Clustering properties of Herbig Ae/Be stars -- CEREAL

Alice Pérez Blanco -- University of Leeds, ISDEFE - ESAC
René Oudmaijer (University of Leeds), Ricardo Pérez-Martinez (ISDEFE - ESAC) and Deborah Baines (QUASAR - ESAC)

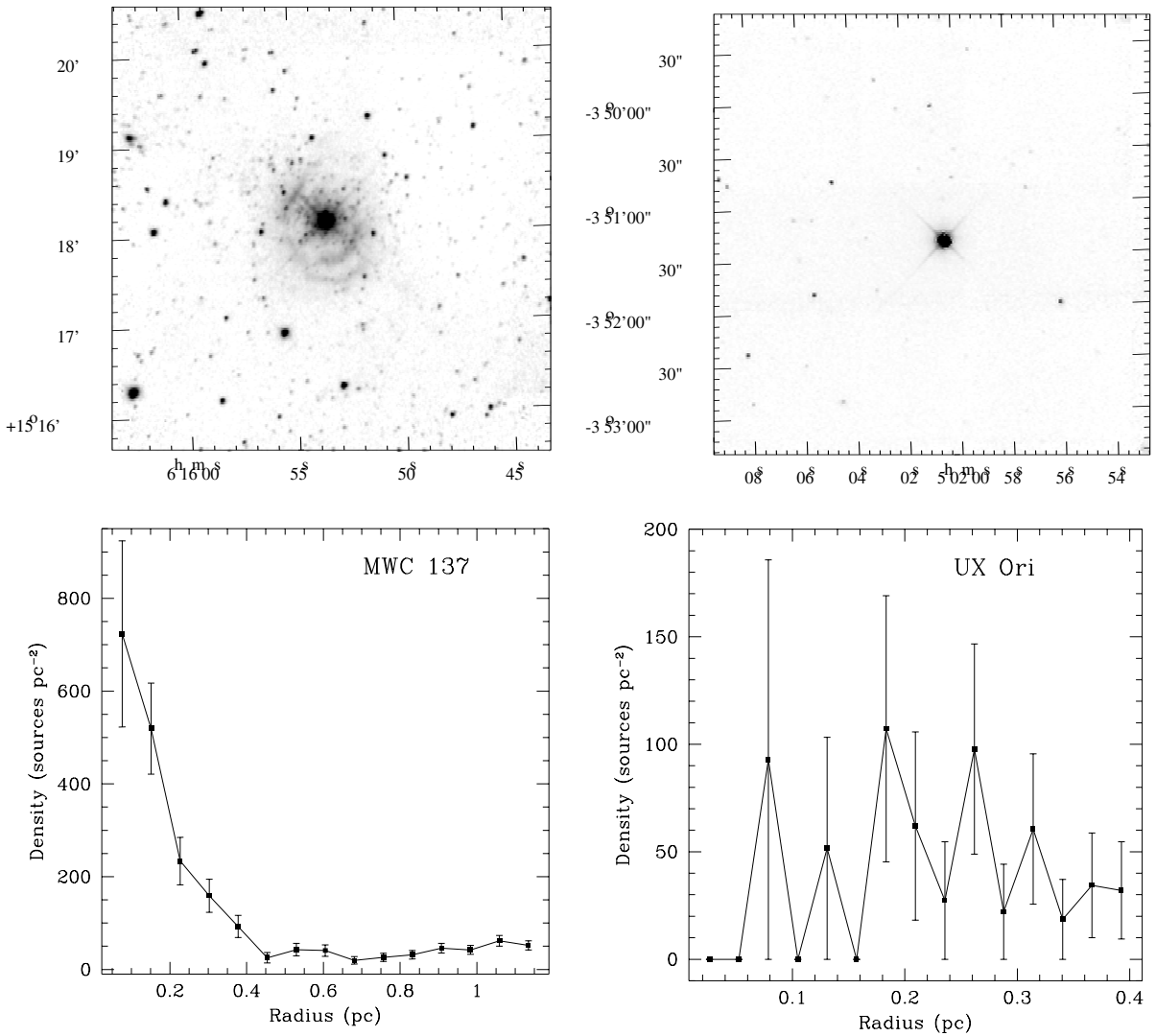
It is a well-established result that many stars do not form in isolation; young stars are usually found to be members of clusters. In particular, evidence that pre-main sequence stars of intermediate and higher masses are found in clusters has been found in several studies at optical and infrared wavelengths. We study Herbig Ae/Be stars which represent the most massive objects to experience an optically visible pre-main sequence phase, bridging the gap between low- and high-mass stars. Studies in the nineties into the occurrence of young stellar clusters around Herbig Ae/Be stars concluded, based on near-infrared imaging data, that there is a difference between the clustering properties of low and high mass stars. We are investigating the presence of clusters around previously known Herbig Ae/Be stars with the detailed astrometric data offered by Gaia. Here, we outline the preliminary results obtained with Gaia DR2 through our code CEREAL.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under MSCA ITN-EID grant agreement No 676036.

