Massive Stars Near and Far
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Hunting for massive binaries with a black-hole component using Gaia data

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Abstract. With the upcoming third Gaia data release (DR3), the first Gaia astrometric orbital solutions for binary sources will become available. Potentially, many rarely seen single-degenerate massive binaries with a black hole (OB+BH) will be revealed. Here, we investigate how many OB+BHs are expected to be detected as binaries in Gaia astrometry by using tailored models for the massive star population. We use a method based on the astrometric data to investigate how many OB+BH binaries will be uncovered by Gaia. We estimate that ∼200 OB+BHs are detectable among the sources in the second Alma Luminous Star massive star catalogue, either in DR3 or in upcoming data releases. Moreover, we show that BH-formation scenarios could be constrained from the distributions of parameters such as the orbital periods and eccentricities.

Keywords. black hole physics, binaries:general, astrometry, stars:statistics

Binary interactions, such as mass transfer and merger, dominate the evolution of massive binaries (Sana et al. 2012). Single-degenerate massive binaries with a black-hole component (OB+BH binaries) play a crucial rule in the evolution towards double-BH mergers. Accreting OB+BH systems have been detected through X-rays (e.g. Corral-Santana et al. 2016). Non-accreting (quiescent) OB+BH systems are harder to detect. Spectroscopy can in principle help. However, in the past two years, spectroscopically reported OB+BH systems have been challenged by follow-up studies (e.g. LB-1 and HR6819; Abdul-Masih et al. 2020; Bodensteiner et al. 2020; El-Badry & Quataert 2020; Irrgang et al. 2020; Mazeh & Faigler 2020; Shenar et al. 2020; Frost et al. 2022), disfavouring the BH nature of the companion, leaving a handful of good candidates (e.g. Casares et al. 2014; Mahy et al. 2022; Shenar et al. 2022, Sana et al. in these proceedings). However, according to recent simulations, there should be about 1200 OB+BHs in the Milky Way Langer et al. (2020). Here, we present predictions on the capability of finding

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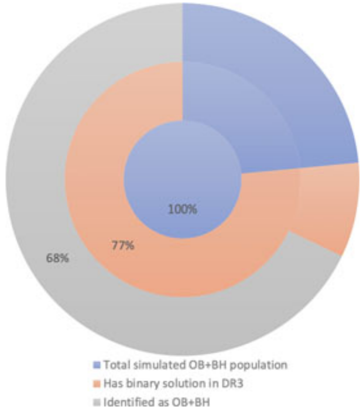

Figure 1. Pie chart of the detectable and identifiable fraction of OB+BHs in the simulated population.

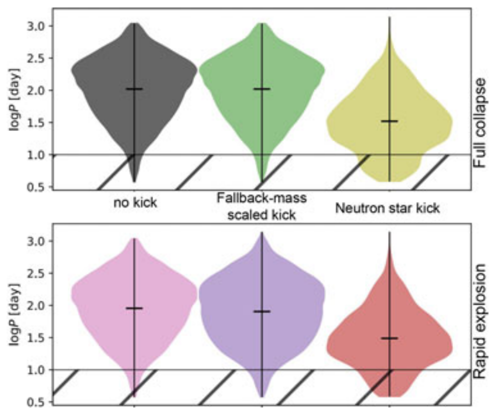

Figure 2. Predicted period distributions of the identifiable OB+BHs for different BH-formation scenarios. The vertical axis indicates different collapse scenarios.

OB+BH binaries with Gaia astrometric orbits using a novel method (Shahaf et al. 2019; Janssens et al. 2022).

We combined tailored simulations for the massive star population (Langer et al. 2020) with the distance distribution of stars in the second Alma Luminous Star massive star catalogue (ALSII; Pantaleoni González et al. 2021) to create a mock population of OB+BH binaries. Assuming that orbits for a system are available if the semi-major axis of the projected photocentre motion α satisfies $\alpha/\sigma_\alpha > 3$, we predicted how many of these OB+BHs are detectable by Gaia and how many are astrometrically identifiable as such with the Astrometric Mass-Ratio Function (AMRF; Shahaf et al. 2019). The method uses the size of the semi-major axis of the photocentre motion of a system to determine the nature of the companion. Almost 70% of our simulated population is identifiable with the AMRF, leading up to around 200 OB+BHs in the ALSII (Fig. 1). Moreover, non-degenerate binaries should not be misidentified as OB+BHs.

The detection of $\sim$200 OB+BHs would increase the sample of known OB+BHs by a factor of around 20. From the distributions of the parameters of the OB+BHs, such as the orbital periods and eccentricities, we can obtain constraints on the kick BHs receive at birth and how much mass is lost in the preceding collapse (Fig. 2).

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