Detection of multiple stellar systems in the Gaia-ESO Survey iDR5

M. Van der Swaelmen[1], T. Merle[1], A. Jorissen[1], S. Van Eck[1] & T. Zwitter[2]

[1] Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, Belgium
[2] Faculty of Mathematics and Physics, University of Ljubljana, Slovenia

Abstract

Binary systems are ideal targets to **test theories** of stellar formation, stellar evolution and nucleosynthesis. Numerous questions are still open and among them, that of the **frequency** of binary systems. A crucial step to shed new light on this topic is to identify and characterise those objects. Thanks to the high-accuracy radial velocities brought by the Gaia-ESO survey (GES), it is possible to **hunt new multiple stellar systems** across the Milky Way.
We exploit the numerous GIRAFFE HR10 and HR21 spectra of the GES to detect spectroscopic multiple system candidates (SBn, $n \geq 2$). To this end, we improved the tool DOE, developed at IAA, which **automatically detects** multi-peaked cross-correlation functions (CCF). We present here the preliminary results of this analysis applied to the **GES iDR5**. Compared to our results for iDR4 (Merle et al., 2017), this analysis benefits from an increased number of recorded spectra and from the **careful re-computation** of the HR10/HR21 CCFs, which allows to significantly improve the number of detected binaries.

1. Binary detection efficiency: predictions

We run Monte-Carlo simulations to generate HR10 and HR21 spectra ($R \sim 21500$ and $R \sim 18000$, resp.) of a pair of twin (non-rotating) stars for various levels of $\mathrm{S/N}$. We then apply our DOE pipeline on the simulated spectra. Fig. 1 show **the SB2 detection efficiency in HR10 and HR21**. The green dots (respectively the red triangles) indicate $(\Delta v_{\mathrm{rad}}, \mathrm{S/N})$ conditions when DOE is able to detect the two expected peaks in more than 95% of cases (resp., conditions when DOE failed at detecting two expected peaks in more than 95% of cases). Blue plusses represent intermediate cases making detection efficiency dependent of the noise: a/ due to the noise, spurious peaks may appear or b/ thanks to the noise, the two peaks have different height (despite being a pair of twins) and become discernible to DOE for small Δv_{rad}.

