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Engels, Trotsky and the natural sciences: a case study in cosmology

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Abstract: The topic of this essay is Trotsky's approach to dialectical philosophy and the natural sciences. We will first summarize the tradition whose mantle Trotsky inherited as it was developed by Engels. We will then consider Trotsky's relationship to the natural sciences. Trotsky, echoing Engels proclamations decades earlier, maintained that a dialectical philosophy is an essential guide to the work of the scientist while at the same time granting the autonomy and freedom of scientists to pursue their research. Trotsky had a lifelong interest in following the developments in the natural sciences. He also had an intuitive grasp of some important developments in the natural sciences that would only come to fruition decades after his death. We will then present a case study of how a dialectical approach to nature can assist in overcoming a crisis that is plaguing contemporary physics. Specifically we will discuss how a dialectical approach to nature can inform cosmology in the 21st century and avoid the philosophical pitfalls and dead–ends that mark the contemporary crisis in physics.

Keywords: Human Sciences; Marxism; Social History; Dialectical Materialism; Philosophy of Nature.

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Engels, Trotsky e as ciências naturais: um estudo de caso em cosmologia

Resumo: O tópico deste ensaio é a abordagem de Trotsky em relação à filosofia dialética e às ciências naturais. Resumiremos primeiro a tradição cujo manto Trotsky herdou à maneira que foi desenvolvida por Engels. Em seguida, vamos considerar a relação de Trotsky com as ciências naturais. Trotsky, ecoando as proclamações de Engels décadas antes, sustentava que a filosofia dialética é um guia essencial para o trabalho do cientista, ao mesmo tempo que garante a autonomia e a liberdade dos cientistas para realizar suas pesquisas. Trotsky teve um interesse em seguir os desenvolvimentos nas ciências naturais por toda a vida. Ele também tinha uma compreensão intuitiva de alguns desenvolvimentos importantes nas ciências naturais que só se concretizariam décadas após sua morte. Em seguida, apresentaremos um estudo de caso de como uma abordagem dialética da natureza pode ajudar a superar uma crise que assola a física contemporânea. Especificamente, discutiremos como uma abordagem dialética da natureza pode informar a cosmologia no século 21 e evitar as armadilhas filosóficas e becos sem saída que marcam a crise contemporânea na física.

Palavras-chave: Ciências Humanas; Marxismo; História Social; Materialismo dialético; Filosofia da Natureza.

Engels, Trotsky y las ciencias naturales: un estudio de caso en cosmología

Resumen: El tema de este ensayo es el abordaje de Trotsky hacia la filosofía dialéctica y las ciencias naturales. Primero resumiremos la tradición cuyo manto heredó Trotsky tal como fue desarrollado por Engels. Luego consideraremos la relación de Trotsky con las ciencias naturales. Trotsky, haciéndose eco de las proclamas de Engels décadas antes, sostenía que una filosofía dialéctica es una guía esencial para el trabajo del científico y, al mismo tiempo, otorga la autonomía y la libertad de los científicos para continuar su investigación. Trotsky tuvo un interés de toda la vida en seguir los desarrollos de las ciencias naturales. También tenía una comprensión intuitiva de algunos desarrollos importantes en las ciencias naturales que solo se materializarían décadas después de su muerte. A continuación, presentaremos un estudio de caso de cómo un enfoque dialéctico de la naturaleza puede ayudar a superar una crisis que azota a la física contemporánea. Específicamente, discutiremos cómo un enfoque dialéctico de la naturaleza puede informar la cosmología en el siglo XXI y evitar las trampas filosóficas y los callejones sin salida que marcan la crisis contemporánea de la física.

Palabras-Clave: Ciencias Humanas; Marxismo; Historia social; Materialismo dialéctico; Filosofía de la naturaleza.

Introduction

It is well known that Trotsky had a lifelong interest in the natural sciences and the convergence of the natural sciences with philosophy. More accurately, Trotsky felt that the philosophy of dialectical materialism – or what Bertel Ollman (1976, Chapter 3) called "the philosophy of internal relations", is critical in the theoretical work of the natural sciences. At the same time, Trotsky was a firm advocate of the right of scientists to pursue their work unencumbered by authority or dogma. Trotsky held this position long before the Stalinist bureaucracy imposed ideological shackles on science in the Soviet Union and the mass repression and murder of some of its leading scientists.

Trotsky's attitude to the natural sciences did not emerge out of nowhere but was part of the Marxist culture that had developed among a circle of the Russian revolutionary intelligentsia in the late 19^{th} and early 20^{th} century. As such, Trotsky stood on the shoulders of Friedrich Engels' *Dialectics of Nature* (1934). Although this unfinished manuscript of Engels was not published until 1925, the broad outlines of Engels view on a dialectical approach to nature were well known for decades. Furthermore, I have argued in a previous essay (STEINBERG, 2019) on Trotsky's Philosophical Notebooks that Trotsky's approach to dialectics was very different than the rigid and dogmatic version that was adopted by the "father or Russian Marxism", Georgi Plekhanov.

Before exploring any further Trotsky's understanding of the relationship between philosophy and the natural sciences, let us try to summarize the tradition that was inaugurated by Engels.

The legacy of Engels as the pioneer of a dialectical orientation for the natural sciences

In the collaboration between Marx and Engels it was left to Engels to systematically elaborate the basic principles of the philosophy of Marxism. This is not to say that Marx had no interest in philosophy and had nothing to say on that subject. But with the exception of his doctoral dissertation Marx never wrote a systematic and definitive treatise on philosophy. To be sure there is a great deal of philosophical material in the *Economic and Philosophical Manuscripts of 1844* and many intriguing reflections on philosophy in such works as the *Holy*

Family, *The German Ideology*, *The Poverty of Philosophy*, as well as the *Grundrisse*. But these works were either unpublished notes (as in the *1844 Manuscripts*) or brief though fertile reflections. That does not mean that Marx did not have a coherent and systematic philosophical outlook. Indeed I think it is possible to reconstruct such a philosophical outlook through a historically informed investigation of the published and unpublished works as well as correspondence. Bertell Ollman (1976, p. 40) has convincingly argued that Marx was a proponent of the philosophy of internal relations and was working within a tradition whose predecessors included Spinoza, Leibniz and Hegel. A key tenet of the philosophy of internal relations is the concept of Things as Relations. This is contrasted with the common sense view that there are Things that have some sort of independent existence and they enter into various Relations. In the philosophy of internal relations a Thing is its network of relations and can be nothing else. Thus for Marx, Capital – which is a "thing" in bourgeois economics, can only be properly conceptualized as a Social Relation. This relational view applies to both society and nature and is at the center of a fundamental part of dialectics. But while Marx employed the relational view in his understanding of human society, he never had the opportunity to systematically expound on his philosophical approach.

