Unifying the Debates: Mathematical and Non-Causal Explanations

Daniel Kostić
University Bordeaux Montaigne/SPH and IHPST-CNRS & University of Paris 1 Panthéon-Sorbonne

In the last couple of years a few seemingly independent debates on scientific explanation have emerged, with several key questions that take different forms in different areas. For example, the questions what makes an explanation distinctly mathematical and are there any non-causal explanations in sciences (i.e., explanations that don't cite causes in the *explanans*) sometimes take a form of the question what makes mathematical models explanatory, especially whether highly idealized models in science can be explanatory and in virtue of what they are explanatory. These questions raise further issues about counterfactuals, modality, and explanatory asymmetries: i.e., do mathematical and non-causal explanations support counterfactuals, and how ought we to understand explanatory asymmetries in non-causal explanations? Even though these are very common issues in the philosophy of physics and mathematics, they can be found in different guises in the philosophy of biology where there is the statistical interpretation of the Modern Synthesis theory of evolution, according to which the post-Darwinian theory of natural selection explains evolutionary change by citing statistical properties of populations and not the causes of changes. These questions also arise in philosophy of ecology or neuroscience in regard to the nature of topological explanations. The question here is can the mathematical (or more precisely topological) properties in network models

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in biology, ecology, neuroscience, and computer science be explanatory of physical phenomena, or are they just different ways to represent causal structures.

The aim of this special issue is to unify all these debates around several overlapping questions. These questions are: are there genuinely or distinctively mathematical and non-causal explanations?; are all distinctively mathematical explanations also non-causal; in virtue of what they are explanatory; does the instantiation, implementation, or in general, applicability of mathematical structures to a variety of phenomena and systems play any explanatory role? What makes them universally applicable: is it the genericity with generic and rudimentary features of particular types of mathematical explanations (such as topological) that makes them universally applicable, or is it because they explain by providing understanding of mathematical structure independently from being instantiated in any particular system? Or if they can be explanatory only when the details of instantiation are provided, is it then some ontological fact that makes them universally applicable to a variety of very diverse phenomena, e.g., is there some fundamental physical fact in virtue of which many real-world systems exhibit or instantiate certain topologies?

This special issue provides a platform for unifying the debates around several key issues and thus opens up avenues for better understanding of mathematical and non-causal explanations in general, but also, it will enable even better understanding of key issues within each of the debates. The topic of mathematical and non-causal explanations is increasingly being discussed in the last couple of years (Bokulich 2008; Saatsi and Pexton 2013; Batterman and Rice 2014; Huneman [2010] 2015; Kostic 2016a, b; Lange [2013] 2016; Saatsi and Jansson 2016; Chirimuuta 2018). A growing literature on mathematical and non-causal explanations enquires into the general features of these explanations and their relation to some of the well understood accounts of causal explanation, such as the mechanistic account (Machamer et al. 2000; Craver 2007; Craver and Darden 2013), the deductive-nomological account (Hempel and Oppenheim 1948), or semantic account (Chalmers and Jackson 2001).

However, not enough attention is devoted to the specific accounts of non-causal and mathematical explanations in their own right, without a comparative point of view of causal explanations. Even more importantly, the lack of discussions about the epistemic norms that specific scientific problems or areas of science impose on the structure of explanation has become increasingly apparent.

The contributions in this special issue respond to these challenges in a very systematic and direct way. Bob Batterman argues that the notion of universality has been misunderstood in the recent philosophical literature.

He argues that to explain how a phenomenon is universal requires recognizing that universality implies a kind of stability of behavior under perturbation. Furthermore, he argues that this stability itself requires explanation. He discusses how the renormalization group can provide the relevant explanation. The explanation of the stability characteristic of universality is then related to the autonomy of certain models or theories at continuum scales from those at scales of molecules or atoms.

