Heuristics of String Theory

Nicolae Sfetcu

27.10.2019

Sfetcu, Nicolae, "Heuristics of String Theory", SetThings (27 octombrie 2019), URL = https://www.setthings.com/en/heuristics-of-string-theory/

Email: nicolae@sfetcu.com

A partial translation of
Sfetcu, Nicolae, "Epistemologia gravitației experimentale – Raționalitatea științifică", SetThings (1 august 2019), MultiMedia Publishing (ed.), ISBN: 978-606-033-234-3, DOI: 10.13140/RG.2.2.15421.61925, URL = https://www.setthings.com/ro/e-books/epistemologia-gravitatiei-experimentale-rationalitatea-stiintifica/

The logical positivists would have considered string theory as a speculative metaphysics. The instrumentalist aspect of logical positivism does not correspond with the opinions of string theorists.

From the point of view of Popper's falsifiability, [1] we clearly distinguish between the context of discovery and the context of justification. In the context of discovery, there are no methodological rules, but there are strict rules for testing hypotheses, avoiding *ad hoc* hypotheses as much as possible, which must be independently verifiable anyway. The string theory has not yet been tested and has already entered an *ad-hoc* hypothesis phase. But it has not been refuted so far, and the theory allows testing through experiments, even though there is not yet the technology needed to develop these experiments. An unexpected situation for Popper?

Kuhn adopted an externalist perspective in the philosophy of science. Scientific motivations do not always succeed in explaining paradigm shifts, as other external causes, including social ones, can enter this equation. [2] Kuhn's theory is rather a retrospective account of the history of science, never intended to provide a normative force methodology. [3] Thomas Kuhn's theory of scientific revolutions by changing "paradigms" can also be applied to string theory as a new paradigm in high energy physics. But a paradigm shift involves renouncing the old paradigm, going through a period of "crisis" in which anomalies occur, and observations that contradict the old paradigm. [4] The anomalies are discrepancies between theory and experiment. But in string theory there are no experiments, and problems of a theoretical nature have been known from the beginning. Thus, the new paradigm does not look any better than the old one.

Since string theory has not been able to explain phenomena to date, it may seem that this confirms Feyerabend's view that there is no "method" of science. And yet, string theory is still the most active research program for quantum gravity. But, compared to other non-falsifiable theories, this has something extra, especially mathematical language, with a clear logic of deductions. Up to a point it can reproduce classical gauge theories and general relativity. And there is hope that in the not too distant future experiments can be developed to test the theory.

---

[1] Karl Raimund Popper, *The Logic of Scientific Discovery* (Psychology Press, 2002).

[2] Thomas S. Kuhn and Jim Conant, *The Road Since Structure: Philosophical Essays, 1970-1993, with an Autobiographical Interview* (University of Chicago Press, 2000), 286–87.

[3] Keizo Matsubara, *Stringed Along Or Caught in a Loop?: Philosophical Reflections on Modern Quantum Gravity Research* (Filosofiska Institutionen, Uppsala universitet, 2012).

[4] Imre Lakatos, *The Methodology of Scientific Research Programmes: Volume 1: Philosophical Papers* (Cambridge University Press, 1980), 202.

String theory is called by Keizo Matsubara a "research program" and this is in the sense of Lakatos. [5] Hacking took over Lakatos theory, [6] but not as a methodological norm, rather as a method of rational reconstruction of the periods of the history of science. Keizo Matsubara supports Lakatos methodology, highlighting its main features in string theory: [7]

Hard core:

1. The fundamental objects are not punctual particles, but extended objects, strings or branes.
2. Acceptance of the basic assumptions of quantum mechanics as given.
3. The necessity of the supersymmetry of the theory.

Protective belt:

- Different variants of string theory are different theoretical formulations, not different theories.
- Compact dimensions are too small to be observed with current technology.
- Explaining the values of the constants of nature, assuming a landscape of universes.

Positive heuristics:

1. Explaining the diversity of the particles as mere manifestations of a fundamental type of objects.
2. Deriving the constants of nature
3. Unification of the standard model with gravity.

