

# Speckle observations with PISCO in Merate: XIII. Astrometric measurements of visual binaries in 2012, and new orbits for ADS 10786 BC, 12144, 12515, 16314 and 16539

J.-L. Prieur<sup>1,2</sup>, M. Scardia<sup>3</sup>, L. Pansecchi<sup>3</sup>, R.W. Argyle<sup>4</sup>, A. Zanutta<sup>3</sup>, and E. Aristidi<sup>5</sup>

<sup>1</sup> Université de Toulouse – UPS-OMP – IRAP, Toulouse, France

<sup>2</sup> CNRS – IRAP, 14 avenue Edouard Belin, 31400 Toulouse, France

<sup>3</sup> INAF – Osservatorio Astronomico di Brera, Via E. Bianchi 46, 23807 Merate, Italy

<sup>4</sup> Institute of Astronomy, Madingley Road, Cambridge, CB3 0HA, United Kingdom

<sup>5</sup> Université de Nice-Sophia Antipolis – Laboratoire Lagrange – CNRS – OCA, Parc Valrose 06108 Nice cedex 2, France

April 13th 2014

**Key words** Stars: binaries: close – binaries: visual — astrometry — techniques: interferometric — stars: individual (ADS 10786 BC, ADS 12144, ADS 12515, ADS 16314, ADS 16539)

We present relative astrometric measurements of visual binaries, made in 2012 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 355 new measurements of 344 visual binary stars, with angular separations in the range  $0''.14$  —  $6''.9$ , and an average accuracy of  $0''.02$ . The mean error on the position angles is  $0^\circ.5$ . Most of the position angles were determined without the usual  $180^\circ$  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 10786 BC, 12144, 12515, 16314 and 16539, partly derived from PISCO observations. The corresponding estimated values for the masses of those systems are compatible with the spectral types.

## 1 Introduction

This paper presents the results of speckle observations of visual binary stars made in Merate (Italy) in 2012 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 thirteenth of a series whose purpose is to contribute to the determination of binary orbits (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, Prieur et al. 2012, and Scardia et al. 2013, herein: Papers I to XII). The focal instrument 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 installed on the INAF Zeiss telescope that has been dedicated to binary star observations since that epoch.

In Sect. 2, we briefly describe our observations. In Sect. 3, we present and discuss the astrometric measurements. We also compare those measurements with the ephemerides computed with the published orbital elements, when available. Finally in Sect. 4 we present the new revised orbits that we have computed for ADS 10786 BC, 12144, 12515, 16314, and 16539, and

discuss the estimated values for the masses of those systems.

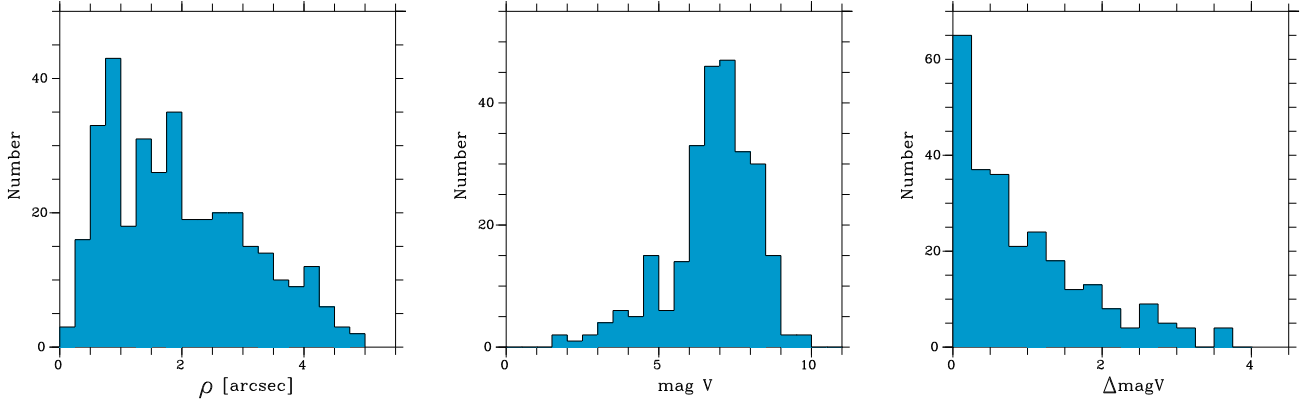
## 2 Observations

The observations were carried out with the PISCO speckle camera and 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.

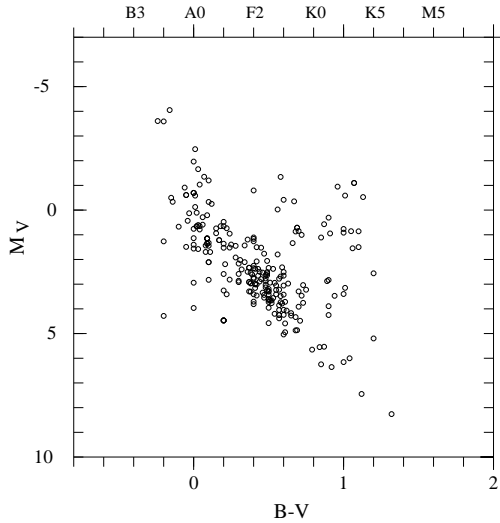
### 2.1 Observing list

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

The distribution of the angular separations measured in this paper is displayed in Fig. 1a and shows a maximum for  $\rho \approx 0''.8$ . The largest separation of  $6''.93$  was obtained for ADS 1670AC. The smallest separation was measured for JCT3Aa,Ab (ADS 6696), with  $\rho = 0''.144$ . Let us recall that the diffraction limit is



**Fig. 1** Distribution of the angular separations of the 355 measurements of Table 3 (a), the total visual magnitudes of the corresponding binaries (b) and the differences of magnitude between their two components (c).



**Fig. 2** HR diagram of the binaries measured in Table 1, for which Hipparcos parallaxes were obtained with a relative error smaller than 50% (i.e., 276 objects).

$\rho_d = \lambda/D \approx 0''.13$  for the Zeiss telescope (aperture  $D = 1.02$  m) and the  $R$  filter ( $\lambda = 650$  nm).

The distribution of the apparent magnitudes  $m_V$  and of the difference of magnitudes  $\Delta m_V$  between the two components are plotted in Figs. 1b and 1c, respectively. The telescope aperture and detector sensitivity led to a limiting magnitude of about  $m_V = 10$  (Fig. 1b) and a maximum  $\Delta m_V$  for speckle measurements of about 3.8 (Fig. 1c).

Using the Hipparcos parallaxes, we were able to construct the HR diagram of those binaries, which is displayed in Fig. 2. We only plotted the objects for which the relative uncertainty on the parallax was smaller than 50%. This concerned 276 objects only.

### 3 Astrometric measurements

The 355 astrometric measurements obtained with the observations made in 2012 are displayed in Table 1. They concern 344 visual binaries. For each object, we report its WDS name (Washington Double Star Catalogue, Mason et al. 2013, 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), the focal length of the eyepiece used for magnifying the image (Col. 6), the angular separation  $\rho$  (Col. 7) with its error (Col. 8) in arcseconds, and the position angle  $\theta$  (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) or about the power spectrum (NF: no fringes). For the systems with a known orbit, the  $(O - C)$  (Observed minus Computed) residuals of the  $\rho$  and  $\theta$  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, 2013, hereafter OC6). When not 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 positions derived from the orbital elements published for this object.

The characteristics of the  $R$ ,  $RL$ , and  $I$  filters used for obtaining those measurements are given in Table 2. Some objects were observed without any filter because they were too faint. This is indicated with  $W$  (for “white” light) in the filter column (Col. 5 of Table 1).

As for the other papers of this series, position measurements were obtained by an interactive processing of the auto-correlation files computed in real time dur-

**Table 1** Table of speckle measurements and O-C residuals with published orbits (begin.)

WDS	Name	ADS	Epoch	Fil.	Eyep. (mm)	$\rho$ (")	$\sigma_\rho$ (")	$\theta$ ( $^\circ$ )	$\sigma_\theta$ ( $^\circ$ )	Notes	Orbit	$\Delta\rho(\text{O-C})$ (")	$\Delta\theta(\text{O-C})$ ( $^\circ$ )
00014+3937	HLD60	17178	2012.040	R	32	1.300	0.019	167.3*0.7			Hrt2011a	0.01	-1.2
00028+0208	BU281AB	9	2012.041	RL	32	1.556	0.022	161.7*0.7					
00049+4540	BU997	41	2012.043	R	32	3.860	0.041	336.5*0.4					
00049+5832	STF3057	36	2012.043	R	32	3.824	0.043	297.4*0.3					
00057+4239	A110	55	2012.043	R	32	2.094	0.032	123.0*0.4					
00059+1805	STF3060AB	60	2012.038	R	32	3.345	0.025	133.6*0.3					
00063+5826	STF3062	61	2012.038	R	20	1.526	0.008	350.6*0.3			Sta1977b	-0.04	-0.1
00093+7943	STF2	102	2012.038	R	20	0.858	0.008	16.9*0.7			Sca1980d	-0.01	2.0
00134+2659	STT2AB	161	2012.068	R	10	0.414	0.003	158.8*0.6	Elongated		Sca2000b	-0.05	-2.5
00209+1059	BU1093	287	2012.043	R	20	0.758	0.008	117.4*0.3			Lin2010c	-0.00	-1.0
00209+3259	AC1	285	2012.068	R	32	1.803	0.017	287.4*0.3					
00302+4557	A910	408	2012.071	R	32	2.604	0.019	35.5*0.5					
00310+3406	STF33	421	2012.071	R	32	2.767	0.016	212.3 0.6					
00455+4324	BU865AB	627	2012.043	R	32	1.220	0.016	192.2*1.6					
00458+5459	ARG2AB	630	2012.043	RL	32	2.514	0.035	49.4*0.4					
00480+5127	STF59AB	659	2012.041	R	32	2.231	0.028	147.5*0.4					
00499+2743	STF61	683	2012.041	R	32	4.236	0.021	114.6*0.3					
00548+0926	STF74	754	2012.041	R	32	3.084	0.022	298.8*0.4					
00550+2338	STF73AB	755	2012.041	R	20	1.065	0.008	325.3*0.3			Doc1990b	-0.03	-0.6
00551+2811	A437AB	758	2012.068	R	32	2.975	0.016	208.9*0.3					
00578+3211	HO307	789	2012.068	W	32	3.046	0.038	83.8*0.3	Elongated				
01095+4715	STT515AB	940	2012.043	R	10	0.514	0.003	118.1*0.3	Elongated		Sca2001d	0.01	-0.8
01099+4011	AG15	953	2012.068	W	32	2.789	0.019	69.7*0.3	Diffuse				
01106+5101	BU235Aa	963	2012.071	R	20	0.832	0.008	137.9*0.3	Elongated				
01122+5132	STF97	981	2012.071	R	32	4.506	0.052	100.5*0.3					
01149+4815	A934	1004	2012.041	W	32	3.108	0.036	183.8*0.3	Elongated				
01401+3858	STF141	1305	2012.041	R	32	1.643	0.024	301.0*0.8					
01559+0151	STF186	1538	2012.043	R	20	0.787	0.008	248.3*0.4			USN2007b	-0.02	0.2 <sup>Q</sup>
02020+0246	STF202	1615	2012.038	RL	20	1.830	0.009	265.4*0.3			Sca1983f	0.06	2.3
02091+5104	STF213AC	1670	2012.071	R	32	6.933	0.038	64.2*0.4	Diffuse				
02091+5104	STF213AB	1670	2012.071	R	32	1.833	0.016	323.9*0.3					
02140+4729	STF228	1709	2012.043	R	20	0.769	0.009	294.4*0.4			Sta1982b	-0.01	-2.7
02176+2214	STF244	1758	2012.071	R	32	4.429	0.024	288.8 0.3					
02262+2105	COU258	-	2012.068	W	32	2.296	0.016	121.5*0.3					
02282+2952	STF269	1868	2012.043	RL	32	1.656	0.022	344.5*1.8					
02294+5532	STF268	1878	2012.071	R	32	2.803	0.022	129.7*0.3					
02309+5311	HJ2139AB	1903	2012.071	R	32	3.825	0.019	297.4*0.3					
02357+4411	A1528	1962	2012.068	RL	32	1.552	0.016	193.5*0.5					
02388+3325	STF285	2004	2012.068	R	32	1.680	0.021	162.5*0.3					
02411+1848	STF291AB	2042	2012.068	RL	32	3.342	0.017	116.8*0.3					
02446+2928	STF300	2091	2012.043	R	32	3.090	0.030	314.3*0.3					
02475+1922	STF305AB	2122	2012.044	R	32	3.595	0.044	306.5*0.3			Rab1961a	-0.13	-0.1
03171+4029	STF369	2443	2012.044	R	32	3.599	0.028	29.3*0.3					
03312+1947	STF403	2584	2012.150	R	32	2.293	0.016	171.4*0.3					
03344+2428	STF412AB	2616	2012.041	RL	20	0.721	0.008	353.6 0.4			Sca2002a	-0.02	0.9
"	"	"	2012.142	R	10	0.744	0.004	352.7 0.3	Elongated		Sca2002a	0.01	0.1
03350+6002	STF400AB	2612	2012.142	R	20	1.589	0.008	266.8*0.3			USN2000b	0.08	-1.5
03356+3141	BU533	2628	2012.150	R	20	1.053	0.008	220.9*0.3					
03377+4807	HLD9AB	2643	2012.142	R	32	1.335	0.016	53.9*1.5					
03401+3407	STF425	2668	2012.071	R	32	1.926	0.016	60.3*0.4					
03466+2728	COU694	-	2012.071	R	32	2.514	0.032	134.0*0.5					
03479+3336	STF448	2772	2012.142	R	32	3.370	0.019	13.1*0.3					
03490+1459	HO324	2787	2012.150	R	32	1.117	0.016	330.9*0.6					
04020+4151	STF477	2934	2012.068	RL	32	3.072	0.016	211.3*0.3					

