Campagne 2020 Contrats Doctoraux Instituts/Initiatives

Proposition de Projet de Recherche Doctoral (PRD)

Appel à projet IPhyInf - Initiative Physique des infinis 2020

Intitulé du Projet de Recherche Doctoral : Gravitational waves in alternative theories of gravity

Directeur de Thèse porteur du projet (titulaire d'une HDR) :

NOM : **BLANCHET** Prénom : **Luc**
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Unité de Recherche :
Intitulé : Institut d'Astrophysiaue de Paris
Code *(ex. UMR xxxx)* : UMR 7095

Ecole Doctorale de rattachement de l'équipe & d'inscription du doctorant : ED564-Physique en IdF

Doctorants actuellement encadrés par le directeur de thèse (préciser le nombre de doctorants, leur année de 1ere inscription et la quotité d'encadrement) : 2 doctorants, 2018 & 2018, 70% et 60%, François Larrouturou & Quentin Henry

Co-encadrant :

NOM : **BERNARD** Prénom : **Laura**
Titre : Chargé de Recherche ou HDR ☐
e-mail : laura.bernard@obspm.fr

Unité de Recherche :
Intitulé : Laboratoire Univers et Théories
Code *(ex. UMR xxxx)* : UMR 8102

Ecole Doctorale de rattachement : ED564-Physique en IdF
Ou si ED non Alliance SU :

Doctorants actuellement encadrés par le co-directeur de thèse (préciser le nombre de doctorants, leur année de 1ere inscription et la quotité d'encadrement) : 0

Cotutelle internationale : ☒ Non ☐ Oui, précisez Pays et Université :

Description du projet de recherche doctoral *(en français ou en anglais)*

3 pages maximum – interligne simple – Ce texte sera diffusé en ligne

Détailler le contexte, l'objectif scientifique, la justification de l'approche scientifique ainsi que l'adéquation à l'initiative/l'Institut.
Le cas échéant, préciser le rôle de chaque encadrant ainsi que les compétences scientifiques apportées. Indiquer les publications/productions des encadrants en lien avec le projet.
Préciser le profil d'étudiant(e) recherché.

Since the firsrt gravitational wave (GW) detection in 2015 by the LIGO-Virgo collaboration, GW astronomy has now entered an era of high precision. The LIGO and Virgo detectors in their third run are now detecting binary black hole mergers at a rate of one per week and have already detected several binary neutron star and black hole - neutron star mergers. The next generation of detectors, such as the Einstein Telescope in Europe and the space-based interferometer LISA, will detect even more events, from different sources, and with a higher signal to noise ratio. These detections, coupled with black hole observations from the Gravity experiment and the event horizon telescope will allow one to test our theory of gravity and fundamental physics with an unprecedented precision. With these new observational windows, we could test the adequacy of general relativity (GR) to describe the strong-field regime of gravity; new fundamental fields beyond the standard model, or new kinds of compact objects, could challenge our understanding of dark matter (DM) and dark energy, or matter in extreme density regime.

However, such detections strongly rely on our capability to have a bank of precise waveform templates to be matched-filtered against the data. Currently, we only have full waveform templates for general relativity, and tests of gravity are done by parametrising phenomenological deviations from these GR waveforms. In order to be able to perform complete and precise tests of gravity, we should model all possible new effects that could arise in modified theories of gravity. This can only be done by having full waveform models for particular alternative theories of gravity.

This thesis proposal consists in deriving specific waveform models in alternative theories of gravity using perturbative techniques such as the post-Newtonian formalism. Such perturbative methods are the only one that allow to describe the tens of thousands of cycles during the inspiral phase of the coalescence. The full waveform is then obtained by incorporating numerical results describing the merger. Our goal is to have an alternative bank of templates to be used by the GW detectors in order to test gravity in the strong-field regime with high precision. Such a proposal falls particularly well in the initiative "Physique des deux Infinis" as GWs are perfect laboratories to tests strong-field effects and fundamental physics in alternative theories of gravity. Such theories are motivated either in cosmology to challenge the cosmological constant problem (e.g. scalar-tensor theories), or at high energy as candidates for a quantum theory of gravity (e.g. Lorentz-violating theories).

The use of the post-Newtonian formalism is particularly well-suited to describe the inspiral part of the coalescence as it applies to slow motion and weak gravitational fields. It has been very successful in GR to obtain the waveform templates currently used to analyse the GW data from the signal. Our goal is to adapt it to the specificities of some alternative theories of gravity such as scalar-tensor theories. During the first part of the thesis, we will focus on scalar-tensor theories and we will compute the gravitational flux and the scalar and gravitational waveforms at the third post-Newtonian order beyond the leading dipolar emission. In the second part of the thesis, we shall extend the previous results to other modified theories of gravity, trying to build an effective way to construct waveform models in alternative theories of gravity.

The thesis will be directed by Luc Blanchet and Laura Bernard, who have complementary skills for this project. Luc Blanchet has been developping the post-Newtonian formalism for almost fourty years and is a world-leading expert in the field

[1]. Laura Bernard has a very good knowledge of alternative theories, and especially of scalar-tensor theories, to which she has recently applied the post-Newtonian formalism to obtain the dynamics of compact binaries at the third post-Newtonian order [2,3].

The PhD student will have to have a master degree in theoretical physics or astrophysics, with a very good knowledge in mathematics and theoretical physics.

References:

[1] L. Blanchet, Living Rev. Relativ. 17, 2 (2014).
[2] L. Bernard, Phys. Rev. D 98, 044004 (2018).
[3] L. Bernard, Phys. Rev. D 99, 044047 (2019).

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à envoyer simultanément par e-mail à l'ED de rattachement et au programme :
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