Massive-star clusters in the Gaia-ESO Survey

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Gaia-ESO Survey (GES)

- The Gaia-ESO Survey (GES) is a public, spectroscopic survey.
- The group of more the 300 Co-Investigators is led by Co-PIs Gerry Gilmore and Sofia Randich.
- GES uses the VLT-Flames instrument on UT2 for the observations, with both the Giraffe and UVES fibres.
- 300 nights of observation are foreseen, spread over 5 years.
- The survey started observations on the last day of 2011.
- GES studies the formation and evolution of the Milky Way and its stellar populations: substructure of the halo, nature of the bulge, formation of thick and thin disks, dynamical and stellar evolution of open clusters
- Some 60 old clusters (> 100 Myr) will be observed, and 40 young clusters, which includes 13 with massive-star content.

Gaia-ESO Survey (GES)

- With the massive star data from the GES, we hope to
  - Test stellar evolution modelling
  - Test rotational mixing
  - Upper part of the Initial Mass Function
  - Be stars
  - Stellar wind clumping
  - Galactic abundance gradients

- The clusters studied so far are:

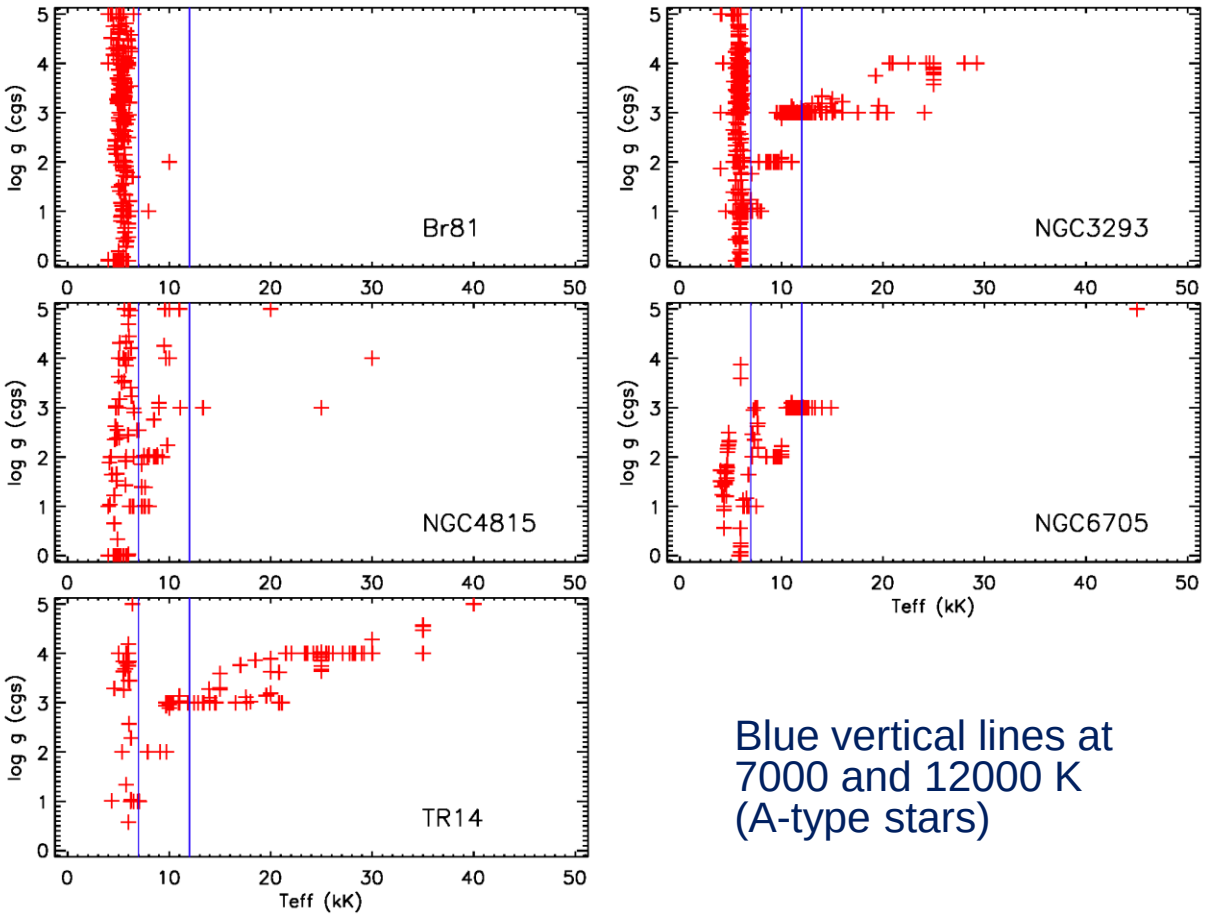
Cluster	Age	Distance (kpc)	Galactocentric distance (kpc)
Berkeley 81	1 Gyr	3	5.8
NGC 4815	0.5 Gyr	2.5	6.9
NGC 6705	250-300 Myr	1.9	6.1
NGC 3293	10 Myr	2.3	7.7
Trumpler 14	1-3 Myr	2.3	7.6

Stellar parameters – all stars

- A first determination is made for all the stars observed with the “hot-star” gratings.
- Other groups then apply more sophisticated models and synthetic spectra to part of the data.
- For the first determination, we use the Bertone et al. (2004) grid.
- We determine effective temperature (Teff), gravity (log g), metallicity ([Fe/H]), rotational velocity (v sin i), and radial velocity (RV).

