

Cataloguing new high-mass Pre-Main Sequence and Classical Be stars using Machine Learning and Gaia

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Abstract

Herbig Ae/Be stars are high-mass Pre-Main Sequence objects which are key to understanding the star formation mechanisms of high-mass stars and the evolution of their protoplanetary discs. By applying Machine Learning techniques to Gaia DR2 data we have constructed a large and homogeneous catalogue of new Pre-Main Sequence sources with, at least, 1361 new Herbig Ae/Be stars. Standard techniques are not efficient for identifying these objects mainly because of their similarity with Classical Be stars, with which they share many characteristics. By focusing on disentangling these two types of objects, our algorithm has also identified 693 new Classical Be stars.

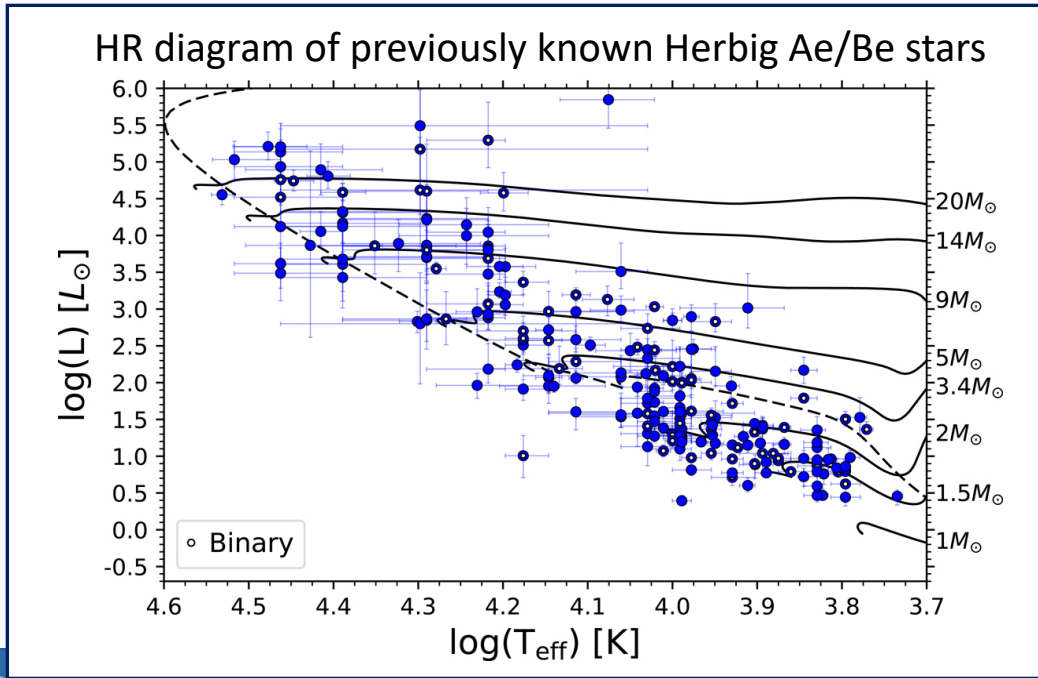
The catalogue of new high-mass Pre-Main Sequence stars that we present here increases the number of known objects of the class by an order of magnitude. In this poster I discuss the methodology used and the general properties of the new sources. Furthermore, I present the results of independent spectroscopic observations of these newly discovered Herbig Ae/Be stars.

[Vioque, M., Oudmaijer, R. D., Schreiner, M., et al. 2020, A&A, 638, A21](#)



~250 Herbig Ae/Be stars were known to date
This is an inhomogeneous and biased set

- We knew very few little evolved Herbig Be stars or massive Herbig Ae stars.
- We were missing many low-mass Herbig Ae stars because of historical selection effects.

