Clues on the formation of massive star clusters from stellar rotation

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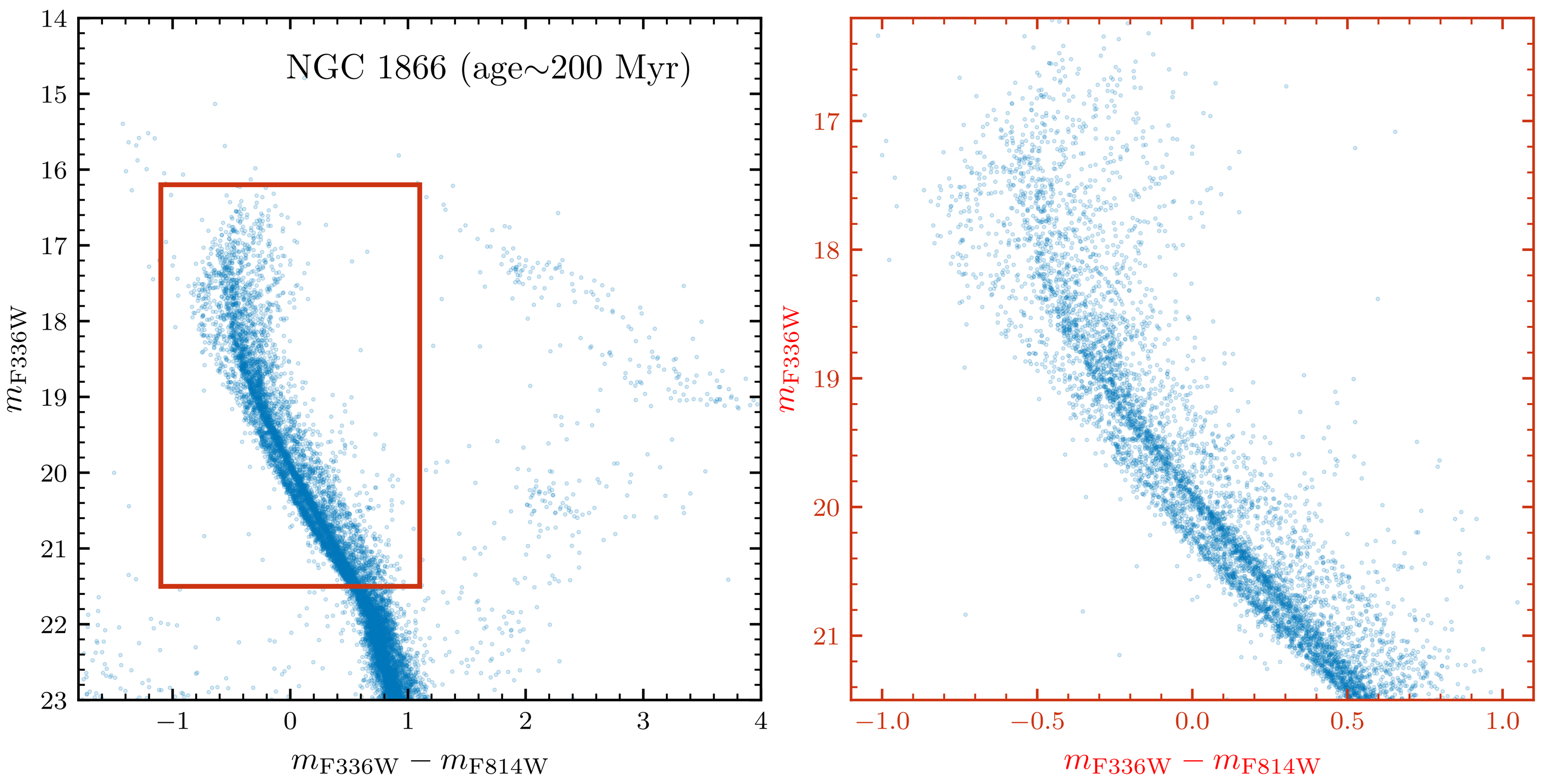
Context

Clusters with ages < 2 Gyr show features in their colour-magnitude diagrams (CMDs) that seem to contradict the idea that they are simple stellar populations. The most prominent of those features are