Filter	Wavelengths
HR03	4033-4201
HR05B	4340-4587
HR06	4538-4759
HR09B	5143-5356
HR14A	6308-6701
UVES 520	4140-6210
UVES 580	4760-6840

T_{eff}, log g diagram

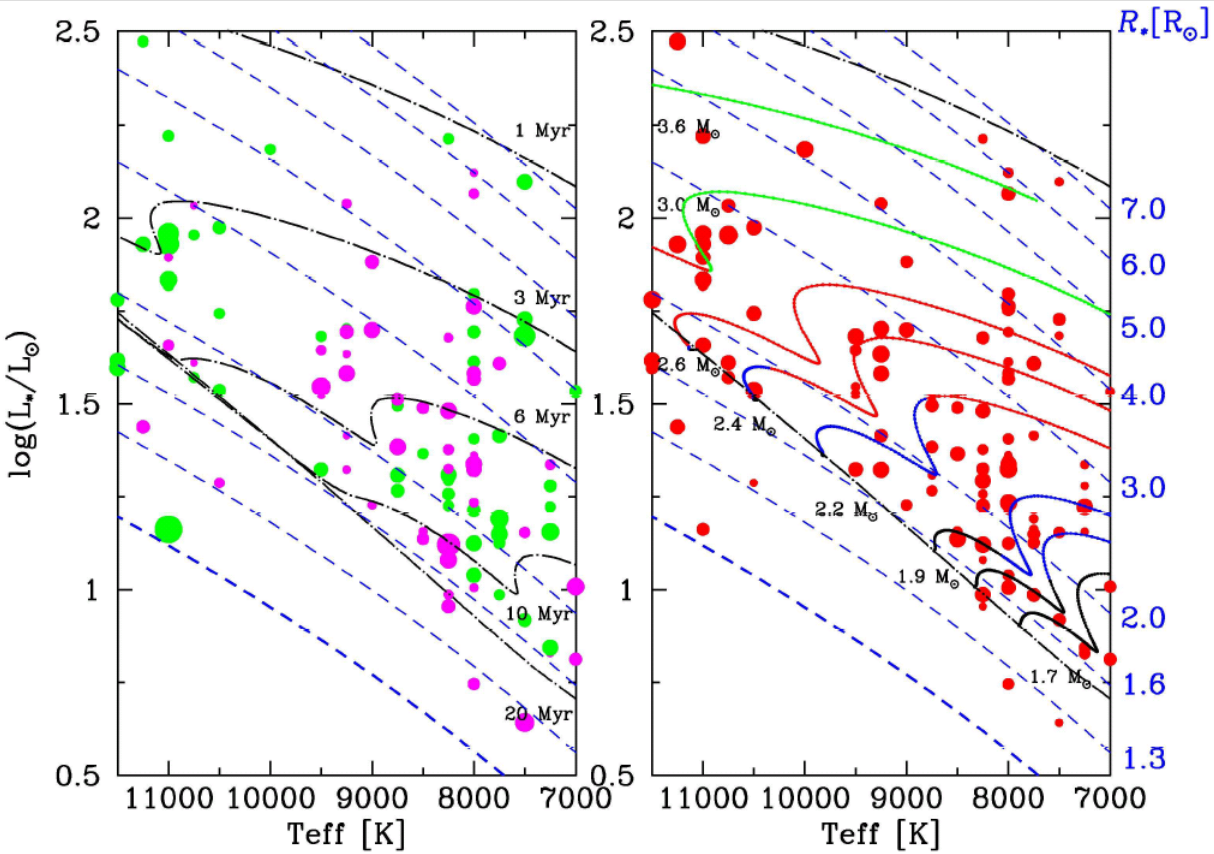


Blue vertical lines at 7000 and 12000 K (A-type stars)

- Older clusters have lost the hottest stars.
- Also for young clusters we have a number of non-members. This is a consequence of the observing strategy.
- The synthetic spectrum grid used covers a wide range of temperatures, and is therefore not the most sophisticated one for the massive stars.
- There are still problems with the interpolation of the spectra between the grid points.