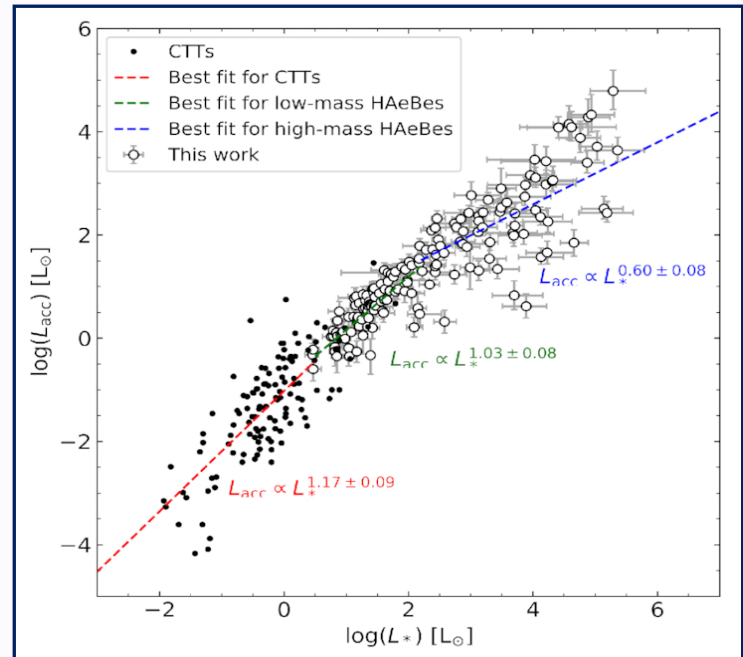


Vioque et al. 2018

Most open problems in high-mass star formation are limited by this small and biased set