- **split main sequences**
- **extended main sequence turn-offs (eMSTOs)**



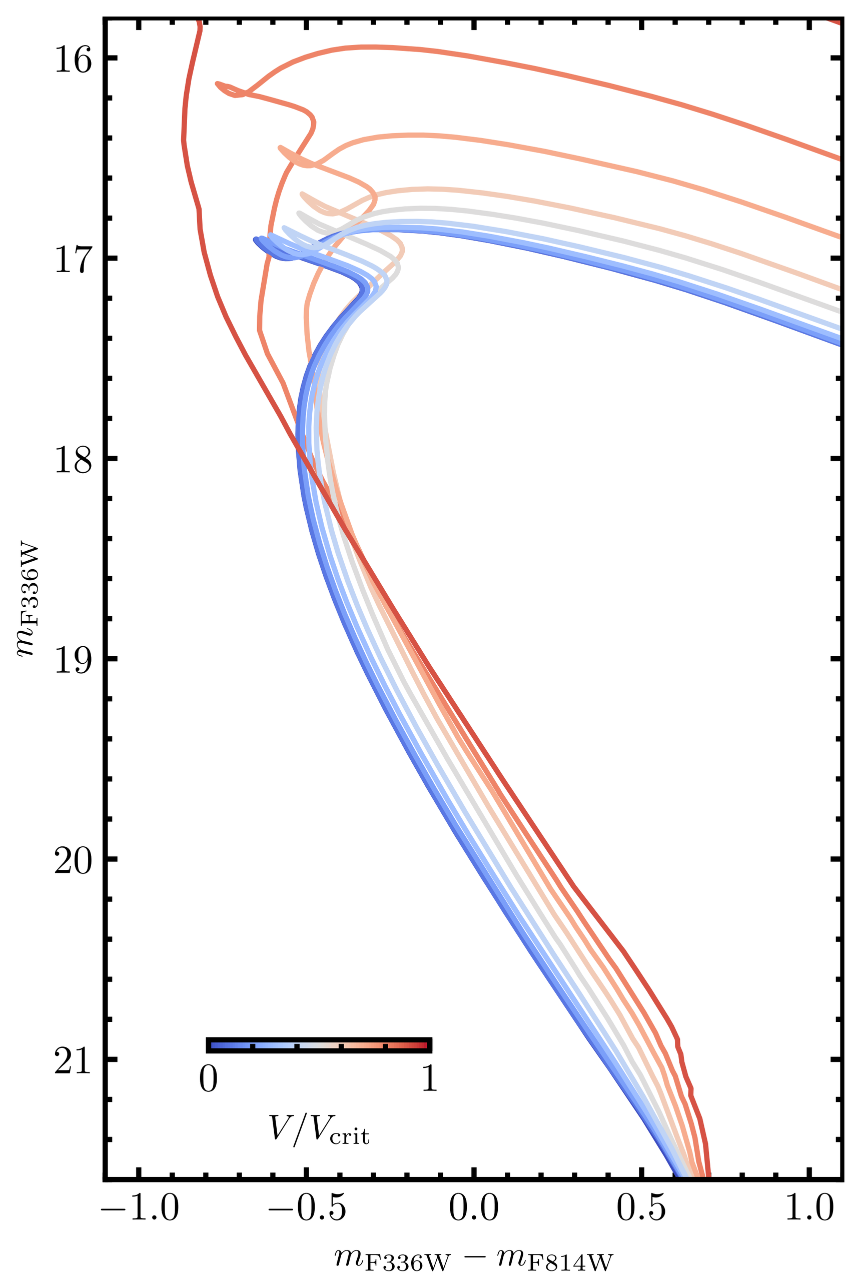
While originally discovered in the massive clusters of the Magellanic Clouds (e.g., NGC 1866 pictured above), *Gaia* data demonstrated that such features are also ubiquitous in low-mass Galactic open clusters.

The impact of stellar rotation

Several lines of evidence suggest that differences in stellar rotation, rather than stellar age spreads or mergers between clusters, are the reason for the observed features. Stellar rotation impacts a star's position on the CMD in several ways.

- It changes the hydrostatic equilibrium.
- It results in additional mixing.
- It causes temperature gradients across the stellar surface.

The plot shows MIST isochrones with the same age and metallicity (200 Myr, [M/H]=-0.24) but different rotation rates (Gossage et al. 2019 ApJ, 887, 199).



