GR 3: Cosmology

Time: Monday 16:15–18:15 Location: GR-H3

GR 3.1 Mon 16:15 GR-H3

Through the Big Bang — •Paula Reichert — Mathematisches Institut, LMU München, Germany

This talk presents latest results regarding the evolution of the universe through the Big Bang singularity on shape space. Relationalism in the form of modern shape dynamics suggests that the Big Bang is only a turning or Janus point within an overall time-symmetric, eternal evolution - a common past in a universe with one past (i.e. the Big Bang) and two futures in both directions away from it. This idea is supported by the 2016 result that, for the quiescent Bianchi IX model of GR, the shape (i.e. angular) degrees of freedom can be evolved uniquely through the (otherwise singular) point of zero spatial volume. Studies of the total collision singularity on non-relativistic shape space further suggest that, at the point of total collision (i.e. the Big Bang of the Newtonian N-body universe), the system is exceptionally homogenous, forming a state of minimal shape complexity and minimal entropy. At the same time, both complexity and entropy increase as the system expands and galaxies form in both directions away from the Janus point, thereby marking two gravitational and entropic arrows of time.

GR 3.2 Mon 16:35 GR-H3

Graviton corrections to the Newtonian potential using invariant observables — •Markus B. Fröb, Constantin Rein, and Rainer Verch — Institut für Theoretische Physik, Universität Leipzig, Brüderstraße 16, 04103 Leipzig, Germany

We consider the effective theory of perturbative quantum gravity coupled to a point particle, quantizing fluctuations of both the gravitational field and the particle's position around flat space. Using a recent relational approach to construct gauge-invariant observables, we compute one-loop graviton corrections to the invariant metric perturbation, whose time-time component gives the Newtonian gravitational potential. The resulting quantum correction consists of two parts: the first stems from graviton loops and agrees with the correction derived by other methods, while the second one is sourced by the quantum fluctuations of the particle's position and energy-momentum, and may be viewed as an analog of a "Zitterbewegung". As a check on the computation, we also recover classical corrections which agree with the perturbative expansion of the Schwarzschild metric.

GR 3.3 Mon 16:55 GR-H3

Spatial Geometry of the Large-Scale Universe: The Role of Quantum Gravity, Dark Energy and Other Unknowns — •Marc Holman — Utrecht University, Utrecht, Netherlands

Most key features of contemporary concordance cosmology can be directly linked to observational facts, such as Hubble's law, the existence and properties of the Cosmic Microwave Background (CMB) - in particular its extreme uniformity - light element abundances and large-scale flatness. In some cases, these features first appeared in the form of further model constraints in the light of new observational data - e.g., the discoveries of distance-proportional galactic redshifts and the CMB, which were taken as irreconcilable with static and steady-state cosmological models, respectively. In other cases, they first appeared in the form of *additional* ingredients in the light of largely existent, but seemingly unaccounted for, observational data - e.g., the near-flatness of the Universe's large-scale spatial geometry and the existence of mass discrepancies, which were argued irreconcilable with standard Big Bang cosmology assuming only "normal matter" to be present. As recent work has emphasized however, the observed near-flatness of the large-scale Universe as a partial, but key motivation for assuming the existence of an ultra-short, inflationary expansion of the very early Universe, has a long and troubled history. In this respect, the present work strengthens earlier results regarding the absence of a cosmological flatness problem of the sort that could potentially be resolved by inflation.

GR 3.4 Mon 17:15 GR-H3

Compact objects from effective quantum gravity — Piero Nicolini[1,2,3] and •Salvatore Samuele Sirletti[2,4] — [1]New York University Abu Dhabi, Abu Dhabi, UAE — [2]Frankfurt Institute for Advanced Studies, Frankfurt am Main, Germany — [3]Johann Wolfgang Goethe-Universität, Frankfurt am Main, Germany — [4]Università degli Studi di Napoli Federico II, Naples, Italy

It has been shown that the UV finiteness of Superstring Theory can led to the derivation of a family of regular black hole solutions in the gravity-matter decoupling limit. The latter is a regime governed by stringy effects like non-commutativity and T-duality. The most natural realization of a non-local structure inheriting noncommutative geometry effects is the Gaussian profile for the energy density in the relativistic stress tensor.

In this talk, we present two interesting regular black hole/compact object alternatives that stem from postulating a smooth transition between a quantum gravity dominated region at the origin, and a corona of degenerate nuclear matter around it. The derivation of the resulting metric allows for the description of a regular horizonless Planckian object and a neutron star with a quantum vacuum at its center.

GR 3.5 Mon 17:35 GR-H3

Generalized Uncertainty Relations and the Problem of Dark Energy — •Matthew J. Lake — Frankfurt Institute for Adavanced Studies, Frankfurt am Main, Germany

We outline a new model in which generalised uncertainty relations are obtained without modified commutation relations. While existing models introduce modified phase space volumes for the canonical degrees of freedom, we introduce new degrees of freedom for the background geometry. The background is treated as a genuinely quantum object, with an associated state vector, and the model naturally gives rise to the extended generalised uncertainty principle (EGUP). Importantly, this approach solves (or rather, evades) well known problems associated with modified commutators, including violation of the equivalence principle, the soccer ball problem for multi-particle states, and the velocity dependence of the minimum length. However, it implies two radical conclusions. The first is that space must be quantised on a different scale to matter and the second is that the fundamental quanta of geometry are fermions. We explain how, in the context of the model, this gives rise to an effective dark energy density, without contradicting established results including the no go theorems for multiple quantisation constants, which still hold for species of material particles, and the spin-2 nature of gravitons.

GR 3.6 Mon 17:55 GR-H3

Power spectrum for perturbations in an inflationary model for a closed universe — •tatevik vardanyan and claus kiefer — Institute for Theoretical Physics, University of Cologne, Köln, Germany

We derive the power spectrum of primordial quantum fluctuations in an inflationary universe for curvature parameter $\mathcal{K} = 1$. This is achieved through a Born-Oppenheimer type of approximation scheme from the Wheeler-DeWitt equation of canonical quantum gravity using gauge-invariant variables. Compared to the flat model, the closed model exhibits a deficit of power at large scales.

Reference: arXiv:2111.07835