
264. Blue stragglers

BLUE STRAGGLER stars were first identified in the globular cluster M3 by Sandage (1953). In a colour-magnitude diagram, they stand out as hotter and bluer than the majority of the other cluster stars – inconsistent with the cluster's expected evolutionary aging. The term 'blue straggler' was adopted in the study of NGC 7789 by Burbidge & Sandage (1958), who asserted that they are '*not understood on current ideas of stellar evolution*'.

Blue straggler stars (BSS) have since been found in open clusters (firstly by Johnson & Sandage, 1955), in the wider Milky Way field population (Preston & Sneden, 2000; Santucci et al., 2015; Ekanayake & Wilhelm, 2018), and in dwarf galaxies (e.g. Momany et al., 2007).

WITH LATER STUDIES inferring that they are stars 'rejuvenated' as a result of a more recent addition of hydrogen fuel, blue stragglers are now believed to originate from two possible mechanisms, both likely to operate: mass transfer in a binary system, or stellar collisions in a high density cluster core (e.g. Stryker, 1993; Mapelli et al., 2006; Boffin et al., 2015; Davies, 2016).

In the former, the more massive component ages, and expands as a red giant whose outer layers extend beyond its Roche lobe, while the less massive gains hydrogen to form a massive, bright blue star (the donor eventually collapses as a white dwarf). In the latter, violent mergers mix unburned H from their outer layers deep into the new core, and the two stars merge into a single massive blue object. In both cases, the resulting star appears younger and more massive than the turn-off age of their host stellar population.

Incidentally, binary mass transfer can also produce 'yellow stragglers' (in an even more advanced evolutionary stage, e.g. Hesser et al., 1984), sub-subgiants (essay 164), and 'stripped stars' (e.g. Dutta & Klencki, 2024), all of these occupying 'unexpected' locations in the colour-magnitude diagram (Mathieu & Pols, 2025).

Blue stragglers demonstrate that a star's position in the HR diagram is determined not only by its original mass and age: binary interactions can substantially alter their mass, composition and subsequent evolution.

THE PRE-GAIA CATALOGUE of blue stragglers by Ahumada & Lapasset (2007) listed 1887 candidates in 427 open clusters. Candidates were known to be affected by field star contamination and, pre-Gaia, it was largely impossible to confirm them without extensive follow-up spectroscopy (Carraro et al., 2008).

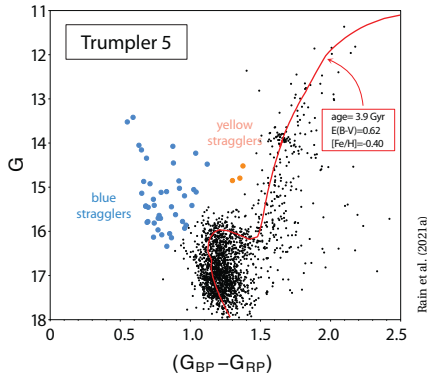
Gaia is making significant contributions to the study of blue stragglers. In its most straightforward application, this is by refining cluster membership (exploiting Gaia's photometry and astrometry), and therefore establishing a much more rigorous candidate selection.

Using Gaia DR2, Rain et al. (2021a) confirmed less than half of the above candidates (rejecting others as field stars), resulting in 897 blue stragglers (and 77 yellow stragglers) in 408 open clusters. They were found to be largely non-existent in young star clusters, only beginning to appear in those with ages $\lesssim 500$ Myr. The smaller number of confirmed candidates also led them to conclude that '*Open clusters are therefore not a preferable environment for these kinds of stars anymore*'. But they are, naturally, much harder to identify in the field.

Jadhav & Subramaniam (2021) identified 868 blue stragglers in 228 clusters, finding that their numbers increase with cluster age and mass. They found that 54% have a fractional mass excess consistent with relatively modest mass gain through binary mass transfer, while others are more consistent with mergers. The fraction favouring mass transfer increases in older clusters.

In their DR2 study of the open clusters Trumpler 5, Trumpler 20, and NGC 2477, Rain et al. (2021b) found that (for example) Trumpler 5 hosts a large blue straggler population, with a rather flat radial distribution.

THE AVAILABILITY of DR3 increased the numbers further. Li et al. (2023) found a further 138 in 50 open clusters. Qin et al. (2026) identified 272 new stragglers in 99 open clusters (153 blue stragglers, 98 probable blue stragglers and 21 yellow stragglers). For the open cluster Berkeley 18, Bisht et al. (2026) identified 24 new candidates. From their large-scale investigation of stellar rotation, Pancino et al. (2026) reported 'a few hundred more'.



