Introduction

Our study of the explanation of the cosmic microwave background (CMB) radiation – the uniform microwave radiation omnipresent across the skies – is philosophically motivated historical analysis. The analysis tells us what viable alternatives to the explanation of the CMB based on the Hot Big Bang model that eventually became the standard CMB interpretation were discussed or neglected after Arno Penzias and Robert Wilson's discovery of the CMB and clarifies their exact role in the developing consensus. The usual impression of a quick consensus ignores multiple methodologically sound alternative explanatory hypotheses of the CMB, now mostly forgotten, but it disappears as soon as we dive into them. This widespread impression has prevented the completion of an adequate detailed picture of both the history and the methodology of cosmology and also precluded the ability to draw some important historic-philosophical lessons relevant to contemporary cosmological research. Even more importantly, a source of potentially valuable ideas may have been sidelined.

In this book, we seek to weave a historical tapestry of this amazing development by considering some forgotten approaches and those presently deemed peripheral and to draw from it methodological and philosophical lessons for modern cosmology. The general motivation for this study is perhaps best expressed by Helge Kragh's comments on the history of cosmology:

> [t]here is the 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 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. (Kragh, 1997, 67–68)

This comment nicely sums up the situation with the alternative interpretations of the CMB. It is a paradigmatic story in this respect. Many scientists and popularizers of science use every opportunity to hail the orthodox interpretation of the CMB

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as one of the greatest triumphs, if not the greatest one, of modern cosmological science. This is certainly justified, but it blurs the distinction between the actual physical phenomenon and the role the now dominant interpretation played historically. It is as if the CMB photons themselves ended the great cosmological controversy of the 1950s and 1960s (Chapter 2), and there was no long and arduous process of ever-increasing consensus on the emerging and constantly developing orthodoxy. One way to remedy this situation is to carefully analyze the nonorthodox interpretations offered by prominent physicists and cosmologists at the time – sometimes by those who were developing the emerging orthodox view.

In fact, all these concerns go back to the complex and insufficiently studied problematic of paradigm formation in modern cosmology (Kragh, 1997; Norton, 2017). Our historical case study of the formation of the alternatives in modern cosmology sets the scene for our assessment of their respective epistemic standing, primarily with respect to their interpretation of the CMB (Parts III and VI). Understanding the exact epistemological role the CMB has played in modern cosmology is also essential if we wish to come up with a substantial response to broad criticisms of cosmology as a scientific field (e.g., Dingle, 1954; Disney, 2000).[3] This sort of criticism has been around throughout the twentieth and twenty-first centuries; it is still alive and aimed at current cosmological endeavors. It prompts us to ask, for instance, how we can justifiably draw predictions based on high-precision models of the physical state of the early universe and the observed corresponding traces if we do not fully understand the methodological premises on which the alternatives were refuted in the case of the CMB. The methodological premises and desiderata have hardly changed since then, despite a more precise observational nexus. The following question remains to be answered as well: What exactly supports extrapolating to the states of matter many orders of magnitude more extreme than anything we encounter in a laboratory? Understanding the emergence and acceptance of the standard CMB interpretation and the rejection of the alternatives will help us answer these general questions on the methodological foundations of current cosmology.

First, this analysis may yield a more accurate historical understanding of how scientific process proceeded and its epistemological and methodological ramifications. It turns out that the alternative explanations of the CMB were surprisingly varied, ranging from cosmological explanations set firmly within the theoretical framework of the general theory of relativity, to purportedly nonrelativistic cosmological explanations and non-cosmological ones relying on regular physical laws alone. Moreover, this episode in the history of modern cosmology offers a model of epistemic and methodological responsibility in generating alternative explanations in the context of a gradually emerging orthodox account predicated on the constantly improving yet indecisive observational results (i.e., during a prolonged

underdetermination of competing theories and models based on available evidence). As such, this episode offers epistemological-methodological lessons for contemporary cosmology, including the role of broader epistemological and metaphysical views, and suggesting viable institutional structures that can facilitate an adequate playing field for efficient progress.

Second, the alternative theories may be a source of still-useful conjectures and ideas. This may be a worthwhile topic in its own right. With this in mind, we discuss some early ideas about baryonic matter in the cosmological context, assumptions about isotropy in the early universe, and the fields generating the expansion of the universe. Discovering relevant ideas in abandoned or ignored theories in the history of modern physics is not as uncommon as we may think. For example, the central concepts of Machian theories of gravitation, such as Brans–Dicke theory (e.g., Dicke, 1962) and Wheeler–Feynman action-at-a-distance classical electrodynamics (Wheeler & Feynman, 1945, 1949; Hoyle & Narlikar, 1964, 1971; Hogarth, 1962) were seen as too radical at their inception. Yet these concepts are now debated in inflationary cosmology and in philosophical discussions of the arrow of time (Linde, 1990; Price, 1991). In fact, overlooking alternatives may slow down the progress.[4]

This reassessment will inevitably lead us to a set of questions concerning the present situation: How convincing is the standard account currently? Are there any viable alternatives now? If not, why not, and is the critical examination in the modern practical work satisfying? We tackle these questions throughout the book but especially in the closing chapters.

Our discussion starts with a brief introduction to the controversial beginnings of physical cosmology (Part I). We move on to the characterization of the current orthodox interpretation of the CMB predicated on the emerging precision cosmology (Part II) and discuss epistemological and methodological ramifications of the formation of the orthodox view and alternatives (Part III). Finally, we analyze both moderate (Part IV) and radical (Part V) alternatives to the orthodox view and draw potentially far-reaching lessons (Parts VI and VII).