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Speckle observations with PISCO in Merate: XI. Astrometric measurements of visual binaries in 2010

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ABSTRACT
We present relative astrometric measurements of visual binaries, made in 2010 with the speckle camera PISCO at the 102 cm Zeiss telescope of Brera Astronomical Observatory, in Merate. Our observing list contains orbital couples as well as binaries whose motion is still uncertain. We obtained new 207 measurements of 191 objects, with angular separations in the range $0''.2$ — $4''.7$, and an average accuracy of $0''.013$ The mean error on the position angles is $0^\circ.64$. Most of the position angles were determined without the usual 180° ambiguity with the application of triple-correlation techniques and/or by inspection of the long integration files.
We also present new revised orbits for ADS 8128, 8239, 10345 and 10850 partly derived from those observations, and infer estimated values for the masses of those systems that are compatible with the spectral types.

Key words: Stars: binaries: close – binaries: visual — astrometry — techniques: interferometric — stars: individual (ADS 8128, ADS 8239, ADS 10345, ADS 10850)

1 INTRODUCTION

This paper deals with the results of speckle observations of visual binary stars made in Merate (Italy) in 2010 with the Pupil Interferometry Speckle camera and COronagraph (PISCO) on the 102 cm Zeiss telescope of *INAF – Osservatorio Astronomico di Brera* (OAB, Brera Astronomical Observatory). It is the eleventh of a series (Scardia et al. 2005, 2006, 2007, 2008a, Prieur et al. 2008, Scardia et al. 2009, Prieur et al., 2009, Scardia et al., 2010, Prieur et al., 2010, Scardia et al., 2011, herein: Papers I to X), whose purpose is to contribute to the determination of binary orbits. PISCO was developed at *Observatoire Midi-Pyrénées* (France) and first used at *Pic du Midi* from 1993 to 1998. It was moved to Merate in 2003 and used there since.

We briefly describe our observations in Sect. 2. Then we present and discuss the astrometric measurements in Sect. 3. Finally in Sect. 4 we propose new revised orbits for ADS 8128, 8239, 10345 and 10850, partly derived from those observations, and discuss the estimated values for the masses of those systems.

2 OBSERVATIONS AND DESCRIPTION OF THE OBSERVING LIST

The observations were carried out with the PISCO speckle camera with the ICCD (Intensified Charge Coupled Device) detector belonging to Nice University (France). This instrumentation is presented in Prieur et al. (1998) and our observing procedure is described in detail in Paper VI.

The description of our observing list can be found in our previous papers (e.g., Paper VI). It basically includes all the visual binaries for which new measurements are needed to improve their orbits, that are accessible with our instrumentation.

The distribution of the angular separations measured in this paper is displayed in Fig. 1a and shows a maximum for $\rho \approx 0''.7$. The largest separation of $4''.7$ was obtained for ADS 6175. The smallest separation was measured for ADS 4229), with $\rho = 0''.20$. The diffraction limit is $\rho_d = \lambda/D \approx 0''.13$ for the Zeiss telescope (aperture $D = 1.02$ m) and the R filter ($\lambda = 650$ nm).

Likewise, the distribution of the apparent magnitudes m_V and of the difference of magnitudes Δm_V between the two components are plotted in Figs. 1b and 1c, respectively. The telescope aperture and detector sensitivity lead to a limiting magnitude of about $m_V = 9$ (Fig. 1b) and a limiting Δm_V of about 4.0 (Fig. 1c).

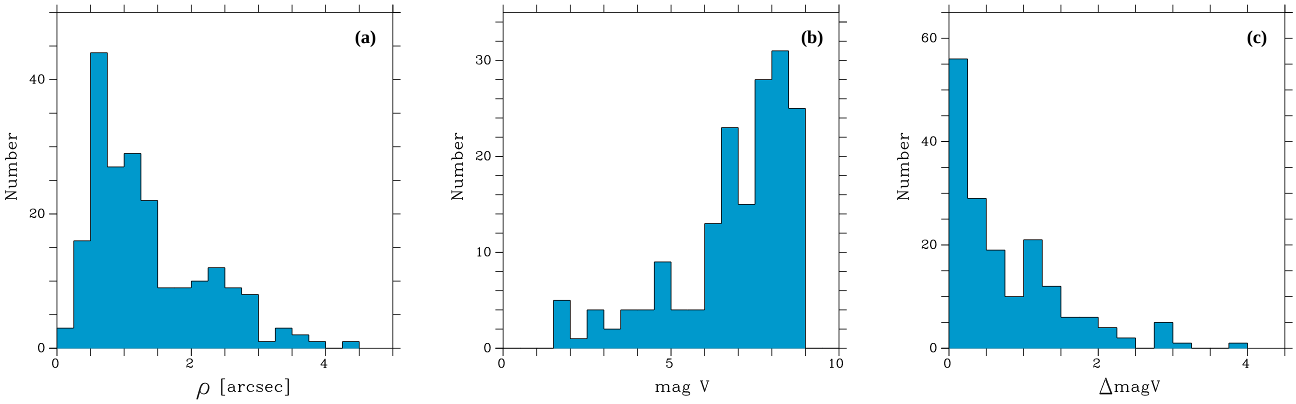

Figure 1. Distribution of the angular separations of the 207 measurements of Table 1 (a), the total visual magnitudes of the 191 corresponding binaries (b) and the differences of magnitude between their two components (c).

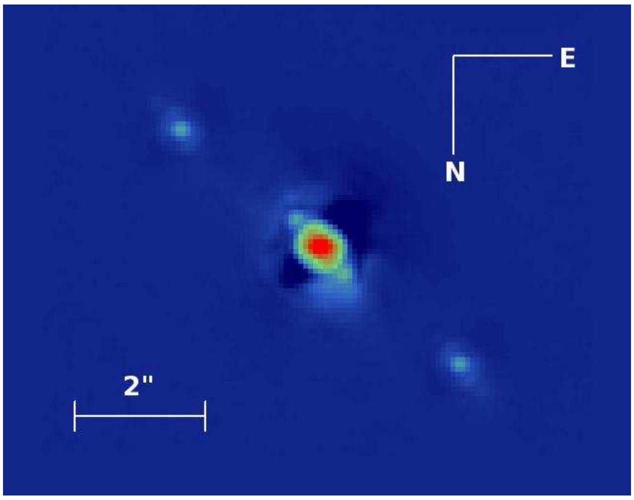

Figure 2. Autocorrelation of ADS 1860 obtained from PISCO observations made on January 19th 2010 with the I filter. The inner and outer secondary peaks corresponds to the pairs Aa,Ab ($\rho = 0''.6$, $\theta = 41°$, $\Delta m_V \sim 4$) and Aa,B ($\rho = 2''.8$, $\theta = 230°$), respectively