Marc Lange discusses the basis on which an explanation of a given phenomenon can be deemed causal or non-causal. When we use one rather than the other type of explanation to explain a phenomenon, we immediately face the question of whether the one we decided not to use is less explanatory, whether the two explain the same facts, and to what extent they are competitors or complementary. Lange discuses two explanations of rocket acceleration, one (which uses forces) that he deems causal-mechanical and the other (which uses conservation laws) that he deems non-causal. Lange argues that the causal explanation explains facts that the conservation-law explanation can't, but also that the conservation-law explanation explains facts that the causal explanation can't. Thus, they are not competitors. Furthermore, the conservation-law explanation has some virtues that the causal one lacks. For instance, the conservation-law explanation unifies various different propulsion mechanisms and that it would still have held even if the rocket's propulsion mechanisms had been replaced. Moreover, it would still have held even if some of the laws governing molecular collisions had been radically different and even if the causal explanation had been different.

Daniel Kostic argues that there are various trade-offs among the complexity in the structure of explanation, scientific understanding, and explanatory depth. The idea is that the level of complexity in the structure of explanation is inversely proportional to the level of intimacy between explanation and understanding, i.e., the more complexity the less intimacy. This further affects the explanatory depth, i.e., the less complexity the greater explanatory depth and vice versa. His account provides a framework for making sense of various levels of intimacy between the explanation and understanding; from the ones in which explanation and understanding are the most distinct, i.e., where there can't be understanding without explanation (Strevens [2008] 2013; Khalifa [2012] 2017) to cases where the explanation has a minimal structure and it seems that scientific understanding is obtained without explanation (Lipton 2009). This is a gradual view of explanation, according to which the less structure it has the more understanding it provides, and vice versa. Thus, he concludes that the topological explanations and some other types of non-causal explanations indeed have a minimal structure by virtue of which they provide greater understanding and explanatory depth.

In his contribution Hugh Desmond argues that it is puzzling why redescribing a phenomenon with different levels of detail should make a difference between whether causal or non-causal explanations are favored. Desmond argues that this particular situation creates a serious problem for the ontic approach to causal and non-causal explanations, and instead he proposes a pragmatic-modal account, which accounts for the relation between granularity and the causal nature of explanation in terms of how contextual factors affect the modal structure of an explanation. Desmond's account has the additional advantage of dissolving some important disagreements concerning the status of non-causal explanation issues.

In his contribution Luca Rivelli revisits Stuart Kaufman's idea about ensemble explanations. Luca argues that in complex systems and evolutionary theory there is a hierarchy of non-mechanistic, non-causal explanations that form an explanatory chain in the hierarchy of levels of explanations, where *explanantia* at the higher level are recursively explained at the lower level. Such a hierarchical ensemble as a whole is grounded in some kind of a mechanistic explanation. The ensemble account of explanation has two very important features, it provides a framework for understanding the multilevel mechanistic explanations of certain aspects of weak emergence and it also provides a framework for thinking about the explanatory unification of non-causal explanations.

Finally, Philippe Huneman argues that the post-genomic turn in evolutionary biology does lead to a greater diversity of explanations, including some of the recently introduced cases of non-causal and mathematical explanations, such as topological explanations and statistical explanations. Huneman argues that the shift in understanding the concepts of genes, variation, and inheritance in postgenomic science provides topological and statistical explanatory frameworks that focus on genomic networks of many sorts and nucleotide-focused statistical tools respectively. These new explanatory practices are difficult to translate into mechanistic frameworks of explanation. Thus, according to him, this situation indicates diversification of explanatory frameworks in postgenomic science and evolutionary biology, which should be a welcomed shift.

The contributions in this special issue paint a clearer picture about the relation between mathematical and non-causal explanations. Not all mathematical explanations are equally non-causal, there are degrees of being non-causal which are reflected in the level of explanatoriness, unification, modal strength, and explanatory depth. For example, explanations of universality and minimal structure explanations seem to be further on the spectrum of being non-causal, and they seem to provide greater unification, whereas statistical explanations, pragmatic-modal explanations, and ensemble explanations work better when they are supplemented or combined with some kind of causal/mechanical explanation. This further implies that the level of unification, modal strength, and explanatory depth are mutually dependent concepts which follow the degrees of being non-causal, i.e., the more non-causal the explanation is, the more unification, modal strength, and explanatory depth it provides. The literature on mathematical and non-causal explanations continues to grow and diversify; that is why it requires an assessment from the unifying perspective. That is why this special issue aims at discussing the broad and converging set of ideas about mathematical and non-causal explanations that only recently started to emerge.

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