**Table 1** Table of speckle measurements and O-C residuals with published orbits (cont.)

WDS	Name	ADS	Epoch	Fil.	Eyep. (mm)	$\rho$ (")	$\sigma_\rho$ (")	$\theta$ ( $^\circ$ )	$\sigma_\theta$ ( $^\circ$ )	Notes	Orbit	$\Delta\rho(\text{O-C})$ (")	$\Delta\theta(\text{O-C})$ ( $^\circ$ )
04022+2808	STF481AB	2944	2012.150	RL	32	2.637	0.040	105.9*0.3		NF			
04045+5544	STF480	2955	2012.150	R	32	3.291	0.016	326.5*0.3					
04076+3804	STT531AB	2995	2012.142	R	32	2.591	0.016	355.6*0.4			Hei1986b	0.16	3.0
04077+1510	STF495	2999	2012.142	R	32	3.651	0.021	221.9*0.3					
04100+8042	STF460	2963	2012.142	R	10	0.757	0.005	142.7*0.3		Elongated	Sca2003a	0.07	-5.3
04140+4235	A1711	3062	2012.167	R	20	0.670	0.011	77.8*0.4		NF			
04159+3142	STT77AB	3082	2012.145	R	20	0.491	0.009	296.7	0.5		Sta1985	-0.05	-0.3
04160+0027	STF517	3095	2012.145	R	32	3.286	0.017	8.0*0.3					
04224+2049	BU87	3158	2012.167	R	20	1.887	0.012	167.3*0.4		NF			
04227+1503	STT82AB	3169	2012.167	R	20	1.249	0.008	332.2*0.3			WSI2004a	0.02	-2.1
04233+1123	STF535	3174	2012.145	R	20	1.124	0.009	271.7	0.3		Hrt2000c	0.07	1.6
04268+5539	STF531	3207	2012.191	R	20	0.963	0.011	324.4*0.3					
04301+1538	STF554	3264	2012.205	R	20	1.538	0.008	16.3*0.3			Baz1980a	-0.08	0.8
04316+3739	BU789	3275	2012.205	R	32	0.844	0.024	322.4*0.7					
04333+5103	STF553	3287	2012.199	R	32	3.053	0.032	134.4*0.3					
04335+1801	STF559	3297	2012.199	R	32	3.062	0.016	275.7*0.6		Elongated			
04367+1930	STF567	3330	2012.142	R	32	2.046	0.033	342.8*0.5			USN2002	0.01	0.3
04381+4207	STF565AB	3338	2012.188	R	20	1.347	0.011	166.9*0.5					
04385+2656	STF572AB	3353	2012.188	R	32	4.389	0.022	9.3*0.3					
04422+3731	STF577	3390	2012.188	R	20	0.740	0.008	338.4	1.3		Hei1998	-0.07	-3.4
04518+0115	STF609	3484	2012.150	R	32	2.931	0.024	69.0*0.3					
04518+1339	BU552AB	3483	2012.169	R	20	0.715	0.008	258.0*0.9			Hei1984b	0.02	-1.5
04549+0836	STT90AB	3517	2012.150	R	32	1.766	0.017	339.4*0.8					
04573+6145	STT88	3526	2012.169	R	20	0.764	0.014	307.3*0.4					
04581+0141	STF622	3568	2012.202	R	32	2.571	0.017	161.3*0.6		Diffuse			
05000+7003	STF604	3551	2012.150	R	32	2.149	0.016	38.2*0.4		Diffuse			
05003+3924	STT92AB	3589	2012.202	RL	32	4.187	0.035	281.9*0.3			Cve2006e	0.07	0.1
05005+0506	STT93	3596	2012.202	R	32	1.537	0.030	244.7*0.5			USN1999a	0.02	0.8
05013+5015	STF619	3593	2012.202	R	32	4.231	0.065	158.2*0.3			Kis2009	0.22	-0.5
05026+5450	AG84	3604	2012.202	R	32	2.487	0.046	152.2*0.3					
05055+1948	STT95	3672	2012.169	R	20	0.928	0.008	296.0*0.3			Jas1996b	-0.03	-1.1
05075+5532	BU749	3683	2012.205	R	20	1.304	0.008	240.8*0.3					
05079+0830	STT98	3711	2012.191	R	20	0.896	0.008	295.3*0.3			Sca2008d	-0.01	-0.4
05079+5459	STF635	3689	2012.205	R	32	1.018	0.016	303.6*0.6					
05245-0224	DA5Aa-B	4002	2012.167	R	20	1.811	0.009	76.8*0.3		Elongated			
05268+0306	KNT3AB	4039	2012.167	R	20	2.979	0.015	327.6*0.3		Faint			
05270+2737	HO226AB	4032	2012.167	R	20	0.672	0.008	89.5*0.7					
05290+3746	BU890	4060	2012.145	R	32	1.231	0.016	282.8	0.4				
05301+2933	STF719AB	4086	2012.145	R	32	1.236	0.016	333.6*0.7					
05308+0557	STF728	4115	2012.142	R	20	1.264	0.008	44.7*0.5			USN1999b	-0.03	-0.0
05309+1015	STF726	4113	2012.145	R	32	1.071	0.017	262.4*1.2					
05347-0424	STF743AB	4176	2012.224	R	32	1.801	0.017	282.0*1.7					
05351+0956	STF738AB	4179	2012.224	R	32	4.386	0.022	43.6*0.3		Diffuse			
05364+2200	STF742	4200	2012.142	R	32	4.078	0.020	273.7*0.5			Hop1973b	-0.05	-1.5
05371+2655	STF749AB	4208	2012.142	R	20	1.154	0.008	139.9*0.3			Sca2007a	-0.01	-0.8 <sup>Q</sup>
05371+4150	STF736	4204	2012.169	R	32	2.582	0.021	359.9*0.3					
05399+3757	STT112	4243	2012.169	R	20	0.887	0.008	46.8*0.3					
05474+2939	BU560	4371	2012.145	R	20	1.702	0.009	124.5*0.3			Sca2008c	0.03	-0.6
05499+3147	STF796AB	4421	2012.142	R	32	3.743	0.019	61.5*0.3					
05511+6545	STF780AB	4405	2012.145	R	32	3.846	0.019	104.2*0.4					
05525+4009	STF802AB	4456	2012.202	R	32	2.441	0.016	103.6*1.1					
05529+3427	STF807	4463	2012.202	R	32	2.477	0.035	150.8*0.4					
05535+3720	BU1053	4472	2012.145	R	32	1.852	0.016	358.9*0.5					
05542+1015	STT123	4491	2012.205	R	32	2.142	0.016	186.8*0.5					