That task fell to his lifelong collaborator, Frederick Engels. To quote Bertell Ollman,

> Marx never dealt with the special problems raised by the materialist content he gave to the philosophy of internal relations… Provided that he could successfully operate with his relational view, he gave low priority to its elaboration and defense. That task was undertaken to some degree by Engels… (Ibid. p. 36)

Some scholars have questioned whether Engels views on the natural sciences coincided with Marx. Without getting into the details of that controversy I think that while it may be a mistake to completely conflate the views of Engels to those of Marx, it is also a mistake to think that Engels views were radically divergent from those of Marx.

Engel's work in the natural sciences in fact owes a great deal to Hegel, both his *Logic* and his *Philosophy of Nature*. This Marxist heritage of Hegel's contribution to the natural sciences has sometimes not been recognized due to the supposition that Hegel's idealism was an absolute barrier to his contributing anything of significance to the natural sciences. Yet not only are certain themes common to both authors, but there are literally dozens of direct references, either quotes or paraphrases, in Engels notes, to the two works of Hegel. To cite one example, take Engels' iconic statement summing up his materialist philosophy of nature, "Matter is unthinkable without motion." (ENGELS, 1934, Chapter 3)

What is not so well–known is that this statement is a paraphrase of a statement in Hegel's *Philosophy of Nature*, "just as there is no motion without matter, so there is no matter without motion." (HEGEL, 1970, p. 95)

Common to both Hegel and Engels was a lifelong interest in the natural sciences where new developments were followed closely. Of course this is not to deny that the science of the late 18th and early 19th century, which defined Hegel's landscape, was very different than the science of the latter part of the 19th century in which Engels was immersed. Engels had the benefit of reading Darwin's account of the evolution of species through a historical process of natural selection. In this way the Life Sciences became a historical science. A similar step was taken in the Physical Sciences with the pioneering nebular hypothesis of the origin of the solar system first articulated by Kant and Laplace. In the Introduction to his *Dialectics of Nature* Engels makes the point that what distinguishes the science of his time from the mechanical world outlook that was completed by Newton was the idea that nature has a history.

Engels characterized the ossified state to which the natural sciences were confined in the 18th century thus,

> In contrast to the history of mankind, which develops in time, there was ascribed to the history of nature only an unfolding in space. All change, all development in nature, was denied. Natural science, so revolutionary at the outset, suddenly found itself confronted by an out–and–out conservative nature in which even today everything was as it had been at the beginning and in which – to the end of the world or for all eternity – everything would remain as it had been since the beginning. (ENGELS, 1883, Chapter 1)

Engels then goes on to explain that this view of the world was first shattered not by the scientists but by philosophers and was only later validated by new discoveries in the natural sciences, specifically citing the Kant–Laplace theory of the origin of the solar system and Darwin's theory of evolution through a historical process of natural selection.

To round out this summary of the tradition in the dialectics of nature that began with Engels we should point out that Engels was motivated in this project by some very concrete political and cultural imperatives. Among these were the rise of very reactionary and reductionist interpretations of Darwinism championed by the German scientist Ernst Haeckel. This represented an accommodation with German imperialism and racism that threatened to infect sections of the German Social Democratic Party. The philosophical roots of these backwards trends were grounded in a form of mechanical, i.e. anti–dialectical, materialism and a positivist approach to the natural sciences.

Trotsky's understanding of the natural sciences within the tradition inaugurated by Engels

Trotsky stood on the shoulders of Engels both in advocating the benefits of a dialectical understanding of nature and his lifelong interest in the progress of the natural sciences. Furthermore, I have argued in a previous essay on Trotsky's *Philosophical Notebooks* that his approach to dialectics was very different than the rigid and dogmatic version that was adopted by the "father or Russian Marxism", Georgi Plekhanov. (STEINBERG, 2019) It was much closer to the spirit of Hegel and Marx and far removed from the stultifying dogma of "diamat" that later became the official ideology of Stalinism. It's worth noting, if only as an aside, the crucial influence that the Italian Marxist Antonio Labriola had on Trotsky. This was argued by Michael Löwy who wrote,

> Trotsky's starting point, therefore, was this critical, dialectical and anti-dogmatic understanding that Labriola had inspired. (LÖWY, p. 152)

Without Labriola's incisive opposition to the sterile reductive materialism of the Second International in the decades prior to the First World War, it's hard to imagine Trotsky being able to make his theoretical breakthrough on permanent revolution in 1906. (see CHATTOPADHYAY, 2006, pp. 78–82). (As regards science, the influence of Labriola is evident in Trotsky's warnings against the dangers of reductionism in the natural sciences, particularly in the 1925 speech, *Dialectical Materialism and Science* – warnings that are remarkably prescient, especially in relation a contemporary field like neuroscience. We once more encounter an even more insistent anti–reductionism in the *Philosophical Notebooks* Trotsky maintained during his final period of exile). Trotsky's views on the natural sciences are expressed in a number of essays and speeches as well as in a series of fragmentary notes he wrote in his *Notebooks* during his last period of exile.

His influence on the philosophical and scientific culture of the early years of the Soviet Union cannot be underestimated. One indication of his prominence in this area can be gauged by the fact that he wrote an open letter to the editors of the first issue of the theoretical journal, *Under the Banner of Marxism*. Trotsky was thrust into the ideological debates that were raging in the Soviet Union in the 1920's as a result of the specific historical circumstances then facing the young revolutionary regime that had just survived a civil war. He wrote about these circumstances in his letter to the journal,

> The soviet state is a living negation of the old world, its social order, personal relationships, views, and beliefs. But, at the same time, the soviet state itself is still full of contradictions, holes, inconsistencies, vague fermentation—in short, the phenomena in which the legacy of the past intertwines with the germs of the future. In such a deeply fractured, critical, and unstable era as ours, education of the proletarian vanguard requires serious and reliable theoretical foundations. It is necessary to arm a young worker's thought and will with the method of the materialist worldview so that the greatest events, the powerful tides, rapidly changing tasks, and methods of the party and state do not disorganize his consciousness and do not break down his will before the threshold of his independent responsible work. (TROTSKY, 2011)

Lenin also wrote a letter to the very next issue of *Under the Banner of Marxism* where he explicitly brought out his view of the relationship between dialectical philosophy and the natural sciences. In his words,

> In my opinion, the editors and contributors of Pod Znamenem Marksizma should be a kind of "Society of Materialist Friends of Hegelian Dialectics". Modern natural scientists (if they know how to seek, and if we learn to help them) will find in the Hegelian dialectics, materialistically interpreted, a series of answers to the philosophical problems which are being raised by the revolution in natural science and which make the intellectual admirers of bourgeois fashion "stumble" into reaction. (LENIN, 1972)

It is noteworthy that whereas Trotsky's remarks were restricted to the need to train young workers in the theoretical foundations of materialism and atheism, Lenin while endorsing those sentiments, chose to zero in on dialectics, to specifically emphasize the necessity of educating not only young workers, but scientists, in dialectics, albeit a materialist reinterpretation of Hegel's dialectics. This is not to imply that Trotsky was less interested in dialectics than Lenin, only that at this point in his work, he did not emphasize it to the degree that Lenin did. This would change in the next few years as Trotsky's grasp of the critical role that education in dialectics would evolve.

