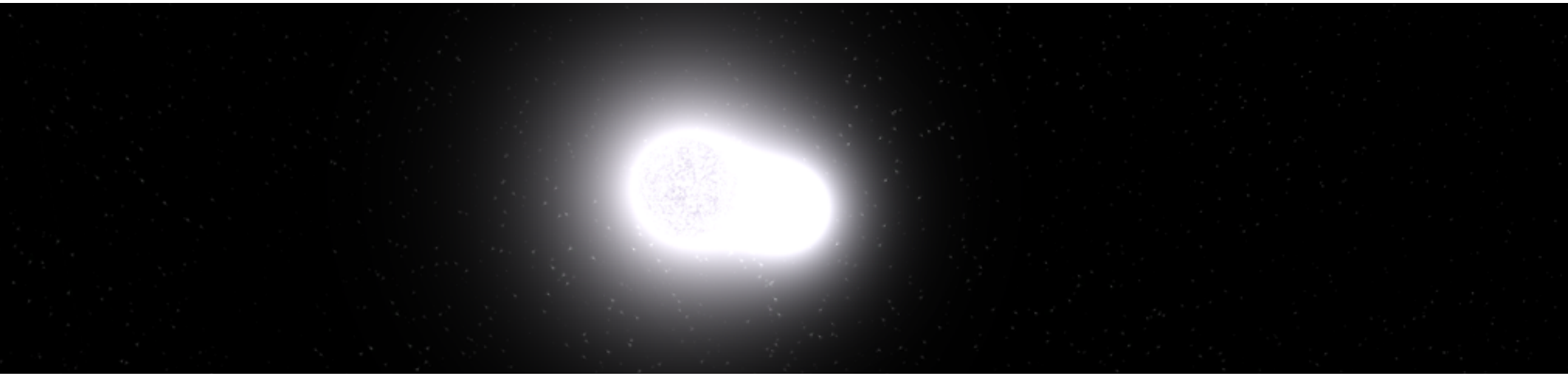
Spectroscopic Binaries (SBs) in the Gaia-ESO Survey



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Contact Group Meeting – Brussels – 2017-09-17

The Gaia-ESO survey

➔ Ground based, mid + high-resolution survey (Gilmore+ 2012, Randich+ 2013)

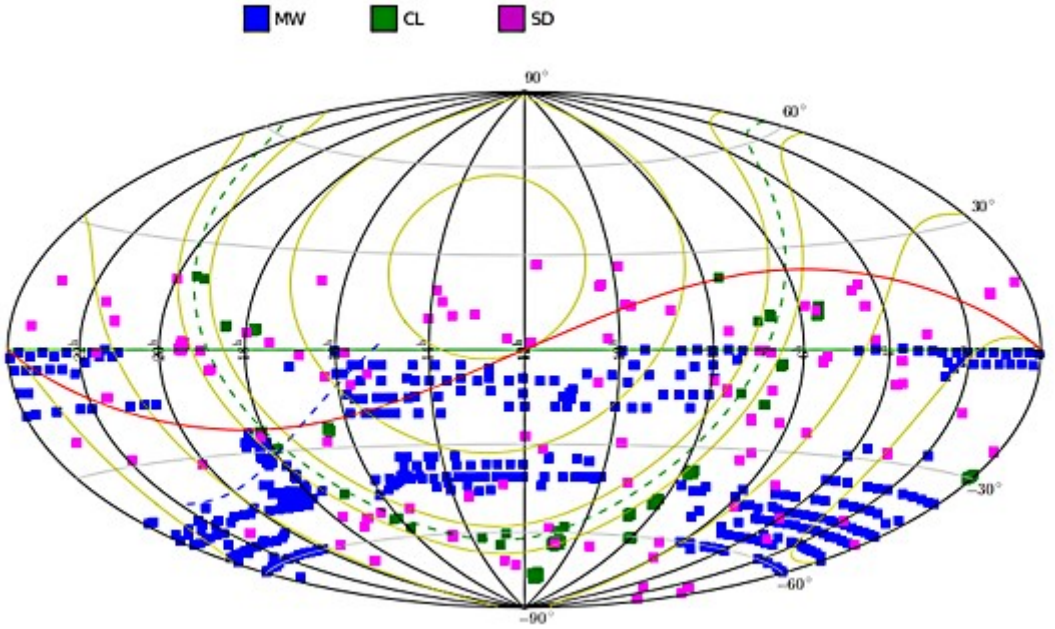
➔ 10^5 MW stars: bulge, thin and thick discs, halo, stellar clusters of all ages

➔ Stars in various evolutionary stages, but mainly MS and RGB stars

➔ Aims

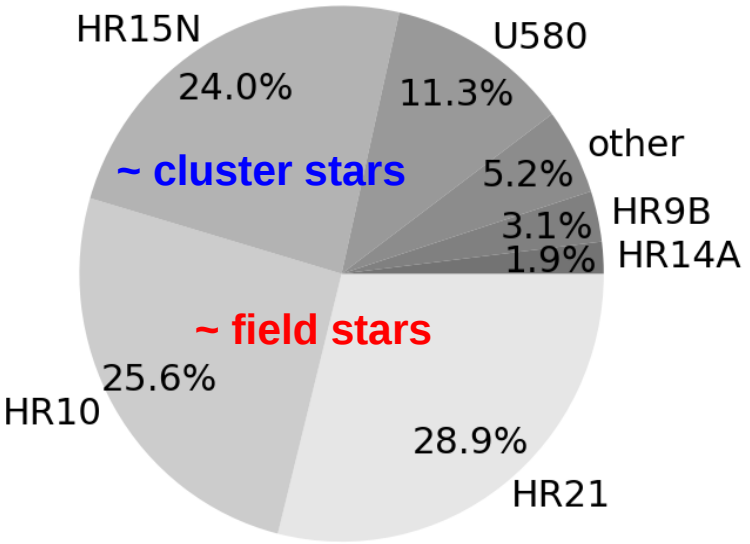
⟹ Kinematical and chemical characterisation of stellar populations

