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Marius Oltean
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Study of the Relativistic Dynamics of Extreme-Mass-Ratio Inspirals

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MEMBRES DU JURY :

- **Emparan García de Salazar, Roberto - Professor d'Investigació ICREA (Institució Catalana de Recerca i Estudis Avançats), Universitat de Barcelona (Espagne)**
- **Pujolàs, Oriol - Investigador Titular a IFAE (Institut de Física d'Altes Energies), Universitat Autònoma de Barcelona (Espagne)**
- **Barack, Leor - Professor of Theoretical Physics, University of Southampton (Royaume-Uni)**
- **Husa, Sascha - Profesor Contratado Doctor, Universitat de les Illes Balears (Espagne)**
- **Román-Roy, Narciso - Catedràtic d'Universitat de Matemàtica Aplicada, Universitat Politècnica de Catalunya (Espagne)**

RÉSUMÉ

The principal subject of this thesis is the gravitational two-body problem in the extreme-mass-ratio regime - that is, where one mass is significantly smaller than the other - in the full context of our contemporary theory of gravity, general relativity. Accordingly, we begin with a general overview of this theory, offering first a historical introduction and current motivation from gravitational wave astronomy (in Chapter 1), then a detailed technical exposition of the theory focusing on its canonical (Hamiltonian) formulation (in Chapter 2), as well as a rigorous development of perturbation methods (in Chapter 3). Then, we proceed to present our novel work in these areas. First (in Chapter 4), we study entropy theorems in classical Hamiltonian systems, and in particular, the issue of the second law of thermodynamics in classical mechanics and general relativity, with a focus on the gravitational two-body problem. Then (in Chapter 5), we develop a general approach based on conservation laws for calculating the correction to the motion of a sufficiently small object due to gravitational perturbations in general relativity. When the perturbations are attributed to the small object itself, this effect is known as the gravitational self-force. It is what drives the orbital evolution of extreme-mass-ratio inspirals: compact binary systems where one mass is much smaller than - thus effectively orbiting and eventually spiralling into - the other, expected to be among the main sources for the next generation of space-based gravitational wave detectors. Finally (in Chapter 6), we present some work on the numerical computation of the scalar self-force - a helpful testbed for the gravitational case - for circular orbits in the frequency domain, using a method for tackling distributional sources in the field equations called the Particle-without-Particle method. We incluse also, in an appendix, some work on the generalization of this method to general partial differential equations with distributional sources, including also applications to other areas of applied mathematics.

Laboratoire de Physique et Chimie de l'Environnement et de l'Espace (LPC2E, CNRS)
Institut de Ciències de l'Espai (ICE, CSIC)
Institut d'Estudis Espacials de Catalunya (IEEC)