Herbig Ae/Be stars with TGAS parallaxes in the HR diagram

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Introduction

The intermediate mass Herbig Ae/Be stars are young stars approaching the Main Sequence and are key to understanding the differences in formation mechanisms between magnetic low mass stars and the non-magnetic high mass stars. A large fraction of known Herbig Ae/Be stars have TGAS parallaxes, which are used to derive luminosities and place 108 of these objects in the HR diagram. The number of Herbig Ae/Be stars that could be placed in the HR diagram using directly determined distances has increased by more than a factor of 5 with this study. By means of the HR diagram, we studied the characteristics of the infrared excesses of this set of Herbig Ae/Be stars and we linked our results to an evolutionary analysis.

Methodology

1. First, we selected 254 Herbig Ae/Be stars candidates (see [1]) and cross-matched them with TGAS, reducing the set to 108 sources.
2. T_{eff}, log(g) and metallicity for these stars were taken from the works of [2], [3] and [4]. When no information was available for a certain Herbig Ae/Be star indirect estimations were made.
3. We used multi epoch and simultaneous photometry when possible. Photometry was dereddened using a $R_V = 3.1$ when applicable and the reddening law of [5].
4. An atmosphere model from [6] of the appropriate Teff, log(g) and metallicity was scaled to the dereddened Johnson V band point for each star. A total flux was obtained by integrating below the atmosphere model.
5. By means of the parallax the total flux was converted to luminosity (in a similar way to what was done by [7]).
6. Finally, as a control sample, a similar procedure was done for 73240 TGAS sources whose parallaxes resulted in better than 3σ detection.

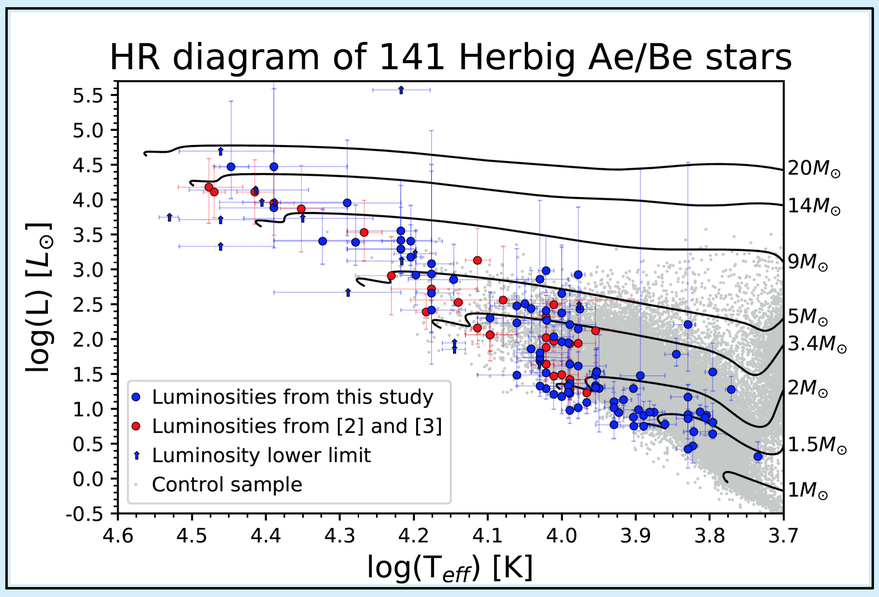

Figure 1: 141 Herbig Ae/Be stars in the HR diagram. Together with the 108 sources with luminosities determined in this study (blue dots), 33 additional Herbig Ae/Be stars whose luminosities are known from spectra (from [2] and [3]) are also plotted (red dots). Vertical error bars are dominated by parallax uncertainties. The mass of each Pre-Main Sequence track (from [8]) is indicated at right.