As one of the leaders of the October Revolution and a prominent official of the Soviet Union, Trotsky was frequently invited to address various audiences. The most well–know of Trotsky's pronouncements on the role of dialectics in the natural sciences was a speech he gave in 1925 to the Mendeleyev Society in Moscow, where he had been invited to receive an honorary degree.

His theme was precisely how the revolution had liberated the sciences from the requirements of capital and how this makes possible the advance of both scientific theory and its practical applications. Trotsky in his talk made a case to this audience that even if they are not Marxists politically, their scientific work can benefit enormously if they learn to think philosophically as dialecticians.

One of the points Trotsky made in his speech to the Mendeleyev society is that the advancement of science can be aided by a proper philosophical approach and hindered by a bad one. That does not mean you can proceed purely with a philosophical approach without mastering chemistry or physics. He called that approach "Communist arrogance" – "*Komchvanstvo*" in Russian. But equally wrong is the idea that you can learn chemistry and ignore philosophy, specifically dialectical philosophy. That is a form of "Chemistry arrogance" – "*Khimchvanstvo*" in Russian.

Trotsky's remarks about "Communist arrogance" have a special significance given the historical context behind his speech. He was speaking shortly after the emergence of the Left Opposition and the growth of a bureaucracy within the Soviet state and the Communist Party. He was both sending a broad message about the dangers of the newly emerging bureaucracy and assuring his audience that the Soviet state would not allow any bureaucrats to dictate an ideological litmus test to scientists. Unfortunately, the Left Opposition, headed by Trotsky, lost the struggle with the Stalinist bureaucracy and not only were ideological litmus tests imposed within a few short years of this speech, but leading scientists such as the physicist Boris Hessen and the agronomist Nikolai Vavilov, were murdered by the bureaucracy.

In this talk Trotsky goes beyond the need for materialism and speaks specifically, as Lenin did, about how an understanding of dialectics could be an invaluable tool for the natural scientist. On the other hand, Trotsky acknowledged that even a scientist who was ignorant of dialectics can adopt dialectics unconsciously. He cites for instance the case of Darwin,

> Darwin can be placed in the same category. This highly gifted biologist demonstrated how an accumulation of small quantitative variations produces an entirely new biologic "quality" and by that token he explained the origin of species. Without being aware of it, he thus applied the method of dialectic materialism to the sphere of organic life. Darwin although unenlightened in philosophy, brilliantly applied Hegel's law of transition from quantity into quality. At the same time we very often discover in this same Darwin, not to mention the Darwinians, utterly naive and unscientific attempts at applying the conclusions of biology to society. To interpret competition as a "variety" of the biological struggle for existence is like seeing only mechanics in the physiology of mating. (TROTSKY, 1940).

But even if a great thinker like Darwin can become, to some extent, an unconscious dialectician, his lack of familiarity with dialectical philosophy will inevitably lead him down some false paths, in this case, that of a crude reductionism.

Trotsky used the occasion of this talk to sound the alarm against the dangers of reductionism. He insisted that you cannot reduce psychology to physiology, and that each branch of the sciences has its own methods and procedures although "in the final instance" they are all interlinked. Thus he says,

> Chemistry is a powerful pillar of physiology with which it is directly connected through the channels of organic and physiological chemistry. But chemistry is no substitute for physiology. Each science rests on the laws of other sciences only in the so–called final instance. But at the same time, the separation of the sciences from one another is determined precisely by the fact that each science covers a particular field of phenomena, i.e. a field of such complex combinations of elementary phenomena and laws as require a special approach, special research technique, special hypotheses and methods. (TROTSKY, 1940)

Another speech, one that Trotsky gave in 1926 to a group of radio technicians, is often cited as representative of his views on science. It was later published with the title, *Radio, Science, Technique and Society*. However, this talk is for the most part a reflection on technology rather than on theoretical issues concerning the natural sciences. Nevertheless, his views on the relationship between philosophy and the natural science are expressed here as well. It is included in the following remark about the philosophical battle against mystifying interpretations of new discoveries about matter,

> The more science learns about matter, however, the more "unexpected" properties of matter it discovers, the more zealously does the decadent philosophical thought of the bourgeoisie try to use the new properties or manifestations of matter to show that matter is not matter. The progress of natural science in the mastering of matter is paralleled by a philosophical struggle against materialism. Certain philosophers and even some scientists have tried to utilize the phenomena of radioactivity for the purpose of struggle against materialism: there used to be atoms, elements, which were the basis of matter and of materialist thinking, but now this atom has come to pieces in our hands, has broken up into electrons, and at the very beginning of the popularity of the electronic theory a struggle has even flared up in our party around the question whether the electrons testify for or against materialism. Whoever is interested in these questions will read with great profit Vladimir Ilyich's work on *Materialism and Empirio–Criticism*. In fact neither the "mysterious" phenomena of radioactivity nor the no less "mysterious" phenomena of wireless transmission of electro–magnetic waves do the slightest damage to materialism. (TROTSKY, 1974)

He also made the following statement on the importance of a dialectical approach to the natural sciences and contrasted that with the non–dialectical thinking that limited one of Russia's greatest scientists, Mendeleyev,

> Radioactivity, as we have already mentioned, in no way constitutes a threat to materialism, and it is at the same time a magnificent triumph of dialectics. Until recently scientists supposed that there were in the world about ninety elements, which were beyond analysis and could not be transformed one into another – so to speak, a carpet for the universe woven from ninety threads of different qualities and colours. Such a notion contradicted materialist dialectics, which speaks of the unity of matter and, what is even more important, of the transformability of the elements of matter. Our great chemist, Mendeleyev, to the end of his life was unwilling to reconcile himself to the idea that one element could be transformed into

> another; he firmly believed in the stability of these "individualities", although the phenomena of radioactivity were already known to him. But nowadays no scientist believes in the unchangeability of the elements. Using the phenomena of radioactivity, chemists have succeeded in carrying out a direct "execution" of eight or nine elements and, along with this, the execution of the last remnants of metaphysics in materialism, for now the transformability of one chemical element into another has been proved experimentally. The phenomena of radioactivity have thus led to a supreme triumph of dialectical thought. (Ibid.)

