A Primitive Ontology for Quantum Spacetime

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Abstract

The canonical quantum gravity programme starts from a Hamiltonian formulation of general relativity, which can be given in terms of ADM (Arnowitt et al., 1962), Ashtekar (Ashtekar, 1986), or loop variables (Rovelli and Smolin, 1990), and seeks to quantize this classical theory using a physically well-defined procedure, such as, most notably, the one put forward in Dirac (1964). There are two striking features that broadly characterize the theories falling in the scope of this programme. The first is that the quantum-gravitational states are taken to represent purely spatial, as opposed to spatiotemporal, physical degrees of freedom. The second is that the equation that describes the dynamical evolution of these states – the Wheeler-DeWitt equation – does not involve any time, be it a physical or just a mathematical parameter. This second fact carries a huge number of conceptual implications (see e.g., Anderson, 2012), in particular the consequence that the notion of temporal evolution seems to be cut off from the fundamental physical picture.

To make things worse, even if we accept that a theory of quantum gravity faithful to the canonical approach should acknowledge an ontological primacy of space over time, still such a theory, being a *quantum* theory, would describe Planck-scale space as a quantum superposition of quantum-gravitational states. It is then not clear how a classical, smooth three-dimensional space – let alone classical spacetime – is supposed to emerge from such a "probabilistic cloud" of states (see Rovelli, 2004, p. 271, for that expression). This illustrates the fact that, in canonical quantum gravity, the ontology becomes obscure to say the least. As a consequence, any ontologically clear theoretical framework has to provide at least a convincing account of (i) why the theory tears space and time apart, contrary to the very spirit of relativistic physics;

(ii) what is the physical significance of its dynamics, especially in relation to the usual notion of temporal evolution; (iii) how the theory addresses the measurement problem (otherwise said, how the theory addresses the quantum-to-classical transition).

In this talk, I will propose a philosophical framework that might help physicists working in the canonical programme to move in the direction of ontological clarity. This framework combines a primitive ontology approach to quantum physics (see Allori et al., 2008, for a precise characterization of this approach) that is Leibnizian in spirit with the doctrine of Humean supervenience about laws of nature (see Hall, 2015, for an introduction to the subject). Moreover, I will point out how the proposed philosophical framework naturally fits and complements an alternative programme to quantize the gravitational field of general relativity, which starts from Julian Barbour's shape dynamics (see Mercati, 2018, for a primer on this theory) and adopts a novel quantization procedure known as *relational quantization* (Gryb and Thébault, 2016).

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