Spacetime: Fundamental or Emergent?

Bonn, 26 – 28 October 2017

Abstracts

Karen Crowther, ***Fundamentality and emergence in quantum gravity***
I explore the ways in which a theory of quantum gravity (QG) may be considered more fundamental than current theories of physics. The different senses in which QG is more fundamental than general relativity are shown to be useful in understanding (classifying) the plurality of different approaches to QG. I present an appropriate account of inter-theory emergence in physics, and suggest how this might apply in particular approaches to QG. This conception of emergence is contrasted with other accounts of emergence in philosophy of science, as well as with the notion of reduction.

Richard Dawid, ***String Theory, Empirical equivalence and fundamentality***
String dualities provide strong arguments against the notions of elementary objects and fundamental spacetime. These arguments are closely tied to the substantial shift dualities bring about with regard to the role of empirically equivalent descriptions in fundamental physics. The talk discusses the connection between those two aspects of string dualities and speculates on their joint implication for the relation between physical structure and intuitive understanding.

Neil Dewar, ***Noether's theorems from the perspective of general covariance***
In this talk, I talk about three issues. The first is how to formulate Noether's theorems in the context of generally covariant theories, given subtleties about setting up Lagrangian mechanics in the absence of a background standard of volume. The second is how to prove Noether's theorems for the case of arbitrary diffeomorphisms, given subtleties about the notion of a local external transformation group. The third concerns the relationship between this application of Noether's theorems and the derivation of a divergence-free stress-energy tensor in generally covariant theories.

Michael Esfeld, ***An argument for fundamental distance relations***
The argument for endorsing distance relations as the – only – fundamental relations is that they are world-making relations: all and only those objects that are spatially related make up a world. Moreover, these objects are discerned by and thus individuated by their place in the network of distance relations. The view of distance relations being fundamental takes space-time neither to be fundamental nor to be emergent. It is a Leibnizian relationalism, with space-time geometry coming in as the means to represent the distance relations and their change. I briefly show how Leibnizian relationalism accounts for contemporary physics.

Dennis Lehmkuhl, ***Is it possible for spacetime to be neither fundamental nor emergent? Learning from Einstein's path towards field realism***

In this talk, I shall examine whether there is an alternative to seeing spacetime as either fundamental or emergent. In elaborating this third option, I will draw inspiration from two lines of thought found in Einstein's work. The first is an analysis of Einstein's views on special relativistic electrodynamics, as compared to the theories of Maxwell and Hertz. The second is Einstein's mature view of how spacetime and matter relate to one another both in general relativity and in theories that Einstein expected to be candidates for succeeding general relativity. I will show that Einstein expected that the distinction between spacetime and (quantum) matter would be overcome in such a theory, rather than one being shown to be more fundamental than the other. Finally, I will discuss whether this is a sensible option in the context of approaches to quantum gravity.

J. Brian Pitts, ***What represents space-time and what follows for substantivalism vs. relationalism and for gravitational energy?***

The questions of what represents space-time in GR, the status of gravitational energy, and the substantivalist-relationalist issue are interrelated. If space-time has energy-momentum, then space-time is substantival. Two extant ways to avoid the substantivalist conclusion deny that the energy-bearing metric is part of space-time or deny that gravitational energy exists. This talk proposes a particle physics-inspired but non-perturbative split that characterizes space-time with a background: space-time is $\langle M, \eta \rangle$, where $\eta = \text{diag}(-1, 1, 1, 1)$ is a constant numerical signature matrix, a matrix already used with spinors. The gravitational potential, to which any energy can be ascribed, is $g_{\mu\nu}(x) - \eta$ (up to field redefinitions), an affine geometric object with a transformation rule, a well-defined Lie derivative and a vanishing covariant derivative. This non-perturbative split permits strong fields, arbitrary coordinates, and arbitrary topology. This thin background, unlike more familiar backgrounds (e.g., Rosen's flat metric tensor field, Møller's orthonormal tetrad, and Sorkin's background connection), involves no extra gauge freedom and so lacks their obscurities and carpet lump-moving. Long ago Papapetrou and more recently Nester et al. have entertained $\eta = \text{diag}(-1, 1, 1, 1)$ as useful in formulating local conservation laws.

Gravitational energy localization in General Relativity has been denied on two main grounds, that pseudotensors behave unreasonably in relation to coordinates and are non-unique; but neither objection is compelling presently. Literal interpretation involving infinitely many energies corresponding by Noether's first theorem to the infinite symmetries of the action answers Schrödinger's false-negative coordinate problem. Fixing coordinates to suit Killing symmetries in outline answers Bauer's false-positive coordinate problem. Non-uniqueness might be handled either by Nester et al.'s finding physical meaning in multiplicity, or by an optimal choice, perhaps Papapetrou-Belinfante.

James Read, ***Two miracles of general relativity***

This is a talk in four parts. In the first, I demonstrate that there exist tensions between (i) the 'minimal coupling' prescription for the constriction of non-gravitational fields in general relativity, and (ii) the 'strong equivalence principle', which regards the local validity of special relativity. In the second, I draw on these observations in order to present two 'miracles' of general relativity—that is, two unexplained coincidences in the foundations of the theory. In the third, I argue that while some versions of the 'geometrical approach' to spacetime theories may purport to be able to account for these two miracles, such forms of the geometrical approach are not viable; thus, the miracles remain in general relativity on any viable form of the geometrical approach, as well as on the alternative, 'dynamical approach'. In the fourth, I demonstrate how these miracles admit of a natural resolution in one candidate quantum theory of gravity—viz., perturbative string theory.

Kian Salimkhani, ***Lorentz invariance and the non-fundamentality of spacetime***
Our best theory of spacetime is Einstein's theory of general relativity (GR). In the standard (or geometrical) view of GR, spacetime is identified as the pair $\langle M, g\rangle$ of manifold structure M and metric structure g. In this talk, I will present Brown's dynamical approach as an alternative to the geometrical view, and argue that turning to quantum field theory provides new insights concerning this debate supporting and radicalizing the dynamical view.

Alastair Wilson, ***Dependence without spacetime***
Existing accounts of metaphysical dependence and of its relation to causal dependence often presuppose (explicitly or implicitly) a background spacetime stucture. I will explore how our understanding of dependence can be adapted to help us make sense of the emergence of spacetime in quantum gravity.

Christian Wüthrich, ***Spacetime is as spacetime does***
In theories of quantum gravity, one often finds that the postulated fundamental structures lack significant aspects of relativistic spacetime. Yet any fundamentally non-spatiotemporal theory must face the challenge of its own empirical incoherence, as we could never believe a theory apparently precluding what appears to be necessary preconditions that must be in place for its own empirical confirmation, even if it were true. Thus, any quantum theory of gravity must establish how it is that relativistic spacetimes are, in many contexts, such excellent descriptions of our spatiotemporal reality. In this talk, it will be argued that in order to secure this emergence of spacetime, it suffices to recover those features of relativistic spacetimes functionally relevant in producing empirical evidence. In order to complete this task, an account must be given of how the more fundamental structures instantiate these functional roles. I will illustrate the general idea in the context of causal set theory and loop quantum gravity, two prominent approaches to quantum gravity.