It should also be noted that Trotsky, while a firm advocate of the benefits of technology in harnessing the power of nature, was also mindful of the destructive potential of technology when its use serves the profit motive.

> Technique and science have their own logic – the logic of the cognition of nature and the mastering of it in the interests of man. But technique and science develop not in a vacuum but in human society, which consists of classes. The ruling class, the possessing class, controls technique and through it controls nature. Technique in itself cannot be called either militaristic or pacifistic. In a society in which the ruling class is militaristic, technique is in the service of militarism. (Ibid.)

An appreciation of Trotsky's approach to the natural sciences and how it matured over the years can be further examined by a look at the philosophical notebooks he kept during his last period of exile in the 1930's (TROTSKY, 1998). By that time, Trotsky's encounter with positivists like Max Eastman had convinced him more than ever that a dialectical approach to the natural sciences is a requirement. By "positivism" we are referring to a philosophical approach to the natural sciences that questions the reality of the objective world. As far as the positivist is concerned, questions about the nature of the real world are meaningless and should be banished from the lexicon of science. The only thing that is relevant to the scientist are observations and experiments they perform and generalizations from those observations. The godfather of positivist philosophy was the physicist Ernst Mach. By the 1920 and 1930's positivism had coalesced into an official movement called Logical Positivism led by a group of Viennese philosophers, Moritz Schlick, Carl Hempel, Otto Neurath and Hans Reichenbach. It was not coincidentally contemporaneous with the adoption by the physics community of that time of an anti–realist philosophical position that came out of the new field of quantum physics known as the "Copenhagen Interpretation". The Logical Positivist provided a philosophical rationalization for the anti–realist position of Copenhagen as presented by Niels Bohr and Werner Heisenberg[2].

It is not clear how conversant Trotsky was with these philosophical debates within the scientific community but he was certainly acquainted with positivism as a philosophical trend that was contemptuous of dialectics and philosophical questions in general. He wrote, in his Notebooks, undoubtedly having his encounter with Max Eastman in mind,

> To the representatives of positivism, with his limited point of view, we say that all the contemporary sciences [...] use the law of dialectical thinking at every step just as the shopkeeper uses the syllogism or as Monsieur Jourdain uses prose: without ever knowing it. Precisely because of this the average scholar preserves many habitual traits resembling those of impermeable bulkheads, not posing those questions which should issue from the general movement of scientific thought, and cravenly ceases to draw general conclusions, when they call for a dialectical leap. (TROTSKY, 1998)

Most astonishing and a clear example of Trotsky's brilliance, was his anticipation of a major breakthrough in evolutionary theory by more than 40 years. It was written as an aside in an assessment of Karl Kautsky. As it follows,

> [...] there are long ages of relative equilibrium in the world of livings things, when the laws of selection operate almost imperceptibly, and different species remain relatively stable, seeming the very embodiment of Plato's ideal types. But there are also ages when the equilibrium between plants, animals, and their geophysical environment is disrupted, epochs of geobiological crisis, when laws of natural selection come to the fore in all their ferocity, and evolution passes over the corpses of entire plant and animal species. On this gigantic scale Darwinian theory stands out above all as the theory of critical epochs in plant and animal development. (TROTSKY, 1977, p. 30)

This passage is a remarkable anticipation of the paradigm shifting theory of punctuated equilibrium developed by Niles Eldridge and Stephen Jay Gould. Trotsky's discussion of long periods of stability of a species when evolution seems to stand still which are then "punctuated" by what appear to be sudden

[2] A good summary of the Logical Positivists and their convergence with the Copenhagen Interpretation of quantum physics can be found in the recently published book, "What is Real? The Unfinished Quest for the Meaning of Quantum Physics", Chapter 8, 'More Things in Heaven and Earth', by Adam Becker. Basic Books, 2019.

transformations that give rise to a new species is a key point of the theory of punctuated equilibrium – a theory that angered many traditional Darwinists. The gradualist approach of the fundamentalist Darwinists did not leave room either for sudden transformations, or for the long periods of stability. Punctuated equilibrium also went against the grain of traditional geology which since the time of Lyell had denied the role of catastrophic changes. We now know that catastrophic environmental changes can lead to mass extinctions and the emergence in a brief time period of new species, even of an entire complex of new species. In order to turn Trotsky's insight into a scientific research project, one more thing is needed; seeing the connection between these long periods of stability interrupted by short periods of dramatic speciation events with the fossil record[3].

If one were to sum up Trotsky's approach to the natural sciences it would be that as his thinking on the subject matured, he became convinced that an understanding of dialectics was of inestimable value to the work of the natural scientist particularly in avoiding the pitfalls of gradualism and reductionism.

Let us now probe in a more systematic manner what a dialectical approach to physics looks like.

A dialectical approach to physics

The field of physics that deals with the Universe as a Whole, cosmology, has made enormous strides in the last few decades. Yet, strangely enough, the progress in cosmology has thrown it into crisis. It was only about 50 years ago that the field of cosmology was almost completely a purely speculative enterprise. Very little could be observed of verified. But in the past few decades there has been a revolution in our understanding of the universe. One of the first was the discovery of the cosmic background radiation which for the first time gave us a window into the early universe. And just a few years ago the world of physics was astonished by the verification of gravitational waves. And most recently the Event Horizon project gave us the first image of a black hole. We can now deduce the age of the universe, the time from the Big Bang, with a great deal of precision. We know now that the Universe is approximately 13.7 billion years old. While today cosmology still retains its speculative element, it now has a good deal of observational data with which to work. But our ability to make sense of all this

[3] For a fuller discussion of Trotsky as a Marxist theoretician, see my essay *Trotsky as a Marxist Theoretician: The Evidence in the Notebooks*, Critique, Volume 47, 2019 – Issue 2, by Alex Steinberg.

new information seems more limited than ever. What this points to is that the growing body of knowledge we have gained has come up against the limits of our ability to develop a coherent theory or theories to understand it. There are a number of reasons for that but one of the most important is the disdain that physicists have developed for philosophy. Unlike the pioneers of the early 20th century such as Einstein who had a deep engagement with philosophical issues and insisted that they were an invaluable aid in working through the fundamental theories of nature, most contemporary physicists have been imbued with the ethos of a pragmatic approach that disdains philosophical issues. This attitude was nicely summed up in the words attributed to Richard Feynman, "Shut up and calculate"! (MERMIN, 2004) But just because you ignore philosophical questions doesn't mean they disappear. They simply return through the back door, as a series of ideas that are simply taken for granted.