pyagyp@leeds.ac.uk

Background

- ✓ *Testi +99* analyzed the occurrence of young stellar clusters around Herbig Ae/Be stars using near-infrared images.
- ✓ Their sample covers the spectral type range O9 to A7.
- ✓ Rich clusters appear only around stars earlier than B5-B7.



Upper panel: the **K band images** of a star in a rich cluster on the left (MWC 137) and a star that appears isolared on the right (UX Ori). *Lower panel:* the **density profiles** of the same stars in the upper panels.

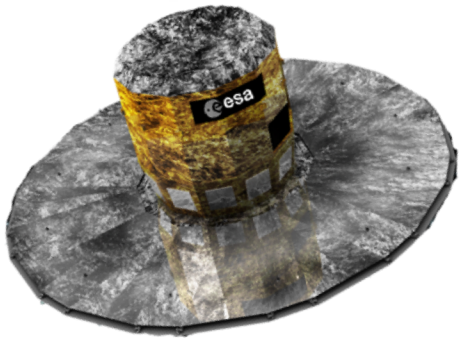
Lada +93; Hillenbrand + 95; Testi + 97

ClustER detEction ALgorithm: CEREAL

Semi-automatic code to make selections using the astrometric parameters of stars.

Targets

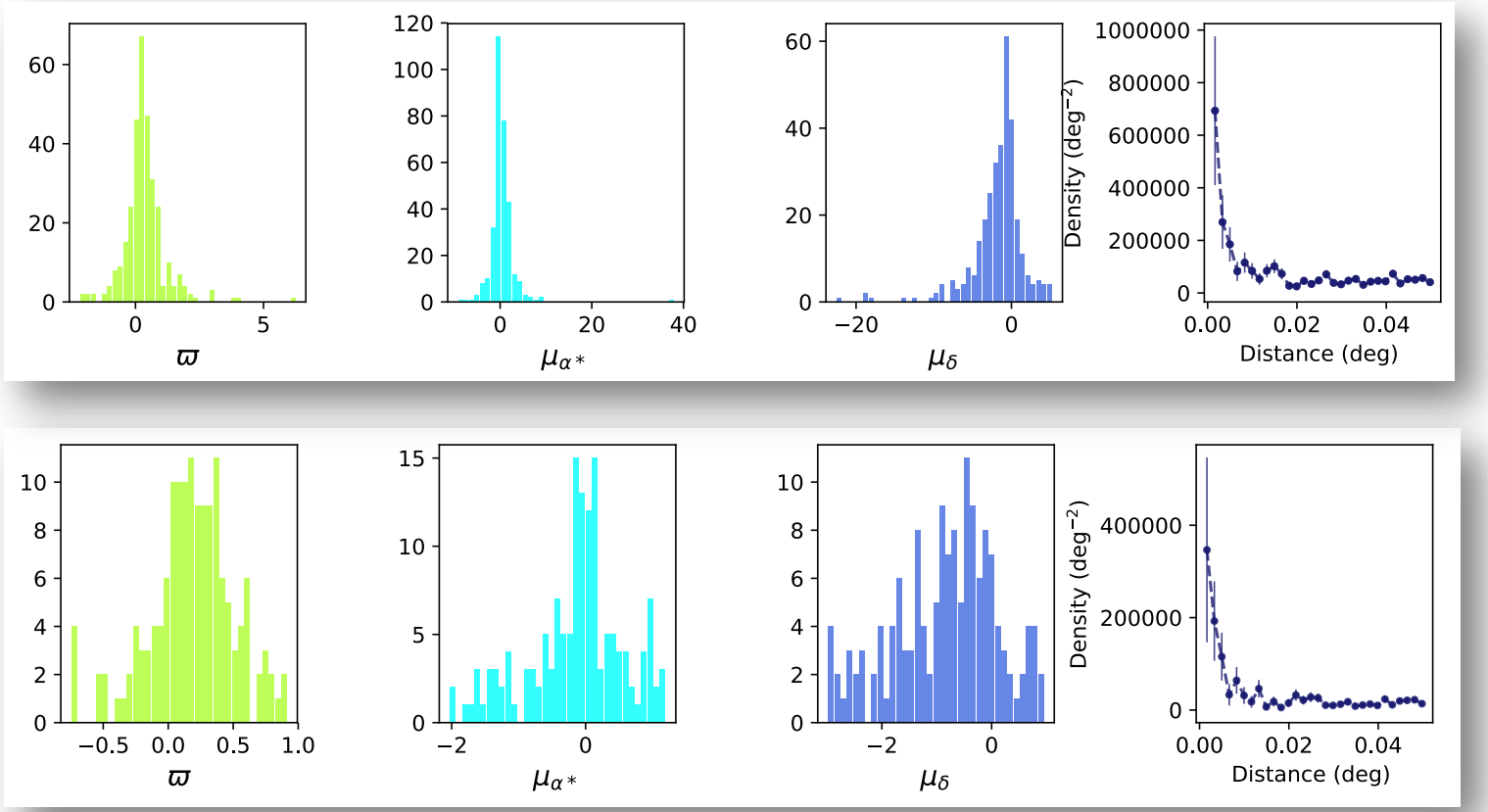
Sample of 269 Herbig Ae/Be stars



Select data around the Herbig Ae/Be stars with radius ~0.5 deg

Data is processed with CEREAL, making selections around the astrometric parameters and asking the question: Is the target in a cluster? Yes? Maybe? or No?

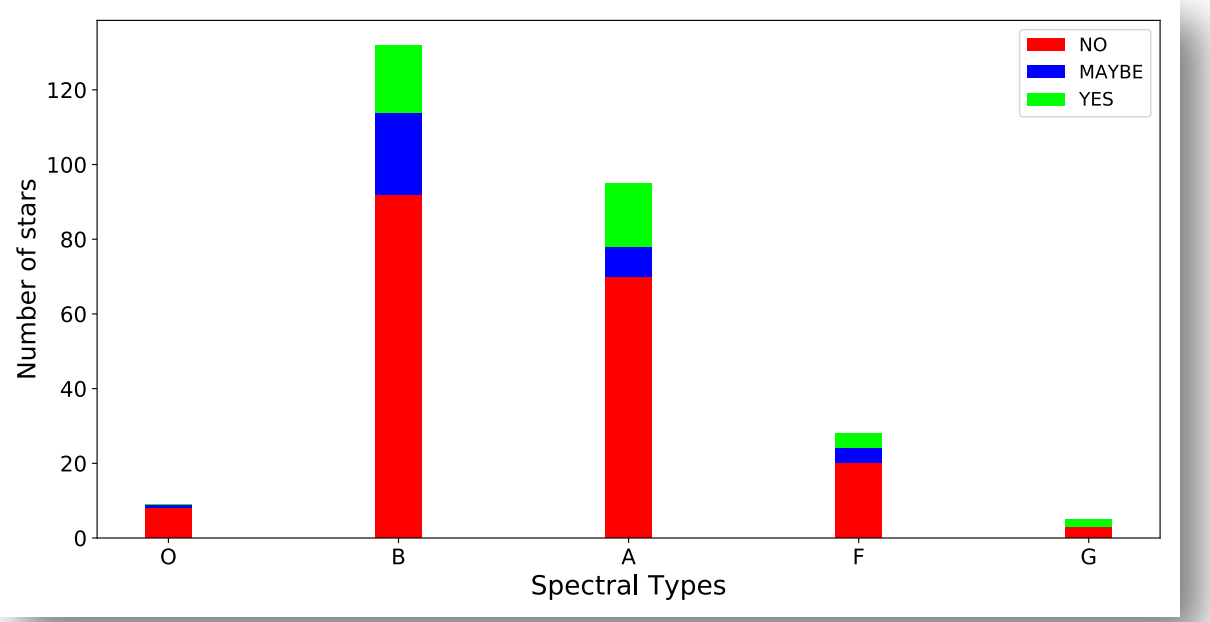
CEREAL



CEREAL images processing.
The upper panel shows the input data from Gaia DR2. The lower panel shows the output data from CEREAL. The histogram represents the parallax (green), the proper motion in RA (light blue) and the proper motion in DEC (dark blue). The stellar density profiles around the central star are also shown.

