Interferometric orbits of new Hipparcos binaries

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Summary. First orbits are derived for 12 new Hipparcos binary systems based on the precise speckle interferometric measurements of the relative positions of the components. The orbital periods of the pairs are between 5.9 and 29.0 yrs. Magnitude differences obtained from differential speckle photometry allow us to estimate the absolute magnitudes and spectral types of individual stars and to compare their position on the mass-magnitude diagram with the theoretical curves. The spectral types of the new orbiting pairs range from late F to early M. Their mass-sums are determined with a relative accuracy of 10-30%. The mass errors are completely defined by the errors of Hipparcos parallaxes.

1 Introduction

Stellar masses can be derived only from the detailed studies of the orbital motion in binary systems. To test the models of stellar structure and evolution, stellar masses must be determined with $\approx 2\%$ accuracy. Until very recently, accurate masses were available only for double-lined, detached eclipsing binaries [1]. The empirical mass-luminosity relation is therefore well-constrained for late-B to late-F stars of the main sequence. At the end of the 1990s, new accurate masses were determined at the bottom of the main sequence using the combination of very precise radial velocities with adaptive optics [5], [11]. With an accuracy of 2-10%, masses for very low-mass stars were also provided by precise astrometric measurements using the Fine Guidance Sensors on board of HST [3], [12]. However, for the mass range between $0.6\,\mathcal{M}_\odot$ and $0.9\,\mathcal{M}_\odot$, the lack of empirical data for stellar masses remains noticeable. This gap can be bridged using the speckle imaging of nearby short-period (P<20 yr) G, K, and M pairs, in combination with the long-term monitoring of their radial velocities.

Since 1998, precise relative positions and magnitude differences for more than 200 new Hipparcos binaries [4] have been measured using the speckle interferometric technique. Many of them show fast relative motion of the components, denoting a possibility of an orbit definition within one decade. The majority of speckle observations was collected by our team at the 6 m BTA telescope in Zelenchuk and by Horch et al. at the WIYN 3.5 m telescope in the USA [7], [8]. Presently, the orbital parameters for approximately 20 new Hipparcos pairs can be obtained. Here we present the orbits for 12 systems from the list. Five pairs belong to the K and M dwarfs, while seven others are late F to G-type stars.

2 Orbits and masses

Due to the high accuracy of speckle measurements (typically 1 to 3 mas), most of the orbits can be considered definitive, despite the small number of observations. The orbital periods and the major semiaxes are defined with a typical accuracy of 1%. However, the relative error of the parallaxes for the stars from our sample is changing in the range between 5 and 10%. This means that the total masses of the systems can be estimated with an accuracy of only 10% or worse. To improve the mass accuracies, we need additional data about the radial velocities of the components or more precise parallaxes.

The main parameters of the orbits for twelve new pairs, together with their physical properties, are given in Table 1. To derive the orbits, in a few cases we made use of the published speckle measurements from other telescopes. For convenience, the Hipparcos parallaxes of the pairs are included in the table. The absolute magnitudes and spectral types of the components were estimated from speckle interferometric magnitude differences in the visible and infrared bands with regard for their Hipparcos parallaxes. Note that two pairs in the list, HIP 4809 and HIP 5531, have evolved components. The last column in Table 1 gives the relative errors of the masses.

Table 1. Main parameters of the orbits, properties of the components, and total masses for 12 new Hipparcos binaries.