3 ASTROMETRIC MEASUREMENTS

The 207 astrometric measurements obtained with the observations made in 2010 are displayed in Table **??**. They concern 191 binaries. For each object, we report its WDS name (Washington Double Star Catalogue, Mason et al. 2011, hereafter WDS Catalogue) in Col. 1, the official double star designation in Col. 2 (sequence is "discoverer-number"), and the ADS number in Col. 3 (Aitken, 1932) when available. For each observation, we then give the epoch in Besselian years (Col. 4), the filter (Col. 5) and the focal length of the eyepiece used for magnifying the image (Col. 6), the angular separation ρ (Col. 7) with its error (Col. 8) in arcseconds, and the position angle θ (Col. 9) with its error (Col. 10) in degrees. In Col. 11, we report some notes and some information about the secondary peaks of the auto-correlation files (e.g. diffuse, faint or elongated). For the systems with a known orbit, the $(O-C)$ (Observed minus Computed) residuals of the ρ and θ measurements are displayed in Cols. 13 and 14, respectively. The corresponding authors are given in Col. 12, using the bibliographic style of the "Sixth Catalogue of Orbits of Visual Binary Stars" (Hartkopf & Mason, 2011, hereafter OC6). Unless explicitly specified, the measurements refer to the AB components of those systems. In Col. 14, the symbol ^{Q} indicates that there was a quadrant inconsistency between our measures and the orbital elements published for this object.

The characteristics of the V, R, RL and I filters used for obtaining those measurements are given in Table -1. Some objects were observed with no filter because they were too faint. This is indicated with W (for "white" light) in the filter column (Col. 5 of Table **??**). In that case, the bandpass and central wavelength correspond to that of the ICCD detector (see Prieur et al., 1998).

As for the other papers of this series, we interactively processed all the auto-correlation files computed in real time during the observations and obtained a series of measurements with different background estimates and simulated noise. The measures and errors displayed in Table **??** were derived from the mean values and the standard deviation of those multiples measurements (see Paper III for more details). The average values of the errors of the measurements reported in this table are $0''.013 \pm 0''.009$ and $0°.64 \pm 0°.50$ for ρ and θ, respectively.

There is only one unresolved object: HO 215. We observed this object in 2004 (Paper I), 2006 (Paper V) and 2010 (this paper) (see Fig: 3). In 2006, close secondary peaks appeared in the autocorrelation after removal of a model of an unresolved star. This detection was suspicious since those peaks were nearly superimposed on the first Airy rings. Indeed those secondary peaks do not appear when processing with the same method the autocorrelations obtained in 2004 and 2010. Therefore we can now conclude that HO 215 appeared as unresolved with our instrumentation during the period 2004–2010.

Wrong quadrant relative to WDS CHARA for 180110_ads2253_sfd_8_a (Q=2, WT=271.0)

Wrong quadrant relative to WDS CHARA for 070210_ads4208ab_Rd_8_a (Q=2, WT=320.0)

Wrong quadrant relative to WDS CHARA for 190410_a2472_sfd_8_a (Q=1, WT=264.0)

Wrong quadrant relative to WDS CHARA for 160710_ads9324_Wd_8_a (Q=1, WT=245.0)

Table 1. PISCO measurements made in 2010 and corresponding $O - C$ residuals

WDS	Name	ADS	Epoch	Fil.	Eyep. (mm)	ρ ($''$)	σ_ρ ($''$)	θ ($^\circ$)	σ_θ ($^\circ$)	Notes	Orbit	$\Delta\rho$(O-C) ($''$)	$\Delta\theta$(O-C) ($^\circ$)
00093+7943	STF2	102	2010.053	R	20	0.820	0.008	17.3*	0.4		Hei1997	−0.05	0.9
00109+5750	KR1	134	2010.053	W	20	2.077	0.011	191.8*	0.5	Elong.			
00209+1059	BU1093	287	2010.053	R	20	0.739	0.008	117.4*	0.6		Lin2010c	−0.02	−0.5
00444+3337	STF55	618	2010.050	W	20	2.185	0.013	330.1*	0.3				
00546+1911	STT20	746	2010.050	R	20	0.578	0.026	183.5*	0.3		Doc2007d	0.02	1.4
00550+2338	STF73	755	2010.050	R	20	1.007	0.008	322.7*	0.5		Mut2010b	−0.04	−0.6
”	”	”	”	”	”	”	”	”	”		Doc1990b	−0.06	−0.8
01030+4723	STT21	862	2010.050	R	20	1.231	0.011	174.1*	0.3		Hei1966	0.12	−1.5
01037+5026	HU517	871	2010.053	R	20	0.594	0.016	31.1	0.7	Diffuse			
01095+4715	STT515	940	2010.053	R	10	0.505	0.003	119.6*	0.4		Mut2010b	−0.01	−0.2
”	”	”	”	”	”	”	”	”	”		Sca2001d	0.00	−0.5
01112+3743	HO215	–	2010.053	R	10	–	–	–	–	Unres			
01443+5732	BU870	1359	2010.053	RL	20	0.569	0.014	331.7*	0.6		Hrt2009	0.03	2.0
01593+2450	STF194	1579	2010.088	R	20	1.258	0.008	278.1*	0.3				
02020+0246	STF202	1615	2010.050	R	20	1.840	0.009	266.4*	0.3		Sca1983f	0.07	1.8
02039+4220	STT38BC	1630	2010.086	R	10	0.219	0.005	95.7*	0.9		Doc2007d	−0.02	−3.7
02052−0058	BU516	1645	2010.105	W	20	0.677	0.011	314.6	1.6				
02062+2507	STF212	1654	2010.105	W	20	1.926	0.010	161.2*	0.5				
02124+3018	STF227	1697	2010.088	R	20	3.952	0.040	68.5*	0.4				
02128+3722	HO497	1701	2010.089	W	20	0.411	0.011	88.4*	1.3	Elong.			
02174+6121	STF234	1737	2010.089	W	20	0.701	0.012	223.8*	1.0		Sca1981e	0.03	−1.3
02231+7021	MLR377	–	2010.053	R	20	0.651	0.017	140.1	1.3		Pal2005b	0.14	−2.6
02291+6724	STF262Aa,B	1860	2010.053	I	20	2.801	0.014	229.7*	0.3		Hei1996b	0.19	0.4
02291+6724	CHR6Aa,Ab	1860	2010.053	I	20	0.584	0.020	41.1*	1.3		Dru2003	−0.01	1.2
02327+0620	STF276	1940	2010.105	W	20	1.896	0.028	273.8	0.6				
02407+2637	STT43	2034	2010.050	W	20	0.676	0.014	346.2*	0.5		Sca2001d	0.02	2.2
”	”	”	”	”	”	”	”	”	”		Hrt2001a	−0.05	−0.0
02589+2137	BU525	2253	2010.050	W	20	0.554	0.023	92.1*	0.6		Csa1978	0.05	−0.8^Q
02592+2120	STF333	2257	2010.050	R	20	1.398	0.008	209.5*	0.3		FMR2009c	0.03	0.1
03122+3713	STF360	2390	2010.105	W	20	2.856	0.018	124.6*	0.3		WSI2004a	0.03	−1.4
03175+6540	STT52	2436	2010.089	R	10	0.467	0.009	58.4*	1.5		Hei1998	0.08	6.7
03196+6714	HU1056	2452	2010.088	R	20	1.082	0.013	257.7	0.4				
03344+2428	STF412	2616	2010.050	R	10	0.735	0.004	353.8	0.3		Sca2002a	0.00	0.5
03354+3341	STF413	2625	2010.105	W	20	2.381	0.012	124.7*	0.4				
03362+4220	A1535	2630	2010.050	W	20	0.752	0.008	339.8	1.0		Hrt2008	0.03	−0.5
”	”	”	”	”	”	”	”	”	”		Mrl1970b	−0.03	−3.0
03407+4601	STT59	2669	2010.105	W	20	2.824	0.021	355.3*	0.5				
03427+6950	STF419	2678	2010.089	R	20	2.989	0.015	72.2*	0.3				
03446+3210	BU880	2730	2010.105	W	20	0.583	0.008	16.5*	1.6				
03454+4952	HU103	2736	2010.089	R	20	1.165	0.014	202.9*	1.3	Elong.			
03463+2411	BU536	2755	2010.053	W	20	0.926	0.015	178.0*	0.5		Hrt2009	−0.06	−1.8
03491+3216	STT516	2784	2010.052	RL	20	2.221	0.011	43.4*	0.3				
03521+4048	STT66	2815	2010.089	W	20	0.975	0.023	144.4*	0.7				
04020+6231	BRD1	2924	2010.105	W	20	2.005	0.011	223.7*	0.4				
04115+4152	BU546	3038	2010.089	W	20	0.896	0.013	228.6	1.0				
04179+5847	STF511	3098	2010.053	R	20	0.535	0.014	77.4*	1.2		Hei1996c	0.03	−1.9
05252+0155	STF708	4012	2010.201	W	20	2.695	0.066	321.1*	0.3				
05308+0557	STF728	4115	2010.105	R	20	1.237	0.008	44.5*	0.8		USN1999b	−0.03	−0.4
05319+2141	COU268	–	2010.201	W	20	0.732	0.008	165.1	1.0				
05351+3056	BU1267	4166	2010.201	W	20	0.356	0.014	172.7	3.6				
05357+2054	COU270	–	2010.201	W	20	0.710	0.012	41.9*	2.1				
05371+2655	STF749	4208	2010.105	R	20	1.146	0.008	140.1*	0.4		Sca2007a	−0.02	−1.0^Q
05381−0011	STF757	4234	2010.195	W	20	1.454	0.014	239.4*	0.4	Elong.			
05386+3030	BU1240	4229	2010.195	R	10	0.200	0.003	327.2	1.4	Elong.	FMR2008	−0.01	−0.1
”	”	”	”	”	”	”	”	”	”		Sca1982f	−0.01	−1.6

