The Dynamics of Asymmetric Binaries

Gran Sasso Science Institute — A.Y. 2025–26
Total: 12 hours

<u>Course description</u>
The course introduces the dynamics and gravitational-wave modelling of asymmetric compact binaries, with particular emphasis on extreme mass-ratio inspirals (EMRIs). Starting from the basic properties and astrophysical formation channels of EMRIs, the course develops the perturbative framework required for their accurate description and provides an introduction to gravitational self-force theory, black-hole perturbation theory, and the Regge–Wheeler–Zerilli formalism for perturbations of Schwarzschild black holes.

Topics

1. Extreme mass-ratio inspirals
    - Properties of asymmetric compact binaries and EMRIs
    - Comparison with sources observed by current gravitational-wave detectors
    - Newtonian perspective on the self-force
    - Dry and wet EMRI formation mechanisms
2. Modelling and perturbative framework
    - Accuracy requirements for EMRI waveform modelling
    - Limitations of the post-Newtonian expansion
    - Black-hole perturbation theory
    - Point-particle sources at second perturbative order
    - Multipolar expansion of the gravitational field
    - Matched asymptotic expansions
    - Phase accuracy of EMRI models
3. Self-force dynamics
    - Structure of the equations of motion
    - Conservative and dissipative contributions
    - Gravitational self-force
    - Balance laws
4. Perturbations of Schwarzschild black holes
    - Linear-order perturbation theory
    - Axial and polar perturbations
    - Tensor-harmonic decomposition of the metric perturbation
    - Regge–Wheeler equation
    - Point-particle source for circular orbits
    - Zerilli equation and polar perturbations
5. Waveforms and fluxes
    - Solutions of the Regge–Wheeler and Zerilli equations
    - Gravitational waveforms
    - Energy fluxes
    - Angular-momentum fluxes
    - Circular-orbit EMRIs

References

1. L. Barack and A. Pound, Self-force and radiation reaction in general relativity, arXiv:1805.10385.
2. E. Poisson, The gravitational self-force, arXiv:gr-qc/0410127.
3. S. A. Hughes, Adiabatic and post-adiabatic approaches to extreme mass ratio inspiral, arXiv:1601.02042.
4. M. Maggiore, Gravitational Waves, Vol. 2.