Causation and Initial Conditions in Time-Reversal Symmetric Physics

A central problem concerning the role of causation and causal notions in scientific explanation is the apparent time-symmetric nature of fundamental physics. Under reasonable assumptions, classical mechanics, quantum mechanics and relativistic quantum field theories can be taken to be symmetric under time reversal (in the latter case under the guise of combined CPT symmetry). It follows that there exist pairs of models of such theories that differ with respect to their temporal orientation that are empirically underdetermined by the relevant data, which implies that if one wishes to use a such a model to provide a causal (time-directed) explanation of some phenomenon, there exists an alternative model that is empirically equivalent to the first in which the causal relations are inverted. This paper examines whether causation can be recovered from time-reversal symmetric theories by means of the alleged time-asymmetric sensitivity of systems to their initial rather than final conditions.

In the recent literature on time-asymmetric phenomena in physics, multiple authors have claimed that there is an important time-asymmetric feature of explanation within the domain of time-reversal symmetric physical theories insofar as placing constraints on *initial*, rather than *final* conditions purportedly offers an explanatory advantage in such cases as cosmology, statistical mechanics, classical electrodynamics, and quantum mechanics. In particular, Arntzenius (1995, 1997) and Maudlin (2007) have argued, in the cases of wave-function collapse and the thermodynamic time asymmetry respectively, that these phenomena are best explained by the relevant physical theories (quantum mechanics and statistical mechanics) on the assumption that there is some sort of causal dependence of states of a system upon earlier and not later states of a system. I assess the common structure of these arguments and whether such an argument can justify the claim that such theories are causal.

The success of the type of argument in question requires that the relevant data (i.e. the physical phenomenon – collapse and the entropy gradient) be accountable by the relevant theory in addition to a constraint on the system's initial condition, and that no analogous constraint on the 'final' condition can yield an empirically adequate account. However, I argue that in general this apparent special sensitivity of systems with respect to initial rather than final condition is due to the way the data under consideration is selected, and disappears if the data is collected in properly time-symmetric way. I argue that the apparent asymmetry between initial and final conditions can be overcome by selecting the ensembles under consideration in terms of both their initial and final states rather than just their initial state, with reference to work by Yakir Aharonov on time-symmetric quantum mechanics.

Aharonov et al. (1964) distinguish between 'preselected-only', 'postselected-only' and 'pre-and-postselected' ensembles. A preselected ensemble of systems is selected in terms of some initial state (e.g. having positive spin in the *x*-axis): each system in the ensemble shares this initial state. A postselected ensemble is grouped in terms of a particular final measurement outcome (e.g. having positive spin in the *z*-axis) (but not necessarily a common initial state). A pre-and-postselected ensemble is grouped in terms of *both* a common initial and final state. In the case of quantum mechanics, I demonstrate that considering only 'postselected' ensembles leads to the explanatory asymmetry between initial and final conditions being reversed. Applying similar reasoning to the statistical mechanical case is more complicated due to the relationship between macroscopic (thermodynamic) and microscopic (mechanical) observables. Here, models are pre/postselected in terms of their macrostate, understood as a course-grained region of the state-space of microscopic systems. I argue that in this case too, a properly time-symmetric ensemble yields no special sensitivity to initial rather than final conditions.

Both case studies are illuminating insofar as they show that the apparent sensitivity of systems to initial rather than final conditions is simply due the relevant statistics being preselected, rather than postselected or pre-and-postselected. This demonstrates that the apparent relevance of causal notions in the quantum and statistical mechanical explanations offered is merely the result of the imposition of a time-asymmetry in the collection of the relevant statistics. This indicates that such theories are not themselves causal. I end with a consideration of whether this imposed time-asymmetry can be defended on pragmatic grounds pertaining to the role of the agent in performing experiments.

References

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