A-type stars

- **NGC 3293: pre-MS stars**

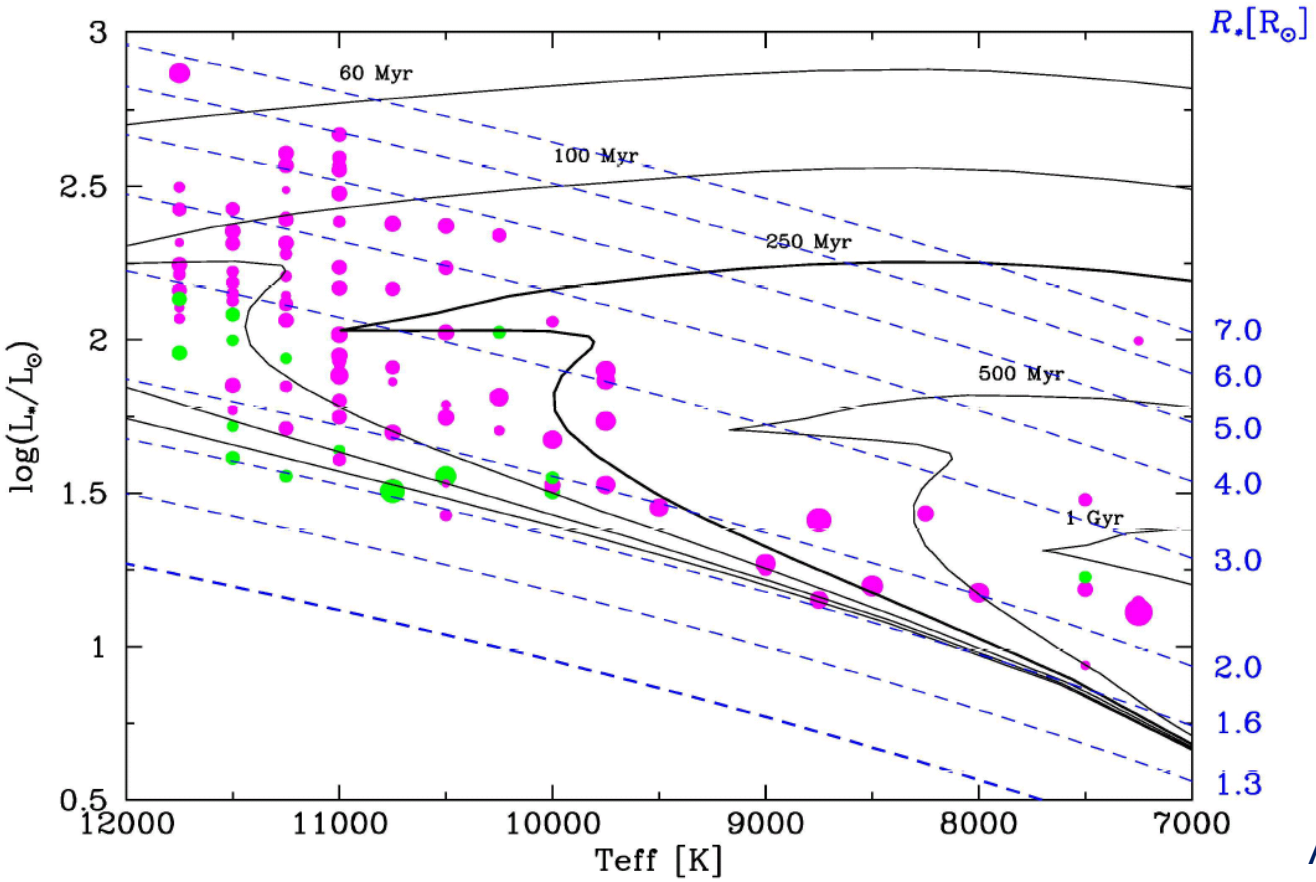


- The majority of stars in NGC 3293 are pre-MS stars contracting onto the ZAMS over 1 to 20 Myr (pre-MS isochrones are shown with dash-dotted lines).
- The bottom dash-dotted line marks the ZAMS, while the solid lines show pre-MS evolutionary tracks for 1.7 to 3.6 $M_{\odot}$.

A. Lobel

A-type stars

- **NGC 6705: post-ZAMS (cluster age 250-300 Myr)**



- The majority of the A stars in NGC 6705 are already on (or moving away from) the ZAMS.
- The solid lines are post-ZAMS isochrones.

