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Testability and epistemic shifts in modern cosmology

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ABSTRACT

During the last decade new developments in theoretical and speculative cosmology have reopened the old discussion of cosmology's scientific status and the more general question of the demarcation between science and non-science. The multiverse hypothesis, in particular, is central to this discussion and controversial because it seems to disagree with methodological and epistemic standards traditionally accepted in the physical sciences. But what are these standards and how sacrosanct are they? Does anthropic multiverse cosmology rest on evaluation criteria that conflict with and go beyond those ordinarily accepted, so that it constitutes an "epistemic shift" in fundamental physics? The paper offers a brief characterization of the modern multiverse and also refers to a few earlier attempts to introduce epistemic shifts in the science of the universe. It further discusses the several meanings of testability, addresses the question of falsifiability as a *sine qua non* for a theory being scientific, and briefly compares the situation in cosmology with the one in systematic biology. Multiverse theory is not generally falsifiable, which has led to proposals from some physicists to overrule not only Popperian standards but also other evaluation criteria of a philosophical nature. However, this is hardly possible and nor is it possible to get rid of explicit philosophical considerations in some other aspects of cosmological research, however advanced it becomes.

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1. Epistemic shifts and theory choice

"Do we need to change the definition of science?" asked an article in the 7 May 2008 issue of *New Scientist* (Matthews, 2008). The occasion for the question was the recent appearance of a class of cosmological theories postulating the existence of an immense number of universes—a multiverse—rather than the single and unique universe in which we live. Multiverse physics or cosmology does not agree very well with the standard "definition" (or intuition) of science, which in this case was taken to include as a crucial element Popper's falsifiability criterion. The answer of some advocates of the multiverse has been to question or disregard the alleged definition of science and to look for a different understanding of what characterizes science, one that will allow multiverse physics to remain safely within the borders of science. They propose what I shall call an *epistemic shift*.[1]

As I shall use the term (Kragh, 2011), epistemic shifts refer to suggestions that traditional criteria of evaluation of scientific theories (or of theories claimed to be scientific) are no longer adequate and should therefore be replaced by new criteria that better fit the problems under investigation. In so far that they relate to the very criteria of what constitutes science, the suggested changes may in effect imply a new meaning or definition of what counts as science. They are, and are meant to be, changes in the demarcation between science and non-science. Such epistemic shifts are related to the paradigm shifts associated with revolutions in Kuhn's philosophy of science, but they differ from them in some respects. According to Kuhn's original view of 1962, methods of a research field, including values and rules of theory evaluation, are implicitly defined by the paradigm. He nonetheless argued for some timeless elements in science, one of them being that acceptability of theories is strongly regulated by observation and experiment.

Whereas two competing paradigms are incommensurable, this is not the case with competing epistemic standards, which mostly

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[1] The term "epistemic shift" is occasionally used in sociological, political and literary theory, sometimes with a meaning close to Kuhnian paradigm shifts. In Michel Foucault's structuralist "archaeology" of knowledge, the emergence of political economy in the eighteenth century is said to be an epistemic shift. Again, scholars have characterized the modern recognition of a global community with sustainable development as an epistemic shift in theories of international politics.

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differ in the ways they evaluate a theory. Given a new theory, which reasons do we have to believe in it or take it seriously? On the other hand, an epistemic shift may be so deep that it affects the significance of empirical tests, which is generally considered a stable epistemic virtue across paradigmatic shifts.

The question raised in *New Scientist* presupposes that there is a generally accepted and more or less invariant definition of science, a presupposition most philosophers, sociologists and historians of science will probably deny. All the same, and restricting myself to the physical sciences, there are undoubtedly some criteria of science and theory choice that the overwhelming majority of scientists agree upon and have accepted for at least two centuries. In a lecture of 1973, Kuhn (1977, pp. 320–339) suggested five "standard criteria for evaluating the adequacy of a theory," namely the following: (1) accuracy; (2) consistency, internal as well as external; (3) broadness in scope; (4) simplicity; and (5) fruitfulness. The first criterion related to the theory's empirical power: within its domain, there must be "consequences deducible from a theory [that] should be in demonstrated agreement with the results of existing experiments and observations." Notice that Kuhn did not specifically refer to predictions, except that he included them under the notion of "fruitfulness," and that he apparently had confirmation rather than disconfirmation in mind.

Kuhn (1977, pp. 290–291) was aware that the criteria or values may contradict each other in a concrete situation and that a relative weighing may therefore be needed; but such weighing cannot be unique, and so the system cannot fully determine an evaluation in a concrete case. In the context of modern cosmology Kuhn's criteria have been discussed by the cosmologist Ellis (2003, 2007, pp. 1242–1245), who points out that although they are all desirable they are not of equal relevance and may even lead to conflicts, that is, to opposing conclusions with regard to theory choice. Still, Ellis (and most other cosmologists) finds the first of Kuhn's criteria to be the one that in particular characterizes a scientific theory and demarcates it from other theories. Empirical testability is more than just one criterion out of many.

