
255. The tidal tails of open clusters

ALMOST A CENTURY AGO, theoretical studies of open clusters showed that they ‘dissolve’ into the field over timescales of hundreds of Myr, as a result of stellar encounters and Galactic tidal forces (Bok, 1934; Spitzer, 1940). More detailed models followed (e.g. Hénon, 1961; Keenan & Innanen, 1975; Fukushige & Heggie, 2000; Baumgardt & Makino, 2003; Chumak et al., 2010).

The first use of the term ‘tidal tail’ that I am aware of appeared in the context of the bridges and tails between interacting galaxies (Toomre & Toomre, 1972). It was later applied to the extended structures around *globular* clusters, first discovered from star counts using the Palomar Sky Survey (Grillmair et al., 1995), and later from SDSS in the case of the clusters Palomar 5 (Odenkirchen et al., 2001) and NGC 5466 (Belokurov et al., 2006).

OPEN CLUSTERS contain far fewer stars than the halo globular clusters. And their less-populated tidal tails are much harder to detect against the more densely populated disk population. Accordingly, appropriately tuned searches, making use of distances, space motions, and photometry, are required to identify them. Algorithms specifically developed in the context of Gaia include DBSCAN (Castro-Ginard et al., 2018), STARGO (Yuan et al., 2018), and STREAMFINDER (Malhan & Ibata, 2018). As well as searches for phase-space overdensities, several studies have adapted the classical convergent-point method to identify coherent space velocities (e.g. Meingast & Alves, 2019; Jerabkova et al., 2021).

The first hints of extended tidal tails associated with *open* clusters came with Berkeley 17 (Chen et al., 2004) and NGC 6791 (Dalessandro et al., 2015).

But they only became truly evident with the Gaia data, and an elongation of the Hyades cluster was already reported from DR1 by Reino et al. (2018). With Gaia DR2, tails were found associated with the Hyades (Röser et al., 2019; Meingast & Alves, 2019; Jerabkova et al., 2021; essay 20), the Pleiades (Lodieu et al., 2019), Blanco 1 (Zhang et al., 2020), Coma Ber (Fürnkranz et al., 2019; Tang et al., 2019), M67 (Gao, 2020), Praesepe (Röser & Schilbach, 2019), and at least a dozen others.

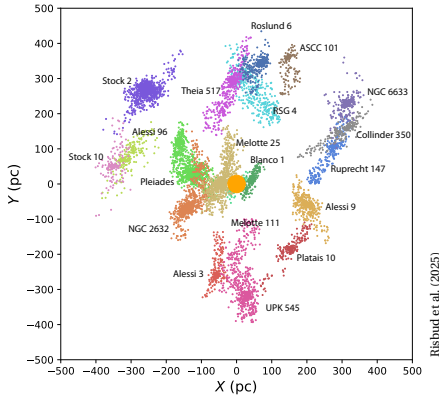
DISCOVERIES AND IMPROVEMENTS accelerated with Gaia EDR3 and DR3, amongst them Coma Ber, NGC 2516 and NGC 6633 (and several others, Pang et al., 2021), Pleiades (Li et al., 2021; Meingast et al., 2021; Vaher et al., 2023), IC 4756 (Ye et al., 2021), and NGC 752 (Bhattacharya et al., 2021; Boffin et al., 2022).

Amongst wider searches, Bhattacharya et al. (2022) identified 46 clusters having a stellar corona beyond the tidal radius, 20 of which exhibit extended tails aligned with the cluster’s Galactic orbit. Kos (2024b) simulated the dissolution of open clusters, and detected tidal tails in 476 using probabilistic arguments. Amongst 21 clusters within 400 pc, selected as being older than 100 Myr and each with more than 100 members, Risbud et al. (2025) identified tidal tails in 19, five of them being new.

THE SHAPES OF TIDAL TAILS encode a wealth of information about the clusters themselves, as well as their Galactic environment. Keenan & Innanen (1975) already noted that clusters rotating in a retrograde sense are more stable in a tidal field than prograde rotators. Indeed, their orientation with respect to the cluster’s velocity vector can constrain the cluster’s rotation (e.g. Jerabkova et al., 2021; Guilherme-Garcia et al., 2023).

Stars with lower or higher Galactic velocities than the cluster itself form the leading and trailing tails respectively, resulting in the tails’ characteristic S-shapes (e.g. Kroupa, 2008). From simulations anticipating the Gaia results, studies have distinguished the different morphology and kinematics of Type I tails (those formed relatively quickly by stars that escape from the cluster just after gas expulsion), and Type II tails which form over hundreds of Myr through their gradual evaporation (Dinnbier & Kroupa, 2020a; Dinnbier & Kroupa, 2020b).

Epicyclic overdensities are predicted at specific locations along the tail for clusters in both circular and eccentric orbits, with dependencies on the cluster mass (and hence age) and on the tidal field strength (Küpper et al., 2008; Just et al., 2009; Küpper et al., 2010). Suggestions of these have been identified in the 800 pc long tidal tails of the Hyades (Jerabkova et al., 2021).