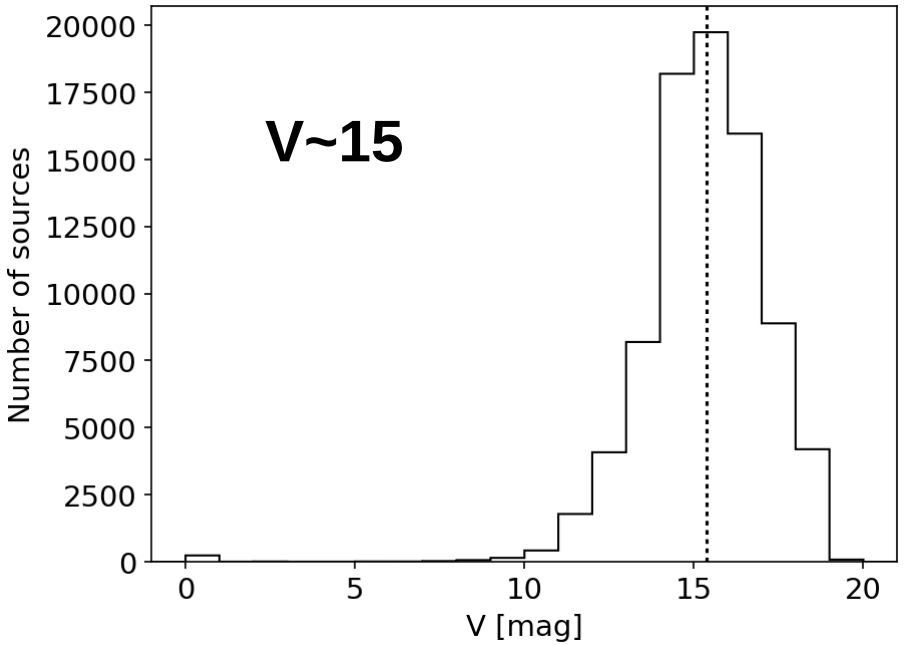
⟹ Constrain formation history of the MW

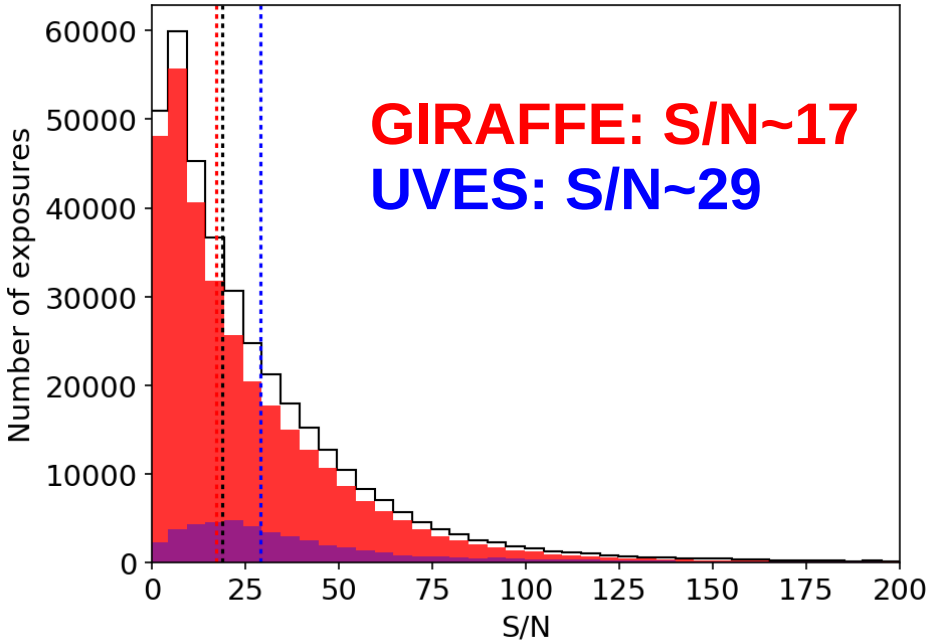


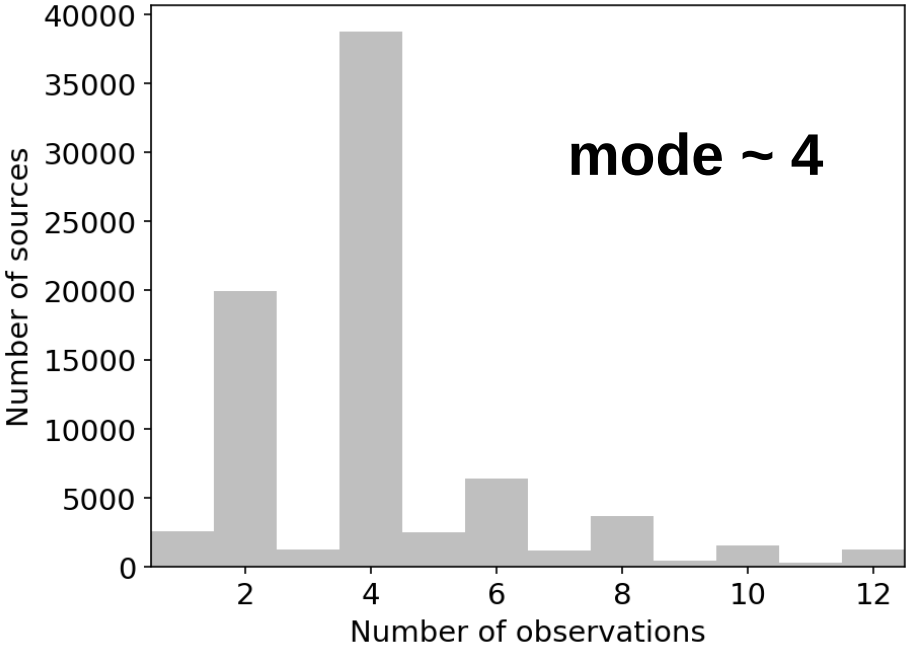
Observed fields (*src*: www.gaia-eso.eu)

The Gaia-ESO survey







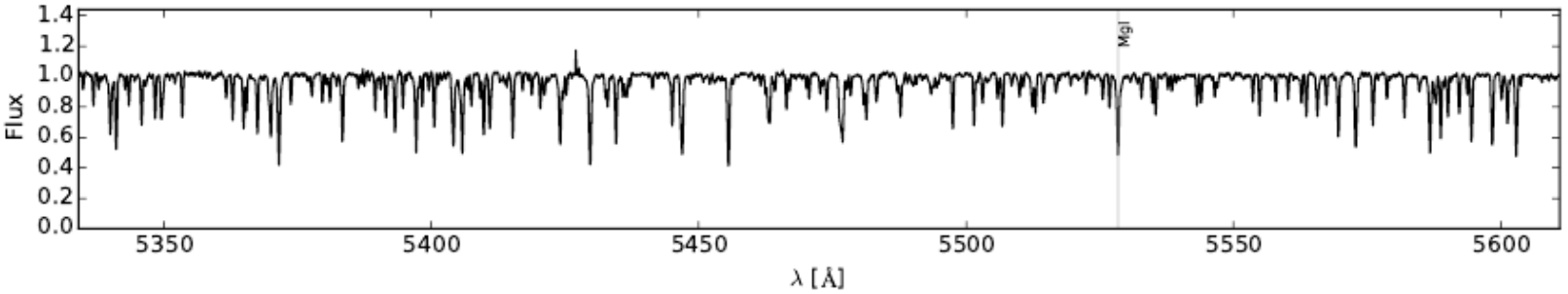


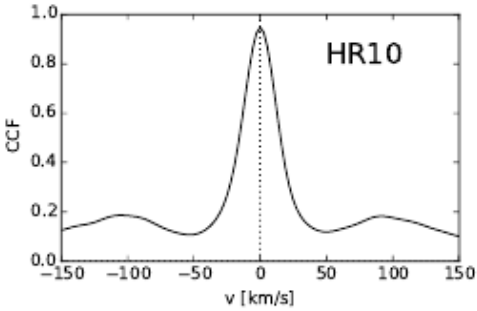
How to measure radial velocities?

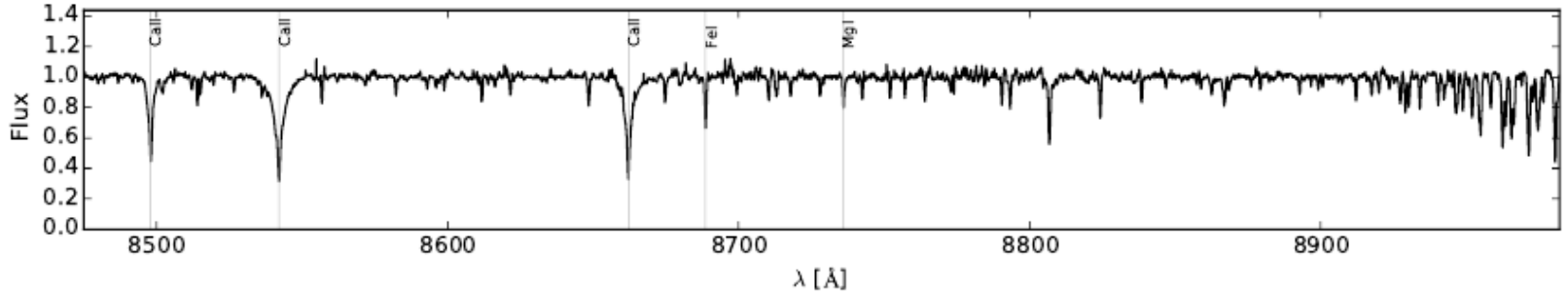
Cross-Correlation Function (CCF):

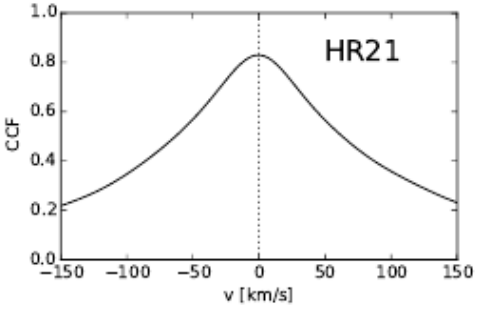
$$CCF(v) = \int_{-\infty}^{+\infty} f(u)\, g(u+v)\, du$$

f spectrum
g template









How to measure radial velocities?