HIP	π_{hp} mas	σ_π mas	M_{VA}	M_{VB}	Sp_A	Sp_B	P yrs	a AU	$\mathcal{M}$ $\mathcal{M}_\odot$	$\sigma_\mathcal{M}$ $\mathcal{M}_\odot$	$\sigma_\mathcal{M}/\mathcal{M}$ %
4809	13.94	0.90	3.1	3.3	G6-G9IV	G6-G9IV	16.41	9.18	2.90	0.57	20
4849	46.61	1.61	6.7	8.4	K3	K8	28.99	9.77	1.17	0.14	12
5531	17.41	0.67	3.2	4.0	G0IV	G0IV	7.30	5.00	2.33	0.30	13
11352	23.19	1.21	5.5	5.7	G8	G9	6.85	4.31	1.71	0.27	16
14075	15.17	1.44	5.5	5.5	G8	G8	13.89	7.07	2.03	0.58	29
14230	29.62	1.09	4.7	6.4	G2	K2	5.91	3.71	1.47	0.26	18
14669	64.83	4.26	9.5	11.2	M2	M4	28.31	8.78	0.84	0.17	20
19206	24.00	0.92	4.1	5.5	G0	G8	21.33	9.29	1.75	0.25	14
105947	17.11	1.13	3.9	5.4	F8	G8	18.79	9.82	2.68	0.58	22
106972	39.78	3.70	9.9	11.1	M2	M4	18.57	6.74	0.89	0.25	28
111685	52.94	1.94	8.2	10.2	K7	M3	16.77	6.23	0.86	0.10	12
114922	31.50	3.85	9.4	9.6	M1	M2	19.72	6.95	0.87	0.32	37

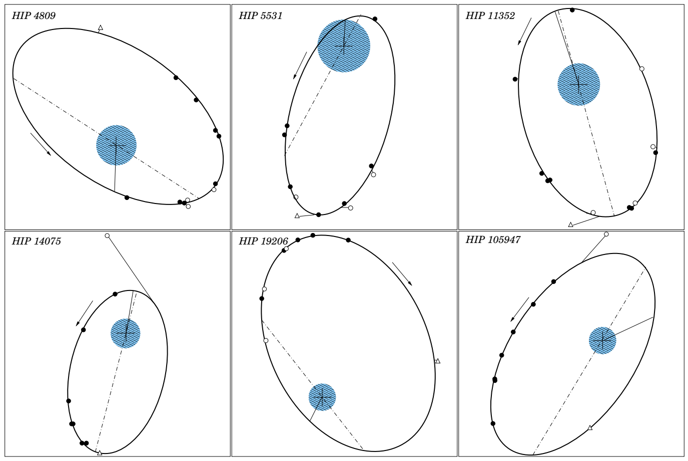

Fig. 1. Apparent ellipses for six F-G type new Hipparcos binaries. BTA speckle data are indicated by filled circles, other interferometric data by open circles, and Hipparcos first measurements by triangles. Residual vectors for all measurements are plotted, but in most cases they are smaller than the points themselves. The orbital motion directions are indicated by arrows. Solid lines show the periastron positions, while the dot-dashed lines represent the lines of nodes. North is up and east is to the left. The shaded circle at the position of the brighter component has a radius of 0.02", corresponding to the diffraction limit of a 6 m aperture.

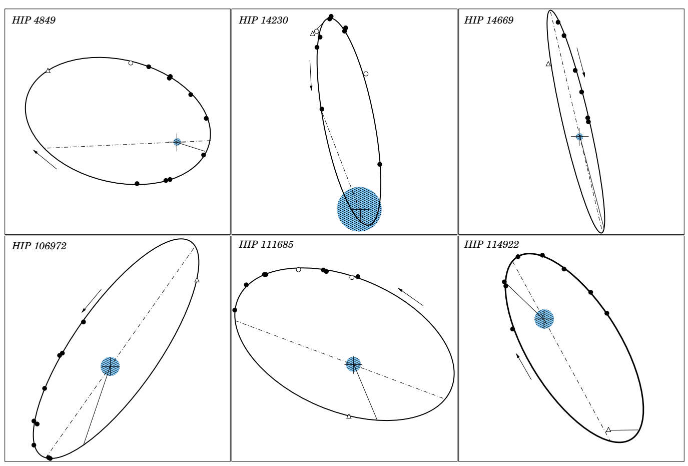

Fig. 2. Apparent ellipses for six K-M type new pairs.

The orbital ellipses for our 12 pairs are shown in Fig. 1 and Fig. 2. For convenience, the binaries are grouped according to the spectral types of the components: 6 pairs belong to the F-G spectral types, and the 6 others are K- to M-type dwarfs.