**Table 1** Table of speckle measurements and O-C residuals with published orbits (cont.)

WDS	Name	ADS	Epoch	Fil.	Eyep. (mm)	$\rho$ (")	$\sigma_\rho$ (")	$\theta$ ( $^\circ$ )	$\sigma_\theta$ ( $^\circ$ )	Notes	Orbit	$\Delta\rho(\text{O-C})$ (")	$\Delta\theta(\text{O-C})$ ( $^\circ$ )
05544+1854	STF813	4490	2012.205	R	32	3.021	0.016	149.5*0.8					
05589+1248	STT124	4562	2012.224	R	10	0.594	0.005	299.1*0.5	Elongated	Baz1988d	0.21	-4.9	
06041+1101	J335	4647	2012.205	R	32	1.253	0.032	270.8*0.4		Ole2002a	0.05	-4.7	
06074+3616	STT131	4691	2012.235	R	20	1.501	0.011	276.9*0.3					
06081+0317	STF851	4726	2012.205	R	32	2.926	0.055	33.4*0.8	Faint				
06082+3759	STT132	4709	2012.235	R	20	1.820	0.009	332.0*0.5	NF				
06085+1358	STF848AB	4728	2012.145	R	32	2.563	0.016	109.7*0.3					
06113+3040	STF861BC	4779	2012.150	R	32	1.665	0.016	314.4*0.3					
06117+1723	STF867AB	4789	2012.150	R	32	2.184	0.016	158.6*0.3					
06118+0228	J52	4796	2012.238	R	32	2.095	0.016	281.6*0.4					
06128+2426	AG107	4810	2012.235	R	32	1.485	0.033	178.8 0.3	Faint				
06135+1015	HO22	4823	2012.238	R	20	0.984	0.010	208.9 0.8	Faint				
06146+1725	J683	4836	2012.238	R	32	1.351	0.016	3.6*0.5					
06192+3947	STF883AB	4905	2012.238	R	32	3.487	0.017	264.0*0.6					
06197+2128	AG109	4933	2012.238	R	32	2.398	0.030	17.1*0.3					
06200+2826	STF888AB-C	4929	2012.241	R	32	2.909	0.016	263.4*0.5					
06221+5922	STF881Aa-B	4950	2012.167	R	10	0.640	0.003	147.1*0.3					
06246+3424	HU702	5014	2012.241	R	32	0.852	0.016	329.1*0.4					
06250+4233	A2356	5016	2012.241	R	32	0.837	0.016	262.6 0.6					
06266+1531	STT140AB	5062	2012.241	R	32	2.983	0.019	119.0*0.3	NF				
06344+1445	STF932	5197	2012.202	R	32	1.662	0.028	305.4*1.2		Hop1960a	0.02	3.5	
06347+3832	STF928AB	5191	2012.202	R	32	3.465	0.024	131.0*0.3					
06387+4135	STF941	5269	2012.202	R	32	1.934	0.016	81.8*0.8					
06531+5927	STF963	5514	2012.167	R	10	0.244	0.003	343.5*0.6		Sca2008d	-0.02	1.6	
06573+5825	STT159	5586	2012.167	R	10	0.658	0.005	231.8*0.3		Sod1999	0.01	1.6	
07028+1305	HO342	5725	2012.170	R	20	1.170	0.008	87.7*0.3					
07128+1511	WEI14	5875	2012.170	R	32	2.108	0.016	160.2*0.3					
07128+2713	STF1037	5871	2012.167	R	20	0.977	0.010	306.9 0.4		Sca1983e	0.04	0.6	
07148+5233	STF1033	5896	2012.170	R	32	1.582	0.016	275.1*0.3					
07274+1519	STF1094	6086	2012.170	R	32	2.507	0.016	95.8*0.3					
07303+4959	STF1093	6117	2012.167	R	20	0.864	0.009	203.5 0.4		Sca1984d	0.07	-0.3	
07345+1218	STF1116	6180	2012.170	R	32	1.732	0.016	95.6*0.3					
07346+3153	STF1110	6175	2012.142	R	20	4.832	0.024	56.3*0.3		Hei1988a	-0.01	-0.2	
07359+4302	STT174	6191	2012.202	R	32	2.193	0.019	88.2*0.3					
07401+0514	STF1126	6263	2012.170	R	20	0.840	0.008	173.9*0.4					
07486+2308	WRH15	6378	2012.235	R	10	0.263	0.004	31.0*0.6		USN2002	-0.00	0.5	
07556+3630	COU2075	-	2012.241	R	20	0.832	0.011	141.8*0.4					
07598+1341	STF1170	6499	2012.205	R	32	2.373	0.016	106.4*0.9					
08024+0409	STF1175	6532	2012.202	R	32	1.406	0.021	284.0*0.6		Ole2001	0.03	-4.9	
08033+2616	STT186	6538	2012.205	R	20	0.994	0.014	73.7*0.5					
08041+3302	STT187	6549	2012.238	R	10	0.420	0.003	339.1 0.9	Elongated	Msn1999a	0.01	0.1	
08056+2732	STF1177	6569	2012.235	R	32	3.504	0.033	349.7*0.4					
08095+3213	STF1187	6623	2012.205	R	32	3.037	0.025	21.4*0.3		Ole2001	0.09	0.5	
08122+1739	STF1196AB	6650	2012.205	R	20	1.101	0.008	31.1*0.3		Hrr1992	0.00	0.9	
08160+1842	JCT3Aa,Ab	6696	2012.235	R	10	-	-	- -	Unres				
08160+1842	JCT3Aa,Ab	6696	2012.205	W	10	0.144	0.011	25.7*3.7	Faint				
08432+3849	BU209	6946	2012.205	R	32	1.245	0.016	8.3*0.7					
08468+0625	STF1273AC	6993	2012.241	R	20	2.756	0.017	303.4*0.3	NF				
08468+0625	SP1AB	6993	2012.241	R	10	0.269	0.003	176.2*1.6		Hrt1996a	-0.00	0.2	
08508+3504	STF1282	7034	2012.235	R	32	3.519	0.018	277.4*0.9					
08514+5732	STF1275	7033	2012.235	R	32	1.874	0.033	197.9*0.3					
08531+5457	A1584	7054	2012.238	R	20	0.678	0.015	86.1 0.3	Faint	Hei1991	0.01	-2.8	
08542+3035	STF1291	7071	2012.241	R	20	1.526	0.008	310.0*0.3					
08554+7048	STF1280	7067	2012.203	R	32	2.787	0.016	353.0*0.5		Hei1997	0.12	-1.0	

**Table 1** Table of speckle measurements and O-C residuals with published orbits (cont.)

WDS	Name	ADS	Epoch	Fil.	Eyep.	$\rho$	$\sigma_\rho$	$\theta$	$\sigma_\theta$	Notes	Orbit	$\Delta\rho(\text{O-C})$	$\Delta\theta(\text{O-C})$
					(mm)	( $''$ )	( $''$ )	( $^\circ$ )	( $^\circ$ )			( $''$ )	( $^\circ$ )
09036+4709	A1585	7158	2012.238	R	10	0.268	0.004	289.6*0.3			SOR2000	-0.01	-0.0
09104+6708	STF1306	7203	2012.203	RL	32	4.342	0.030	348.6*0.3	NF		Sca1985c	0.12	-0.7
09184+3522	STF1333	7286	2012.238	R	20	1.944	0.010	49.6*0.3					
09210+3643	STF1339	7308	2012.238	R	32	1.424	0.016	63.9*0.6					
09210+3811	STF1338	7307	2012.235	R	20	1.094	0.008	303.9*0.3			Sca2002b	0.09	-4.2
09245+0621	STF1348	7352	2012.235	R	20	1.956	0.010	134.1*0.3					
09273+0614	STF1355	7380	2012.238	R	32	1.782	0.030	353.2*0.6			Lin2011b	-0.06	-0.6
09521+5404	STT208	7545	2012.339	R	10	0.370	0.004	298.2*0.4			Hei1996c	-0.03	-1.2
10163+1744	STT215	7704	2012.369	R	20	1.469	0.008	176.5*0.3			Zae1984	-0.08	-2.3
10181+2731	STF1421	7715	2012.361	R	32	4.543	0.023	330.9*0.3					
10200+1950	STF1424AB	7724	2012.356	R	32	4.727	0.041	125.2*0.5			WSI2006b	0.11	-0.8
10234+2630	A1990	7747	2012.361	R	32	1.420	0.017	288.7 0.4					
10236+2617	A1991	7748	2012.361	R	32	1.466	0.038	189.2*0.3					
10256+0847	STF1431	7764	2012.361	R	32	3.569	0.018	73.7*0.3					
10260+5237	STF1428	7762	2012.380	R	32	2.784	0.016	87.4*0.3					
10269+1713	STT217	7775	2012.380	R	20	0.770	0.008	148.4*0.3			Sca2013b	-0.00	0.2
10279+3642	HU879	7780	2012.380	R	10	0.541	0.003	224.5*0.3			Msn2001c	-0.01	0.3
10493-0401	STF1476	7936	2012.378	R	32	2.441	0.019	16.4*0.3					
11037+6145	BU1077	8035	2012.339	R	10	0.668	0.003	4.7*0.3			Sca2011a	0.00	-2.0
11182+3132	STF1523AB	8119	2012.339	R	20	1.627	0.008	193.5*0.3			Msn1995	-0.01	-0.9
11190+1416	STF1527	8128	2012.339	R	10	0.312	0.005	209.4 0.3	NF		Tok2012b	-0.00	-0.9
"	"	"	2012.356	R	10	0.308	0.003	211.4 0.3			Tok2012b	-0.01	0.9
"	"	"	2012.378	R	10	0.312	0.003	212.0 0.4	NF		Tok2012b	-0.00	1.2
"	"	"	2012.413	R	10	0.306	0.004	211.8 0.3			Tok2012b	-0.01	0.5
11239+1032	STF1536	8148	2012.356	R	20	2.066	0.010	98.6*0.3			Hei1986a	-0.01	1.8
11279+4434	STF1542	8171	2012.361	R	32	3.467	0.017	264.8*0.3	NF				
11308+4117	STT234	8189	2012.356	R	10	0.470	0.004	175.0 0.3	NF		Doc2009g	0.01	-0.4
11323+6105	STT235	8197	2012.356	R	20	0.813	0.011	29.2*0.5			Hei1990c	-0.03	1.2
11328+6004	KR38	8203	2012.361	R	32	2.812	0.016	52.9 0.4					
11347+1648	STF1552	8220	2012.339	R	32	3.525	0.018	207.9*0.5					
11363+2747	STF1555	8231	2012.339	R	20	0.728	0.008	148.7*0.3			Doc2007i	0.04	-1.0
11390+4109	STT237	8252	2012.378	R	32	2.041	0.016	243.2*0.3			USN2002	0.02	-1.5
11547+0944	BRT1276	-	2012.380	W	32	2.861	0.016	357.9*0.8					
11551+4629	STF1579AB-C	8347	2012.378	R	32	3.901	0.020	41.9*0.3					
11561+4533	STF1581	8354	2012.380	W	32	2.386	0.016	169.9*0.3					
12060+6842	STF3123	8419	2012.378	R	10	0.284	0.003	201.9 1.1	NF		Hrt1996a	-0.00	-1.1
12108+3953	STF1606	8446	2012.356	R	10	0.506	0.004	151.3*0.5			Msn1999a	-0.00	1.5
12244+2535	STF1639	8539	2012.339	R	20	1.803	0.009	323.7*0.3			Ole2000b	-0.00	0.3
12257+4444	STF1642	8546	2012.408	R	32	2.530	0.022	179.4*0.3					
12272+2701	STF1643	8553	2012.356	R	32	2.823	0.028	5.0*0.3			WSI2004a	0.09	0.4
12306+0943	STF1647	8575	2012.356	R	20	1.328	0.008	248.1 0.3			Hop1970	0.08	-2.6
12360+1124	STF1661	8606	2012.380	W	32	2.218	0.030	251.7*0.4					
12417-0127	STF1670	8630	2012.356	R	20	1.816	0.009	13.0*0.3			Sca2007c	-0.02	-0.2
"	"	"	2012.380	R	20	1.817	0.009	12.9*0.3			Sca2007c	-0.03	-0.2
12563+5406	STF1695	8710	2012.413	R	32	3.828	0.025	279.7*0.3					
12587+2728	STF1699	8721	2012.361	R	32	1.659	0.021	8.5 0.3					
13007+5622	BU1082	8739	2012.356	RL	20	0.992	0.008	108.0*0.3			Sca2012c	-0.03	1.1
"	"	"	2012.413	R	20	0.992	0.008	107.7*0.3			Sca2012c	-0.03	0.7
13025+2330	STF1709	8749	2012.361	R	32	2.727	0.016	250.7*0.3					
13064+2109	COU11Aa-B	-	2012.361	I	32	1.716	0.016	314.4*0.3					
13084+1529	STF1722	8796	2012.361	R	32	2.651	0.016	335.7*0.3					
13128+4030	A1606	8820	2012.460	R	32	1.267	0.022	16.8 0.6					
13189+0030	A2585	8855	2012.463	R	32	0.839	0.016	216.7 1.9					
13235+2914	HO260	8887	2012.463	R	32	1.618	0.016	86.0*0.4			WSI2004a	-0.05	0.8

