Studies in History and Philosophy of Modern Physics 57 (2017) 41–52

Contents lists available at ScienceDirect

Studies in History and Philosophy of Modern Physics

journal homepage: www.elsevier.com/locate/shpsb

Cosmology and convention

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ARTICLE INFO

Article history:
Received 23 September 2016
Accepted 29 December 2016
Available online 20 January 2017

Keywords:
Astrophysics
cosmology
falsification
Popper
Lakatos

ABSTRACT

I argue that some important elements of the current cosmological model are 'conventionalist' in the sense defined by Karl Popper. These elements include dark matter and dark energy; both are auxiliary hypotheses that were invoked in response to observations that falsified the standard model as it existed at the time. The use of conventionalist stratagems in response to unexpected observations implies that the field of cosmology is in a state of 'degenerating problemshift' in the language of Imre Lakatos. I show that the 'concordance' argument, often put forward by cosmologists in support of the current paradigm, is weaker than the convergence arguments that were made in the past in support of the atomic theory of matter or the quantization of energy.

When citing this paper, please use the full journal title *Studies in History and Philosophy of Modern Physics*

1. Introduction

The idea that scientific theories contain 'conventional' aspects is attributed to Henri Poincaré (Poincaré, 1902). From his work on non-Euclidean geometries and higher spaces, Poincaré reached the conclusion that many elements of scientific theories which had been held to be fundamental truths were in fact just conventions. Thus any geometry can be adopted for space, if the necessary revision is made in the definition of a straight line. The laws of mechanics can likewise be interpreted as defining the concepts of force and inertial motion. While noting that some conventions might be more convenient than others, Poincaré asserted that any set of conventions could always be replaced by a different set without changing the content of a theory. In Poincaré's view, the parts of a scientific theory that are conventional cannot be said to be true or false; they are simply definitions, and as such, are immune to testing.

Unlike Poincaré, Pierre Duhem (1914) believed that experimental refutation of a theoretical system is possible. Nor did Duhem accept that any part of a theory could be singled out as definitional. Nevertheless, Duhem, like Poincaré, is often regarded as a conventionalist. Duhem noted that the prediction that a phenomenon will be observed is based on a set of premises, including laws, initial conditions, assumptions about the reliability of the experimental apparatus etc. In the face of a falsifying instance, the experimenter has no way of knowing which of these premises is false. Thus, no experiment or observation can ever be considered decisive against a particular hypothesis, and no hypothesis can be conclusively falsified.

Karl Popper was concerned with finding a criterion that demarcates science from non-science (or 'metaphysics'). He argued that falsifiability is such a criterion: scientific theories are falsifiable; non-falsifiable theories are non-scientific. Popper acknowledged the strength of the conventionalist position: "I regard conventionalism as a system which is self-contained and defensible" (Popper, 1959, p. 80). But Popper equated conventionalism with non-falsifiability, and he rejected it, in part because he saw conventionalism as impeding the growth of knowledge:

> Whenever the 'classical' system of the day is threatened by the results of new experiments which might be interpreted as falsifications according to my point of view, the system will appear unshaken to the conventionalist. He will explain away the inconsistencies which may have arisen … We, and those who share our attitude, will hope to make new discoveries; and we shall hope to be helped in this by a newly erected scientific system. Thus we shall take the greatest interest in the falsifying experiment. We shall hail it as a success, for it has opened up new vistas into a world of new experiences. (Popper, 1959, p. 80.).

Popper nevertheless acknowledged that the "conventionalist mode of thought" is useful, in that it can expose certain logical shortcomings in his doctrine of falsification:

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http://dx.doi.org/10.1016/j.shpsb.2016.12.002

> I admit, a conventionalist might say, that the theoretical systems of the natural sciences are not verifiable, but I assert that they are not falsifiable either. For there is always the possibility of '… attaining, for any chosen axiomatic system, what is called its "correspondence with reality" ' (Carnap 1923, p. 100); and this can be done in a number of ways… Thus we may introduce *ad hoc* hypotheses. Or we may modify the so-called 'ostensive definitions'… Or we may adopt a sceptical attitude as to the reliability of the experimenter whose observations, which threaten our system, we may exclude from science on the ground that they are insufficiently supported, unscientific, or not objective, or even on the ground that the experimenter was a liar…. In the last resort we can always cast doubt on the acumen of the theoretician. (Popper, 1959, p. 81.).

