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Speckle observations with PISCO in Merate.

II. Astrometric measurements of visual binaries in 2004.

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ABSTRACT

We present relative astrometric measurements of visual binaries made during the second semester of 2004, with the speckle camera PISCO at the 1-metre Zeiss telescope of Brera Astronomical Observatory, in Merate. We performed 207 new observations of 194 objects, with angular separations in the range $0''.1 - 4''.0$, and with an accuracy better than $\sim 0''.01$. Our sample contains orbital couples as well as binaries whose motion is still uncertain. Our purpose is to improve the accuracy of the orbits and constrain the masses of the components.

Those measurements show that the orbit of ADS 15115 needs to be revised; we propose a new orbit for this object.

Key words: Stars: binaries: close, visual — Astrometry — Techniques: interferometric

1 INTRODUCTION

In the last thirty years, the study of binary stars has undergone a significant development with the advent of speckle interferometry, proposed by Labeyrie (1970). By exploiting statistical properties of short-exposure images, this technique overcomes the loss of angular

resolution caused by the atmospheric turbulence. Binary stars are the objects which have most taken advantage of speckle interferometry, mainly because of their simple geometry. Indeed, we have found that this technique can lead to astrometric measurements up to the diffraction limit of the telescope, even when atmospheric conditions are not particularly good.

Surveys have shown that more than half of the stars are binaries (e.g., Duquennoy & Mayor, 1991). The study of binary systems is thus fundamental in astrophysics. It is the only direct method of deriving stellar mass, and the combination of various observation techniques (e.g. astrometry, spectroscopy and photometry) allows the determination of physical parameters of the stellar components. Statistical studies of binaries can also lead to constraints on stellar formation, the initial mass function and stellar evolution (using the fact that the two components have the same age).

In this paper, we present astrometric measurements of close visual binary stars with the speckle camera PISCO¹ on the 1-metre Zeiss telescope of *I.N.A.F. – Osservatorio Astronomico di Brera* (OAB, Brera Astronomical Observatory) in Merate (Italy). This paper is the second of a new series whose purpose is to contribute to the determination of binary orbits, using speckle observations made in Merate. The results of the first observations performed during the first semester of 2004, were published in Scardia et al. (2005, hereafter Paper I).

In Section 2, we present our sample and the observations performed during the second semester of 2004. The astrometric measurements are given in Section 3 with a detailed discussion of some particular cases. Finally, in Section 4 we provide new orbital parameters of ADS 15115, partly derived from those observations, and give some estimates of the component masses.

2 OBSERVATIONS

As stated in Paper I, the purpose of this work is to observe all the visual binaries accessible with PISCO on the Zeiss telescope in Merate. Our sample consists of visual binaries with the following characteristics:

- declination north of -5 degrees,

¹ PISCO stands for “Pupil Interferometry Speckle camera and COronagraph”.

- brighter than 9th magnitude in V,
- a magnitude difference less than 4,
- an angular separation smaller than $4''.0$.

Our observations were carried out with the PISCO speckle camera developed at the Midi-Pyrénées Observatory (Priour et al., 1998), with the ICCD detector (Intensified CCD with a micro-channel plate) belonging to Nice University. Details of the telescope, the instrumentation and the data reduction procedure can be found in Paper I.

In Paper I, we had shown that the variations of the focal length of the Zeiss Cassegrain telescope, caused by the temperature changes between summer and winter periods, were negligible, i.e., smaller than the calibration errors. Hence, for this work, we used the calibration values that we determined for Paper I².

Two eyepieces, of focal lengths 10 and 20 mm, were used to control the last magnification stage of PISCO. The scale values for the angular separation ρ were $0''.03183 \pm 0.00012/\text{pixel}$ and $0''.07438 \pm 0.00021/\text{pixel}$ for the 10 and 20 mm eyepieces, respectively. The uncertainty for the calibration of the position angle θ was $\pm 0^\circ.13$. Those uncertainties were included in the error budget of ρ and θ , displayed in Cols. 8 and 10 of Table 1.

3 ASTROMETRIC MEASUREMENTS

The astrometric measurements are displayed in Table 1. The designation of the binary is given in the first 3 columns: the WDS name (Washington Double Star Catalogue, Mason et al., 2005) in Col. 1, the official double star designation in Col. 2 (sequence is discoverer-number), and the ADS number in Col. 3 (Aitken, 1932). For each observing sequence, we give the epoch of observation (Col. 4) in fraction of Besselian years (2004+), the filter (Col. 5) (whose characteristics are listed in Table 1 of Paper I), the focal length of the eyepiece used for magnifying the image (Col. 6) the angular separation ρ (Col. 7) and its error (Col. 8) in arcseconds, and the position angle θ (Col. 9) and its error (Col. 10) in degrees. The errors were estimated by adding quadratically the calibration errors (see Paper I) to the standard deviation of a series (from 4 to 8) of independent measurements obtained with the same

² To allow an independent scale determination in the future, a calibrating grating mask is under construction. Placed at the entrance of the telescope, this mask will generate a diffraction pattern that will be used to calibrate the magnification of the whole optical system (telescope+instrument+detector).

data set (see Prieur et al. 2001). This procedure generally leads to good error estimates, but may underestimate the errors on θ in the case of diffuse autocorrelation peaks.

Note that two objects were observed without any filter: ADS 11186 and ADS 12889. This is shown with a dash in the filter column (Col. 5).

The position angle follows the standard convention: it is measured relative to the north direction and increasing in the direction of increasing right ascension (i.e. eastwards). This angle was measured on the autocorrelation function, which leaves a 180° ambiguity. In Col 9, an asterisk indicates that this ambiguity could be solved by a triple correlation method (see Sect. 3.1). Otherwise, we used the quadrant determination of the “Fourth Catalogue of Interferometric Measurements of Binary Stars” (Hartkopf et al., 2004).

In Col. 11, a flag was set to one for the objects for which an orbit is known; the residuals with the corresponding ephemerides will be discussed in Sect. 3.2.

In the notes column, HF n indicates that “High Frequency noise” was present in the power spectrum (see more details in Paper I), NF means that “No Fringes” were visible in the power spectrum. We also give some information about the secondary peaks in the autocorrelation (e.g., “elongated”, “very faint peaks”, “diffuse”, ...).

The smallest (one-sigma) errors for the angular separation (Col. 8) were estimated at $0''.003$ for close pairs (i.e., $\rho < 1''$) which corresponds to 0.1 pixel in the elementary frames and at 0.05% of ρ for wide pairs (i.e., $\rho > 1''$), on the basis of the uncertainties coming from the determination of the center of the autocorrelation peak and those affecting the scale calibration (see Paper I). Similarly, the smallest (one-sigma) error for the position angle (Col. 10) was $0^\circ.3$.

3.1 Quadrant determination

To solve the 180° ambiguity of the θ measurements made from the autocorrelation files and determine the quadrant where the companion was, we used the restricted triple-correlation technique described in Aristidi et al. (1997)

For this purpose, we computed restricted triple-correlation files for all our observations and examined the location of the faintest secondary spot, which corresponded to that of the companion. When the signal-to-noise ratio was good enough (i.e. 143 out of 207 observations, corresponding to 69%), we were able to determine the location of this spot and thus solve

the 180° ambiguity. The corresponding “absolute” values of the position angle are noted with an asterisk in Col 9 of Table 1.

We then checked whether those “absolute” θ values were consistent with the ones tabulated in the Fourth Catalogue of Hartkopf et al. (2004). We found a good agreement for all objects, except for the following five cases, where a difference of 180° was observed for θ : ADS 768, 10850, 10905, 16266, and 17050.

