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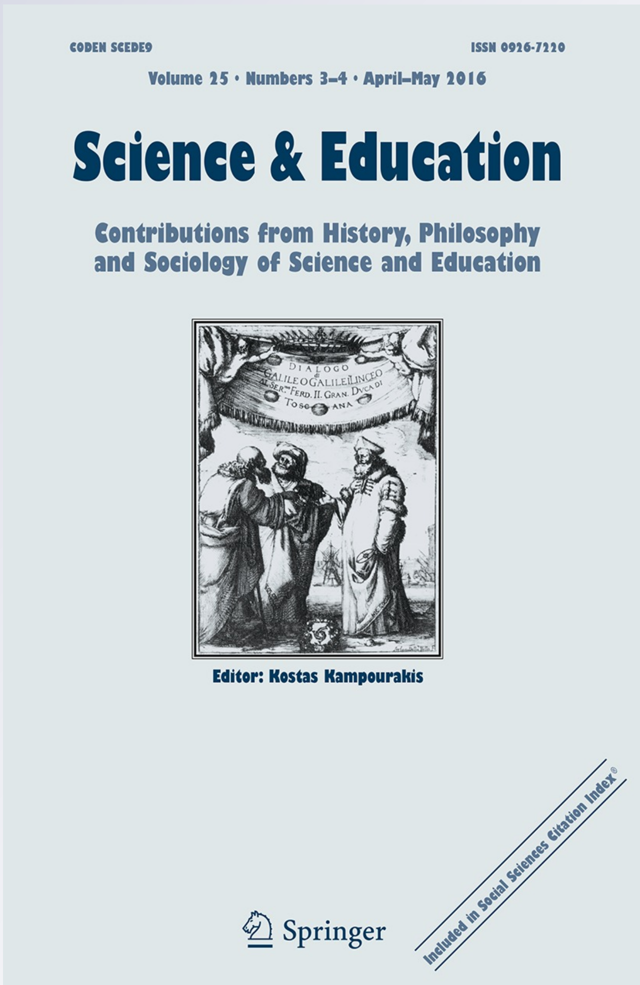

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BOOK REVIEW

Are Untestable Scientific Theories Acceptable?

Richard Dawid: *String Theory and the Scientific Method*, 2nd edn, Cambridge University Press, New York, 2013, ISBN 978-1-107-02971-2, 202 pp, US$ 95.00 (hardback)

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1 Introduction

One strategy for discussing philosophy of science in the classroom is to study some interesting scientific controversy, since that is an occasion when scientists use philosophical arguments against their rivals, and when non-epistemic factors, such as emotions, personality traits, institutional pressures, political influence, national rivalry or even fraud, are included in the discussion (see Engelhardt and Caplan 1987). The so-called string wars is an especially interesting case study, since it is happening right now, involves the most fundamental and overarching theories of physics and cosmology, and can be presented in a conceptual (non-quantitative) and simplified way to our students. In 2006, two books sparked the controversy, written by Smolin (2006) and Woit (2006), criticizing string theory and string theorists, and various rebuttals ensued (see, for instance, Polchinski's 2007 review of both books). The main philosophical point raised by Smolin and Woit is that string theory has not been able to propose empirical predictions that can be experimentally tested. Even stronger is the charge that the theory is not "falsifiable," since parameters in the theory could be adjusted to fit any new data. If this is true, then string theory could not be considered scientific, following the demarcation criterion that the philosopher of science Karl Popper proposed for distinguishing scientific claims, which should be clear about what possible data would be in disagreement with the predictions of the theory, from metaphysical or pseudoscientific assertions, which usually offer explanations for *any* possible observable state of affairs.

The Austrian physicist and philosopher of science Richard Dawid answers this challenge in a surprising way, arguing that the problem is not with string theory, but with the philosophical and methodological theories developed to explain science. Science has changed and so must philosophy of science: Instead of what Dawid calls the "classical paradigm of theory assessment," one should recognize that the most highly theoretical physics must be evaluated according to non-empirical criteria, that is, in a context where experiments lag behind theory construction, and experimental confirmation plays only a

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very remote role. This, of course, happens because of the practical limitations in performing experiments involving energies higher than the ones necessary for the recent experimental detection of the Higgs particle, predicted by the so-called standard model of elementary particle physics. This might have been the last great successful prediction of particle physics in the coming decades. In view of this, philosophy of science should be reformulated to explain why such a large part of the community of particle physicists remains so enthusiastic about string theory, even in the lack of empirical confirmation. Dawid's methodology of "non-empirical theory assessment" is a very important proposal for such a reformulation of philosophy of science. It takes one step further the tendency of twentieth-century philosophy of science to emphasize the independence of the theoretical side of science, in opposition to the positivist view, which conceived of theories merely as an economical means of organizing empirical knowledge. Popper's philosophy of science was inspired by the highly abstract and successful approach of Einstein's general theory of relativity. The emphasis on the theoretical side of science is clear in most philosophers of science in the last fifty years, reflecting the growing mathematization of natural science and the increasing sophistication of computer-assisted model building.