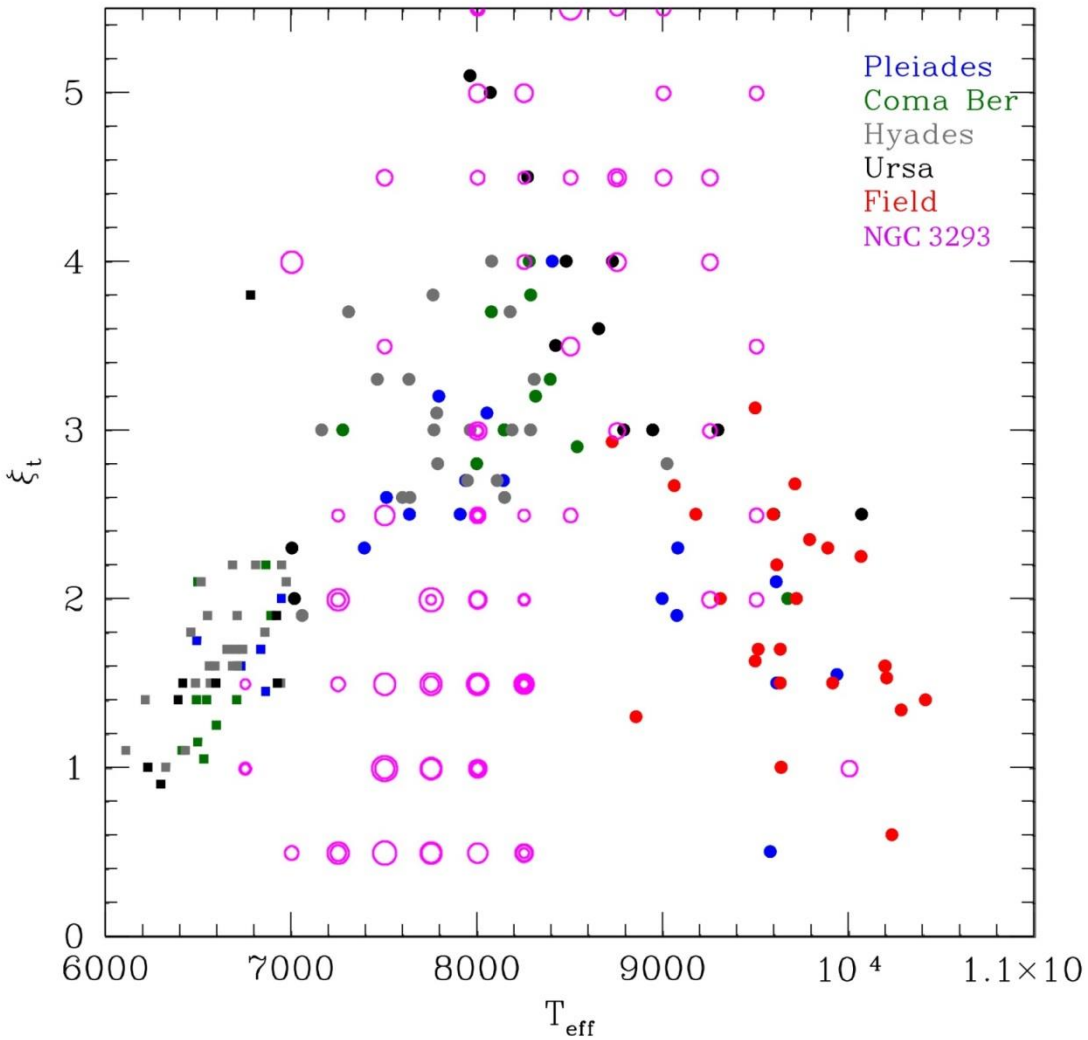
A. Lobel

A-type stars

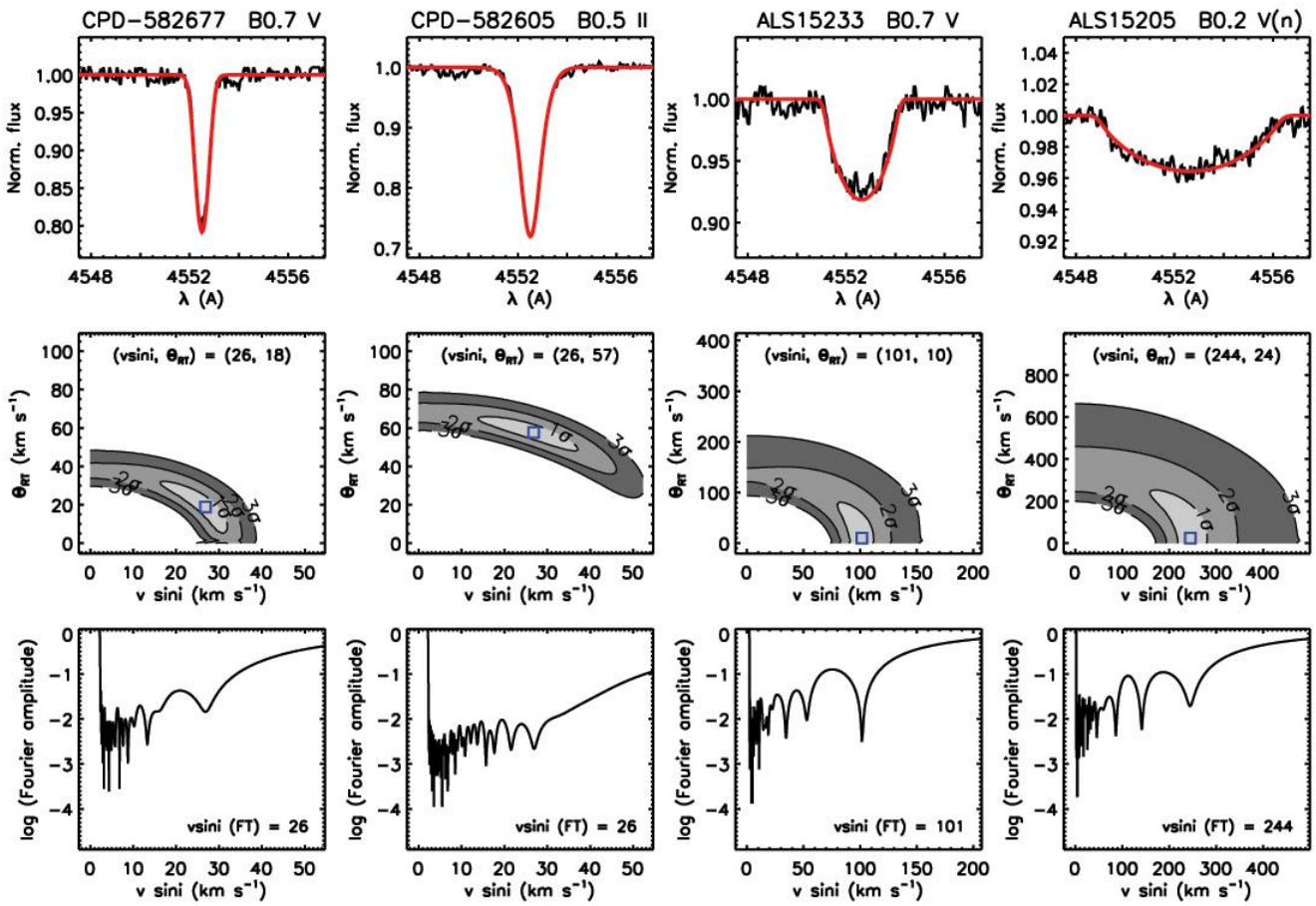
NGC 3293: microturbulence

- Microturbulent velocity as a function of effective temperature for the A and F stars.
- Open magenta symbols are members of the young open cluster NGC 3293.
- The size of the symbols is inversely proportional to log g ranging between 1.0 and 5.0 dex.
- The maximum in microturbulent velocity is observed around 8000 - 9000 K.