For those objects, except ADS 10905, we noticed that the order in which the corresponding components were tabulated in the Fourth Catalogue was reversed (with the faintest component first, followed by the brightest one), with respect to the general case. Brian Mason (private communication) explained that it was because Tycho-Hipparcos photometric measurements were not in agreement with the quadrant previously determined by other observers. To be in agreement with Hipparcos magnitudes and our quadrant determination, he corrected the quadrants of those four objects in the updated online version of his Fourth Catalogue.

Hence, there is only one remaining object, namely $17564+1820 = \text{ADS } 10905$, for which our quadrant determination is not in agreement with the latest measurements reported in the Fourth Catalogue of Hartkopf et al. (2004). When looking at the numerous measurements made since 1829, the position angle of this binary has shown little variation over this long period of time, but it was either reported $\sim 112^\circ$ or $\sim 292^\circ$, according to the observers. The reason is because the luminosity difference between the two components in the V band is very small, which makes quadrant determination very uncertain in V . Sinachopoulos et al. (1999) have found $\Delta m_V = 0.05$, whereas a significant magnitude difference $\Delta m_B = 1.24$ was measured by Tycho-Hipparcos (with $\theta = 292.1^\circ$). The observation reported in this paper was made with a red filter (R , centered at $\lambda = 644$ nm with a width of 70 nm). We are rather confident in our quadrant determination (with $\theta = 111.6^\circ$) because the triple correlation image showed clear secondary peaks. This is also an indication that the magnitude difference is rather large in R ($\Delta m_R \sim 0.7\text{--}1.0$).

Those photometric data indicate that the A and B components of ADS 10905 have clearly different spectral types. If we assume that the primary (A component) is an A-type star (A0III in SIMBAD data base), the secondary must be a cool star of type K5–M0, of the same luminosity class (III) to obtain $\Delta m_V \sim 0$. This combination would also lead to the estimated Δm values in B and R , according to Landolt-Bornstein (1996). Hence, for ADS 10905, the brightest component in B is the faintest in R , and the “quadrant swap”

occurs in V . This explains the apparent discrepancies of the quadrant values reported by the observers for this object.

3.2 Comparison with published ephemerides

Table 2 contains the ($O - C$) (Observed minus Computed value) residuals of the 55 objects with a known orbit, whose origin is given in Col. 2. The residuals relative to the separation and position angles are given in Cols. 5 and 6, respectively. The orbital elements used for computing the ephemerides were retrieved from the ‘‘Sixth Catalogue of Orbits of Visual Binary Stars’’ (Hartkopf & Mason, 2004) and the bibliographic references of Col. 2 can also be found in this catalogue. The values in Col. 4 are the relevant observed separations we extracted from Col. 7 of Table 1. They are repeated here for the convenience of the reader, to be able to identify the cases when ρ is small.

In the Sixth Catalogue of Hartkopf & Mason (2004), note that the orbit of ADS 14839 is reported with $\omega = 351.92^\circ$ (periastron longitude), whereas this parameter was 171.92° in the original publication of Fekel et al. (1997). We found that the good value is the latter one, since it leads to quadrant values compatible both with our measurements and with the other values listed in Hartkopf et al. (2004).

The residuals of our measurements are displayed in Fig. 1. Most of them are well centered around the origin ($\Delta\rho = 0, \Delta\theta = 0$), with a rather large scatter that can be explained by the (old) age of many orbits.

Let us examine now the cases with large residuals. We shall then select here all the objects for which the absolute values of $\Delta\rho_{O-C}$ and $\Delta\theta_{O-C}$ are larger than $0.2''$ and 5° , respectively. From Table 2, we see that this corresponds to the following list: ADS 10696, 11635 AB, 13256, 13850, 14573, 15115, 16057, DJU 4, and COU 14.

Among this list, we have found that orbit revision was justified for only one couple, namely ADS 15115. We present a new orbit in Sect. 4 that will replace the orbit computed by Starikova (1977). For the other objects, the number of observations made since the last orbit computation is unfortunately not sufficient to justify the revision of their orbits.

For ADS 10696, the orbit of Heintz (1996) seems to slowly deviate from the observations. Our measurement made at Pic du Midi in 1998 (Scardia et al. 2000) had already significant residuals ($\Delta\rho_{O-C} = -0''.01, \Delta\theta_{O-C} = +3.2^\circ$). The present measurements confirm that this deviation has increased in the same direction ($-0''.02, +5.4^\circ$).

For ADS 11635 AB, the old orbit of Güntzel-Lingner (1956) is also slowly deviating from the observations. Note that the period is of the order of 1000 yr; the companion has moved along a very small arc of the orbit only.

For ADS 13256, the orbit proposed by Hopmann (1973) can be considered as a tentative only, because the arc of the orbit is very small and the trajectory has a small curvature.

For ADS 14573, the two orbits that are proposed are not fully satisfactory. The orbit from Hopmann (1960) is in good agreement with our θ measurement but leads to a large residual in ρ . On the contrary, the orbit of Popovic (1969) is more satisfactory for ρ , but leaves a rather large residual in θ .

In the case of DJU 4, the large ρ residual may be due to an error in the published elements (Popovic & Olevic 2002) which do not yield the published ephemeris positions. However, extrapolating those positions to the epoch of the PISCO measurement leads to a much better agreement ($+0''.06, -0^\circ.1$). A recent observation by Argyle (2002) agrees with the wider separation obtained with PISCO. Although the orbit of Popovic and Olevic was published recently, the 863 year period is based on observations from 1953 to 1993 which define an arc of only 5 degrees: it is therefore largely unconstrained.

We shall not discuss the large residuals $\Delta\theta$ of COU 14, ADS 13850 and ADS 16057 since they might be explained by the small separations of those objects. They are currently close to the diffraction limit of the telescope, and the uncertainties on θ measurements are large.

For all the other orbital couples, the residuals are still acceptable and the corresponding orbits can be considered as valid.

3.3 Unresolved objects

There are 4 unresolved objects: HO 215, ADS 14412, ADS 14783, and COU 144 in Table 1.

Among those, only ADS 14412 and 14783 have a published orbit. For ADS 14412, the ephemerides predict an angular separation of $0''.17$, close to the diffraction limit of the telescope ($0''.11$ in V), which may explain the absence of detection. On the contrary, we did not resolve ADS 14783 although the expected separation is $0''.38$, which is large enough to be detected, if the orbit proposed by Söderhjelm (1999) is valid. Note that this discrepancy has been confirmed by Alzner (2005) who also found this star single with a 32.5 cm aperture, in 2004. Clearly more observations are needed for this object.

4 NEW ORBIT OF ADS 15115

Our observations showed that the orbit of ADS 15115 computed by Starikova (1977) needs to be revised. Fortunately, the list of past observations kindly supplied by the United States Naval Observatory of Washington had sufficient new observations to justify this revision.

The preliminary orbital elements calculated with the analytical method of Kowalsky (1873) are presented in Table 3 and the ephemerides in Table 4. The orbit is displayed in Fig. 2.

In Table 3, “node” and “omega” are the position angle of the ascending node and the longitude of the periastron, respectively. The former is measured in the plane of the sky from north through east; the latter in the plane of the true orbit, from the ascending node to the periastron, in the direction of motion of the companion. i is the inclination of the orbit relative to the plane of the sky, e the eccentricity, T the epoch of periastron passage, P the period, n the mean angular motion, and a is the mean semi-major axis. The four parameters A, B, F, and G are the Thiele-Innes constants (useful for an easier computation of the ephemerides).