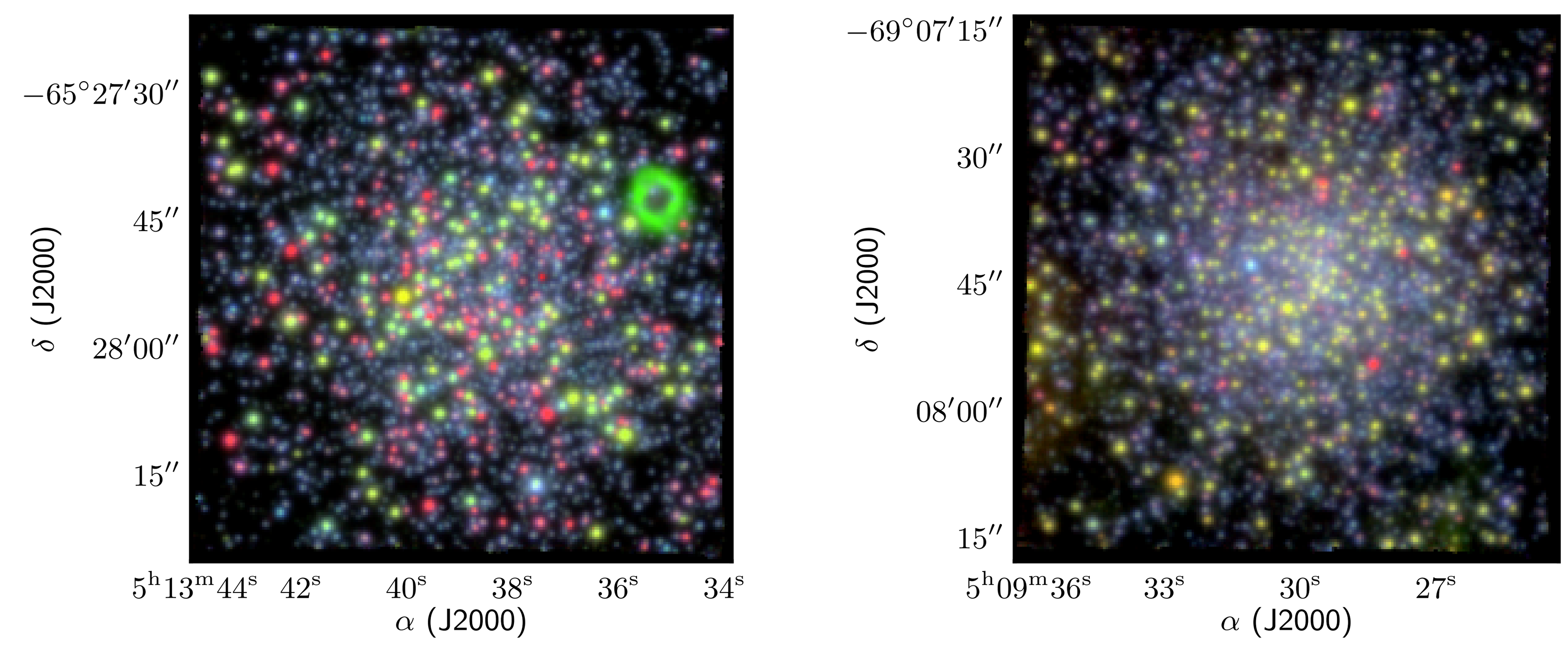
What sets the stellar spins?

Why do clusters form with distinct populations of slowly and fast rotating stars? In Bastian, Kamann, et al. (2020, MNRAS, 495, 1978), we proposed that a star's fate is determined by the **lifetime of its circumstellar disk** during the pre-main-sequence phase. Via magnetic coupling, the disk effectively moderates the angular momentum of the star as it contracts onto the main sequence. In our scenario

- Slow rotators retain their disks until settling on the main sequence.
- Fast rotators lose their disks early, via photoionisation from nearby massive stars.

Our scenario makes predictions about the properties of the two populations that we want to test using our observations and the results from state-of-the-art cluster formation simulations. For example, a centrally concentrated population of fast rotators may be observed in a cluster that formed with initial mass segregation.