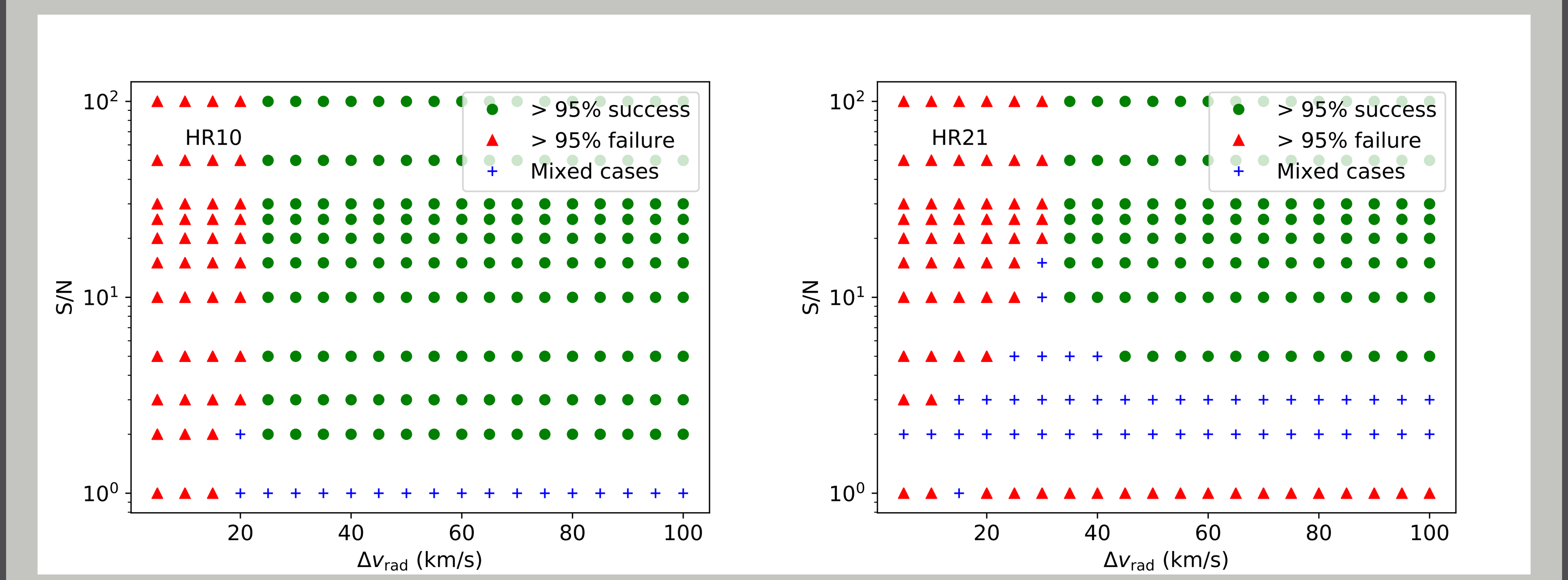

Figure 1: Detection efficiency for HR10 and HR21

Our simulations show that **HR10 allows a more efficient detection**, with a good detection rate **as soon as** $\mathrm{S/N} > 2$ and $\Delta v_{\mathrm{rad}} > 25\,\mathrm{km\,s^{-1}}$. On the other hand, HR21 allows the detection of SB2 with $\Delta v_{\mathrm{rad}} > 35\,\mathrm{km\,s^{-1}}$ with $\mathrm{S/N} \gtrsim 10$.

2. Binary detection efficiency: observations in iDR4

Merle et al. (2017) performed a **full analysis of GES iDR4** looking for stellar multiplicity. This histogram shows that the smallest Δv_{rad} is $25\,\mathrm{km\,s^{-1}}$ for HR10 and $60\,\mathrm{km\,s^{-1}}$ for HR21, **well in line with our predictions**.

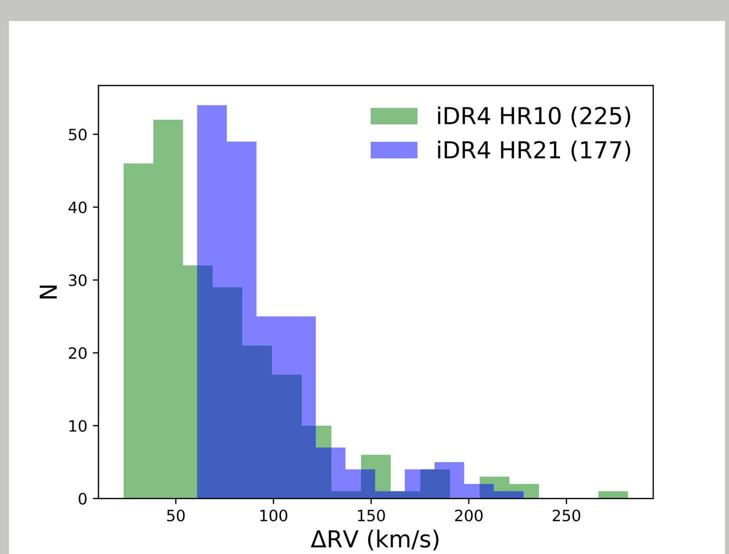

Figure 2: Detection efficiency for HR10 and HR21 in GES iDR4

References

Gilmore, G. et al. 2012, The Messenger, 147, 25
Merle, T., Van Eck, S., Jorissen, A., Van der Swaelmen, M., et al. 2017, A&A, arXiv:1707.01720
Randich, S. et al. 2013, The Messenger, 154, 47