➔ Detection Of Extrema (DOE) code

➔ CCF and its successive derivatives used to detect multiple peaks in the CCF

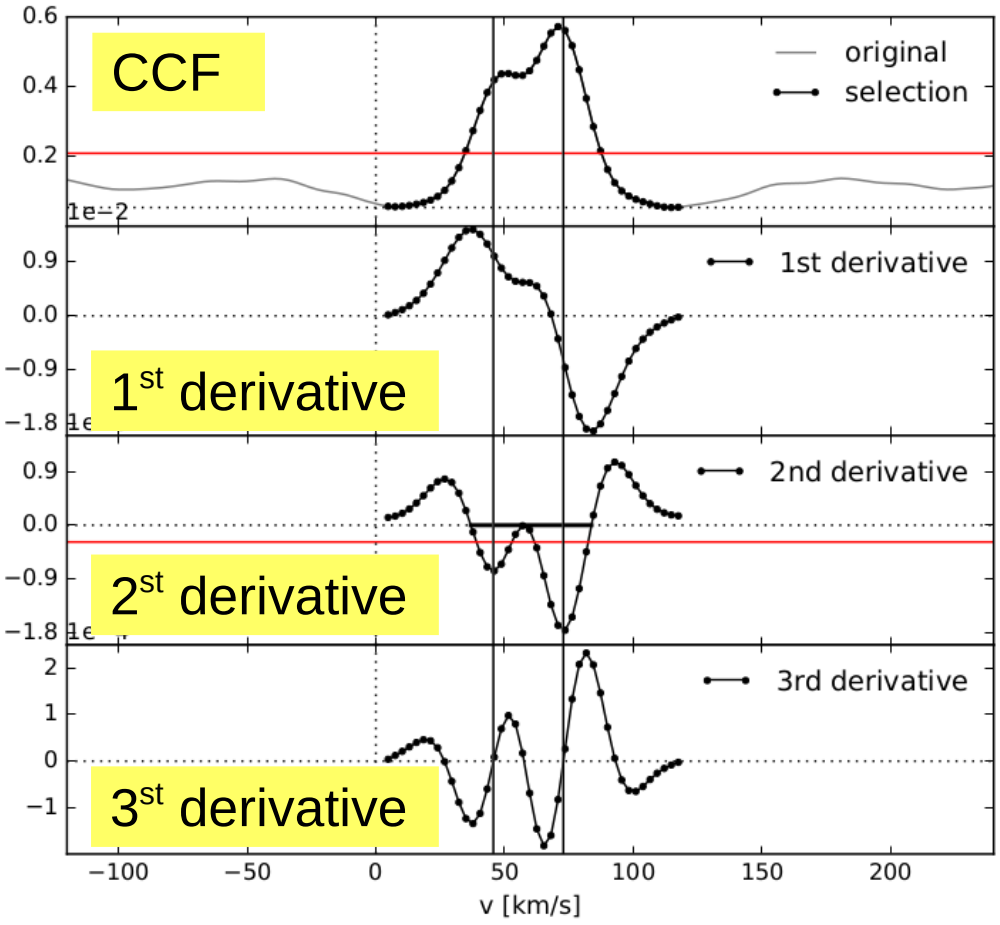
➔ Derivatives obtained by convolving the CCF with the derivative of a Gaussian kernel

⟹ technique used in signal processing (e.g., Foster 2013)

⟹ allows to smooth and derive simultaneously

➔ CCF computed by the data reduction node of the GES collaboration

CCF = Cross-Correlation Function



Strategy for SBs detection

see Merle et al. (in prep.)
for the analysis of iDR5

GES
Current release
~380000 CCFs

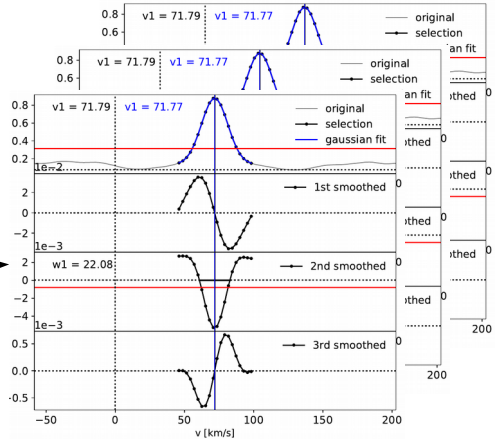
DOE

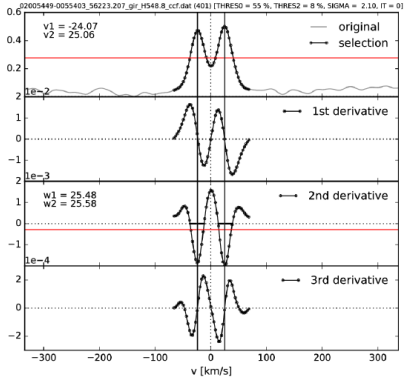
Single-peaked
~ 320000 CCF
SB1

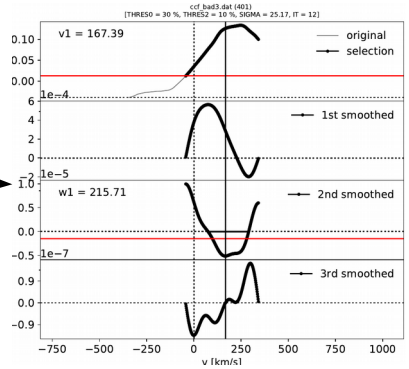
Multi-peaked
~ 24000 CCF
SB*n*, *n*≥2

Pathological
~32000 CCF

see Merle et al. 2017 arXiv:1707.01720
for the analysis of iDR4
see Van der Swaelmen et al. (in prep.)
for the analysis of iDR5