Popper coined the term 'conventionalist stratagem' to describe these four ways of evading the consequences of a falsifying experiment. While admitting that there was no strictly logical basis on which to exclude such stratagems, he argued that in order to maintain falsifiability, conventionalist methods needed to be strictly avoided, and that "The only way to avoid conventionalism is by taking a *decision*: the decision not to apply its methods. We decide that, in the case of a threat to our system, we will not save it by any kind of *conventionalist stratagem*" (Popper, 1959, p. 82). Popper presented methodological rules for the practice of science that were designed to rule out the incorporation of conventionalist elements.[1]

Critics of Popper have debated whether falsification is a primary goal of scientists. Thomas Kuhn (1962) famously argued that the main occupation of scientists is not falsification but 'puzzle-solving,' an activity that implies uncritical acceptance of the current scientific paradigm. However, interpreted narrowly as a definition of the conventionalist program, Popper's list of stratagems need not be problematic. In what follows, I identify 'conventionalism' with Popper's list. A 'conventionalist' approach is defined as one which (whether deliberately or not) evades the consequences of a falsifying experiment or observation by the application of one or more of Popper's conventionalist stratagems.

2. The standard model of cosmology

At any given time, discrepancies exist between the predictions of an accepted scientific theory and the experiments or observations that test those predictions. Kuhn argued that most such discrepancies, which he called 'anomalies', are not viewed by scientists as falsifying instances. Rather, they are considered puzzles to be solved within the existing paradigm.

The standard model of cosmology[2] is not exceptional in this regard. The list of anomalies is impressively long, and some of them have persisted so stubbornly and for so long a time that they have achieved the status of 'named' problems. Examples include the 'Lithium problem' (Fields, 2011); the 'core-cusp problem' (de Blok, 2010); the 'missing satellites problem' (Moore et al., 1999); the 'too big to fail problem' (Boylan-Kolchin, Bullock & Kaplinghat, 2011); and the 'missing baryons problem' (McGaugh, 2008). In textbooks and review articles, these discrepancies are rarely described as falsifying; they are presented rather as problems that remain to be solved from within the existing paradigm.[3] Typical is the following statement by Malcolm Longair in the 2008 monograph *Galaxy Formation*: "There is no limit to the ingenuity of astronomers and astrophysicists in finding ways of reconciling theory and observation. As more parameters are included in the models, the easier it will be to effect the reconciliation of theory with observation" (p. 419).

At the same time, there *have* been instances since the 1960s where anomalies were interpreted by the community as being incompatible with the cosmological model as it existed at the time. A famous example is the discovery around 1998 that the expansion of the universe is accelerating, rather than decelerating as the standard model had predicted.

It is with the latter sort of discrepancy that this paper is concerned: that is: discrepancies that seem immune to reconciliation by (as Longair might say) adjusting the parameters of astrophysical theory. Three such instances are identified below. In each case, it will be argued that the response of the scientific community (whether intentionally or not) has been conventionalist in the sense defined by Popper. On this view, some essential components of the current, standard model of cosmology—including dark matter and dark energy—owe their existence to conventionalist stratagems.

3. Popper's "conventionalist stratagems"

Herbert Keuth (2005) provides a succinct re-statement of Popper's four conventionalist stratagems:

> (i) we may introduce ad hoc hypotheses (which make refuting evidence seem irrelevant); (ii) we may modify the so-called ostensive definitions (so as to alter the content of a hypothesis and thus possibly its truth value); (iii) we may doubt the reliability of the experimenter (and declare his observations that threaten the tested theory to be irrelevant); (iv) we may doubt the acumen of the theoretician (who does not produce ideas that can save the tested theory). (Keuth, 2005, p. 72.).

Popper believed that scientists should avoid such stratagems, and to that end, he proposed a set of methodological rules that were designed to preserve falsifiability (Popper, 1959, chapter 4). Now, nothing in the present work is intended as *prescriptive*: neither the content of the current model of cosmology, nor the methodology that led to that content, are being critiqued here. Popper's prescriptivist rules are therefore not of direct interest; nor are the criticisms, by others, of those rules, of which there are many. However, in the process of specifying how falsifiability could be preserved, Popper sharpened and clarified the definitions of the four conventionalist stratagems, and those clarifications will be useful in what follows.

The first stratagem employs 'ad hoc hypotheses'.[4] Popper writes:

> As regards *auxiliary hypotheses* we decide to lay down the rule that only those are acceptable whose introduction does not diminish the degree of falsifiability or testability of the system in question, but on the contrary, increases it…. If the degree of falsifiability is increased, then introducing the hypothesis has

[1] In so doing, Popper showed himself to be a conventionalist with regard to methodology (Akinci, 2004).

[2] Here and below, the 'standard model of cosmology' refers to the 'ΛCDM [Lambda-cold-dark-matter] model' or the 'concordance' or 'benchmark' cosmological model as it is presented in current textbooks and review articles. That model purports to describe the universe going back to times as early as the era of 'big-bang nucleosynthesis' (BBN) and possibly earlier. The discussion in this paper refers to the evolution of the universe from the era of BBN until the present. There is nearly perfect unanimity concerning the predictions of the standard model over this interval of time; for a list of representative texts, see Table 1.

[3] An exception is Kroupa's (2012) closely-reasoned argument that many of the outstanding anomalies should be considered falsifying. See also Kroupa, Pawlowski, and Milgrom (2012).

[4] Popper uses the terms 'ad hoc hypothesis' and 'auxiliary hypothesis' synonymously.