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DETECTION OF SPECTROSCOPIC BINARIES IN THE GAIA-ESO SURVEY

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Abstract. The Gaia-ESO survey (GES) is a ground-based spectroscopic survey, complementing the Gaia mission, in order to obtain high accuracy radial velocities and chemical abundances for 10^5 stars. Thanks to the numerous spectra collected by the GES, the detection of spectroscopic multiple system candidates (SBn, $n \geq 2$) is one of the science case that can be tackled. We developed at IAA (Institut d'Astronomie et d'Astrophysique) a novative automatic method to detect multiple components from the cross-correlation function (CCF) of spectra and applied it to the CCFs provided by the GES. Since the bulk of the Milky Way field targets has been observed in both HR10 and HR21 GIRAFFE settings, we are also able to compare the efficiency of our SB detection tool depending on the wavelength range. In particular, we show that HR21 leads to a less efficient detection compared to HR10. The presence of strong and/or saturated lines (Ca II triplet, Mg I line, Paschen lines) in the wavelength domain covered by HR21 hampers the computation of CCFs, which tend to be broadened compared to their HR10 counterpart. The main drawback is that the minimal detectable radial velocity difference is $\sim 60\,\mathrm{km\,s^{-1}}$ for HR21 while it is $\sim 25\,\mathrm{km\,s^{-1}}$ for HR10. A careful design of CCF masks (especially masking Ca triplet lines) can substantially improve the detectability rate of HR21. Since HR21 spectra are quite similar to the one produced by the RVS spectrograph of the Gaia mission, analysis of RVS spectra in the context of spectroscpic binaries can take adavantage of the lessons learned from the GES to maximize the detection rate.

Keywords: Surveys: Gaia-ESO Survey, Stars: binaries: spectroscopic, Methods: data analysis, Techniques: radial velocities, Techniques: spectroscopic

1 Introduction

Merle et al. (2017) presented a (semi-automated) pipeline, Detection Of Extrema (Doe), and applied it to the fourth data release (iDR4) of the Gaia-ESO Survey (Gilmore et al. 2012; Randich et al. 2013). We quickly repeat the principles of Doe: 1/ a cross-correlation function (CCF) is simultaneously smoothed by a Gaussian kernel and derived three times; 2/ first and third derivatives are used to look for local maxima and/or inflexion points; 3/ the positions of those remarkable points provide the velocity of the stellar components forming the suspected multiple stellar system; 4/ multi-epoch and multi-setting observations are used to qualitatively (with flags: probable, possible or tentative) estimate the probability that the stellar multiplicity is real.

Merle et al. (2017) noted that the SB2 detection efficiency (here, we mean the smallest detectable velocity difference between the two stellar components) strongly depends on the setting. In order to investigate this sensitivity, we generate Monte-Carlo HR10 and HR21 spectra ($R \sim 21500$ and $R \sim 18000$, resp.) of a pair of twin (non-rotating) stars for various levels of S/N and radial velocity separations $\Delta v_{\rm rad}$. We then build the maps of SB2 detection efficiency for both setups (Fig. 1) by running the Doe pipeline on the simulated spectra. In Fig. 1, the green dots (respectively the red triangles) indicate ($\Delta v_{\rm rad}$, 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: (i) due to the noise, spurious peaks may appear or (ii) thanks to the noise, the two peaks have different height (despite being a pair of twins) and become discernible to Doe. Our simulations show that HR10 allows a more efficient detection, with a good detection rate as soon as S/N ≥ 2 and $\Delta v_{\rm rad} \geq 25\,\mathrm{km\,s^{-1}}$. On the other hand, HR21 allows the detection of SB2 with $\Delta v_{\rm rad} \geq 45\,\mathrm{km\,s^{-1}}$ and S/N ≥ 5. In their full analysis of GES DR4 spectra, Merle et al. (2017) noted that the smallest detected $\Delta v_{\rm rad}$ is $25\,\mathrm{km\,s^{-1}}$ for HR10 and $60\,\mathrm{km\,s^{-1}}$ for HR21, in rather good agreement with our predictions.

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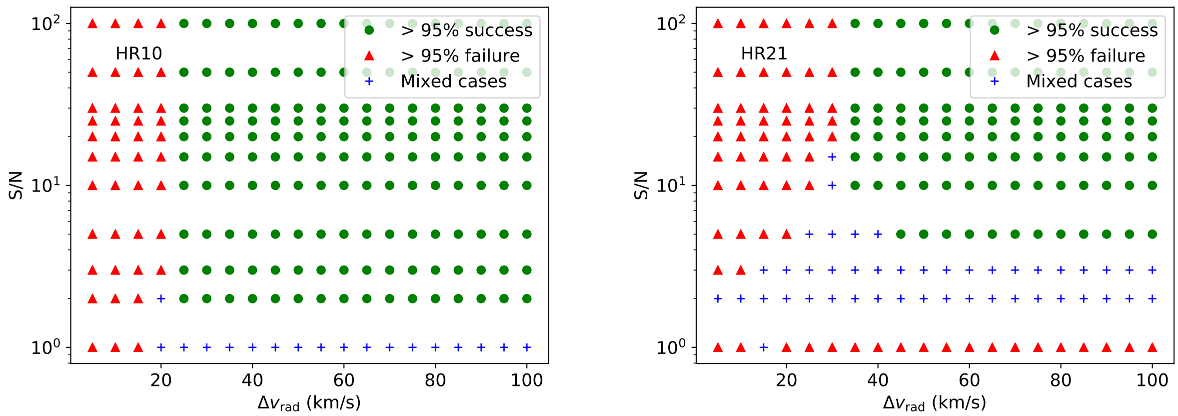

