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A systematic method to identify runaways from star clusters produced from single-binary interactions: A case study of M67

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We create a methodology to look for runaway pairs produced from triple disintegrations from single-binary interactions. We search for these pairs in the cluster M67, from which the binary and single produced from the interaction should have been ejected. One pair passes all of our selection criteria.

Stars ejected from a star cluster with unusual kinematics are known as runaway stars. They can be ejected either by supernova explosions in binaries or the disintegration of triple systems (e.g. Renzo et al. 2019; Leigh et al. 2020; Toonen et al. 2022). Our aim is to find observationally the products of triple disintegrations interactions, that produce a runaway star (RS) and a runaway binary (RB). Their relative velocity vectors are determined by linear momentum conservation. We use Gaia DR3 data to search for these interactions. We define our selection criteria as follows: Velocity vectors of the objects should have a 180° angle between them. The mass and luminosity of the RB should at least double the mass of the RS. RS should have a velocity $>$ 2 that of the RB. Both traceback times from the currently observed positions to the hypothetical origin should be equal. Position in the CMD compared with known M67 stars. From GAIA DR3, we searched a circular area with a radius of 150 pc centered on M67's CoM. We apply a cylindrical cut using the parallaxes, with a length of 300 pc. We keep sources with velocities greater than the cluster escape velocity $v_{esc} > 2.6$ km s^{-1}, relative to the CoM motion of M67. We combine each remaining source, producing nearly 120 million pairs. Each of our criteria reduces the total number of pairs as follows: **(1)** For the velocity ratio criterion, the sample is reduced by a factor of about 2. **(2)** Requiring that the dimmer object be faster reduces our total sample size by one order of magnitude. **(3)** The traceback time criterion reduces the total sample by one order of magnitude. **(4)** Requiring that the angle between the velocity vectors be consistent with 180 degrees decreases our sample size by two orders of magnitude. **(5)** Requiring that the fastest and dimmer star lies in the CMD in a location consistent with an isochrone and that the binary lies slightly above the isochrone, reduces our sample size by two orders of magnitude. After applying all of our

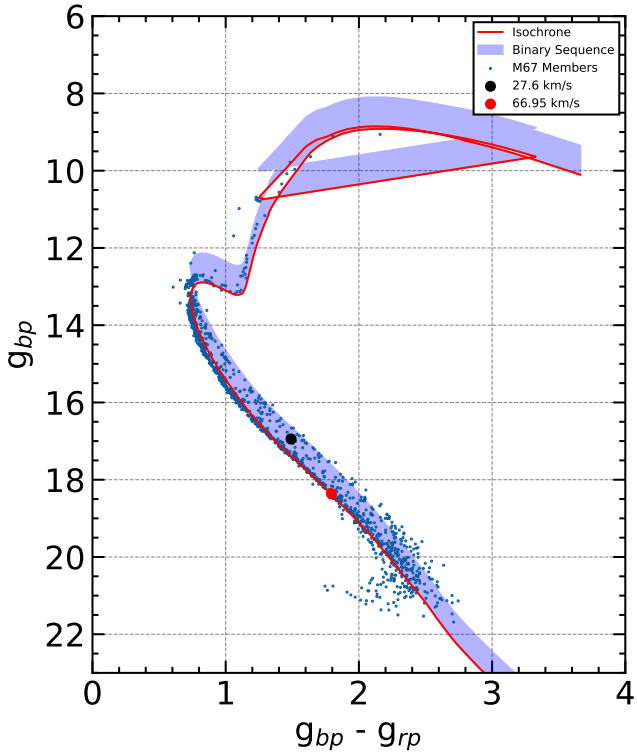

Figure 1. CMD of M67, with high-probability members in Childs et al. (2024) as the small dots. Red lines show the best-fitting isochrone as well as the equal-mass binary sequence shifted 0.75 mag above it. Resulting pair, red and black dots, are the faster and slower-moving objects.

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criteria, we are left with only one pair that satisfies them all simultaneously. Our sample size is reduced by eight orders of magnitude, from $\sim 10^8$ to 1. It is important to validate our method by applying it to other star clusters. Our candidate pair that we identify is still highly preliminary, and subsequent observations should be performed.

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