**Table 1** Table of speckle measurements and O-C residuals with published orbits (cont.)

WDS	Name	ADS	Epoch	Fil.	Eyep. (mm)	$\rho$ (")	$\sigma_\rho$ (")	$\theta$ ( $^\circ$ )	$\sigma_\theta$ ( $^\circ$ )	Notes	Orbit	$\Delta\rho(\text{O-C})$ (")	$\Delta\theta(\text{O-C})$ ( $^\circ$ )
13243+0124	STF1742	8890	2012.463	R	32	0.945	0.027	356.0*	0.3				
13284+1543	STT266	8914	2012.463	R	32	1.972	0.016	357.0*	0.4		Hrt2011d	-0.03	-0.2
13324+3649	STF1755	8934	2012.413	R	32	4.206	0.025	129.9*	0.3				
13341+6746	STF1767	8959	2012.460	R	32	4.116	0.021	343.9*	0.3				
13367+6947	STF1771	8976	2012.460	R	32	1.814	0.016	80.2*	0.4				
13375+3618	STF1768	8974	2012.460	R	20	1.752	0.009	96.1*	0.3		Sta1976b	0.01	1.1
14024+4620	SWI1	9090	2012.487	R	32	3.752	0.019	24.8	0.3				
14033+0557	HWE29AB	9091	2012.463	W	32	1.280	0.017	235.8	0.3	Elongated			
14152+4658	STF1826	9183	2012.463	W	32	4.321	0.022	309.3*	0.5	Diffuse			
14153+0308	STF1819	9182	2012.460	R	20	0.897	0.010	173.3*	0.3		Sca2012b	0.00	0.3
14158+1018	STF1823AB-C	9185	2012.506	W	32	3.841	0.054	147.0*	0.3				
14165+2007	STF1825	9192	2012.506	R	32	4.331	0.022	153.6*	0.4				
14411+1344	STF1865	9343	2012.460	R	10	0.500	0.004	292.9	0.3	Elongated	Sca2007f	-0.01	-0.3
14421+6116	STF1878	9357	2012.520	R	32	4.144	0.038	314.0*	0.3				
14436+3745	STF1875	9362	2012.520	W	32	3.040	0.027	128.1*	0.3				
14475+6210	KR43	9391	2012.523	W	32	2.740	0.038	211.7*	0.9	Elongated			
14525+1844	BU31	9423	2012.542	R	32	1.973	0.022	220.1*	0.9				
14526+5903	STF1892	9428	2012.542	W	32	3.090	0.038	235.9*	0.3				
14531+7811	HU908	9445	2012.523	RL	20	1.522	0.008	237.3*	0.3				
14568+7050	STF1905	9460	2012.523	R	32	2.803	0.021	160.0*	0.9				
14584+4403	STF1896	9461	2012.498	R	32	4.116	0.021	275.9*	0.3				
15038+4739	STF1909	9494	2012.457	R	20	1.353	0.008	61.7*	0.3		Sod1999	0.06	-0.4
15075+0914	STF1910	9507	2012.457	R	32	4.002	0.020	210.8*	0.3				
15183+2650	STF1932AB	9578	2012.457	R	20	1.626	0.008	263.6	0.3		Sca2013b	0.00	-0.6
15208+3459	HO62	9599	2012.498	W	32	1.335	0.019	101.6*	0.4				
15232+3017	STF1937AB	9617	2012.498	R	10	0.660	0.003	187.3*	0.3	Elongated	Sod1999	0.00	-0.0
15245+3723	STF1938Ba,Bb	9626	2012.457	R	20	2.274	0.011	4.8*	0.3		Sca2013a	0.05	0.2
15264+0822	A1119	9635	2012.498	W	32	1.571	0.033	178.5*	1.1				
15264+4400	STT296AB	9639	2012.463	R	32	2.127	0.016	274.0*	0.3				
15300+2530	STF1950	9675	2012.542	R	32	3.297	0.052	90.4*	0.3				
15361+5531	A1124	9720	2012.457	R	32	1.383	0.016	143.2*	0.3	Diffuse			
15405+1840	A2076	9742	2012.460	R	20	0.733	0.008	185.1	0.8				
15416+1940	HU580	9744	2012.569	R	10	0.218	0.004	249.4*	0.9		Doc2007d	0.01	-0.5
15427+2618	STF1967	9757	2012.569	R	10	0.575	0.005	111.3*	0.6	Elongated	Mut2010b	-0.01	-0.0
15432+1340	BU619	9758	2012.586	R	20	0.647	0.011	358.3*	1.1				
15476+5523	BU946	9793	2012.591	RL	20	2.323	0.015	128.5*	0.3	NF			
15487+8337	STF2034	9853	2012.591	R	20	1.099	0.008	108.3*	0.4				
15589+2147	STF1990BC	9865	2012.586	R	32	4.091	0.027	26.3	0.7				
16009+1316	STT303AB	9880	2012.460	R	32	1.550	0.016	172.7*	0.3				
16160+0721	STF2026	9982	2012.460	R	32	3.493	0.025	17.2*	0.3		Sca2011a	0.03	-0.2
16188+3154	HU1172	9998	2012.523	W	32	1.706	0.024	327.3*	0.8				
16231+4738	STF2047	10038	2012.586	R	32	1.751	0.016	324.0*	0.6				
16289+1825	STF2052AB	10075	2012.460	R	32	2.282	0.016	119.3*	0.3		Sca1984d	-0.02	-1.0
16309+0159	STF2055AB	10087	2012.586	R	20	1.396	0.008	38.9*	0.4	Elongated	Hei1993b	-0.04	-0.2
16448+3544	STF2097AB	10193	2012.569	R	32	1.934	0.016	77.5*	0.6				
16458+3538	STF2101AB	10203	2012.569	R	32	4.034	0.065	47.3*	0.3	Elongated			
16476+2538	WEI31	10216	2012.542	W	32	4.873	0.024	316.1*	0.3	Diffuse			
16483+0244	BU43	10217	2012.605	R	32	1.405	0.016	54.9*	0.9				
16492+4559	BU627AB	10227	2012.602	RL	20	1.896	0.009	34.7*	0.3				
16492+4559	BU627AC	10227	2012.602	RL	20	2.107	0.011	41.4*	0.3				
16492+4559	BU627A,BC	10227	2012.602	RL	20	1.998	0.010	38.2*	0.3		FMR2012a	-0.03	0.5
16492+4559	A1866BC	10227	2012.602	RL	20	0.316	0.008	85.9	0.3		DRs2012	0.03	-0.7 <sup>Q</sup>
16511+0924	STF2106	10229	2012.569	R	20	0.744	0.008	171.5*	0.8		Sca2001g	-0.03	-0.2
16518+2840	STF2107AB	10235	2012.586	R	20	1.423	0.015	102.8*	0.3		Sca2003c	0.03	-0.9