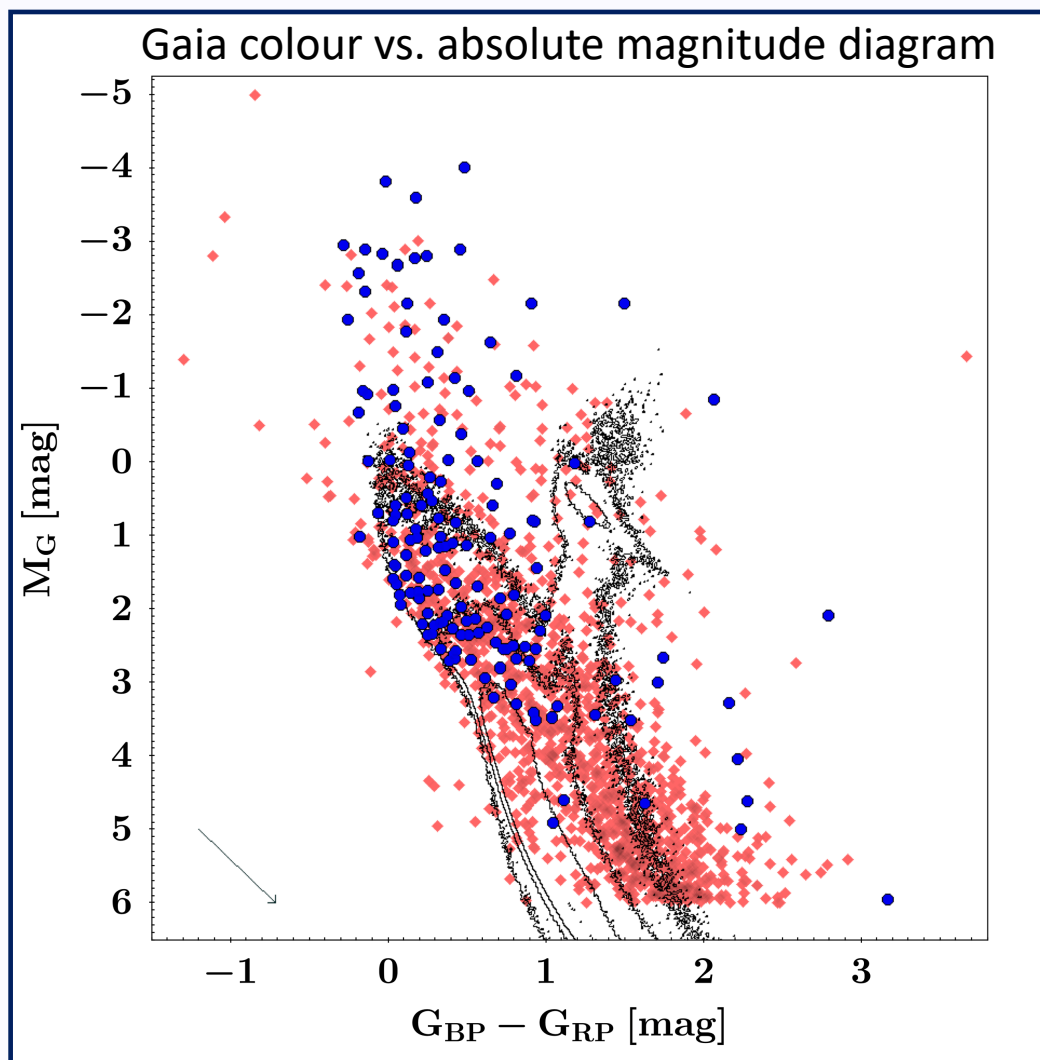
Examples

- Accretion properties of high-mass Pre-Main Sequence objects
- Clustering properties of Herbig Ae/Be stars - see poster by A. Pérez-Blanco
- Properties of protoplanetary discs around high-mass Pre-Main Sequence objects



Wichittanakom et al. 2020

By applying Machine Learning techniques to 4,150,983 sources with data from **Gaia DR2**, **2MASS**, **WISE**, and **IPHAS** or **VPHAS+** we have constructed a large and homogeneous catalogue of new high-mass Pre-Main Sequence objects.



Selection is based on **infrared excess**, **H α emission**, and **photometric variability**

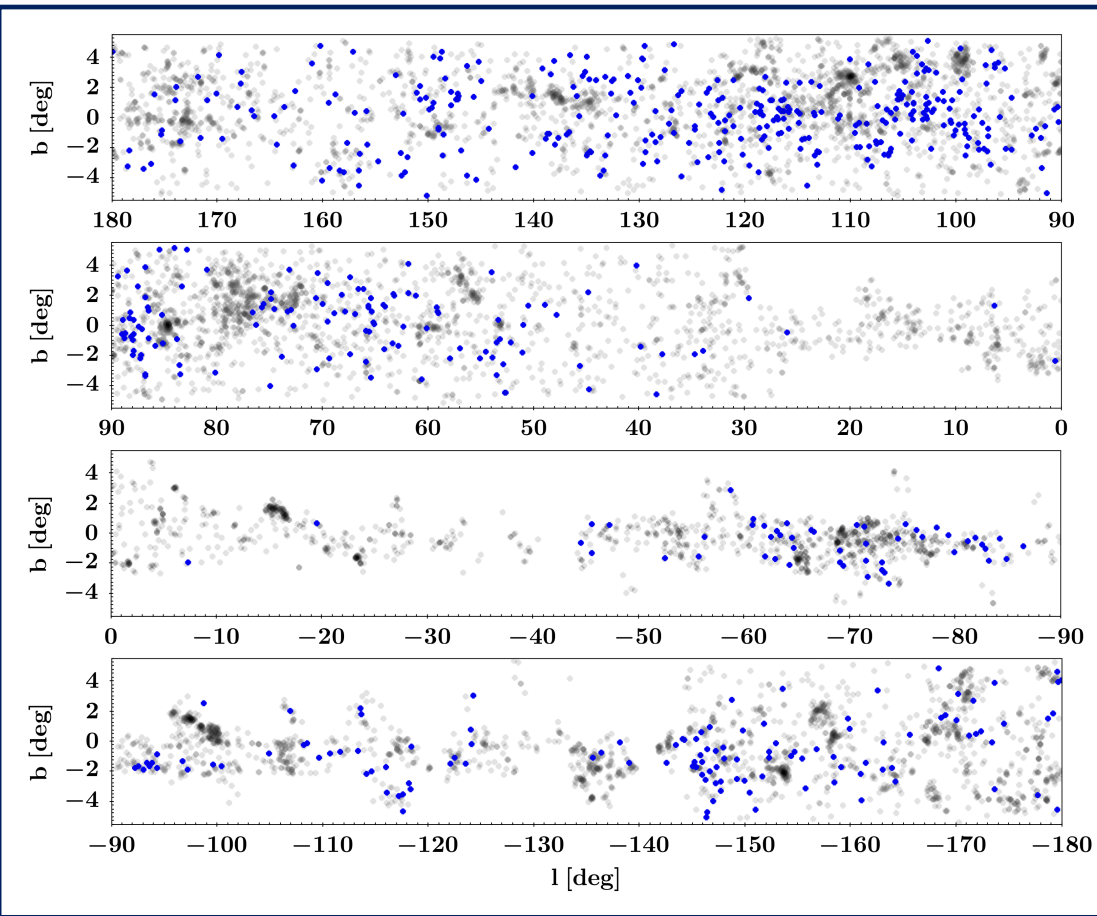
Our artificial neural network obtained a homogeneous catalogue of Pre-Main Sequence stars with at least **1361 new Herbig Ae/Be candidates**