To get beyond these conceptual limitations it is necessary to turn to the philosophical enterprise that has evolved in partnership with the natural sciences, the dialectical philosophy of nature.

In the period following the Scientific Revolution of the 17th century, the German philosopher Gottfried Wilhelm Leibniz articulated a version of dialectical philosophy. Credit must be given to Bertel Ollman for drawing attention to Leibniz's important role in the development of dialectical philosophy which can be called more broadly "the philosophy of internal relations".

Leibniz was also an important contributor to the Scientific Revolution in his own right, having developed, independently of Newton, the modern calculus. Leibniz was a philosophical opponent of Newton. In the Newtonian universe, there is matter and there is motion and the two are irreducible to each other. Motion happens as a result of an external force acting on matter. In the Leibnizian universe matter and motion are intrinsically related concepts. We cannot understand what matter is without motion and vice versa. Also, space and time must be brought into the picture since it makes no sense to speak of motion without at least an implicit understanding of what we mean by space and time.
The significance of the Leibniz/Hegel/Engels philosophical standpoint for physics is – in the words of a contemporary physicist – that

> […] there should be nothing in the universe that acts on other things without itself being acted upon. All influences or forces should be mutual.

> Einstein invoked this principle to justify his replacement of Newton's theory of gravity by general relativity. His point was that Newton's absolute space tells bodies how to move, but nothing is reciprocated; the bodies in the universe do not influence absolute space. Absolute space just is. In Einstein's theory of general relativity, the relationship between matter and geometry is reciprocal: Geometry tells matter how to move and, in turn, matter influences the curvature of spacetime. Nor can anything affect the flow of Newton's absolute time. Newton hypothesizes that it flows the same whether the universe is empty or full of matter. In general relativity, the presence of matter affects the behavior of clocks." (SMOLIN, 2014, p. 2014)

Dialectical thinking is how we can conceptualize movement and change and the Whole and Parts relationship. The complex forms of progress made in the natural sciences (as well as in philosophy) can be rationally reconstructed dialectically. This is often explained as a mysterious process requiring a mastery of Hegelian terminology to understand. But this is a false assumption. While a study of Hegel can be beneficial for the scholar, it is not a requirement for grasping what we mean by dialectics. One way of conceiving this process that demystifies it is to see it as a movement by indirect proof. And contrary to what has been asserted by both friends and enemies of dialectics, it is perfectly consistent with the law of the excluded middle that is a cornerstone of traditional logic. Dialectical logic does not assert that a thing can both be and not be in the same way at the same time since its province is motion and change while formal logic has for its province an idealized set of relations that are timeless.

To illustrate what we mean when we say that dialectical thinking progresses through contradiction, I offer the following simplified narrative.

We begin when the implication of a theory reveals itself to be self–contradictory. Either its predictions are falsified by empirical evidence or some of the implications of the theory contradict each other. You can call this the moment of negation.

What does "implication" mean in this context? Simply that the properties that define A require B and its properties. An example of this in the writings of Marx is his statement that "Production is [...] at the same time consumption and consumption is at the same time production." (MARX, 1971).

The initial theory contains a previously unknown feature or argument. A–>B (A implies B). But when examined further B–>C (B implies C) we learn that, contrary to our expectations, A does NOT imply C (A=/C). Or to put it another way, if C is true, A, as originally formulated, cannot be true. That is when we need to find a new formulation of A that preserves its relationship to B while also being consistent with C.

The recognition of the problem is the impulse to resolve the contradiction through a higher more comprehensive truth, one that pays due respect to what was the relative truth contained in each side of the previous articulation.

A new conception of A, a candidate theory if you like, emerges that allows B and C to both be true. The discovery of the new more comprehensive theory is the moment of the negation of the negation.

Of course in the natural sciences we are not dealing with just a logical construction. All theories must be confirmed empirically through experiment and observation. Furthermore, the very impulse to develop new theories and new technologies is rooted in history, in the practical impulses grounded in class society. For example, while scientific curiosity is certainly a motive for driving many scientific enterprises, it is rarely the whole story. We know for instance that Galileo was encouraged in his experiments on the motion of falling bodies by the requirement of the Italian city states of the time to develop more accurate artillery weapons.

We can illustrate this movement through contradiction by examining a famous thought experiment [*Gedankenexperiment*] that Einstein devised in formulating his special theory of relativity. I am referring to the thought experiment of the observer at a train embankment and an observer on a moving train both seeing beams of light from two different points.

There are two postulates that Einstein makes before any further consideration.

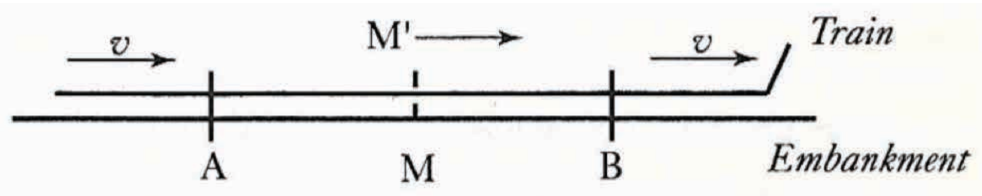
1. Motion is relative. The effects of the laws of physics must look the same to every observer in uniform motion.

2. The speed of light through empty space is constant. The velocity of light through empty space should be the same as that measured by every observer in uniform motion. The thought experiment then considers the following scenario:

- Observer *M* stands on an embankment, while observer *M'* rides on a rapidly traveling train. At the precise moment that *M* and *M'* coincide in their positions, lightning strikes points *A* and *B* equidistant from *M* and *M'*.

- Light from these two flashes reach M at the same time, from which M concludes that the bolts were synchronous.
- The combination of Einstein's first and second postulates implies that, despite the rapid motion of the train relative to the embankment, *M'* measures exactly the same speed of light as does *M*. Since *M'* was equidistant from *A* and *B* when lightning struck, the fact that *M'* receives light from *B* before light from *A* means that to *M'*, the bolts were *not* synchronous. Instead, the bolt at *B* struck first. (EINSTEIN'S THOUGHT EXPERIMENTS)

Figure 1: *Albert Einstein - Scanned from Relativity, the Special and General Theory (1916). Public Domain.*



It was already known that the speed of light is constant, 300,000 kilometers per second, regardless of the frame of reference of an observer. This was proven in the famous Michelson–Morley experiment. Therefore, how to account for the fact that an observer in one frame of reference sees two events as occurring simultaneously while an observer in another frame of reference sees the same two events as not simultaneous. In the example we are considering observer M' sees the lightning strike from point B before the lightning strike from point A. It cannot be a result of the beam of light reaching the observers at different speeds from point A and point B because that was disproven in the Michelson–Morley experiment. We expect the two observers to experience the two events in the same way – either simultaneous or B striking before A – because we assume that the experience of time is the same for both observers. The only way out of this conundrum is to hypothesize that the experience of time is different for the observer on the moving train than the observer on the embankment. If we abandon the assumption that the experience of time is the same for both observers, then we can maintain Einstein's two postulates.