Infrared Excesses

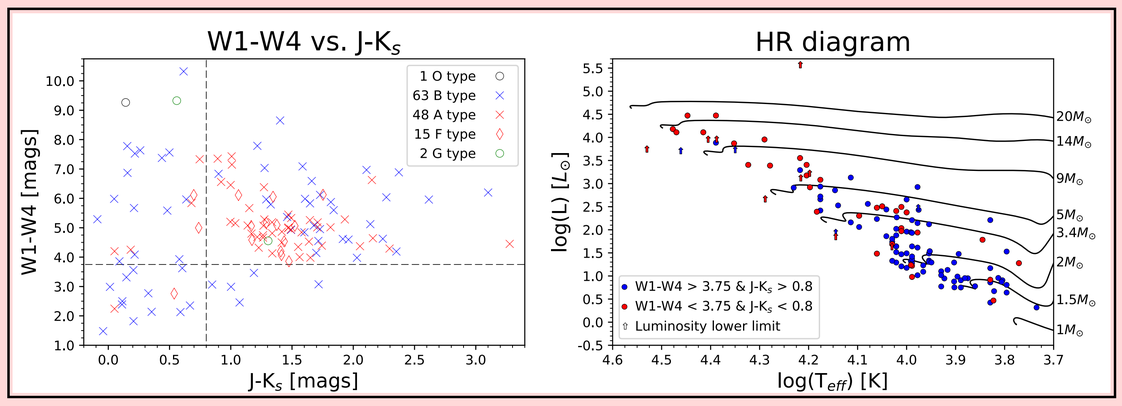

Figure 2: Stars lying within the top right region of the colour-colour diagram are plotted in blue in the HR diagram, otherwise they are plotted in red. Note that most A stars have a very cool IR excess. The infrared J, K_s, W1 and W4 bands were obtained from AllWISE (1.235μm, 2.159μm, 3.4μm and 22μm respectively).

We can study infrared properties of our set of Herbig Ae/Be stars by grouping similar sources in colour-colour diagrams, colour-excess or even excess-excess diagrams and then observing how they are placed in the HR diagram.

For example, in Figure 2 we can appreciate how the majority of A type stars are mostly only present at high J-K_s and W1-W4 whilst many very luminous B type stars are more mixed with no excess Main Sequence stars. This may indicate that they are more evolved and have already cleared most of their dust. Some may be misclassified Be stars.

Evolutionary Analysis

Another approach for studying the evolution of Herbig Ae/Be stars towards the Main Sequence is through the SEDs. Fixing a mass value and picking several stars on the corresponding Pre-Main Sequence track provides an evolutionary movie of a Herbig Ae/Be star of that mass. Doing this for several masses will lead to a general understanding of the evolution of dust and gas around these objects.

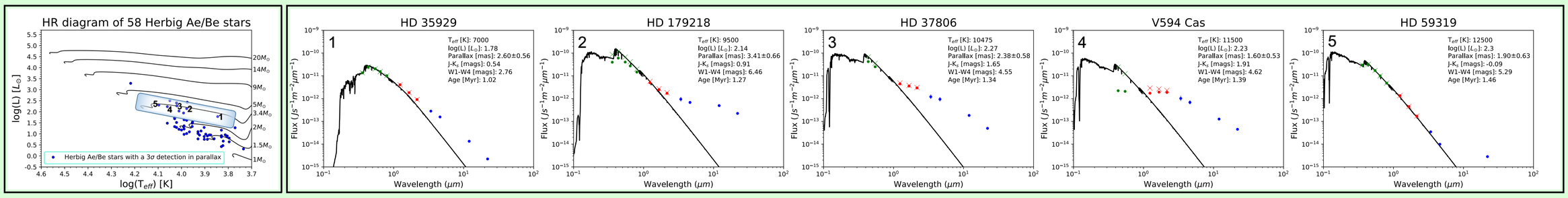

Figure 3: SED evolution of Herbig Ae/Be stars for a Pre-Main sequence track of 3.4$M_\odot$. Each SED is linked to its position in the HR diagram by the number at the top left. Just a clean subsample of stars with a 3σ detection in parallax was considered in this case. Observed (points) and dereddened (crosses) photometry are shown: U, B, V, R and I bands in green; J, H and K_s bands in red and W1, W2, W3 and W4 bands in blue.

Conclusions

- Largest to date homogeneous analysis of Herbig Ae/Be stars using directly determined distances.
- An example of how useful the HR diagram can be in order to study general properties of these stars with different approaches.

Forthcoming Research

This work serves as an illustration for our longer term Gaia based project to search, identify and analyse new Herbig Ae/Be stars; for which the study of already catalogued ones constitutes the first logical step.

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