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

<u>Instructor</u>: Alessandra Buonanno
<u>Time</u>: Spring 2006 semester, TuTh 9:30am-10:45am
<u>Place</u>: PHY 4208
<u>Office hours</u>: Fr 1:00pm-2:30pm
<u>Texts</u>: articles available online and some chapters in L.D. Landau and E.M. Lifshitz, "Field theory"; B. Schutz, " A first course in general relativity"; S. Weinberg, "Gravitation and Cosmology"; C. Misner, K.S. Thorne and J.A. Wheeler, "Gravitation"; P. Saulson, "Fundamentals of interferometric gravitational wave detectors".
<u>Coursework</u>: lectures, homework problems, students projects.

The last few years have been marked by the construction and the first scientific runs of long-baseline ground-based interferometers, such as LIGO, aimed at detecting gravitational waves and using them to study astrophysical systems. New upper limits on event rates for various classes of astrophysical sources have already been obtained. A laser-interferometer space antenna (LISA) is also planned by the European Space Agency and NASA.

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; gravitational radiation from (i) inspiralling two-body systems, (ii) rotating rigid bodies and (iii) 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 LISA; 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, e.g., PHY-675. By contrast it is not necessary to have followed a course in astrophysics and/or cosmology.