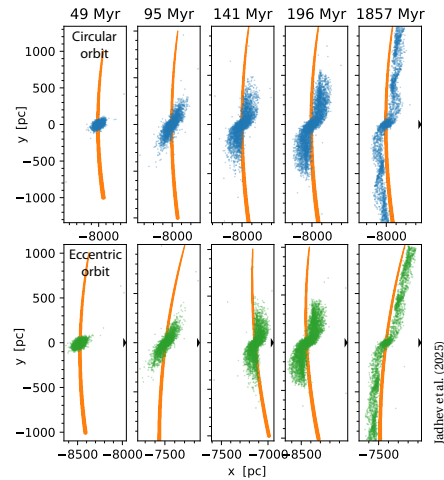
THE FACT THAT the shapes of tidal tails are influenced by the gravitational potential of the Galaxy provides prospects for further characterisation of the potential (e.g. Küpper et al., 2015). For open clusters with orbits approaching the Galaxy centre, the shape, morphology, and stellar density profile along the tails also depend on resonances induced by the central bar, and in particular on the bar pattern speed (Kos, 2024a).

More speculatively, the relative numbers of stars in the leading and trailing tails provides a constraint on gravitation theories (Kroupa et al., 2022; Kroupa et al., 2024; Pflamm-Altenburg, 2025). While the current evidence presented in these works points to asymmetries more consistent with Milgromian dynamics (MOND), certain caveats are noted by Jadhav et al. (2025, §5.3).

RETURNING TO the 21 clusters within 400 pc studied by Risbud et al. (2025), the figure above (their Figure 1) shows the cluster extents in Galactic coordinates. The tails have a tip-to-tip span of 20–200 pc with 30–700 tail members. The tail-aligned proper motions are mostly along the tail elongation, and point towards the leading tail, consistent with theoretical predictions.

Tidal shapes, they reiterate, are expected to be \mathcal{Z} -shaped, with the tilt of the leading tails being towards the Galactic centre, while the trailing tails tilt away from the Galactic centre. However, 4 out of their 19 clusters show S-shaped tails. Together with the numerical asymmetries in the leading and trailing tails, they conclude that the tidal tails observed with Gaia ‘appear to show features that are not understood at present and are certainly unexpected.’

IN A FOLLOW-UP PAPER, Jadhav et al. (2025) assessed the reliability of 58 unique cluster tails within 500 pc of the Sun, amongst 122 published catalogues of tidal-tails. They constructed a grid of 68 – 20000 M_{\odot} cluster simulations (see above opposite), followed the evolution of their tidal tails, and graded the observations according to a set of diagnostic tests based on photometric, morphological, and dynamical signatures.



They found that during the first 100–200 Myr of evolution, the tails typically form a characteristic \mathcal{Z} -shape, with an amplitude that scales with cluster mass. The tail span increases at a rate of $4\times$ the initial velocity dispersion, and the near-tail (within 100 pc) is predominantly populated by recent escapees. The age, metallicity, binary fraction, and mass function of stars in the tails were generally consistent with those of their parent clusters.

Of the published catalogues, they considered that 15 ‘gold-quality’ catalogues and 55 ‘silver-quality’ catalogues passed the majority of their tests (listed below). For the remaining 51 catalogues, they advocate that care should be taken before using them for further analysis.

Reference	Clusters
<i>Gold sample</i> (16)	
Jerabkova et al. (2021)	Melotte 25 (M1), Melotte 25 (M5)
Kos (2024b)	Melotte 22, NGC 1039, Platais 3, UPK 612
Meingast & Alves (2019)	Melotte 25
Meingast et al. (2021)	Blanco 1, Theia 517
Oh & Evans (2020)	Melotte 25
Risbud et al. (2025)	Alessi 96, Blanco 1, Melotte 25, Stock 10
Röser et al. (2019)	Melotte 25
Zhang et al. (2020)	Blanco 1
<i>Silver sample</i> (55)	
Bhattacharya et al. (2022)	Melotte 20, NGC 1662, NGC 1901, Stock 12, Teutsch 35, Theia 517
Boffin et al. (2022)	NGC 752
Fürnkranz et al. (2019)	Melotte 111
Kos (2024b)	ASCC 99, Alessi 9, Alessi 96, Blanco 1, Collinder 350, Herschel 1, IC 4756, Mamacjek 4, Melotte 111, Melotte 25, NGC 2422, NGC 3532, NGC 6475, NGC 6633, Renou 23, Ruprecht 147, Stock 12, Stock 2, Teutsch 35, Theia 517, UBC 32
Meingast et al. (2021)	Melotte 20, Melotte 22, NGC 2516
Olivares et al. (2023)	Melotte 111
Pang et al. (2022)	Alessi 3, Collinder 350, LP 2429, Theia 517
Risbud et al. (2025)	ASCC 101, Alessi 9, Melotte 111, Melotte 22, NGC 2632, NGC 6633, Platais 10, Roslund 6, Ruprecht 147, Stock 2, Theia 517
Röser & Schilbach (2019)	NGC 2632
Tang et al. (2019)	Melotte 111
Vaher et al. (2023)	IC 2391, IC 2602, Melotte 20, Melotte 22, NGC 2451A