GR 15: Quantum Gravity II

Zeit: Freitag 9:00–10:30 Raum: NW-Bau - HS3

GR 15.1 Fr 9:00 NW-Bau - HS3

Renormalizable and unitary quantum theory of gravity — •Christian Steinwachs[1], Andrei Barvinsky[2,3], Diego Blas[4], Mario Herrero-Valea[5], and Sergey Sibiryakov[4,5,6] — [1]Albert-Ludwigs-Universität, Freiburg, Germany — [2]Lebedev Physics Institute, Moscow, Russia — [3]Tomsk State University, Tomsk, Russia — [4]Theoretical Physics Department, CERN, Geneva, Switzerland — [5]École Polytechnique Fédérale, Lausanne, Switzerland — [6]Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia

In the construction of a quantum theory of gravity there seems to be a fundamental conflict between renormalizability, unitarity and Lorentz invariance. All these properties are considered as indispensable features of a quantum field theory. Giving up Lorentz invariance as a fundamental principle allows to construct a renormalizable and unitary quantum theory of gravity. Recently, for the first time, the one-loop beta functions have been calculated for this theory in 2+1 dimensions, suggesting that the theory is asymptotically free. I summarize recent progress and discuss the new challenges one is faced with when extending this theory to the physically relevant case of 3+1 dimensions.

GR 15.2 Fr 9:15 NW-Bau - HS3

Semiclassical approximation to quantum geometrodynamics of Weyl-Einstein gravity and emergence of classical Einstein gravity — Claus Kiefer and •Branislav Nikolic — Institute for Theoretical Physics, Zülpicher Straße 77a, 50937 Cologne, Germany

It is known that a semiclassical approximation to the quantum geometrodynamics based on the Einstein-Hilbert action gives, to the highest order, classical Einstein gravity, while the following order gives the quantum field theory on curved spacetimes in the Schrödinger picture, which is a desirable result. In addition, higher derivative classical theories of gravity are being investigated as alternatives to or extensions of General Relativity. If one wants to study quantum gravity via quantum geometrodynamics, it is natural to investigate whether such alternative theories emerge in the semiclassical approximation to their corresponding quantum gravity theories. We study a particular theory of Weyl-Einstein gravity, in which the Einstein-Hilbert action is extended to include the quadratic Weyl tensor term. It is shown that an appropriate semiclassical approximation, motivated by the method of perturbative constraints, does not lead to the classical Weyl-Einstein gravity, but to the classical Einstein equations. Signatures of the Weyl-tensor term appear in the following order, where a modified functional Schrödinger equation emerges. We discuss the implications of these results.

GR 15.3 Fr 9:30 NW-Bau - HS3

Quantum gravitational correction from the Wheeler-DeWitt equation — Chrsitian Steinwachs and •Matthijs van der Wild — Physikalisches Institut, Universität Freiburg, Germany

In recent years, inflationary scalar field models with a strong non-minimal coupling to gravity have gained much attention.

In particular, the model of non-minimal Higgs inflation, where the inflaton field is identified with the Standard Model Higgs field, allows for a unified description of cosmology and particle physics.

We perform the canonical quantization of a general scalar-tensor theory and derive the first quantum gravitational corrections following from a semi-classical expansion of the Wheeler-DeWitt equation.

We discuss how a strong non-minimal coupling affects these corrections and give a brief estimate of their possible impact on cosmological observations.

GR 15.4 Fr 9:45 NW-Bau - HS3

Quantum properties of $f(R)$ gravity — •Michael Ruf and Christian Steinwachs — Physikalisches Institut, Albert-Ludwigs Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany

We present the one-loop counterterms in $f(R)$ gravity for an arbitrary background manifold. This extends previous results in $f(R)$ gravity, which were limited to spaces of constant curvature. The calculation can be most efficiently performed by a combined use of the background field method and the heat kernel approach. Compared to similar calculations in higher derivative theories of gravity, the main technical difficulty of $f(R)$ theory is related to the special degenerate structure of the principal symbol of the fluctuation operator, which prevents the straightforward application of standard techniques. We discuss a new method which allows to reduce the problem to the evaluation of known functional traces. Our result has important applications in cosmology and black hole physics and allows to study the quantum equivalence between $f(R)$ gravity and its reformulation as a scalar-tensor theory.

GR 15.5 Fr 10:00 NW-Bau - HS3

Black Holes within the Asymptotically Safe Scenario of Quantum Gravity — •Dennis Stock — University of Bremen, Center of Applied Space Technology and Microgravity (ZARM), 28359 Bremen

We study the effects of quantum gravity on black hole geometries within the set-up of asymptotically safe quantum gravity. Under the assumption that leading order quantum effects are taken into account, by promoting Newton's and the cosmological constant to scale-dependent functions, we arrive at a quantum-improved metric for Schwarzschild-(A)dS and Kerr-(A)dS. Different constructions, to relate the momentum scale within the FRG-formalism to a length scale, are discussed using numerical as well as analytical methods. Depending on parameters such as the mass and angular momentum of the black hole, the quantum-improved black holes can display a different number of horizons to their counterparts in general relativity. Further results addressed include the Penrose diagrams, the investigation of the central curvature singularity via the Kretschmann scalar, and the Hawking temperatures, together with the implications for the endpoint of the black hole evaporation process.

GR 15.6 Fr 10:15 NW-Bau - HS3

Quantum signatures of area-metric deviations from a metric — •Roberto Tanzi — University of Bremen, Center of Applied Space Technology and Microgravity (ZARM), 28359 Bremen

The most general theory of electrodynamics with linear field equations introduce a new geometry, the area metric, that regulates the propagation of light rays and massive particles instead of the usual Lorentzian metric. In the majority of the experimental situations, the area metric is expected to be a small perturbation around a metric background. In this perturbative case, the concerning quantum theory of electrodynamics can be shown to be renormalizable and can be used to compute various fundamental processes.

I will show that, when one combines the results of these quantum electrodynamics with the dynamics of an area-metric perturbation, the anomalous magnetic moment of the electron, the cross sections of Bhabha scattering, and the hyperfine splitting of the hydrogen pick up a dependence on the position. This way, measurements of the position dependence of these quantities provide a new channel to investigate area-metric deviations from a metric spacetime.