GR 12: Relativistic Astrophysics III / Gravitational waves III

Time: Thursday 13:45–15:15 Location: KH 01.016

GR 12.1 Thu 13:45 KH 01.016

The Thermal Index for Interacting Fermi Gases — •Timon Kleiber, Ishfaq Ahmad Rather, Selina Kunkel, Sarah Pitz, and Jürgen Schaffner-Bielich — Goethe Universität Frankfurt, Institut für Theoretische Physik

We analyze and compare the influence a simple repulsive interaction between particles has on a single component Fermi gas. Our focus is on the thermal part of the equation of state. This model can be used to calculate an EOS at nonvanishing temperature for pure neutron matter or fermionic dark matter. The coupling constant for the interactions uses the scale of strong interactions as a baseline. We additionally look at the effects of higher and lower coupling strengths with respect to the QCD baseline. A special focus is put on the isentropes within the area that is relevant for Proto-Neutron star evolution and or thermal evolution of fermonic dark matter. The inclusion of interactions leads to an increase in pressure compared to energy density along the isentropes and causes their ratio to reach values above the maximum limit without interactions.

GR 12.2 Thu 14:00 KH 01.016

Impact of in-situ nuclear networks and atomic opacities on neutron star merger ejecta dynamics, nucleosynthesis, and kilonovae — •Fabio Magistrelli — TPI, FSU Jena

Binary neutron star merger (BNSM) ejecta are key sites of rapid neutron-capture (r-process) nucleosynthesis and power kilonovae through the radioactive decay of freshly synthesized nuclei. I will present a systematic study of how nuclear burning, particle thermalization, and atomic opacity treatments impact the nucleosynthesis and electromagnetic emission from BNSM ejecta, starting from ejecta profiles extracted from ab-initio numerical-relativity simulations and evolved up to $\sim$ 30 days with radiation-hydrodynamics calculations with in-situ nuclear reaction networks (NN). I will compare simplified and composition-dependent thermalization schemes, as well as gray opacity models and frequency-dependent, atomic-physics-based opacities. Finally, I will discuss how NN coupling and detailed thermalization and opacity treatments significantly modify the temperature evolution of the ejecta, the structure of the r-process peaks, and the brightness and color evolution of the associated kilonova for realistic ejecta profiles.

GR 12.3 Thu 14:15 KH 01.016

Dynamo processes and jets from long-lived remnants from binary neutron star mergers — •Michael Mueller[1], Luciano Combi[2], and Daniel Siegel[1] — [1]University of Greifswald, Greifswald, Germany — [2]Perimeter Institute for Theoretical Physics, Waterloo, Canada

Identifying the mechanisms behind the generation of short gammaray bursts (GRBs) in compact object mergers, such as the one accompanying GW170817, is necessary to connect the observed GRB and merger populations. Current observations indicate that accreting neutron star remnants are a likely outcome for binary neutron star (BNS) mergers, and it is key to understand whether such systems can give rise to GRB emission. Dynamo processes and magnetic winding have been identified as critical components in producing the necessary large-scale coherent magnetic field to power the jet without a black hole central engine. We present new results from three-dimensional general-relativistic magnetohydrodynamic simulations of equal-mass binary neutron star mergers resulting in a long-lived hypermassive neutron star. The binary system is evolved without symmetry assumptions, employing a tabulated, composition-dependent, finite-temperature equation of state, a vector potential formalism for the magnetic field evolution, and approximate neutrino transport. We demonstrate that the magnetorotational instability is well resolved in the disk, and we study the dynamo action of the resulting turbulence in the disk and at the disk-star interface with new diagnostics to identify the processes involved in generating coherent field structures.

GR 12.4 Thu 14:30 KH 01.016

Fibre-based Phase Camera for the Einstein Telescope — •Stuti Sharma, Benjamin Schwab, Adrian Zink, and Stefan Funk for the Einstein Telescope-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander University

The Einstein Telescope (ET) is a planned third-generation underground gravitational wave observatory. The telescope requires precise monitoring of optical wavefront quality. Mode mismatches and wavefront aberrations in the sidebands used for interferometer control can lead to the excitation of higher order Gaussian modes (HOMs) which reduce detector performance. To address this, a fibre-based 56-pixel proof-of-concept phase camera has been developed. This camera is capable of simultaneously measuring the spatial amplitude and phase of multiple sidebands. Its multimode fibre array provides stable spatial phase relations between pixels at high frame rates. A dedicated digitisation setup is built via the CTC ASIC, that has been adopted from camera readout electronics for CTAO. Commissioning of such a setup at the ET Pathfinder demonstrated reliable visualisation of wavefronts and identification of HOMs.

Future work will build on enhancing the analysis of phase camera images to distinguish and classify higher order Gaussian modes. Therefore, an optical resonator capable of generating arbitrary, well-defined higher-order mode content will be added to the setup for future wavefront studies. The system will be scaled toward a 4096-pixel camera with FPGA based real-time demodulation. These developments aim to establish a robust and scalable wavefront sensing framework for ET.

GR 12.5 Thu 14:45 KH 01.016

Exploring Machine Learning Techniques for Gravitational-Wave Detection with Einstein Telescope — •Sebastian Wein, Alexander Kappes, and Waleed Esmail — Universität Münster, IKP, Wilhelm-Klemm-Str. 9, 48149

Einstein Telescope is a planned third-generation gravitational-wave observatory, that is expected to be more sensitive by at least one order of magnitude compared to current facilities such as LIGO/Virgo. With this increased sensitivity, challenges for signal detection arise due to longer signal duration and frequent signal overlap. Matched filtering, the current standard numerical signal detection algorithm, cannot be easily adapted to meet these challenges: neural networks might be a better fit instead. This talk describes the design of a machine-learning architecture for handling large inputs and detecting multiple, possibly overlapping signals.

GR 12.6 Thu 15:00 KH 01.016

RealTime Seismic Waveform Prediction Using Low-Latency Transformer-Based Models — •Kyrill Emanuel Blümer, Alexander Kappes, and Waleed Esmail for the Einstein Telescope-Collaboration — Institut für Kernphysik Uni Münster

The Einstein Telescope (ET) is a planned third-generation gravitational-wave detector, that will be built underground. It is designed to improve the detection sensitivity by up to an order of magnitude relative to existing detectors, especially at low frequencies. Because gravitational waves generates an extremely small strains, seismic and Newtonian noise becomes a limiting factor for the low-frequency sensitivity of the ET. Transformer-based deep learning models are well suited for learning long-range temporal and spatial dependencies in seismic waveform data and can provide accurate short-term forecasts of the 3D ground motion. However, for longer prediction horizons, waveform prediction quality degrades due to the error accumulation, when predictions are produced autoregressively. This talk will explore architectural and algorithmic improvements aimed at achieving stable, real-time, low-latency seismic waveform prediction.