GR 5: Relativistic Astrophysics I

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

GR 5.1 Tue 16:15 KH 01.016

Magnetic field instabilities and late-time equilibria in isolated neutron stars — •Aurora Capobianco — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743, Jena, Germany

The late-time equilibrium geometry of magnetic fields in neutron stars remains poorly constrained, despite its importance for observable signatures. We investigate the development and long-term evolution of strong magnetic fields in isolated neutron stars using the general relativistic magnetohydrodynamics (GRMHD) code AthenaK. Our simulations follow the full general-relativistic evolution of neutron stars with an external dipole-like field and a range of initial internal magnetic-field configurations. We focus on the symmetry properties, stability, and equilibrium structure of the resulting magnetic-field. In particular, we examine the onset and nonlinear evolution of magnetic-field instabilities and assess their role in redistributing magnetic energy. We also discuss the implications of these dynamics for the gravitational-wave emission produced.

GR 5.2 Tue 16:30 KH 01.016

Curvature invariants and trace anomaly in neutron stars — •Iván Garibay[1,2], Christian Ecker[1], and Luciano Rezzolla[1,3,4] — [1]Institut für Theoretische Physik, Goethe Universität, Max-von-Laue-Str. 1, 60438 Frankfurt am Main, Germany — [2]Instituto de Astronomía, Universidad Nacional Autónoma de México, Ciudad de México, CDMX 04510, Mexico — [3]School of Mathematics, Trinity College, Dublin 2, Ireland — [4]Frankfurt Institute for Advanced Studies, Ruth-Moufang-Str. 1, 60438 Frankfurt am Main, Germany

We investigate the behaviour of curvature invariants for a large ensemble of neutron stars built with equations of state (EOSs) that satisfy constraints from nuclear theory and perturbative QCD, as well as measurements of neutron-star masses, radii, and gravitational waves from binary neutron-star mergers. Surprisingly, our analysis reveals that stars with negative Ricci scalar $\mathcal{R}$ are rather common, and about $\sim 49\%$ of our EOSs produce one or more stars with Ricci curvature that is negative somewhere inside the star. Furthermore, this negative curvature is found mostly but not exclusively at the highest densities and pressures, and predominantly for stiff EOSs. Furthermore, using a well-known relation between the Ricci scalar and the trace anomaly, Δ, our analysis also allows us to determine the general conditions under which the conformal symmetry of matter is broken and restored in neutron stars. Finally, we determine a number of correlations among the different scalar invariants and map the ranges of their allowed values inside neutron stars.

GR 5.3 Tue 16:45 KH 01.016

Photon phenomenology in the accelerated Schwarzschild black hole — •Eva Hackmann[1] and Shokoufe Faraji[1,2,3,4] — [1]Center of Applied Space Technology and Microgravity (ZARM), University of Bremen — [2]Department of Physics and Astronomy, University of Waterloo — [3]Waterloo Centre for Astrophysics, University of Waterloo — [4]Perimeter Institute for Theoretical Physics

We analyse null geodesics in an accelerated Schwarzschild black hole sustained by a cosmic string and/or strut (C-metric) in the sub-extremal regime, and investigate if the acceleration and, in particular, the conicity parameter induced by the string/strut can be constrained from observations. For photons the conformal Hamilton-Jacobi equation separates, and we reduce the radial and polar motion to the Bierman-Weierstrass form, yielding new forms of closed analytic solutions. We show that the conicity parameter has no impact on the location of the fixed photon cone that replaces equatorial symmetry when the acceleration is nonzero, or on the single spherical photon surface shared by all latitudes. On the observational side, we prove that the shadow seen by any observer is an exact circle: its screen radius depends on the acceleration and observer distance but not on observer inclination or the conicity, so the local shadow cannot bound the string tension. We also show how a single shadow measurement with known mass-distance relation uniquely infers the dimensionless acceleration. Finally, we provide compact expressions for the photon circle orbital frequency and Lyapunov exponent and use them to obtain eikonal quasinormal estimates.

GR 5.4 Tue 17:00 KH 01.016

mw-atlas: Bayesian reconstruction of the magnetic field from synchrotron emission — •Richa Halder[1] and Philipp Mertsch[2] — [1]RWTH Aachen University — [2]RWTH Aachen University

This project aims to build a 3D map of the Galactic magnetic field of the Milky Way from synchrotron emission, using a fully Bayesian framework. The magnetic field shapes cosmic-ray propagation, regulates interstellar gas and star formation, and distorts the signals used in precision cosmology, so its 3D structure must be known to interpret many astrophysical observations correctly. We use NIFTy, a variational inference framework, to infer the magnetic field from synchrotron data for a given distribution of cosmic-ray electrons. This provides full posterior distributions instead of single best-fit parameter sets, so uncertainties are explicitly quantified and can be propagated into other, derived quantities. Compared to previous reconstructions based on low-dimensional parametric GMF models fitted to integrated observables, our approach allows far more flexible field geometries, reduces bias from mis-specified parametric forms, and will be tested both on realistic simulations and future observational datasets.

GR 5.5 Tue 17:15 KH 01.016

Post-Newtonian N-Body Simulations — •Felix Heinze, Gerhard Schäfer, and Bernd Brügmann — Friedrich-Schiller-Universität Jena, Theoretisch-Physikalisches Institut, Fröbelstieg 1, 07743 Jena

The post-Newtonian formalism is a central tool for constructing approximate solutions of Einsteins field equations in the weak-field, slow-motion regime, in particular for gravitational systems of multiple point masses. This talk gives an overview of the current status of post-Newtonian N-body simulations and focuses on recent developments in the derivation of the N-body Hamiltonian at second post-Newtonian order, as well as on the numerical integration of the resulting equations of motion.