The ephemerides are presented in Table 4, with the date in Besselian years in Col. 1, the angular separation ρ in arcseconds in Col. 2 the position angle θ in degrees in Col. 3.

Table 5 of the new ($O - C$) residuals is restricted for reasons of space to the observations made since 1983. For each observation, the date in Besselian years is given in Col. 1, the observed separation ρ in arcseconds in Col. 2, the observed position angle θ (reduced to 2000) in degrees in Col. 3, the $\Delta\rho_{(O-C)}$ residual in Col. 4, the $\Delta\theta_{(O-C)}$ residual in Col. 5, the number of nights used for obtaining this measurement in Col. 6 and the name of the observer in Col. 7, as given in the Sixth Orbit Catalogue of Hartkopf & Mason (2004).

Figure 2 shows the apparent orbit obtained by us (solid line) and the observational data used for the calculation of the orbital elements. The big cross (+) indicates the location of the primary component, and the straight line through this point is the line of apsides. The orientation of the orbit is in conformity with the convention adopted by the observers of visual binary stars.

With a spectral type of A3V and a Hipparcos parallax of $0''.00473$, we found a sum of masses of $4.8 M_{\odot}$ and a semi major axis of 56.4 au.

Using the method of Baize-Romani (Couteau, 1978) we obtained a dynamical parallax of $0''.0042$, which is then in very good agreement with the Hipparcos measurement.

The position angle measurements are well represented with our orbit, but the angular separation residuals still show some systematic offset. This offset was already present in the previous orbit of Starikova (1977), and will disappear when more observations are available. Note that our new orbit is also more satisfactory than Starikova's, concerning the plausibility of the astrophysical parameters of the star components.

5 CONCLUSION

In 2004, we have performed a total of 342 observations of 297 objects, of which 207 observations of 194 objects were made in the second semester.

Over this year of observation with the 1-metre Zeiss telescope, we have found the following limitations of PISCO with the ICCD detector:

- Smallest separation: $\rho \sim 0''.14$
- Largest separation: $\rho \sim 4''.0$
- Average accuracy: $\sigma(\rho) \sim 0''.01$ and $\sigma(\theta) \sim 0^\circ.5$
- Faintest target observed: $V \sim 9.4$

The minimum angular separation is close to the diffraction limit of the telescope (i.e., $0''.11$ in V). The astrometric measurements presented here have an accuracy comparable to those obtained with the 2-metre telescope of Pic du Midi. The magnitude of the faintest objects observed in Merate is comparable to the value we found when using PISCO and the ICCD at the 2-metre telescope of Pic du Midi (Prieur et al., 2002). This was expected from a theoretical point of view (see e.g., Dainty & Greenaway, 1979): at low flux, the signal-to-noise ratio obtained with speckle interferometry for a given angular frequency is proportional to n_{ph} , the number of photons per speckle in the elementary frames. Of course, a larger telescope leads to a larger angular frequency coverage, but, within this domain, the key parameter which determines the limiting magnitude is n_{ph} (the value of the diameter has a negligible influence). Hence, this work shows that a significant contribution can be provided with PISCO on the OAB 1-metre telescope.

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sending on request some lists of measurements of visual binaries.

This work has made use of the “Fourth Catalogue of Interferometric Measurements of Binary Stars” (<http://ad.usno.navy.mil/wds/int4.html>), the “Sixth Catalogue of Orbits of Visual Binary Stars” (<http://ad.usno.navy.mil/wds/orb6.html>), and the Washington Double Star Catalogue maintained at the U.S. Naval Observatory (<http://ad.usno.navy.mil/wds/wds.html>). For bibliographic references, we used the SIMBAD data base, operated by the “Centre de Données Astronomiques de Strasbourg” (France).

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Table 1. Measurements

WDS	Name	ADS	Epoch	Fil.	Eyep. (mm)	ρ (arcsec)	σ_ρ (arcsec)	θ (deg.)	σ_θ (deg.)	Orb.	Notes
00022+2705	BU 733 AB	17175	2004.952	R	20	0.788	0.025	233.3*	0.7	1	
00047+3416	STF 3056 AB	32	2004.955	R	20	0.720	0.010	143.3*	1.2	0	
00063+5826	STF 3062	61	2004.881	R	20	1.497	0.007	338.0*	0.5	1	
00093+7943	STF 2	102	2004.944	R	10	0.810	0.004	18.8	0.4	1	
00134+2659	STT 2 AB	161	2004.950	R	10	0.398	0.003	164.7*	0.9	1	
00162+7657	STF 13	207	2004.972	R	20	0.951	0.007	51.3*	0.3	1	
00209+3259	AC 1	285	2004.944	R	20	1.839	0.010	288.5*	0.3	0	
00442+4614	STF 52	616	2004.955	R	20	1.387	0.007	4.3*	0.4	0	
00546+1911	STT 20 AB	746	2004.952	R	10	0.541	0.003	187.7*	0.3	1	
00550+2338	STF 73 AB	755	2004.944	R	20	0.949	0.012	316.2*	0.6	1	
"	"	"	2004.944	R	10	0.965	0.005	316.5*	0.3	1	
00554+3040	BU 500	768	2004.950	R	20	0.510	0.015	122.2*	2.0	0	
00568+6022	BU 1099 AB	784	2004.952	R	10	0.269	0.007	357.0	2.1	1	
01015+6922	A 2901	836	2004.952	R	10	0.438	0.003	58.9	0.6	0	
01030+4723	STT 21	862	2004.972	R	20	1.182	0.007	175.0*	0.7	1	
01095+4715	STT 515 AB	940	2004.972	R	10	0.501	0.004	122.7*	0.6	1	
01097+2348	BU 303	955	2004.950	R	10	0.623	0.004	292.5	0.3	0	
01112+3743	HO 215		2004.950	R	10	–	–	–	–	0	NF
01401+3858	STF 141	1305	2004.972	R	20	1.645	0.013	302.6	0.4	0	
01493+4754	STF 162 Aa-B	1438	2004.972	R	20	1.890	0.009	200.6*	0.3	0	
01559+0151	STF 186	1538	2004.950	R	10	0.933	0.005	64.1	0.3	1	
02020+0246	STF 202 AB	1615	2004.950	V	20	1.823	0.013	269.9*	0.3	1	
02037+2556	STF 208 AB	1631	2004.944	R	20	1.216	0.008	337.3*	0.8	1	
02039+4220	STT 38 BC	1630 BC	2004.955	V	10	0.375	0.003	101.2*	0.5	1	
02140+4729	STF 228	1709	2004.972	R	10	0.915	0.005	286.8*	0.3	1	
02157+2503	COU 79		2004.972	V	10	0.164	0.019	262.1	2.8	1	Fuzzy
02589+2137	BU 525	2253	2004.955	R	10	0.544	0.003	269.1	0.3	1	
03140+0044	STF 367	2416	2004.972	R	20	1.160	0.007	134.3*	0.3	1	
03184-0056	AC 2 AB	2459	2004.972	R	20	1.198	0.016	256.0	0.3	1	
03344+2428	STF 412 AB	2616	2004.950	R	10	0.706	0.004	355.4	0.3	1	
03350+6002	STF 400 AB	2612	2004.955	R	20	1.517	0.010	265.1*	0.3	1	
16413+3136	STF 2084	10157	2004.659	V	10	0.864	0.004	231.4*	0.3	1	
16442+2331	STF 2094 AB	10184	2004.687	V	20	1.183	0.007	73.0*	0.3	0	HF _n
16511+0924	STF 2106	10229	2004.659	V	20	0.710	0.016	174.4*	0.3	1	HF _n
16514+0113	STT 315	10230	2004.673	V	10	0.580	0.004	316.2*	0.5	1	HF _n
16518+2840	STF 2107 AB	10235	2004.670	V	20	1.400	0.016	99.2	0.3	1	HF _n
16564+6502	STF 2118 AB	10279	2004.585	V	20	1.089	0.010	66.2*	0.3	1	
"	"	"	2004.692	V	20	1.079	0.013	66.3*	0.3	1	
17020+0827	STF 2114	10312	2004.670	V	20	1.318	0.011	193.2	0.5	0	HF _n
17053+5428	STF 2130 AB	10345	2004.618	V	20	2.307	0.012	14.2*	0.4	1	
"	"	"	2004.690	V	20	2.306	0.012	14.2*	0.3	1	
17166-0027	A 2984	10429	2004.659	R	10	0.867	0.006	10.3*	0.9	1	HF _n
17237+3709	MCA 48 Aa		2004.673	V	10	0.476	0.025	33.3	0.8	0	
17237+3709	STF 2161 Aa-B	10526	2004.618	V	20	3.962	0.025	319.3*	0.3	0	
17240+3835	HU 1179	10531	2004.690	R	10	0.253	0.005	276.7	1.2	1	
17290+5052	STF 2180	10597	2004.690	R	20	3.030	0.019	259.4*	0.3	0	
17304-0104	STF 2173	10598	2004.673	V	10	0.208	0.003	189.9	0.3	1	HF _n
17350+6153	BU 962 AB	10660	2004.692	R	20	1.437	0.007	326.6*	0.3	1	
17386+5546	STF 2199	10699	2004.692	R	20	1.974	0.010	57.3*	0.3	1	
17400-0038	BU 631	10696	2004.659	V	10	0.234	0.008	94.2	2.1	1	elongated, HF _n
17403+6341	STF 2218	10728	2004.692	R	20	1.490	0.010	313.4*	0.4	0	

