NPAC Noyaux Particules Astroparticules Cosmologie

Master 2 Recherche

Course Title : **General Relativity**

Number of hours/semester : 30 h, 1st Semester

Number of ECTS : 3

Lecture outline, contents : This course begins with a very brief overview of general relativity, and its link to special relativity. In particular, we discuss the role of inertial and gravitational mass, the equivalence principle, and introduce the idea of understanding gravity as a manifestation of the geometry and curvature of space-time. After this, the course continues with a review of the salient features of Special Relativity, both in standard Minkowski coordinates, and also in curvilinear coordinates. We then discuss geodesic motion in curvilinear coordinates. This naturally introduces the concept of a metric. The next section introduces general covariance, vectors and tensors, as well as the covariant derivative and the Riemann tensor. We also discuss geodesic motion in an arbitrary space-time together with the geodesic deviation equation. This is followed by the introduction of Einsteins equations, and spherically symmetric space-time solutions are derived (Birkhoff theorem), leading on to a discussion of symmetries in GR and the Lie Derivative. We then derive the trajectories of particles around a massive body, and hence to tests of GR in the solar system. The next section is dedicated to Black Holes of different kinds and in different sets of coordinate systems. After a brief chapter on stars and gravitational collapse, we turn to gravitational waves (GWs). After linearizing the Einstein Equations, we obtain the wave equation, and discuss the polarization and number of degrees of freedom carried by GWs, as well as their interactions with a GW detector. The last part of the course focuses on the calculation of the GW signal from binary black holes and neutron stars. We also derive the quadrupole formula for the rate of energy loss. Finally, we compare the theoretical calculation to the data from LIGO-Virgo. The last lecture introduces the cosmology that can be done with GWs, such as the measurement of the Hubble constant.

Pedagogical methods : Lectures and Tutorials

Prerequisites : Special relativity

Modalities of knowledge assessment : Written examination at the end of the semester for the first session and Oral examination for second session (for the second session, the maximum grade is limited to 10)

Bibliography :

1. “Relativité Générale”, D.Langlois, cours de Polytechnique, 2013, (Editions Vuibert)
2. “Spacetime and geometry”, S.Carroll, 2014 (Pearson publishers)
3. Gravitation and Cosmology: Principles and applications of the general theory of relativity”, S.Weinberg,1972, (Wiley)