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NEW SB2 BINARIES FOR ACCURATE STELLAR MASSES WITH GAIA*

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Abstract. The forthcoming Gaia mission will make possible the derivation of accurate stellar masses of binary components, by combining the astrometric measurements and the elements of SB2 orbits. We present a list of 16 long period SB1 systems observed with the T193/Sophie, and for which we measured the radial velocity of the secondary component, changing them in SB2. The 32 components of these systems could get masses with errors around 1 % when the Gaia astrometric measurements and a sufficient set of RV measurements will be available.

Keywords: binaries: spectroscopic, stars: fundamental parameters

1 Introduction

The Gaia astrometric measurements will make possible the derivation of masses of double-lined spectroscopic binary (SB2) components, with relative errors around 1 % (Halbwachs & Arenou 1999, 2009). For that purpose, a large observation programme was undertaken at the OHP observatory with the T193/Sophie in order to get very accurate SB orbital elements. Two hundred and eight target stars were selected among known SB, taken in the SB9 catalogue (Pourbaix & Tokovinin 2003; Pourbaix et al. 2004) and also in Halbwachs et al. (2003) and Halbwachs et al. (2011), but only 52, ie 25 % of them, were already known as SB2. The priority of the first ongoing observing runs is then to detect the secondary components of the SB1, changing them in SB2.

2 The observations

In order to optimize the observing time, ephemerides were computed and the SB are observed only when the radial velocities (RV) of the components are sufficiently different to allow the detection of the secondary. Since many SB have periods as long as a few years, this selection criterion results in observing only a part of the sample, and in accumulating measurements for the stars which are in the best conditions, instead of observing the others. After one year and one additional mission, totalizing 8 nights, 265 radial velocity (RV) measurements were obtained for 123 stars, 29 SB2 and 94 single-lined spectroscopic binaries (SB1). The signal-to-noise ratios (SNR) of the spectra were adapted to the magnitudes of the stars, and were chosen between 50 and 150.

3 Detection of the secondary components

For each observation, the SOPHIE automatic pipe-line provides the cross–correlation function (CCF) of the spectrum of the SB with a mask. This mask usually corresponds to a spectral type close to that of the primary component, but masks adapted to the presumed secondary were also used. For a SB1, the CCF is a single bell-shape dip, that may be approximately fitted with a normal distribution. For a SB2, the dip corresponding to the secondary component is also visible when it is not too close to that of the primary, and the resulting CCF looks like the sum of two normal distributions.

Among the 94 SB1 observed, 16 had a CCF exhibiting a small secondary dip aside from the primary one. These CCF are shown in Fig. 1.

A few cases in Fig. 1 deserve explanations:

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* Based on observations performed at the Haute-Provence Observatory

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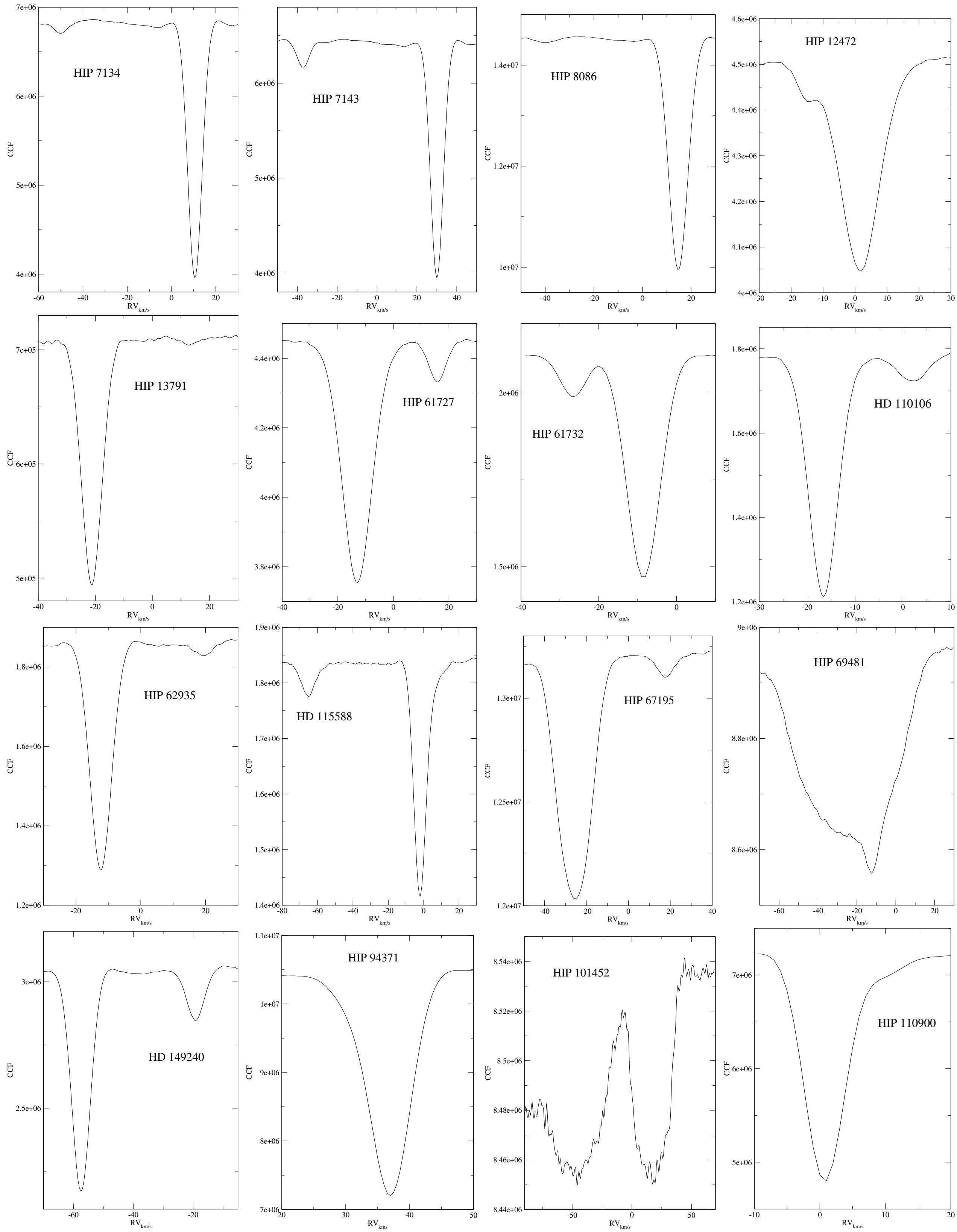

