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Orbital elements of five close visual binary stars.

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Summary:

Revised orbital elements of the visual binary stars STT 2, STT 4, BU 1015, STT 6 and BU 395 are given. Dynamical parallaxes and total masses of the systems have been calculated.

Key words: visual binaries: orbits

1 Introduction

In the years 1994-98 numerous high quality observations of close visual binary stars were obtained with the speckle interferometry technique, using the PISCO speckle camera developed by Observatoire Midi-Pyrénées and used on the Cassegrain focus of the 2-meter *Télescope Bernard Lyot* (TBL) of the Pic du Midi Observatory (Aristidi et al. 1997, Aristidi et al. 1999, Scardia et al. 2000). These observations made it possible to revise numerous orbits which were no longer valid, particularly with regard to the calculation of the sum of the masses of the binary systems being studied. The following explanations concern all the binary stars studied in the present work. The observations were taken from lists kindly supplied by the Naval Observatory of Washington. For the calculation of the preliminary orbital elements the analytical method of Kowalsky (1873) was used. If possible the preliminary elements thus obtained were improved with least squares, using the method

of Hellerich (1925). In particular the orbital elements node, omega, i and n are in degrees while a is in arcsec. In the tables containing the ephemerides column 1 contains the date in years, column 2 the separation ρ in arcsec and column 3 the position angle θ in degrees. In the tables of the O-C, restricted for reasons of space to the observations following 1979, column 1 contains the date in years, column 2 the observed separation ρ in arcsec, column 3 the $\Delta\rho$, column 4 the observed position angle θ (reduced to 2000) in degrees, column 5 the $\Delta\theta$, column 6 the number of nights and column 7 the name of the observer. For the calculation of the dynamical parallax the method of Baize-Romani (Couteau, 1978) was used, while for the calculation of the uncertainty concerning the sum of the masses of the systems being studied the following expression was used:

$$\epsilon_{\%} = 100 * \sqrt{\left(3\frac{\Delta a}{a}\right)^2 + \left(3\frac{\Delta\pi}{\pi}\right)^2 + \left(2\frac{\Delta P}{P}\right)^2} \quad (1)$$

(Scardia, 1984) where a is the semi-major axis, Δa its error, π the measured trigonometrical parallax, $\Delta\pi$ its error, P the period and ΔP its error. The figures show the apparent orbit obtained by us and the observations used for the calculation of the orbital elements. The orientation of the orbit is in conformity with the convention accepted by the observers of visual binary stars.

2 WDS 00134 +2659 - STT 2 - ADS 161

The previous orbits of Heintz (1979) and Scardia (1980) no longer represent the observations of recent years, carried out mostly with the speckle interferometry. The real period is probably very long but for the moment it is still inaccurate (fig. 1).

node	=	8.1	+/-	5.7	(2000)
omega	=	95.6	"	9.2	
i	=	132.5	"	3.5	A = -0.00127
e	=	0.832	"	0.086	B = -0.64390
T	=	1968.680	"	0.58	F = -0.94224
P	=	932.22	"	698.0	G = -0.07128
n	=	0.38618	"	0.29	
a	=	0.947	"	0.053	

The parallax measured by the satellite Hipparcos is $0''.00808 \pm 0''.00115$, to which corresponds a sum of the masses of the system of $1.9 M_{\odot}$, slightly underestimated for a double star of a spectral type F8V (C.D.S. reports

G0III), while the semi-major axis is 117.2 A.U.. The dynamical parallax is $0''.0053$, considerably different from the measured one.

