

Clustering properties of Herbig Ae/Be stars: CEREAL



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Abstract 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 conclude, based on near-infrared imaging data, that there is a difference in clustering properties between 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.

CEREAL

CEREAL was developed to assess whether a Herbig Ae/Be star is associated with a cluster or not. This code can detect a cluster given the known value of the star's astrometric parameters. We took

Gaia DR2 data in a circular area (radius ~ 0.5 degrees) centred around the HAeBe star. We found a significant number of low mass stars which share similar astrometric parameters with the HAeBe star. Figure 1 shows the final result obtained with CEREAL for two HAeBe stars (green stars) which are surrounded by a group of stars which share similar properties (Table 1).

Is it the first time this has been found?

In 1999, *Testi et al.* analysed the occurrence of young stellar clusters around HAeBe stars from near-infrared images. They studied 44 fields around stars with spectral types from A7 to O9, where rich clusters appear only around stars earlier than B5-B7. Currently, we have a sample of ~ 200 Herbig Ae/Be stars located at different distances (Figure 4). For comparison, we only took the 43 stars we have in common with their sample (Figure 2). We found that $52 \pm 10\%$ of B-type stars and $25 \pm 10\%$ of A-type stars are likely to be in a cluster. *Testi et al.* found that $50 \pm 10\%$ of B-type stars are likely to be in clusters, and no A-type stars in clusters (Figure 1 and 3). Further analysis will need to be done to understand these differences.

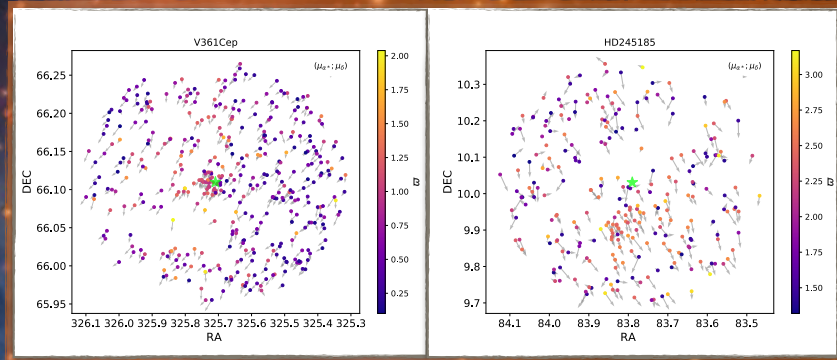


Figure 1. Sky distribution for two HAeBe stars from CEREAL results. The colour bar represents the parallax and the arrows the proper motions of the sample. Both targets belong to the list of Herbig Ae/Be members and candidate members from *Thé et al. 1994*. **Left panel:** Our results agree with *Testi et al. 1999* on the presence of a cluster around the star, which is located in the Cocoon Nebula. **Right panel:** An A-type star associated with the open cluster Collinder 69, where some stars are outshone by a very bright nearby star. *Testi et al. 1999* only find a small aggregate or background stars in the field where the target is located ($IC < 10$, figure 3).

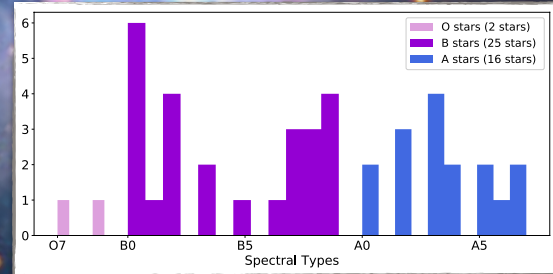


Figure 2. Histogram of the spectral type for the stars in common between CEREAL and *Testi et al. (1999)*.

Table 1. Astrometric parameters from Gaia DR2

Stars/ Parameter	Parallax (mas)	Pmra (mas/yr)	Pmdec (mas/yr)	Spectral type	Location
V361 Cep	1.11 ± 0.02	-1.90 ± 0.04	-3.75 ± 0.04	B2	NGC7129
HD 245185	2.32 ± 0.10	0.33 ± 0.14	-1.93 ± 0.10	A2	Collinder 69

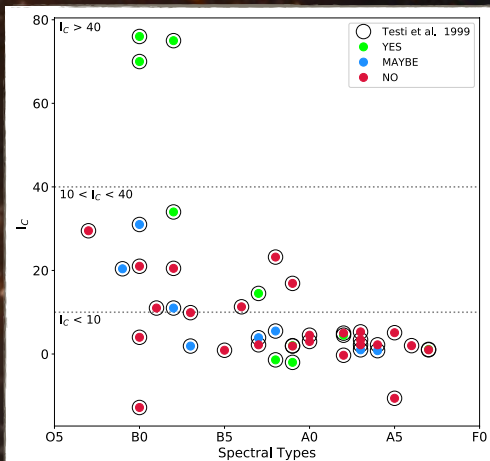


Figure 3. Richness indicator (I_c) vs Spectral type. Here we show the clusters classification made by CEREAL and *Testi et al. (1999)* from the 43 stars of Figure 2.

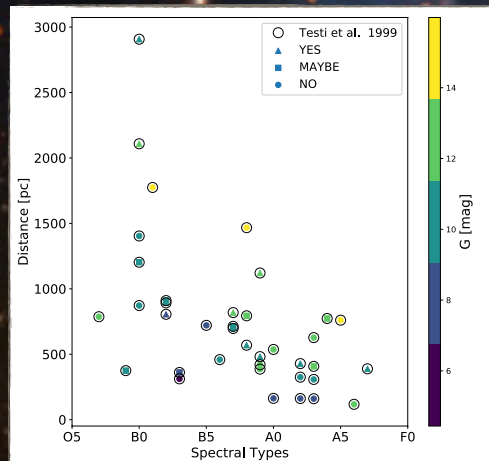


Figure 4. Distance vs Spectral type. These are the same stars from figure 3 with a colour bar which represents the G magnitude from Gaia DR2.

Summary

We have analysed a sample of ~ 200 HAeBe stars with CEREAL using Gaia DR2 to increase the number of objects studied by *Testi et al. (1999)*. So far, we have found 76 clusters, with the fraction of B-stars in clusters similar to that of A-stars. However, the A-stars seem to be part of larger scale clusters.