Fig. 1. The CCF of the new SB2. Small secondary dips are visible aside those of the primary components

Table 1. The mass ratios of the new SB2. Very uncertain estimations are indicated with a ":" in the place of the last digit.

Star	$q = \mathcal{M}_2/\mathcal{M}_1$	Star	$q = \mathcal{M}_2/\mathcal{M}_1$
HIP 7134	0.72	HIP 62935	0.71
HIP 7143	0.58	HD 115588	0.36
HIP 8086	0.5 :	HIP 67195	0.65
HIP 12472	0.68	HIP 69481	0.2 :
HIP 13791	0.53	HD 149240	0.42
HIP 61727	0.64	HIP 94371	0.9 :
HIP 61732	0.66	HIP 101452	0.92
HD 110106	0.75	HIP 110900	0.85

- HIP 8086: The secondary dip is very small, but it was observed at 3 different epochs, and its position is moving as expected. The detection is then certain.
- HIP 69481: A narrow secondary dip is emerging from a wide primary dip. A second observation, at another phase, confirms the detection.
- HIP 94371: Only one dissymmetric dip is visible, and the detection must still be confirmed.
- HIP 101452: An A0V-type star, at the very earliest limit of the range covered by SOPHIE. Since the earliest mask is F0, the CCF profile is not really the expected one, with a background much lower on the left side than on the right one.
- HIP 110900: The secondary dip is in the wing of the primary one, and it has to be confirmed.

4 Mass ratios of the new SB2

Since the barycentric velocities of the systems, V_γ, were already obtained with the elements of the SB1 orbits, the mass ratios may be obtained from one observation only. For that purpose, the velocities of the components were derived, fitting the CCF with two normal distributions subtracted to a linear background. The mass ratio is then $q = |V_1 - V_\gamma|/|V_2 - V_\gamma|$, where V_1 and V_2 are the RV of the primary and of the secondary component, respectively. The resulting q are in Table 1. It is worth noticing that these estimations are rather uncertain, since they are based on barycentric velocities obtained with another spectrograph than SOPHIE, and we still have too few measurements for correcting the systematic shift between our SOPHIE measurements and the ones used in the derivation of the SB orbit.

The mass ratios in Table 1 range from around 0.2 to 0.92, with a median around 0.65. We remind that, with spectrographs earlier than the CCD era, the luminosity ratio of binary star components generally prevents detection of secondaries with mass ratio smaller than 0.65 in the best conditions (Halbwachs et al. 2003). Therefore, half of the new SB2 detected with SOPHIE were obviously not detectable with the previous generation. Moreover, three new SB2 have a mass ratio well above this limit :

- HIP 101452. The primary is a A0p-type star, and its radial velocity, obtained in the past from photographic plates, was probably measured thanks to the peculiar lines of the spectrum. These lines could be missing in the secondary spectrum. The two components are clearly visible on the CCF obtained with an early-type mask.
- HIP 94371 and HIP 110900. If the secondary is confirmed in the future, it seems to be underluminous. It is obvious that the relation between the mass ratio and the visibility of the secondary is not unique: for instance, the secondary dip of HD 149240 (q=0.42) is much more visible than that of HIP 62935 (q=0.71).

5 Conclusions

Thanks to the ability of the SOPHIE spectrograph, the detection limit in mass ratio is shifted from around 0.7 to around 0.4. This leads to a selection of $52 + 16 = 68$ SB2, ie 136 stars for which we expect to derive the masses with an accuracy near 1 % at the end of the Gaia mission. Since 62 SB1 remain to be measured, we still expect to find around 10 new SB2, leading to a total amount of a bit more than 150 individual masses. Since the combined astometric+spectroscopic solution will also provide the luminosity ratio of the components, the luminosities of the stars in the Gaia *G*-band will be obtained together with the masses. Therefore, the mass–luminosity relation will then be revisited thanks to our programme.

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