Gebran et al. 2013



B-type stars – Tr 14



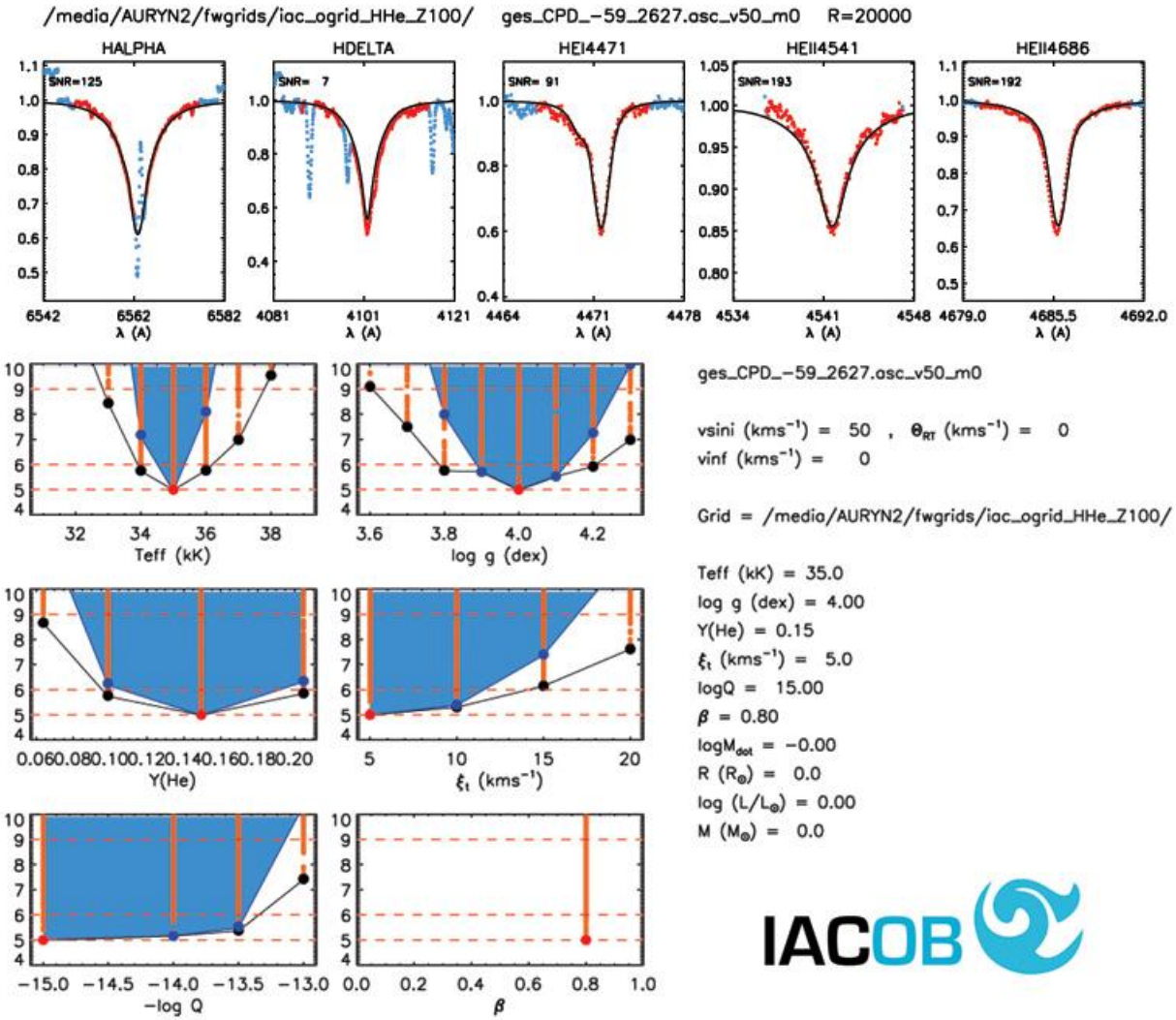
Four examples of rotational velocity determination in late-O and early B-type.

It uses a combined Fourier transform (FT) + goodness of fit (GOF) technique.

S. Simón-Díaz

O-type stars – Tr 14

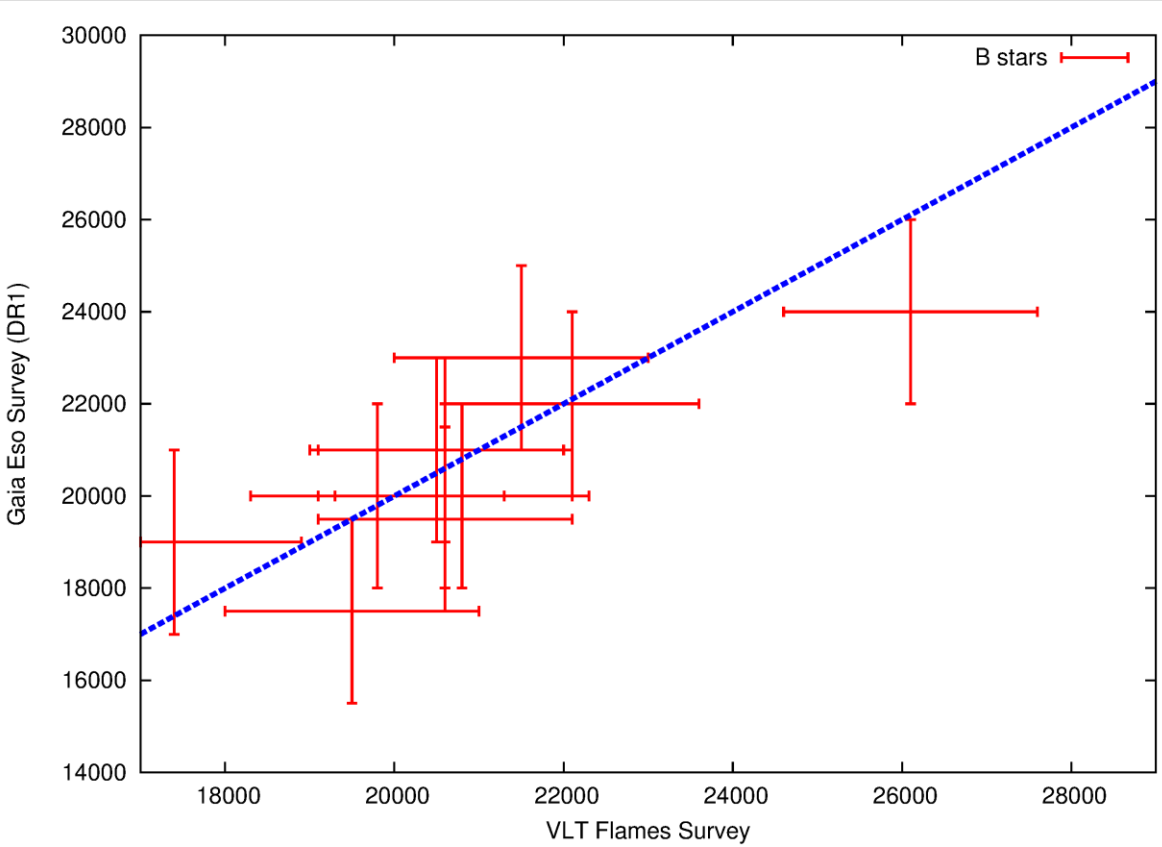
- IACOB-GBAT analysis of the O9.5V star in Carina CPD-59 2627.
- IACOB-GBAT is a fast grid-based automatized tool to perform quantitative spectroscopic analysis of large samples of O-type stars in a reasonable amount of time.
- Based on a vast grid of FASTWIND models and a chi2 fitting technique.



