Orbits of Speckle Interferometric Binaries. Long-Term Monitoring at the SAO RAS BTA

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Abstract. A comparison of the residuals of observational data used to construct the orbital solutions for a sample of 10 speckle interferometric binaries is presented. It is shown that the residuals of measurements, obtained at BTA SAO RAS using speckle interferometer and calculated for each object, are the lowest. Obtaining homogeneous data over a long periods of time allows for the constructing of high-precision orbits, and therefore determining of the accurate fundamental parameters.

Keywords: binaries: general; techniques: image processing
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1 Introduction

Monitoring of binaries with low-mass components began in the group of high-resolution methods in astronomy of the SAO RAS since the end of the 90s of the 20th century. Orbital periods of such objects are usually between 1 and 100 years. At one time, the release of the Hipparcos catalog (ESA 1997) increased interest in this kind of research. Despite a large amount of studies in this area, the orbits of some such binaries are still not accurate, or have not been constructed at all. The reason for this may be both an insufficient amount of observational data and an erroneous reconstruction of the position of the secondary relative to the primary. The last is often the determinative one.

It should also be noted that the heterogeneity of the observational data (that is, the fact that data were obtained with different telescopes and using different instrumentation) does not work in favor of the accuracy of the orbits. However, this is a necessary measure. When obtaining orbital solutions, measurements with large residuals "pull" the arc of the orbit over themselves, so they have to be given lower weights. Residuals show how much the observational parameters differ from the orbital solution. This study is devoted to the analysis of the residuals on ρ (angular separation) and θ (position angle) for a sample of 10 stars. This sample consists of HIP 14524, HIP 16025, HIP 18856, HIP 28671, HIP 46199, HIP 47791, HIP 53731, HIP 60444, HIP 61100, and HIP 73085, a detailed study of which is presented by Mitrofanova et al. (2020a,b); Efremova et al. (2020).

2 Observations, Data Reduction and Orbit Construction

The first observations of the objects under study were carried out by ESA (1997); McAlister et al. (1993); Balega et al. (2013). Further monitoring was carried out at 2.1 meter OAN-SPM telescope by Orlov et al. (2011), at 3.5 meter WIYN telescope by Horch et al. (2002, 2004, 2008, 2010, 2012, 2017), at 3.6 meter CFHT and 4 meter KPNO telescope by McAlister et al. (1993); Hartkopf et al. (2000), at 4.1 meter SOAR telescope by Hartkopf et al. (2012); Tokovinin et al. (2014, 2015, 2016, 2018), at 6 meter BTA by Balega et al. (2002, 2004, 2006, 2007, 2013); Rastegaev et al. (2007, 2008); Mitrofanova et al. (2020a,b); Efremova et al. (2020), and at 8.4 meter LBT and 10 meter Keck II by Schlieder et al. (2016). A total of 191 measurements were obtained to construct the orbits of these objects, including 134 measurements obtained at BTA.

The orbits of HIP 16025, HIP 18856, HIP 28671, HIP 46199, HIP 47791, HIP 53731, HIP 61100, and HIP 73085 were improved, and of HIP 14524 and HIP 60444 were constructed for the first time, taking into account the new data obtained from 2007 at BTA using a speckle interferometer (Maksimov et al. 2009). Data reduction and orbit construction are standard procedures described by Mitrofanova et al. (2020b). The typical values of the errors are 0.1°-0.4° in θ, 1 mas in ρ, and $0.1^m - 0.2^m$ in Δm. A comparison of the amount of previously published data with new ones is presented in Table 1. It should be noted that new measurements are crucial in most cases.

The Figure 1 shows the improved orbit of HIP 53731, the detailed study of which is described by Mitrofanova et al. (2020a). Triangles are measurements from literature, open circles are data obtained at BTA since 2007, crosses are measurements that are the worst in agreement with the orbital solution.

There are measurements that have very large discrepancies relative to the orbital solution. It depends on the diameter of the main mirror of the telescope, instrumentation, data reduction methods, etc., which have various systematic errors. These measurements need to be given less weight when constructing orbits. However, they still contribute to the average residuals on angular separation ρ and position angle θ. Average residuals are listed in Table 2 and shown in Figure

Table 1. Number of previously published and new measurements for the systems under study

Object	Published measurements	New measurements	Object	Published measurements	New measurements
HIP 14524	16	7	HIP 47791	4	14
HIP 16025	10	13	HIP 53731	10	21
HIP 18856	10	10	HIP 60444	8	18
HIP 28671	12	9	HIP 61100	10	16
HIP 46199	15	16	HIP 73085	12	11