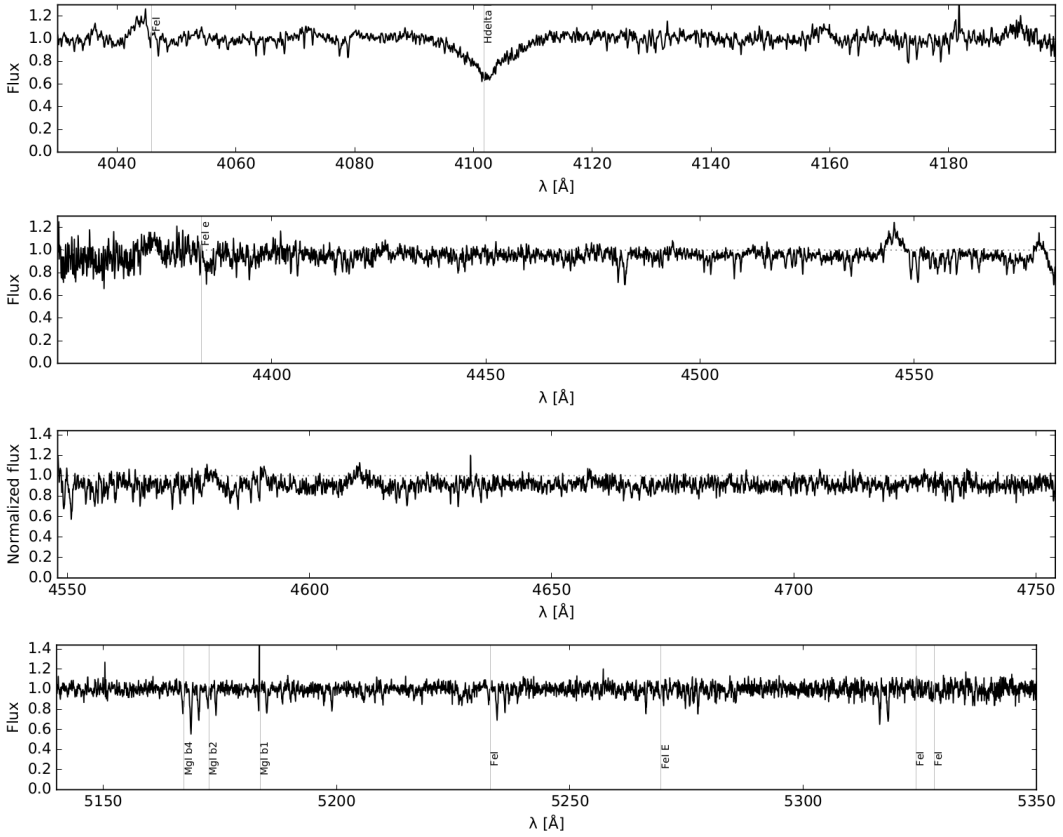


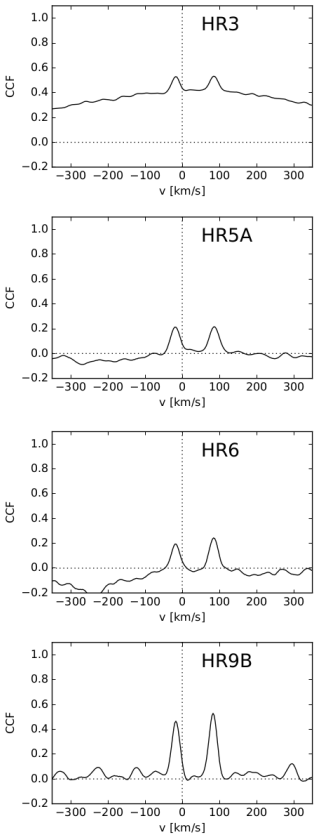


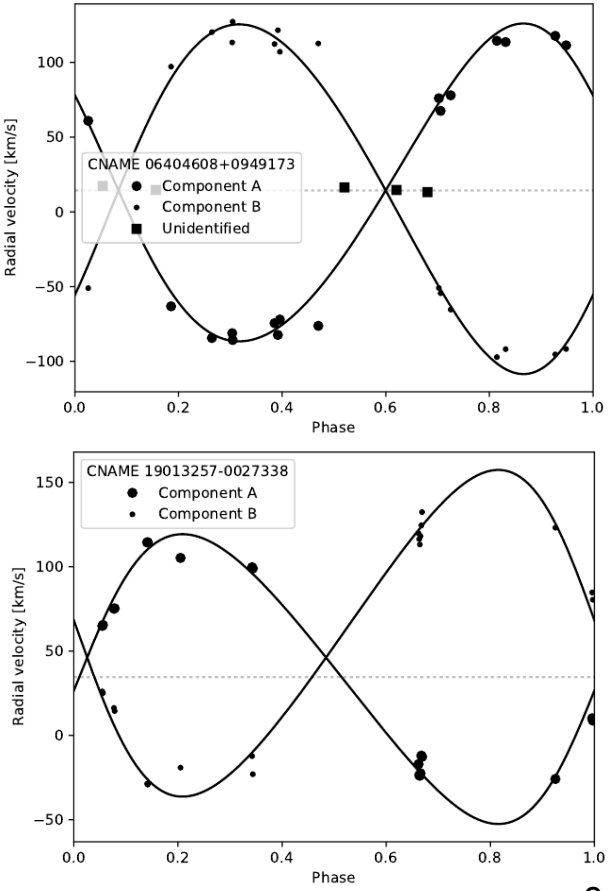
GES SB2 candidates

Confidence flag	A	B	C	Total
SB2	127	107	108	342
SB3	7	1	3	11
SB4	1	0	0	1

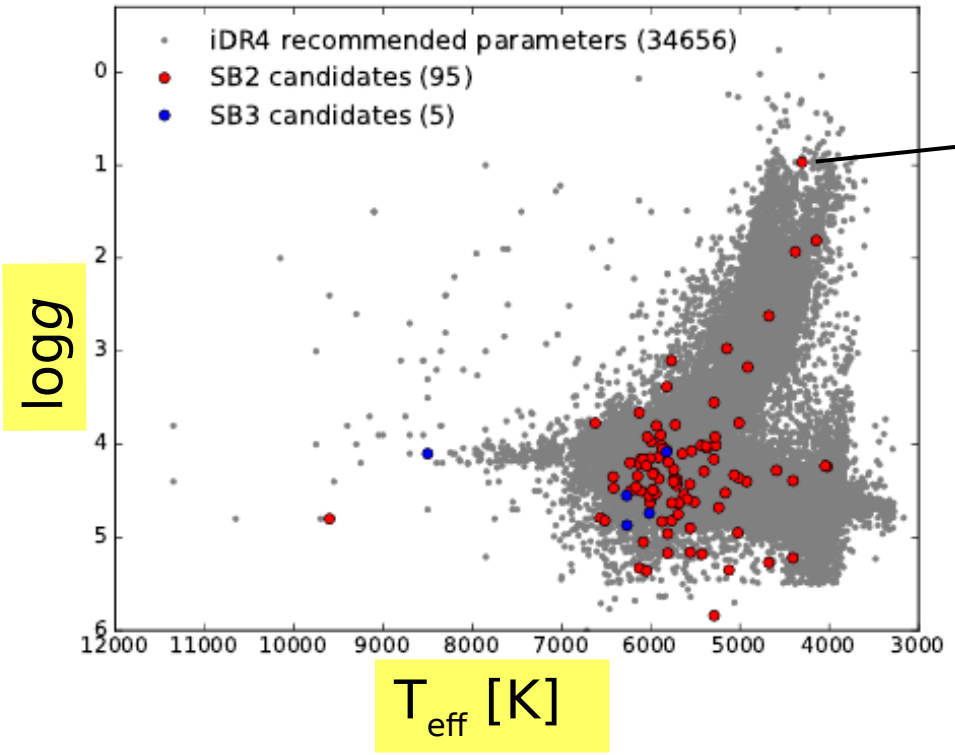
A: probable
B: possible
C: tentative

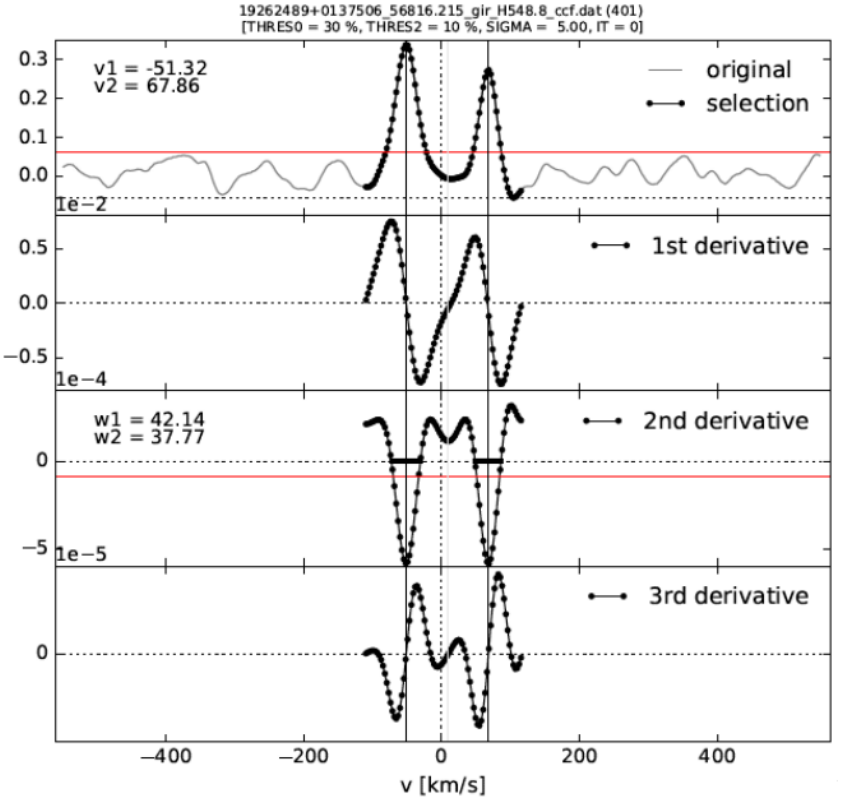






Twin giant stars?





