern us. You could ask, 'But how *could* something explain if it was not true?' In *The Scientific Image* (1980) van Fraassen argues this question is a mistake. He asks what reasons do we have for inferring from the fact that a set of concepts and equations explain the phenomena to the fact that they are true. We need not a conclusive reason, but we do need *a* reason. We know they do not literally represent the facts in the real world. But if correspondence to experience is *not* the ultimate arbiter of truth, what independent criteria do we have? Once you go soft on your notion of truth, you have started on a slippery slope. Many arguments hold their validity on their sleeve, like those of the 'I think, therefore I am' variety. But not 'A explains B. B is true, ergo A is true' (Cartwright 1983).

If you are convinced the laws of nature are universal and necessary truths and you build a theory of reality which relies on such a notion you must also be confident the concepts of 'law of nature' and their mysterious property of being 'necessary' are coherent ones with significant application. I have presented some reasons to undermine this confidence. To sum over all possibilities our minds can come up with and say they hold in different worlds may offer a structural and general criteria of reality and may bear the burden of explaining away the annoying property of 'contingency' of the free parameters and initial conditions of our theories; which may seem to be a great advantage. But things are not that simple. At any rate in science when you wish to interpret a theory you must ask, at minimum, what has the world to be like in order for the theory to be true. The mind boggles when that question is asked of many-worlds models in Cosmology and a rigorous answer is required. I do not mean by this I think there cannot be other worlds, other universes in addition to the one we observe. Of course there might be. Many-worlds theories are however built upon the assumption that laws of nature remain fixed under counterfactual perturbations in all possible worlds—due to their universality and strict necessity—whereas the constants, free parameters and initial conditions obtain with values varying along the real line; due to their contingency. It strikes me as implausible that the actual laws hold, say, in a lone-proton world devoid of electrons, neutrons, fields, etc.—entities to which protons are connected nomologically in our theories. Or that special and general relativity hold *in toto* within worlds in which super-luminal propagation is allowed. Retain Minkowski spacetime and Lorentz invariance and all sorts of causal pathologies would emerge in worlds where information is conceded to propagate outside the light-cone.

One more example may be helpful. Think of the entropic increase of the universe in its entirety. The expansion of the universe in one but not the opposite direction of time is not *per se* enough to explain the time-asymmetric entropic behavior of the universe in light of the underlying time-symmetric probability posit of thermodynamics. The existence of a macroscopic arrow of time in physics—and of course in biology, chemistry, in society, and so on—is related to boundary conditions in the past and future states of our universe. The fundamental physical laws we have are time-symmetric. All of them. They do not bear the burden of explaining this feature (Ellis & Sciama 1972, Zeh 1992, Uffink 2007). Cosmologist Roger Penrose has given strong arguments in favor of the claim according to which the observed existence of an asymmetric arrow of time is based crucially on our universe taken as a whole having had rather special initial conditions (Penrose 1989a, b, Earman 1992, Wald 2005). What we take to be a fundamental law of nature—the highly dear and famous Second Law of Thermodynamics—is in light of these suggestions the result of specific boundary conditions which obtained at the start of the universe. This is an extraordinarily significant idea. The Second Law determines, in a remarkable way, the form of many phenomena in chemistry and physics—it is equivalent to an *empirically determined principle of entropy increase* which has itself a treasure of applications (that does not involve knowledge of what that something is) but which also seems to be a consequence of specific quantitative and qualitative *contingent* physical processes. On reflection we reach the fruitful conclusion that there seem to exist particular constraints Nature imposes on phenomena in order for the general, time-asymmetric probability posit over micro-states of temporarily isolated systems to hold and not its false, time-reflected, anti-thermodynamic twin. We cannot of course change the initial boundary conditions of the universe and see what happens. The conclusion according to which had different cosmological initial conditions obtained, things may not have behaved thermodynamically seems to me, however, inescapable in light of these remarks.

I have suggested some values of constants of nature and initial conditions are a vital component of our overall description of the universe and I have rejected the contingent status ascribed to them on such grounds. I do not wish to defend here, however, some sort of Leibnizianism according to which only one world is possible, initial conditions, parameters, laws and all that. That is not what my words are meant to imply. I am skeptic about the extent of necessary truths, and about their status. One must keep in mind that solutions of equations regarding any physical system rarely hold outside the very controlled environment of the laboratory. This is not to say, note, that there are no truths in science or that there is no such thing as a law of nature. I think the field equations or the equations of motion of the most fundamental theories represent our best guesses as to the form of the basic structure of reality. But we have no reason to believe in their necessity, universality or strict truth. To say that something is necessary and universal is to say it holds in all circumstances and to say something is true requires exact correspondence. Empirical investigation and philosophical reflection show us that laws of nature are none of those. Our current fundamental physics is composed by a number of theories, the laws of which cannot all be true since they contradict one another. Quantum mechanics and general relativity are obvious examples. We do not know exactly what kind of world they are talking about when they describe our world; they leave us, more often than not, quite befuddled with respect to what properties and entities they posit. In closing, the morals I want to draw here are the following: we do not have, at the end of the day, a consistent, complete ontology of Nature we can truly rely on in order to make well-grounded counterfactual claims.

