High Precision Black Hole Astronomy Through the Lens of Gaia

Black holes are among the most mysterious objects in the Universe. Stellar-mass black holes are formed from the deaths of the most massive stars in the Galaxy, sometimes via energetic supernovae. An unknown fraction of black holes in the Galaxy are born in binary star systems. The population and evolution of these binaries has been studied in theoretical models and simulations. However, probing them observationally is particularly challenging. While identifying black holes in tight interacting binaries (in which the black hole accretes from the companion star) is generally feasible (through the signatures of energetic flow of matter interacting with the black hole), it is very difficult to identify and study them in non-interacting or weakly-interacting binaries (where the binary appears a single star in observations and the black hole is hidden with little or no electromagnetic signature). It is thought that many black holes may lurk undetected in such binaries.

Research Field
Astronomy, black holes

Project Suitability
PhD

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Over the last few years, a handful of such “hidden” black holes in binaries have been discovered in new large observational surveys. This implies that many more such systems may be found with new high-precision astrometric surveys such as the one currently being conducted by ESA’s Gaia observatory, which will improve our understanding of the black hole population of our Galaxy.

In this project, we aim to study dynamical properties of black holes, using both new and ongoing large observational surveys of the sky, and more targeted observing programs. Particularly, we will use the ongoing Gaia survey (which has provided precise measurement of distance and motion for more than 1.2 billion stars for the first time, with more measurements underway; see Figure), and obtain new observations (e.g., using radio very long baseline interferometry) to achieve a deep observational characterization of black hole kinematics. Particularly, we will:

1- Develop tools and data models to mine and explore Gaia’s upcoming massive datasets to search for hidden black hole candidates and study known black holes in the light of new data.
2- Perform and analyze new observations (e.g., precise radio astrometry) to study new and known black holes and characterize their properties (like distance and mass).
3- Constrain the population of hidden black holes (in binaries) in our Galaxy, which will greatly influence our understanding of stellar evolution and black hole formation.

Left: Artist’s impression of a binary stellar system in which a black hole has trapped another star and feeds off the material from the star. **Right**: Top view of our Galaxy with distribution of stars for which the Gaia survey has so far estimated distance and proper motion.