WDS	Name	ADS	Epoch	Fil.	Eyep. (mm)	ρ (arcsec)	σ_ρ (arcsec)	θ (deg.)	σ_θ (deg.)	Orb.	Notes
17412+4139	STF 2203	10722	2004.687	V	20	0.732	0.018	295.2	1.0	0	HF _n
17471+1742	STF 2215	10795	2004.657	V	10	0.508	0.004	256.1*	0.4	1	HF _n
17512+4454	STF 2242	10849	2004.687	V	20	3.333	0.017	326.2	0.3	0	HF _n ,
17520+1520	STT 338 AB	10850	2004.657	V	20	0.818	0.010	166.7*	1.2	0	
17533+4000	BU 130	10875	2004.673	R	20	1.586	0.034	111.7*	0.5	0	
17564+1820	STF 2245 Aa-B	10905	2004.690	R	20	2.593	0.015	111.6*	0.3	0	
17571+0004	STF 2244	10912	2004.657	V	10	0.593	0.010	97.2	0.6	1	HF _n
18018+0118	BU 1125 AB	10990	2004.676	R	10	0.517	0.004	130.6*	1.1	1	HF _n
18096+0400	STF 2281 AB	11111	2004.657	V	10	0.570	0.008	293.0*	0.4	1	HF _n
18101+1629	STF 2289	11123	2004.618	V	20	1.217	0.016	220.5*	0.6	1	
18146+0011	STF 2294	11186	2004.687	-	20	1.260	0.018	93.5*	0.3	1	
18208+7120	STT 353 AB	11311	2004.673	V	10	0.465	0.007	269.0*	0.3	1	elongated, HF _n
18218+2130	BU 641	11287	2004.670	V	20	0.771	0.018	340.6	1.2	0	HF _n
18239+5848	STF 2323 AB	11336	2004.670	V	20	3.676	0.018	349.2*	0.3	0	
18250-0135	AC 11	11324	2004.657	V	20	0.887	0.007	354.9*	0.3	1	
18250+2724	STF 2315 AB	11334	2004.659	V	10	0.634	0.007	122.2	0.6	1	HF _n
18253+4846	STT 351 AC	11344	2004.690	R	20	0.802	0.014	25.7*	1.0	0	
18339+5221	A 1377 AB	11468	2004.657	V	10	0.248	0.004	120.2	0.9	1	
18355+2336	STT 359	11479	2004.640	R	10	0.722	0.006	6.3	0.3	1	HF _n
18359+1659	STT 358 AB	11483	2004.640	V	20	1.629	0.023	152.8	0.5	1	faint peaks, HF _n
18389+5221	STF 2368 AB	11558	2004.657	V	20	1.851	0.019	320.3	0.6	0	HF _n
18413+3018	STF 2367 AB	11579	2004.659	V	10	0.353	0.009	78.1	0.9	1	HF _n ,
18443+3940	STF 2383 Cc-D	11635 CD	2004.640	V	20	2.323	0.012	80.9*	0.3	1	
18443+3940	STF 2382 AB	11635 AB	2004.640	V	20	2.341	0.015	349.5*	0.3	1	
18455+0530	STF 2375 Aa-Bb	11640	2004.659	V	20	2.524	0.013	119.1*	0.3	0	HF _n
18545+2037	STF 2415	11816	2004.690	R	20	1.965	0.010	290.3*	0.3	0	
18570+3254	BU 648 AB	11871	2004.659	V	20	0.782	0.045	280.9*	0.8	1	
18571+2606	STF 2422	11869	2004.673	V	20	0.770	0.012	71.3	0.5	0	HF _n
18575+5814	STF 2438	11897	2004.640	V	20	0.850	0.012	359.8	0.8	1	
19070+1104	HEI 568		2004.618	V	10	0.308	0.009	278.6	0.9	0	HF _n
19126+1651	BU 139 AB	12160	2004.673	V	20	0.626	0.013	136.1*	0.7	0	HF _n
19159+2727	STT 371 AB	12239	2004.673	V	20	0.877	0.008	160.3*	0.3	0	HF _n
19169+6312	STF 2509	12296	2004.753	R	20	1.771	0.009	328.5*	0.3	0	
19266+2719	STF 2525	12447	2004.659	V	20	2.112	0.012	289.7	0.6	1	
19426+1150	STT 380 AB	12808	2004.657	V	10	0.418	0.007	76.7*	0.4	0	HF _n
19429+4043	STT 383 AB	12831	2004.673	V	20	0.814	0.013	14.9*	0.7	0	HF _n
19450+4508	STF 2579 AB	12880	2004.585	V	20	2.602	0.014	221.2	0.3	1	
"	"	"	2004.657	R	20	2.614	0.013	221.6*	0.4	1	
"	"	"	2004.690	R	20	2.625	0.013	222.2*	0.3	1	
"	"	"	2004.717	R	20	2.616	0.013	221.4*	0.5	1	
"	"	"	2004.878	R	20	2.623	0.013	221.5*	0.3	1	
19456+3337	STF 2576 AB	12889	2004.618	-	20	2.745	0.014	161.7*	0.3	1	
19482+7016	STF 2603	13007	2004.753	R	20	3.149	0.016	19.5*	0.4	0	
19487+1149	STF 2583 AB	12962	2004.640	V	20	1.425	0.016	105.6*	0.3	0	faint peaks
19487+3519	STT 387	12972	2004.657	V	20	0.594	0.036	133.1*	1.3	1	HF _n
19535+2405	DJU 4		2004.657	V	20	1.306	0.021	245.9*	0.7	1	faint peaks
19556+5226	STF 2605 AB	13148	2004.659	V	20	2.887	0.014	175.7*	0.3	0	
19585+3317	STF 2606 AB	13196	2004.673	V	20	0.721	0.014	146.0	0.9	0	HF _n ,
19586+3806	STF 2609	13198	2004.676	V	20	1.950	0.014	23.1*	0.3	0	HF _n
20014+1045	STF 2613	13256	2004.676	V	20	3.613	0.018	354.4*	0.4	1	HF _n
20020+2456	STT 395	13277	2004.640	V	20	0.806	0.024	123.8	1.0	0	faint peaks