S. Simón-Díaz

B-type stars - NGC 3293

- **Comparison with Hunter et al. (2009)**

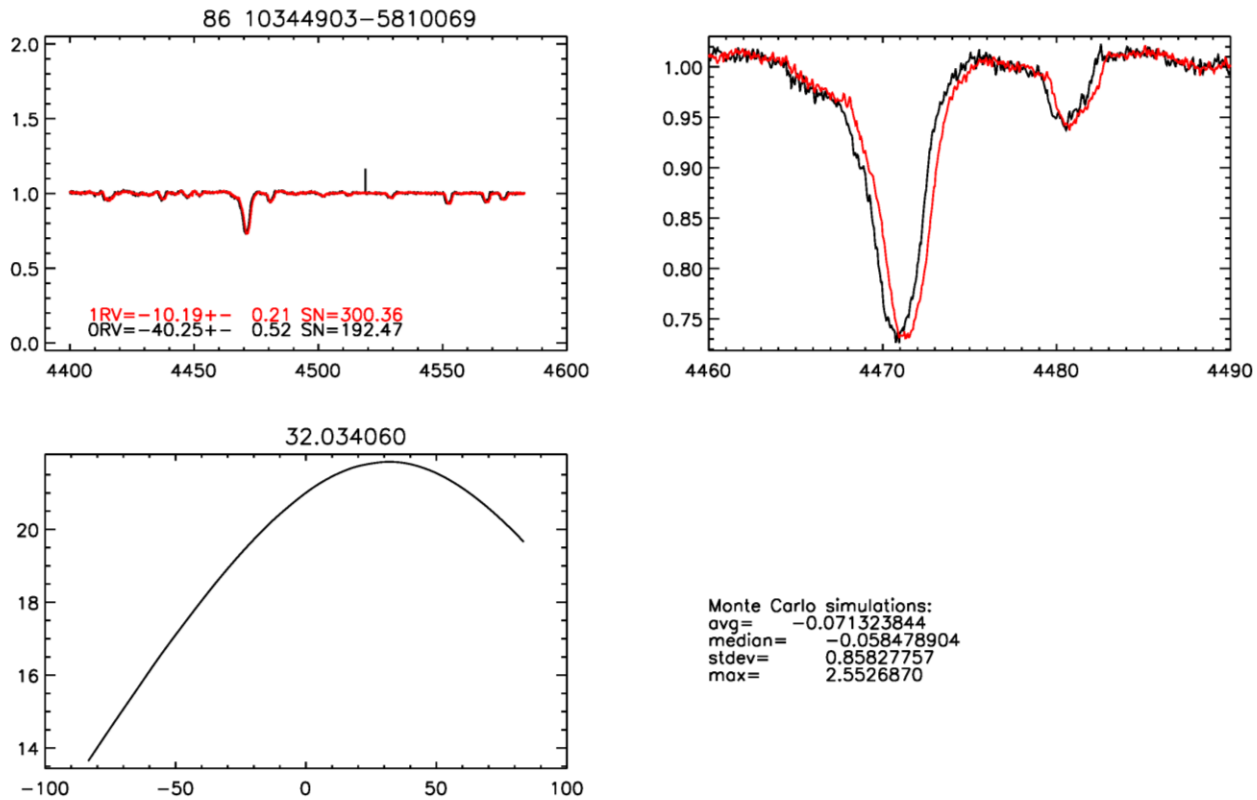


- We used GIRFIT (Frémat et al. 2005) to determine the astrophysical parameters of the B stars in NGC 3293.
- This program uses theoretical spectra computed with the SYNSPEC program on the basis of TLUSTY and/or ATLAS model atmospheres
- .
- We compare our results with those of Hunter et al. (2009) and we find good agreement between the two determinations.

