Quantum Gravity and the 3D vs. 4D Controversy*

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The philosophical debate between proponents of the endurance view of time and those of the perdurance view reflects a disagreement concerning whether, and to what degree, time is on a par with spatial dimensions. On the one hand, there are those who argue that an object can be wholly present at different times, and that time, therefore, enjoys a privileged role among the four dimensions of spacetime. An object is said to *endure* just in case it exists at more than one time. If we foliate four-dimensional spacetime and compare the set of enduring objects in any two spacelike hypersurfaces, the intersection of the two sets will be, in general, non-empty. In this view, thus, we expect an overlap between different times in the sense that one hypersurface shares some enduring objects with another. On the other hand, there are those who maintain that temporally extended objects consist of temporal parts just as spatially extended objects are comprised of spatial parts. According to this conception, objects *perdure* by having different temporal parts at different times with no part being present at more than one time. Perdurance implies that two hypersurfaces as above do not share enduring objects but rather harbour different parts of the same four-dimensional object.

In this paper, I endeavour to connect this 3D vs. 4D controversy in philosophy with fundamental physics. Physics poses many challenges to philosophers of time. In a field theory, for instance, the identification of enduring concrete objects is aggravated by the difficulty of formulating identity conditions through time. Field theories, therefore, militate against the endurance theory. However, the perdurance view seems to face similar challenges: consider a four-dimensional spacetime co-habiting with four-dimensional matter fields. Here, problems of identification likewise seem to exacerbate the perdurance theorist's cause. But I shall not be concerned with the difficulty of identifying objects.

Rather, I urge that the philosophical debate may benefit from recent advances in quantum gravity, thus rendering its dependence on considerations of utility in philosophical discourse less suffocating. To this end, I present two, by no means exhaustive, approaches to quantum gravity: loop quantum gravity

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(LQG) and causal sets. LQG and causal sets seem to disagree as to whether space or spacetime should be considered the gravitational 'substance.' In this sense, they represent the two camps of the philosophical debate. This talk is aimed at elucidating how they relate to and how they can inform the 3D vs. 4D debate.

LQG is a non-perturbative, background independent canonical quantisation of general relativity. As any other canonical quantisation of general relativity, it applies a standard procedure for obtaining a quantum theory from a classical theory to a 3-space, i.e. a spacelike hypersurface of spacetime. Because of the Hamiltonian constraints, all observables, i.e. physically real magnitudes, seem to be time-independent, thus resulting in a 'frozen dynamics.' This and related problems, often referred to as the *problem of time*, seem to be rather direct consequences of the canonical quantisation scheme and of the way in which general covariance manifests itself in this scheme. In LQG, time can be recovered one way or another from the evolution regime imposed on the 3-space. To this end, once the 3-space is quantised, it is subjected to a dynamical evolution. This evolution can be understood either in a canonical or in a sum-over-histories framework. Several models exist for the latter. These so-called spin foam models mend the separation between space and time and thus appear to restore, at least in the continuum limit, a four-dimensional spacetime. However, in LQG and its dynamical extensions, time does not appear on a par with spatial dimensions.

The causal sets approach does not suffer from the Hamiltonian disease. It attempts to construct a quantum spacetime *ab initio* without recourse to a quantisation scheme. It regards the causal structure of spacetime as fundamental, codifies this structure as causal sets at the Planck level, and aspires to recover the classical spacetime in the continuum limit. Thus, it claims to have the four-dimensional character of spacetime built in from the start. Unfortunately, this road to quantum gravity hasn't been articulated to the same degree of detail as LQG. In particular, causal sets as such do not have dimensionality and efforts to fully recover the four-dimensional character of the continuum limit have been frustrated so far. However, there are indications that unless the universe is four-dimensional, it cannot grow to an appreciable size. While causal sets have a well-established kinematical framework, they currently lack a quantum dynamics. So far, the approach has only been endowed with a classical, though stochastic, dynamics.

Quantum gravity has not yet achieved the status of an empirical science, but it soon may. Observational evidence from astrophysics may soon challenge or even refute some of the approaches taken. The fact that there exist competing quantum theories of gravity that take an—admittedly indirect—stance on the philosophical debate concerning whether or not objects possess temporal parts thus leaves philosophers of time with the exciting prospect that some of their deepest disagreements may be settled empirically. While this will hardly end the debate concerning issues in philosophy of spacetime, and in particular not in the interpretation of whatever quantum theory of gravity we will end up with, it is likely to severely constrain the possible range of stances that can reasonably be defended.