School of Mathematical Sciences

Project title: The two-body problem in numerical and perturbative general relativity

Supervisor: Dr. Charalampos Markakis

The School of Mathematical Sciences of Queen Mary University of London invite applications for a PhD project commencing either in September 2019 for students seeking funding, or at any point in the academic year for self-funded students. The deadline for funded applications is 31 January 2019.

This project will be supervised by Dr Charalampos Markakis. Students can express interest in either one of the following projects, which involve modelling astrophysical sources for LIGO and LISA respectively.

1) Numerical relativity is a rapidly developing field. The development of black-hole simulations has been revolutionary, and their predictions were recently confirmed with the detection of gravitational waves by LIGO. The next expected source, neutron-star binaries, was detected very recently, but their simulation is more complicated, as one needs to model relativistic fluids in curved spacetime, and the behaviour of matter under the extreme conditions found in neutron-star cores. In this project, one will use methods familiar from classical (Lagrangian or Hamiltonian) mechanics, to model fluids. One finds that a seemingly complex hydrodynamic problem can be reduced to solving a non-linear scalar wave equation. This powerful approach allows one to accurately model oscillating stars or radiating binaries, some of the most promising sources expected to be observed in the next LIGO science runs.

2) Moreover, a principal goal of the planned space-based LISA detector is to observe the inspiral of stellar-size black holes orbiting supermassive black holes. Detection and parameter estimation require accurate waveforms associated with generic orbits, that are most efficiently computed within a perturbative expansion. The prospective students will join the LISA Consortium and participate in source modelling. The focus will be on the development of novel collocation methods for numerically evolving PDEs with time-domain gravitational self-force computation in a radiation gauge to construct high-precision gravitational waveforms.

The proposed research is aimed at mathematically and computationally exploring the theory of neutron stars and black holes, in order to improve our understanding of fundamental physical laws and reveal how nature operates on scales where our current understanding breaks down.

Student background: The successful applicants will be able to solve such wave equations numerically in their favourite programming or scripting language (C, Python, Mathematica, etc). A background in classical mechanics and numerical methods is useful. Familiarity with fluid dynamics or scalar fields is helpful, but training will be provided.

The application procedure is described on the School website. For further inquiries please contact Dr Charalampos Markakis at c.markakis@qmul.ac.uk. This project is eligible for full funding, including support for 3.5 years’ study, additional funds for conference and research visits and funding for relevant IT needs. Applicants interested in the full funding will have to participate in a highly competitive selection process.
**Funding notes:** This project can be also undertaken as a self-funded project, either through your own funds or through a body external to Queen Mary University of London. Self-funded applications are accepted year-round.

The School of Mathematical Sciences is committed to the equality of opportunities and to advancing women’s careers. As holders of a Bronze Athena SWAN award we offer family friendly benefits and support part-time study. Further information is available here. We strongly encourage applications from women as they are underrepresented within the School.

We particularly welcome applicants through the China Scholarship Council Scheme.

**References:**

C. Markakis et al., Conservation laws and evolution schemes in geodesic, hydrodynamic and magnetohydrodynamic flows  

C. Markakis, Hamiltonian Hydrodynamics and Irrotational Binary Inspiral  

C. Markakis and L. Barack, High-order difference and pseudospectral methods for discontinuous problems  

C. Markakis, Constants of motion in stationary axisymmetric gravitational fields  