Contribution ID: **9** Type: **Talk**

Eccentric Mergers in AGN Discs: Influence of the Supermassive Black-Hole on Three-body Interactions

Friday, 23 August 2024 11:05 (20 minutes)

There are indications that stellar-origin black holes (BHs) are efficiently paired up in binary black holes (BBHs) in Active Galactic Nuclei (AGN) disc environments, which can undergo interactions with single BHs in the disc. Such binary-single interactions can potentially lead to an exceptionally high fraction of gravitational-wave mergers with measurable eccentricity in LIGO/Virgo/KAGRA. We take the next important step in this line of studies, by performing post-Newtonian N-body simulations between migrating BBHs and single BHs set in an AGN disc-like configuration with a consistent inclusion of the central supermassive black hole (SMBH) in the equations of motion. With this setup, we study how the fraction of eccentric mergers varies in terms of the initial size of the BBH semi-major axis relative to the Hill sphere, as well as how it depends on the angle between the BBH and the incoming single BH. We find that the fraction of eccentric mergers is still relatively large, even when the interactions are notably influenced by the gravitational field of the nearby SMBH. However, the fraction as a
function of the BBH semi-major axis does not follow a smooth functional shape, but instead shows strongly varying features that originate from the underlying phase-space structure. The phase-space further reveals that many of the eccentric mergers are formed through prompt scatterings. Finally, we present the first analytical solution to how the presence of an SMBH in terms of its Hill sphere affects the probability for forming eccentric BBH mergers through chaotic three-body interactions.
We present the main results from https://arxiv.org/abs/2402.16948

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Session Classification: Chris Belczynski memorial session on compact objects and gravitational wave sources

Track Classification: Chris Belczynski memorial session on compact objects and gravitational wave source