Gravitational waves – Projects list

Sebastiano Bernuzzi, Matteo Breschi

Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena

Here we collect a list of projects for the GW class. The student can present one of the following projects at the final exam. However, we encourage students to come up with their own projects and ideas.

- **The Hulse-Taylor binary pulsar**: theory on eccentric binaries in linearized GR; computation of observational delays in radio pulsars; comparison with observational data of period decay.
- **Binary waveform at 1PN**: analytical computation of the next-to-leading order phase contribution for quasi-circular binaries in post-Newtonian formalism; time-domain and frequency-domain waveform.
- **The effective-one-body formalism**: Hamiltonian formulation of the quasi-circular two-body problem; conservative dynamics and inclusion of radiation reaction; spinning and tidal contributions.
- **Infalling particle in perturbation theory**: analytical studies of infalling point-particle in Schwarzschild black hole; radiated waveform and comparison with Newtonian estimates; generalization to finite-size particle and Kerr metric.
- **Quasi-normal modes of black holes**: Analytical studies of perturbed black holes and the Regge-Wheeler-Zerilli equations; numerical computation of quasi-normal modes with Pöschl-Teller potential.
- **Extreme mass ratio inspirals**: theory of supermassive black holes; formation and evolution of binaries; extreme mass ratio inspirals with self-force approach; radiated waveform and energy spectrum.
- **Quantum noise in GW detectors**: theoretical studies on noise sources in current ground-based interferometers; focus on quantum noise contributions, i.e. shot noise and radiation pressure; squeezing techniques.
- **Markov-chain Monte Carlo methods**: development of adaptive Metropolis-Hastings MCMC algorithm for the analysis of mock GW data; gravitational-wave likelihood and application to quasi-circular binaries.

- **Testing general relativity with GW150914**: studies on signal processing and Bayesian inference; parameter estimation of LIGO-Virgo data of GW150914; tests of general relativity, i.e. consistency tests and parameterized tests.
- **Cosmological evolution of tensor perturbations**: FLRW metric and formalism; the evolution of tensor perturbations and current constraints from GW observations; inflation and primordial perturbations.