M2 Internship proposal

Title:
Study of scattered light in the Advanced Virgo+ gravitational wave detector.

Internship supervisor

Name of supervisor	Romain Gouaty	**Experiment**	Virgo
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Subject / activities

Summary of the work required:

The Virgo gravitational wave detector, installed in Pisa, works on the principle of a laser interferometer with 3 km long arms. In August 2017, the first joint observation of gravitational waves, detected by the LIGO and Virgo detectors, from the coalescence of a binary neutron stars system, and a gamma-ray burst, followed by the observation of an optical signal, opened a whole new chapter in multi-messenger astronomy. A period of joint observation of LIGO (in the United States) and Virgo detectors followed from April 2019 to March 2020, allowing the weekly detection of coalescence of compact binary systems (notably black holes). Since May 2020, the Virgo detector has entered a phase of modifications and improvements (upgrade Advanced Virgo +) with the goal of starting a new observation period in 2022.

Several optical benches, suspended and placed under vacuum, are used to extract the laser beam in different locations (at the output of the interferometer, but also in the transmission of the kilometer arms, for example). These benches host optical elements and light sensors (photodiodes, quadrant photodiodes, cameras, etc.) which have the role of extracting the signals used for the detection of gravitational waves and for the control of the position of the interferometer mirrors. These elements can diffuse part of the incident light or generate parasitic reflections. This unwelcome light can recombine with the main beam, and by interference generate variations in the laser power measured on the main photodiodes, variations which are interpreted as the passage of a gravitational wave. In addition, this scattered light also couples by modulating the radiation pressure of the laser beam on the interferometer mirrors, generating a real variation in differential length and therefore variations in laser power on the main photodiodes. By these various couplings, this scattered light therefore limits the sensitivity of the detector. In the context of the Advanced Vigo + upgrade, a review of the optical benches is undertaken in order to identify mitigation actions to reduce the scattered light and thus improve the sensitivity of the detector.

LAPP offers a Master 2 internship in order to participate in the characterization of the light scattered on the suspended optical benches of the Virgo interferometer. To this purpose, the student will identify the possible sources of light diffused on these optical benches and simulate the propagation of stray light. This work should lead to the definition of specifications for the development of diaphragms or light traps to absorb stray light. In addition, the Virgo group at LAPP is developing an experiment to quantitatively measure light back-scattered by various optical elements. This experiment will use a simple Michelson interferometer, with a suspended diffusing element at the end of one of the arms. The student will participate in the sizing of this test bench and in estimating the needs in terms of seismic and acoustic insulation in order to bring this experiment to the sensitivity needed to characterize the light scattered in the Virgo detector.

Optional information on a possible PhD subject:

This internship can lead to a PhD subject encompassing the problem of scattered light in the detection system, the study of its effect on the Virgo sensitivity and, more generally, the study and improvement of the sensitivity of the Virgo detector during the next data-taking run which will start in 2022.

Members of the team	R. Bonnand, D. Buskulic, R. Flaminio, R. Gouaty, F. Marion, T. Regimbau, L. Rolland, E. Tournefier, D. Verkindt, M. Was