3. Improved CCFs

It appeared that some targets exhibit the **signature of binarity in their HR10** GES CCFs but **do not in their HR21** GES CCFs while the HR10 and HR21 spectra have been **recorded during the same night** (see black curves in Fig. 3). Our investigation showed that HR21 GES CCFs tend to have a broad profile, due to the **presence of the strong Ca II triplet** and/or **a strong Mg line** and/or **Paschen lines** in the range [8430 Å, 8990 Å]. This broad profile "hides" the two stellar components in the below example.
In order to improve the HR21 CCFs, we selected a set of weakly-blended non-saturated lines in the range [8430 Å, 8990 Å] and used them to compute synthetic mask. For instance, our masks do not include the Ca II triplet, which leads to narrower CCF peaks. Figure 3 compares the GES/CASU CCF (old) to our ULB CCF (new) for the object 07272578-0310066: the new HR21 CCF shows now the two stellar components.

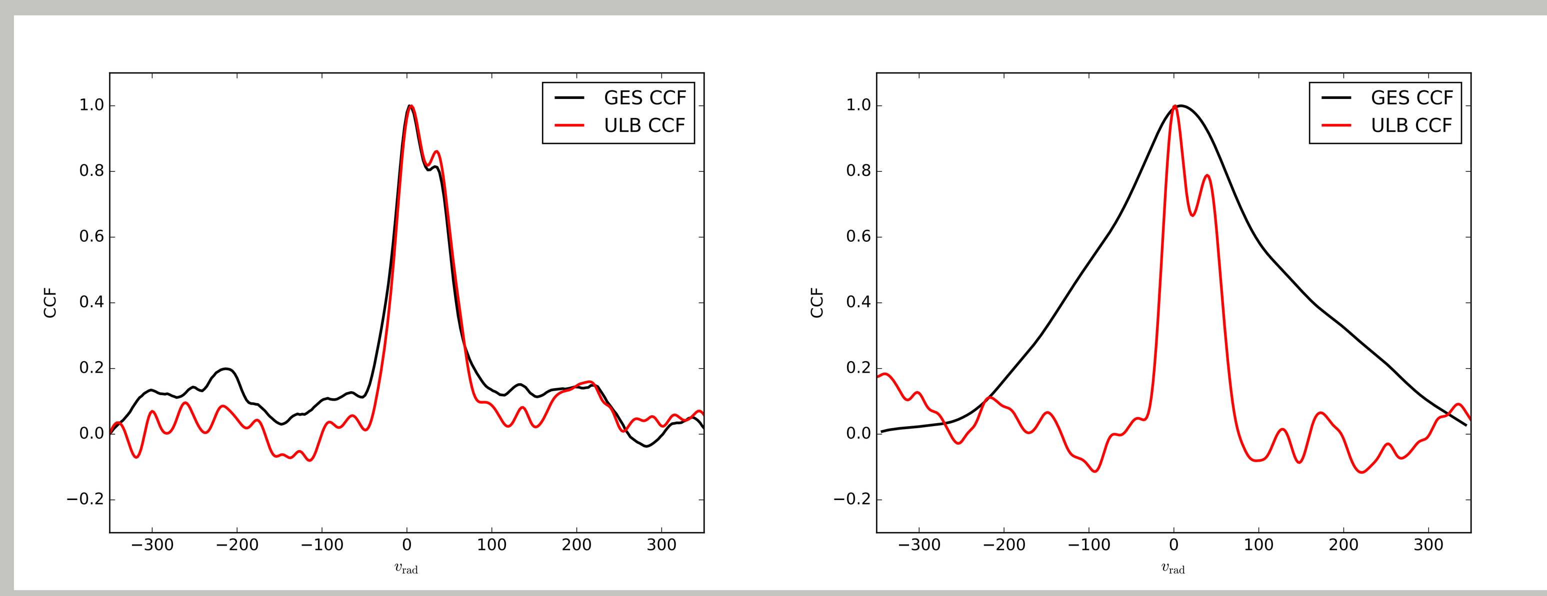

Figure 3: HR10 (left) and HR21 (right) CCF of 07272578-0310066 at MJD 57032.153726 and 57032.247332 (resp.). Black curve is the GES/CASU CCF, red curve is the ULB CCF.