This number can be increased by relaxing the constraints to the parallax quality

- **In blue** the previously known Herbig Ae/Be stars.
- **In red** the newly discovered Herbig Ae/Be stars, which are those new Pre-Main Sequence candidates placed in the more massive locations of this diagram.

Code YODA (Young Object Discoverer Algorithm) available here: <https://github.com/MVioque/YODA>

We discovered **693 new Classical Be stars** because of their similarity with Herbig Be stars



- In grey the newly discovered Pre-Main Sequence candidates. They mostly appear in associations that trace nebulosities.
- In blue the newly discovered Classical Be candidates. They do not trace the associations of Pre-Main Sequence candidates.

The selection and resulting catalogues are independent of coordinates and distances

	Number of sources	Completeness	Precision
New Pre-Main Sequence candidates	8470	$78.8 \pm 1.4\%$	$\geq 81\%$
New Classical Be candidates	693	$85.5 \pm 1.2\%$	$\geq 89\%$

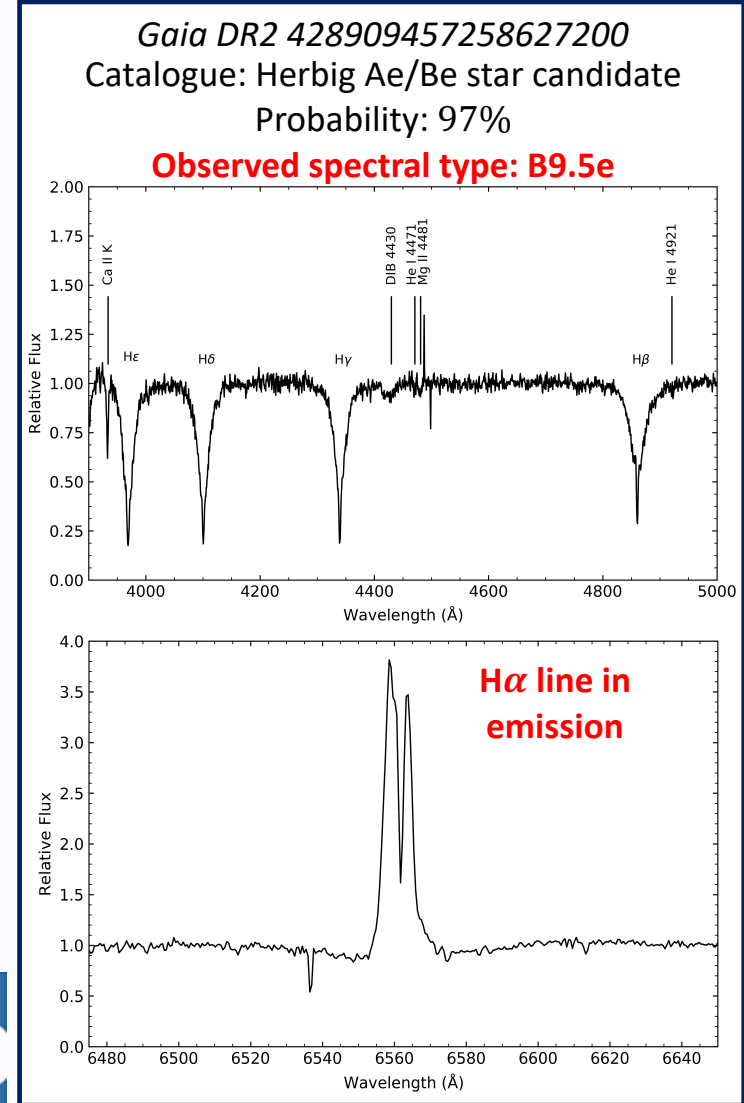
Further analysis with selection-independent observables confirm the quality of the classification:

- The Pre-Main Sequence candidates tend to be associated with nebulosities and star-forming regions, and appear mostly in Pre-Main Sequence locations in the Hertzsprung-Russell diagram.
- The Classical Be candidates do not trace the associations of Pre-Main Sequence candidates or nebulosities and appear mostly in Classical Be locations in the Hertzsprung-Russell diagram.

