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Resolved double-lined spectroscopic binaries: a source of hypothesis-free parallaxes

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Spectroscopic binaries resolved visually allow us to obtain the orbital parallaxes (as well as masses and other parameters) of both components without involving any assumptions about their nature. Orbital parallax is the only way, apart from trigonometric parallax, to directly determine (rather than estimate) the distance to the star. A comprehensive catalog of resolved spectroscopic binaries contains orbital elements, multicolor photometry, and astrophysical parameters for 173 systems. A comparison of trigonometric and orbital parallaxes shows that the latter are preferred in a certain range of large semi-major axis ($a > 26$–27 AU) and brightness ($V > 9$–10 mag). Also, we present the most promising systems from the SB9 catalogue in terms of resolution into components.

Keywords: Binaries: spectroscopic, binaries: visual, binaries: catalogues, stars: parameters, parallaxes

1 Introduction

A significant fraction of stars in the Milky Way are binary or multiple stars. Studies conducted by [4, 17, 3, 21, 18] allow us to conclude that the F-G-K-M stars may have an observed binary fraction of 20–40%, while that for O and B type stars may reach 100%.

A very interesting observational class of binary systems are resolved spectroscopic binaries (RSB). Similar to some other observational classes (for example, double-lined eclipsing binaries, DLEB), they are suppliers of dynamic stellar masses and other component parameters, but most importantly, they provide us with the only way (apart from trigonometric parallax) to directly determine (rather than estimate) the distances to stars. Pourbaix was one of the first to draw attention to this fact and compiled a list of about forty RSB systems [13]. Later authors ([10], [13], [1], [8]) presented more representative lists, and finally, recently published a catalogue containing presumably all RSB systems studied to date. The catalogue [22] is the most

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comprehensive list of RSB systems to date, and it contains orbital elements, masses, orbital and trigonometric parallaxes, spectral classification, multicolor photometry, and reddening for 173 objects.

In Section 2 we describe the RSB catalogues, while in Section 3 we compare orbital and trigonometric parallaxes of RSB. In Section 4 we present a list of candidates for RSB, i.e., stars that, according to our estimates, could in principle be observed as RSB. We draw our conclusions in Section 5.

2 Catalogue

Our catalogue of resolved spectroscopic binaries [22] contains orbital elements, masses of components, orbital parallaxes taken from studies presented in [14], [13], [1], [8], and fifty other publications for 173 RSB. We have also supplied our objects with trigonometric parallaxes, spectral classification, photometry and reddening taken from external sources.

The RSB catalogue contains the following information.

- Identifiers: sequential number, HD, HIP, Bayer/Flamsteed/GCVS/other name;
- Equatorial J2000 coordinates α, δ (deg);
- Orbital elements: orbital period P (yr), time of periastron $T0$ (JD) with flag (see below), eccentricity e, inclination of the orbital plane i (deg), position angle of the ascending node Ω (deg), periastron longitude ω (deg), semi-major axis a (mas), semi-major axis a (AU), with uncertainty;
- Orbital parallax ϖ_{orb} (mas) with uncertainty;
- Masses of components M_1, M_2 ($M_\odot$) with uncertainty;
- Reference to the source of the above parameters;
- Various flags: "earlier publications are available" flag, "other astrophysical parameters ($T_{\rm eff}$, $\log L$, etc.) are given in publication" or "other orbital solutions can be found in the publication" flag, "member of a multiple system" flag, "notes" flag (the notes are given in a separate file);
- Trigonometric parallax ϖ_{tri} (mas) with uncertainty and reference;
- Spectral type and B,V,G,J,H,K fluxes from SIMBAD;
- Reddening E_{B-V} from Stilism service[1] [11].