G AIA'S CONTRIBUTIONS go further than refining and augmenting BSS candidates. The Gaia data also provides constraints on theories of binary evolution and mass-transfer, and whether BSS are formed by a direct physical collision, or by a binary merger/mass transfer (e.g. Leiner & Geller, 2021; Carrasco-Varela et al., 2025).

One way that this is possible is to note that, as a consequence of dynamical mass segregation, more massive stars gradually sink toward the dense cluster centre over millions of years. As a result, if a BSS population is found to be concentrated within the high-density cluster core, it would suggest a collisional origin. In contrast, if they are found in the cluster's less-dense outer regions, where direct collisions are far less likely, formation by binary mass transfer or binary merger may be indicated.

Gaia studies of the binary population of host clusters have demonstrated a strong correlation between a cluster's binary fraction and the number of blue stragglers, providing further evidence that binaries produce the stragglers (Rain et al., 2024; Tasneem et al., 2026). Furthermore, BSS numbers anti-correlate with a cluster's core density and collision rate, again suggesting that binary evolution is the dominant mechanism in most environments (Ferraro et al., 2026).

For the old open cluster Berkeley 18, Bisht et al. (2026) also concluded that *'dynamical interactions are inefficient, and that binary evolution is likely the dominant formation channel'*.

Amongst their results, Rain et al. (2024) found that binary evolution tracks can reproduce the bulk of the BSSs distribution in the colour-magnitude diagrams of their 12 open clusters. They also found evidence of a double sequence of blue stragglers in Melotte 66. Specifically, they identified one strip lying close to the cluster zero-age main sequence, while the other more closely follows the binary evolution tracks.

This is similar to the double sequences recently found in some globular clusters, e.g. NGC 6256 (Cadelano et al., 2022). These have been linked to single short-lived events such as core collapse, which are expected to boost the blue straggler formation (e.g. Simunovic et al., 2014; Tasneem et al., 2026).

FURTHER CONSTRAINTS on formation come from stellar rotation. Here, Gaia's rotational velocity measures (from photometric variability and spectral line broadening) have characterised rotation for more than 3 million stars (Frémat et al., 2023, see also essay 103).

Broadly, blue stragglers formed through binary mass transfer can gain angular momentum from their companions, leading to rapid rotation (e.g. Packet, 1981; Mastrozis et al., 2017). However, blue stragglers in short-period binaries can also be spun down by tidal friction (Ferraro et al., 2006). Some simulations suggest that strong magnetic fields can be generated after the binary merger, which might also brake the straggler's rotation (e.g. Schneider et al., 2019; Wang et al., 2022).

For stragglers resulting from direct stellar collisions, head-on collisions tend to produce slower rotation, while off-axis collisions contribute angular momentum to the coalesced star, resulting in faster rotators (Sills et al., 1997; 1999; 2005). In summary, binary evolution and stellar collisions can both produce stragglers with a wide range of rotation velocities.

Amongst such studies, Ferraro et al. (2023) measured the rotational velocities of 320 blue stragglers in eight globular clusters, and found a higher fraction of fast rotators in loose clusters.

Of 15 stragglers in the globular cluster NGC 1851, Billi et al. (2026) found four fast-rotators ($>40 \text{ km s}^{-1}$), with a monotonically decreasing trend between the fraction of fast-spinning stragglers and the central concentration and density of the host cluster. This supports a scenario in which recent blue straggler formation preferentially occurs in low-density environments from the evolution of binary systems.

In their large-scale statistical exploration of stellar rotation in open clusters using Gaia DR3, Pancino et al. (2026) reported more than 44 000 rotationally characterised stars, and more than 22 000 binary systems. Alongside a few hundred new blue stragglers, they provide a new parametrisation of the number of blue stragglers as a function of cluster mass and age.

IN ONE EXAMPLE of follow-up observations in the ultraviolet, HST-ACS is being used in attempts to detect hot ($T > 20000 \text{ K}$) orbiting white dwarf companions, which would confirm that the blue straggler was formed via binary mass transfer. Reggiani et al. (2025) found one out of 5 blue stragglers in the globular cluster 47 Tuc to be so accompanied, indicating that it likely formed through mass transfer, in this case less than 12 Myr ago. The lack of evidence for a hot companion to the others is consistent with the ultraviolet-excess photometric signature being a relatively transient phenomenon.

Other white dwarf companions have been reported using ultraviolet data from UVIT-Astrosat (e.g. Sindhu et al., 2019; Pandey et al., 2021; Dattatreya et al., 2023; Panthi et al., 2023; Dattatreya et al., 2024; Pal et al., 2024).