60% of Gaia-ESO stars have measured atmospheric parameters

30% of SB2 candidates have measured atmospheric parameters

A short period spectroscopic binary with 2 giants

Need a double confirmation on:

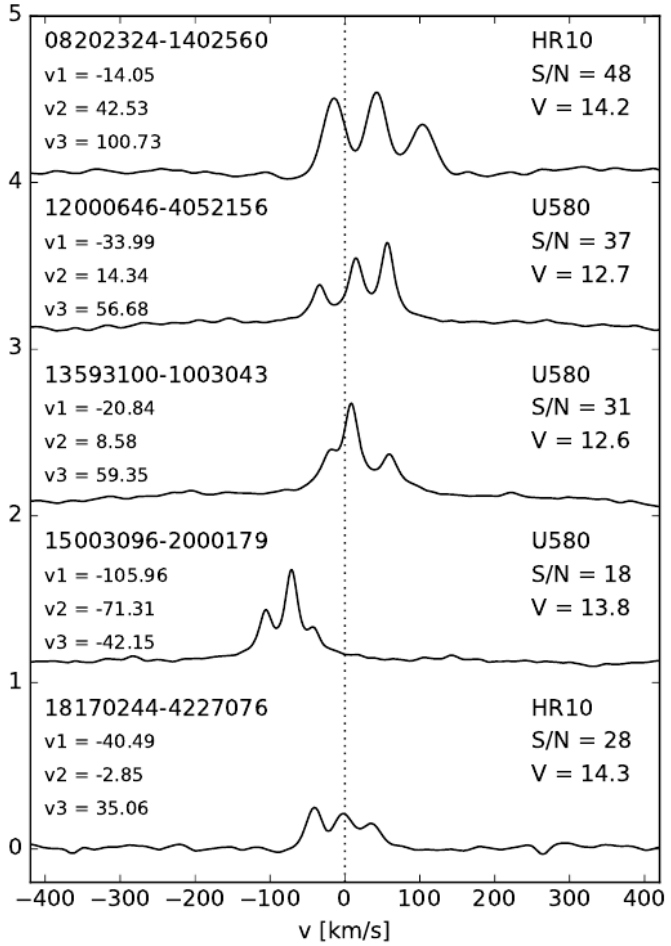
- The binarity
- The giant nature star

Follow-up required!

GES SB3 candidates

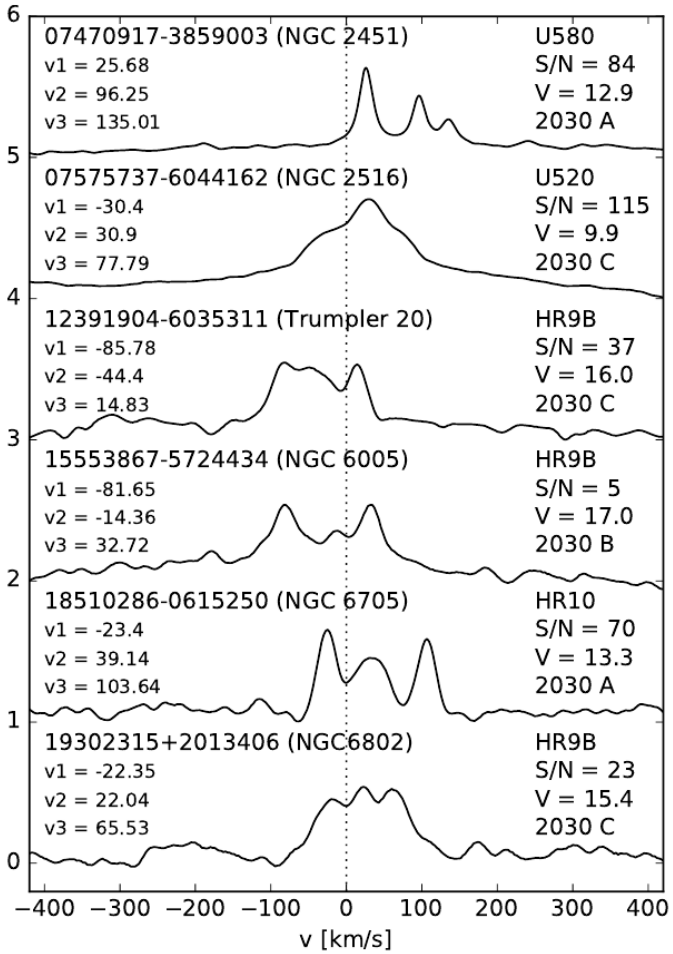
Confidence flag	A	B	C	Total
SB2	127	107	108	342
SB3	7	1	3	11
SB4	1	0	0	1