Negative heuristics:

1. No modus tollens argument is allowed to be directed against the hard core.

Compared to other programs, string theory seems to be more progressive in a more general sense. And the distinction between progressive/degenerative program cannot be made because empirical tests are lacking. But the failed attempts of the theorists over a large period to determine the constants of nature starting from the principles of the theory can be considered as a degenerative phase in the sense of Lakatos in which the empirical findings determine the theoretical development, although in this case the empirical results were known in advance, and had not predicted. Matsubara's conclusion is that string theory is a degenerative program, so it

[5] Keizo Matsubara, "Realism, Underdetermination and String Theory Dualities," *Synthese* 190, no. 3 (2013): 471–489.

[6] Ian Hacking, "Representing and Intervening by Ian Hacking," Cambridge Core, October 1983, https://doi.org/10.1017/CBO9780511814563.

[7] Matsubara, *Stringed Along Or Caught in a Loop?*

should be rejected if there would be such a progressive rival program.[8] Unfortunately, at present the other research programs are at least as inconclusive.

> "I hold Lakatos theory, MSRP, to be the most reasonable analysis of scientific development; it fits quite a number of episodes from history of science and I think it strikes the right balance between a descriptive and a normative account of science. It is also, to some extent, useful for discussing string theory and its competitors, mainly loop quantum gravity. However one cannot really say that one programme is progressive and one degenerative, because the distinction and comparison is made in terms of theoretical and empirical development, and no empirical development has occurred. On the other hand, without using Lakatos criteria and instead merely relying on our somewhat vague notion of development, one is tempted to say that string theory has been theoretically progressive, but not empirically progressive. One could say that adherents to string theory believe that theoretical progressiveness is sufficient for continuing work on the theory, whereas critics think it's not."[9]

Cartwright and Frigg reached similar conclusions by analyzing string theory from the perspective of Lakatos methodology, evaluating the degree of progressivity of the theory according to: the range of empirical applications, the predictions of success, the reproduction of new technologies, the answer to problems, the coherence, the elegance, the explanatory power, the truth. Their conclusion was that string theory was progressive as explanatory and unifying power, but this is insufficient to state the progressiveness of the theory as a whole. But the authors do not recommend rejecting the theory, appealing to the methodological tolerance proposed by Lakatos.[10]

Reiner Hedrich states that currently "string theory" is not a theory at all, but a labyrinth structure of mathematical procedures and intuitions. His only motivations over loop quantum gravity are the mutual incompatibility of the standard model of quantum field theory and general relativity, and the metaphysics of the physics unification program.[11] Delaying a philosophical decision on string theory after the consolidation of the research program could lead to more appropriate conditions for an evaluation.

The great asset of the theory is the hope that it will succeed in unifying the two seemingly incompatible theories, quantum and general relativity, and implicitly all the fundamental forces, in a great unified theory. In addition, the theory conformed to an approach considered fundamental in the scientific methodology by Einstein, Duhem, and others: simplification. String theory unified the standard model and general relativity, in this sense being a "better"

---

[8] Matsubara.

[9] Matsubara, 43.

[10] N. Cartwright and Roman Frigg, "String Theory Under Scrutiny" (2008), 14–15.

[11] Reiner Hedrich, "The Internal and External Problems of String Theory: A Philosophical View," *Journal for General Philosophy of Science / Zeitschrift Für Allgemeine Wissenschaftstheorie* 38, no. 2 (2006): 261–278.

model even though it still does not make predictions. [12] Greene also appreciates his "elegance".[13]

Some of the predictions made by string theorists, such as microscopic black holes and low-energy super-symmetrical particles, were falsified by observation. [14] But these problems do not refute the theory, because they are indirect observations, rather than direct results of the theory.

In the case of string theory, the experimental aspects are beyond our technological capacity. [15] But the fact that all predictions of the theory have so far been falsified is a problem. In addition, the landscape problem is another problem that makes the theory not falsifiable. To solve this problem, it was proposed to use the anthropic principle, according to which we can choose from different permutations those universes that create conditions suitable for the appearance of life, [16] but this principle is controversial. [17] Another problem concerns dark matter/energy, which are not predicted by string theory.