Ephemerides

1	2	3	1	2	3
2001.0	0.394	169.2	2006.0	0.425	165.3
2002.0	0.400	168.4	2007.0	0.431	164.6
2003.0	0.407	167.6	2008.0	0.437	163.9
2004.0	0.413	166.8	2009.0	0.443	163.2
2005.0	0.419	166.0	2010.0	0.448	162.6

O-C

1	2	3	4	5	6	7
1978.750	0.200	-0.003	105.3	2.1	4	HEI
1980.610	0.240	0.017	197.3	-0.6	3	HEI
1981.897	0.280	0.043	201.8	7.1	1	WOR
1984.760	0.240	-0.026	189.6	0.8	3	HEI
1986.897	0.286	0.000	184.5	-0.7	1	MCA
1986.910	0.280	-0.006	185.4	0.3	2	LIN
1987.970	0.310	0.015	187.9	4.4	3	GII
1988.359	0.300	0.001	185.0	2.1	4	WOR
1988.807	0.300	-0.003	175.0	-7.3	1	ISO
1988.827	0.250	-0.053	185.6	3.3	3	GII
1989.000	0.270	-0.034	187.4	5.4	2	LBU
1989.616	0.312	0.002	181.3	0.1	1	FU
1989.947	0.340	0.028	186.1	5.4	2	GII
1991.250	0.321	-0.002	178.0	-1.1	1	HIP
1995.607	0.344	-0.012	174.4	0.2	1	HRT
1995.768	0.347	-0.011	173.9	-0.1	1	HRT
1995.919	0.347	-0.012	173.1	-0.7	1	HRT
1998.663	0.364	-0.015	171.0	-0.1	1	PIC

3 WDS 00167 +3629 - STT 4 - ADS 221

Scardia's orbit (1982) no longer represents recent observations. The residuals in the position angle are by now systematically negative and quite consistent. Our observation, carried out at Pic du Midi in 1998 with the B.

Lyot telescope, is the first speckle observation of this double star.

node	=	150.7	+/-	15.5	(2000)
omega	=	134.8	"	15.3	
i	=	165.0	"	3.5	A = 0.33788
e	=	0.5558	"	0.0037	B = 0.08995
T	=	1907.819	"	0.10	F = 0.10164
P	=	108.806	"	0.61	G = -0.33461
n	=	3.30865	"	0.018	
a	=	0.356	"	0.016	

Since its discovery, the companion has already completed about 1.5 revolutions; thus the dynamical elements of the orbit are by now well defined and will certainly change very little in the future, while the geometrical elements, in particular node and omega, still show great uncertainty (fig. 2). The Hipparcos parallax is $0''.01115 \pm 0''.00130$, to which corresponds a semi-major axis of 31.9 A.U. and a sum of the masses of the system of $2.75 M_{\odot}$, with an uncertainty of 38%, overestimated for a binary star of a spectral type G0. The dynamical parallax is $0''.0108$, agreeing well with the measured parallax.

Ephemerides

1	2	3	1	2	3
2001.0	0.332	134.5	2006.0	0.265	115.4
2002.0	0.319	131.3	2007.0	0.251	110.4
2003.0	0.306	127.9	2008.0	0.237	104.7
2004.0	0.293	124.1	2009.0	0.222	98.3
2005.0	0.279	120.0	2010.0	0.208	91.0

O-C

1	2	3	4	5	6	7
1978.780	0.490	-0.023	175.7	0.3	2	ZUL
1978.942	0.500	-0.012	179.1	3.9	2	HLN
1980.670	0.520	0.016	175.5	2.6	3	HEI
1980.695	0.570	0.066	172.6	-0.3	2	ZUL

1980.829	0.970	0.467	172.4	-0.3	1	POP
1982.909	0.450	-0.042	173.4	3.5	3	WOR
1983.020	0.460	-0.032	169.0	-0.8	4	SCA
1987.970	0.380	-0.080	160.3	-2.1	3	GII
1988.730	0.490	0.036	163.5	2.3	1	DOC
1988.730	0.550	0.096	162.1	0.9	1	ELI
1988.773	0.400	-0.054	161.3	0.2	2	GII
1988.789	0.400	-0.054	163.9	2.8	4	WOR
1989.625	0.520	0.073	158.3	-1.4	1	DOC
1989.625	0.510	0.063	157.6	-2.1	1	LIN
1991.250	0.420	-0.014	156.0	-0.9	1	HIP
1996.870	0.360	-0.020	151.4	5.9	3	HEI
1997.840	0.330	-0.039	138.7	-4.4	3	ALZ
1998.679	0.342	-0.018	138.6	-2.4	1	PIC
1999.938	0.330	-0.015	134.8	-2.8	1	WSI