And this was the move that Einstein made. But that simple step overturns 400 of years of established physics. What Einstein's special theory of relativity introduces is the idea of the "relativity of simultaneity". It's a conception that would have been inconceivable in the framework of Newtonian physics. For according to Newton, time is absolute and does not depend on the frame of reference of an observer. The measurement of time has no relation to the velocity of the motion of a body through space. Einstein overturns this entire edifice. With this thought experiment he was able to bring together space and time into something called "spacetime". Time and space are intrinsically related to each other. Of course physicists represent the relationships between time, space, matter and motion in the language of mathematics. But mathematics is not required to grasp the conceptual basis behind those relationships. A simple thought experiment will do.

Einstein's thought experiment has had numerous empirical confirmations. The relative experience of time according to the frame of reference of an observer has been verified by an experiment in which an atomic clock was taken on an airplane travelling for several thousand miles at a speed of hundreds of miles per hour. The plane was also travelling in the direction of the rotation of the Earth. A companion atomic clock whose time setting was coordinated with the travelling clock was left on the ground. When the two clocks were compared at the end of the journey it was found that the clock in motion had lost a fraction of a second compared to the stationery clock. This was direct evidence that time slows down for the observer in motion compared to an observer in a stationary state.

Examining this thought experiment in the language of dialectics, one can say that it is a great illustration both of the moment of negation when the implications of an existing theory are found to be self–contradictory and the moment of the negation of the negation when the contradiction is resolved through a higher more comprehensive theory.

In those areas of the natural sciences where direct observation or experimentation is not possible or highly impractical, this is where we see the kind of thought experiments that are very similar to the enterprise of philosophy. What we often witness is that these thought experiments develop in conjunction with experiment and observation. Sometimes the level of technology does not permit an experiment to confirm or falsify a thought experiment when it is initially formulated. But then perhaps decades after the initial thought experiment is constructed, the level of technology catches up and experiments are possible. And it's also possible that certain thought experiments – even backed up by elegant mathematics – are in principle impossible to confirm or falsify. In those cases, the thought experiment has simply gone astray. That is undoubtedly the case with the "multiverse" hypothesis which one contemporary critic, Sabine Hossenfelder (2019), has called a "religious" statement instead of a scientific one since it is in principle impossible for us to have any interaction with other universes.

Einstein was certainly not the first scientist to conduct thought experiments. They are already prominent in the work of Galileo. And he has been followed by many other physicists who have the tools of thought experiments to explore the limits of our conceptual understanding of the fundamental phenomenon of nature. And in a dialectical philosophy of nature, if it is not to be a vacuous mental exercise, the science of one's time must be the underlying prerequisite. This means that in those areas of fundamental theory about the nature of the universe, the work of the physicist needs to be informed philosophically and you can also say that philosophy must be scientifically literate to be relevant in this area.

A case study of the crisis in cosmology and its possible resolution

The following discussion is meant to illustrate how a dialectical approach to the natural sciences provides the key for a fundamental breakthrough in cosmology. It is a case study in the dialectical approach to physics. We are not suggesting that either Engels or Trotsky had a hand in this endeavor, merely that the approach they championed in the natural sciences, one that is derived from the philosophical tradition of Leibniz, Hegel and Marx, provides the theoretical foundation for advances in our understanding of the universe.

In regard to the physics of the 21st century one can say that the failure of physicists working in the area of fundamental theory to ground their scientific endeavors within a philosophical foundation has led to a crisis in physics. This is a topic that has received much attention recently. One of the first explorations of the contemporary crisis in physics was Lee Smolin's book *The Trouble with Physics* (2006). In that work he berates string theorists for spinning out theories simply because they can find elegant mathematical solutions without any connection to their philosophical coherence or the possibility of their observational confirmation. The results are that speculation in cosmology, that branch of physics that attempts to grasp the Universe as Whole, has now led to some absurd hypotheses unmoored from any connection to Reality. For instance, there is the challenge posed by the idea that we do not inhabit a Universe, but a Multi–verse in which there are multiple universes, perhaps an infinite number, to which we can have no access.

Or take the hypothesis put forward by many contemporary cosmologists, and which has gained acceptance by a large section of the lay public thanks to the popular works of Stephen Hawking and others, that Time did not exist prior to the Big Bang.

I would maintain that the philosophical tradition that is most accommodating to the work of the cosmologist is the one inaugurated by Engels and championed by Trotsky, the dialectical philosophy of nature. The physicist Lee Smolin has provided a dialectical approach to cosmology that offers a unique solution to the philosophical and scientific problems involved in a theory of the origin and evolution of the universe. Smolin is not explicitly a proponent of dialectics, but there is little doubt that he is a practitioner of this tradition. He often cites the 17th century German philosopher Leibniz as his inspiration and contrasts Leibniz's relational view of nature with Newton's idea of absolute space and time. As we have noted, the Marxist philosopher Bertel Ollman gives credit to Leibniz as being one of the first to articulate what he calls the philosophy of internal relations. Smolin also argues for a view of the world that is always in a process of motion and change. Nothing is static and unchanging in Smolin's ontology. Over the past 25 years Smolin has developed a theory of the nature and origin of the universe that is radically dialectical and fulfills the project first envisioned by Engels – of completing the transformation of natural science into historical science.

In a series of books and scientific papers, including *The Life of the Cosmos*, published in 1997, *Time Reborn*, published in 2014, and *The Singular Universe and the Reality of Time* written with Roberto Mangabeira Unger and published in 2015, Smolin provides what I would call a positive, dialectical speculation about the Universe as a Whole, its beginning and its evolution.

In summarizing Smolin's project we first need to see what he is reacting against. He calls it the *Newtonian paradigm*. The *Newtonian paradigm* emerges with the Scientific Revolution of the 17th century but it has much older roots. Those roots go back to Plato and even prior to Plato to the philosopher Parmenides. For it was Parmenides who first identified Reality with that which is unchanging. Parmenides nemesis in the history of philosophy was the philosopher of Motion and Change, Heraclitus. And you might say that dialectical philosophy looks to Heraclitus as its inspirer while opponents of dialectics, those who deny the reality of motion and change are followers of Parmenides.