4. First results

Figure 4 compares our preliminary results for the SBn detection using {iDR5+ULB HR21 CCFs}, in red, to the results we obtained using {iDR4+GES/CASU HR21 CCFs}, in blue. The histogram shows the number of single exposures (*i.e.*, the same CNAME may appear more than once across the velocity bins) as a function of Δv_{rad}. It shows that **with the new CCFs** we are able to **detect systems** with a Δv_{rad} **as low as** $25\,\mathrm{km\,s^{-1}}$. The fact that the red bars are shorter than the blue bars is due to: a) our preliminary iDR5 results deal with field stars so far while our iDR4 results dealt with field+cluster+association stars, b) for the time being, our set of detection criteria are strict in order to keep a fully automated analysis while our iDR4 analysis has benefited from a careful visual check.

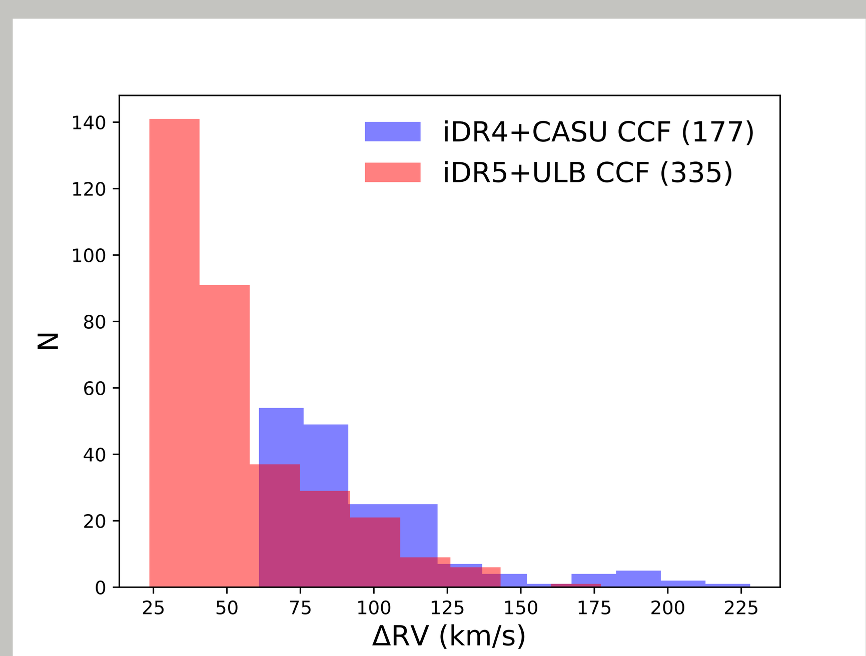

Figure 4: Comparison of the detection efficiency for HR21 in iDR4 and iDR5

5. Conclusion

For iDR4, using only HR21 CCFs (and restricted to field targets observed with this setup), we could detect 75 SB2 out of 26 951 CNAMES ($0.28\,\%$). For iDR5, using only our new HR21 CCFs, we detect 201 SB2 CNAMES out of 37 495 field CNAMES ($0.54\,\%$). While the number of observed field stars in this setup has increased by $40\,\%$ between iDR4 and iDR5, we have **multiplied** the number of **detected SB2 in HR21** by **more than two**.
In our previous analysis, we could not detect any SB3 with the help of HR21 CCFs while we **now detect three SB3** thanks to the new HR21 CCFs. Two of them were already identified in iDR4 (thanks to their HR10 CCFs only) while the third one was identified as an SB2 in iDR4.