Independent observations

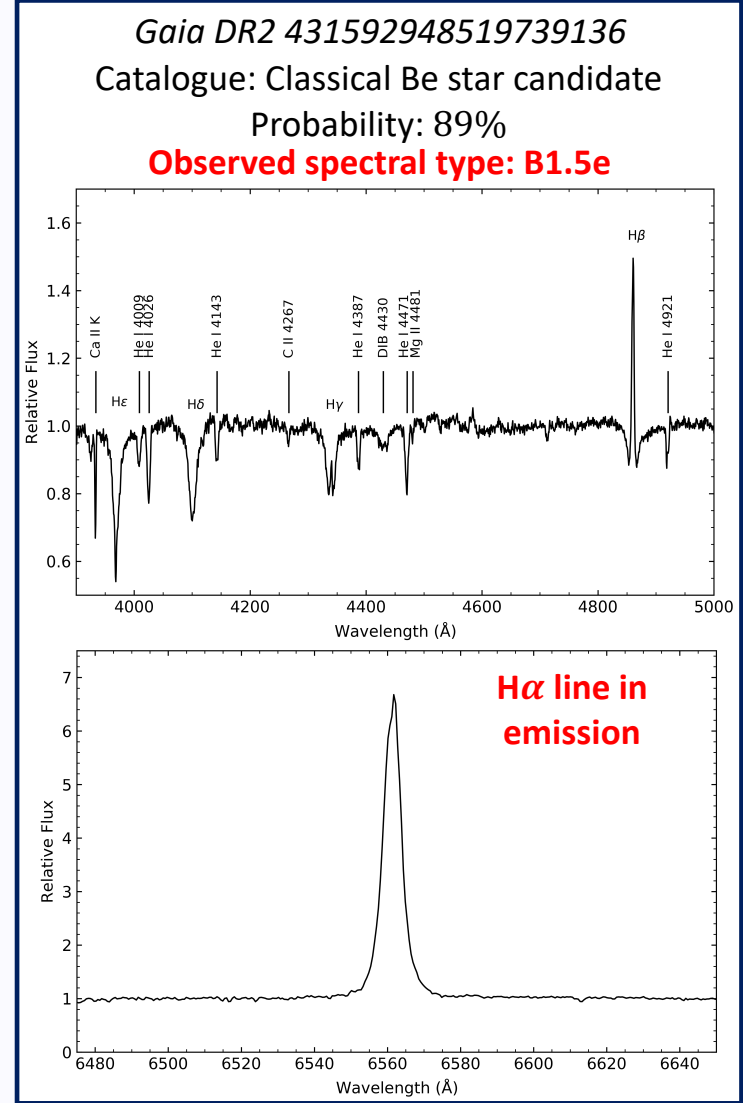
A subsample of **145 Herbig Ae/Be candidates**, **14 Classical Be candidates** and **7 catalogue tagged contaminants** have been observed with optical spectroscopy for further confirmation of their nature

Examples:



