GRACE-BH - Gravitational waves from crowded environments: simulating intermediate-mass black hole formation and evolution with supercomputers.

The discovery of gravitational waves (GWs) marks the dawn of a new era for astronomy. On 2019 May 21, the gravitational-wave (GW) detectors LIGO and Virgo observed the coalescence of a massive binary black hole: the merger remnant of GW190521 is the first intermediate-mass black hole (IMBH) observed through GWs. This opens new perspectives for the study of IMBHs, bridging the gap between stellar-mass and supermassive black holes. The interpretation of current and future observations requires a theoretical framework capable of modelling both the formation of IMBHs and their co-evolution with the host star clusters. Numerical simulations offer a unique tool to model IMBHs from the seeding phase to their full growth. However, the existing literature misses a thorough study that fully explores the parameter space and captures the complex physics behind IMBHs.
Including these aspects represents a fundamental step to bridge stellar dynamics and GW astronomy. The GRACE-BH project aims at building such a bridge providing a solution to one of the challenging questions of modern astrophysics:

What are the best conditions favouring the formation of IMBHs in star clusters?

To address this open question, I will combine forefront numerical simulations and semi-analytic techniques to probe the
parameter space, focusing on the role of stellar multiplicity and primordial mass segregation in star clusters. I will model the complex physics associated with IMBH formation, investigating the impact of dynamical interactions, runaway collisions, pair-instability and relativistic kicks on IMBH formation. The exploitation of these models will enable us to describe the survival and growth of IMBH seeds in different environments, shedding a light on the conditions that favour IMBH formation in star clusters. This will allow us to dissect the demography of GW sources powered by IMBHs and to make predictions for next-generation ground-based and spaceborne GW detectors like LISA.

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