GR 8: Quantum Cosmology and Quantum Gravity I

Zeit: Mittwoch 14:00–16:15 Raum: HS 4

Hauptvortrag GR 8.1 Mi 14:00 HS 4

Loop quantum cosmology, signature change, and the no-boundary proposal — •Martin Bojowald — The Pennsylvania State University, University Park, PA, USA

Loop quantum gravity suggests a discrete structure of space which should be relevant for physics at large energy scales, in particular near the big bang. Several unexpected consequences have been derived in loop quantum cosmology. The possibility of signature change at high density is one example, which not only reveals a heuristic kinship with the no-boundary proposal of Hartle and Hawking but also helps to solve stability problems recently found by Feldbrugge, Lehners and Turok in an application of Lorentzian path integrals.

GR 8.2 Mi 14:45 HS 4

Singularity Avoidance of the Quantum LTB Model for Gravitational Collapse — •Tim Schmitz and Claus Kiefer — Institut für Theoretische Physik, Universität zu Köln, Zülpicher Straße 77, 50937 Köln, Germany

We quantize the marginally bound Lemaître–Tolman–Bondi model for spherically symmetric dust collapse by considering each dust shell in it individually, taking the outermost shell as a stand-in for every other one. Because the dust naturally provides a preferred notion of time, one can construct a quantum theory for this shell analogously to ordinary quantum mechanics, and impose unitary evolution. It then generically avoids the classical singularity, provided the quantization ambiguities fulfill some (weak) conditions. We demonstrate that the collapse to a singularity is replaced by a bounce. Finally we construct a quantum corrected spacetime describing bouncing dust collapse and discuss some of its properties, for example the black hole lifetime.

GR 8.3 Mi 15:00 HS 4

Gauge Fixing and the Semiclassical Interpretation of Quantum Cosmology — •Leonardo Chataignier — Institut für Theoretische Physik, Universität zu Köln, Zülpicher Straße 77, 50937 Cologne, Germany

We make a critical review of the semiclassical interpretation of quantum cosmology and emphasise that it is not necessary to consider that time emerges only when the gravitational field is (semi)classical. We show that the usual results of the semiclassical interpretation can be obtained by a gauge fixing, both at the classical and quantum levels. By 'gauge fixing' we mean a particular choice of the time coordinate. In the quantum theory, we adopt a tentative definition of the (Klein-Gordon) inner product, which is positive definite for solutions of the quantum constraint equation found via an iterative procedure that corresponds to a weak coupling expansion in powers of the inverse Planck mass. We conclude that the wave function should be interpreted as a state vector for both gravitational and matter degrees of freedom, the dynamics of which is unitary with respect to the chosen inner product and time variable.

GR 8.4 Mi 15:15 HS 4

Dynamical Properties of the Mukhanov-Sasaki Hamiltonian — •Michael Kobler, Kristina Giesel, and Max Joseph Fahn — Institut für Quantengravitation, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 7, 91058 Erlangen, Deutschland

In the context of linearized cosmological perturbation theory, the Mukhanov-Sasaki equation plays a pivotal role. Each mode of this equation resembles a time-dependent harmonic oscillator. We consider the single-mode Mukhanov-Sasaki Hamiltonian as a toy model in mechanics and use the known Lewis-Riesenfeld invariant and the extended phase space formalism introduced in previous works in order to analyze this system. These techniques allow to classically construct an extended canonical transformation that maps an explicitly time-dependent Hamiltonian into a time-independent one, as well as to implement the corresponding unitary map in the quantum theory. Our further analysis leads us to a closed form of the time-evolution operator for the single-mode Mukhanov-Sasaki Hamiltonian, that is to the associated Dyson series. Finally, we discuss an extension of these techniques to the bosonic Fock space, together with some applications for a quasi-de Sitter background.

GR 8.5 Mi 15:30 HS 4

Dynamics of Dirac observables in canonical cosmological perturbation theory — •David Winnekens and Kristina Giesel — University of Erlangen-Nürnberg, Institute for Quantum Gravity, Institute for Quantum Gravity, Staudtstr. 7, 91058 Erlangen

Canonical cosmological perturbation theory describes a Hamiltonian framework for cosmology. Ultimately, a link to the standard Lagrangian treatment is of interest. Proceeding into this direction, Pons et al [1] chose the extended ADM phase space as natural footing that allows for a complete treatment of cosmological gauges that also rely on perturbations of lapse and shift, as it treats them not only as Lagrange multipliers but as dynamical variables. A recent approach [2] generalized their formalism by using geometrical clocks as reference fields and constructing gauge invariant Dirac observables for all conjugate pairs of metric and matter perturbations. Choosing specific clocks corresponds to different Gauge fixings and thereby lead naturally to the respective gauge invariant variables. These are the Bardeen potential for the longitudinal gauge and the Mukhanov-Sasaki variable for the spatially flat gauge. We also present an efficient method to obtain the second order evolution equations of these variables and find accordance with the literature at linear order.

[1] J. M. Pons, D. C. Salisbury and K. A. Sundermeyer. Phys. Rev. D, 80:084015, 2009 & J. Phys.: Conf. Ser., 222, 2010 [2] K. Giesel, A. Herzog. Int. J. Mod. Phys., D27(08):1830005, 2018; K. Giesel, A. Herzog and P. Singh. Class. Quant. Grav., 35(15):155012, 2018 & K. Giesel, P. Singh and D. Winnekens. https://arxiv.org/abs/1811.07972

GR 8.6 Mi 15:45 HS 4

Ramsey Gravity Resonance Spectrosopy with Ultracold Neutrons as a Tool to Probe the Dark Sector — •René Sedmik[1], Joachim Bosina[1,2], Peter Geltenbort[2], Andrei Ivanov[1], Tobias Jenke[2], Jakob Micko[1,2], Mario Pitschmann[1], Tobias Rechberger[1], Martin Thalhammer[1], and Hartmut Abele[1] — [1]Technische Universität Wien, Atominstitut, 1020 Vienna, Austria — [2]Institut Laue-Langevin, 38042 Grenoble, France

While being very successful, general relativity and the standard model of particle physics – presently forming the basis of our physical understanding – seem incomplete due to their incapability to adequately describe dark energy and dark matter. Slowly being accepted, this fact has fuelled a surge in developments of possible modifications of these two theories. Accordingly, numerous experimental attempts testing such modifications have been reported. In this respect, neutrons have proven to be ideal test bodies. With their vanishing electric charge and negligible polarizability, they evade many of the technical difficulties typically plaguing high precision measurements with atoms, molecules, or macroscopic test bodies. The qBounce collaboration has repeatedly used ultracold neutrons to set tight limits on several candidate models aiming to explain the observed dark sector effects. In this talk, we present the next step in the development of qBounce: Ramsey-type gravity resonance spectroscopy. We discuss the implementation, prospects, and challenges of this new method, and show first results yielding an unambiguous proof of principle.

GR 8.7 Mi 16:00 HS 4

Post-Newtonian corrections to Schrödinger equations in gravitational fields — •Philip Schwartz and Domenico Giulini — Institute for Theoretical Physics, Leibniz University Hannover, Appelstraße 2, 30167 Hannover, Germany

With the aim of comparing different methods for the post-Newtonian description of single quantum particles in gravity, we develop a WKB-like systematic 'non-relativistic' expansion scheme for the classical minimally coupled Klein–Gordon equation to arbitrary order in $1/c$. Comparing the results to canonical quantisation of free particles, as widely employed in the literature, we find differences which could in principle become relevant for precision tests of General Relativity using quantum systems.