2 String Theory

The book offers a rather difficult reading, being directed especially to philosophers of science. It is dense and well argued, and I would rank it together with the great classics of philosophy of science. After its ideas have been digested and criticized, one might expect a lighter version of the book to appear, which would be more helpful for science teaching and popularization.

To read the book, one may start with chapter one, which summarizes string theory and the main ideas of non-empirical theory assessment, and then jump to chapter four, which presents a nice history of high energy theoretical physics from the 1960s onward. In this twenty-page summary, the ideas associated with non-empirical theory assessment are illustrated with descriptions of important theoretical proposals in physics, such as grand unified theories, supersymmetry, supergravity, cosmic inflation, and loop quantum gravity. The latter is Smolin's proposal for a rival theory to string theory, but Dawid downplays the importance of loop quantum gravity by arguing that it has a much more limited scope than string theory, since it does not encompass the standard model of particle physics, as is done by string theory, but only quantum gravity.

String theory is a highly mathematical and speculative branch of theoretical physics, the core idea of which is the postulation of extended fundamental entities (strings of finite length or membranes in two or higher dimensions). Since the fundamental entities are not point-like particles, the problems of divergence in quantum field theory (when two particles are brought arbitrarily close to each other) disappear. To ensure that the quantization of the string is free of anomalies, the motion of strings has to be described in nine spatial dimensions plus one temporal dimension. The theory offers a procedure for unifying the standard model of particle physics (which encompasses the electric, the weak, and the strong nuclear forces) with gravity. Rich mathematical ideas, such as T-duality and supersymmetry, have generated a theory which is considered "too good to be false" by many of its proponents.

However, string theory has been unable to make novel predictions that can be experimentally tested, and therefore, one concludes that it lacks empirical confirmation. Dawid accepts this conclusion, but argues that this situation of lack of empirical confirmation is becoming the norm in those areas of physics in which empirical results lag behind the postulation of theoretical models.

3 The Metatheory

The methodology of non-empirical theory assessment is based on three principles. First, there is the investigation of whether there are alternatives for the theory that is being evaluated. If there are not any, then one may give the no alternative argument (NAA) in favor of the theory being evaluated. Second, the theory being evaluated may not give any novel predictions that can be tested, but if it is consistent with other accepted theories, especially if this occurs unexpectedly, then this may be considered a great advantage. This is the argument of unexpected explanatory coherence (UEA). Third, now suppose that these other theories, with which our evaluated theory is consistent with, are well confirmed. This surely should also count in favor of our theory. This is the meta-inductive argument from the success of other theories in the research program (MIA).

With these three principles, Dawid gives a highly positive assessment of string theory, considering it "the only promising approach for a full unification of all interactions" (p. 92). First, it has no viable alternatives in the project of unifying the standard model of particle physics with quantum gravity. Loop quantum gravity stands in the tradition of canonical quantum gravity and has challenged string theory in the domain of quantum gravity, but it offers as yet no unification with the standard model of particle physics. In this sense, NAA may be used in favor of string theory, since there is no alternative theory that covers the full range of its intended applications.

The second point of positive assessment involves examples of unexpected explanatory coherence (UEA). String theory as originally proposed extended elementary objects to avoid the problems of infinities associated with the attempt to renormalize quantum field theories that include gravity. "Remarkably," comments Dawid, string theory "actually implies the existence of gravity" (p. 33), as the gravitational field emerges as an oscillation mode of the string. Another unexpected explanation mentioned by the author involves the coupling constants associated to the three gauge interactions, electromagnetic, weak and strong, which assume roughly the same value at a very high energy (called the grand unified theory scale). This situation was unexpectedly derived from an approach within string theory called low energy supersymmetry. Another theoretical success of string theory was the derivation of black hole entropy.

The third point to be mentioned is the empirical success of the standard model of elementary particles, the most striking result of which was the detection of the Higgs boson in 2012. Since the standard model is part of the string theory research program, its empirical confirmation lends indirect support to string theory, via the meta-inductive argument (MIA).

Underlying these criteria for non-empirical theory assessment is the issue of "scientific underdetermination": To what extent may the empirical data be explained by different theories, or to what extent is there a best explanation for the data? Non-empirical theory assessment is the analysis of how far scientific underdetermination can be limited or restricted. If there are reasons for limiting such underdetermination, there are reasons for preferring a certain theory, and the scientist has practical reasons for choosing to work in a certain problem within a scientific research program, rather than working in a rival program or within another field.

