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REVIEW

A PACKAGE OF POSITIONS IN THE PHILOSOPHY OF PHYSICS

Dean Rickles, (ed), *The Ashgate Companion to Contemporary Philosophy of Physics*, Farnham: Ashgate, 2008. Pp. 396. £65.00 HB.

By Jonathan Bain

This is a very useful and easily assimilated summary of recent work in the philosophy of physics. It focuses on four areas: philosophy of non-relativistic quantum mechanics (David Wallace), foundations of statistical mechanics (Roman Frigg), philosophical aspects of quantum information theory (Chris Timpson), and current approaches to quantum gravity (Dean Rickles). The intended audience is ‘‘beginning graduate (or advanced undergraduate) students of philosophy and physics’’, and the aim is ‘‘to prime the budding philosopher of physics to as advanced a level as possible without lapsing into research writing mode’’ (p. 1). Each chapter is distinctly flavoured by the particular positions its author has staked out in the literature, and this should make the book useful to more advanced researchers, too.

WALLACE ON QUANTUM MECHANICS

The chapter by Wallace on ‘Philosophy of Quantum Mechanics’ (QM) consists of a survey of interpretations of QM ranging from orthodox approaches and Everettian interpretations, to dynamical collapse theories and hidden variables theories. Prominence is given to the role of decoherence, and a key theme is the contrast between a ‘Traditional Account’ of QM that Wallace associates with the philosophical literature, and an account associated with the physics literature. Wallace advocates the latter and encourages philosophers to do likewise. Both accounts adopt the same basic formalism; namely, a Hilbert space of states $\mathscr{H}$ endowed with a dynamics. The

‘Traditional Account’ identifies properties with projection operators, and subscribes to the Eigenvalue–Eigenvector (EE) link and the Born rule. The account that Wallace advocates is given by what he calls the ‘Quantum Algorithm’. This first imposes a macroscopic/microscopic decomposition on $\mathscr{H}$ and then constructs Gaussian wave-packet states localised around particular values of the macroscopic degrees of freedom. One then expands the state of the system in terms of these macroscopically definite states, and regards this expansion as a probabilistic mixture.

At base, the distinction between these accounts corresponds to a distinction between projection-valued measurements (PVMs) and positive operator-valued measurements (POVMs). POVMs can model measurement processes that produce ‘fuzzy’ outcomes. For instance, a POVM associated with the measurement of the position of a localised wave-packet state allows for a determinate value of position (the value around which the wave-packet is peaked); whereas a PVM associated with such a measurement, under the EE link, entails there is no determinate value. The ‘Quantum Algorithm’ is eminently compatible with POVMs, and Wallace’s claim is that, in so far as POVMs are to be preferred over PVMs, we should adopt the ‘Quantum Algorithm’ and reject the ‘Traditional Account’. According to Wallace, the latter “distorts the philosophy of QM, forcing interpretations into Procrustean beds and encouraging wild metaphysics” (p. 22). Freeing philosophy of QM from the ‘Traditional Account’ impacts the standard assessments of interpretations in the philosophical literature. In particular, the Bare Theory is no longer seen as the minimalist Everettian interpretation (p. 45), dynamical collapse theories no longer face the problem of wave-function tails (p. 58), and modal interpretations no longer face the problem of inexact measurements (p. 70). On the other hand, the ‘Quantum Algorithm’ itself is not interpretation-neutral: as Wallace admits, it assumes a macro-/microscopic split. This manifests itself in Wallace’s survey in the heavy role it assigns to decoherence.

FRIGG ON STATISTICAL MECHANICS

As Frigg notes in his contribution ‘A Field Guide to Recent Work on the Foundations of Statistical Mechanics’, while there is no general consensus on how best to formulate classical statistical mechanics, one can distinguish two dominant approaches: the Boltzmann formalism and the Gibbs formalism. Frigg notes that while the Gibbs formalism has a wider range of applications, and 'delivers the goodies', when it comes to actual practice there is a general consensus that it lacks the resources to address foundational issues. Such issues are typically addressed in the Boltzmann formalism. However, the latter is not typically used in practice due to its simplifying assumptions (it assumes weakly or non-interacting particles). Hence, given the fact that these approaches are not inter-translatable, much work still needs to be done in explaining the success of classical statistical mechanics.

