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Book Review

Mauricio Suárez (ed.), Probabilities, Causes and Propensities in Physics

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Title: Mauricio Suárez (ed.), Probabilities, Causes and Propensities in Physics, Springer, Heidelberg 2011. 264 pp., ISBN: 978-1-4020-9904-5.

The chapters of this book discuss in a detailed and technical, but accessible and clarifying way, the notions that connect physics with philosophical analyses of causation, probability and propensities. The work is a selection of presentations from the Second Workshop on Causal and Classical Concepts in Science held in Madrid in 2006.

Although the chapters of the book are written by numerous authors, the contributions facilitate the comprehension of a unified account of the role of causality, probabilities and propensities in physics. A special focus is put on quantum mechanics since it has obvious connections to the philosophical difficulties about these notions.

In the first chapter, which summarizes the following ones in a very lucid and articulate way, *Mauricio Suárez* introduces the topic of the book by explaining the basic notions and approaches. Four main theses that are important for the book chapters are introduced and distinguished:

T_1 Probabilities in physics are not mere degrees of belief or the results of measurements only, but real features of nature.

T_2 Transitional probabilities describe these characteristics better than do conditional probabilities.

T_3 These features are neither mere frequencies nor standard, long-term propensities.

T_4 Causal connections are a fundamental part of physics and they are best analyzed in terms of propensities and probability distributions.

The first part of the book is about probabilities. In its first chapter, Ch. 2, *Guido Bacciagaluppi* presents the problem of the asymmetry of time and discusses possible solutions to it. The focus of this chapter is on probabilistic Markov processes. Roughly, the conditional probability of some state (or a conjunction of states) of a Markov process given previous states equals the probability of the same state given the immediately precedent state.

According to Bacciagaluppi, the Markov condition defining Markov processes is time symmetric, i.e., the forwards and backwards transition probabilities of Markov processes have the same features, and there is thus no distinction between future and past.

There seem to be two options to explain time asymmetry in physics. Either there are time-asymmetric natural laws or the asymmetry is due to the system's initial conditions. Bacciagaluppi rejects the first option. But the second option has its problems too because it presupposes a non-equilibrium initial state.

The Principle of Indifference is the topic of the third chapter by *Sorin Bangu*. According to the principle, one should assign equal probabilities to equal regions in a space of possible outcomes if no relevant background information is available. Inconsistencies and paradoxes generated by this principle might be avoided by appealing to eliminativism, according to which the events in physical reality need not necessarily follow human reason. Such an argument accords well with the thesis T_1 mentioned in Suárez' introduction.

Bangu analyzes two attempts to apply the eliminativist strategy and argues that they are not convincing. The first one, Reichenbach's strategy, fails because it already presupposes the validity of the principle. The second one, Gillies' heuristic strategy, does not work because it is confronted with the same problems about justification as the principle that is rejected.

Roman Frigg, in Ch. 4 discusses the notion of typicality, i.e., the property to occur in the great majority of cases. The approach to equilibrium and the Second Law of Thermodynamics are often explained using this very notion. Different strategies of this type are examined, and Frigg concludes that the boldest fails for mathematical reasons, while more cautious versions leave the problems without a solution.

The principal difficulties for a typicality-based explanation of the approach to equilibrium are the following: What appears to be typical in a system according to one certain measure μ (e.g. the Lebesgue measure) might be atypical under a different measure μ'. The fact that the equilibrium macro-state is larger than other states does not imply that it satisfies typicality. Also, the largest macro-state in systems with interaction might not be the equilibrium state. Moreover, explanations based upon typicality are not satisfactory.

The second part of essays is focused on causality and starts with *Federico Laudisa's* chapter about the relation between a metaphysical concept of causation and its reception in physics (Ch. 5). This connection seems to be of great relevance, especially with reference to space-time structures. Causation also plays an important role in quantum mechanics, although its definition cannot be model-independent, according to Laudisa.

Non-locality is discussed in connection to the Einstein-Podolsky-Rosen thought experiment, which suggests the existence of causal inconsistencies in quantum mechanics. Nevertheless, it is then argued that, from the perspective of Bohmian mechanics, based upon a preferred foliation of space-time, temporal precedence of the cause in relation to the effect need not to be assumed and that events with a space-like separation can be causally related to each other.

In Ch. 6, backward causation is analyzed by *Joseph Berkovitz*. He presents some arguments for its impossibility, which are based upon deterministic, indeterministic and predictive models of causal loops. The arguments show that inconsistencies arise in such models. A Bohmian model seems to be the best candidate to avoid the problem as it is causally symmetric and and thus does not imply that the result of a measurement is its own cause because, in such cases, measurements are only indirect and partial causes of themselves. Therefore, retro-causal interpretations of quantum mechanics are not explanatory vacuous.

