GR 3: Classical General Relativity I

Time: Monday 16:15–17:30 Location: KH 02.012

GR 3.1 Mon 16:15 KH 02.012

What can Holography teach us about scale without conformal invariance? — •Lavish Chawla and Mario Flory — Jagiellonian University in Krakow, Poland

Whether Poincaré invariance together with scale invariance necessarily enhances to full conformal symmetry in quantum field theories remains a longstanding and subtle question. In this talk, we will present our results on this problem from the perspective of the holographic correspondence. In holography, the isometry group of the bulk spacetime corresponds to the global symmetries of a dual quantum field theory. Motivated by this relation, we study spacetimes with one warped extra dimension whose isometry group corresponds to scale without conformal invariance. We show that the Weyl tensor provides an important diagnostic: it vanishes for metrics corresponding to conformal invariance and is nonzero for those corresponding only to scale invariance. With this local geometric condition, we prove the following theorem: For putative boundary theories in two and higher dimensions, the bulk metric cannot exhibit scale without conformal invariance if its warped extra dimension is compact and the null energy condition is required to hold.

GR 3.2 Mon 16:30 KH 02.012

Formulating the complete initial boundary value problem in numerical relativity to model black hole echoes — •Conner Dailey — Institute for Theoretical Physics, Jena, Germany, Fröbelstieg 1 07743 Jena

In an attempt to simulate black hole echoes (generated by potential quantum-gravitational structure) in numerical relativity, we recently described how to implement a reflecting boundary outside of the horizon of a black hole in spherical symmetry. Here, we generalize this approach to spacetimes with no symmetries and implement it numerically using the generalized harmonic formulation. We cast the evolution equations and the numerical implementation into a Summation By Parts (SBP) scheme, which seats our method closer to a class of provably numerically stable systems. We implement an embedded boundary numerical framework that allows for arbitrarily shaped domains on a rectangular grid and even boundaries that evolve and move across the grid. As a demonstration of this framework, we study the evolution of gravitational wave scattering off a boundary either inside, or just outside, the horizon of a black hole. This marks a big leap toward the goal of a generic framework to obtain gravitational waveforms for behaviors motivated by quantum gravity near the horizons of merging black holes.

GR 3.3 Mon 16:45 KH 02.012

Revisiting Synchronisation Systems and Applications in Geodesy — •Bennet Grützner, Eva Hackmann, and Claus Lämmerzahl — ZARM, Universität Bremen

Establishment of International Atomic Time (TAI) requires a global clock network and definitions of synchronisation and simultaneity. On the rotating Earth, this is a non-trivial task due to the Sagnac effect. In geodesy and positioning, this is usually addressed within a post-Newtonian framework. In our work, we extend the synchronisation framework beyond such approximative approaches. We introduce synchronisation systems and provide them with a mathematically rigorous characterisation. We then classify them according to their properties and describe an operational realisation. Finally, we illustrate the framework by discussing synchronisation via the electronically stabilised (ELSTAB) fibre link between Braunschweig and Potsdam.

GR 3.4 Mon 17:00 KH 02.012

Discrete Spacetime Blocks for Visualizing GR: Interactive Geodesics in a (2+1D) Schwarzschild Sector Model — •Vassilios Marakis, Rahel Gabriel, Corvin Zahn, and Ute Kraus — Universität Hildesheim

We present an interactive web application that constructs sector models of curved spacetime. The spacetime is discretized into a mesh of locally flat Minkowski ”blocks” in two spatial dimensions and time. Within each block, massive particles and light trajectories are represented as straight worldline segments, while block to block transition implemented as rotations and local Lorentz boosts encode the gravitational curvature. This piecewise flat approach enables an intuitive, visual treatment of general relativity. Geodesics emerge from local inertial motion plus the accumulated effect of successive boundary transformations. The result is a browser based sandbox for geodesics, that combines the concept of local flatness and global curvature understandable without requiring a full differential geometry toolkit during exploration.

GR 3.5 Mon 17:15 KH 02.012

Relativistic orbital perturbation theory — Oleksii Yanchyshen, Eva Hackmann, and •Claus Lämmerzahl — ZARM and ITP, University of Bremen

Within a Newtonian framework orbital perturbation theory is based on the Keplerian orbits as exact solution of the Kepler problem. Perturbation forces lead to time dependent orbital parameters like the semimajor axis, eccentricity, inclination, perigee, and ascending node. Within a relativistic framework we start with the exact solution of the geodesic equation in Schwarzschild space-time. Perturbation forces then lead to a time-dependence of orbital parameters, some of which we newly defined. Their time dependence is described by a relativistic generalization of the Gauß equations. In the presentation this formalism is explained and some applications to perturbations like radiation reaction will be outlined. This new approach is mathematically more challenging but leads to a faster convergence of results than post-Newtonian approaches in the strong field regime.