Studies in History and Philosophy of Modern Physics 62 (2018) 1–18

Contents lists available at ScienceDirect

Studies in History and Philosophy of Modern Physics

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

Alternative explanations of the cosmic microwave background: A historical and an epistemological perspective

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ARTICLE INFO

Article history:
Received 5 December 2016
Accepted 25 April 2017
Available online 21 October 2017

Keywords:
Astrophysics
Cosmology
Cosmic microwave background
History of astronomy
Falsificationism
Theory change
Evidence

ABSTRACT

We historically trace various non-conventional explanations for the origin of the cosmic microwave background and discuss their merit, while analyzing the dynamics of their rejection, as well as the relevant physical and methodological reasons for it. It turns out that there have been many such unorthodox interpretations; not only those developed in the context of theories rejecting the relativistic ("Big Bang") paradigm entirely (e.g., by Alfvén, Hoyle and Narlikar) but also those coming from the camp of original thinkers firmly entrenched in the relativistic milieu (e.g., by Rees, Ellis, Rowan-Robinson, Layzer and Hively). In fact, the orthodox interpretation has only incrementally won out against the alternatives over the course of the three decades of its multi-stage development. While on the whole, none of the alternatives to the hot Big Bang scenario is persuasive today, we discuss the epistemic ramifications of establishing orthodoxy and eliminating alternatives in science, an issue recently discussed by philosophers and historians of science for other areas of physics. Finally, we single out some plausible and possibly fruitful ideas offered by the alternatives.

1. Introduction

The discovery of the cosmic microwave background (CMB) in 1965 by Arno Penzias and Robert Wilson and interpreted by Robert H. Dicke and his co-workers was a turning point in 20th century cosmology. It divided cosmology into an epoch of sometimes heated *cosmological controversy* (Kragh, 1996) and an epoch of solidified support for the standard cosmological paradigm, popularly known as the *hot Big Bang cosmology* (Peebles, Page, & Partridge, 2009). Actually, attributing the discovery of the CMB to Penzias and Wilson is a bit misleading, first, because they were not looking for it and, second, because it had been predicted by Gamow and his collaborators a few decades earlier.[1] They initially interpreted the accidentally detected signal as a noise caused by an artefact; they were not aware it had anything to do with a physical phenomenon of the utmost importance for cosmology. Their detection of the signal had far-reaching implications, however, not least of which was a now overlooked interpretation race in which they themselves did not participate.

The fact that the 1965 discovery was a clear watershed creates the impression of inevitability of the currently standard interpretation of the great CMB discovery as a remnant of primordial fireball, and that no alternative interpretations have been offered, seriously or half-seriously, by distinguished cosmologists. The impression of the inevitability of the current view is shared by astronomers and laypersons alike. Two of the best cosmology textbooks available, by Coles and Lucchin (1995) and Peacock (1999), reinforce this impression. Peacock even notes, with a poetic flourish, "The fact that the properties of the last-scattering surface are almost independent of all the unknowns in cosmology is immensely satisfying, and gives us at least one relatively solid piece of ground to act as a base in exploring the trackless swamp of cosmology" (p. 290).

From the point of view of the astrophysics community, the validity of the orthodox interpretation of CMB is largely resolved, with some doubts voiced from time to time (e.g., Baryshev, Raikov & Tron, 1996). And as far as the general issue of the choice of cosmological models is concerned, the standard cosmological

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[1] There are claims of earlier CMB detections, as described Peebles et al. (2009). Normative understanding of scientific discovery correctly rejects such claims in the same manner as we reject the idea that Galileo discovered Neptune, although he did observe it in 1612–13, giving the credit to Le Verrier in 1846.

https://doi.org/10.1016/j.shpsb.2017.04.005
1355-2198/

model seems to rest on a secure foundation (for review of some exotic alternatives, see Ellis, 1984).

Yet López-Corredoira (2014) has quite recently examined some alternative cosmological models from a sociological point of view. This is important, as the emergence of alternatives and their destiny is a complex issue at the heart of scientific knowledge production and the discovery process. For instance, Cushing (1994) argues that a perfectly viable alternative to the Copenhagen interpretation of Quantum Mechanics, Bohm's mechanics, has been side-lined because it was devised later on. And Chang (2009, 2010) says forgotten and abandoned alternatives are often alternate routes to discoveries that were never taken. He demonstrates this using relevant examples in chemistry. Perovic (2011) analyses how subtle changes in experimental conditions influence the possibility of emerging and often crucial alternative theoretical accounts in particle physics, while Dawid, Hartmann, and Sprenger (2015) offer a Bayesian analysis of theoretical preferences when viable theoretical alternatives are not available.