3 Parallaxes

Orbital and trigonometric parallaxes of RSB were compared in [23]. The SIMBAD database was used to obtain the latter. According SIMBAD, Gaia EDR3 [6] parallaxes are available for 109 objects, 14 more objects are supplied by Gaia DR2 [5] parallaxes. 47 objects do not have Gaia data and are provided with parallaxes from new Hipparcos reduction (hereafter Hip2007) [20]. The faintest star in the catalogue GJ 65AB (V=12.08 mag) was not observed by Hipparcos or Gaia, its trigonometric parallax is taken from [9]. It is these 171 (of 173 studied) stars that are plotted in Fig. 1.

[1] https://stilism.obspm.fr/

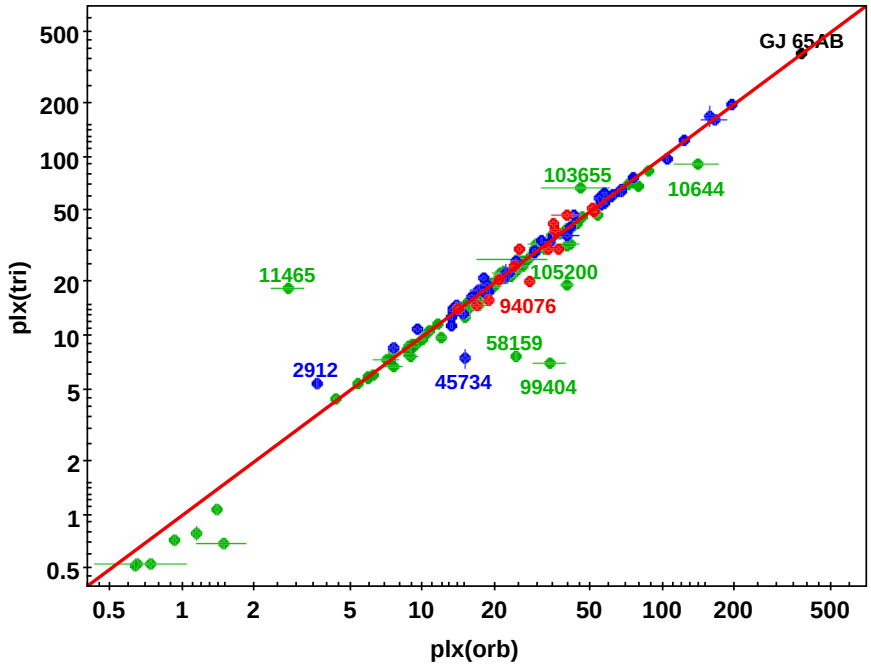


Figure 1 Trigonometric vs. orbital parallaxes (mas) of 171 resolved spectroscopic binaries. Sources for trigonometric parallaxes are Hip2007 [20] (blue), Gaia DR2 [5] (red), Gaia EDR3 [6] (green). Nine outliers are marked with their HIP numbers. The group of seven low-parallax outliers are discussed in the text. The one-to-one relation is shown as a solid line, for reference. Note a logarithmic scale for both axes.

The remaining two stars are HIP 71683 and HIP 91636. For HIP 71683 (α Cen) SIMBAD prefers *orbital* parallax from [15], where the authors found that their result is in excellent agreement with the latest asteroseismologic results. At last, the remaining star from our list, HIP 91636, first studied by [2], has no trigonometric parallax in SIMBAD, in [5] or [6], and has a negative parallax in [20]. It is one of the longest-period ($P = 92.22 \pm 0.41$ yr), most eccentric ($e = 0.91 \pm 0.00$) and most distant ($\varpi = 8.40 \pm 0.30$ mas) pairs in our list. Trigonometric parallax value $\varpi = 6.15 \pm 1.32$ mas is given in original Hipparcos data [12] (hereafter Hip1997), where however, it is pointed out the observed duplicity of the object, which obviously complicates the determination of trigonometric parallax. These two objects, HIP 71683 and HIP 91636, are a clear demonstration of the usefulness of RSB as an additional source of information about distances.