WDS	Name	ADS	Epoch	Fil.	Eyep. (mm)	ρ ($''$)	σ_ρ ($''$)	θ ($^\circ$)	σ_θ ($^\circ$)	Notes	Orbit	$\Delta\rho$(O-C) ($''$)	$\Delta\theta$(O-C) ($^\circ$)
05416+1913	STF770	4268	2010.195	W	20	1.037	0.022	329.8*	0.3	Elong.			
05512+5623	A1313	4425	2010.195	W	20	0.802	0.008	134.1*	1.3	Faint			
05535+3720	BU1053	4472	2010.105	W	20	1.828	0.009	358.8*	0.3				
05557+6420	HU1114	4479	2010.196	W	20	1.289	0.053	85.6	2.0	Faint			
05584+2938	STF821	4544	2010.105	W	20	2.161	0.011	3.9*	0.4				
06344+1445	STF932	5197	2010.105	W	20	1.648	0.014	306.0*	0.3		Hop1960a	0.00	3.4
06487+0737	A2731	5469	2010.201	W	20	1.238	0.025	64.3*	1.0		Hei1998	−0.16	−2.0
06555+3010	STF981	5570	2010.196	W	20	1.063	0.011	122.4*	1.4		Hop1971	−0.01	4.8^{Q}
07128+2713	STF1037	5871	2010.196	R	20	1.031	0.008	307.1	1.2		Sod1999	0.01	−2.0
”	”	”	”	”	”	”	”	”	”		Sca1983e	0.06	−0.4
07303+4959	STF1093	6117	2010.196	W	20	0.867	0.018	202.2*	0.8		Hrt2009	−0.01	0.1
”	”	”	”	”	”	”	”	”	”		Sca1984d	0.07	−0.6
07346+3153	STF1110	6175	2010.196	R	20	4.746	0.052	57.4*	0.3		Hei1988a	0.05	−0.3
07401+0514	STF1126	6263	2010.269	R	20	0.864	0.008	173.6*	1.0				
07573+0108	STT185	6483	2010.269	RL	10	0.323	0.005	12.6	1.3		Msn2009	−0.01	−0.5
”	”	”	”	”	”	”	”	”	”		Doc1994d	0.03	−1.7
08024+0409	STF1175	6532	2010.269	W	20	1.414	0.019	282.4*	0.3		Ole2001	0.04	−5.2
08213−0136	STF1216	6762	2010.299	R	20	0.513	0.016	303.6	0.6		Doc1994d	0.07	−1.9
08413+2029	BU585	6930	2010.302	R	10	0.330	0.009	74.5	1.1				
08444+1555	A2472	6963	2010.299	W	20	0.782	0.020	81.0*	0.3	Elong.			
08468+0625	SP1	6993	2010.264	R	10	0.259	0.004	154.8*	0.6		Hrt1996a	-0.00	−0.9
08468+0625	STF1273AB,C	6993	2010.264	RL	20	2.765	0.018	302.9*	0.5		Hei1996b	−0.12	−2.2
08482+0235	BU335	7003	2010.324	W	20	2.583	0.023	264.8*	0.3	Diffuse			
08500+3935	STF1279	7019	2010.300	W	20	1.297	0.009	87.4*	0.8	Elong.			
08505+2308	AG157	7035	2010.324	W	20	2.297	0.015	75.8*	0.3				
08512+0820	PER1	7046	2010.327	W	20	0.898	0.012	352.7*	0.8				
08542+3035	STF1291	7071	2010.269	R	20	1.506	0.009	309.5*	0.3				
08561+4341	STF3120	7092	2010.302	R	20	1.360	0.008	1.8*	0.3				
08571+1045	A2968	7102	2010.302	W	20	1.173	0.019	133.4*	0.4	Elong.			
09033+4740	HU720	7153	2010.269	W	20	0.731	0.020	133.1*	1.4	Elong.			
09036+4709	A1585	7158	2010.264	R	10	0.249	0.003	292.2*	0.3		Mut2010b	−0.01	−0.4
”	”	”	”	”	”	”	”	”	”		SOR2000	−0.01	0.1
09104+6708	STF1306	7203	2010.196	RL	20	4.296	0.053	349.6*	0.3		Sca1985c	0.14	−0.3
09127+1632	STF1322	7236	2010.264	R	20	1.788	0.011	53.1*	0.4				
09136+4659	STF1318	7243	2010.302	W	20	2.681	0.044	229.2*	0.3	Elong.			
09179+2834	STF3121	7284	2010.264	R	20	0.419	0.008	219.0*	1.1		Sod1999	−0.03	1.9
09184+3522	STF1333	7286	2010.264	R	20	1.953	0.010	49.3*	0.3				
09188+3648	STF1334	7292	2010.264	RL	20	2.654	0.013	223.7*	0.5				
09208+6121	STF1331	7300	2010.270	W	20	0.897	0.009	151.9*	0.9	Elong.			
09210+3643	STF1339	7308	2010.302	W	20	1.424	0.020	64.5*	0.5	Elong.			
09210+3811	STF1338	7307	2010.196	R	20	1.089	0.010	300.6*	1.0		Sca2002b	−0.03	−0.8
09239+2754	STT201	7344	2010.300	W	20	1.258	0.011	205.8*	0.3	Elong.			
09252+1449	HU869	7359	2010.327	W	20	0.762	0.008	272.8*	0.7				
09277+1545	STF1353	7386	2010.327	W	20	3.256	0.017	126.0	0.3				
09277+4456	A1762	7378	2010.300	W	20	0.762	0.011	106.2	0.6	Elong.			
09285+0903	STF1356	7390	2010.196	R	10	0.738	0.010	102.7*	0.6		Mut2010b	-0.00	−0.4
”	”	”	”	”	”	”	”	”	”		vDl1976	-0.00	−0.9
09290+1917	COU936	–	2010.327	W	20	0.879	0.008	226.3*	1.1				
09300+4216	A1985	7398	2010.196	W	20	1.553	0.008	24.8	1.1				
09414+3857	STF1374	7477	2010.264	R	20	2.832	0.014	308.8*	0.5				
09435+0612	A2761	7499	2010.324	W	20	1.026	0.018	250.8*	0.4	Elong.			
09476+5057	HU630	7514	2010.324	W	20	2.215	0.022	73.2*	0.3				
09513+6037	STF1381	7536	2010.270	W	20	0.847	0.009	186.9*	0.8				
09521+5404	STT208	7545	2010.264	R	10	0.357	0.003	292.9*	0.4		Hei1996c	−0.02	−1.9
10056+3105	STF1406	7632	2010.270	W	20	0.767	0.008	218.4*	0.6	Elong.			
10057+4103	A2142	7631	2010.264	R	20	1.055	0.008	294.9*	0.3				
10151+1907	STF1417	7695	2010.270	W	20	2.329	0.013	76.4	0.3				
10163+1744	STT215	7704	2010.264	R	20	1.461	0.011	177.6*	0.3		Zae1984	−0.08	−1.6