**Table 1** Table of speckle measurements and O-C residuals with published orbits (cont.)

WDS	Name	ADS	Epoch	Fil.	Eyep. (mm)	$\rho$ (")	$\sigma_\rho$ (")	$\theta$ ( $^\circ$ )	$\sigma_\theta$ ( $^\circ$ )	Notes	Orbit	$\Delta\rho(\text{O-C})$ (")	$\Delta\theta(\text{O-C})$ ( $^\circ$ )
16541+0826	HEI857	–	2012.629	R	20	0.554	0.011	140.4*	1.1	Elongated			
16564+6502	STF2118AB	10279	2012.523	R	20	0.994	0.010	66.6*	0.7		Sca2002d	–0.16	–0.3
"	"	"	2012.602	R	20	1.025	0.008	65.5*	0.3		Sca2002d	–0.13	–1.4
16567+1408	STT318	10270	2012.635	RL	32	2.855	0.035	241.8*	0.3				
16581+1509	STT319	10277	2012.635	R	20	0.851	0.014	65.1*	0.8				
17020+0827	STF2114	10312	2012.569	R	20	1.323	0.017	195.1*	0.6				
17047+1936	PRY2AB	10326	2012.605	RL	20	1.828	0.011	227.4*	0.3				
17053+5428	STF2130AB	10345	2012.569	R	20	2.472	0.036	5.1*	0.3		Pru2012	0.02	–0.2
17082–0105	A1145	10355	2012.629	R	20	0.655	0.008	343.4*	0.9		WSI2006b	–0.00	–1.2
17128–0403	STF2132	10395	2012.630	R	32	1.931	0.016	112.5*	0.5				
17131+5408	STF2146AB	10410	2012.569	W	32	2.615	0.035	224.3*	0.4				
17190+4408	STF2154A,Aa	10474	2012.709	R	32	0.863	0.052	182.2	3.0	New?			
17190+4408	STF2154AB	10474	2012.709	R	32	2.026	0.035	251.5*	0.3				
17229+1628	STF2157AB-C	10508	2012.709	R	32	3.345	0.017	208.6*	0.5				
17234+4209	STF2163	10523	2012.709	W	32	1.329	0.049	75.5*	0.6				
17240+3835	HU1179	10531	2012.635	R	10	0.279	0.004	272.7	0.6	Elongated	Hrt2000b	0.01	2.2
17290+5052	STF2180	10597	2012.591	R	32	3.068	0.043	258.4*	0.5				
17386+5546	STF2199	10699	2012.591	R	32	2.057	0.019	55.4*	0.4		Pop1995d	0.13	2.0
17399+4119	A695	10706	2012.687	R	32	3.433	0.065	230.5*	0.5				
17427+0520	AG212	10730	2012.687	W	32	2.672	0.022	25.2*	0.3				
17432+2245	COU629	–	2012.690	W	32	4.056	0.020	206.7*	0.3	Elongated			
17433+1018	HEI551	–	2012.711	W	32	3.212	0.016	76.5*	0.5	Diffuse			
17436+2237	HU1285	10743	2012.687	W	20	0.514	0.026	211.4*	1.5	Elongated	USN2002	0.00	–1.6
17456+1553	HU1287	10768	2012.690	W	32	1.901	0.035	62.9*	0.3				
17462+7629	MLR209	–	2012.711	W	32	2.280	0.038	53.4*	0.3				
17465+2743	AC7BC	10786	2012.605	R	32	0.970	0.024	258.9	1.4		Cou1960b	0.03	–0.4
"	"	"	"	"	"	"	"	"	"		This paper	0.03	–1.8
17490+2511	COU501	–	2012.690	W	32	1.877	0.016	318.0*	0.3				
17506+0714	STT337	10828	2012.605	W	20	0.584	0.022	166.9*	1.3	Diffuse	Doc1990a	0.07	2.7
17520+1520	STT338AB	10850	2012.591	R	20	0.823	0.009	163.7*	0.7		Pru2012	–0.00	–1.0
17571+0004	STF2244	10912	2012.602	R	20	0.650	0.010	100.1*	1.0		Hei1997	0.12	–0.8
18025+4414	BU1127	11010	2012.602	R	20	0.698	0.008	49.0*	0.4		Cve2006e	–0.11	–2.4
18113+1713	HU317	11141	2012.690	R	32	1.462	0.021	204.6	0.8				
18121+2739	STF2292	11155	2012.591	R	20	0.900	0.017	274.9	0.3	Faint			
18126+3836	BU1091	11170	2012.630	R	20	0.738	0.008	318.3	0.6		Pru2012	–0.01	–1.7
18146+0011	STF2294	11186	2012.635	R	20	1.349	0.017	92.6*	0.4	Faint	Luy1934a	0.14	–0.5
18234+2327	STF2314	11309	2012.690	R	32	2.506	0.016	329.1*	0.6				
18386+2706	HJ1333	11533	2012.712	W	32	2.836	0.057	225.6*	0.7				
18386+3043	STF2358	11535	2012.709	W	32	2.515	0.027	223.2*	0.3	Elongated			
18443+3940	STF2382AB	11635	2012.687	R	20	2.308	0.022	346.7*	0.6		WSI2004b	–0.06	0.1
18443+3940	STF2383Cc-D	11635	2012.687	R	20	2.403	0.034	77.2*	0.9		Doc1984b	0.03	0.2
18461+1655	HEI259	–	2012.709	W	32	1.885	0.016	247.5*	0.8				
19266+2719	STF2525	12447	2012.810	R	32	2.135	0.016	289.4*	0.6		Hei1984b	–0.00	–0.3
19450+4508	STF2579	12880	2012.630	RL	20	2.707	0.021	217.9*	0.3		Sca2012c	0.00	–0.5
"	"	"	2012.687	RL	20	2.710	0.014	217.8*	0.3		Sca2012c	0.00	–0.6
"	"	"	2012.813	R	20	2.705	0.014	217.4*	0.3		Sca2012c	–0.00	–0.9
19458+4033	STT385	12904	2012.815	R	32	1.231	0.028	50.9*	1.2				
19464+3344	STF2576	12889	2012.687	R	32	2.914	0.016	157.6*	1.1		Sca1981f	–0.08	–0.9
19471+3321	HU758	12930	2012.878	R	32	0.877	0.016	144.2	0.7				
19515+2332	BU978	13030	2012.813	R	32	0.937	0.016	59.2*	0.3				
19525+2227	HO580	13055	2012.813	R	20	0.689	0.034	274.5*	0.7				
19535+2405	DJU4	–	2012.813	R	20	1.400	0.032	245.1*	0.5		Cve2008d	0.06	–1.4
"	"	"	2012.854	R	20	1.409	0.019	244.6*	1.0		Cve2008d	0.07	–1.9
19540+1518	STF2596	13082	2012.630	R	32	2.041	0.025	298.1*	0.4				
19576+1524	A1663	13166	2012.687	R	32	1.313	0.021	236.3	0.6	Faint			



**Table 1** Table of speckle measurements and O-C residuals with published orbits (cont.)

WDS	Name	ADS	Epoch	Fil.	Eyep. (mm)	$\rho$ (")	$\sigma_\rho$ (")	$\theta$ ( $^\circ$ )	$\sigma_\theta$ ( $^\circ$ )	Notes	Orbit	$\Delta\rho(\text{O-C})$ (")	$\Delta\theta(\text{O-C})$ ( $^\circ$ )
19579+4216	STF2607AB-C	13186	2012.810	R	32	2.978	0.122	289.1*	1.2	NF			
19584-0214	AC12	13178	2012.815	R	32	1.488	0.022	298.5*	0.8				
19585+3317	STF2606	13196	2012.815	R	20	0.687	0.008	146.5*	0.6				
19594+3206	A378	13212	2012.854	R	32	0.811	0.024	290.5*	0.7				
20010+3742	BU1289AB	13262	2012.889	R	20	0.666	0.020	54.2*	1.1				
20014+1045	STF2613	13256	2012.810	R	32	3.550	0.077	354.4*	0.3		Hop1973b	-0.61	2.5
20028+1435	STF2616	13290	2012.878	R	32	3.492	0.040	266.6*	0.3	NF			
20040+1221	A1194	13314	2012.690	W	32	0.904	0.074	314.5	0.4				
20043+3033	STF2626	13329	2012.815	W	20	0.952	0.013	127.8*	0.8	Elongated			
20051-0418	BU56	13334	2012.878	R	32	1.326	0.016	187.4*	0.6				
20056+6342	STF2642	13392	2012.712	R	32	1.759	0.047	190.4	0.7				
20074+3543	STT398	13405	2012.889	R	20	0.992	0.022	80.6*	0.8				
20080+4223	A382	13415	2012.889	R	20	1.712	0.009	95.6*	0.3				
20262+3712	HO130	13856	2012.810	W	32	1.852	0.019	287.7*	0.3	Elongated			
20337+3835	A1431	14007	2012.813	R	32	0.901	0.016	25.4*	1.1				
20370+1203	STF2701	14063	2012.709	R	32	2.122	0.019	220.5*	0.3				
20396+4035	STT410	14126	2012.813	R	20	0.862	0.024	3.9	0.7		Hrt2011a	-0.00	-0.1
20397+6325	DOB15	14155	2012.813	W	32	3.139	0.019	88.6	0.5	Elongated			
20445+2356	STF2724	14227	2012.810	R	32	2.465	0.022	149.5	1.2				
20595+5013	BU68	14520	2012.878	R	32	1.901	0.033	148.9*	1.4				
20598+2004	STF2739	14515	2012.878	R	32	3.297	0.022	253.0*	0.3	Faint			
21105+1958	STF2767	14708	2012.810	R	32	2.492	0.028	28.4*	0.3				
21186+1134	BU163	14839	2012.889	R	20	0.829	0.010	257.8*	0.7		Fek1997	-0.02	-0.4 <sup>Q</sup>
21208+3227	STT437AB	14889	2012.889	R	32	2.444	0.055	19.8*	0.8		Hrt2011a	0.02	0.7
21318+3349	STF2802	15060	2012.813	R	32	3.732	0.021	9.1*	0.4				
22110+6324	STF2879AB	15712	2012.889	R	20	0.780	0.017	233.8*	0.9				
22136+5234	BU991	15756	2012.889	R	20	0.699	0.011	134.5*	1.0	Faint			
23244+6917	A789	16738	2012.890	R	32	1.958	0.049	82.8*	0.6				
23256+3326	AG292	16744	2012.890	W	32	3.760	0.071	233.7*	0.3	Elongated			
23375+4426	STT500AB	16877	2012.890	R	10	0.460	0.007	11.5	1.0		Zul1981	0.04	-5.1
23439+0715	STF3033	16958	2012.890	R	32	3.042	0.036	183.2	0.3				
23516+4205	STT510AB	17050	2012.890	R	20	0.611	0.023	118.7	1.1	NF	Nov2005	0.02	-1.7 <sup>Q</sup>

Note: In column 9, the exponent \* indicates that the position angle  $\theta$  could be determined without the  $180^\circ$  ambiguity. In column 14, the exponent <sup>Q</sup> indicates discrepant quadrants between our measurements and the published orbits.

**Table 2** Characteristics of the filters used for the measurements of Table 1.

Name	Identification	$\lambda_c$ (nm)	$\Delta_\lambda$ (nm)
R	ORIEL/57621	644	70
W	ICCD alone	650	420
RL	ORIEL/57661	743	69
I	ORIEL/57701	855	74

ing the observations. This processing led to a series of measurements with different background estimates and simulated noise, from which we derived the mean values and the standard deviation of those multiple measurements (see Paper III for more details). The final measures and their errors are displayed in Table 1. The average error values of the measurements reported in

this table are  $0''.020 \pm 0''.014$  and  $0^\circ.5 \pm 1^\circ.4$  for  $\rho$  and  $\theta$ , respectively.

### 3.1 Quadrant determination

As our astrometric measurements were obtained from the *symmetric* auto-correlation files, the  $\theta$  values first presented a  $180^\circ$  ambiguity. To resolve this ambiguity and determine the quadrant containing the companion, Aristidi et al. (1997) have proposed a method that can be considered as a restricted triple correlation (RTC hereafter). The quadrants of the measurements indicated in Table 1 were mostly derived from the RTC files that were computed in real time during the observations. However, for the couples with the largest separations, a straightforward determination was done

**Table 3** Objects with discrepant quadrants

Name	Q	Filter	$\Delta m_V$	Spectral type
ADS 758 AB	3	R	0.11	F8
ADS 3353 AB	1	R	0.15	F0
ADS 4208 AB	2	R	0.01	B8IV
ADS 7352 AB	2	R	0.12	F5

when the companions could be directly spotted on the long integration files.

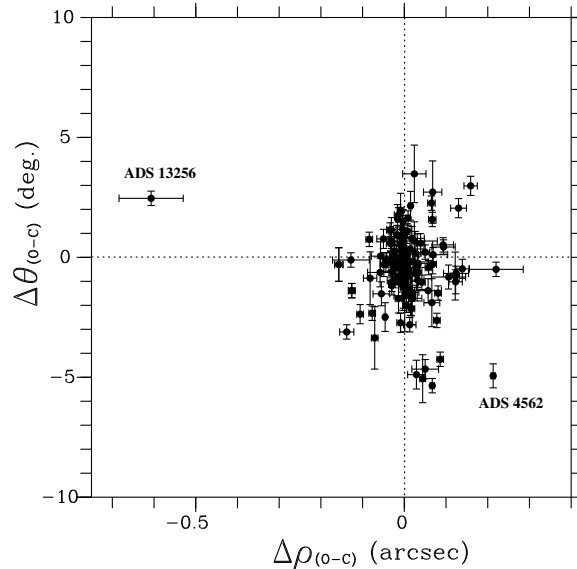
As a result, in Table 1, we are able to give the unambiguous (i.e. “absolute”) position angles of 305 out of 355 measurements, i.e. 86% of the total. They are marked with an asterisk in Col 9. When our quadrant determination procedure failed, the angular measurement was reduced to the quadrant reported in the WDS catalogue, which is extracted from the Fourth Catalogue of Interferometric Measurements of Binary Stars (Hartkopf et al. 2013, hereafter IC4).