The comparison of orbital and trigonometric parallaxes is shown in Fig. 1. It can be seen that the data are in good agreement. For nine stars $|\varpi_{orb} - \varpi_{tri}|/\varpi_{tri}$ exceeds 0.2, they are marked with their HIP numbers. Having analyzed the characteristics of these outliers, we can draw preliminary conclusions about the region in the observational parameter space, where orbital parallaxes can be preferable to trigonometric parallaxes. Orbital parallaxes are preferred for faint (V > 9–10 mag) stars or wide ($a >$ 26–27 AU) pairs.

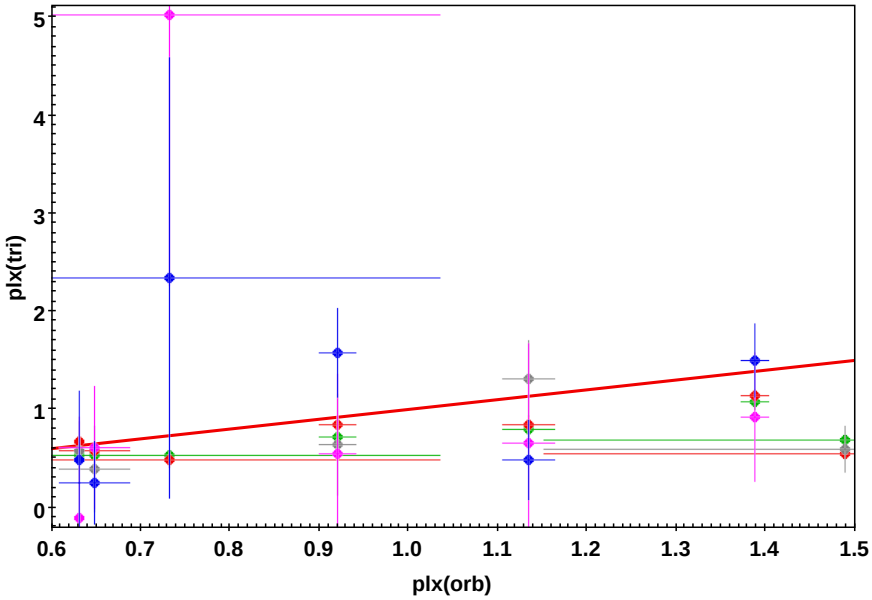


Figure 2 Trigonometric vs. orbital parallaxes (mas) of seven most distant resolved spectroscopic binaries. Sources for trigonometric parallaxes are Hip1997 [12] (magenta), Hip2007 [20] (blue), Gaia DR1 TGAS [7] (grey), Gaia DR2 [5] (red), Gaia EDR3 [6] (green). The one-to-one relation is shown as a solid line, for reference.

The group of seven low-parallax outliers irrefutably demonstrates that the space-born parallax values of distant ($\varpi <\approx 1$ mas, $d >\approx 1$ kpc) orbital binaries are biased downward (i.e., the distances appear to be overestimated) due to orbital motion. It is interesting to compare the different trigonometric parallaxes within the group of these stars. They are presented in Fig. 2. It can be seen that the values presented in different Gaia releases and different Hipparcos releases differ, sometimes quite markedly. Apparently, the presence of such differences can be considered a sufficient (but not necessary) indicator of the hidden binarity of the object.

4 Candidates for resolved spectroscopic binaries

Long-period spectroscopic binaries could be resolved with various interferometric techniques. The most comprehensive and regularly updated list of spectroscopic binaries is The Ninth Catalogue of Spectroscopic Binary Orbits, SB9 [16]. In Zeleke et al. 2025 (submitted to *Galaxies*) we proposed a methodology for estimating the probability for a spectroscopic binary system to be resolved into components, performed the first step of its application to the SB9 catalogue, and presented preliminary results. One of the most promising parameters found to be of interest for investigation, as one would expect, is the angular separation ρ. Figure 3 shows the ρ distributions of stars from SB9, already known as RSB (green) and stars from SB9 that are not RSB (non-