Along these lines, Dawid gives a clarifying explication of his views by expressing it in terms of inference to the best explanation (pp. 64–68). In the traditional view of theory assessment, which emphasizes confirmation or falsification of hypothesis by empirical tests, one may have different theories that explain a set of data (underdetermination), and one therefore tries to establish which one is the "best" explanation, according to certain criteria. In the case of non-empirical theory assessment, such a procedure is not effective, since the relation between theory and data is very indirect. However, according to Dawid, one can work with a set of sociological observations which indicate a restriction of the scope of scientific underdetermination, such as: (a) No alternatives have been found (NAA); (b) a number of explanatory interconnections arose unexpectedly (UEA); (c) in similar situations in the past, within the field, the scientific theory turned out to be predictively successful (an allusion to the success of the standard model, which ends up lending indirect support to string theory, via MIA). Therefore, the best explanation for these observations in the sociology of science would be that scientific underdetermination is limited and that our theory (in the case being studied, string theory) has been successfully evaluated within the methodology of non-empirical theory assessment. These sociological observations are what Dawid means by evidence placed "at a meta-level" (p. 123).

4 Assessing the Metatheory

How is one to assess the merits of Dawid's metatheory of science? One might try to apply the three criteria of non-empirical theory assessment to the metatheory itself. First, one may consider whether there are plausible alternatives to Dawid's methodological proposal for highly theoretical fields. What first comes to mind is Imre Lakatos' methodology of scientific research programs, which allows for a scientific program to be temporarily progressive even in the lack of empirical confirmation of its novel predictions. This situation in which no predictions are confirmed is tolerable as long as the research program is theoretically progressive, generating and solving theoretical problems, and proposing novel predictions. Johansson and Matsubara (2011) applied the Lakatosian methodology to string theory and concluded that the theory should be considered "degenerative" (not progressive), after more than three decades without any novel empirical prediction. But Lakatos also recommended treating budding programs "leniently," and there is no alternative research program to string theory that is progressive, so the adherence to the string program may be considered rational. Therefore, the NAA does not seem to lend clear support to Dawid's metatheory.

It is true that his metatheory is much more detailed in its description of non-empirical theory assessment, but maybe the insights he established could be incorporated into the needed refinements in the protective belt of the Lakatosian research (meta)program. At any rate, Dawid emphasizes correctly that the scientific method grows out of scientific practice and that therefore scientific methodology should be expected to evolve (p. 29) (which reminds us of the lattice model of scientific rationality of Laudan 1984).

String theory is only a single case study: How does non-empirical assessment fare in other episodes in the history of science? Dawid presents some other interesting case studies, such as the situation related to atomism in the end of the nineteenth century, the case of the standard model before the empirical confirmation of the top quark and of the Higgs particle, and even an example taken from paleontology. He also explores in detail the claim that string theory is a "final theory," and the status of anthropic reasoning in cosmology. He does not abandon the idea that empirical testing is of “crucial importance for scientific inquiry” (p. 98), but recognizes in modern physics what he describes as a growing “marginalization of the phenomena.” These successful applications of his method to other episodes of the history of science might be considered as a fulfillment of explanatory coherence (UEA).

One may also investigate how Dawid’s method of non-empirical theory evaluation fits in with other successful approaches in the philosophy of science (MIA). The author explicitly establishes such connections in relation to the inference to the best explanation (as we have seen), to Bayesian analysis, and, in the last chapter of the book, to the discussion of scientific realism.

5 Structural Realism

Dawid’s position regarding the debate between realists and empiricists is also original and interesting. As is implicit in the expression “non-empirical theory assessment” and in the defense of the truth of string theory, with all its unobserved entities and symmetries, the author’s view is basically realist. However, he criticizes the “no miracles argument” usually employed by realists to explain the success of science: If one does not acknowledge that science faithfully describes reality, including its unobserved parts, then one must conclude that the success of science is a miracle. Dawid considers that the success of science should be explained locally, by analyzing in each case the limitations of scientific underdetermination.

Considering the case of string theory, the claim that it may constitute the framework for a final theory of fundamental physics is akin to realism. However, the proposal made by string theory of the existence of “dualities” weakens the assertion that the theory describes the ontology of reality (i.e., how nature really is), since a certain description of reality is shown to be empirically equivalent to another. For example, according to T-duality:

> […] a model where a string with characteristic length l is wrapped n times around a [compactified] dimension with radius R and has momentum eigenvalue m is dual to a model where a string is wrapped m times around a dimension with radius l^2/R and has momentum eigenvalue n. The two descriptions give identical physics. (p. 132)

The ontological realist could, of course, pick one of these descriptions as the true one, based on some arbitrary criterion, but the author dismisses this as running against the spirit of string theory. Dawid’s conclusion is that string theory implies a weaker form of realism, “consistent structural realism,” which conflates truth and empirical adequacy (where the latter should be understood in a potential way, since we are in the context of non-empirical theory assessment). This variety of realism rejects the meaningful identification of real ontological objects, accepting only the existence of unique non-spatiotemporal real structures.

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