A: probable
B: possible
C: tentative



← **In the field**

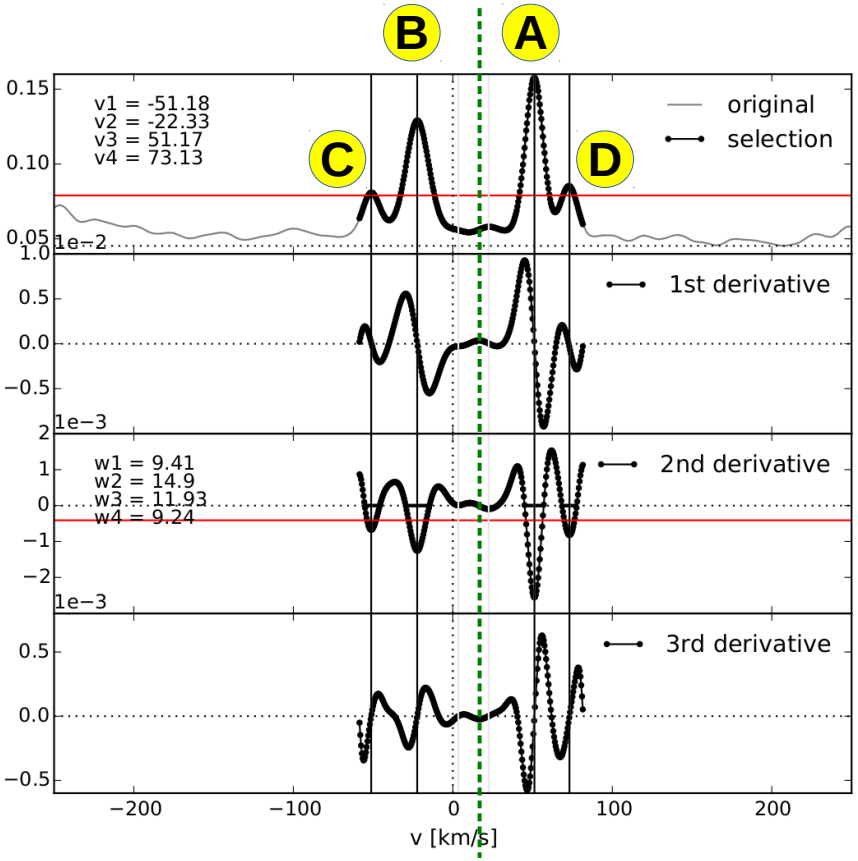
In clusters →



GES SB4 candidate

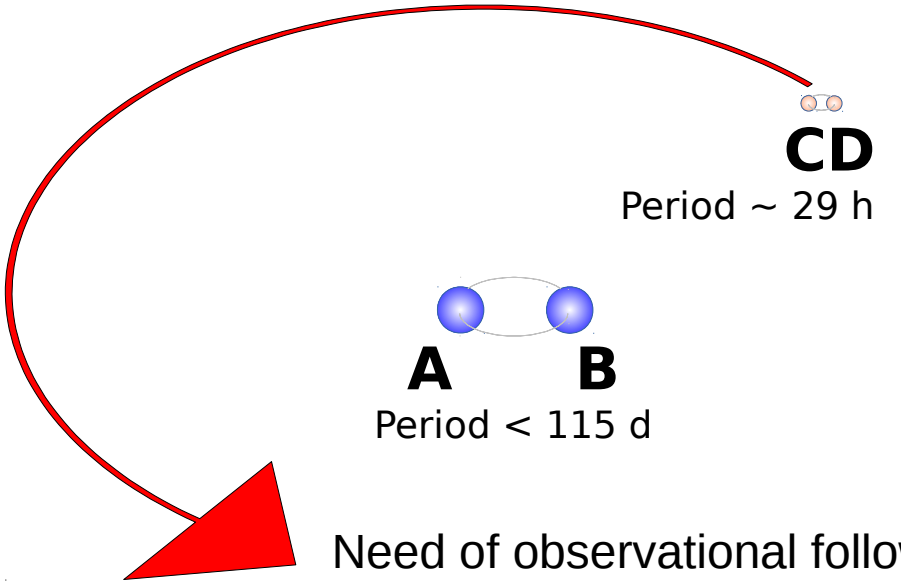
Confidence flag	A	B	C	Total
SB2	127	107	108	342
SB3	7	1	3	11
SB4	1	0	0	1

A: probable
B: possible
C: tentative



Cluster velocity ~ 15 km/s

System HD 74438 (V = 7.6)
in IC 2391



Need of observational follow-up to confirm the quadruple nature of this system

SB1 detection: strategy

- χ^2-test on radial velocities per star: $\chi^2_{N-1} = \sum_{i=1}^{N} \left(\frac{v_i - \bar{v}_i}{\sigma_i} \right)^2$

with $\begin{cases} v_i = v_{DOE} - v_{\Delta setup} \quad \text{(HR10 as reference setup)} \\ \sigma_i = \sqrt{\sigma^2_{emp}(R, S/N, T_{eff}, v \sin i) + \sigma^2_{DOE}} \end{cases}$

↳ using Jackson et al. 2015, A&A, 580, A75

- Check with the F2 statistics (Wilson & Hilferty 1931):

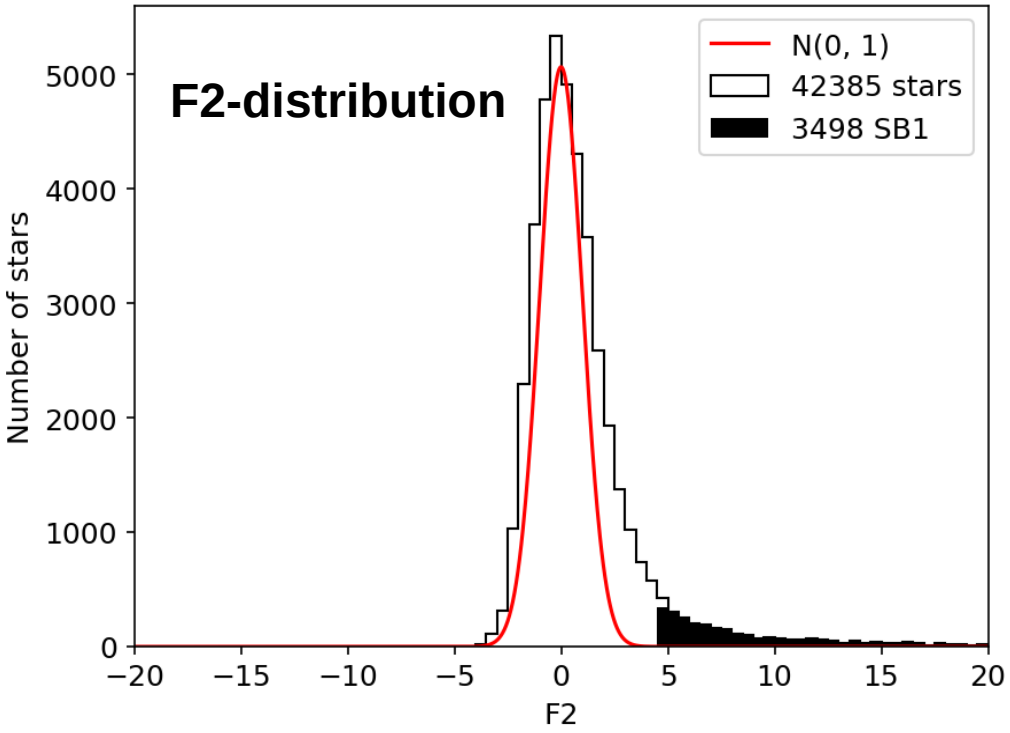
$$F2 = \sqrt{\frac{9(N-1)}{2}} \left[\sqrt[3]{\frac{\chi^2}{N-1}} + \frac{2}{9(N-1)} - 1 \right]$$

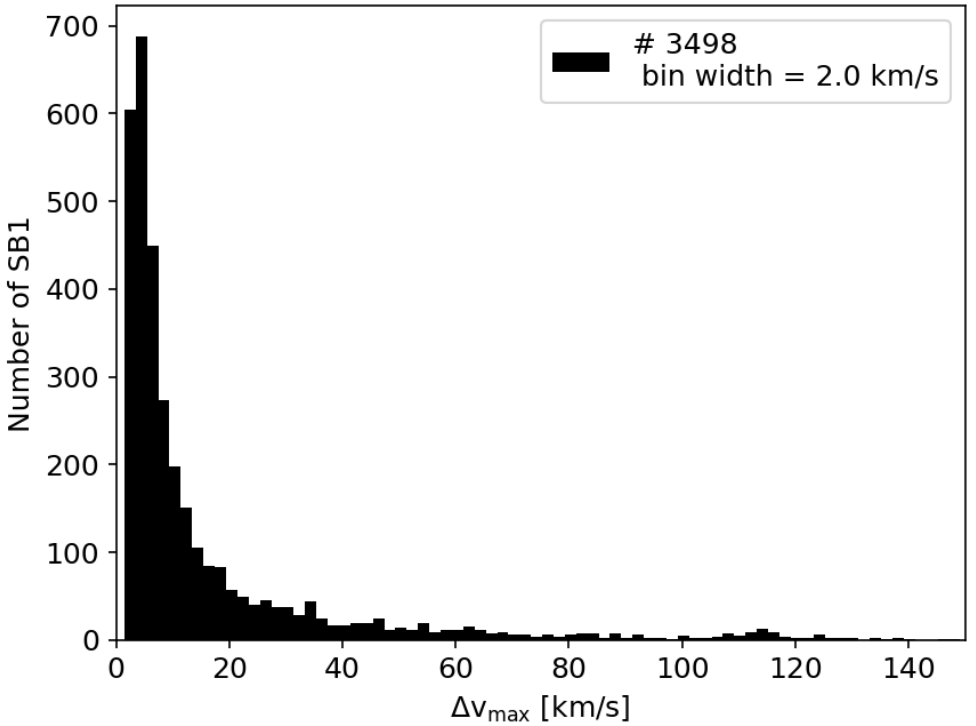
for the control of the normality of the uncertainties

GES SB1 sample: results

Minimum number of exposures : 3
Minimum SNR: 2
Bound factor for σ-clipping: 2.5
Confidence level: 99.9999%