As the string theory changed its scope (and in this context also all the requirements of a research program, including strategy) from hadron physics to quantum gravity, internal problems began to emerge that, by trying to eliminate them with ad-hoc hypotheses, led to other internal problems, resulting in a growing self-referentiality and a simultaneous removal of phenomenology. Her empiricism dropped steadily, remaining a labyrinth mathematical structure of unclear physical relevance.

In addition, the theoretical developments have led to a self-immunization of the theory against empirical refutations, including in the case of supersymmetry. [18] String theory does not make predictions for supersymmetric particle masses; thus, if future experiments in accelerators do

---

[12] Hakon Enger, "String Theory and the Scientific Method," 2003, http://home.simula.no/~henger/publ/mnvit-essay.pdf.

[13] Brian Greene, *The Elegant Universe: Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory*, 2nd ed. edition (New York London: W. W. Norton & Company, 2010), 137.

[14] Matthias Blau and Stefan Theisen, "String Theory as a Theory of Quantum Gravity: A Status Report," *General Relativity and Gravitation* 41, no. 4 (April 1, 2009): 743–55, https://doi.org/10.1007/s10714-008-0752-z.

[15] Richard P Feynman, "The Feynman Lectures on Physics," 2013, http://www.feynmanlectures.caltech.edu/.

[16] Paul Verhagen, "Understanding the Theory of Everything: Evaluating Criticism Aimed at String Theory" (Amsterdam University College, 2015), http://www.uva.nl/binaries/content/documents/personalpages/h/a/s.deharo/en/tab-three/tab-three/cpitem%5B8%5D/asset.

[17] Lee Smolin, "A Perspective on the Landscape Problem," *Foundations of Physics* 43, no. 1 (January 2013): 21–45, https://doi.org/10.1007/s10701-012-9652-x.

[18] Richard Dawid, "On the Conflicting Assessments of the Current Status of String Theory," Preprint, April 2008, 984–96, http://philsci-archive.pitt.edu/4009/.

not discover these particles, it can be argued that they have masses beyond the range of the experimental device. [19] It has thus become that the inability to make quantitative forecasts is used as a strategic advantage for auto-immunization, a unique aspect in physics. [20]

Dawid believes that a confirmation of a scientific theory is based on three main factors:

1. the existence of alternative solutions to a particular problem (string theorists claim that their theory is the only viable option for unification);
2. the degree of connection with the already confirmed theories (string theorists consider their program as a natural continuation of the particle physics research program);
3. number of unexpected intuitions/predictions.

Confidence in theory would depend on conformity with these factors, even in the absence of empirical confirmation. Basically, Dawid suggests a switch from empirical falsifiability to a Bayesian model that defines probability not "how often something happens" but "what degree of confidence we should have in our knowledge."

Some physicists propose to evaluate alternative theories to string theory. The main difference would be that the string theory aims to solve the problem of quantum gravity in the context of unification. Unfortunately, many of the problems of string theory remain in the alternative theories. The main rival, loop quantum gravity, has not yet been developed sufficiently to make falsifiable statements. Smolin claims the alternatives have been consistently neglected. [21] The problem with alternatives is that at present there is not sufficiently developed and consolidated theory to take the place of string theory. [22] Looking for "everyone's theory" there seems to be no other way than to continue working on string theory (the argument "There are no alternatives.") [23]

A scientific realist would only consider a well-tested mature theory that predicted new facts. String theory does not meet these requirements. The dualities of string theory reinforce this belief. The underdetermination of theories by data is a problem that concerns scientific realism. Realists will differentiate by simplicity, lack of *ad-hoc*, explanatory power, etc., between theories. Alternatively, it can be argued that underdetermination involves only two ways of

---

[19] Greene, *The Elegant Universe.*

[20] Hedrich, "The Internal and External Problems of String Theory."

[21] Lee Smolin, *The Trouble With Physics: The Rise of String Theory, The Fall of a Science, and What Comes Next*, Reprint edition (Boston u.a: Mariner Books, 2007).

[22] Joanes Lizarraga et al., "Fitting BICEP2 with Defects, Primordial Gravitational Waves and Dust," *Journal of Physics: Conference Series* 600 (April 28, 2015): 600 (2015): 012025, https://doi.org/10.1088/1742-6596/600/1/012025.