Fig. 1. SB2 detection efficiency for HR10 and HR21 GIRAFFE setups

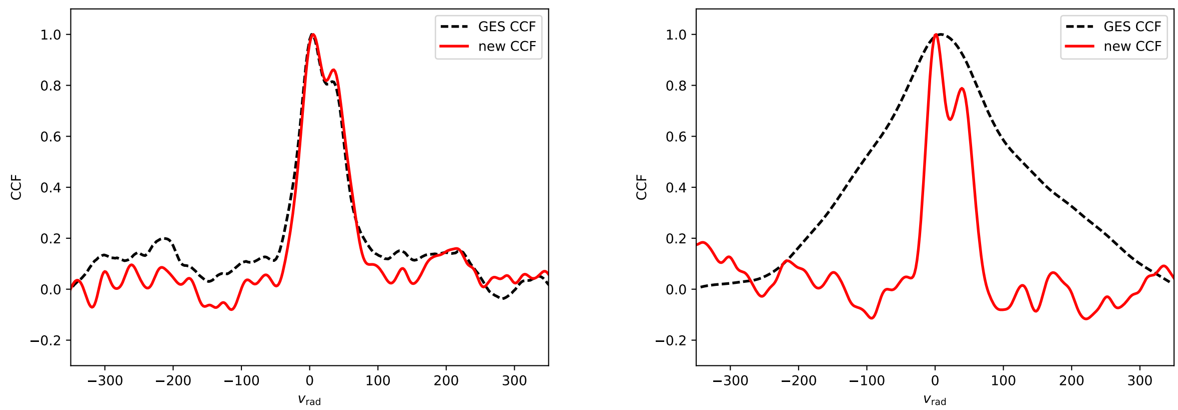

Fig. 2. HR10 (left) and HR21 (right) CCF of 07272578-0310066 at MJD 57032.153726 and 57032.247332 (resp.). Black dashed curve is the GES/CASU CCF, red solid curve is the newly computed CCF.

Fig. 2 exhibits a puzzling case. The same object, namely 07272578-0310066, is observed twice during the same night, once with the HR10 grating, once with the HR21 grating. The black curves in Fig. 2 display the CCFs provided by the GES/CASU: while the binary nature is clearly visible in the HR10 CCF, it is not the case in the HR21 CCF. This kind of disagreement between HR10 and HR21 CCFs has motivated our effort to recompute the GES CCFs.

2 Method

In order to improve the HR21 CCFs, we selected a set of weakly-blended lines in the range [8430 Å, 8990 Å] and used them to compute HR21 synthetic masks. Though we do not expect to significantly improve the computation of HR10 CCFs (detection is already very efficient), we apply the same procedure to recompute new HR10 synthetic masks: HR10 will serve to validate our method. We then recompute the CCFs by cross-correlating the GES spectra and our HR10/HR21 synthetic masks.

Fig. 2 compares the GES/CASU CCF (black curves) to our new CCF (red curves) for the object 07272578-0310066. As expected, our new CCFs give the same results for HR10, showing that the method is robust and that our new mask allows to retrieve already known SB2s. However, unlike the GES CCF, the new HR21 CCF has narrower peaks and now also indicates the SB2 nature. The presence of strong saturated lines (Ca II triplet, strong Mg line, Paschen lines) in the range [8430 Å, 8990 Å] tends to broaden HR21 CCFs. Therefore, binary systems with small $\Delta v_{\rm rad}$ tend to have their components hidden in the unique broad peak of their HR21 CCF. Since our masks do not include such lines, we get narrower CCFs.

3 Conclusion

We performed preliminary tests on a subset (72 objects) of SB2s identified by Merle et al. (2017) for which the SB2 nature is detected in HR10 GES CCFs but not in HR21 ones. Our new CCFs now allow to detect the SB2 nature of $\sim 35\%$ objects based on their HR21 CCFs (26 objects out of 72). With the new HR21 CCFs we are also able to detect systems with a $\Delta v_{\rm rad}$ as low as $25\,{\rm km\,s^{-1}}$, to be compared to the smallest $\Delta v_{\rm rad}$ reported in Merle et al. (2017) ($60\,{\rm km\,s^{-1}}$).

Our work shows that very low S/N spectra ($>\sim 3$) are still usable in the context of radial velocity measurement and moreover, for SB detection. Since the HR21 spectral domain resembles that of the Gaia RVS, RVS CCFs may suffer from similar broadening issues and may benefit from a careful design of correlating masks.

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