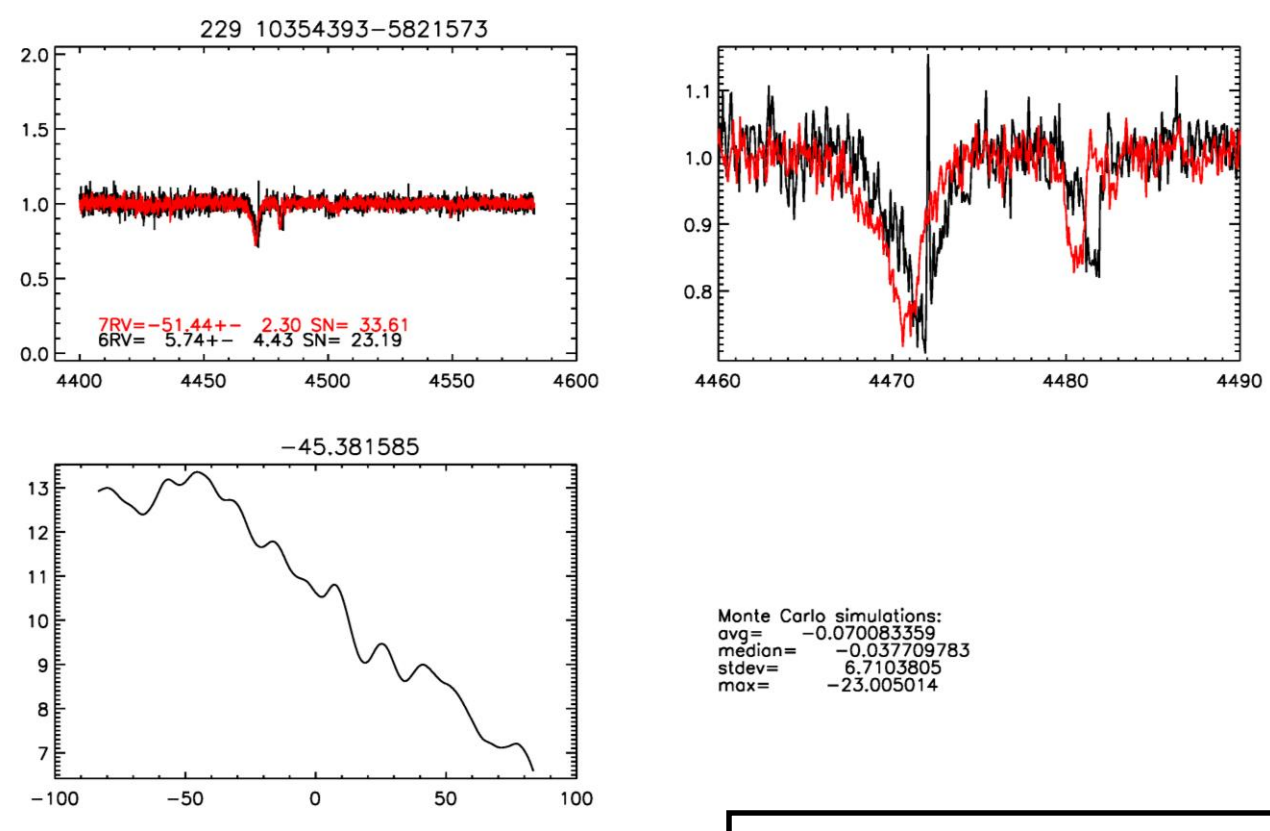
Semaan and Morel

Binarity in NGC 3293 and Br 81

- We use the repeat observation of the HR05 filter for NGC 3293 (HR09B for Br 81) to check for radial velocity changes that indicate binarity.
- We judge the significance of these changes by using Monte-Carlo simulations.
- The standard deviation on the Monte-Carlo result is also a good indicator of the radial velocity precision we can hope to attain.