[23] Richard Dawid, Stephan Hartmann, and Jan Sprenger, "The No Alternatives Argument," Preprint, February 24, 2013, 66.1 (2014): 213-234, http://philsci-archive.pitt.edu/9588/.

describing the same theory. Undetermination should force the scientific realist to abandon either semantic or epistemic realism. [24]

Traditional logical positivists are kind of anti-realists, considering that the significant cognitive part of a theory is limited to its empirical content. So, string theory would not be accepted in the current situation. If string theory were to have empirical success in the future, the dualities would only be considered as semantic equivalents, because only the empirical content would be considered relevant.

[24] Matsubara, "Realism, Underdetermination and String Theory Dualities."

Bibliography

Blau, Matthias, and Stefan Theisen. "String Theory as a Theory of Quantum Gravity: A Status Report." *General Relativity and Gravitation* 41, no. 4 (April 1, 2009): 743–55. https://doi.org/10.1007/s10714-008-0752-z.

Cartwright, N., and Roman Frigg. "String Theory Under Scrutiny," 2008.

Dawid, Richard. "On the Conflicting Assessments of the Current Status of String Theory." Preprint, April 2008. http://philsci-archive.pitt.edu/4009/.

Dawid, Richard, Stephan Hartmann, and Jan Sprenger. "The No Alternatives Argument." Preprint, February 24, 2013. http://philsci-archive.pitt.edu/9588/.

Enger, Hakon. "String Theory and the Scientific Method," 2003. http://home.simula.no/~henger/publ/mnvit-essay.pdf.

Feynman, Richard P. "The Feynman Lectures on Physics," 2013. http://www.feynmanlectures.caltech.edu/.

Greene, Brian. *The Elegant Universe: Superstrings, Hidden Dimensions, and the Quest for the Ultimate Theory*. 2nd ed. edition. New York London: W. W. Norton & Company, 2010.

Hacking, Ian. "Representing and Intervening by Ian Hacking." Cambridge Core, October 1983. https://doi.org/10.1017/CBO9780511814563.

Hedrich, Reiner. "The Internal and External Problems of String Theory: A Philosophical View." *Journal for General Philosophy of Science / Zeitschrift Für Allgemeine Wissenschaftstheorie* 38, no. 2 (2006): 261–278.

Kuhn, Thomas S., and Jim Conant. *The Road Since Structure: Philosophical Essays, 1970-1993, with an Autobiographical Interview*. University of Chicago Press, 2000.

Lakatos, Imre. *The Methodology of Scientific Research Programmes: Volume 1: Philosophical Papers*. Cambridge University Press, 1980.

Lizarraga, Joanes, Jon Urrestilla, David Daverio, Mark Hindmarsh, Martin Kunz, and Andrew R. Liddle. "Fitting BICEP2 with Defects, Primordial Gravitational Waves and Dust." *Journal of Physics: Conference Series* 600 (April 28, 2015): 012025. https://doi.org/10.1088/1742-6596/600/1/012025.

Matsubara, Keizo. "Realism, Underdetermination and String Theory Dualities." *Synthese* 190, no. 3 (2013): 471–489.

———. *Stringed Along Or Caught in a Loop?: Philosophical Reflections on Modern Quantum Gravity Research*. Filosofiska Institutionen, Uppsala universitet, 2012.

Popper, Karl Raimund. *The Logic of Scientific Discovery*. Psychology Press, 2002.

Smolin, Lee. "A Perspective on the Landscape Problem." *Foundations of Physics* 43, no. 1 (January 2013): 21–45. https://doi.org/10.1007/s10701-012-9652-x.

———. *The Trouble With Physics: The Rise of String Theory, The Fall of a Science, and What Comes Next*. Reprint edition. Boston u.a: Mariner Books, 2007.

Verhagen, Paul. "Understanding the Theory of Everything: Evaluating Criticism Aimed at String Theory." Amsterdam University College, 2015. http://www.uva.nl/binaries/content/documents/personalpages/h/a/s.deharo/en/tab-three/tab-three/cpitem%5B8%5D/asset.