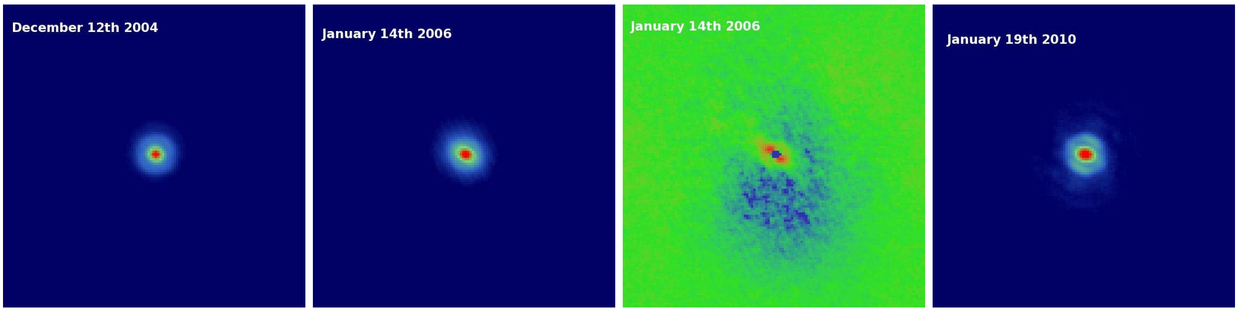

Figure 3. HO215: autocorrelations obtained with PISCO observations 2004, 2006 and 2010.

Table -1. Characteristics of the filters used for the measurements of Table **??**.

Name	Identification	λ_c (nm)	Δ_λ (nm)
V	ORIEL/57581	530	57
R	ORIEL/57621	644	70
RL	ORIEL/57661	743	69
I	ORIEL/57701	855	67
W	ICCD alone	650	420

Input file: astrom10_09sep11.tex*

Number of objects: 191

Number of observations: 207 with 208 measurements and 1 cases of no detection

Quadrant was determined for 165 measurements (including 13 uncertain determinations)

Warning: 4 quadrant values are inconsistent with CHARA theta last measurements!

OK: 160 quadrant values are consistent with CHARA theta last measurements!

In column 9, $*$ indicates that θ was determined with our quadrant value (or with the long integration)

In column 9, ! indicates that θ could not be determined neither with this value, nor with WDS CHARA last measurement

ADS 1860: this object is known as a wide triple system. In 2010, we measured the Aa,B and Aa,Ab pairs, with $\rho = 2''.801$ and $\rho = 0''.584$, respectively. The closest pair (CHR 6 Aa) is an orbital couple with a period of 46 years and a very large difference of luminosity in V: $\Delta m_V \sim 4$. The primary is an A5 star and the companion must be a cool star. In order to reduce the contrast between the two components, we observed this object with the I filter.

3.1 Quadrant determination

As our measurements were obtained from the *symmetric* auto-correlation files, the θ values first presented a 180° ambiguity. To resolve this ambiguity and determine the quadrant containing the companion, we have used Aristidi et al. (1997)'s method, by analysing the restricted triple correlation (RTC hereafter) files that were computed in real time during the observations. For the couples with the largest separations, a straightforward determination could be done when the companions were visible in the long integration files.

As a result, in Table **??**, we are able to give the unambiguous (i.e. "absolute") position angles of 165 out of 207 measurements, i.e. 80% of the total. They are marked with an asterisk in Col 9. Otherwise, our angular measurements were reduced to the quadrant reported in the WDS catalogue, which is extracted from the IC4.

Our "absolute" θ values are consistent with the values tabulated in WDS for all objects except for ADS 2253, 4208, 9324 and A 2472. We display some parameters of all those objects in Table 0. In Col. 2, we indicate the quadrant (Q) we found with the RTC, using the usual convention of numbering them from 1 to 4 to indicate the North-East, South-East, South-West and North-West quadrants, respectively. In Col. 3 we recall the filter we have used (W indicates the absence of filter: the corresponding central wavelength is close that of the R filter). In Col. 4 and 5, we give the differences of magnitude between the two components and the global spectral types found in the WDS catalogue, and the French SIMBAD astronomical data base.

