GR 4: Gravitational waves

Time: Tuesday 16:30–18:30 Location: H6

Invited Talk GR 4.1 Tue 16:30 H6

News from the Gravitational-Wave Sky — •Alessandra Buonanno — Max Planck Institute for Gravitational Physics, Potsdam

The solution of the two-body problem in General Relativity is playing a crucial role in observing gravitational waves from binary systems composed of black holes and neutron stars, and inferring their astrophysical, cosmological and gravitational properties. After reviewing the synergistic approach that successfully combines analytical and numerical relativity to produce highly accurate waveform models, I will discuss the most compelling and puzzling findings from the most recent LIGO-Virgo observing run.

GR 4.2 Tue 17:15 H6

GW190521: A dynamical capture of two black holes — •Rossella Gamba — TPI, Friedrich-Schiller-Universität Jena

We analyze the gravitational-wave signal GW190521 under the hypothesis that it was generated by the merger of two nonspinning black holes on hyperbolic orbits. The best configuration matching the data corresponds to two black holes of source frame masses of $81^{+62}_{-25}M_\odot$ and $52^{+32}_{-32}M_\odot$ undergoing two encounters and then merging into an intermediate-mass black hole. Under the hyperbolic merger hypothesis, we find an increase of one unit in the recovered signal-to-noise ratio and a 14 e-fold increase in the maximum likelihood value compared to a quasi-circular merger with precessing spins. We conclude that our results support the first gravitational-wave detection from the dynamical capture of two stellar-mass black holes.

GR 4.3 Tue 17:30 H6

Training Strategies for Deep Learning Gravitational-Wave Searches — Marlin Benedikt Schäfer[1,2], •Ondřej Zelenka[3,4], Alexander Harvey Nitz[1,2], Frank Ohme[1,2], and Bernd Brügmann[3,4] — [1]Max-Planck-Institut für Gravitationsphysik, Albert-Einstein-Institut, D-30167 Hannover, Germany — [2]Leibniz Universität Hannover, D-30167 Hannover, Germany — [3]Friedrich-Schiller-Universität Jena, D-07743 Jena, Germany — [4]Michael Stifel Center Jena, D-07743 Jena, Germany

Deep learning may be capable of finding gravitational wave signals where current algorithms hit computational limits. We restrict our analysis to signals from non-spinning binary black holes and systematically test different strategies by which training data is presented to the networks. To assess their impact, we re-analyze the first published networks and directly compare them to an equivalent matched-filter search. We find that the deep learning algorithms can generalize low signal-to-noise ratio (SNR) signals to high SNR ones but not vice versa. As such, it is not beneficial to provide high SNR signals during training, and fastest convergence is achieved when low SNR samples are provided early on. We found that the networks are sometimes unable to recover any signals when a false alarm probability $< 10^{-3}$ is required. We resolve this by applying a modification we call unbounded Softmax replacement (USR) after training. With this alteration we find that the machine learning search retains $\geq 97.5\%$ of the sensitivity of the matched-filter search down to a false-alarm rate of 1 per month.

GR 4.4 Tue 17:45 H6

A Deep Learning Gravitational-Wave Coincidence Search — •Marlin Benedikt Schäfer[1,2] and Alexander Harvey Nitz[1,2] — [1]Albert-Einstein-Institut, D-30167 Hannover, Germany — [2]Leibniz Universität Hannover, D-30167 Hannover, Germany

Gravitational waves emitted by a coalescing binary system of compact objects are now routinely observed by Earth bound detectors. The most sensitive search algorithms convolve many different precalculated waveform models with the detector data and look for coincident matches between different detectors. Machine learning is now being explored as an alternative search algorithm that has the prospect to reduce computational costs and target more complex signals. In this work we construct a two detector machine learning search from a neural network trained on non-spinning binary black hole data from a single detector. The network is applied to the data from both observatories independently and we check for events coincident in time between the two. We compare our findings to an equivalent matched filter search and a comparable two-detector neural network search.

GR 4.5 Tue 18:00 H6

Search for lensing signatures in the gravitational-wave observations from the first half of LIGO-Virgo's third observing run — •David Keitel for the LIGO-Virgo-Collaboration — Departament de Física, Edifici Mateu Orfila, Universitat de les Illes Balears, Carretera de Valldemossa, km 7,5, 07122 Palma de Mallorca, Illes Balears, Spain

The Advanced LIGO and Advanced Virgo detectors are now observing large numbers of gravitational-wave signals from compact binary coalescences, with 50 entries in the latest catalogue GWTC-2. With this rapidly growing event rate, our chances become better to detect rare astrophysical effects on these novel cosmic messengers. One such rare effect with a long and productive history in electromagnetic astronomy and great potential for the future of GW astrophysics is gravitational lensing. This presentation covers the first LIGO-Virgo collaboration search for lensing signatures in data from the O3a observing run. We study: 1) the expected rate of lensing at current detector sensitivity and the implications of a non-observation of strong lensing or a stochastic gravitational-wave background on the merger-rate density at high redshift; 2) how the interpretation of individual high-mass events would change if they were found to be lensed; 3) the possibility of multiple images due to strong lensing by galaxies or galaxy clusters; and 4) possible wave-optics effects due to point-mass microlenses. Overall, we find no compelling evidence for lensing in the observed gravitational-wave signals from any of these analyses.

GR 4.6 Tue 18:15 H6

Dark Sirens to Resolve the Hubble-Lemaître Tension — •Ssohrab Borhanian[1,2], Arnab Dhani[2], Anuradha Gupta[3], K.G. Arun[4], and Bangalore Sathyaprakash[2] — [1]Friedrich-Schiller-Universität Jena, Jena, Germany — [2]Institute for Gravitation and the Cosmos, State College, USA — [3]University of Mississippi, Oxford, USA — [4]Chennai Mathemartical Institute, Chennai, India

The planned sensitivity upgrades to the LIGO and Virgo facilities could uniquely identify host galaxies of dark sirens, compact binary coalescences without any electromagnetic counterparts, within a redshift of z = 0.1. This is aided by the higher-order spherical harmonic modes present in the gravitational-wave signal, which also improve distance estimation. In conjunction, sensitivity upgrades and higher modes will facilitate an accurate, independent measurement of the host galaxy's redshift in addition to the luminosity distance from the gravitational-wave observation to infer the Hubble-Lemaître constant to better than a few percent in five years. A possible Voyager upgrade or third-generation facilities would further solidify the role of dark sirens for precision cosmology in the future.