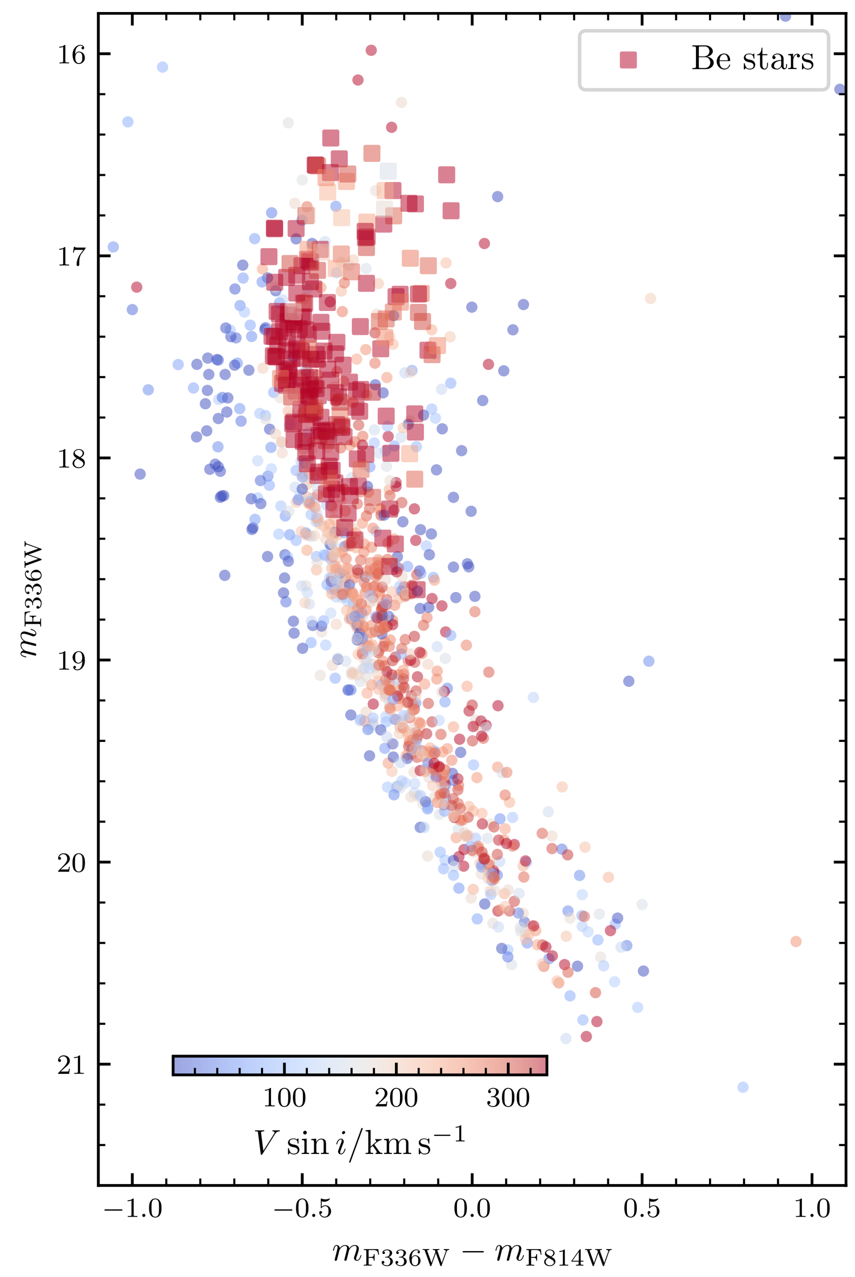
Our project



Using **MUSE**, we observed young massive clusters in the Magellanic Clouds. The unique capabilities of the instrument enable us to **measure stellar rotation across the clusters' entire upper CMDs**. Above, we show the MUSE data for two of our clusters, *NGC 1866 (left)* and *NGC 1866 (right)*, using narrow-band images centred on O[III] (blue), N[II] (green), and Hα (red). Stars appearing in red are Be stars, extremely fast rotators with decretion disks that show Hα emission.

Other clusters in our sample include NGC 1850 (Kamann et al. 2023, MNRAS, 518, 1505; talk by Sara Saracino) and NGC 1846 (Kamann et al. 2020, 492, 2177 MNRAS).

Stellar rotation in NGC 1866



As illustrated by the example of NGC 1866 to the left, we observe a bimodality between **slow rotators** (*V*sin*i* < 100 km/s) on the blue and **fast rotators** (*V*sin*i* ~ 200 km/s) on the red main sequence. **Be stars** are the fastest rotators, with spin velocities close to the critical values. They are predominantly found towards the eMSTO.

We are now comparing the spin velocities obtained for clusters of different ages to understand **the evolution of angular momentum** during the main sequence lifetimes of the stars. This will provide important constraints on stellar evolutionary models.

3-year postdoc available

We are looking for someone to join our group in Liverpool. Are you looking for a postdoc and also interested in stellar kinematics, stellar rotation, binary star analyses, or star cluster simulations? Then talk to me or scan the QR code to find out more.

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