Perhaps the butterfly's flapping its wings in China can be a highly contingent matter, but by the time the storm hits Brazil it can be both difficult to change and also highly noncontingent. Perhaps it is a matter of necessity of some obscure sort that if I let go the mug of coffee I hold on my left hand it *must* fall.[17] But my intuition states that it is a purely contingent matter that I do, in fact, let go of the mug. Of course it is easier to think of possibilities than of necessities, easier to know that something is possible than that it is necessary. Whatever is necessary is possible, but not vice-versa. It is, however, I insist, a delicate matter to reason counterfactually in physics when we do not really know what we speak of, metaphysically, when we speak of the world. It is not clear where apples and mugs of coffee belong in a world of relativistic quantum fields. Science consists of many different types of theories and simple-minded accounts for the 'ultimate reduction' of all non-foundational theories in science to foundational ones just won't do. The hard fact is that, by the end of the day, only realization gives indubitable proof of what is possible.

The idea that infinitely many possible worlds in which laws of nature remain invariant and free parameters and initial conditions vary promiscuously exist *in the same way as our world does* appears, in the light of these suggestions, very hasty indeed. Surprisingly enough, *the mere assertion* of the existence of these counterfeit worlds is by many-worlds advocates understood as having explanatory power[18]. When we explain something in physics, however, we reveal its causes. To say other worlds are such and such does not explain *why our world* is such and such. There are no facts of the matter to support this view and the particulars of such worlds, assuming they exist, are unbeknown to us. We have no

[17] Sklar (1990) also emphasizes this fact.
[18] See the appendix attached to this paper.

resources whatsoever to access other-wordly behavior nor, I think, any theoretical *motivation* to focus our efforts on this direction. Their existence does not illuminate features of relevance of *this world* (Hacking 1975). I am ready to believe in the existence of many universes *if* and *when* I have direct empirical evidence for them. But as an empiricist I resist to do so merely because they are said to be 'the best explanation' for something which seems to me in need of no explanation to begin with.

§5. *Note regarding objections*. It may be argued that the laws themselves vary in different universes, thus 'contingency is all there is'.[19] If other worlds are ruled by different 'laws', however, invoking them to explain away the contingency found within the laws which rule *our world* loses meaning and intelligibility. Physics as we know it could not serve as springboard for many-worlds building, then—and what other jumping-off point for counterfactual speculation could there be, in this case? Being predicated, as we have seen, on the specifics of the (assumed!) contingency of the parameters and initial conditions related to the laws *we know*, many-worlds arguments which claim 'Laws of Nature themselves are subject to the wills of Chance' are fundamentally unsuccessful. An explanatory description says nothing when attached to absolutely everything.

Appendix: The many-worlds argument in Cosmology

Premise 1. The Laws of Physics are the same everywhere in our Universe (world);[20] *ergo* there exists some sort of necessity attached to them (they are 'physically necessary').

Premise 2. The values of the constants and free parameters of our theories, as the initial conditions which obtained in our Universe, could have been different. They are contingent aspects of Nature (Susskind 2006, Barrow & Tipler 1986, Wheeler 1977, Carter 1973, Carr & Rees 1979, Dyson 1979, Dirac 1937).

Premise 3. From all possible values and all possible initial conditions, only a small subset of those allows carbon-based life to emerge (Teller 1948, Leslie 1983, Barrow & Tipler 1986, Hogan 2000, Rees 2000).

(P1, P2) Conclusion 1. The Universe we observe is improbable with respect to the set of all possible values of constants, free parameters, and initial conditions (fine-tuned for carbon-based life).

(C1) Premise 4. The improbability of our Universe cries out for explanation (Dyson 1979, Leslie 1989, Parfit 1998, Rees 2000, Nozick 2001, Rundle 2004, Carroll 2010).

(P1, P2, P3) Premise 5. A choice between different contingent possibilities has somehow happened; the fundamental issue is what underlies this choice. Two possible explanations present themselves. Hypothesis 1: Cosmic Coincidence (either by (1a) creation *ex nihilo* (Vilenkin 1982, Swinburne 1991) or by (1b) a self-referential or self-sustaining universe (Dicke & Peebles 1979, Hawking 1987, Gott & Li 1997)). Hypothesis 2: Multiverse.

Premise 6. All proposals are mutually exclusive.

(P3) Premise 7. The Laws of Physics must be the same in all possible universes (worlds), if they exist (Ellis 2009, Rees 2007, Smolin 1997, Barrow & Tipler 1986, Lewis 1973).

Premise 8. Cosmic Coincidence does not explain away why our Universe is how it is, and not otherwise. It by-passes the contingent aspects of Nature; it does not *explain* them (Ellis 2007 and references therein).

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[19] I direct the curious reader to Leonard Susskind's *The Cosmic Landscape* (2006) for wild counterfactual flees of the imagination grounded on this view.

[20] Isotropy everywhere. See Walker (1944), Ehlers (1993) and Ellis (1971).

Premise 9. An improbable event is more likely to occur in a long sequence of trials than in a single trial (Law of Large Numbers; see Kolmogorov 1999).

(C1, P4, P5, P6, P8, P9) Conclusion 2. Hypothesis 2 is a better explanation of C1 than is Hypothesis 1 because (a) it fits the facts better and (b) it renders the existence of our Universe more likely.

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