For all the discrepant objects, there is a good contrast between the two secondary peaks of the RTC, which is a good indication of the validity of our quadrant determination.

Except for ADS xxx, the small value of Δm_V can account for the difficulty of measuring the quadrant for those binaries. However, the measurements from other observers reported in IC4 were all obtained in B or V, whereas we observed in R (or W which is similar). A quadrant inversion between V and R is likely, when the two stars have a different spectral type (e.g. blue primary and red secondary). This would well explain a different quadrant measurement in V (in the IC4) and in R (with PISCO).

For ADS xxxx, there is instead a rather large difference of magnitude between the components (1.6 mag). Our estimation of Q=3 seems reliable in the RTC and is consistent with 23 out of the 26 measurements made since 2000, reported in IC4, and with our previous quadrant determination of 2004.950.

3.2 Comparison with published ephemerides

The $(O - C)$ (Observed minus Computed) residuals of the measurements for the 72 systems with a known orbit in Table **??** are displayed in Cols. 13 and 14 for the separation ρ and position angle θ, respectively.

Those residuals were computed with a selection of valid

WDS	Name	ADS	Epoch	Fil.	Eyep. (mm)	ρ ($''$)	σ_ρ ($''$)	θ ($^\circ$)	σ_θ ($^\circ$)	Notes	Orbit	$\Delta\rho$(O-C) ($''$)	$\Delta\theta$(O-C) ($^\circ$)
10205+0626	STF1426	7730	2010.270	R	20	0.911	0.008	310.6	0.5		Sca2008c	0.01	−0.8
”	”	”	”	”	”	”	”	”	”		Nov2006	−0.01	−0.8
10279+3642	HU879	7780	2010.300	R	10	0.523	0.004	223.7*	0.6	Elong.	Msn2001c	0.00	0.8
10397+0851	STT224	7871	2010.300	R	20	0.510	0.011	139.5	0.6	Faint	Hrt2010a	-0.00	−1.7
10426+0335	A2768	7896	2010.324	R	20	0.613	0.018	250.0*	0.6		Hrt2010a	0.02	0.2
10480+4107	STT229	7929	2010.324	R	20	0.677	0.011	262.2	1.0		Alz1998a	0.02	1.0
11000−0328	STF1500	8007	2010.387	R	20	1.370	0.015	299.9	0.3				
11037+6145	BU1077	8035	2010.264	V	10	0.586	0.003	17.8*	0.3		Sca2010d	−0.01	−1.4
”	”	”	2010.324	V	10	0.588	0.003	17.2*	0.5		Sca2010d	−0.01	−1.6
”	”	”	2010.327	V	10	0.597	0.004	17.7*	0.3		Sca2010d	0.00	−1.1
”	”	”	2010.384	V	10	0.592	0.006	17.7*	0.7		Sca2010d	-0.00	−0.7
11050+3825	HO378	8047	2010.387	R	20	1.058	0.012	237.2	0.3				
11154+2734	STF1521	8105	2010.392	R	20	3.678	0.035	96.8*	0.3				
11158+4227	COU1904	–	2010.327	W	20	0.459	0.016	213.4	1.0				
11190+1416	STF1527	8128	2010.264	R	10	0.310	0.003	186.0*	0.3		Pru2009	0.08	−7.2
”	”	”	2010.300	R	10	0.326	0.003	187.0	0.4	Faint	Pru2009	0.10	−7.0
”	”	”	2010.324	R	10	0.317	0.003	187.5	0.8		Pru2009	0.09	−7.1
”	”	”	2010.327	R	10	0.318	0.005	188.2	0.3	NF	Pru2009	0.09	−6.4
”	”	”	2010.384	R	10	0.318	0.005	187.6	0.6		Pru2009	0.10	−8.4
”	”	”	2010.395	R	10	0.323	0.003	186.5*	0.4		Pru2009	0.10	−9.8
11245+2037	STF1537	8149	2010.393	W	20	2.266	0.011	358.0*	0.4				
11267+6654	HU1133	8159	2010.395	W	20	0.781	0.008	346.4*	0.8				
11332+4927	HU727	8210	2010.300	W	20	1.256	0.008	203.5	0.5	Elong.			
11371+4040	A1996	8241	2010.393	W	20	2.011	0.023	189.5	0.7				
11406+2102	STF1566	8263	2010.393	W	20	2.382	0.012	349.7*	0.4				
11428+2105	HU888	8275	2010.393	W	20	0.550	0.008	175.9*	0.4				
11431+3715	HU1135	8276	2010.393	W	20	0.695	0.008	335.3	0.7				
11517+4449	HJ842	8324	2010.387	W	20	3.150	0.016	88.6*	0.8	Elong.			
11547+0944	BRT1276	–	2010.395	W	20	2.875	0.014	358.2*	0.3				
11563+3527	STT241	8355	2010.387	R	20	1.802	0.009	144.7*	0.6				
11598+5324	STT243	8378	2010.387	W	20	1.217	0.013	8.9*	0.3				
12126+3546	STF1613	8460	2010.395	W	20	1.162	0.008	7.3	0.4				
12291+3123	STT251	8569	2010.327	W	20	0.724	0.008	58.3*	0.8		Sca2003c	0.06	−2.0
12329+5448	A1600	8594	2010.396	W	20	0.837	0.015	8.3*	0.7				
12417−0127	STF1670	8630	2010.300	R	20	1.440	0.008	22.2*	0.3		Sca2007c	−0.01	0.2
”	”	”	2010.324	R	20	1.433	0.008	22.5*	0.5		Sca2007c	−0.02	0.7
”	”	”	2010.384	R	20	1.468	0.009	21.8*	0.7		Sca2007c	-0.00	0.3
”	”	”	2010.426	R	20	1.467	0.010	21.1*	0.3		Sca2007c	−0.01	−0.2
12438+0733	STF1674	8646	2010.387	W	20	2.322	0.013	173.5*	0.7				
12533+1310	HU894	8696	2010.396	W	20	1.188	0.008	143.9*	0.3				
12533+2115	STF1687	8695	2010.387	RL	20	1.132	0.008	192.9*	0.5		Hei1997	0.10	−2.8
12564−0057	STT256	8708	2010.327	R	20	1.072	0.008	99.0	0.3				
12574+3022	STF1696	8716	2010.324	W	20	3.631	0.056	203.7*	0.4	Diffuse			
13007+5622	BU1082	8739	2010.324	RL	20	1.069	0.010	101.8*	0.3		Sod1999	0.01	−2.2
13100+1732	STF1728	8804	2010.445	R	10	0.633	0.003	12.3	0.3		Mut2010b	−0.01	0.1
”	”	”	”	”	”	”	”	”	”		WSI2006b	−0.01	0.0
13101+3830	BU608BC	8805	2010.387	RL	20	1.288	0.015	267.4*	0.6				
13120+3205	STT261	8814	2010.387	R	20	2.554	0.013	338.4*	0.5				
13166+5034	STT263	8843	2010.393	W	20	1.743	0.009	136.1*	0.3				
13207+0257	STF1734	8864	2010.387	R	20	1.106	0.012	174.4*	0.8				
13235+2914	HO260	8887	2010.393	W	20	1.573	0.011	85.5*	0.3		WSI2004a	−0.06	0.9
13288+5956	STF1752	8919	2010.396	W	20	0.968	0.017	107.9*	0.4				
13329+4908	STF1758	8940	2010.396	W	20	3.389	0.017	291.6*	0.3	Elong.			
13340+0847	A1792	8946	2010.385	W	20	0.713	0.030	306.4*	0.7				

orbits mainly found in the "master" file of the OC6 catalogue. We did not always use the most recent orbits since sometimes older orbits led to equivalent or even smaller residuals.

