GR 2: Gravitational Waves I

Time: Monday 16:15–17:30 Location: KH 01.016

GR 2.1 Mon 16:15 KH 01.016

Insights from the test-mass limit for effective-one-body models: elliptic and hyperbolic motion — •Simone Albanesi for the Einstein Telescope-Collaboration — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743, Jena, Germany — INFN sezione di Torino, Torino, Italy

The effective-one-body (EOB) approach provides an accurate description of the dynamics of comparable mass binaries, including non-circularized configurations. By construction, the EOB formalism incorporates the test-mass limit and can therefore strongly benefit from results obtained in black-hole perturbation theory. In this talk, we discuss recent test-mass results for elliptic and hyperbolic motion and show how these results can be used to better understand and inform the analytical prescriptions employed in EOB models. We further analyze the merger properties of eccentric binaries and dynamical captures in the test-mass limit. These results provide guidance for the construction of a generic mass-ratio ringdown model, enabling a more complete description of non-circularized plunge-mergers. Finally, we discuss new numerical relativity simulations and highlight their analogies with the test-mass case.

GR 2.2 Mon 16:30 KH 01.016

Identifying Sub-Solar Primordial Black Holes for Einstein Telescope Using Deep Learning Methods — •Caner Bahceci, Waleed Esmail, and Alexander Kappes — Institut für Kernphysik, Universität Münster, Wilhelm-Klemm-Straße 9, 48149, Münster

The development of the third-generation gravitational-wave detectors marks a significant advance in the search for primordial black holes (PBHs). In particular, the Einstein Telescope (ET), with its excellent low-frequency sensitivity, will allow an early detection of gravitational-wave signals from compact binaries, including sub-solar-mass systems. In this talk, I will present the methodology used to simulate large-scale datasets of sub-solar-mass PBH binary coalescences developed for ET. Additionally, the talk will discuss how these datasets are employed to train deep learning models to distinguish signals originating either from astrophysical black holes or potentially primordial black holes.

GR 2.3 Mon 16:45 KH 01.016

Astrophysical insights from hierarchical black hole mergers in the era of next-generation detectors — •Angela Borchers[1,2] and Frank Ohme[1,2] — [1]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Hannover, Germany — [2]Leibniz Universität Hannover, Hannover, Germany

Black-hole binaries can form through a variety of astrophysical pathways, each leaving distinct imprints on their observable properties. One such pathway is the hierarchical formation of black holes through repeated mergers, which produces black holes with characteristic spin signatures. These spins carry information about both the escape velocity of the host environment and the spins of first-generation black holes. Currently, however, observations of binary black hole mergers by the LIGO-Virgo-KAGRA Collaborations typically have spin measurements with substantial uncertainties, limiting our ability to extract this information. The improved sensitivities of next-generation gravitational-wave detectors, such as the Einstein Telescope and Cosmic Explorer, will enable the observation of many more mergers and provide significantly more precise measurements of binary parameters, including spins. In this talk, I will present simulations of mock observations for Einstein Telescope based on the population properties inferred from the latest gravitational-wave catalog, GWTC-4, and discuss whether spin measurements from next-generation detectors can be used to gain insight into the astrophysical environments and merger histories of binary black holes.

GR 2.4 Mon 17:00 KH 01.016

Effective Gravitoelectric Lagrangian for Neutron Star Dynamical Tides — •Felix Lichtner — Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Potsdam, Germany

The tidal deformations of neutron stars in binary systems can have a significant impact on the emitted waveforms of gravitational waves. Studying these effects provides a direct window into the internal dynamics of neutron stars, in particular their still unknown equation of state. We characterize the tidal dynamics of a rotating neutron star in an external gravitational field by a systematic construction of a Lagrangian in the framework of effective field theory. This Lagrangian is constructed from the degrees of freedom describing the leading order gravitoelectric effects for neutron stars modeled as a perfect fluid, as is done e.g. in [Gupta, Steinhoff, Hinderer (2021)]. Integrating out the gravitational interactions to third post Newtonian order, we produce an effective description of the gravitoelectric binary dynamics. Further, we characterize the tidal spin via an analysis of the symmetries in the Lagrangian. Finally, we show that the equations of motion as well as the stress-energy tensor attained from the Lagrangian reproduce the Mathisson–Papapetrou–Dixon (MPD) equations of motion describing general extended objects in General Relativity.

GR 2.5 Mon 17:15 KH 01.016

Accounting for the Known Unknowns: Systematic Waveform Errors in Gravitational-Wave Analyses — •Frank Ohme[1,2], Sumit Kumar[1,3], and Max Melching[1,4] — [1]Max Planck Institute for Gravitational Physics, Hannover, Germany — [2]Leibniz University, Hannover, Germany — [3]Utrecht University, Utrecht, The Netherlands — [4]California Institute of Technology, Pasadena, USA

The analysis of gravitational-wave observations relies heavily on models of the instrument noise and the expected signal shape. While models of the instrument's calibration and its noise naturally incorporate some uncertainty, the signal templates are typically treated as perfect. However, we know that this is an idealisation. In this talk, I present a versatile and robust method to incorporate systematic waveform-model uncertainties in the analysis of compact binary mergers. I show that treating signal models as uncertain may decrease the accuracy of the inferred source parameters, but otherwise ignored systematic biases are also reduced. Applying our method to real events, I illustrate that instead of losing accuracy, the main effect is to gain confidence in any results that remain robust with respect to the introduction of systematic errors.