Gravitational Waves seminar series, Fall 2016:
Physical and mathematical aspects behind the Advanced LIGO detections

Institut de Mathématiques de Bourgogne (IMB) and Laboratoire Interdisciplinaire Carnot de Bourgogne (ICB)
Dijon, France

This series of seminars will review some of the mathematical and physical aspects relevant in the scientific setting of the gravitational wave detection by the Advanced LIGO gravitational antennae. The goal is to provide a broad, though sound, perspective on the different elements needed to understand the nature and implications of this detection. More specifically, this series aims at presenting a discussion of the two main General Relativity phenomena involved in the detection: **gravitational wave radiation** and (binary) **black holes**. This series is understood as a first one inside a more extended program of seminars that will cover the different mathematical, physical and observational aspects relevant in the emerging gravitational wave science.

The seminars in this initial series are (see abstracts in the next page):

- October 20, **Badri Krishnan** (Albert-Einstein-Institut, Hannover, Germany)
"The observation of two binary black hole coalescence events by Advanced LIGO"
(16h30, room René Baire, bât. Mirande-mathématiques)

- November 16, **Alexandre Le Tiec** (Observatoire de Paris, Meudon, France)
"General relativistic dynamics of binary black holes"
(16h15, room D116, bât. Mirande-physique)

- November 30, **Carlos F. Sopuerta** (ICE-CSIC, Barcelona, Spain)
"LISA Pathfinder and the future of Gravitational Wave Astronomy from Space"
(16h15, room A318, bât. Mirande-mathématiques)

- December 15, **Joerg Frauendiener** (University of Otago, Dunedin, New Zealand)
"Mathematical aspects of isolated self-gravitating objects in General Relativity"
(16h30, room René Baire, bât. Mirande-mathématiques)

This series of seminars is organized jointly by the IMB and the ICB, in the understanding that this scientific event offers a rich and potentially fruitful opportunity for the interaction between our mathematics and physics communities.

Abstracts

- **Badri Krishnan,** "The observation of two binary black hole coalescence events by Advanced LIGO"
Abstract :
The advanced LIGO gravitational wave detectors have observed two binary black hole coalescence events with high significance: GW150914 on September 14, 2015 and GW151226 on December 26, 2015. These detections enable us, for the first time, to probe the properties of black holes in full non-linear general relativity. In this talk I will summarize these events and other results from the first observational run of the Advanced LIGO detectors. In particular, I will discuss the statistical significance of the events, the data analysis methods applied in the detection, the properties of the systems, and some implications for fundamental Physics.

- **Alexandre Le Tiec,** "General relativistic dynamics of binary black holes"
Abstract:
The celebration of general relativity's centennial also marked the first-ever observation, by the two ground-based Advanced LIGO interferometers, of gravitational waves emitted during the coalescence of two stellar-mass black holes. This was the first direct detection of gravitational waves, but also the first direct evidence for the existence of black holes. This discovery was made possible not only by the exquisite sensitivity of the detectors, but also by an accurate modelling of the orbital dynamics and gravitational-wave emission of black hole binaries. These can be investigated using a variety of approximation schemes and numerical methods in general relativity: the post-Newtonian formalism, black hole perturbation theory, numerical relativity simulations, and the effective one-body model. I will give an introductory overview of each of these analytical and numerical techniques, emphasizing the various interplay between them.

- **Carlos F. Sopuerta,** "LISA Pathfinder and the future of Gravitational Wave Astronomy from Space"
Abstract:
On February 11th, 2016 we witnessed the annoucement of the first direct detection of gravitational waves by the US Laser Interferometer Gravitational-Wave Observatory (LIGO). This remarkable event marks the beginning of a new area of Astronomy: Gravitational Wave Astronomy. Moreover, the first detection has shown very clearly the great potential of this new form of Astronomy. Indeed, apart from being the first detection, it is also the first time we have observational evidence of a binary black hole and of stellar-mass black holes with more than 30 times the mass of the Sun.
In parallel, the LISA Pathfinder mission of the European Space Agency was launched on December 3rd, 2015 to demonstrate the readiness of the main technology for the future space-based gravitational-wave observatory, the ESA-L3 mission. On June 7th, 2016, the first results of the LISA Pathfinder mission were announced, showing that the performance achieved is much better than the initial requirements.
In this talk I will describe the LISA Pathfinder mission and results and the prospects for Gravitational Wave Astronomy from Space with the future ESA-L3mission. I will put these results in the context of the LIGO detections and other developments, in particular the possible detection of very-low frequency gravitational waves by Pulsar Timing Arrays.

- **Joerg Frauendiener,** "Mathematical aspects of isolated self-gravitating objects in General Relativity"
Abstract:
The phenomenon of gravitational waves goes back a century and it has a somewhat convoluted history. It took about 50 years to clarify the conceptual issues and another 50 years until the first detection was made. This talk will touch upon the historic development and then describe some of the fundamental issues involved in the description of gravitational waves and how they are resolved using geometric methods.