One aspect of Frigg's survey is its focus on the role of probabilities. In the Boltzmann formalism, probabilities are introduced in order to underwrite Boltzmann's Law (BL) – i.e., the statement that it is highly probable that the Boltzmann entropy of a system at a given time is greater than or equal to its Boltzmann entropy at a later time, provided the former is far below its maximum value. Frigg identifies two types of probabilities: macro-probabilities, assigned directly to macro-states *via* a 'Proportionality Postulate', and micro-probabilities, assigned directly to micro-states *via* a 'Statistical Postulate' (SP). Frigg argues that, to the extent that macro-probabilities are unconditional, they do not imply anything about the succession of states, hence they fail to underwrite BL. Micro-probabilities might seem to fare better, given that they involve the underlying dynamics, but Frigg points out that they fail just for this reason, since the time reversal invariance of the underlying dynamics entails that whenever the system is very likely to have a high entropy future, it is also very likely to have a high entropy past.

One attempt at making micro-probabilities respectable is by appeal to the Past Hypothesis. In particular, Frigg reviews a suggestion by David Albert (*Time and Chance*, 2000) that would replace SP with a 'Past Hypothesis Statistical Postulate' (PHSP). PHSP states that SP holds for some past macro-state (for instance, the state of the universe shortly after the Big Bang), and that probability distributions conditionalise on this past macro-state and the current macro-state. As Frigg explains, this resolves the problem of time reversal invariance of the underlying dynamics, but the discussion ultimately implies that this resolution is not entirely successful. In particular, Frigg claims micro-probabilities are best understood as epistemic (p. 133), thus to the extent to which an epistemic interpretation of statistical mechanical probabilities is problematic (a view associated with a general consensus of writers, p. 173), so is PHSP. Furthermore, as Frigg notes (p. 128), John Earman has recently argued that actual models of cosmological initial states in general relativity indicate that associated probabilities are ill-defined or meaningless; hence the Past Hypothesis is "not even false" (*Studies in History and Philosophy of Science, Part B*, 2006).

TIMPSON ON QIT

In addition to the standard topics of crytography, dense coding, teleportation, and computation, Timpson's survey of 'Philosophical Aspects of Quantum Information Theory' is notable for its analysis of the concept of information. According to Timpson, "In both classical and quantum information theory, the term 'information' functions as an abstract, not a concrete, noun" (p. 222). In slightly more detail, Timpson defines information as "what is produced by an information source that is required to be reproducible at the destination if the transmission is to be counted as a success" (p. 223). An information source is an object that produces a sequence of elements with corresponding probabilities (in a classical source, these elements are drawn from a discrete alphabet of symbols; in a quantum source, they are drawn from a fixed set of quantum states). The specific claim, then, is that both classical and quantum information consists of sequence types, and not particular instances of these types.

Timpson then puts this definition to work in addressing controversies over the nature of information exchange in quantum teleportation, and ends the survey with a review of the physical side of computation (focusing in part on explanations of what accounts for the speed-up associated with quantum algorithms), and a discussion of various attempts to derive quantum mechanics from information-theoretic first principles. The latter is noteworthy for Timpson's critique of the CBH Theorem of Clifton, Bub and Halvorson.

RICKLES ON QUANTUM GRAVITY

A key issue in research on quantum gravity that Rickles identifies in the final chapter is the notion of background independence. As

Rickles points out, there is a general consensus among researchers that this is a desirable property of a theory of quantum gravity (QG), but there has been little work on just what this property amounts to (pp. 354, 362). This lack of clarity subsequently infects other issues related to QG, and Rickles is not completely immune to this himself. For instance, he characterises the problem of time as "a consequence of background independence" (p. 281). Belot argues, through examples, that the problem of time is *not* due to any of the following: the $3+1$-decomposition of space–time associated with the Hamiltonian formulation of general relativity (GR), a lack of a preferred slicing in GR, the 'jiggleability' of admissible slicings, or the invariance of GR under a group of space–time diffeomorphisms (G. Belot, in Butterfield and Earman (eds), *Philosophy of Physics*, 2007, p. 210). Thus to the extent that background independence involves any of these characteristics, it is at least debatable whether the problem of time is a consequence of it. Rickles further suggests that the fact that the invariance group of GR is "not a finite-dimensional Lie group" underwrites its background independence (p. 294). But, again, without a precise definition of background independence, it is unclear what its relation is to the invariance group of GR. For instance, Belot gives examples of sectors of GR that are, in an appropriate sense, diffeomorphism-invariant but not background independent (http://sitemaker.umich.edu/belot/background-independence).

These quibbles aside, the central part of Rickles' survey is an informative review of the standard approaches to quantum gravity: covariant quantisation (originally associated with attempts to construct a relativistic quantum field theory of gravity and now associated with string theory); canonical quantisation (associated with loop quantum gravity); and Feynman quantisation (associated with the Euclidean path-integral approach to QG). In addition, Rickles offers a comprehensive list of 'external' approaches that have appeared in the contemporary physics literature. The overall account is effective in addressing its intended audience, and should help direct more philosophers of physics to this emerging field.

Humanities and Social Sciences
Polytechnic Institute of New York University
NY, USA