PHYS 879 – Special Topics in General-Relativity: Gravitational-Wave Physics

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Instructor: Alessandra Buonanno
Time: Spring 2013 semester, TuTh 9:30am-10:45am
Place: PHY 4102
Office hours: after classes or by appointment
TA: TBD
Texts: articles available online and the book by M. Maggiore, "Gravitational Waves Volume 1: Theory and Experiments".
Grading: homework problems, final project.

The last few years have been marked by the construction and the first scientific runs of long-baseline ground-based interferometers, such as LIGO and Virgo, aimed at detecting gravitational waves and using them to study astrophysical and cosmological systems. New upper limits on event rates for various classes of astrophysical and cosmological sources have already been obtained. Within the next 3-5 years those detectors will be upgraded to a sensitivity such that event rates for coalescing binary systems composed of neutron starts and/or black holes will increase by a factor of one thousand, thus making very likely the first detection and establishing the field of gravitational-wave astronomy.

The course will start with a brief overview of gravitational-wave physics. Motivations and goals of gravitational-wave research will be outlined and order of magnitude estimates of potential astrophysical and cosmological sources will be discussed. The course will be roughly composed of three topics, although those topics will be discussed in an intertwined manner.

1. **Description, generation and properties of gravitational waves:** Einstein equations for weak gravitational fields; plane-wave solution; interaction of gravitational-wave with free-falling test particles; propagation of gravitational waves in curved spacetime; generation of gravitational-waves; energy and angular-momentum carried off; systematic multipolar expansion; basics of post-Newtonian formalism and of numerical relativity; gravitational radiation from (i) inspiralling two-body systems, (ii) merging binary systems composed of neutron stars and/or black holes, (iii) rotating rigid bodies and (iv) accelerated masses.

2. **Gravitational-wave sources:** Compact binaries composed of neutron-star and/ or black holes; pulsars; low-mass X-ray binaries; supernovae; supermassive black holes; cosmological signals produced during the very early Universe (from inflation, phase transitions, cosmic strings).

3. **Data analysis and gravitational-wave detectors:** Basic techniques and algorithms used in current ground-based interferometer data-analysis to detect astrophysical and cosmological sources; key ideas underlying the functioning of gravitational-wave detectors, such as LIGO and Virgo; discussion of the main sources of noise (quantum-optical noise, thermal noise, seismic noise, etc.).

To follow the classes, students should have already mastered the material covered in an introductory general relativity course. By contrast it is not necessary to have followed a course in astrophysics and/or cosmology.