In cosmology and other areas of fundamental physics it has been agreed for more than a century that both when it comes to theory construction (the context of discovery) and theory evaluation (the context of justification) considerations of an empirical-inductive kind must enter together with hypothetical-mathematical considerations in some proper balance that depends on the case in question. It is also agreed that the empirical elements need not be very important, or can be wholly absent, in the creative or constructive phase of a scientific theory.

Let me illustrate this consensus view with an address that the eminent American physical chemist and mainstream cosmologist Richard Tolman gave in 1932, shortly after the expanding universe had become generally known. In this address, given to the Philosophical Club at the University of California, Los Angeles, Tolman distinguished between two ways of constructing cosmological models, one guided by observational data and the other—paraphrasing Einstein—based on "desiderata for the inner harmony and simplicity of the theoretical structure the physicist is attempting to build" (Tolman, 1932, p. 373). Realizing that Einstein had found the field equations of general relativity by the second method, Tolman was nonetheless careful to delimit the purely mathematical considerations to the construction of theories. The physical principles underlying a cosmological theory "must of course in any case agree with observational facts," and even those principles obtained "from the inner workings of the mind" must have consequences that can be presented "to the arbitrament of experimental test."

This was also Einstein's view, even as he moved from a cautious empiricist position inspired by Ernst Mach to an almost full-blown rationalism. In his Herbert Spencer lecture of 1933 he famously stated that "we can discover by means of pure mathematical considerations the concepts and the laws …, which furnish they key to the understanding of natural phenomena. … In a certain sense, therefore, I hold it true that pure thought can grasp reality, as the ancients dreamed" (Einstein, 1982, p. 274; Norton, 2000). But in between these two expressions of his rationalist credo, there was the no less important sentence: "Experience remains, of course, the sole criterion of the physical utility of a mathematical construction." As late as 1950, commenting on his new generalized theory of gravitation, he readily admitted that "Experience alone can decide on truth" (Einstein, 1950, p. 17). As we shall see, similar rhetoric is common among modern cosmologists and shared even by many advocates of the existence of numerous unobservable worlds.

2. Examples from the past

The modern situation in multiverse cosmology is of great interest from a methodological point of view, but it is not quite unique in the history of cosmological thought. Attempts to introduce major epistemic shifts can be found earlier, both in cosmology and in other parts of the physical sciences (Kragh, 2011). I shall briefly discuss a couple of episodes from the twentieth century in which epistemic shifts were on the agenda and in which a few physicists suggested to change the "rules of science" in such a way that the first of Kuhn's criteria was essentially disregarded or given very little significance.[2]

The ambitious project of reconstructing fundamental physics that Arthur Eddington pursued between 1929 and his death in 1944 was not a cosmological theory as ordinarily understood, but an attempt to unify quantum mechanics and cosmology under a single mathematical and epistemological framework (Eddington, 1936, 1946; Kilmister, 1994). It was meant to be a theory of everything in the physical universe. The goal of the British astronomer was none other than to deduce all laws and phenomena of nature from epistemological considerations alone, meaning that empirical facts were in principle irrelevant: the laws of nature corresponded to a priori knowledge. In the introduction to his main work *Relativity Theory of Protons and Electrons* (Eddington, 1936, pp. 3–5), he expressed his apriorism as follows:

> All that we require from observation is evidence of identification—that the entities denoted by certain symbols in the mathematics are those which the experimental physicist recognizes under the names "proton" and "electron." Being satisfied on this point, it should be possible to judge whether the mathematical treatment and solutions are correct, without turning up the answer in the book of nature. My task is to show that our theoretical resources are sufficient and our methods powerful enough to calculate the constants exactly—so that the observational test will be the same kind of perfunctory verification that we apply sometimes to theorems in geometry. … I think it will be found that the theory is purely deductive, being based on epistemological principles and not on physical hypotheses.

Despite its a priori nature, Eddington's theory was rich in empirical consequences, resulting in a large number of precise and apparently testable predictions (or, in most cases, postdictions). To mention just a few, he claimed to have deduced the numerical values of the fine-structure constant $2\pi e^2/hc$, the proton–electron mass ratio M/m, the cosmological constant Λ, and Hubble's

[2] Much has been written about the world systems of Eddington and Milne. References to the literature, both primary and secondary, can be found in Kragh (2011). For the steady state theory, see Balashov (1994) and Kragh (1996).