WDS	Name	ADS	Epoch	Fil.	Eyep. (mm)	ρ (arcsec)	σ_ρ (arcsec)	θ (deg.)	σ_θ (deg.)	Orb.	Notes
20035+3601	STF 2624 Aa-B	13312	2004.692	R	20	1.926	0.024	174.8	0.5	0	
"	"	"	2004.717	V	20	1.933	0.010	174.1*	0.3	0	
20102+4357	STT 400	13461	2004.673	R	20	0.552	0.007	340.9	2.1	1	HF _n
20144+4206	STT 403 AB	13572	2004.673	V	20	0.936	0.018	172.6	1.0	0	HF _n
20153+2536	BU 983 AB	13589	2004.657	V	10	0.480	0.003	182.8	0.8	0	HF _n
20181+4044	STF 2666 Aa-B	13672	2004.753	R	20	2.738	0.014	245.1*	0.3	0	
20184+5524	STF 2671 AB	13692	2004.690	R	20	3.621	0.018	337.4*	0.3	0	
20251+5936	A 730	13850	2004.717	V	10	0.188	0.020	292.8	1.5	1	Diffuse
20303+1054	BU 63 AB	13920	2004.878	V	20	0.919	0.007	349.4*	0.6	0	
20375+1436	BU 151 AB	14073	2004.585	V	10	0.570	0.003	358.1*	0.6	1	
20377+3322	STF 2705 AB	14078	2004.673	R	20	3.124	0.016	262.1*	0.3	0	HF _n
20396+4035	STT 410 AB	14126	2004.640	V	20	0.851	0.016	5.4	1.6	0	
20410+3218	STF 2716 Aa-B	14158	2004.878	V	20	2.753	0.014	45.5*	0.3	0	
20423+5723	BU 152	14196	2004.717	V	20	1.134	0.013	83.4*	0.4	0	
20474+3629	STT 413 Aa-B	14296	2004.640	V	20	0.889	0.013	6.8*	1.5	1	v. faint peaks
20511+5125	BU 155 AB	14370	2004.717	V	20	0.756	0.013	38.5*	0.7	0	
20537+5918	A 751	14412	2004.878	R	10	–	–	–	–	1	NF
20548+3242	STT 418	14421	2004.892	R	20	1.012	0.015	283.7	0.3	0	
20585+5028	STF 2741 AB	14504	2004.717	V	20	1.941	0.010	25.6*	0.3	0	
20591+0418	STF 2737 AB	14499	2004.640	V	20	0.675	0.024	284.5	0.3	1	v. faint peaks, HF _n
21018+3916	STF 2746	14558	2004.892	R	20	1.183	0.007	319.9*	0.3	0	
21021+5640	STF 2751	14575	2004.857	V	20	1.588	0.010	355.4*	0.5	0	
21022+0711	STF 2742	14556	2004.892	R	20	2.855	0.014	214.6*	0.3	0	
21031+0132	STF 2744 AB	14573	2004.857	R	20	1.270	0.015	115.7*	0.3	1	
21086+3012	STF 2762 AB	14682	2004.900	R	20	3.338	0.017	303.5*	0.3	0	
21105+1958	STF 2767	14708	2004.947	R	20	2.443	0.018	29.0*	0.3	0	
21115+4115	STT 431 AB	14733	2004.947	R	20	2.638	0.018	124.6	0.3	0	
21118+5959	STF 2780 Aa-B	14749	2004.857	V	20	1.015	0.010	214.0*	0.8	0	
21135+0713	BU 270 AB	14759	2004.950	R	20	0.597	0.013	348.8*	1.9	1	
21135+1559	HU 767	14761	2004.857	R	10	0.210	0.006	157.7	3.5	1	
21137+6424	H 1 48	14783	2004.878	R	10	–	–	–	–	1	NF
"	"	"	2004.944	R	10	–	–	–	–	1	NF
21141+5818	STF 2783	14784	2004.944	R	20	0.724	0.013	357.3	1.3	0	
21143+4109	STT 432	14778	2004.892	R	20	1.323	0.013	115.6*	0.3	0	
21148+3803	AGC 13 AB	14787	2004.941	V	10	0.731	0.008	269.6*	0.9	1	
21171+3546	BU 162 AB	14822	2004.947	R	20	1.242	0.022	251.9	0.3	0	
21186+1134	BU 163 AB	14839	2004.950	R	20	0.715	0.024	257.8*	0.5	1	
21197+0931	STF 2786	14856	2004.950	R	20	2.722	0.014	188.7*	0.5	0	
21208+3227	STT 437 AB	14889	2004.881	R	20	2.368	0.012	21.1*	0.3	0	
21238+4710	A 765 AB	14944	2004.952	V	20	0.454	0.009	25.6*	2.5	0	
21267+1341	STF 2797	14977	2004.955	R	20	3.463	0.017	217.6*	0.3	0	
21289+1105	STF 2799 AB	15007	2004.936	R	20	1.839	0.014	262.1	0.4	1	
21318+3349	STF 2802	15060	2004.955	R	20	3.770	0.019	9.7*	0.3	0	
21330+2043	STF 2804 AB	15076	2004.955	R	20	3.247	0.016	356.6*	0.3	0	
21355+2427	HU 371	15115	2004.881	V	10	0.270	0.014	312.6*	1.2	1	
21395-0003	BU 1212 AB	15176	2004.955	R	10	0.528	0.003	280.1*	0.3	1	
21426+4103	BU 688 AB	15251	2004.955	R	10	0.423	0.003	201.1	0.6	1	
21441+2845	STF 2822 AB	15270	2004.857	V	20	1.779	0.016	310.4*	0.3	1	
21501+1717	COU 14		2004.936	R	10	0.195	0.010	330.7	2.2	1	Very fuzzy, dubious.
"	"	"	2004.952	V	10	–	–	–	–	1	NF
21510+6137	STT 451	15390	2004.944	R	20	4.128	0.021	218.8*	0.3	0	