Confirmed new Herbig Be discovery

Mass: $2.40^{+0.25}_{-0.22} M_{\odot}$
Distance: 2590^{+200}_{-170} pc



Confirmed new Classical Be discovery

Mass: $8.3^{+10}_{-2.3} M_{\odot}$
Distance: 3470^{+340}_{-280} pc



Independent observations

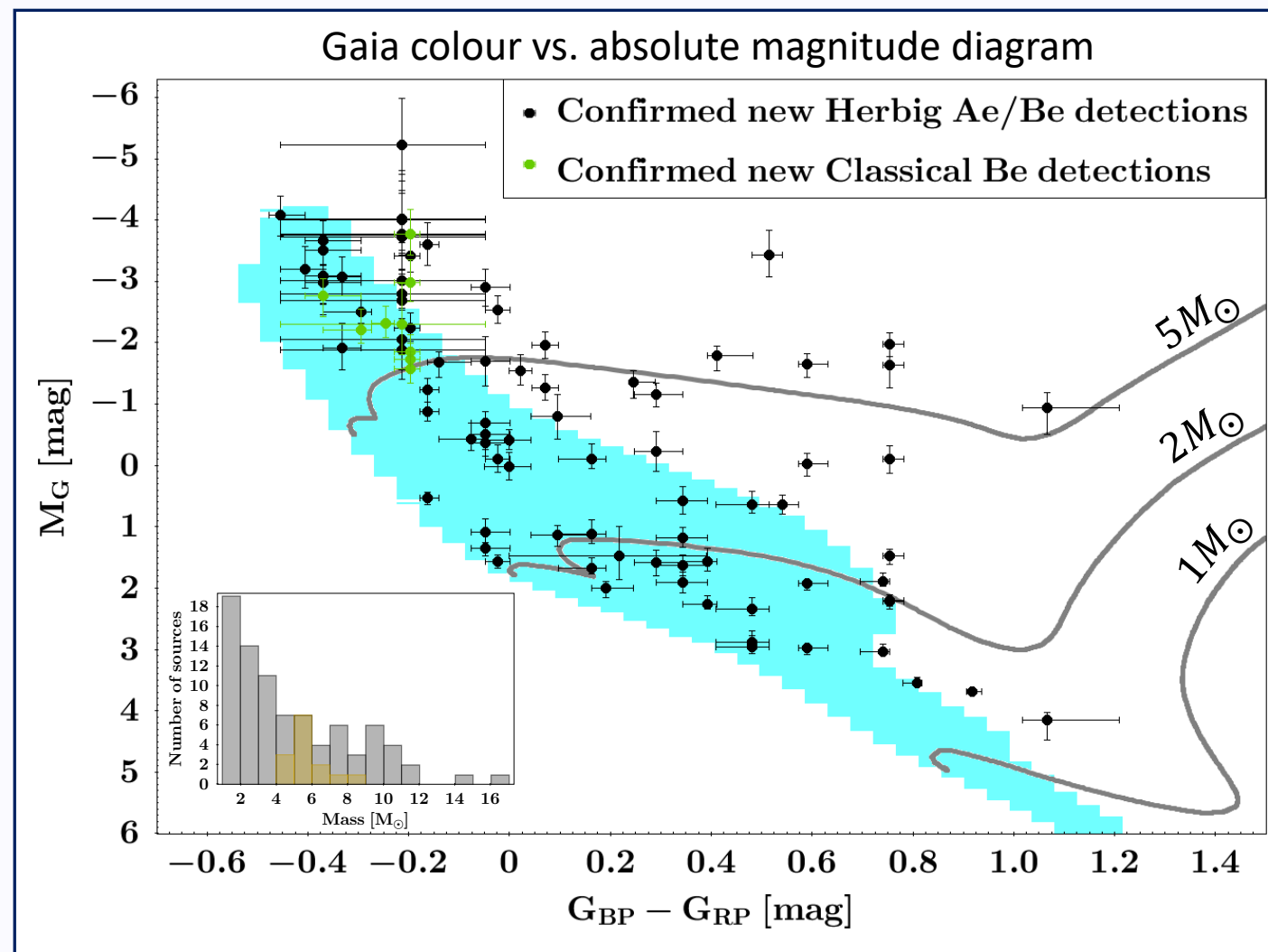
- 89% of the observed Herbig Ae/Be candidates are indeed of a Pre-Main Sequence nature.
- 14/14 of the observed Classical Be candidates display line broadening and other spectral characteristics typical of Classical Be objects.
- 6/7 of the observed catalogue tagged contaminants are not Pre-Main Sequence or Classical Be, and hence were correctly tagged in the published catalogues.

These independent observations provide further support for the high quality and accuracy of the new catalogues

Independent assessment of catalogue precision $\gtrsim 90\%$.

References:

- Vioque, M., Oudmaijer, R. D., Schreiner, M., et al. 2020, A&A, 638, A21
Wichittanakom, C., Oudmaijer, R. D., Fairlamb, J. R., et al. 2020, MNRAS, 493, 234
Vioque, M., Oudmaijer, R. D., Baines, D., et al. 2018, A&A, 620, A128



Theoretical Pre-Main Sequence tracks in grey and Main Sequence in blue