"particulars" (90)—sounds metaphysical! Perhaps the authors will object that they don't mean anything metaphysically substantial by those terms; I would say the same for my neutral reading of minimal mechanism.

Despite these objections, I mostly agree with the authors' central theses and recommend the book to all philosophers of science interested in mechanism. I agree that scientific practice is consistent with many different metaphysical theories, among which we can remain neutral in our account of mechanism. And I view our updated account of mechanism and constitutive relevance as, if not a sibling of the authors' account, much closer than previous accounts (Craver, Glennan, and Povich 2021). I think we are converging, and this book will push the field forward, hopefully toward further convergence.

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References

Craver, Carl F. 2007. *Explaining the Brain*. Oxford: Oxford University Press.
Craver, Carl F., Stuart Glennan, and Mark Povich. 2021. "Constitutive Relevance and Mutual Manipulability Revisited." *Synthese* 199:8807–28.
Harinen, Totte. 2018. "Mutual Manipulability and Causal Inbetweenness." *Synthese* 195 (1):35–54.
Prychitko, Emily. 2021. "The Causal Situationist Account of Constitutive Relevance." *Synthese* 198: 1829–43.
Salmon, Wesley. 1984. *Scientific Explanation and the Causal Structure of the World*. Princeton, NJ: Princeton University Press.

Review of Boyd et al.'s *Philosophy of Astrophysics: Stars, Simulations, and the Struggle to Determine What is Out There*

Philosophy of Astrophysics: Stars, Simulations, and the Struggle to Determine What is Out There, edited by Nora Mills Boyd, Siska De Baerdemaeker, Kevin Heng, and Vera Matarese, Cham: Springer, 2023.

This open access volume is a must read for all those who want to enter the discussion of relevant philosophical questions in scientific practice by considering one of the most exciting and expanding fields of the natural sciences, i.e., astrophysics.

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With this volume, Nora Boyd and colleagues provide an important service to the community of philosophers of science by setting up the scene for fruitful and continuous dialogue among philosophers debating epistemological and ontological questions related to scientific modeling and detection of astrophysical phenomena. The unification of scattered debates within the new framework of the philosophy of astrophysics is the relevant achievement of this book.

The volume is divided into three parts, to which established philosophers of science contributed. Part I is devoted to "Theory, Observation and the Relation Between Them." In it, Nora Boyd, Marie Gueguen, Jamee Elder, Lydia Patton, Niels Martens, and Martin King contribute to several facets of current and past debates in the philosophy of science. In particular, in "Laboratory Astrophysics: Lessons from Epistemology of Astrophysics" (Chapter 2), Nora Boyd addresses the challenge posed by Ian Hacking, who dismissed astrophysics in the 1980s, and in a sense her contribution represents the spirit of the whole book, which can be interpreted as a reply to Hacking's skepticism towards astrophysics. In particular, Boyd's reply emphasizes that laboratory astrophysics experimentation can shed light on the little significance that we should attribute to the distinction between experimental and non-experimental sciences in the case of astrophysics, thereby showing that more attention should be paid to the reconstruction of the causal chain of empirical data to establish the epistemic authority of astrophysics. Chapter 3, titled "A Crack in the Track of the Hubble Constant," deals with a pressing issue in current astrophysics and cosmology, i.e., the Hubble tension. In it, Marie Gueguen reconstructs the debates from the 1970s onward and comments on the methodology of astrophysical measurements. In her view, the "Hubble crisis" is due to a misconception of managing the uncertainties associated with the required experimental measurements. Whereas this take is debatable and more experimental results coming from large collaborations hint something more than this, this contribution rightly identifies this topic as of crucial relevance for future philosophical debates. Jamee Elder in "Theory Testing in Gravitational-Wave Astrophysics" (Chapter 4) offers a thorough discussion of the circularity problem of theory-ladenness of the LIGO–Virgo methods in observing events such as GW150914, produced by binary black hole mergers. According to Elder, these methods represent serious concerns since they do not allow comparisons of signals with alternative theories: any event is interpreted as the signature of a predicted phenomenon of GR. Even the refinement of techniques to obtain higher sensitivity are not enough to solve this issue. On the contrary, to mitigate the problem a cross-check among different models, simulations, and observations with other domains must be pursued. In Chapter 5, "Hybrid Enrichment of Theory and Observation in Next-Generation Stellar Population Synthesis," Lydia Patton develops a critique of a straightforward empiricist view by discussing the case study of population synthesis methods. The latter use theories and models to interpret and analyze data, and more importantly they necessarily need them to measure the physical parameters: no meaningful physical variable can be targeted without using theoretical sources. Part I of the volume ends with Chapter 6, "Doing More with Less: Dark Matter and Modified Gravity" by Niels Martens and Martin King. They explore the problem and the implication of underdetermination of data between two theories that are neither empirically equivalent nor empirically

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coherent, i.e., the Λ-CDM model and modified gravity. They claim that one cannot purely rely on the examination of the empirical data to solve the underdetermination of the two competing models. One should rather focus on the explanatory ideals of these two approaches, such as simplicity, synthetized by the slogan "to explain more with less," and unification in order to compare them in a philosophically enriching way.