WDS	Name	ADS	Epoch	Fil.	Eyep. (mm)	ρ (arcsec)	σ_ρ (arcsec)	θ (deg.)	σ_θ (deg.)	Orb.	Notes
21516+6545	STF 2843 AB	15407	2004.941	R	20	1.365	0.018	148.5*	0.3	0	
21555+1053	BU 75 AB	15447	2004.974	R	20	0.878	0.007	19.9*	0.3	1	
21555+5232	STT 456 AB	15460	2004.974	R	20	1.591	0.011	36.4*	0.4	0	
21555+6519	STT 457	15467	2004.944	R	20	1.301	0.022	245.4*	0.4	0	
21565+5948	STT 458 AB	15481	2004.974	R	20	0.962	0.007	348.5*	0.8	0	
21573+6118	BU 275	15499	2004.974	R	10	0.425	0.004	170.4*	0.4	0	
22029+4439	BU 694 AB	15578	2004.881	V	20	0.984	0.007	6.1*	1.1	0	
22044+1339	STF 2854	15596	2004.974	R	20	1.716	0.009	82.9*	0.3	0	
22086+5917	STF 2872 BC	15670	2004.944	R	20	0.819	0.015	298.2	0.4	1	
22100+2308	COU 136		2004.717	R	20	0.504	0.030	26.2	4.8	1	
22110+6324	STF 2879 AB	15712	2004.944	R	20	0.764	0.014	232.6*	1.1	0	
22145+0759	STF 2878 AB	15767	2004.947	R	20	1.476	0.017	116.7*	0.4	0	
22146+2934	STF 2881	15769	2004.878	R	20	1.296	0.022	76.9*	0.3	0	
22158+4354	HO 180	15794	2004.936	R	20	0.750	0.016	239.6	0.9	0	
22241-0450	BU 172 AB	15902	2004.952	V	10	0.348	0.005	49.4*	0.3	1	
22288-0001	STF 2909	15971	2004.878	V	20	1.891	0.013	178.1*	0.3	1	
22300+0426	STF 2912	15988	2004.952	V	10	0.218	0.011	119.0*	2.1	1	
22330+6955	STF 2924 AB	16057	2004.950	V	10	0.160	0.023	161.9	2.5	1	Fuzzy, dubious.
22388+4419	HO 295 AB	16138	2004.717	V	10	0.293	0.004	153.1	1.1	1	
22431+4710	STT 476 A-BC	16214	2004.878	V	20	0.504	0.011	304.6*	1.5	0	
"	"	"	2004.878	R	10	0.495	0.004	302.9*	0.4	0	
22441+3928	STF 2942 AB	16228	2004.881	R	20	2.837	0.026	277.7*	0.3	0	
22470+4446	A 189 AB	16266	2004.881	R	20	1.006	0.007	26.4*	0.4	0	
22496+6633	STF 2948	16298	2004.892	R	20	2.652	0.013	4.2*	0.3	0	
22514+2623	HO 482 AB	16314	2004.878	R	10	0.474	0.003	20.8	0.5	1	
22514+6142	STF 2950 AB	16317	2004.892	R	20	1.313	0.011	280.1*	0.3	0	
22520+5743	A 632	16326	2004.892	R	20	0.567	0.016	144.0*	1.6	1	
22537+4445	BU 382 AB	16345	2004.936	V	20	0.850	0.009	227.3*	1.0	1	
22542+7620	STF 2963	16371	2004.950	R	20	1.912	0.010	2.0*	0.3	0	
22564+2257	COU 240		2004.947	R	20	0.774	0.012	292.5*	0.7	0	
22565+6252	STF 2961	16394	2004.892	R	20	1.845	0.012	347.6*	0.3	0	
22569+1151	STF 2958	16389	2004.972	R	20	3.851	0.019	14.1*	0.3	0	
23050+3322	STF 2974	16496	2004.947	R	20	2.634	0.013	165.8*	0.3	0	
23072+6050	BU 180 AB	16518	2004.974	R	10	0.555	0.006	137.9	0.9	0	
23078+6338	HU 994	16530	2004.950	V	10	0.202	0.029	315.5	1.8	1	
23079+7523	STT 489 AB	16538	2004.974	R	20	1.082	0.015	350.5*	1.0	1	
23103+3229	BU 385 AB	16561	2004.947	R	20	0.659	0.016	85.7*	1.1	0	
23186+6087	STF 3001 AB	16666	2004.974	R	20	3.324	0.017	220.7*	0.3	1	
23260+2742	HO 489 AB	16748	2004.947	R	20	0.551	0.065	221.9	1.8	0	
23339+2342	COU 144		2004.972	R	20	-	-	-	-	0	NF
23411+4613	MLR 4		2004.955	R	10	0.185	0.009	281.9	2.3	1	Fuzzy
23413+3234	BU 858 AB	16928	2004.952	R	20	0.823	0.012	223.7*	0.5	0	
23420+2018	STT 503 AB	16937	2004.955	R	20	1.073	0.007	133.4*	0.4	0	
23461+6028	STF 3037 AB	16982	2004.974	R	20	2.614	0.013	211.8*	0.3	0	
23476+4650	BU 995	17006	2004.955	R	20	0.778	0.026	246.2*	0.8	0	
23487+6453	STT 507 AB	17020	2004.972	R	10	0.714	0.004	316.2*	0.3	1	
23488+6213	STT 508 AB	17022	2004.972	R	20	1.476	0.007	196.1*	0.6	0	
23516+4205	STT 510 AB	17050	2004.952	R	20	0.582	0.012	121.8*	1.1	0	
23522+4331	BU 728	17063	2004.952	R	20	1.215	0.007	8.8*	0.5	0	
23590+5545	STF 3049 AB	17140	2004.955	R	20	3.102	0.016	326.1*	0.3	0	
23592+7448	BU 1154	17143	2004.972	R	20	1.197	0.007	330.2*	0.3	0	
23595+3343	STF 3050 AB	17149	2004.881	R	20	2.106	0.011	332.3*	0.3	1	
"	"	"	2004.944	R	20	2.130	0.018	332.4*	0.3	1	
"	"	"	2004.952	R	20	2.109	0.011	332.3*	0.3	1	

Table 2. Residuals with published orbits (begin.)

