SPECIAL SECTION: BUILDING UNIVERSES: THE PHILOSOPHICAL AND MATHEMATICAL UNDERPINNINGS OF COSMOLOGY (EIGHTEENTH–TWENTIETH CENTURIES)

SPECIAL SECTION INTRODUCTION

Silvia De Bianchi and Federico Viglione

1. Introduction

The present special section is meant to foster interaction between philosophers and historians of science by presenting contributions focused on the mathematical and philosophical underpinnings of physical cosmology. The period under consideration begins with the eighteenth century, in which the scientific community witnessed the great revolution introduced in observational cosmology by William Herschel, and ends in the twentieth century, with the proposal of the big bang theory, the detection of cosmic microwave background radiation, and new multiverse hypotheses. A number of cosmological models were formulated during that 300-year period, thanks to the development of mathematics and physics and of technological devices including telescopes and satellites. Astronomy and astrophysics disclosed the existence of celestial objects, such as binary stars, black holes, and nebulae (Kragh and Longair 2019).[1] Despite their variety,

Contact Silvia De Bianchi at the University of Milan, Italy, and the Autonomous University of Barcelona, Spain (silvia.debianchi@unimi.it), and Federico Viglione at the Autonomous University of Barcelona, Spain (federico.viglione@uab.cat).

This special section is part of the PROTEUS project that has received funding from the European Research Council under the Horizon 2020 research and innovation program (grant agreement no. 758145).

1. The latter were first presented in Herschel's "Catalogue" in 1786 (Herschel 1786; see also Mullaney 2007; Smith 2019).

Electronically published March 3, 2022.

HOPOS: The Journal of the International Society for the History of Philosophy of Science, volume 12, number 1, Spring 2022. Published by The University of Chicago Press for the International Society for the History of Philosophy of Science. https://doi.org/10.1086/718991

the cosmological models proposed from the late eighteenth century onward had to account for the fact that our universe was far older than previously thought, leaving aside once and for all any literal interpretation of the Bible and opening the path for a more radical distinction between cosmology and theology (De Bianchi 2016). Furthermore, on the ground of Herschel's work in the 1780s, the scientific community acknowledged that looking far away into space also meant looking back in time:[2]

> I shall take notice of an evident consequence attending the result of the computation; which is, that a telescope with a power of penetrating into space, like my 40-feet one, has also, as it may be called, a power of penetrating into time past. To explain this, we must consider that, from the known velocity of light, it may be proved; that when we look at Sirius, the rays which enter the eye cannot have been less than 6 years and 4 1/2 months coming from that star to the observer. Hence it follows, that when we see an object of the calculated distance at which one of these very remote nebulae may still be perceived, the rays of light which convey its image to the eye, must have been more than nineteen hundred and ten thousand, that is, almost two millions of years on their way; and that, consequently, so many years ago, this object must already have had an existence in the sidereal heavens, in order to send out those rays by which we now perceive it. (Herschel 1802, 498–99)

Herschel's work generated the need to provide a historical reconstruction in evolutionary terms of the universe and its objects, on the ground of astronomical observations and in agreement with physical laws. This practice is still present in our current cosmology, but its motivation and philosophical grounds changed over time.[3]

Eighteenth-, nineteenth-, and twentieth-century models of the cosmos alike underwent deep scrutiny by scientific communities. Twentieth-century models have the undisputed merit of having disclosed with unprecedented accuracy the structure of our universe, allowing human beings to make ever-more precise statements concerning the origins of the universe and predictions regarding its evolution. However, as shown in this special section, many debates that took place in the proper domains of philosophy and mathematics have historically influenced, and sometimes determined, both the formulation and the further development of

2. Kant was among the first to notice this implication in the 1790s (De Bianchi 2018).

3. Even if it must be said that discussion on, e.g., Kant's first antinomy was still present in many cosmological debates in the twentieth century.

these cosmological models. The present section thus is meant to investigate both foundations by focusing on the work of scientists (Slipher, Lemaître, Einstein, Hoyle), mathematicians (Weyl), and philosophers (Kant) who contributed to interpreting and to grounding cosmological models. Moreover, given the richness of the mathematical and philosophical debates at stake, this special section contains suggestions that open the path for future discussion on the most effective way of thinking of the current cosmological models, by integrating the history and philosophy of science. Indeed, as shown in this special section, historical and philosophical investigations can hardly be detached in cosmology, so they are both necessary to spell out its content and implications.

