COSMOLOGY AND THE FUTURE OF SPACETIME

June 12 - 14, 2017
North Campus Building, Room 114
Western University
London, Ontario

MONDAY, JUNE 12

9:30 a.m. – 10:00 a.m. – Coffee Break

10:00 a.m. – 11:00 a.m. – Robert Brandenberger (McGill University), *"Emergent space and its possible observational signatures"*

> The physical theories which are used in cosmology break down in the very early universe. I will discuss what conditions a theory of the very early universe has to obey in order to be able to explain current observations on the large-scale structure of the universe. One class of models which obey these conditions is ``emergent cosmology". I will explain how such a scenario could emerge from basic principles of superstring theory and how it can be tested with observations.

11:00 a.m. – 12:00 p.m. – Daniele Oriti (Max Planck Institute for Gravitational Physics – Albert Einstein Institute), *"Cosmology as quantum gravity hydrodynamics: emergent universe without fundamental space and time"*

> We discuss a new perspective on the nature of cosmology from the quantum gravity point of view, and more specifically in an emergent spacetime scenario. It is based on the interpretation of cosmological dynamics as the hydrodynamic description of the microscopic quantum dynamics of the building blocks of spacetime. In this picture, the universe can be seen as sort of (quantum) fluid, the result of their collective interaction, and its cosmological description as appropriate for its coarsest approximation, close to equilibrium. Beside outlining this picture and its general implications for quantum gravity and cosmology, we also offer some examples of its realisation taken from current research in group field theory, and related quantum gravity formalisms.

12:00 p.m. – 1:00 p.m. – Panel discussion

1:00 p.m. – 2:00 p.m. – Lunch

2:00 p.m. – 3:00 p.m.– Francesca Vidotto (Institute for Mathematics, Astrophysics and Particle Physics Radboud University Nijmegen - The Netherlands), *"Quanta of spacetime in a non-singular universe"*

> Loop Quantum Gravity describes the dynamics of quanta of spacetime. What is the relation between those quanta and the classical spacetime? Moving from this question, I will introduce the covariant dynamics of the theory and discuss how this does not allow curvature singularities to form.

3:00 p.m. – 3:30 p.m.– Coffee break

3:30 p.m. – 4:30 p.m.– Henrique Gomes (Perimeter Institute for Theoretical Physics), *"Timeless cosmology with records"*

On the path towards quantum gravity we find friction between temporal relations in quantum mechanics (QM) (where they are fixed and field-independent), and in general relativity (where they are field-dependent and dynamic). In this talk, I will erase that distinction. I encode gravity, along with other types of interactions, in the timeless configuration space of spatial fields, with dynamics obtained through a path integral formulation. The framework demands that boundary conditions for this path integral be uniquely given. Such uniqueness arises if a reduced configuration space can be defined and if it has a profoundly asymmetric fundamental structure. These requirements place strong restrictions on the field and symmetry content of theories encompassed here. When these constraints are met, the emerging theory has no non-unitary measurement process; the Born rule is given merely by a particular volume element built from the path integral in (reduced) configuration space. Time, including space-time, emerges as an effective concept; valid for certain curves in configuration space but not assumed from the start. When some notion of time becomes available, conservation of (positive) probability currents ensues. I will show that, in the appropriate limits, a Schroedinger equation dictates the evolution of weakly coupled source fields on a classical gravitational background. Due to the asymmetry of reduced configuration space, these probabilities and currents avoid a known difficulty of standard WKB approximations for Wheeler DeWitt in minisuperspace: the selection of a unique Hamilton-Jacobi solution to serve as background. I illustrate these constructions with a simple example of a quantum gravitational theory for which the formalism is applicable, and give a formula for calculating gravitational semi-classical relative probabilities in it. Although this simple model gives the same likelihood for the evolution of all TT gravitational modes, there is evidence that a slightly more complicated model would favor modes with the smallest eigenvalues of the Laplacian and thus drive towards homogeneity.