ADS/Name	Orbit	Epoch	$\rho(O)$ (arcsec)	$\Delta\rho(O - C')$ (arcsec)	$\Delta\theta(O - C')$ (deg.)
61	Söderhjelm (1999)	2004.881	1.497	-0.03	0.7
102	Heintz (1997)	2004.944	0.810	-0.02	1.3
102	Scardia (1980)	2004.944	0.810	0.00	2.2
161	Scardia (2000)	2004.950	0.398	-0.02	-1.4
161	Olevic (2001)	2004.950	0.398	0.04	4.2
207	Olevic (2001)	2004.972	0.951	0.05	0.1
746	Docobo (2001)	2004.952	0.541	0.01	0.3
755	Docobo (1990)	2004.944	0.949	-0.03	-0.3
	"	2004.944	0.965	-0.02	0.0
784	Cole (1992)	2004.952	0.269	-0.02	-0.5
862	Heintz (1966)	2004.972	1.182	0.10	-0.5
940	Scardia (2001)	2004.972	0.501	0.00	-0.4
1538	Mourao (1977)	2004.950	0.933	0.04	-2.2
1615	Scardia (1983)	2004.950	1.823	0.03	1.7
1630	Docobo (2000)	2004.955	0.375	0.00	-1.7
1631	Heintz (1996)	2004.944	1.216	-0.13	-3.8
1709	Söderhjelm (1999)	2004.972	0.915	-0.02	-0.2
COU 79	Hartkopf (1996)	2004.972	0.164	0.01	-0.2
2253	Costa (1978)	2004.955	0.544	0.04	-1.0
2416	Heintz (1963)	2004.972	1.160	0.04	2.4
2459	Popovic (1997)	2004.971	1.198	-0.04	0.7
2612	Seymour (2000)	2004.955	1.517	0.06	-1.5
2616	Scardia (2002)	2004.950	0.706	0.00	0.3
10157	Söderhjelm (1999)	2004.659	0.864	-0.03	0.9
10229	Scardia (2001)	2004.659	0.710	-0.01	0.9
10230	Docobo (1991)	2004.673	0.580	-0.01	0.7
10235	Scardia (1984)	2004.670	1.400	0.05	-1.8
10279	Scardia (2002)	2004.585	1.089	-0.07	-1.4
	"	2004.692	1.079	-0.08	-1.3
10345	Heintz (1981)	2004.618	2.307	0.03	2.0
	"	2004.690	2.306	0.03	2.0
10429	Olevic (1993)	2004.659	0.867	-0.17	0.1
10531	Hartkopf (2000)	2004.690	0.253	0.00	3.3
10598	Heintz (1994)	2004.673	0.208	-0.01	1.0
10660	Söderhjelm (1999)	2004.692	1.437	-0.04	0.5
10696	Heintz (1996)	2004.659	0.234	-0.02	5.4
10699	Popovic (1995)	2004.692	1.974	0.06	1.7
10795	Popovic (1995)	2004.657	0.508	-0.06	-0.7
10912	Heintz (1997)	2004.657	0.593	0.07	-1.6
10990	Popovic (2000)	2004.676	0.517	-0.06	-2.7
11111	Söderhjelm (1999)	2004.657	0.570	-0.01	1.6
11123	Hopmann (1964)	2004.618	1.217	-0.02	3.3
11186	Luyten (1934a)	2004.687	1.260	0.07	0.1
11311	Olevic (1994)	2004.673	0.465	0.03	2.6
11324	Heintz (1995)	2004.657	0.887	0.04	0.0
11334	Heintz (1960)	2004.659	0.634	-0.17	-0.1
11468	Scardia (1984)	2004.657	0.248	0.00	-2.0
11479	Symms (1964)	2004.640	0.722	0.01	1.1
11483	Heintz (1995)	2004.640	1.629	0.06	0.7
11579	Pourbaix (2000)	2004.659	0.353	-0.01	1.7
11635AB	Günztel-Lingner (1956)	2004.640	2.341	-0.20	0.4
11635CD	Docobo (1984)	2004.640	2.323	-0.03	0.4
11871	Heintz (1994)	2004.659	0.782	-0.04	3.4
11897	Hartkopf (2001)	2004.640	0.850	0.01	0.7
12447	Heintz (1984)	2004.659	2.112	0.05	-1.1
12880	Scardia (1983)	2004.585	2.602	-0.03	-1.2
	"	2004.657	2.614	-0.02	-0.8
	"	2004.690	2.625	-0.01	-0.2
	"	2004.717	2.616	-0.02	-0.9
	"	2004.878	2.623	-0.01	-0.8
12889	Söderhjelm (1999)	2004.618	2.745	-0.05	0.0
12972	Heintz (1996)	2004.657	0.594	-0.03	-4.0
DJU 4	Popovic (2002)	2004.657	1.306	0.29	-1.3
13256	Hopmann (1973)	2004.676	3.613	-0.54	2.4

Table 2. Residuals with published orbits (end)

ADS/Name	Orbit	Epoch	$\rho(O)$ (arcsec)	$\Delta\rho(O - C)$ (arcsec)	$\Delta\theta(O - C)$ (deg.)
13461	Heintz (1997)	2004.673	0.552	-0.01	1.5
13850	Heintz (1986)	2004.717	0.188	0.00	-7.9
14073	Alzner (1998)	2004.585	0.570	-0.02	-0.2
14296	Rabe (1948)	2004.640	0.889	-0.01	2.3
14412	Hartkopf (1989)	2004.878	–	(0.17)	(77.8)
14499	Zeller (1965)	2004.640	0.675	-0.02	0.1
14573	Hopmann (1960)	2004.857	1.270	-0.19	0.5
14573	Popovic (1969)	2004.857	1.270	0.05	5.1
14759	Heintz (1979)	2004.950	0.597	-0.01	0.5
14761	Hartkopf (1996)	2004.857	0.210	-0.01	-3.3
14783	Söderhjelm (1999)	2004.878	–	(0.38)	(239.7)
	”	2004.944	–	(0.38)	(239.8)
14787	Söderhjelm (1999)	2004.941	0.731	-0.01	-0.7
14839	Fekel (1997)	2004.950	0.715	0.02	-1.9
15007	Popovic (1987)	2004.936	1.839	0.11	1.7
15115	Starikova (1977)	2004.881	0.270	-0.01	-6.0
15176	Heintz (1994)	2004.955	0.528	-0.01	-0.2
15251	Baize (1981)	2004.955	0.423	-0.02	-1.0
15270	Heintz (1995)	2004.857	1.779	0.02	-1.7
COU 14	Hartkopf (1989)	2004.936	0.195	0.04	13.8
15447	Heintz (1996)	2004.974	0.878	-0.02	0.3
15670	Seymour (2002)	2004.944	0.819	0.00	-0.7
COU 136	Couteau (1999)	2004.717	0.504	0.00	-0.6
15902	Heintz (1996)	2004.952	0.348	-0.03	3.1
15971	Heintz (1984)	2004.878	1.891	-0.17	-0.1
15988	Söderhjelm (1999)	2004.952	0.218	-0.02	-0.5
16057	Söderhjelm (1999)	2004.950	0.160	0.03	-6.5
16138	Hartkopf (1996)	2004.717	0.293	-0.01	-0.3
16314	Starikova (1982)	2004.878	0.474	-0.01	2.4
16326	Heintz (1991)	2004.892	0.567	0.02	-3.2
16345	Söderhjelm (1999)	2004.936	0.850	-0.03	-0.6
16530	Docobo (1991)	2004.950	0.202	-0.05	3.4
16538	Baize (1992)	2004.974	1.082	-0.09	-4.0
16666	Docobo (2002)	2004.974	3.324	0.04	-0.1
MLR 4	Hartkopf (1996)	2004.955	0.185	0.03	-0.6
17020	Zulevic (1977)	2004.972	0.714	-0.01	2.5
17149	Starikova (1977)	2004.881	2.106	0.05	0.4
	”	2004.944	2.130	0.08	0.4
	”	2004.952	2.109	0.06	0.3
17175	Söderhjelm (1999)	2004.952	0.788	-0.01	1.3

Table 3. New orbital elements

Name	node (2000)	omega (deg.)	i (deg.)	e	T (yr)	P (yr)	n (deg./yr)	a (")	A (")	B (")	F (")	G (")
ADS 15115	138.5	311.6	59.1	0.277	1875.993	194.152	1.85422	0.265	-0.06434	0.19280	-0.20829	0.06364

Table 4. New ephemeris of ADS 15115.

Epoch	ρ ($''$)	θ ($^\circ$)
2005.0	0.310	312.4
2006.0	0.309	313.1
2007.0	0.309	313.7
2008.0	0.308	314.4
2009.0	0.307	315.1
2010.0	0.306	315.8
2011.0	0.304	316.5
2012.0	0.303	317.2
2013.0	0.301	317.9
2014.0	0.300	318.6
2015.0	0.298	319.3