For ADS 8128, 10345 and 10850 we reported the residuals obtained with our new orbits presented in Sect. 4.

Fig. 4 shows that the residuals have a rather large scatter that can be explained by the (old) age of many orbits. The mean values computed with the residuals of Table **??** are $< \Delta\rho_{O-C} >= -0''.01 \pm 0''.06$ and $< \Delta\theta_{O-C} >= -0^\circ.9 \pm 2^\circ.3$.

WDS	Name	ADS	Epoch	Fil.	Eyep. (mm)	ρ ($''$)	σ_ρ ($''$)	θ ($^\circ$)	σ_θ ($^\circ$)	Notes	Orbit	$\Delta\rho$(O-C) ($''$)	$\Delta\theta$(O-C) ($^\circ$)
13346+3308	BU933	8958	2010.396	W	20	2.759	0.014	22.5*	0.3				
13356+4939	AG190	8964	2010.426	W	20	2.632	0.013	12.3*	0.5				
13571+3426	BU937	9067	2010.393	W	20	1.040	0.011	134.3*	0.5				
13577+5200	A1614	9071	2010.396	W	20	1.399	0.008	300.9*	0.3		Hei2001	−0.06	-2.0^Q
13598+1953	STF1794	9078	2010.426	W	20	1.897	0.012	125.9*	0.3				
14101+2636	STF1808	9136	2010.426	W	20	2.604	0.017	81.5*	0.3	Elong.			
14116+2802	STF1810	9150	2010.426	W	20	2.315	0.012	183.7*	0.6	Elong.			
14184+3412	HU901	9214	2010.426	W	20	0.571	0.008	35.5*	0.9				
14203+4830	STF1834	9229	2010.393	R	20	1.589	0.011	102.0	0.3		USN2000c	0.04	−1.5
14220+5107	A148	9238	2010.393	R	20	0.556	0.008	7.7	1.1				
14234+4736	A149	9249	2010.426	W	20	0.803	0.014	120.0*	0.6				
14369+4813	A347	9324	2010.540	W	20	0.562	0.021	62.8*	1.2	Elong.	Doc2004a	−0.01	-0.8^Q
14380+5135	STF1863	9329	2010.540	R	20	0.659	0.019	59.6	1.1				
14407+3117	STF1867	9340	2010.541	W	20	0.702	0.008	355.9*	0.8	Elong.			
14411+1344	STF1865	9343	2010.538	R	10	0.548	0.003	294.4	0.3		Mut2010b	-0.00	0.1
”	”	”	”	”	”	”	”	”	”		Sta1980a	−0.11	−2.1
14417+0932	STF1866	9345	2010.541	W	20	0.740	0.008	203.5*	1.2				
14489+0557	STF1883	9392	2010.546	W	20	0.952	0.018	279.5	0.3		USN2000c	0.00	1.3
15183+2650	STF1932	9578	2010.538	R	20	1.614	0.008	263.7	0.3		Hei1965c	−0.02	0.0
15245+3723	STF1938Ba,Bb	9626	2010.538	R	20	2.269	0.011	5.5*	0.3		Sod1999	0.02	0.5
”	”	”	”	”	”	”	”	”	”		Sca1986b	0.04	0.2
15257+2638	STF1941	9630	2010.582	W	20	1.373	0.011	213.0*	0.3				
15277+0606	STF1944	9647	2010.546	W	20	0.707	0.008	298.4*	0.9				
15485+2600	COU616	–	2010.582	W	20	0.761	0.012	160.7*	0.9				
15498+4431	BU621	9802	2010.541	W	20	0.703	0.008	27.4*	0.3	Diffuse			
15509+1911	A2078	9809	2010.541	W	20	1.089	0.019	166.3*	0.6				
16009+1316	STT303	9880	2010.538	R	20	1.558	0.008	173.0*	0.3				
16071+1654	BU812	9925	2010.601	W	20	0.698	0.008	97.1*	1.0				
16112+4734	STF2025	9956	2010.601	W	20	2.555	0.013	163.3*	0.3				
16115+1507	A1799	9952	2010.582	W	20	0.752	0.008	116.4*	1.0				
16160+0721	STF2026	9982	2010.538	W	20	3.450	0.017	17.7*	0.3	Elong.	Sca2010d	0.02	−0.1
16188+1724	STF2037	9997	2010.582	W	20	1.188	0.023	252.8	0.3				
16289+1825	STF2052	10075	2010.538	R	20	2.251	0.011	120.3*	0.3		Lmp2001a	0.01	0.4
”	”	”	”	”	”	”	”	”	”		Sod1999	0.03	0.1
”	”	”	”	”	”	”	”	”	”		Sca1984d	−0.01	−0.6
16422+4112	STF2091	10169	2010.601	W	20	0.363	0.024	324.4*	2.6				
16433+2508	STF2089	10174	2010.601	W	20	2.701	0.016	60.7*	0.3				
16511+0924	STF2106	10229	2010.538	R	20	0.738	0.008	172.1*	0.7		Sca2001g	−0.02	−0.1
16564+6502	STF2118	10279	2010.538	R	20	1.035	0.008	66.2*	0.4		Sca2002d	−0.12	−0.9
17020+0827	STF2114	10312	2010.538	R	20	1.315	0.008	194.9*	0.3				
17053+5428	STF2130	10345	2010.538	R	20	2.414	0.012	7.6*	0.3		Sca2010d	0.00	0.2
17055+1033	BU357	10336	2010.601	W	20	1.458	0.008	305.4*	0.8				
17096+0356	HEI894	–	2010.601	W	20	0.559	0.027	24.3*	2.1				
17175+3205	BU629	10450	2010.601	W	20	1.188	0.008	339.1*	0.6				
17178+4535	STF2152	10458	2010.669	W	20	1.948	0.016	237.3*	0.3	Elong.			
17179+4918	STF2153	10460	2010.669	W	20	1.477	0.011	245.3*	0.4	Elong.			
17457+1743	STF2205	10769	2010.582	W	20	1.013	0.008	3.1*	0.5		Cve2008a	−0.04	0.1
17479+1449	STF2222	10803	2010.669	W	20	2.290	0.011	61.9*	0.3				
17518+2814	STF2239	10851	2010.669	W	20	2.423	0.012	318.3*	0.3				
17520+1520	STT338	10850	2010.669	R	20	0.818	0.008	164.3*	0.4		Sca2010d	−0.01	−0.9
17531+4212	COU1599	–	2010.669	W	20	0.594	0.021	125.8*	3.9				
17567+4837	STF2258	10924	2010.669	W	20	2.090	0.010	221.0*	0.4				
19143+1904	STF2484	12201	2010.669	W	20	2.130	0.011	239.4*	0.5		Hop1973b	−0.14	0.3
19148+4756	A706	12229	2010.669	W	20	1.570	0.008	73.2*	0.3				
19251+1839	HU339	12416	2010.669	W	20	0.825	0.018	246.0*	0.5				
19261+3849	HO450	12446	2010.669	W	20	0.971	0.014	262.4*	0.9				
19266+2719	STF2525	12447	2010.669	W	20	2.135	0.011	289.0*	0.3		Hei1984b	0.02	−0.9