2. Kant's Legacy in the History and Philosophy of Cosmology

In composing this special section, we prioritized the need to deepen Kant's account of cosmology in order to emphasize (1) its impact on modern cosmological debates and (2) the relevance of the *pars construens* of Kant's 1755 cosmology and its later development, which inevitably played a role in informing the early debates of German idealists, including Schelling and Hegel. The contributions aim to integrate historical and philosophical perspectives and to investigate Kant's 1755 cosmology. In her contribution, "A 'Physiogony' of the Heavens: Kant's Early View of Universal Natural History," Cinzia Ferrini highlights the role of philosophical and scientific sources. The special section aims to underscore the philosophical underpinnings of Kant's cosmological principle, as spelled out in the *Critique of Pure Reason*, and to open a path for further investigation of Kant's late cosmology, which Silvia De Bianchi in her contribution labels "functional cosmology." The latter is an approach devised by the mature Kant to provide a limited teleological account of the universe in view of our practical and aesthetic experience. The problem of giving meaning to the universe as an indirect object of experience and subject of discourse is central to Kant's late philosophy, and it mirrors the need of the scientific community of astronomers of that time to account for Herschel's observations.

The close of the eighteenth century witnessed a surge of works regarding matter and the universe that were hylozoistic and pantheistic in nature, something deeply opposed to Kant's spirit. In "Cosmology, Astronomy, and Philosophy around 1800: Schelling, Hegel, Herder," Laura Follesa shows how the alternative offered by Herder to Kant's philosophy of nature represented a source of inspiration for Schelling and the young Hegel. In a nice contrast, Kant's attempt to oppose Herder's pantheistic approach to the cosmos emerges in De Bianchi's contribution, together with the need to understand teleological accounts of the universe from a broader transcendental perspective.

There is a third reason to prioritize Kant's work in this special section. In the field of philosophy of cosmology,[4] it has been suggested that we should distinguish deductive from inductive methodologies when comparing different authors and works. However, even if the history of cosmology offers a variety of examples in which these two approaches compete in investigating the cosmos, things are more complex: the two approaches sometimes intertwine in ways that escape a rigid classification. This fact in turn sheds light on the complex interrelation that we find even today between observational and theoretical cosmology. The special section brings together four contributions that are mainly focused on Kant's philosophy and cosmology precisely because the latter is a clear example of an approach to cosmology that is difficult to classify: while Kant's approach has sometimes been classified as an example of inductive methodology applied to cosmology, the matter is actually subtler. De Bianchi's, Howard's, Ferrini's, and Beisbart's works provide evidence for this. As both De Bianchi and Ferrini show, Kant's system offers a far richer view involving both deductive and inductive inferences in cosmology, as well as analogical reasoning. The latter is not only present in Kant's work; it is necessary to grasp his account of what humans do when describing the cosmos. De Bianchi's and Ferrini's contributions demonstrate the relevance of previous deductive methods and empirical observations to the development of Kant's mature view of cosmology. Even if Newton's inverse square law is a physical and mathematical underpinning of Kant's idea of the cosmos, philosophically and conceptually only the assumption of a hierarchical structure of the universe via analogy can complete the picture.

