GR 9: Numerische Relativitätstheorie I

Zeit: Mittwoch 14:00–16:00 Raum: HS 6

GR 9.1 Mi 14:00 HS 6

Status Report on the Numerical Relativity/Analytical Relativity collaboration — •Ian Hinder — Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Potsdam, Germany

I report on the current status of the Numerical Relativity/Analytical Relativity (NR/AR) collaboration. In this project, a collaboration between 14 numerical relativity (NR) and 7 analytical relativity (AR) groups, we aim to use gravitational waveforms from NR simulations of binary black holes to construct accurate analytical templates to be used in the search for gravitational waves with the LIGO and Virgo detectors. I describe our target requirements on waveform length and accuracy, as well as the techniques we use to process the NR data into a form suitable for use with analytical models. Simulations from the first stage, encompassing mostly aligned-spin configurations, are complete, and I present an overview of the numerical results obtained so far.

GR 9.2 Mi 14:15 HS 6

Numerical Relativity in Spherical Polar Coordinates — •Pedro Montero — Max Planck Institute for Astrophysics

Development of numerical relativity codes in spherical polar coordinates has been hampered by the need to handle the coordinate singularities at the origin and on the axis, for example by careful regularization of the appropriate variables. Assuming spherical symmetry and adopting a covariant version of the BSSN equations, Montero and Cordero-Carrión recently demonstrated that such a regularization is not necessary when a partially implicit Runge-Kutta (PIRK) method is used for the time evolution of the gravitational fields. Here we report on an implementation of the BSSN equations in spherical polar coordinates without any symmetry assumptions. Using a PIRK method we obtain stable simulations in three spatial dimensions without the need to regularize the origin or the axis. We perform and discuss a number of tests to assess the stability, accuracy and convergence of the code, namely weak gravitational waves, "hydro-without-hydro" evolutions of spherical and rotating relativistic stars in equilibrium, and single black holes.

GR 9.3 Mi 14:30 HS 6

Black-hole lattices — •Eloisa Bentivegna[1] and Mikolaj Korzynski[2] — [1]Max Planck Institute for Gravitational Physics — [2]Center for Theoretical Physics at the Polish Academy of Sciences

Regular black-hole lattices have recently been proposed as a testbed to investigate the role of small-scale inhomogeneities in spaces that are homogeneous on larger scales. I will present a brief history of the developments in this area and then discuss the construction of black-hole lattices in two cases, characterized by whether the corresponding spacetime contains a time-symmetric spatial hypersurface. Finally, I will illustrate the cosmological relevance of these models by comparing them to the zero-pressure Friedmann-Lemaître-Robertson-Walker class.

GR 9.4 Mi 14:45 HS 6

1+log Trumpet Initial Data in Numerical Relativity — •Tim Dietrich and Bernd Brügmann — Friedrich-Schiller-Universität, Jena, Germany

A key ingredient for reliable numerical simulations is the accurate construction of initial data. One typical method is the puncture approach. When constructing puncture initial data by solving the Hamiltonian constraint, the coordinate singularity requires special attention.

The standard way to treat the pole singularity occurring in wormhole puncture data is not applicable to trumpet puncture data. Therefore, we investigate a new approach based on inverse powers of the conformal factor and present numerical examples for single punctures of the wormhole and 1+log trumpet type. Specifically, we describe a method to solve the Hamiltonian constraint for two 1+log trumpets for given extrinsic curvature with non-vanishing trace and investigate properties of our constructed initial data during binary black hole evolutions.

GR 9.5 Mi 15:00 HS 6

numerical solution of the 2+1 Teukolsky equation on a hyperboloidal and horizon penetrating foliation of Kerr — •Enno Harms, Sebastiano Bernuzzi, and Bernd Brügmann — Theoretical Physics Institute, University of Jena, 07743 Jena, Germany

We present a novel formulation of the Teukolsky equation for generic spin perturbations on the hyperboloidal and horizon penetrating foliation of Kerr proposed recently by Racz and Toth. An additional, spin-dependent rescaling of the field variable can be used to achieve stable, long-term, and accurate time-domain evolutions of generic spin perturbations. As an application we investigate numerically the late-time decays of scalar, electromagnetic, and gravitational perturbations by means of 2+1 evolutions.

GR 9.6 Mi 15:15 HS 6

Spectral time evolution of wave equations on hyperboloidal slices — •Rodrigo Panosso Macedo and Marcus Ansorg — Theoretical Physics Institute - University of Jena, Jena, Germany

We present a new numerical scheme for the time evolution of axisymmetric wave equations around a black hole. The code relies on two features: i) the surfaces of constant time extend all the way towards future null infinity (hyperboloidal slices), which is included in the computational domain by a compactification of the radial coordinate, ii) the wave equations are solved by means of a pseudo-spectral method, which is applied here to both spatial and time directions. The inversion of the resulting dense matrix is efficiently performed with a specifically designed iterative method. We obtain extreme precision of the numerical solution close to machine accuracy, which allows us to study in detail the field's tail, i.e., the decay as an inverse power law in the asymptotic time evolution.

GR 9.7 Mi 15:30 HS 6

Modeling neutron stars using a GR Resistive MHD formalism — •Daniela Alic[1], Kyriaki Dionysopoulou[1], Carlos Palenzuela[2], Luciano Rezzolla[1], and Bruno Giacomazzo[3] — [1]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Potsdam-Golm, Germany — [2]Canadian Institute for Theoretical Astrophysics, Toronto, Canada — [3]JILA, University of Colorado and National Institute of Standards and Technology, Boulder, USA

We present numerical results obtained with a general-relativistic resistive magnetohydrodynamics (GR-RMHD) version of the Whisky code, using an algebraic Ohm law that accounts for the effects of finite resistivity. The numerical method adopted exploits the properties of Implicit-Explicit Runge-Kutta (RKIMEX) numerical schemes to treat the stiff terms of the equations. We report simulations of magnetized neutron stars both in the Cowling approximation and in dynamical spacetimes. In addition, we present the case of a collapsing star, which provides a very good testbed for numerical codes with dynamical electromagnetic fields in strong gravity and has interesting astrophysical implications. Finally, we show that our results are in good agreement with the perturbative studies of the dynamics of electromagnetic fields in a Schwarzschild background.

GR 9.8 Mi 15:45 HS 6

Initial Data for Eccentric Neutron Star Binaries — •Niclas Moldenhauer and Charalampos Markakis — Friedrich-Schiller Universität, Jena, Germany

We present a way to construct initial data for neutron star binaries on quasi-circular or eccentric orbits. Therefore, a self-consistent field method is used, in which we solve the Einstein constraints in the conformal thin-sandwich approach. A single TOV star can be constructed in this way and afterwards, two such TOV stars are superimposed. Then the method is applied again to minimize the constraint violations and induce tidal deformations.