Gaia Collaboration+2018; Lindegren+18a; Vioque+18

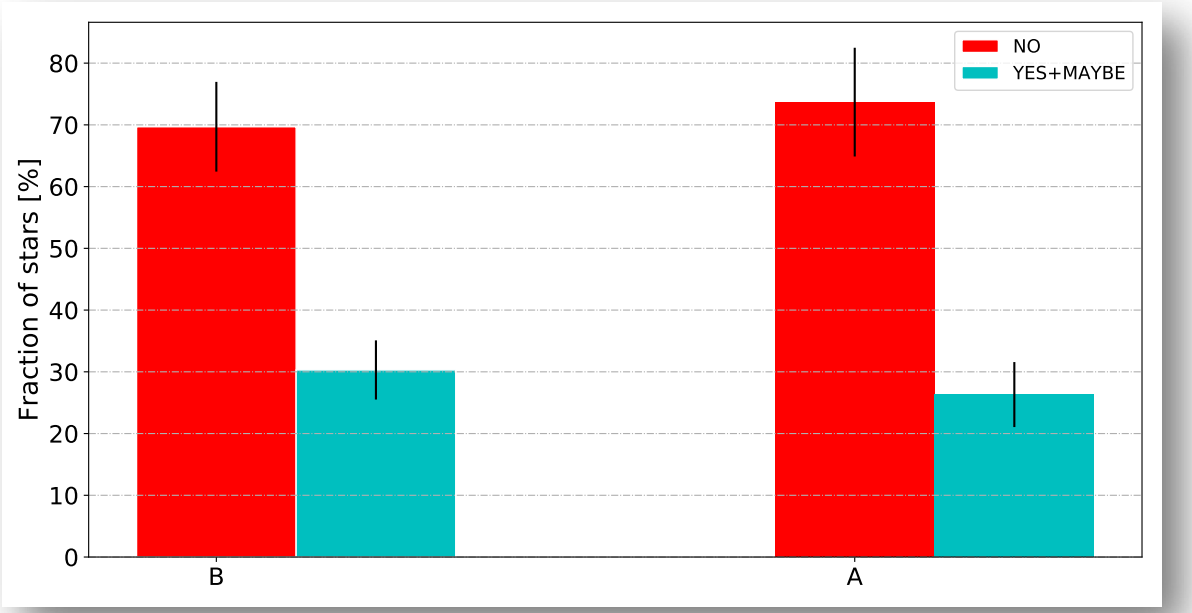
How many clusters were found with CEREAL



This figure shows the spectral type distribution of the clusters found with CEREAL for the sample of 269 stars, which cover the spectral range from O7 to G9. The green bars represent the stars found in clusters; the blue bars represent the stars found to possibly be in clusters and the red bars the stars found not to be in clusters.

A total of ~70 clusters was found.

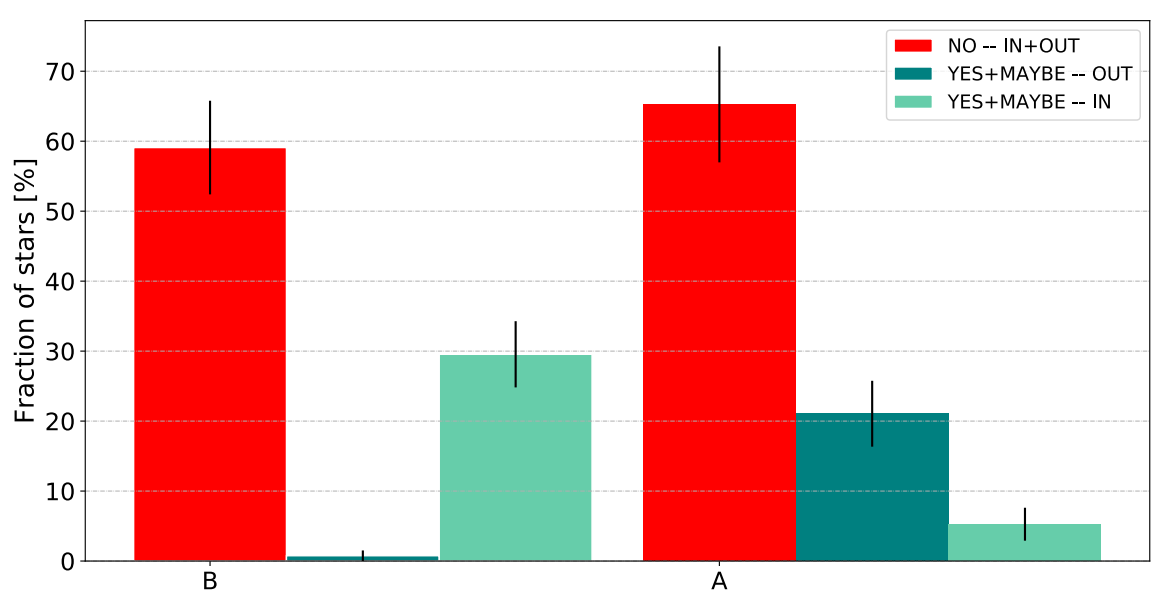
Are the clustering fractions of B type and A type different?