Our “absolute”  $\theta$  values are consistent with the values tabulated in WDS for all objects except for ADS 758, 3353, 4208 and 7352. We display some information about those objects in Table 3. In Col. 2, we indicate the quadrant (Q) that we obtained from our observations, using the usual convention of numbering it from 1 to 4 to indicate the North-East, South-East, South-West and North-West quadrants, respectively. In Col. 3 we indicate which filter we have used. We report the difference of magnitude between the two components from the IC4 in Col. 4, and the global spectral type found in the SIMBAD astronomical data base in Col. 5. For all those objects, the small value and the uncertainty in the magnitude difference  $\Delta m_V$  account for the discrepancy.

### 3.2 Comparison with published ephemerides

The ( $O - C$ ) (Observed minus Computed) residuals of the measurements for the 112 systems with a known orbit in Table 1 are displayed in Cols. 13 and 14 for the separation  $\rho$  and position angle  $\theta$ , respectively. Those residuals were obtained with a selection of valid orbits found in 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 10786 BC we also reported the residuals obtained with our revised orbit presented in Sect. 4.

Fig. 3 shows that the residuals have a rather large scatter. This scatter is not indicative of the overall quality of the measures presented. It is naturally explained by the (old) age of many orbits that need revision. The mean values computed with the residuals of Table 1 are  $\langle \Delta \rho_{O-C} \rangle = -0''.001 \pm 0''.081$  and  $\langle \Delta \theta_{O-C} \rangle = -0^\circ.4 \pm 1^\circ.6$ . The small values obtained for those offsets provide a good validation of our calibration (see Paper XII).

**Fig. 3** Residuals of the measurements of Table 1 computed with the published orbits.

In the following, we examine the cases of ADS 4562, and 13256, that appear with the largest residuals in Fig. 3. This is not surprising since those two binaries have a Grade 5 orbit (i.e. “indeterminate”) in the OC6 catalogue.

**ADS 4562:** the residuals with the orbit of Baize (1988) begin to be rather large. A new orbit will be needed in the future, when a larger part of the orbit is monitored.

**ADS 13256:** this object has the largest residual in Table 1 of ( $\Delta \rho = -0''.607$ ,  $\Delta \theta = 2^\circ.5$ ) with Hopmann (1973)’s orbit. This orbit was computed a long time ago, with insufficient data. The arc of the monitored orbit was very short in 1973, but has not increased very much since. It cannot be excluded that the motion is rectilinear.

## 4 Revised orbits of ADS 10786 BC, 12144, 12515, 16314, and 16539

In this section we present the new revised orbits, partly deduced from PISCO observations, that we have computed for ADS 10786 BC, 12144, 12515, 16314, and 16539.

We have followed the same method for those five 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 4. The errors reported in this table were obtained by Hellerich’s least-squares method. For ADS 12515, the errors could not be estimated since Hellerich’s method did not converge. The format of the tables contained in this section is self-explanatory, but a detailed description of those formats can be found in Papers VI and VII.

[h]

The ( $O - C$ ) residuals of the new orbits, restricted to the last observations for reasons of space, are given in Tables 5, 6, 7, 8, and 9, for ADS 10786 BC, 12144, 12515, 16314, and 16539, respectively. The name of the observer is reported in the last column, using the US Naval Observatory convention.

The ephemerides for 2014–2023 are presented in Table 10. The apparent orbits are shown in Fig. 4 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 (that appear in red in the electronic version). 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 11, we present some physical parameters of those systems. The (total) visual magnitudes (Col. 3), the difference of magnitude between the components (Col. 4) and the spectral types (Col. 5) were extracted from the IC4 and the SIMBAD data bases. The dynamical parallaxes are presented in Col. 6. Those parallaxes were derived from our orbital elements using Baize & Romani (1946)’s method, with our revised formulae presented in Scardia et al. (2008b). In Col. 7, we report the Hipparcos parallaxes from ESA (1997) or the revised values from van Leeuwen (2007), as indicated in Col. 11. In Cols. 8, 9 and 10, we give the corresponding angular and linear sizes of the semi-major axis  $a$  and the total mass  $\mathcal{M}_{\text{total}}$ , respectively, that were computed from our orbital elements and the Hipparcos parallaxes.

#### 4.1 New orbit of ADS 10786 BC

##### WDS 17465+2743 – AC 7 BC – ADS 10786 BC

This couple belongs to the wide system STF 2220 A-BC, and was discovered by Alvan Clark in July 1856 with a 19.7 cm refractor (Dawes, 1857). Dawes noticed that this faint star was not resolved by F.G.W Struve with the Dorpat 25-cm refractor in 1829, 1832 and 1836, and with the 38-cm Merz-Mahler Poulkova refractor in 1851. Dawes added “... it is, therefore, truly

astonishing that Mr. Alvan Clark should have detected its unsuspected duplicity with an object-glass whose aperture is only 7.75 inches!...”.

This couple is one of the faintest systems that has been observed in Merate: the primary is a red dwarf (M4V spectral type) with a visual magnitude of 10.2 only. It is also known as GJ 695 C or  $\mu$  Her C. It is very close from the sun, with an estimated distance of 8.3 pc only (see Table 11, where we reported the parallax of ADS 10786 A).

The orbital period of AC 7 BC is rather short, close to 43 yr, which explains why many orbits have been computed until now. The first orbit was proposed by Doberck (1879). The last one, from Starikova (1976) leads to systematic residuals both for  $\rho$  and  $\theta$ , whereas the previous orbit, from Couteau (1959), is still valid.

Couteau’s orbit is nevertheless very old, with observations made before 1957. Taking profit of more than 55 years of new and precise observations, which represents about 1.3 orbital revolutions, we recomputed an orbit to improve the accuracy of the orbital elements. Our new orbit of AC 7 BC was calculated by fitting the set of all the 353 observations, made since its discovery. Using the procedure described above, we obtained a straightforward convergence. On the second iteration, we discarded the bad measurements that led to very large residuals (more than  $5^{\circ}.6$  and  $0''.20$  for  $\theta$  and  $\rho$ , respectively). The orbital elements reported in Table 4 fit the observations well (see Fig. 4), with mean residuals of  $\Delta\rho_{O-C} = 0''.079$  and  $\Delta\theta_{O-C} = 1^{\circ}.9$ . The uncertainties of the orbital elements are very small and this orbit is close to being definitive, since 3.7 orbital revolutions have been well monitored by the observations.

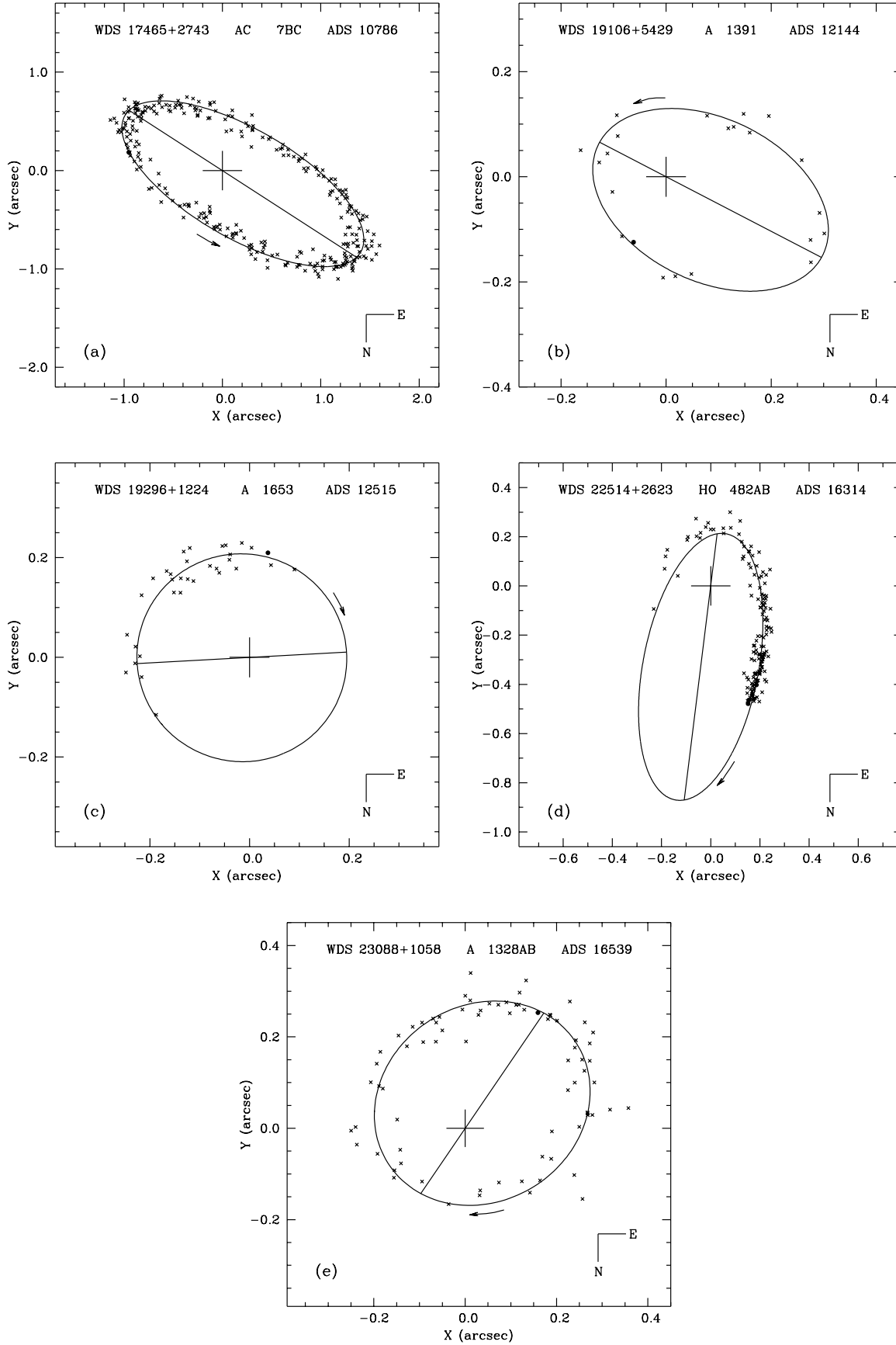
The dynamic parallax obtained with the formula of Scardia et al. (2008b) is close to the Hipparcos parallax of van Leeuwen (2007) and the sum of the masses is in good agreement with theoretical values (see Table 11).

#### 4.2 New orbit of ADS 12144

##### WDS 19106+5429 – A 1391 – ADS 12144 (HIP 94194)

This couple was discovered by R.G. Aitken (1907) with the 91-cm refractor of Lick Observatory in 1906. It is a faint and close binary with a separation angle always smaller than  $0''.35$ , which makes it difficult to observe. We have not yet managed to measure it in Merate, but we resolved it at the Pic du Midi Observatory in 1998, when PISCO was mounted on a 2-meter telescope.