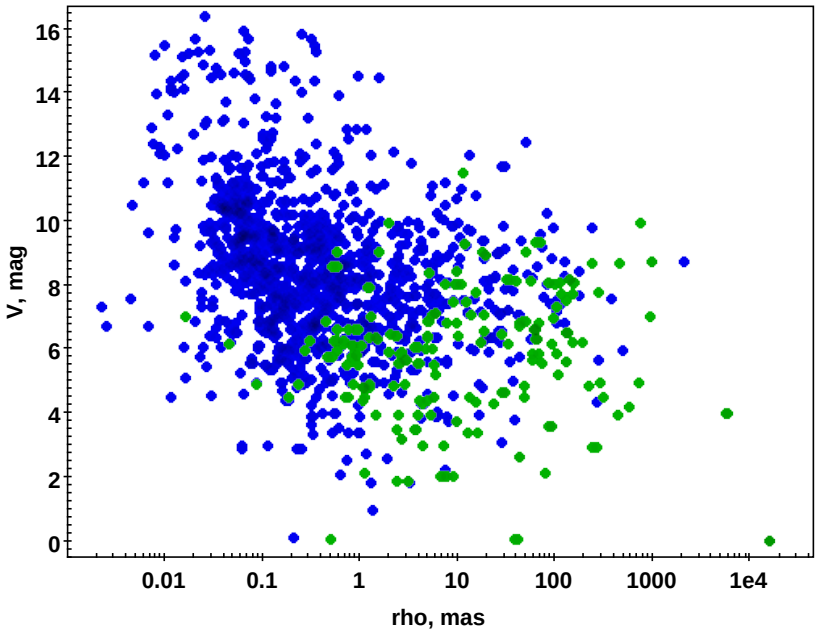


Figure 3 Objects from the SB9 catalogue, known as RSB (green) and non-RSB objects (blue). Angular separation ρ vs. V-mag.

RSB, blue). The top fifteen widest (i.e., most promising) systems are summarised in Table 1. A complete list of promising candidates is available upon request.

It should be noted that another source for potential RSB are short-period visual binaries with known orbital elements.

Table 1 The most promising systems in terms of resolution into components spectroscopic binaries from the SB9 catalogue. The ρ values are given in the last column. The trigonometric parallax values ϖ are taken from SIMBAD, the other parameters are from SB9.

HIP number	V, mag	SpType	P, day	ϖ, mas	ρ, mas
105585	8.1	G8V	87658.0	30.24 ± 4.85	2067.5
64212	6.02	K3III	50000.0	9.4397 ± 0.1381	481.1
111570	7.58	F5	18504.0	11.84 ± 0.53	377.7
76832	11.049	M3.0V	7927.0	73.2573 ± 0.3008	365.8
13498	7.73	G1V?	18794.0	11.965 ± 0.3677	303.6
104440	5.68	F9.5	1947.5	46.993 ± 0.8751	280.9
111022	4.36	K7Ib	15321.9	1.4838 ± 0.1383	263.6
87991	9.8	K8V	5299.047	23.6934 ± 0.3749	236.6
58669	6.96	G0V	56978.0	17.87 ± 0.77	233.9
103735	7.66	G3V	4251.8	23.5527 ± 0.4683	176.9
14313	8.59	K1V	6648.1	18.42 ± 0.8	173.4
23824	6.8	F8V	9857.21125	21.1629 ± 0.2491	126.7
31089	8.28	G1V	11568.0	15.09 ± 0.4201	125.1
117666	8.73	G5V	10984.0	13.3973 ± 1.2719	124.2

5 Conclusions

Resolved spectroscopic binaries (RSB) provide an exceptional opportunity to determine orbital parallax and to measure fundamental properties of stars. In the present study, we report on a comprehensive list of RSB, containing 173 systems with visual and spectroscopic orbits. We compared trigonometric and orbital parallaxes for these systems and found that the latter ones are preferable in a certain range of large semi-major axis ($a > 26$–27 AU) and brightness ($V > 9$–10 mag). We also present a list of candidates for RSB, i.e., spectroscopic binaries, that, according to our estimates, could in principle be observed as RSB.

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