Emphasis on the deductive type of reasoning present in Kant's system is shown by Stephen Howard in "From the Boundary of the World to the Boundary of Reason." As Howard argues, one has to distinguish Kant's critique of rational cosmology in the *Critique of Pure Reason* from the *pars construens* and detailed analysis of the universe and of our solar system in his 1755 *Universal Natural History and Theory of the Heavens*. For only such consideration can shed light on the development of the nineteenth-century cosmology and philosophy of nature, as the thorough study by Follesa shows. Herder, Schelling, and Hegel were called to reply to Kant's view of cosmology, but they also had to consider the science of their time in order to offer a coherent and systematic worldview, including a theory of matter and a cosmology. Further implications of Kant's critical approach to rational cosmology are scrutinized by Claus Beisbart in "What Is the Spatio-Temporal Extension of the Universe? Underdetermination according to Kant's First Antinomy and in Present-Day Cosmology," which explores Kant's arguments in the

4. For recent studies in the philosophy of cosmology, see Zinkernagel (2014). For a study of cosmology and inductive inferences, see Norton (2010).

first antinomy to highlight how far, exactly, we can appeal to them to understand the principle of underdetermination characterizing our current approach in the philosophy of cosmology.[5] As Beisbart's analysis reveals, we must be careful in extending the analogy too far, since Kant based his principle of underdetermination on pure a priori grounds rather than empirical considerations.

3. Integrating the History and Philosophy of Cosmology

Classifying cosmological models and their philosophical underpinnings solely on the grounds of the dichotomy between deductive and inductive reasoning shows weaknesses that do not seem helpful in structuring the field of philosophy of cosmology. We suggest finding another rationale for classifying cosmological models. For the time being, we suggest classifying philosophical arguments supporting a cosmological model on the basis of their scope. The specific proposal is to group such arguments on the basis of their being supportive, or not, of the idea of the historical evolution of the universe and of its property of undergoing phase transitions. This guideline allows us to provide a coherent treatment of accounts ranging from the work of Kant and the German idealists to the scientific achievements characterizing twentieth-century cosmology.

This classification emerges in the contributions in the special section that offer a reconstruction of the philosophical and mathematical underpinnings of cosmological models in the twentieth century, taking their cue from important achievements in nineteenth-century spectroscopy and the development of Riemannian geometry. Craig Fraser's contribution, "Vesto Slipher, Nebular Spectroscopy, and the Birth of Modern Cosmology, 1912–22," explores the genesis of this exciting new branch of physics generated by the results of nebular spectroscopy. C. D. McCoy's "The Constitution of Weyl's Pure Infinitesimal World Geometry" investigates the mathematical underpinnings of general relativity, with emphasis on the relevance of the Riemannian legacy for Hermann Weyl's interpretation of Einstein's theory, providing a counterproposal to Ryckman's (2005) view that suggested it was, instead, a result of Weyl's adherence to Husserl's phenomenology.

In our journey toward the modern relativistic, evolutionary, and expanding universe, we find intermediate steps that are worth investigation, since they reveal how mathematics is used in cosmology (recall that there were different solutions proposed to Einstein's equations) and how philosophical arguments are generated in support of a static or a dynamic account of the cosmos. It is clear that the sea change effected by Einstein's theory on our view of cosmology did not

5. For a discussion of the cosmological principle today and underdetermination, see Butterfield (2014).

happen suddenly and is the result of a series of debates among scientists, philosophers, and mathematicians. Cosmology passed from being a branch of philosophy in the eighteenth century—being at the same level, say, with theology—to a niche occupied by only a few professional scientists. As Siska De Baerdemaeker and Mike D. Schneider point out in their contribution, "Better Appreciating the Scale of It: Lemaître and de Sitter at the BAAS Centenary," only a small community of cosmologists in the first half of the twentieth century considered the universe as dynamic, that is, in evolution. They had to address the problems of cosmic time and of the origin of the universe, ultimately finding diverse solutions. The lively debate on the evolution of the universe and its structure that stirred up the small community of cosmologists in the 1930s came to involve the rest of the scientific community and professional philosophers, thereby going beyond the boundaries of this small group of theoretical physicists.