A few orbits have been published for this object. The orbit from Baize (1987) leads to big residuals for the most recent observations. In 2000, we revised this orbit (Scardia et al., 2001), but our orbit now leads to systematic residuals for the position angle. Taking



**Fig. 4** New orbits of ADS 10786 BC (a), ADS 12144 (b), ADS 12515 (c), ADS 16314 (d) and ADS 16539 (e). The observations by PISCO are plotted as filled circles which appear in red in the electronic version.

**Table 4** New orbital elements of ADS 10786BC, 12144, 12515, 16314, and 16539.

ADS	$\Omega_{2000}$ ( $^{\circ}$ )	$\omega$ ( $^{\circ}$ )	$i$ ( $^{\circ}$ )	$e$	$T$ (yr)	$P$ (yr)	$n$ ( $^{\circ}/\text{yr}$ )	$a$ ( $''$ )	A ( $''$ )	B ( $''$ )	F ( $''$ )	G ( $''$ )
10786BC	60.07 $\pm 0.17$	172.85 $\pm 0.64$	66.06 $\pm 0.15$	0.1796 $\pm 0.0009$	2008.335 $\pm 0.073$	43.127 $\pm 0.013$	8.3474 $\pm 0.002$	1.385 $\pm 0.038$	-0.74628	-1.15605	0.39725	-0.42762
12144	64.4 $\pm 6.4$	177.4 $\pm 4.4$	44.9 $\pm 3.8$	0.401 $\pm 0.033$	1981.135 $\pm 0.87$	138.12 $\pm 11$	2.6065 $\pm 0.198$	0.238 $\pm 0.032$	-0.10963	-0.21111	0.14721	-0.08250
12515	65.8	322.4	171.5	0.073	2039.864	229.1	1.5710	0.211	-0.01153	0.21019	0.20876	0.01336
16314	166.1 $\pm 1.8$	347.2 $\pm 1.4$	121.9 $\pm 1.4$	0.6080 $\pm 0.050$	1925.180 $\pm 0.85$	383 $\pm 72$	0.93996 $\pm 0.176$	0.555 $\pm 0.026$	-0.54097	0.06694	-0.05066	0.30716
16539	114.3 $\pm 4.8$	145.7 $\pm 5.0$	153.5 $\pm 2.3$	0.2773 $\pm 0.005$	1963.25 $\pm 0.21$	72.0 $\pm 0.29$	5.0006 $\pm 0.020$	0.247 $\pm 0.021$	0.19750	-0.13471	-0.10915	-0.20200

**Table 5** ADS 10786 BC: O-C residuals of our new orbit (after 2007). The symbol  $^P$  indicates PISCO measurements.

Epoch	$\Delta\rho$ (O-C) ( $''$ )	$\Delta\theta$ (O-C) ( $^{\circ}$ )	Observer
2008.344	-0.069	-0.7	Ant
2008.369	0.000	0.1	Ant
2008.452	0.002	0.5	Msn
2008.527	0.018	-2.2	Gii
2010.511	0.027	0.5	Los
2010.681	-0.003	-4.0	Ant
2012.605	0.030 $^P$	-1.8 $^P$	Sca

**Table 6** ADS 12144: O-C residuals of our new orbit (after 1990). The symbol  $^P$  indicates PISCO measurements.

Epoch	$\Delta\rho$ (O-C) ( $''$ )	$\Delta\theta$ (O-C) ( $^{\circ}$ )	Observer
1990.523	-0.028	-3.0	Lin
1996.699	0.004	1.7	Hrt
1998.679	-0.003 $^P$	2.1 $^P$	Sca
2006.570	0.014	-3.7	Hrt
2007.602	0.007	0.2	Msn
2008.639	0.002	6.6	Gii

profit of the last few precise measurements, we propose here a new revision of the orbital elements.

Using a selection of 22 valid measurements made since 1906, we obtained the orbital elements reported in Table 4. Although the number of available measurements was small, we still had to reject six bad observations whose position angles were clearly erroneous. Our new orbit fit the observations well (see Fig. 4), with mean residuals of  $\Delta\rho_{O-C} = 0''.019$  and  $\Delta\theta_{O-C} = 3^{\circ}.9$ .

The corresponding systemic mass computed with Hipparcos parallax (van Leeuwen, 2007) is larger than what is expected from theory for an F8 couple (see Table 11), but the agreement is reasonable when considering the large uncertainties. Furthermore, the luminosity class of this object may have been badly determined. The dynamic parallax computed with our

**Table 7** ADS 12515: O-C residuals of our new orbit (after 1985). The symbol  $^P$  indicates PISCO measurements.

Epoch	$\Delta\rho$ (O-C) ( $''$ )	$\Delta\theta$ (O-C) ( $^{\circ}$ )	Observer
1987.720	-0.009	-2.4	LBu
1989.680	0.022	-7.0	LBu
1991.250	0.013	-9.4	HIP
1996.660	-0.014	-12.6	Hei
1998.673	0.010 $^P$	-6.2 $^P$	Sca
2007.601	-0.002	-8.1	Msn

**Table 8** ADS 16314: O-C residuals of our new orbit (after 2003). The symbol  $^P$  indicates PISCO measurements.

Epoch	$\Delta\rho$ (O-C) ( $''$ )	$\Delta\theta$ (O-C) ( $^{\circ}$ )	Observer
2004.878	-0.015 $^P$	0.4 $^P$	Sca
2005.745	-0.044	1.3	WSI
2006.717	-0.000	1.1	Slm
2007.707	-0.026	0.4	Gii
2007.972	-0.019 $^P$	-0.4 $^P$	Sca
2009.808	-0.029	-0.2	WSI
2011.907	-0.029 $^P$	0.5 $^P$	Sca

**Table 9** ADS 16539: O-C residuals of our new orbit (after 1996). The symbol  $^P$  indicates PISCO measurements.

Epoch	$\Delta\rho$ (O-C) ( $''$ )	$\Delta\theta$ (O-C) ( $^{\circ}$ )	Observer
1998.679	-0.005 $^P$	0.5 $^P$	Sca
1999.869	0.004	-0.7	WSI
2001.685	0.002	4.0	WSI
2002.700	0.002	3.4	WSI
2005.861	-0.009	-1.0	Msn
2007.588	-0.007	-2.1	Msn
2008.887	0.010	-0.3	Orl

**Table 10** New ephemerides of ADS 10786BC, 12144, 12515, 16314, and 16539.

Epoch	ADS 10786BC		ADS 12144		ADS 12515		ADS 16314		ADS 16539	
	$\rho$ ( $''$ )	$\theta$ ( $^\circ$ )	$\rho$ ( $''$ )	$\theta$ ( $^\circ$ )	$\rho$ ( $''$ )	$\theta$ ( $^\circ$ )	$\rho$ ( $''$ )	$\theta$ ( $^\circ$ )	$\rho$ ( $''$ )	$\theta$ ( $^\circ$ )
2014.0	0.791	272.7	0.219	20.4	0.198	139.7	0.543	16.2	0.280	102.9
2015.0	0.685	284.6	0.225	22.3	0.198	137.9	0.549	15.8	0.274	99.5
2016.0	0.599	300.3	0.230	24.2	0.197	136.2	0.555	15.4	0.268	96.0
2017.0	0.556	319.7	0.236	25.9	0.197	134.4	0.560	15.0	0.262	92.2
2018.0	0.571	340.2	0.241	27.6	0.197	132.6	0.566	14.7	0.255	88.3
2019.0	0.639	357.9	0.246	29.2	0.197	130.8	0.571	14.3	0.248	84.1
2020.0	0.743	11.5	0.251	30.8	0.196	129.0	0.577	13.9	0.240	79.7
2021.0	0.864	21.4	0.256	32.3	0.196	127.3	0.582	13.6	0.232	75.0
2022.0	0.990	28.9	0.261	33.7	0.196	125.5	0.588	13.2	0.224	70.0

**Table 11** Physical parameters ( $\pi_{\text{dyn}}$ ,  $a$  and  $\mathfrak{M}_{\text{total}}$ ) derived from the new orbital elements.

ADS	HIP	$m_V$	$\Delta m_V$	Spectral type	$\pi_{\text{dyn}}$ (mas)	$\pi_{\text{HIP}}$ (mas)	$a$ ( $''$ )	$a$ (AU)	$\mathfrak{M}_{\text{total}}$ ( $M_\odot$ )	Source of $\pi_{\text{HIP}}$
10786BC	–	10.2	0.5	M4V	123.0	120.33 <sup>(1)</sup>	1.39	11.5	0.82	van Leeuwen (2007)
						$\pm 0.16$	$\pm 0.04$	$\pm 0.3$	$\pm 0.07$	
12144	94194	8.65	0.9	F8V	6.2	5.58	0.238	42.7	4.1	van Leeuwen (2007)
						$\pm 0.85$	$\pm 0.032$	$\pm 8.7$	$\pm 2.6$	
12515	95845	7.83	1.3	A3V	3.3	3.62	0.211	58	3.8	ESA (1997)
						$\pm 1.19$		$\pm 19$ <sup>(2)</sup>	$\pm 3.7$ <sup>(2)</sup>	
”	”	”	”	”	”	1.91	”	110	26	van Leeuwen (2007)
						$\pm 1.01$		$\pm 58$	$\pm 41$	
16314	112871	6.96	1.0	A3V	6.5	6.89	0.555	81	3.6	ESA (1997)
						$\pm 1.62$	$\pm 0.026$	$\pm 19$	$\pm 2.9$	
”	”	”	”	”	”	7.54	”	74	2.7	van Leeuwen (2007)
						$\pm 0.84$		$\pm 9$	$\pm 1.4$	
16539	114280	7.61	0.6	F5V	9.8	9.25	0.247	27	3.7	ESA (1997)
						$\pm 1.16$	$\pm 0.021$	$\pm 4$	$\pm 1.7$	
”	”	”	”	”	”	8.36	”	29	5.0	van Leeuwen (2007)
						$\pm 0.82$		$\pm 4$	$\pm 1.9$	

<sup>(1)</sup> Parallax of ADS 10786A.<sup>(2)</sup> lower estimate of the error, using the parallax error only, and neglecting all the other (unknown) errors.

formula (Scardia et al., 2008b) is in good agreement with the value obtained with Hipparcos (see Table 11).

### 4.3 New orbit of ADS 12515

#### WDS 19106+5429 – A 1653 – ADS 12515 (HIP 95845)

This couple was discovered by R.G. Aitken in 1907 with the 91-cm refractor of Lick Observatory. It is a close binary with an average angular separation of around  $0''.2$ , which is difficult to observe with a small telescope. Like ADS 12144, we only managed to resolve ADS 12515 when PISCO was operated at the Pic du Midi, on the 2-meter Bernard-Lyot telescope. About half of the orbit that appears nearly circular has been monitored since its discovery.