Note: In column 9, the exponent * indicates that the position angle θ could be determined without the 180° ambiguity.

Table 0. Objects with discrepant quadrants

Name	Q	Filter	Δm_V	Spectral type
ADS xxxx	2	R	0.1	F2
ADS 2253	x	xx	xxx	xx
ADS 3038	x	xx	xxx	xx

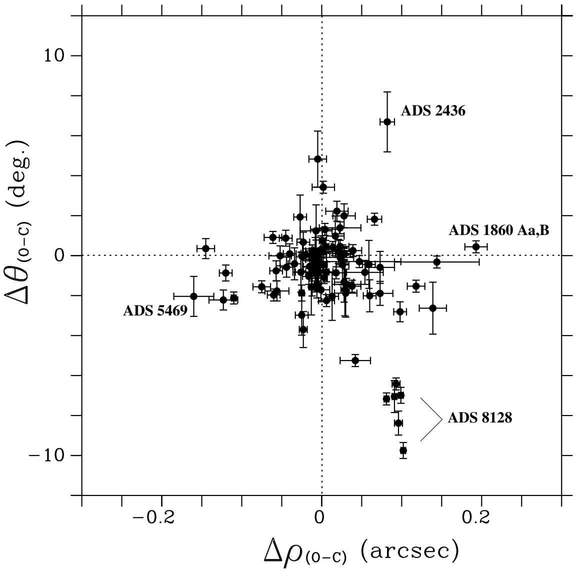

Figure 4. Residuals of the measurements of Table 1 computed with the published orbits.

In the following, we examine the cases of ADS 8128, xxxx that appear with the largest residuals in Fig. 4.

4 REVISED ORBITS OF ADS 8128, 8239, 10345 AND 10850

In this section we present the new orbits we have computed for ADS 8128, 8239, 10345 and 10850.

We have followed the same method for those xxx objects. Using our last measurements with PISCO and the other available observations contained in the data base maintained by the United States Naval Observatory (USNO), we first computed the preliminary orbital elements with the analytical method of Kowalsky (1873). We then used them as initial values for the least-squares method of Hellerich (1925). When convergence was achieved, Hellerich's method led to an improvement of the orbital elements (with the exception of the major axis) and to an estimation of the corresponding errors. The final value of the major axis was then set to the value that minimized the residuals in separation of Hellerich's solution.

The final orbital elements are presented in Table 1. The description of the format of the tables contained in this section can be found in Papers VI and VII. The errors reported for ADS xxxx and xxxx were obtained by Hellerich's least-squares method. For ADS xxx, this method failed to converge, which explains the absence of errors for this orbit.

The corresponding $(O-C)$ residuals, restricted to the last observations for reasons of space, are given in Tables **??**, 2, 3 and 4 for ADS 8128, 8239, 10345 and 10850, respectively. In the last column, we report the name of the observer, using the US Naval Observatory convention.

Table 2. ADS 8239: O-C residuals of our new orbit (after 1990.0).

Epoch	$\Delta\rho$ (O-C) ($''$)	$\Delta\theta$ (O-C) ($^\circ$)	Observer
1991.250	0.041	−0.184	HIP
1991.860	0.090	−1.096	TYC
1996.160	−0.039	−1.864	Pri
1996.370	0.139	−2.993	Hei
1998.392	−0.150	1.491	WSI
2000.339	−0.009	−0.435	WSI
2001.327	−0.039	2.009	WSI
2007.317	−0.020	1.355	Hrt
2009.260	0.037	0.703	Tok

The ephemerides for 2012–2021 are presented in Table 5. The apparent orbits are shown in Fig. 5 as solid lines. The observational data used for the calculation of the orbital elements are plotted as small crosses or, in the case of PISCO observations, as filled circles. The orientation of the graphs conforms to the convention adopted by the observers of visual binary stars. For each object, the location of the primary component is indicated with a big cross. The straight line going through this point is the line of apsides. An arrow shows the sense of rotation of the companion.

In Table **??**, we present some physical parameters of those systems. The visual magnitudes (col. 3) and the spectral types (col. 4) were extracted from the SIMBAD data base. The dynamical parallaxes derived from our orbital elements are presented in col. 5. Those values were obtained with Baize & Romani (1945)'s method, using our revised formulae presented in Scardia et al. (2008b). In col. 6, we report either the Hipparcos parallaxes from ESA (1997) or the revised values from van Leeuwen (2007), as indicated in col. 10. In cols. 8 and 9, we give the corresponding linear sizes of a and $\mathfrak{M}_{\rm total}$, respectively, that were computed from our orbital elements and the Hipparcos parallaxes.

Table 1. New orbital elements of ADS 8128, 8239, 10345 and 10850

ADS	Ω_{2000} (°)	ω (°)	i (°)	e	T (yr)	P (yr)	n (°/yr)	a (″)	A (″)	B (″)	F (″)	G (″)
ADS 8128	.85	.31	.21	0.5	1900.	8.0		4.	−0.	0.	0.	0.
ADS 8239	42.3	327.1	53.3	0.748	1914.42	706.0	0.5099	1.69	1.39998	0.54176	0.10759	1.22864
	±1.32	±2.26	±1.90	±0.046	±0.579	±191	±0.138	±0.094				
ADS 10345	282.85	193.31	142.21	0.5139	1946.189	812.0		4.476	−0.17482	4.42758	3.58503	−0.23915
	±0.80	±0.83	±1.3	±0.029	±0.718	±70.5	±0.039	±0.026				
ADS 10850	28.2	111.1	124.2	0.582	1799.906	1276.6	0.28200	1.144	−0.07946	−0.72332	−1.05000	−0.30034