The CMB is another case, and in many respects, a different and fruitful case, the study of which can enrich this strand of methodological and philosophical research. Generally speaking, in the scientific fields that reconstruct evidence from observations, the epistemic standing of orthodox thought is tied to the epistemic standing of available alternatives. Evidence in such cases is, on the whole, very different from evidence provided in, say, experiments in solid state physics, in the sense that the underdetermination of theoretical accounts by evidence is bound to be much more pronounced and longer lasting. The wiggle room for alternative interpretations is much wider in a field such as cosmology than in experimental physics, as the latter provides much more direct evidence in debates and thus severely constrains theoretical accounts of relevant phenomena. The CMB was a milestone discovery, but it would be misleading to think it played a role identical to that, for instance, played by the evidence delivered by a particle collider in competing theoretical approaches to the existence of an elementary particle. Its role unravelled much more gradually.

Given this, it is wise to avoid treating side-lined alternative interpretations in the same way as we justifiably would experimentally falsified alternatives in experimental physics. Instead, we should generally regard them as a resource that can potentially be revised and revived (despite occasional fairly straightforward falsifications of its certain aspects) The evidence of orthodoxy does not necessarily justify our outright discarding of the alternatives in cosmology. In fact, establishing orthodoxy may unjustifiably boost the CMB's epistemic standing by eliciting ignorance or a too-hasty dismissal of the existing alternatives, in part by propagating an inadequate history of the field and systematically, albeit unjustifiably, downplaying existing alternatives. Failing to understand the subtleties of the history of how orthodox thought about CMB was established runs the risk of generating widespread prejudice that opinions dissenting from the standard paradigm are both few and insignificant.

In short, the CMB provides an incentive for philosophically minded historical research. Just how convincing was the account that became the standard CMB interpretation in the first years after Penzias' and Wilson's discovery or during the first decade or two thereafter? Were any viable alternatives neglected at the time? How convincing is the account currently, and are there any viable alternatives now? Has there been enough critical examination in the modern practical work on the issue? All these questions are part of the complex and insufficiently studied problematic of paradigm formation in modern cosmology (Kragh, 1997; Norton 2017). In the first part of the paper (Sections 2, 3, and 4), we offer a historical case study of the formation of the alternatives in modern cosmology, setting the basis for an assessment of their respective epistemic standing in the second part of paper (Sections 5 and 6).

Peebles (1999) commentary on the centennial re-edition of Penzias and Wilson (1965) paper is a good starting point for our research into the historical context of the CMB:

> A willingness to believe such an elegant gift from nature surely also played a significant role in the early acceptance of the CBR [cosmic background radiation] interpretation… During four decades of involvement with this subject, I have grown used to hearing that such advances have at last made cosmology an active physical science. I tend to react badly because I think cosmology has been an active physical science since 1930, when people had assembled a set of measurements, a viable theoretical interpretation, and a collection of open issues that drove further research. This equally well describes cosmology today.

This comment sets the stage for the article. The "willingness to believe" the standard model and a lack of confidence in the seriousness of the pre-1965 cosmological research are key ingredients in the standard, streamlined view of the history of physical cosmology. (Peebles 2014) There is a widespread impression that the microwave noise detected serendipitously by Penzias and Wilson threw us into an epoch of serious, quantitative cosmology and that the essential validity of the hot Big Bang paradigm has remained unchallenged ever since. As Coles and Lucchin (1995) suggest, "it is reasonable to regard this discovery as marking the beginning of 'Physical Cosmology'" (p. xiii).

Yet the impression is wrong and creates a false picture of both the history and the methodology of cosmology. The facts about multiple methodologically sound alternative explanatory hypotheses of the CMB are mostly forgotten. Consequently, important historic-philosophical lessons about contemporary cosmological research are missed, and a source of potentially valuable ideas side-lined. It is worth trying to weave a historical tapestry of this admittedly amazing development by considering some strands presently deemed peripheral. The general motivation for this study is perhaps best expressed by Kragh's (1997) comments on the history of cosmology:

> There is a tendency to streamline history and ignore the many false trails and blind alleys that may seem so irrelevant to the road that led to modern knowledge. It goes without saying that such streamlining is bad history and that its main function is to celebrate modern science rather than obtain an understanding of how science has really developed. The road to modern cosmology abounded with what can now be seen were false trails and blind alleys, but at the time were considered to be significant contributions.

The story of the CMB alternative interpretations is paradigmatic in this respect. Many scientists and popularizers of science, perhaps justifiably, use every opportunity to hail the orthodox interpretation of CMB as one of the greatest, often as *the* greatest triumph of modern cosmological science. Yet its often professed role in terminating the cosmological controversy blurs the distinction between the physical phenomenon and the historical role of the dominant interpretation, ascribing some form of "progressive" value to the CMB photons themselves. The necessary palliative is certainly the study of the non-standard, minority interpretations which challenged the prevailing orthodoxy. In addition, as frequently happens in such circumstances, alternative theories may contain valuable side ideas, motivations, and conjectures. Because these theories are usually regarded as failures, their insights are