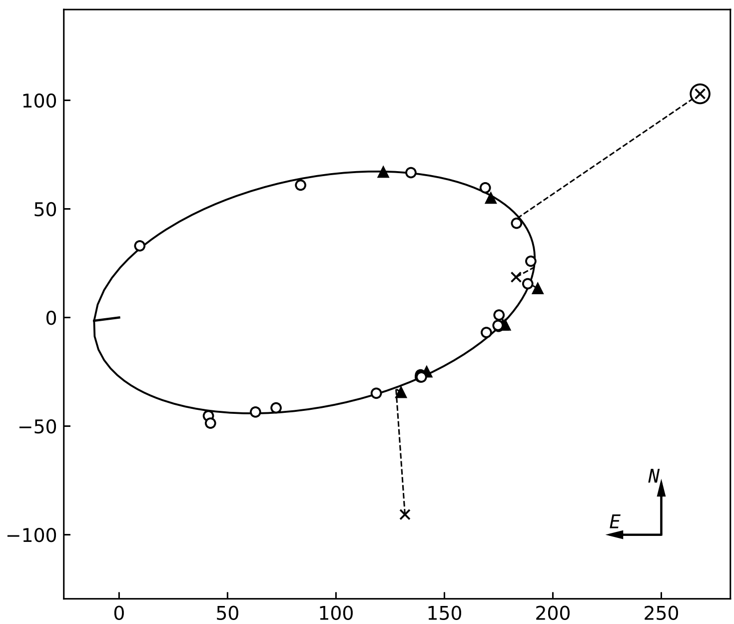

Fig. 1. Orbit of HIP 53731.

2. The designations are $\Delta\rho$(all) and $\Delta\theta$(all) if we use all measurements to construct orbits; $\Delta\rho$(bp) and $\Delta\theta$(bp) if we exclude data with the largest residuals (in Figure 1 are marked with crosses); and $\Delta\rho$(BTA) and $\Delta\theta$(BTA) if we only use measurements obtained at BTA since 2007.

Table 2. Average residuals of measurements.

Object	$\Delta\rho$(all), mas	$\Delta\rho$(bp), mas	$\Delta\rho$(BTA), mas	$\Delta\theta$(all), °	$\Delta\theta$(bp), °	$\Delta\theta$(BTA), °
HIP 14524	2.6	2.3	0.9	0.8	0.5	0.4
HIP 16025	4	1.3	0.7	1.3	0.6	0.5
HIP 18856	6	1.3	1.2	2.2	2.1	0.5
HIP 28671	9.8	2.5	1.7	3.2	1.4	1
HIP 46199	6.7	5.6	2.6	1	1	0.8
HIP 47791	1	0.7	0.4	1.7	0.9	0.9
HIP 53731	18	2	2	4	0.8	0.7
HIP 60444	21.6	5.1	4.3	7.4	0.8	0.8
HIP 61100	1.5	1.5	1.4	1.4	1.4	1.3
HIP 73085	4	3	1.7	2.4	1.5	1.5

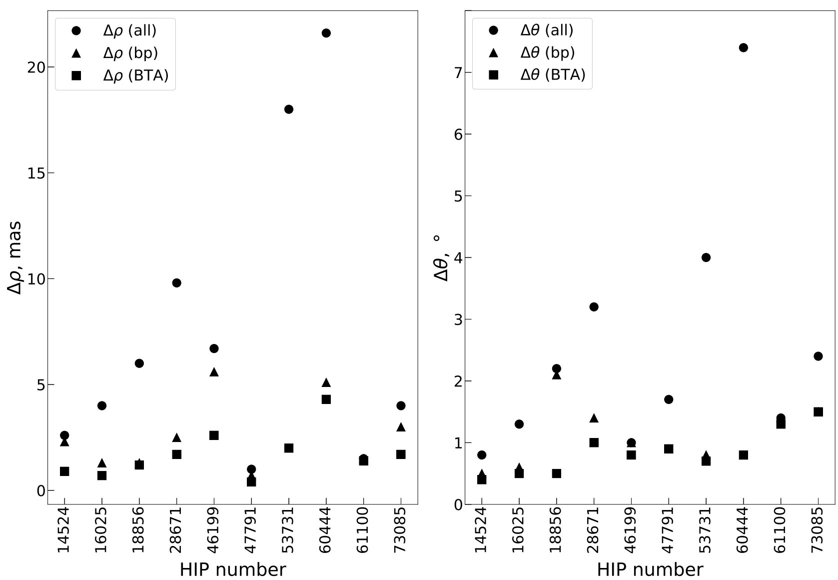

Fig. 2. Average residuals of measurements.

3 Discussion

The residuals calculated from the new data are the lowest one, as shown in Figure 1 and Table 2. Therefore, long-term monitoring of speckle interferometric binaries allows for construction of accurate orbits, and the use of a single instrument provides homogeneous data. The fact that the orbits of binaries are being improved or constructed for the first time indicates the justification of the long-term monitoring of objects carried out in the group of high-resolution methods in astronomy of the SAO RAS.

Despite the fact that studies of such objects are carried out using different telescopes and by different teams all over the world, the discrepancies of measurements for orbital solutions (if we exclude data that do not agree well with the orbit) are small. This indicates the good accuracy of actual orbital solutions. After Gaia DR3 is released, the orbital parameters will be further refined using high-precision observational data.

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