In the next chapter, Ch. 7, *Balazs Gyenis* and *Miklós Rédei* explain the notion of causal completeness and tackle the problem connected to it in probability theory. A probability space is causally complete if and only if, for every correlation between causally independent variables, there is an element that is the common cause of the correlations.

This can be interpreted as a version (or as a consequence) of Reichenbach's common cause principle. The authors analyze the general definition of completeness and show its many applications, especially in quantum field theory. It is finally argued that classical Reichenbachian completeness cannot provide a sufficient explanation of why a common cause can be inferred from a correlation between variables that are not directly causally connected. It only establishes the common cause as part of a stronger, screening-off correlation between both of them. In order to avoid circularity and endless regress, Gyenis and Rédei introduce a causal independence relation that replaces the notion of common cause, and they suggest a directed graph structure to ensure the direction of causal dependence.

The Einstein-Podolsky-Rosen thought experiment is used by *Mauricio Suárez* and *Iñaki San Pedro* in order to explain the relation between causal robustness and the Markov condition (Ch. 8). A causal correlation between two variables is robust if and only if there is a class of sufficiently small disturbances of either of the causal relata that cannot affect the causal relation. The causal Markov condition—inspired both by the common cause principle and by the type of processes discussed in the second and seventh chapters—establishes that a variable in a directed acyclic graph is independent of its non-descendents, given its parents.

This is important for accounts that pretend to unify relativity theory and quantum mechanics, since they violate such a condition. Suárez and San Pedro show that robustness can be derived from the notion of a total cause and the causal Markov condition taken together. Suppose that event b is the total cause of a and that there is a small disturbance d affecting the process. Then

$$p(a|d \wedge b) = p(a|b) \ .$$

This should not lead us to dismiss the focus on the notion of robustness though, I think, as it is recommended in this chapter. For in structures where total causes cannot be fully described, the Markov condition might not be sufficient to explain the causal relation, especially in over-determination or in common cause scenarios.

Finally, it is argued that, if the causal Markov condition is dispensable for the definition of causality, then causality does not imply determinism. If the Markov condition is needed, by contrast, this identity must be accepted and an orthodox interpretation of quantum mechanics cannot refer to causality.

The third and last part of the book is about propensities, and in Ch. 9, *Mauro Dorato* discusses the relevance of dispositions and propensities to quantum mechanics. After having established some distinctions between dispositional and categorical properties, Dorato argues that the notion of propensity has advantages for the understanding of problematic concepts. Localization, for instance, is something that occurs to a micro-system; it exists previously, as a propensity to be localized. This in turn benefits the interpretation of quantum wave-particle duality. Under this interpretation though, dispositions might only support an instrumentalist approach of quantum mechanics if these are only defined in a contextualist interpretation of measurement and if measurements are understood as selections of dispositions that do not describe real physical processes.

Nicholas Maxwell criticizes orthodox quantum mechanics because it only explains the wave-particle duality using measurements (Ch. 10). In order to provide a realist account, Maxwell introduces probabilistic entities called propensitons. Maxwell's strategy is clearly in accordance with the claim T_3 as defined by Suárez at the beginning of the volume. An interpretation based upon the existence of propensitons is able to reconcile indeterminism and realism. The propensiton quantum theory also avoids the indispensable use of measurement, observables and environment, and, according to Maxwell, it is based upon Planck's original explanation of the black body radiation. However, the approach might be criticized not only for violating parsimony, but also for its realism about probabilities (i.e., the claim that there are real probabilistic entities), which could complicate the causal understanding of physical processes. It is furthermore troublesome that propensitons constitute a non-local reality.

In the last chapter, *Ian Thompson* analyzes the possibility of more specific notions of disposition. A detailed distinction of several kinds of dispositions might serve as a response to the well-known criticism that simple dispositions are dispensable in some interactions. Thompson introduces different kinds of dispositions as being part of different levels. In particular, in Thompson's framework, dispositions can undergo changes. Such changes may be due to a rearrangement of the physical structure of an object that carries the disposition. But it may also depend on the derivation of one disposition from another. The chapter focuses particularly on derivative dispositions.

The book is an incisive inspection of the philosophical and scientific treatments of the interrelated notions of causality, probability and propensity in the field of modern physics and it traces the potentials of these notions in research from the last decades. The chapters are well written and define the relevant concepts in a clear way, which allows one to follow the discussions with ease. Moreover, the contributions to the book discuss the most recent accounts of causality, propensity and probability and add new and important insights to the discussion. The book is thus recommended to philosophers of physics and physicists interested in the foundations of their discipline.