GR 9: Gravitational Waves and Astrophysics I

Time: Wednesday 16:00–18:00 Location: ZEU/0260

GR 9.1 Wed 16:00 ZEU/0260

Numerical-Relativity-Informed Effective-One-Body model for Black-Hole-Neutron-Star Mergers with Higher Modes and Spin Precession — •Alejandra Gonzalez[1], Rossella Gamba[1], Francesco Zappa[1], Gregorio Carullo[1], Sebastiano Bernuzzi[1], and Alessandro Nagar[2] — [1]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, Fröbelstieg 1, 07743 Jena, Germany — [2]INFN Sezione di Torino, Via P. Giuria 1, 10125 Torino, Italy

We present the first effective-one-body (EOB) model for generic-spins quasi-circular black-hole - neutron-star (BHNS) inspiral-merger-ringdown gravitational waveforms (GWs). Our model is based on a new numerical-relativity (NR) informed expression of the BH remnant and its ringdown, it reproduces the NR (l, m) = (2, 2) waveform with typical phase agreement of about less than 0.5 rad (less than 1 rad) to merger (ringdown). The maximum (minimum) mismatch between the (2, 2) and the NR data is 4% (0.6%). Higher modes (HMs) (2, 1), (3, 2), (3, 3), (4, 4) and (5, 5) are included and their mismatch with the available NR waveforms are up to (down to) a 60% (1%) depending on the inclination. Phase comparison with a 16 orbit precessing simulation shows differences within the NR uncertainties. We demonstrate the applicability of the model in GW parameter estimation by perfoming the first BHNS Bayesian analysis with HMs (and non-precessing spins) of the events GW190814 and GW200105, together with a new (2, 2)-mode analysis of GW200115.

GR 9.2 Wed 16:20 ZEU/0260

To ring or not to ring, the tale of black hole quasi-normal modes — •Peter James Nee, Sebastian H. Völkel, and Harald Pfeiffer — Max Planck Institute for Gravitational Physics (Albert Einstein Institute), D-14476 Potsdam, Germany

The extraction of quasi-normal modes from compact binary mergers (also referred to as black hole spectroscopy) is one of the most promising pillars in current and future strong gravity tests. Recent works have sought to push current ringdown analysis into the non-linear merger part of the waveform via the inclusion of overtones, to better reproduce the waveform and ascertain the remnant black hole parameters. However it is well-believed that the presence of overtones is a non-trivial question, and as such caution is warranted. In this work we explore the potential pitfalls in both waveform reconstruction and parameter extraction in ringdown analysis. To this extent, we revisit the simpler problem of wave propagation in both Regge-Wheeler and Pöschl-Teller systems. We employ several modelling approaches to waveforms generated via a finite-difference evolution scheme, allowing for a varying number of overtones. The fitting is also performed over differently sized windows of the waveforms.

GR 9.3 Wed 16:40 ZEU/0260

Constraining modifications of black hole perturbation potentials near the light ring with quasinormal modes — •Sebastian Völkel[1,2,3], Nicola Franchini[1,2,4,5], Enrico Barausse[1,2], and Emanuele Berti[6] — [1]SISSA and INFN Sezione di Trieste, Trieste, Italy — [2]IFPU, Trieste, Italy — [3]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Potsdam, Germany — [4]Université Paris Cité, Paris, France — [5]CNRS-UCB International Research Laboratory, Berkeley, US — [6]Johns Hopkins University, Baltimore, USA

In modified theories of gravity, the potentials appearing in the Schrödinger-like equations that describe perturbations of non-rotating black holes are also modified. In this talk, we ask how such modifications can be constrained with future, high-precision measurements of quasi-normal modes. We use a perturbative framework that allows one to map modifications of the effective potential, in powers of M/R, to deviations in the quasi-normal mode spectrum. Using MCMC methods, we recover the coefficients in the M/r expansion in an "optimistic" scenario where we vary them one at a time, and in a "pessimistic" scenario where we vary them all simultaneously. In both cases, we find that the bounds on the individual parameters are not robust. However, inspired by WKB theory, we demonstrate that the value of the potential and its second derivative at the light ring can be robustly constrained. These constraints allow a more direct comparison between tests based on black hole spectroscopy and observations of black hole "shadows".

GR 9.4 Wed 17:00 ZEU/0260

Packed Message delivered by Tides in Binary Neutron Star Mergers — •Hao-Jui Kuan[1] and Kostas Kokkotas[2] — [1]Albert-Einstein-Institut, Potsdam, Germany — [2]University of Tübingen, Tübingen, Germany

The morphology of gravitational waveforms depends on almost all source parameters, and thus encodes a bunch of information about the radiating objects. In particular, tidal parameters of neutron stars may stringently constrain the nuclear equation of state, thus their precise estimation is of fundamental importance. Emphasizing the tidal phase shift by aligned, rotating stars, we provide an accurate, yet economical, method to generate f-mode-involved, premerger waveforms. We find for slow-rotating stars that the dephasing effects of the dynamical tides can be uniquely, equation-of-state-independently determined by the direct observables. In addition, for binaries with fast rotating members, the dephasing due to f-mode is larger than that caused by equilibrium tides by a factor of $\sim$5, which may lead to a considerably overestimated tidal deformability if the dynamical tidal contribution is not accounted for. The influence of inclination angles of stellar spins will be discussed also, as well as the possibility of accompanying precursors flares associated with f-mode excitation.

GR 9.5 Wed 17:20 ZEU/0260

Binary neutron star merger simulations with neutrino transport and turbulent viscosity: impact of different schemes and grid resolution — •Francesco Zappa — Friedrich-Schiller-Universität Jena, Theoretisch-Physikalisches Institut, Jena, Germany

We present a systematic numerical relativity study of the impact of different treatment of microphysics and grid resolution in binary neutron star mergers.

We find that viscosity helps to stabilise the remnant against gravitational collapse but grid resolution has a larger impact than microphysics on the remnant's stability. The gravitational wave (GW) energy correlates with the maximum remnant density, that can be thus inferred from GW observations.

Simulations employing the M1 transport schemes show the emergence of a neutrino trapped gas that locally decreases the temperature a few percent when compared to the other simulation series. This out-of-equilibrium effect does not alter the GW emission at the typical resolutions considered for mergers.

Different microphysics treatments impact mass, geometry and composition of the remnant's disc and ejecta. Ejecta composition influences the nucleosynthesis yields, that are robust only if both neutrino emission and absorption are simulated. Synthetic kilonova light curves can be reliably predicted only including the various ejecta components.

We conclude that advanced microphysics in combination with resolutions higher than current standards appear essential for robust long-term evolutions and astrophysical predictions.

GR 9.6 Wed 17:40 ZEU/0260

GRMHD simulations with GR-Athena++ — •William Cook — Friedrich-Schiller-Universität Jena

We demonstrate the performance of the new code GR-Athena++ in evolving general relativistic magnetohydrodynamics (GRMHD) in a dynamically evolving spacetime. GR-Athena++ utilises the task-based parallelism and oct-tree based adaptive mesh refinement of the highly scaling Athena++ code, as well as its approach to solving GRMHD problems in stationary spacetimes; combined with new functionality to solve the Einstein equations in the Z4c formulation. We show the performance of this new code by simulating the evolution of Neutron Stars in a dynamical spacetime, presenting tests of our code, as well as strong and weak scaling tests.