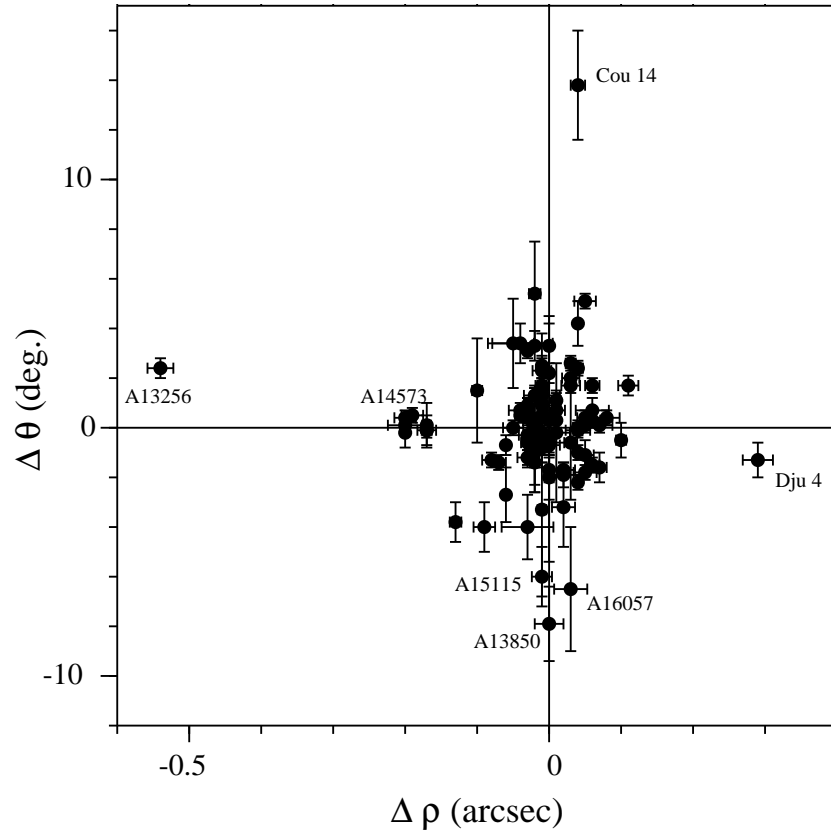

Figure 1. Residuals from published orbits.

Table 5. ADS 15115: residuals with new orbit (for measurements made after 1983).

Epoch	$\rho(O)$ ($''$)	$\theta(O)$ ($^{\circ}$)	$\Delta\rho(O - C)$ ($''$)	$\Delta\theta(O - C)$ ($^{\circ}$)	N_{obs}	Observer
1983.431	0.293	296.4	0.01	-0.9	1	MCA (McAlister)
1983.713	0.294	296.8	0.01	-0.7	1	MCA
1983.834	0.30	294.4	0.01	-3.2	4	SCA (Scardia)
1984.701	0.297	297.5	0.01	-0.8	1	MCA
1984.84	0.27	298.1	-0.02	-0.3	1	COU (Couteau)
1985.518	0.297	298.4	0.01	-0.5	1	MCA
1985.552	0.32	296.1	0.03	-2.8	3	SCA
1985.74	0.31	299.6	0.02	0.6	3	LBU (Le Beau)
1985.744	0.300	299.7	0.01	0.7	1	TOK (Tokovinin)
1985.848	0.297	298.0	0.00	-1.1	1	MCA
1985.940	0.28	299.1	-0.01	-0.1	4	WOR (Worley)
1987.69	0.33	297.3	0.03	-3.3	1	GII (Gili)
1987.754	0.301	300.0	0.01	-0.6	1	MCA
1988.67	0.28	297.4	-0.02	-3.9	2	HEI (Heintz)
1988.724	0.29	299.5	-0.01	-1.8	1	GII
1988.812	0.31	308.0	0.01	6.6	1	ISO (Isobe)
1990.774	0.295	303.0	-0.01	0.2	1	BAG (Balega)
1991.25	0.301	303.0	0.00	-0.1	1	HIP (Hipparcos)
1992.682	0.299	304.0	-0.01	-0.1	1	BAG
1992.689	0.30	303.0	0.00	-1.1	1	MIU (Miura)
1994.701	0.30	305.9	-0.01	0.4	1	WSI (Washington Speckle Interf.)
1994.816	0.31	310.3	0.00	4.7	1	WSI
1994.824	0.30	304.6	-0.01	-1.0	1	WSI
1994.860	0.31	308.4	0.00	2.8	1	WSI
1994.860	0.31	303.1	0.00	-2.5	1	WSI
1995.31	0.33	301.5	0.02	-4.4	4	ALZ (Alzner)
1995.571	0.32	309.6	0.01	3.5	2	DOC (Docobo)
1995.624	0.29	305.4	-0.02	-0.7	1	WSI
1995.624	0.29	304.0	-0.02	-2.1	1	WSI
1995.760	0.299	306.1	-0.01	-0.1	1	HRT (Hartkopf)
1995.769	0.30	304.8	-0.01	-1.4	1	WSI
1996.71	0.30	312.5	-0.01	5.6	2	ALZ
1996.710	0.35	312.5	0.04	5.6	2	ALZ
1996.749	0.30	307.2	-0.01	0.3	1	WSI
1997.468	0.296	306.7	-0.01	-0.7	1	ARI (Aristidi)
2000.789	0.30	308.7	-0.01	-0.9	3	WSI
2001.757	0.30	311.9	-0.01	1.7	3	WSI
2002.24	0.30	310.9	-0.01	0.4	2	ALZ
2003.891	0.29	312.2	-0.02	0.6	1	WSI
2004.881	0.273	312.4	-0.04	0.1	1	SCA

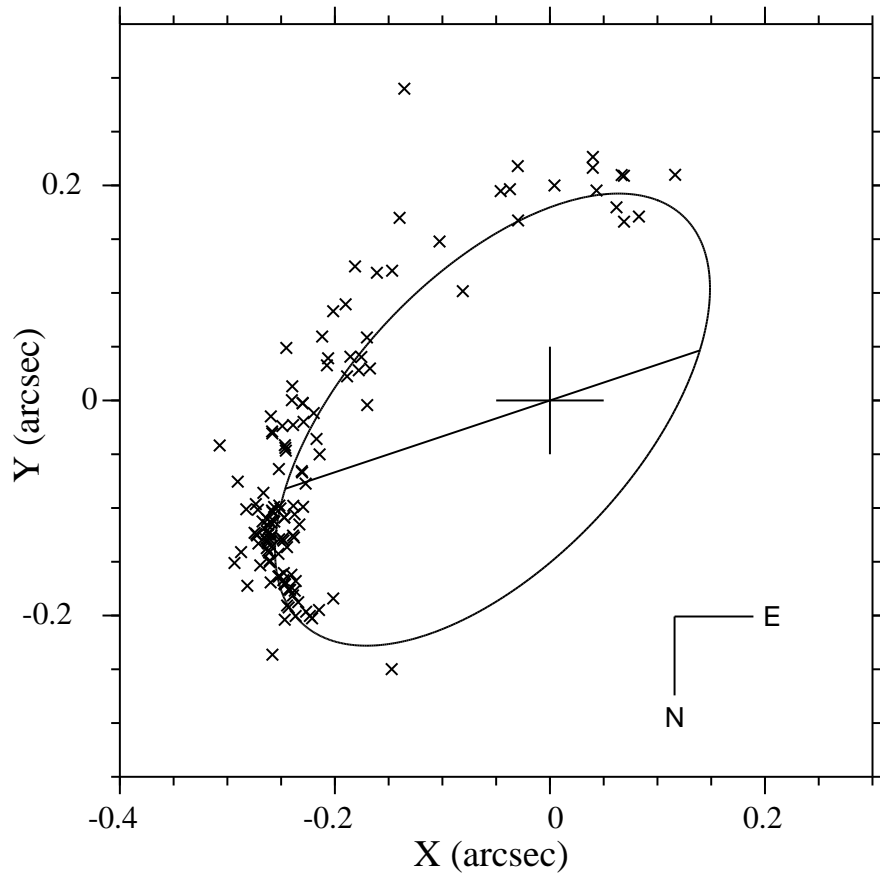


Figure 2. New orbit of HU 371 - ADS 15115.