➡ **~3500 SB1 candidates**

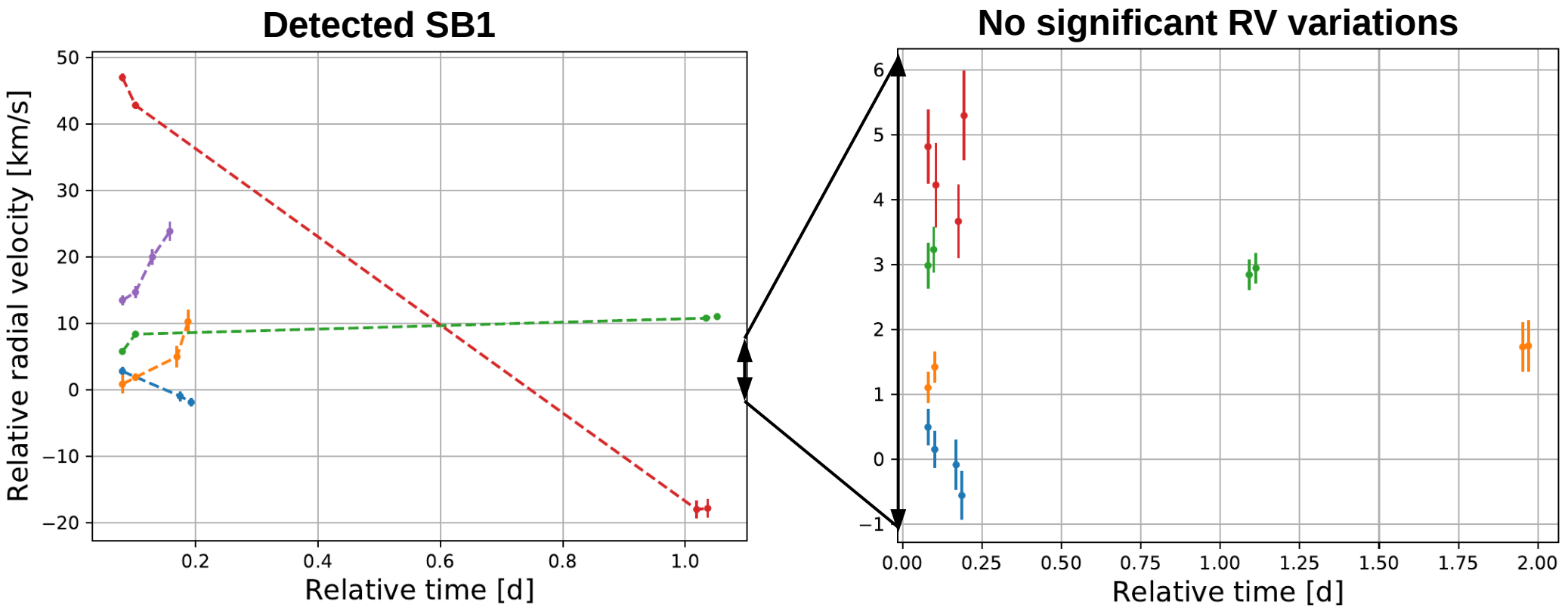




Preliminary binary frequency ~30 %

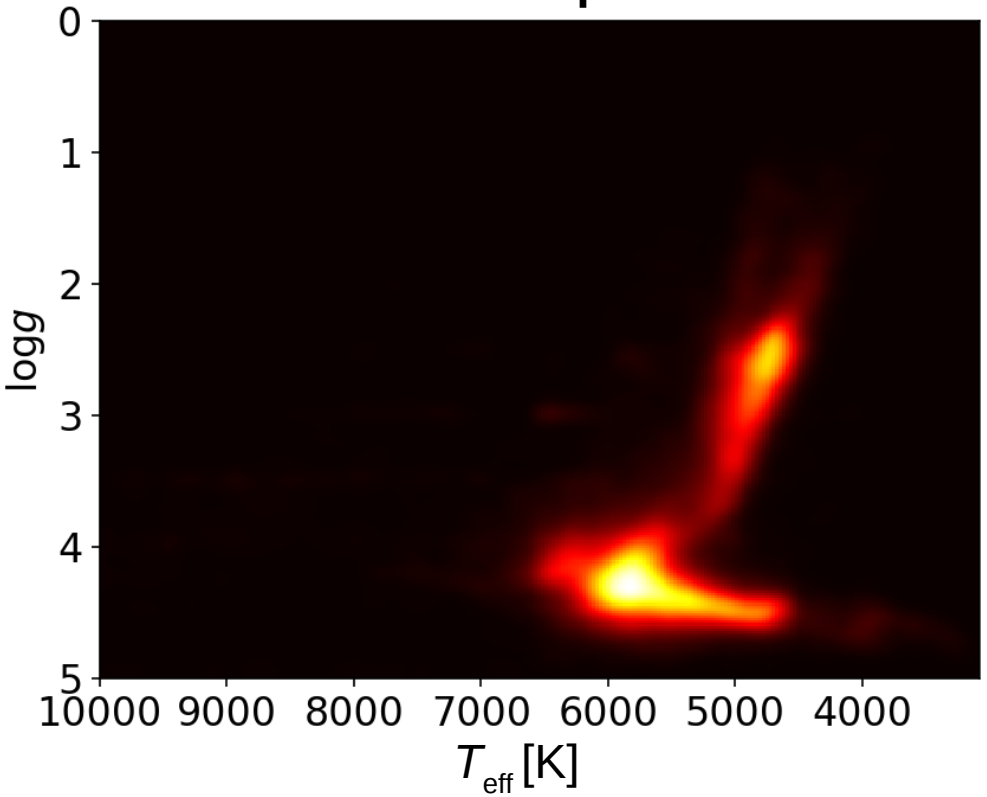
GES SB1 sample: results

SB1 in the field: ~ 4 exposures

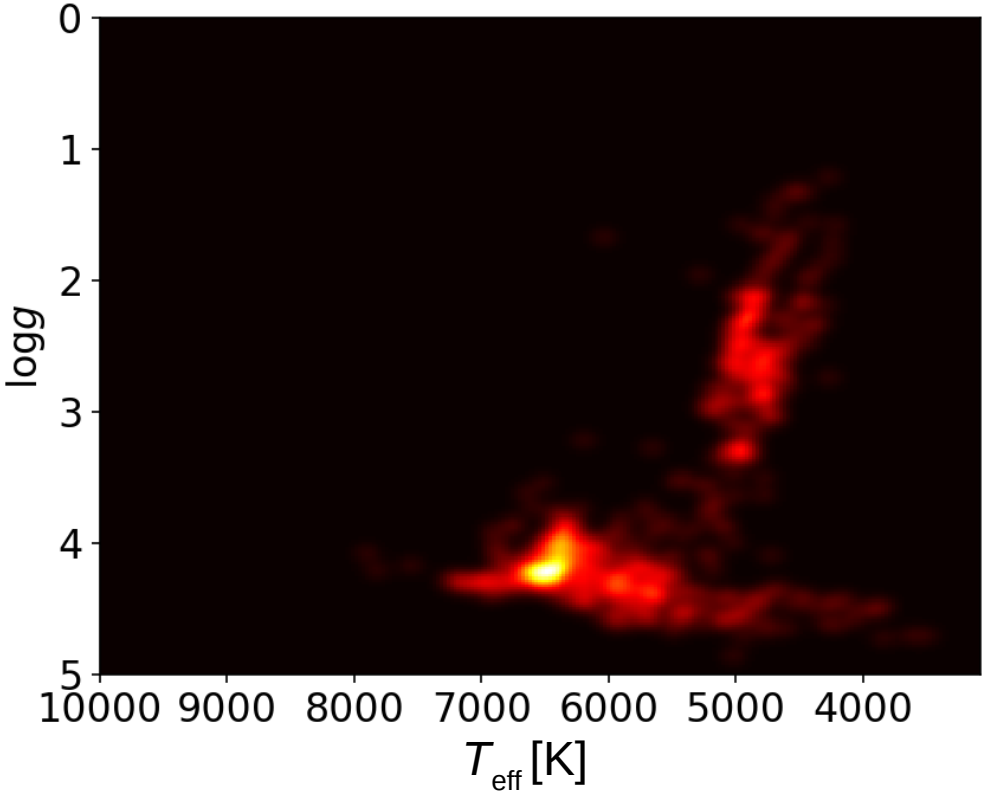


GES SB1 sample: preliminary analysis

iDR5 recommended parameters



Detected SB1



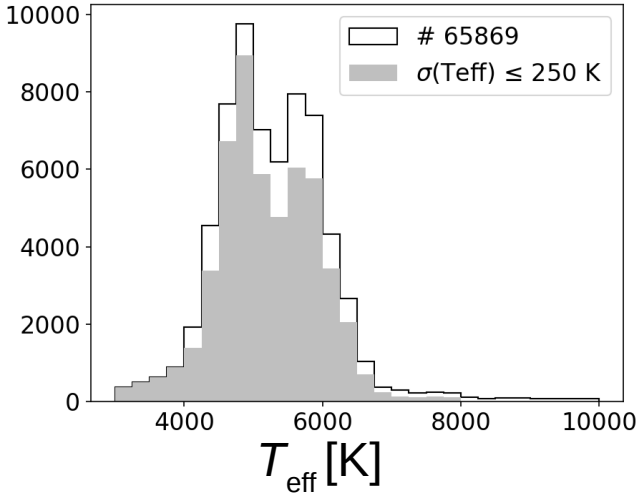
$\sigma(T_{eff}) \leq 250$ K

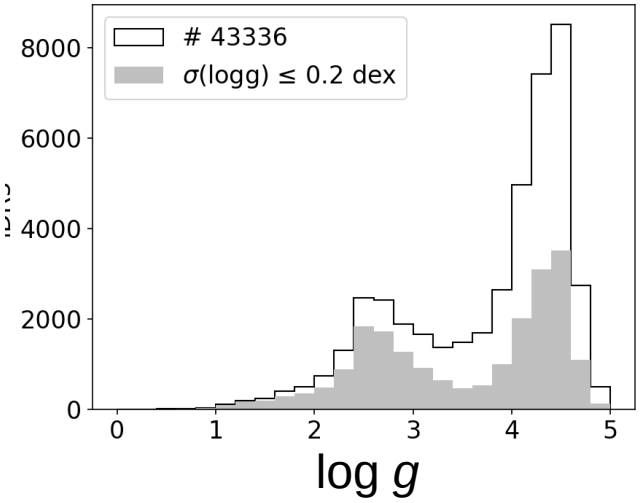
$\sigma(\log g) \leq 0.2$ dex

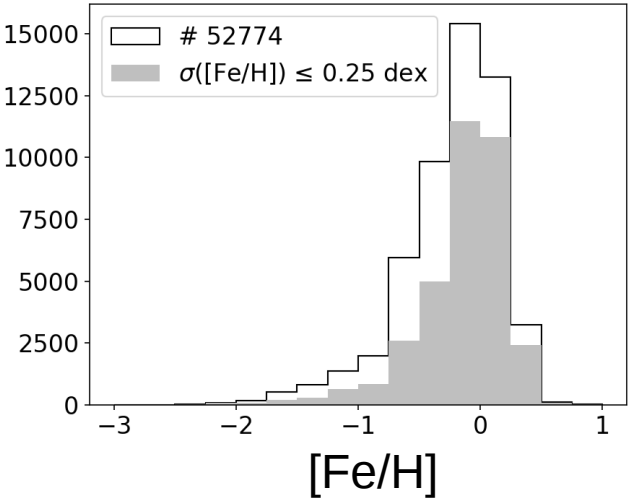
$\sigma([Fe/H]) \leq 0.25$ dex

GES SB1 sample: preliminary analysis

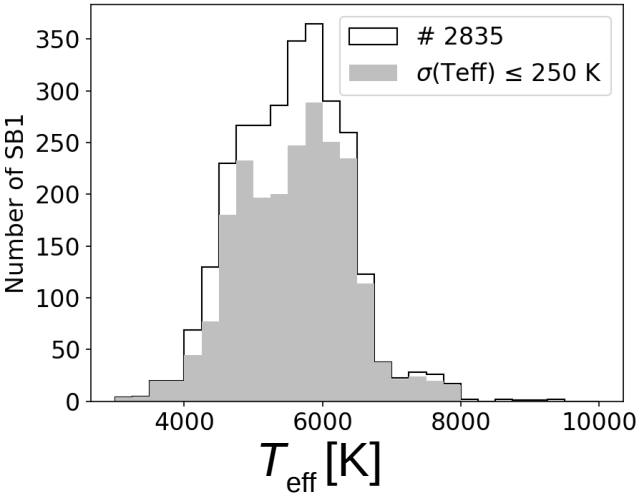
iDR5 recommended parameters

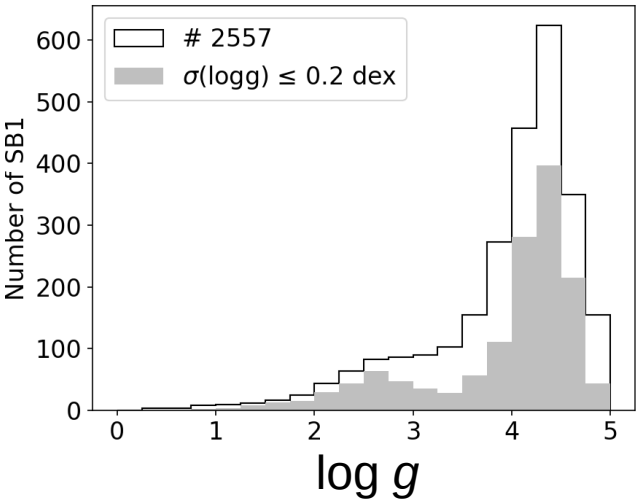


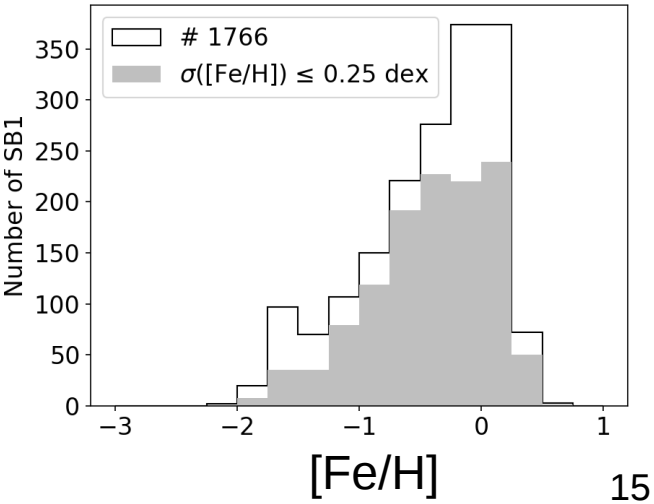




Detected SB1







Conclusions & prospects

- SB*n* (*n*≥2) detection by identification of multi-peaked CCFs:

  - Detection of **342 SB2**, **11 SB3** and **1 SB4 candidates** among 51000 sources
  - 2 SB2 in open clusters with an **orbital solution**
  - 98% are new because of their **faint visual magnitude**

  ➔ **see Merle, Van Eck, Jorissen, Van der Swaelmen et al. 2017 (arXiv:1707.01720)**
  ➔ **see M. Van der Swaelmen's poster on the computation of new CCFs**

- Preliminary results on SB1 detection:

  - Statistical χ^2-test: ~**3500 SB1** among 42000 sources: 60% field, 40% clusters
  - Work in progress:
    - Known issues under investigation (wavelength calibration, unusable CCF, etc.)
    - Identification of RV variations due to **rotation, pulsation, jitter,** etc.
  - Correction of the **selection function for MW** field stars (Stonkute et al. 2016)
  - **Binary frequency per spectral type and metallicity**
    (comparison with Raghavan et al. 2010, Duchêne & Kraus 2013, etc.)

  ➔ **Merle et al. (in prep.)**