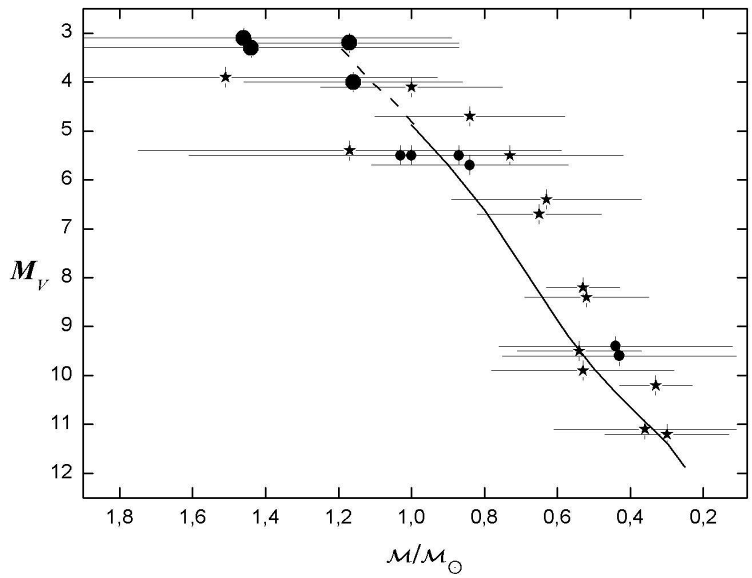

Fig. 3. Positions of the components of 12 new Hipparcos binaries on the mass-magnitude diagram. Binaries with $\Delta m < 1$ are plotted as filled circles, while those with $\Delta m > 1$ are shown as stars. The larger circles indicate two systems with evolved components, HIP 4809 and HIP 5531. Error bars are the same as for the mass-sums. The two curves are 5 Gyr theoretical isochrones from [2] (solid line) and [6] (dashed line) for solar metallicities.

The positions of the components on the $\mathcal{M}/M$ diagram are presented in Fig. 3. The mass ratios of the systems were derived from speckle photometric data and the empirical $\mathcal{M}/M_V$ relation [9]. For two systems, HIP 5531 and HIP 19206, we used mass ratios from the spectroscopic survey [10]. For comparision, two theoretical isochrones for 5 Gyr and solar metallicity taken from [2] and [6] are plotted on the diagram. The components of the systems with magnitude differences less than 1 magnitude are given as circles, while for designation of the components with larger magnitude differences we use asterisks. This helps to single out those systems which can be observed as SB2. The components of evolved pairs are shown by the larger circles.

3 Conclusions

Speckle monitoring of new nearby (distance less than 77 pc) Hipparcos binaries and Hipparcos "problem" stars allows us to determine new orbits in a comparatively short time interval. Differential speckle interferometry helps to estimate the individual luminosities and spectral types of the components. In view of the results given above for 12 pairs, we can make the following concluding remarks. First, the semimajor axes of the systems lie in the rather narrow range between 4 and 10 AU. This fact reflects the optimal range of orbital periods and angular separations for the nearby binaries (median distance 50 pc), which can be studied by means of speckle interferometry. About 40 new orbits for the nearby Hipparcos binaries could be obtained before 2010 if the speckle monitoring of fast pairs continues. Second, we note the higher luminosity for the components of most of the systems in comparison with the theory for the mass range 0.5-1.0 $\mathcal{M}_\odot$. This can be a sign of the evolved status of the stars or the result of their lower metallicity. Third, the calculated mass-sums of the pairs have comparatively low relative accuracy, between 10 and 30%, which is explained by the dominating input of the Hipparcos parallax errors. The further improvement of speckle orbits will not lead to significantly more precise masses. To reduce the mass-sum errors to 5% or below, it is necessary to collect systematic data of their radial velocities with a precision of $\sim 0.5\ \mathrm{km\,s^{-1}}$ or to measure the parallaxes with a typical accuracy of 0.1 mas.

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