The history and philosophy of science, which is central to our understanding of cosmology, appears in Helge Kragh's contribution, "Philosophical Contexts of the Steady-State Universe," in which he draws attention to a crucial passage of the history of cosmology. A controversy took place in the 1950s between the steady-state theories formulated by Fred Hoyle, Hermann Bondi, and Thomas Gold and the relativistic models of cosmological evolution. Criticisms were advanced against the steady-state models (as well as against other models that entailed infinite space, such as Einstein–de Sitter's 1932 model) in a Kantian fashion: both philosophers and theologians criticized steady-state models with philosophical arguments against the possibility of actual infinites outside of the mathematical realm, arguments that recalled the first antinomy of pure reason and the long tradition behind it (even if, as Kragh notes, this kind of criticism rarely captured the attention of cosmologists).

There is a twofold moral at the end of our road: if we want to understand current cosmology, we must consider its mathematical underpinnings and the historical debates surrounding them, as shown by McCoy's contribution devoted to Weyl's interpretation of general relativity. However, if we want to show the implications of current cosmology, we must go beyond it and enter the field of philosophy.

4. Future Perspectives

With this special section, we aim to stimulate debate within the communities of historians and philosophers who are interested in scientific inquiry into the structure of the universe and to foster their mutual interaction. Moreover, this special section is intended to encourage the interface of these communities with other fields of research, including but not limited to the history of mathematics and of modern physics broadly conceived. There is an enormous amount of research still to be done to create a dialogue across these fields in order to produce a multidisciplinary perspective on cosmology. There are few fields with the potential for fruitful collaboration among philosophers, historians, scientists, anthropologists, and mathematicians. Among these, cosmology stands out as an excellent one, spanning ages and cultures.

One notices a paradigm shift in this field that is mirrored in a cultural shift. The progressive growth of the relevance of mathematics for cosmology, and the recognition of the latter as a branch of physics, is a sign of the increasing distance of modern cosmology from theological considerations. The attribution of meaning to the cosmos and the appeal to aesthetic considerations, legacies of theological arguments for the disposition of the cosmos, are rarely employed by the scientific community in formulating cosmological theories. Study in philosophy and cognate fields will deepen our understanding of this progressive detachment of cosmology from theology, and the result will throw a fresh perspective on our way of conceiving the universe and our role within it.

REFERENCES

Butterfield, Jeremy. 2014. "On Under-Determination in Cosmology." *Studies in History and Philosophy of Modern Physics* 46 (1): 57–69.

De Bianchi, Silvia. 2016. *La fenice della natura*. Milan: Mimesis.

———. 2018. "Kant's Transcendental Philosophy and Scientific Observation." In *Natur und Freiheit*, ed. V. Waibel, M. Ruffing, and D. Wagner, 1469–76. Berlin: de Gruyter.

Herschel, William. 1786. "Catalogue of One Thousand New Nebulae and Clusters of Stars." *Philosophical Transactions of the Royal Society of London* 76:457–99.

———. 1802. "Catalogue of 500 New Nebulae, Nebulous Stars, Planetary Nebulae, and Clusters of Stars; with Remarks on the Construction of the Heavens." *Philosophical Transactions of the Royal Society of London* 92:477–528.

Kragh, Helge, and Malcolm S. Longair, eds. 2019. *The Oxford Handbook of the History of Modern Cosmology*. Oxford: Oxford University Press.

Mullaney, James. 2007. *The Herschel Objects and How to Observe Them.* Astronomers' Observing Guides. New York: Springer.

Norton, John D. 2010. "Cosmic Confusions: Not Supporting versus Supporting Not." *Philosophy of Science* 77:501–23.

Ryckman, Thomas. 2005. *The Reign of Relativity: Philosophy in Physics, 1915–1925*. Oxford: Oxford University Press.

Smith, Robert. 2019. "Observations and the Universe." In *The Oxford Handbook of the History of Modern Cosmology*, ed. Helge Kragh and Malcolm S. Longair, 40–76. Oxford: Oxford University Press.

Zinkernagel, Henrik, ed. 2014. "Philosophy of Cosmology." Special issue. *Studies in History and Philosophy of Modern Physics* 46 (1).