






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 role 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

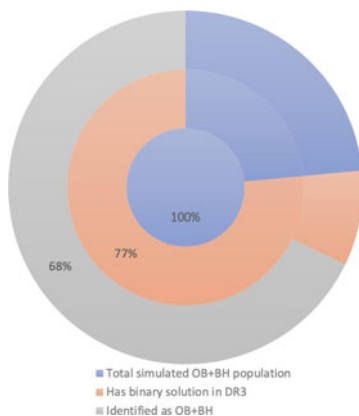


Figure 1. Pie chart of the detectable and identifiable fraction of OB+BHs in the simulated population.

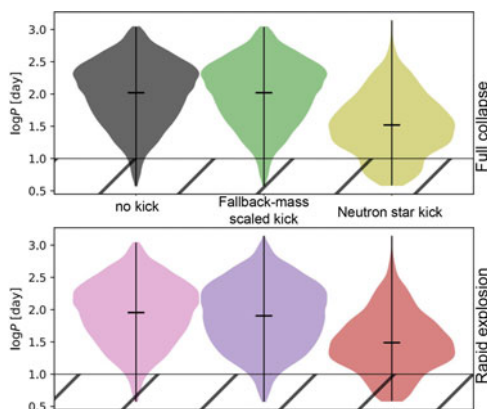


Figure 2. Predicted period distributions of the identifiable OB+BHs for different BH-formation scenarios. The vertical axis indicates different collapse scenarios.

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 ~ 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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