Now what the Newtonian paradigm takes from the tradition or Parmenides and Plato is the idea that there are Eternal Truths and that the role of philosophy and of science is to discover those Eternal Truths that exist in some realm outside of history and outside of Time. The modern version of this states that mathematics is the language by which we discern the eternal and never changing laws that describe our world. Indeed, the world is in some sense forced to conform to those laws. It cannot do otherwise.

A corollary of this is the thesis of determinism. This is strongly implied in Newton already and contemporary physics, despite quantum theory, has really not gone beyond it. What this means is that given the initial conditions and given those laws that govern the behavior of objects in the universe, you can predict with absolute precision their future behavior. This means that novelty, contingency, do not really exist in our universe. The only reason we think there is contingency is because we do not have sufficient knowledge either of the Laws or of their initial conditions. But theoretically, if we did, then we can truly say that there is nothing new under the sun.

Still another tenet of the Newtonian paradigm is that you can extrapolate the results you see experimentally from a system that you isolate from the surrounding environment, and use those results to apply to the larger environment. This model for doing science has been very successful up to a point, but breaks down completely when that larger environment is the universe as a whole.

Finally, what the Newtonian paradigm encapsulates is a non–relational view of the Universe. It is the polar opposite of the relational view of Spinoza, Leibniz, Hegel and Marx. Space and Time are external to matter and are little more than a kind of container within which matter moves. Relativity theory did much to shatter that view, by showing an intrinsic relationship between space, time and matter in motion, but it did so at a price, as we shall see, by making Time disappear into a line on a graph representing something called "spacetime".

Lest I overstate things, Smolin makes it clear that he thinks the Newtonian paradigm has in many ways been highly successful. The method it employs has been called "doing physics in a box". By this is meant that to make progress we look at certain phenomena and try to understand how they work by taking certain factors as intrinsic to those phenomena, and isolating those from other factors, that we deem to be external and irrelevant. This procedure has, according to Smolin, proved very successful.

But physics in a box breaks down when the box in question is the entire universe, i.e. there is nothing outside of the box which we can set aside. And cosmology is where we consider a whole that contains all there is. There is no larger whole of which it is a part. At that point whatever relative progress was made by analysis of parts breaks down completely. This is what Smolin refers to as the crisis of physics. It is the inability of physics to rework its understanding of basic concepts such as space, time matter and motion that prevents it from making fundamental progress in unifying the different strands of physics and presenting a coherent picture of the workings of the universe as a whole. And although Smolin does not say so explicitly, I think what he is getting at is that non–dialectical thinking has reached its limits.

The importance of Smolin's work is that he very clearly shows the limits of the non–dialectical understanding of nature that has emerged out of the Scientific Revolution of the 17th century. And he suggests a dialectically grounded theory of the origins of the universe that can get us beyond this crisis in physics. He does not claim to have proven his theory. There are gaps in his theory that he acknowledges, but he provides a unique and original solution to the problem of the origin and evolution of the universe and he does insist that his theory can be either validated or falsified through further research.

Smolin, when he gets to explain his theory in the book *Time Reborn*, challenges the last 400 years of physics by stating that "Time is Real", i.e. it is the fundamental phenomenon in the universe and everything else, space, matter and motion are emergent properties of time itself. In fact Smolin shows just how radical that position is by demonstrating in the first half of his book that the direction of science from Galileo to Einstein has been to make time disappear. How did the march of science accomplish this? By positing a timeless mathematics that governed motion both in heaven and on earth. The insights of Galileo and Kepler were unified into a single coherent theory by Newton, a theory of universal gravity. And if motion can be expressed in terms of mathematical formulas then it can be represented on a graph with the Y axis being time and the X axis being space. With Einstein the graph is completed as a representation of a body in 4 dimensions, the three of space and one of time and together they represent what has been called spacetime. Time has here been disappeared into space.

To quote Smolin,

> Some physicists since Newton have embraced the mystic's view that the mathematical curve is "more real" than the motion itself. The great attraction of the concept of a deeper, mathematical reality is that it is timeless, in contrast to a fleeting succession of experiences. By succumbing to the temptation to conflate the representation with the reality and identify the graph of the records of the motion with the motion itself, these scientists have taken a big step toward the expulsion of time from our conception of nature. And as the graph suggests, there is no preferred direction of time. Once you know the laws that govern motion, there is theoretically no reason you cannot wind up those laws going forward as well as going back [...]
>
> And the mathematical conjunction of the representations of space and time, with each having its own axis, can be called spacetime. (SMOLIN, 2014, p. 34)

Recall that in his *Dialectics of Nature* Engels gave special prominence to those moments in the history of science when the dimension of history was introduced into what was previously considered timeless. He gives credit to the Kant–Laplace theory of the origin of the solar system for providing a historical dimension to our understanding of the solar system (this was long before the discovery that our solar system is just a tiny part of one galaxy and that our galaxy is one among many other galaxies in the universe). They asked and tried to answer the question of how the solar system came into being. In the field of geology this began with Lyell and in biology of course with Darwin. With Darwin's theory of evolution through natural selection the historical dimension was introduced into the last redoubt of science after the notion of a timeless universe had already been breached.

The reason the concept of time being real is so radical is not only due to this heritage we have inherited, but also due to the fact that all the advances in science in the 20th century seem to have further expelled time into an epiphenomenon of more fundamental forces. So before Smolin can introduce his own argument for the reality of time, he first needs to deconstruct the prevailing theories. Let us take a look at how he does that with the theory of relativity.

Recall that for Newton, space was posited as absolute and infinite and there was one clock that could measure the same time throughout the universe. It mattered not where the observer was placed. However, Einstein showed that the frame of reference of the observer in relation to the event matters. What appears to be two simultaneous events to one observer situated at point A can appear to another observer situated at a different point in the universe as two events that are not simultaneous. Neither one of the observers can be said to be right or wrong. Rather the Newtonian assumption that you can measure time throughout the universe by the same clock is an unwarranted assumption.

To quote Smolin,

> So there's no right answer to questions that observers disagree about, such as whether two events distant from each other happen simultaneously. Thus, there can be nothing objectively real about simultaneity, nothing real about "now". The relativity of simultaneity was a big blow to the notion that time is real […]
> This is a timeless picture, because it refers to the whole history of the universe at once. There is no preferred moment of time, no reference to what time it is now, no reference at all to anything corresponding to our experience of the present moment. No meaning to "future" or "past" or "present". (SMOLIN, 2014, p. 58)

There is also one more thing that comes out of relativity theory that undermines the notion of the reality of time. That is the idea that the universe must have had a beginning. It's a conclusion derived from the equations of general relativity and is the theoretical basis for the conjecture of the Big Bang. If the universe had a beginning, then time had a beginning, or so goes the argument, and if time had a beginning then it had to have been through something that is not time in time itself. Stephen Hawking has called this "the Singularity" and he is one of those scientists who says that it is absurd to speak of Time before the Big Bang.