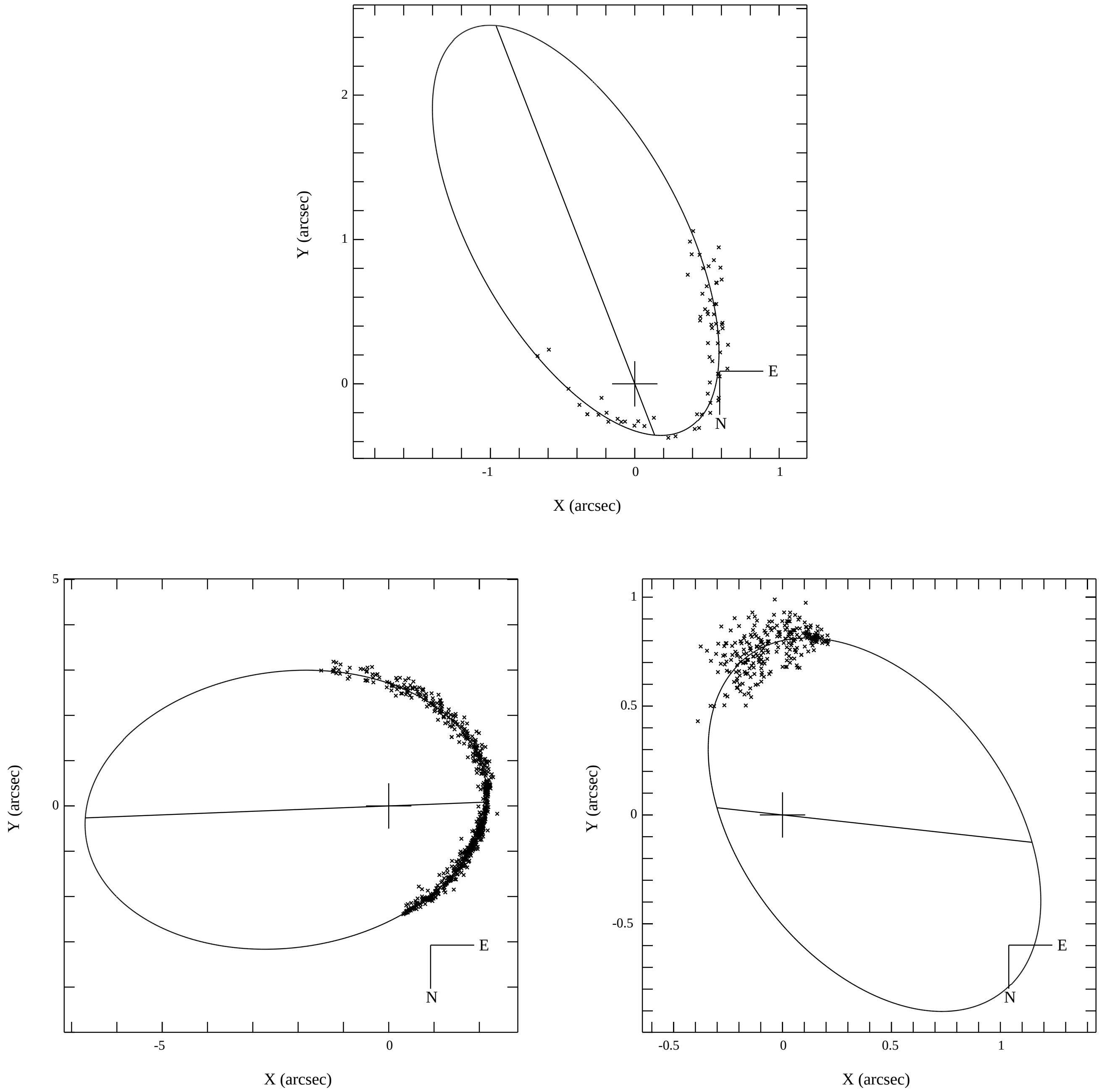

Figure 5. New orbits of ADS 8128 (a) ADS 8239 (b), ADS 10345 (c) and ADS 10850 (d).

Table 3. ADS 10345: O-C residuals of our new orbit (after 2006.0). The symbol ^{P} indicates PISCO measurements.

Epoch	$\Delta\rho$ (O-C) ($''$)	$\Delta\theta$ (O-C) ($^\circ$)	Observer
2007.356	−0.007	0.226	Izm
2007.503	−0.010	0.087	WSI
2007.567	0.002^P	0.057^P	Sca
2007.772	−0.054	0.379	Ary
2008.369	−0.025	0.125	Ant
2008.383	−0.015	−0.460	Ant
2008.388	0.015	0.445	Ant
2008.458	−0.146	0.321	WSI
2008.564	0.006^P	0.235^P	Sca
2008.859	−0.033	0.552	Ary
2009.304	−0.001	0.526	Ant
2009.541	-0.001^P	0.077^P	Sca
2009.608	0.004	−0.151	WSI
2010.538	0.001^P	0.226^P	Sca

Table 4. ADS 10850: O-C residuals of our new orbit (after 2000.0). The symbol ^{P} indicates PISCO measurements.

Epoch	$\Delta\rho$ (O-C) ($''$)	$\Delta\theta$ (O-C) ($^\circ$)	Observer
2000.489	−0.001	−0.232	Doc
2000.521	−0.017	−0.724	WSI
2001.610	−0.027	3.051	Ary
2004.657	-0.010^P	0.020^P	Sca
2005.460	−0.058	2.721	WSI
2007.655	-0.004^P	-0.427^P	Sca
2008.473	0.021	0.179	Thr
2008.475	0.001	−0.521	Thr
2008.659	-0.009^P	-0.075^P	Sca
2009.615	-0.019^P	-0.335^P	Sca

Table 5. New ephemerides of ADS 10345 and 10850.

	ADS 10345		ADS 10850		ADS xxxx		MLR xxx	
Epoch	ρ ($''$)	θ ($^\circ$)	ρ ($''$)	θ ($^\circ$)	ρ ($''$)	θ ($^\circ$)	ρ ($''$)	θ ($^\circ$)
2012.0	0.653	8.5	3.451	17.6	0.374	74.9	0.258	63.3
2013.0	0.683	3.2	3.467	17.5	0.373	74.0	0.263	61.0
2014.0	0.710	358.3	3.483	17.3	0.372	73.1	0.268	58.7
2015.0	0.734	353.7	3.499	17.2	0.372	72.2	0.272	56.5
2016.0	0.754	349.4	3.514	17.0	0.370	71.3	0.276	54.4
2017.0	0.772	345.3	3.530	16.9	0.369	70.4	0.279	52.3
2018.0	0.786	341.4	3.545	16.7	0.368	69.5	0.282	50.3
2019.0	0.798	337.6	3.560	16.6	0.367	68.6	0.284	48.2
2020.0	0.807	334.0	3.575	16.4	0.366	67.7	0.286	46.3
2021.0	0.813	330.3	3.589	16.3	0.364	66.8	0.287	44.3