Part II is titled "Models and Simulations" and represents the heart of the volume, with deeper discussion of idealizations and simulations in astrophysics. In more detail, Mauricio Suárez (Chapter 7) and Melissa Jaquart and Regy-Null R. Arcadia (Chapter 8) deal in great detail with the use of fictional posits as false idealization in astroseismology and the de-idealization involved in simulations of collisional ring galaxy models, respectively. Chapter 9, titled "Simulation Verification in Practice," by Kevin Kadowaki comments on Winsberg's "Verification and Validation" framework applied to astrophysical magnetohydrodynamics models and concludes that this framework is not applicable therein. On the contrary, a mixed approach is preferable: mathematical and physical aspects of complex simulations should not be disentangled. Chapter 10, "(What) Do We Learn from Code Comparison? A Case Study of Self-Interacting Dark Matter Implementations" by Helen Meskhidze, continues with developing the discussion of code comparisons, understood in terms of eliminative reasoning in computer simulations, whereas Chapter 11, "Simulation and Experiment Revisited: Temporal Data in Astronomy and Astrophysics" by Shannon Sylvie Abelson, focuses on simulation and experiment from an intriguing perspective. The contribution focuses on temporal data in astronomy and astrophysics, and underlines that a specific subclass of simulations includes a large amount of empirically obtained temporal data that count as experiments. In other words, there is a small class of simulations that are experiments and encode a high level of representational adequacy. Part II contains a last chapter by Sarah C. Gallagher and Chris Smeenk titled "What's in a Survey? Simulation-Induced Selection Effects in Astronomy" that deals with the problems of selection effects to be taken into account when interpreting data taken from astronomical surveys. The incompleteness of datasets is structural, and simulations are used to mitigate this feature by creating "mock" catalogues to account for multiple selection effects. However, this also means that observational data cannot be interpreted independently from simulations, and that one should address the reliability of background knowledge. Other open problems are discussed with emphasis on the "problem of uncomputed alternatives," consisting in a novel kind of computational selection effect leading to neglecting observational signatures.

Part III is devoted to "Black Holes" and contains three chapters. The first one, by Juliusz Doboszewski and Dennis Lehmkuhl, is titled "On the Epistemology of Observational Black Hole Astrophysics" and discusses three relevant issues: first, whether and in which sense black holes exist; second, how to handle the multiplicity of definitions of black holes and opt for one of them; and finally, they address the question of the dynamical timescales for observations of black holes and optimistically conclude that evidence in observational black holes concerns a wide range of dynamic processes across different timescales, and in the case of Sagittarius A* multiple timescales are accessible simultaneously. Alex Mathie in "Black Holes and Analogy" (Chapter 14) offers an intriguing contribution to the debate and examines

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the analogical reasoning deployed in contemporary black hole physics. He finds three strategies for resolving the tension between the physical significance of black hole thermodynamics (BHT) and the pessimism about the epistemic warrant of analogue gravity experiments. However, the major concern remains the fact that at present the analogical argument for BHT implies the success of the analogical argument for the derivation of astrophysical Hawking radiation and the legitimacy, at least an epistemic one, of analogue gravity. However, the contributor suggests that the possibility still remains open of interpreting analogy in heuristic terms and waiting for the analogical arguments to be superseded by more robust non-analogical arguments in the future. In "Extragalactic Reality Revisited: Astrophysics and Entity Realism" (Chapter 15), Simon Allzén discusses the status of astrophysics within the debates on scientific realism, thereby latching onto the first contributions of the volume addressing Hacking's challenge. Astrophysical realism is discussed and its viability is analyzed with respect to Cartwright and Chakravartty's entity realism, concluding that these positions are not compatible with being realist with respect to black holes. In Allzén's view, contemporary epistemic practices of science could rather open new, more suitable, realistic stances and are worth pursuing.

The volume concludes with the contribution of Kevin Heng, "Reflections by a Theoretical Astrophysicist," in which the reader can appreciate the perspective of a professional astrophysicist and the difficulties surrounding the interpretations of models and simulations in practice. Apart from the limits of the "Verification and Validation" framework, and the difficulties encountered in attaining robustness in modeling the behavior of dark matter on large scales, the contribution also focuses on fundamental unanswered questions, such as the status of turbulence, which lacks a unified model and theory, to accomplish the ideal of universality in the natural sciences and engineering.

At the end of the volume, a useful bibliography by Cameron C. Yetman covers approximately 40 years of publications, containing references to monographs and journal articles. It is divided into sections corresponding to relevant topics including modeling, methods in astrophysics, simulations, the realism/antirealism debate, theory testing, modified Newtonian dynamics, and sociological sources related to the analysis of the work of the astronomy and astrophysics community. This is also a useful tool for those working at the intersection of the history, philosophy, and sociology of science and constitutes a preliminary collection serving as common basis for interdisciplinary research.

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