Thus, relativity theory apparently puts the final nail in the coffin for the reality of time argument.

After summing up the arguments against the reality of time, Smolin begins the second part of his book by presenting the problems in this view of nature.

First there are some absurd conclusions that follow from the view that time is not real. If the universe is nothing other than a block universe without the reality of time, then there is no reason in principle you cannot go back in time as well as move forward in it. But all the evidence we have ever seen in nature is that there is an arrow of time and it cannot be wound backward as the representations of time or spacetime suggest they can.

How to account for this arrow of time if time is not real?

Smolin's response to the implication of relativity theory is strictly within the spirit if not the letter of Einstein. He is saying that relativity theory cannot be the whole story but is only presenting us with an approximate truth. He does not deny its validity but posits that it cannot be the final answer, that there must be a more comprehensive explanation, as yet undiscovered, that can account for the truths of relativity theory while validating the reality of time.

Smolin further cites two questions that need to be answered by any science that would account for the universe as a whole:

1. Why these laws? Why is the universe governed by a particular set of laws? What selected the actual laws from other laws that might have governed the world?
2. The universe starts off at the Big Bang with a particular set of initial conditions. Why these initial conditions? Once we fix the laws, there are still an infinite number of initial conditions the universe might have begun with. What mechanism selected the actual initial conditions out of the infinite set of possibilities? (SMOLIN, 2014, p. 57-98)

Posing those questions is to bring up the principle of sufficient reason, first articulated by Leibniz. It follows from the principle of sufficient reason that a property of anything in the universe cannot simply be "given", it must be explained. According to this essentially relational view of nature, any science that simply accepts the given, that does not ask why this given is the way it is and not some other way, is not a complete science. Even if we don't have the answer, we need to begin by asking the question.

For example, why not ask why the cosmological constant, the very tiny number that represents the rate of acceleration of the expansion of the universe, is exactly the quantity that it is and not some other quantity. If it was just slightly higher, the universe would be expanding at a rate that would make it unstable and therefore could not have existed for longer than a brief period. If it was slightly lower, then the expansion of the universe would come to an end with the Big Crunch. It seems as if the cosmological constant is tuned just right. Why is that?

Smolin's answer is to propose an analogy to the response that the evolutionary biologist provides when asked the question, why are humans endowed with just the right biological traits to allow them to survive in the world they inhabit. The answer in that case is that the human you see today is the end product of a long historical process of natural selection. Smolin is positing a process of Cosmological Natural Selection to explain why the universe we live in is tuned just right. It is an astounding claim.

Smolin proposes a mechanism for how the Laws of Nature could evolve. You can understand it by way of an analogy to biological Natural Selection.

The basic idea is that the universe reproduces new universes forming out of black holes. The more black holes a universe has the more it is likely to reproduce.

In Smolin's theory of Cosmological Natural Selection, what corresponds to organisms producing more offspring than could survive is the idea that there are many possible laws of nature and many possible initial conditions at the time of the origin of the universe. The universe we now inhabit has survived, but it is possible that other universes with different laws and different initial conditions did not survive. He theorizes that the great majority of earlier universes could not have survived longer than a mere fraction.

Now in what way can we speak of offspring, of a new generation, inheriting properties when it come to the Universe? Smolin's idea is that there has been not just one Big Bang but a series of many Big Bangs, perhaps an infinite number, each giving rise to some kind of Universe.

In biological natural selection, we find random variations in offspring because genes mutate. Darwin did not know about genes when he formulated his theory but he did see that there must be random variations from one generation to another.

In Cosmological Natural Selection there are random variations in the new universe created from black holes from the universe that spawned it. But instead of variations among genes, these are variations of laws of nature and in their initial conditions. The offspring universe resembles its parent, but with small variations. These variations make the new offspring universe either more or less fit.

In the biological natural selection, we measure "fitness" by the ability of an organism to reproduce and propagate itself into the next generation. In Cosmological Natural Selection the measure of "fitness" is the number of black holes a universe can produce. That is because the number of black holes in a universe is a direct measure of its ability to reproduce itself. And the number of black holes in a universe is itself determined by a set of parameters – of initial conditions and laws. In Smolin's words, "Many parameters lead to universes that have no black holes at all. A few parameters lead to universes that have lots of black holes". (SMOLIN, 2014, p. 125)

Remember that we mean by parameters such things as the value of the cosmological constant. This is a measure of the rate of expansion of the universe. If it varies just slightly from its current value in our universe, if it was slightly higher for instance then our universe would expand so fast that there would not be sufficient time to create black holes.

If we follow the logic of cosmological natural selection, it leads to a historical explanation of why our universe has the laws and initial conditions that it has. We can say that our own universe must be the typical kind of universe one would expect as a result of the mechanism of natural selection having worked on many generations of universes.

Note that for Cosmological Natural Selection to make sense, Time must be real. The Big Bang is just a moment in time, though of course a special one. Time does not begin with the Big Bang but precedes it.

Let me stress that Smolin's speculation is more a blue print for a theory yet to come than a completely worked–out theory. But he does maintain that it makes predictions that are testable, unlike much speculation.

And it does answer the question "why these laws and not others" very nicely if true.

The radical idea that the Laws of Nature themselves evolve was first formulated by the American philosopher Charles S. Peirce. Smolin's hypothesis points to a realm of historical science that even Engels did not dream of. While Engels correctly saw that the progress of science can be measured when a phenomenon that previously had been thought of as being static and eternal is superseded by an understanding of that same phenomenon as having a history of coming into being and passing away, it never occurred to him that this can be applied to the Laws of Nature themselves. This idea did have a certain prehistory among physicists in the 20th century. It was suggested by Paul Dirac and John Wheeler. Fortuitously, it was also suggested by Engels most prominent supporter in the area of the dialectics of nature, the British scientist who edited Engels work, J.B. S. Haldane, who proposed the idea in 1940. He wrote,

> […] far from being laid down by the arbitrary word of a creator, they [the laws of nature] may prove to be a system as intimately and rationally knit together as the propositions of geometry, and yet changing and evolving with time like the forms of plants and animals. (HALDANE, p. 42).

If Smolin succeeds in establishing his speculations into Cosmological Natural Selection, then he will have made an epochal contribution to our understanding of the universe. But even if he doesn't succeed, I think something like Smolin's theory must be true. For otherwise, we would be left with the strange conclusion that everything in the universe is changing, except the laws that govern those changes. But that would be un–dialectical.

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