Binarity in NGC 3293 and Br 81

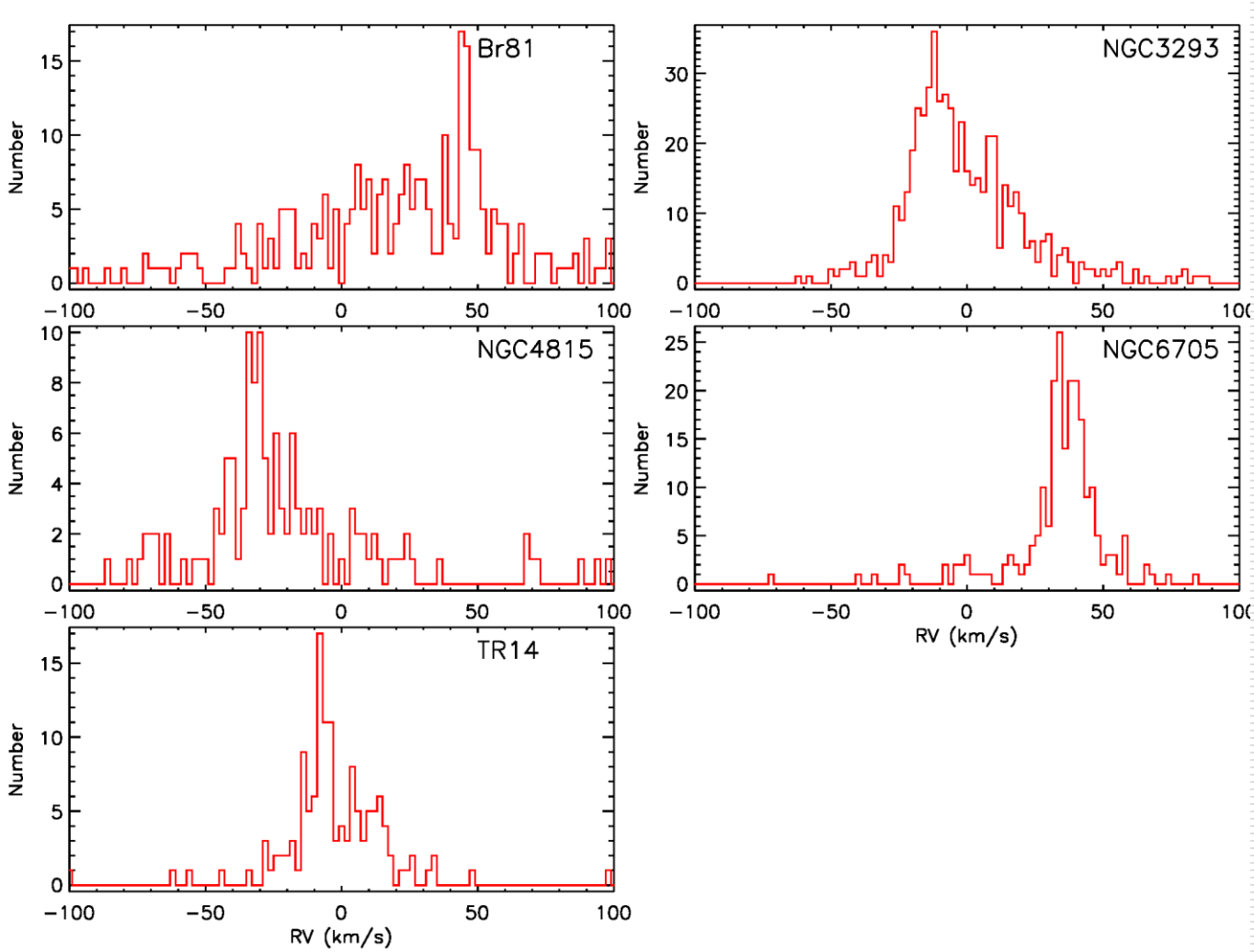


- "raw" binary fraction is based on just 2 epochs.
- Correction factors need to be applied to obtain the true binary fraction.

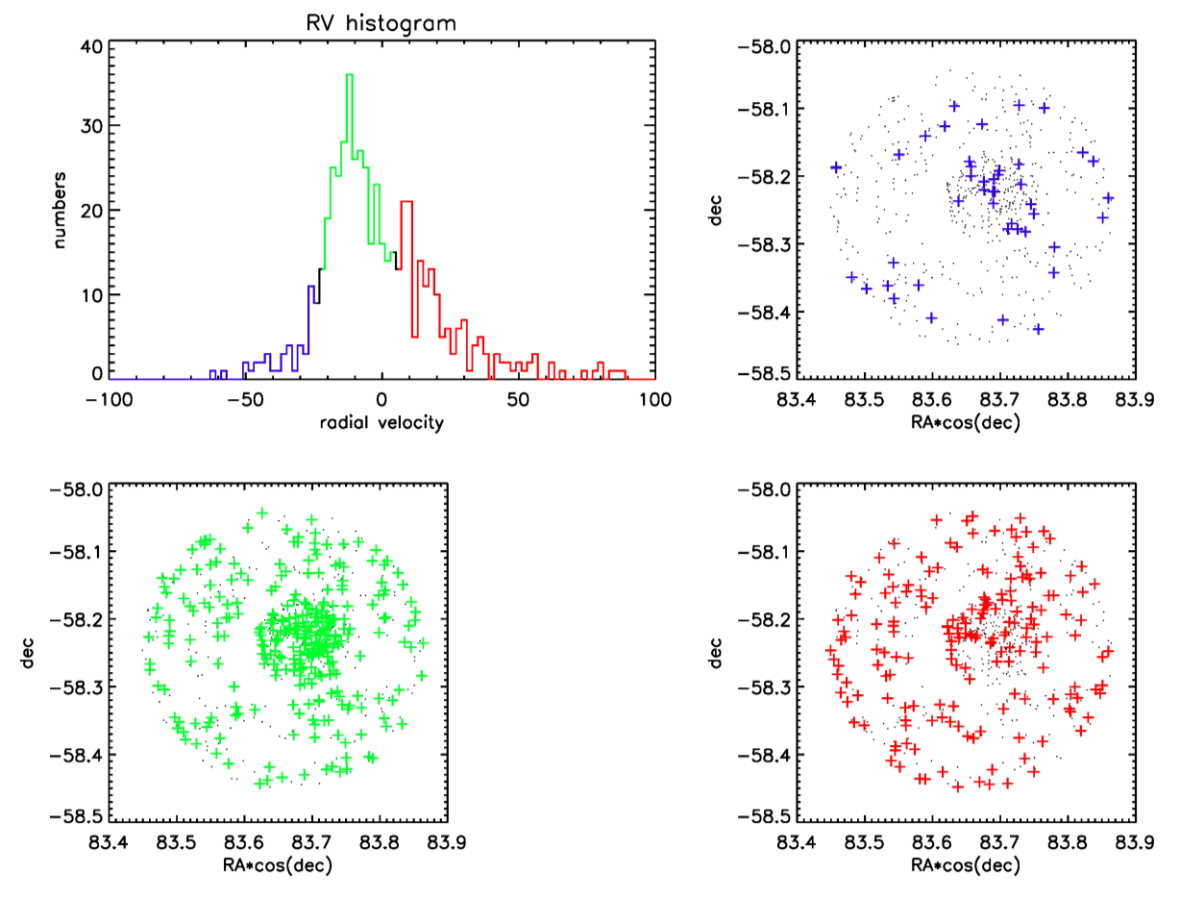
"raw" binary fraction NGC 3293: ~15 %
Br 81: ~ 5 %

Histogram of radial velocities (RVs)

We plot histograms of the radial velocities. These can help in determining cluster membership.



Cluster membership NGC 3293



- We split up the radial velocity histogram in three regions, and map them back on to their sky coordinates.
- The most frequent radial velocities map back to a large range in distances from the cluster centre.
- This suggests that NGC 3293 is larger than assumed so far.

Summary:

- Stellar parameter determination 5 GES clusters
  - Br 81, NGC 4815, NGC 6705, NGC 3293 and Tr 14
- A-type stars
  - NGC 3293 are pre-MS
  - NGC 6705 post-ZAMS
- Microturbulence A-type stars peaks at ~8000 K
- B-type stars: rotational velocity determination; good agreement with previous determinations stellar parameters
- O-type stars: analysis started
- Radial velocities: binary fraction + membership