GR 5: Gravitational Waves

Time: Tuesday 16:15–18:35 Location: GR-H2

GR 5.1 Tue 16:15 GR-H2

The scientific potential of gravitational waves from Extreme Mass Ratio Inspirals — •Lorenzo Speri — Max Planck Institute for Gravitational Physics (Albert Einstein Institute) Am Muehlenberg 1, 14476 Potsdam, Germany

One of the primary sources for the future space-based gravitational wave detector, the Laser Interferometer Space Antenna, are the inspirals of small compact objects into massive black holes in the centers of galaxies. The gravitational wave observations of such Extreme Mass Ratio Inspiral (EMRI) systems have a huge scientific potential. The compact object typically completes hundred thousand cycles in band, during which time it is orbiting in the strong field region close to the central rotating black hole. Because of this, EMRI signals encode a detailed map of the background space-time and offer a unique opportunity to measure the properties and environment of Massive Black Holes, and to test for deviations from General Relativity (GR). Properly modeling EMRIs is of paramount importance to unlock such potential. In this talk I will review how EMRI waveform models are constructed, and show how environmental and beyond GR effects can be included. I will discuss the ability of EMRI signals to constrain accretion disk and beyond GR parameters. I will conclude by highlighting the future challenges for EMRI gravitational wave modeling.

GR 5.2 Tue 16:35 GR-H2

Detecting long-duration gravitational wave signals — •Liudmila Fesik and Maria Alessandra Papa — Max Planck Institute for Gravitational Physics (Albert Einstein Institute) and Leibniz University, Callinstraße 38, 30167 Hannover, Germany

Spinning neutron stars are sources of long-duration continuous waves (CWs) that may be detected by interferometric detectors. We focus on glitching pulsars with abrupt spin-ups and long term spin-down, which imprint in CWs as transient signals from weeks to months. Standart method for identifying transient signals is the match-filtering, which combines a coherent detection statistics over time intervals of different duration. We propose a new method, where the most information from an initial search is considered in order to set up the post-following transient searches. We characterize the method by determining the false alarm and false dismissal probabilities for different signal strengths, and appropriate choices of the relative detection thresholds. We compare the sensitivity of this method with the standart match-filtering.

GR 5.3 Tue 16:55 GR-H2

Interference of strongly lensed Gravitational Waves — •Stefano Savastano[1], Filippo Vernizzi[2], and Miguel Zumalacarregui[1] — [1]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Am Mühlenberg 1, D-14476 Potsdam-Golm, Germany — [2]Institut de Physique Theorique, Universite Paris Saclay CEA, CNRS, 91191 Gif-sur-Yvette, France

Gravitational waves (GW) can be lensed by inhomogeneities on their journey from source to observer, just as electromagnetic radiation. Lens parameters can be extracted from the phase evolution of lensed signals. Continuous GWs (CGW) have a negligible frequency evolution, so the full degeneracy between source and lens parameters limits the extraction. I will discuss how studying the interference pattern produced by strongly lensed CGWs images can enhance the inference of lens parameters. In particular, I will show that the relative motion of the lens to the source or a small frequency evolution can break this degeneracy for some systems. Finally, I will discuss detection perspectives of CGWs lensing for Earth and space-based detectors and elaborate on some possible applications of this tool.

GR 5.4 Tue 17:15 GR-H2

Scattering gravitational waves off effective spinning black holes — •Venkata Sai Saketh Muddu and Justin Vines — Max Planck institute for gravitational physics, Potsdam Science Park Am Mühlenberg 1 D-14476 Potsdam, Germany

The scattering of gravitational waves off a black hole contains valuable information characterizing the response of a black hole to an external gravitational field. We present a new method for computing scattering amplitudes for this process, using an effective worldline theory where the black hole is treated as a point particle equipped with multipole moments. These moments can be intrinsic or induced. The effective action couples the black hole's moments to an external gravitational field via interaction terms, which contain unknown coefficients. We consider a plane wave impinging on the black hole and consider its response to the incoming wave. In the effective theory, this leads to a scattered wave produced by the black hole. Comparing the scattered wave to the incident wave gives us the amplitude. We solve for the amplitude iteratively in powers of spin (the Kerr ring radius). Comparing the amplitude from the effective theory to that obtained by solving the Teukolsky equation in a Kerr background can fix the unknown coefficients in the effective action. Using our amplitude as an effective "gravitational Compton amplitude" in a triangle unitarity cut, we can also compute contributions to the relativistic scattering amplitude and subsequently the radial action for black-hole–black-hole scattering.

GR 5.5 Tue 17:35 GR-H2

Black-hole ringdown as a probe of higher-curvature gravity theories — •Abhirup Ghosh[1], Hector O. Silva[1], and Alessandra Buonanno[1,2] — [1]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Am Mühlenberg 1, Potsdam 14476, Germany — [2]Department of Physics, University of Maryland, College Park, MD 20742, USA

Observations of gravitational waves from the mergers of compact objects like black holes have allowed us to test, for the first time, the nature of strong-field gravity. Albert Einstein's theory of General relativity (GR) remains our best description of gravitational interaction, and most of the strong-field tests of gravity demonstrated on LIGO-Virgo signals have been null tests of GR, i.e, they check for consistency between observations and predictions of GR and place bounds on possible deviations from these predictions. Issues such as the quantization of GR and the cosmological constant problem suggest that Einstein's theory might not be a complete description of gravity and might require modifications. In this work, we use observations of the black hole ringdown from the latest LIGO-Virgo catalog of gravitational wave signals (GWTC-3) in an attempt to constrain possible deviations due to well-motivated higher-curvature theories of gravity.

GR 5.6 Tue 17:55 GR-H2

Probing new physics on the horizon of black holes with gravitational waves — •Elisa Maggio — Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Am Mühlenberg 1, 14476 Potsdam, Germany

Black holes are the most compact objects in the universe. According to general relativity, black holes have a horizon that hides a singularity where Einstein's theory breaks down. Recently, gravitational waves opened the possibility to probe the existence of horizons and investigate the nature of compact objects. This is of particular interest given some quantum-gravity models which predict the presence of horizonless and singularity-free compact objects. Such exotic compact objects can emit a different gravitational-wave signal relative to the black hole case. In this talk, I overview the gravitational-wave phenomenology of exotic compact objects. I infer how extreme mass-ratio inspirals observable by future gravitational-wave detectors will allow for model-independent tests of the black hole paradigm.

GR 5.7 Tue 18:15 GR-H2

General Relativity from Worldline Quantum Field Theory — •Gustav Uhre Jakobsen — Humboldt-Universität zu Berlin, Berlin, Germany — Max-Planck-Institut für Gravitationsphysik, Potsdam, Germany

The worldline quantum field theory (WQFT) has recently been developed in order to describe classical gravitational interactions. While the goal is to analyse bound dynamics of binaries and their gravitational waves, this framework most naturally describes scattering (unbound) events. This in line with other quantum field theoretic approaches. However, several insights from this field has shown that the two regimes of unbound vs bound motion are intrinsically related.

I will present our current supersymmetric WQFT which describes spinning black holes or stars. Here, the supersymmetry encodes the symmetries of the spin degrees of freedom. I will consider several of the scattering observables that we have derived from this WQFT and how they can be related to bound ones. Examples are the eikonal, the spin kick and the total deflection.

Finally, I will consider future perspectives and challenges of the WQFT. This includes extending the WQFT in order to describe new phenomenological aspects of e.g. neutron stars and improving the integration techniques in order to increase precision of observables.