The first orbit of ADS 12515 was computed by Heintz (1963). It leads now to systematic residuals both for  $\rho$  and  $\theta$ . In this paper we present the new orbit that we computed by fitting the set of 36 available observa-

tions obtained between 1907 and 2007. We first drew the apparent ellipse and applied Kowalsky’s method on the apparent ellipse. Hellerich’s method did not converge and we had to improve this orbit using a trial-and-error method. Our final orbit is nearly circular and fits the observations with means residuals of  $0''.020$  and  $4^\circ.1$  in  $\rho$  and  $\theta$ , respectively. The large value for the position angle residuals is due to the poor quality of the measurements. Only two speckle measurements have been obtained yet (PISCO in 1998 and Mason in 2007).

This object has a spectral type of A3V and is very far from the sun, with an estimated parallax of  $0''.00191 \pm 0''.00101$  (van Leeuwen, 2007) or  $0''.00362 \pm 0''.00119$  (ESA 1997). Although they are based on the same observations (from Hipparcos), those two determinations are quite different, but the uncertainties are very large. The systemic mass is excessive and unreasonable ( $25.7 M_\odot$ ) when using van Leeuwen (2007)’s parallax, whereas it is in fair agreement with the theory ( $3.8 M_\odot$ ) with ESA (1997)’s value. In the “General Cat-

alogue of Trigonometric Parallaxes” (van Altena et al., 1995), the parallax is even larger ( $0''.0045 \pm 0''.0070$ ), which leads to a total mass of  $2.0 M_{\odot}$ . The dynamic parallax computed with our formula (Scardia et al., 2008b) is in agreement with the values from ESA (1997) or van Altena et al. (1995), but in disagreement with van Leeuwen (2007)’s parallax, which seems underestimated.

#### 4.4 New orbit of ADS 16314

##### WDS 22514+2623 – HO 482 AB – ADS 16314 (HIP 112871)

This couple was discovered in 1889 by G.W. Hough with his 47-cm refractor in Evanston (Illinois, USA) (Hough, 1890). Its angular separation was very small until (and around) the periastron passage that occurred in 1925, and this binary was not easy to resolve with small telescopes. Since then, the companion has been moving away from the primary, which makes it easier to measure. The observations of ADS 16314 are numerous, especially after 1925, and their dispersion is rather small (see Fig. 4).

The first orbit of ADS 16314 was proposed by Arend (1944), and a few others have been computed since. The last one, from Starikova (1982) now leads to systematic residuals. We thus decided to take profit of more than thirty years of new observations to determine new orbital elements. The orbital elements reported in Table 4 were obtained by fitting the set of the 145 observations made since its discovery. They fit the observations very well (see Fig. 4), with mean residuals of  $\Delta\rho_{O-C} = 0.028''$  and  $\Delta\theta_{O-C} = 2.5^{\circ}$ . Only part of the orbit has been monitored yet, which explains the large uncertainty of the period. However, as the dispersion of the measures is rather small, the other orbital elements are rather well determined with a small uncertainty.

The total mass of the system is in good agreement with the theoretical values (see Table 11) and the dynamical parallax computed with our formula (Scardia et al., 2008b) is consistent with the Hipparcos parallax.

#### 4.5 New orbit of ADS 16539

##### WDS 23088+1058 – A 1328 AB – ADS 16539 (HIP 114280)

This couple was discovered by R.G. Aitken in 1905 with the 91-cm refractor of Lick Observatory (Aitken, 1905). It has always been difficult to measure, since its angular separation has never been larger than  $0''.35$ . Since 1905, the companion has made about 1.5 orbital revolutions, which were regularly monitored by the observers. A few orbits have been computed until now, and the last one was calculated in 2000 by our group (Scardia et al., 2001). This orbit leads to systematic residuals with the last speckle observations, so

we decided to use those precise observations to revise it.

The new orbital elements presented in Table 4 have been computed by fitting the 78 available measurements, using the general procedure that was described above. Our elements lead to a good representation of the observations (see Fig.4) with mean residuals of  $\Delta\rho_{O-C} = 0.031''$  and  $\Delta\theta_{O-C} = 3.4^{\circ}$ . The uncertainties for the period and the semi-major axis are very small, so we do not think new observations will change their values in the future.

The total mass computed with the Hipparcos parallax value of  $0''.00839$  determined by van Leeuwen (2007), is slightly in excess for a F5V binary. This excess is smaller with the ESA (1997)’s determination of  $0''.00925$ . The dynamic parallax computed with (Scardia et al., 2008b) is slightly larger ( $0''.0098$ ) and would lead to a smaller systemic mass, in good agreement with theoretical masses (see Table 11).

## 5 Conclusion

In 2012, we obtained 355 new measurements of 344 visual binaries with PISCO in Merate, with an average accuracy of  $0''.02$  for the angular separation and  $0^{\circ}.5$  for the position angles. The total number of measurements made with PISCO in Merate since 2004 now exceeds 3200. Our group has thus provided a good contribution to the continuing monitoring of long period visual binary systems, which is important for refining systemic stellar masses.

We finally presented new orbital elements computed for ADS 10786 BC, 12144, 12515, 16314 and 16539. Those orbits were partly derived from PISCO observations. The total mass values we have obtained are compatible with the expected theoretical values.

*Acknowledgements.* We thank the members of the United States Naval Observatory, Washington DC, for kindly 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>), the “Sixth Catalogue of Orbits of Visual Binary Stars” (<http://ad.usno.navy.mil/wds/orb6>), the Washington Double Star Catalogue (<http://ad.usno.navy.mil/wds/wds>) maintained at the U.S. Naval Observatory, and the SIMBAD astronomical data base (<http://simbad.u-strasbg.fr/simbad>) operated by the *Centre de Données Astronomiques de Strasbourg* (France).

## References

- Aitken, R.G., 1905, Lick Obs. Bull. n. 93
- Aitken, R.G., 1907, Lick Obs. Bull. n. 109
- Aitken, R.G.: 1932, “New General Catalogue of Double Stars”, Carnegie Institute, Washington
- Arend, M.S., 1944, Journ. Observ., 27, 23
- Aristidi, E., Carbillet, M., Lyon, J.-F., Aime, C., 1997, A&AS, 125, 139
- Baize, P., Romani, L., 1946, Ann. Astrophys. 9, 13
- Baize, P., 1987, A&AS, 71, 177
- Baize, P., 1988, A&AS, 74, 507
- Couteau, P., 1959, Bull. Astron. Paris 23, 127
- Dawes, W.R., 1857, MNRAS 17, 257
- Doberck, W.A., 1879, Astron. Nachr. 96, 111
- ESA: 1997, The Hipparcos and Tycho Catalogues, ESA SP-1200, ESA Publications Division, Noordwijk
- Hartkopf, W.I., Mason, B.D., 2013, “Sixth Catalogue of Orbits of Visual Binary Stars” <http://ad.usno.navy.mil/wds/orb6.html> (OC6)
- Hartkopf, W.I., Mason, B.D., Wycoff, G.L., McAlister, H.A., 2013, “Fourth Catalogue of Interferometric Measurements of Binary Stars” <http://ad.usno.navy.mil/wds/int4.html> (IC4)
- Heintz, W.D., 1963, Veroff. Sternw. München 5, 19
- Hellerich, J., 1925, Astron. Nachr. 223, 335
- Hopmann, J, 1973, Astron. Mitt. Wien, 13, 322
- Hough, G.W., 1890, AJ, 9, 177
- Kowalsky, M., 1873, Procès-verbaux de l’Université Impériale de Kasan
- Mason, B.D., Wycoff, G.L., Hartkopf, W.I., 2013, “Washington Double Star Catalogue” <http://ad.usno.navy.mil/wds/wds.html> (WDS)
- Prieur, J.-L., Koechlin, L., André, C., Gallou, G., Lucuix, C., 1998, Experimental Astronomy, vol 8, Issue 4, 297
- Prieur, J.-L., Scardia, M., Pansecchi, L., Argyle, R.W., Sala, M., Ghigo, M., Koechlin, L., Aristidi, E., 2008, MNRAS, 387, 772 (Paper V)
- Prieur, J.-L., Scardia, M., Pansecchi, L., Argyle, R.W., Sala, M., 2009, MNRAS, 395, 907 (Paper VII)
- Prieur, J.-L., Scardia, M., Pansecchi, L., Argyle, R.W., Sala, M., 2010, MNRAS, 407, 1913 (Paper IX)
- Prieur, J.-L., Scardia, M., Pansecchi, L., Argyle, R.W., Sala, M., 2012, MNRAS, 422, 1057–1070 (Paper XI)
- Scardia, M., Prieur, J.-L., Koechlin, L., Aristidi, E., 2001, IAU Commission 26, Inf. Circ. n. 144
- Scardia, M., Prieur, J.-L., Sala, M., Ghigo, M., Koechlin, L., Aristidi, E., Mazzoleni, F., 2005, MNRAS, 357, 1255 (with erratum in MNRAS 362, 1120) (Paper I)
- Scardia, M., Prieur, J.-L., Pansecchi, L., Argyle, R.W., Sala, M., Ghigo, M., Koechlin, L., Aristidi, E., 2006, MNRAS, 367, 1170 (Paper II)
- Scardia, M., Prieur, J.-L., Pansecchi, L., Argyle, R.W., Basso, S., Sala, M., Ghigo, M., Koechlin, L., Aristidi, E., 2007, MNRAS, 374, 965 (Paper III)
- Scardia, M., Prieur, J.-L., Pansecchi, L., Argyle, R.W., Sala, M., Basso, S., Ghigo, M., Koechlin, L., Aristidi, E., 2008a, Astron. Nach., 329, 1, 54 (Paper IV)
- Scardia, M., Prieur, J.-L., Pansecchi, L., Argyle, R.W., 2008b, AN 329, 379
- Scardia M., Prieur J.-L., Pansecchi L., Argyle R.W., Sala M., 2009, Astron. Nach., 330, 1, 55 (Paper VI)
- Scardia, M., Prieur, J.-L., Pansecchi, L., Argyle, R.W., Sala, M., 2010, Astron. Nach., 331, 286 (Paper VIII)
- Scardia, M., Prieur, J.-L., Pansecchi, L., Argyle, R.W., Sala, M., 2011, Astron. Nach., 332, 508 (Paper X)
- Scardia, M., Prieur, J.-L., Pansecchi, L., Argyle, R.W., Spanó, P., Riva, M., Landoni, M., 2013, MNRAS, 434, 2803–2813 (Paper XII)
- Starikova, G.A., 1976, Trud. Astron. Inst. Sternberg 47, 96
- Starikova, G.A., 1982, Pisma Astron. Zh. 8, 306
- van Altena, W.F., Truen-Liang, L., Hoffleit, E.D., 1995, “The General Catalogue of Trigonometric Stellar Parallaxes”, Yale University Observatory ed., New Haven, U.S.A.
- van Leeuwen, F., 2007, “Hipparcos, the new reduction of the raw data”, Springer Netherlands Ed.