4:30 p.m. – 5:30 p.m. - Panel discussion

TUESDAY, JUNE 13th

9:30 a.m. – 10:00 a.m. – Coffee Break

10:00 a.m. – 11:00 a.m. – Simon Saunders (University of Oxford), *What is space-time geometry? — the non-relativistic case*

I consider recent work of Wallace (BJPS forthcoming) on the status of inertial structure in non-relativistic classical physics, and on the underlying vector-space relationalism introduced in my 'Rethinking Newton's Principia' (PoS 2103), with particular attention to the sense or senses in which spacetime geometry is emergent or has otherwise only a functional significance, as argued by Knox in the non-relativistic case, and by Brown in special and general relativity.

11:00 a.m. – 12:00 p.m. – Tessa Baker (University of Oxford), *"Agnostic Tests of Gravity"*

> I'll introduce the plethora of alternative gravity theories currently under discussion by cosmologists, using Lovelock's theorem as a useful way to classify them. This proliferation of theories motivates us to develop model-independent, agnostic tools for testing this theory space with cosmological data. I'll introduce the effective field theory for cosmological perturbations, a framework designed to unify modified gravity theories in terms of a manageable set of parameters. Having outlined the formalism, I'll talk about the constraints we expect to obtain on this parameterisation with the next generation of large galaxy clustering, weak lensing and intensity mapping experiments.

12:00 p.m. – 1:00 p.m. – Panel discussion

1:00 p.m. – 2:00 p.m. – Lunch

2:00 p.m. – 3:00 p.m. – Michela Massimi (University of Edinburgh), *"Three problems about multi-scale modelling in contemporary cosmology"*

> Scientific modelling is often tied to particular scales, and in recent times philosophers of science have investigated some of the methodological challenges multi-scale modelling faces. Batterman, for example, refers to the "tyranny of scales" and advocates the importance of modelling 'in between' scales as an alternative to what he regards as a mistaken reductionist picture. In this talk, I discuss three challenges faced by contemporary cosmology at the meso scale of galaxies, and I review the respective performance of rival approaches (ΛCDM, MOND, GMOND, EG) in satisfactorily modelling 'in between' scales.

3:00 p.m. – 3:30 p.m.– Coffee break

3:30 p.m. – 4:30 p.m. – Karen Crowther (University of Geneva), *"Emergence, Reduction, and Correspondence in the Context of Quantum Gravity"*

> An acceptable theory of quantum gravity (QG) must recover general relativity (GR) in the regimes where GR is known to be successful. What this recovery amounts to, however, is an open question, and concerns the inter-theory relations of correspondence, reduction, and emergence. Depending on the form of the theory, these relations may also play a role in connecting QG to the framework of quantum field theory, and to particular quantum field theories. In this talk, I explore these three inter-theory relations both in general, and from the tentative perspectives of particular approaches to QG. I argue that it is important to clearly articulate and distinguish these relations, since they are each useful in different ways for understanding QG and current physics---perhaps most significantly, they are expected to play a non-trivial role in defining what would count as a successful theory of QG.

4:30 p.m. – 5:30 p.m. – Panel discussion

WEDNESDAY, JUNE 14, 2017

9:30 a.m. – 10:00 a.m. – Coffee Break

10:00 a.m. – 11:00 a.m. – Nick Huggett (University of Illinois at Chicago), *"Cosmological Aspects of Quantum Gravity"*

> Theories of quantum gravity can put pressure on classical notions of spacetime, and perhaps even dissolve it altogether. Not only does this circumstance require one to 'derive' spacetime as a higher level object, but (as Oriti has emphasized) perhaps opens the possibility that there was a transition from an entirely non-spatiotemporal phase in the early universe, replacing the big bang singularity. In this talk I will discuss some big bang scenarios in quantum gravity, and ask whether they fit this picture: and to the extent that they do, I will point out some of the philosophical issues that they raise.

11:00 a.m. – 12:00 p.m. – Niayesh Afshordi (Perimeter Institute for Theoretical Physics), *"Reflections on Spacetime"*

> I outline why I think convergence of empirical evidence and theoretical insights from particle physics, astrophysics, and cosmology point to a concrete and more fundamental paradigm for spacetime.

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2:00 p.m. – 3:00 p.m. – Lee Smolin (Perimeter Institute), "*Galaxy rotation curves: missing matter, or missing physics?"*

3:00 p.m. – 3:30 p.m.– Coffee break

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