This figure represents the distribution of the fraction of B and A stars found to be in clusters by CEREAL. The red bars are the stars not found in clusters and the cyan bars are the sum of both the stars found in clusters (YES) and those possibly found in clusters (MAYBE).

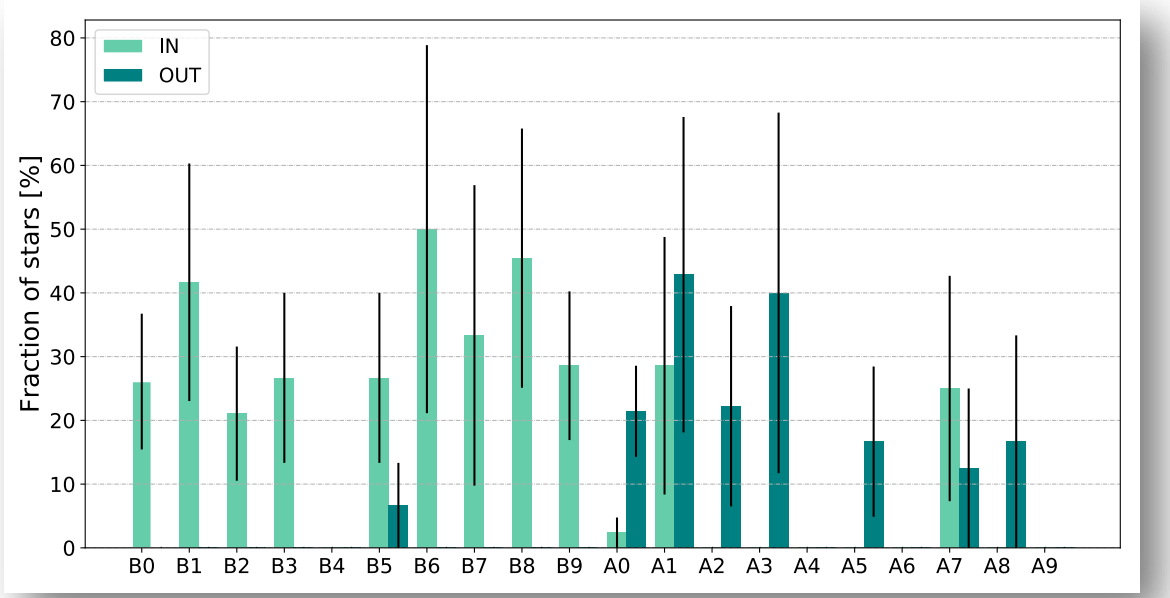
Both distributions appear to be similar for both samples.

Would the position of the Herbig Ae/Be stars in clusters have any effect on their clusters properties?



This figure represents the distribution of the fraction of B and A stars located either in the centre of a cluster or not. The red bars represent the stars not found in clusters. The dark green bars represent the stars in clusters that are not located in the centre (OUT) and; the light green bars represent the stars in clusters that are located in the centre (IN).

Both distributions appear to be similar for both samples for the stars not located in clusters, but it is clear that B stars are located at the centre of their cluster in comparison with the A stars.



This figure shows the distribution of the fraction the stars located at the centre of their cluster or not as a function of spectral type. The light green bars represent the stars in clusters that are located in the centre (IN) and the dark green bars represent the stars in clusters that are not located in the centre (OUT).

It is evident that for the sample of B stars found in clusters, each sub spectral type was located at the centre of their cluster (light green bars). The A stars (dark green bars) that were found in clusters are generally not in the centre.

Conclusion

CEREAL found that 28% of the sample was located in clusters (15% yes and 13% maybe) and those clusters were not just around early Btype stars.

The clustering fractions of B type and A type stars *are similar*. This similarity remained even when additional analysis was performed, which evaluated the susceptability of this result to any possible bias present in the astrometric parameters.

Looking closer at the cluster properties of the Herbig Ae/Be stars, it was found that ***their position*** does not effect their cluster propertes, but shows that B stars are more predominantly found to be the centre of their own cluster than A stars. The A stars appear to be associated with known star formation regions.

Futher studies will be made to characterise the cluster properties of the B and A stars, and CEREAL will be used to analyse a new sample of Herbig Ae/Be stars (see Miguel Vioque poster).

Thank you =)

pyagyp@leeds.ac.uk