4 WDS 00206 +1219 - BU 1015 - ADS 281

Since its discovery the companion has almost completed one revolution around the principal star. The observations are quite numerous, but very scattered especially before the perihelion passage. The previous orbits of Baize (1974) and Scardia (1980), although still acceptable, show a marked systematic nature in the speckle observations of recent years. Thus we have recalculated the orbital elements obtaining:

node	=	107.9	+/-	4.4	(2000)
omega	=	195.4	"	4.6	
i	=	28.7	"	2.9	A = 0.16420
e	=	0.5282	"	0.0088	B = -0.26813
T	=	1961.786	"	0.14	F = 0.22922
P	=	126.951	"	2.73	G = 0.16250
n	=	2.83573	"	0.061	
a	=	0.317	"	0.026	

Also in this case the dynamical elements seem sufficiently well defined, while the geometrical ones show greater uncertainty (fig.3). The Hipparcos parallax is $0''.00883 \pm 0''.00207$. The sum of the masses of the system, corresponding to such a measurement, is $2.87 M_{\odot}$, with an uncertainty of 75%, slightly in excess for a binary of spectral type F5, while the semi-major axis is 35.9 A.U.. The great uncertainty concerning the sum of the masses of this system is largely due to the consistent error in the measured parallax. The dynamical parallax is $0''.0085$, agreeing well with the observed parallax.

Ephemerides

1	2	3	1	2	3
2001.0	0.430	97.7	2006.0	0.451	103.1
2002.0	0.434	98.8	2007.0	0.455	104.2
2003.0	0.439	99.9	2008.0	0.458	105.2
2004.0	0.443	101.0	2009.0	0.461	106.2
2005.0	0.447	102.1	2010.0	0.464	107.2

O-C

1	2	3	4	5	6	7
1978.790	0.220	-0.040	56.5	-1.3	3	HEI
1978.905	0.220	-0.041	61.4	3.2	3	WOR
1978.948	0.220	-0.041	58.5	0.2	2	HLN
1979.598	0.240	-0.028	62.6	2.3	3	WAK
1981.882	0.260	-0.030	74.0	7.5	2	WOR
1982.830	0.290	-0.010	71.7	2.9	2	HEI
1982.900	0.260	-0.040	66.5	-2.5	4	MSS
1983.830	0.330	0.021	67.2	-3.9	3	COU
1985.790	0.260	-0.066	79.6	4.3	3	HEI
1985.860	0.320	-0.007	69.0	-6.4	3	LBU
1986.690	0.330	-0.004	76.5	-0.5	2	HEI
1986.829	0.300	-0.035	73.0	-4.3	4	SCA
1987.754	0.340	-0.003	78.5	-0.5	1	MCA
1988.658	0.355	0.004	80.6	0.0	1	MCA
1988.732	0.340	-0.011	84.4	3.7	1	DOC
1988.732	0.380	0.029	85.5	4.8	1	ELI
1988.760	0.310	-0.041	80.8	0.1	2	HEI
1988.773	0.320	-0.031	82.2	1.4	2	GII
1988.903	0.330	-0.022	83.8	2.0	4	WOR
1989.619	0.430	0.072	80.7	-1.5	1	DOC
1989.619	0.410	0.052	79.2	-3.0	1	LIN
1989.910	0.320	-0.040	81.3	-1.4	3	LBU
1990.855	0.360	-0.007	82.4	-1.8	2	PRI
1991.250	0.371	0.001	84.0	-0.8	1	HIP
1995.607	0.399	-0.001	91.1	0.1	1	HRT
1995.918	0.406	0.004	90.5	-0.9	1	HRT
1996.651	0.410	0.004	91.7	-0.7	1	WSI

1998.679	0.423	0.005	94.7	-0.2	1	PIC
1999.835	0.440	0.016	98.7	2.4	2	WSI

5 WDS 00214 +6700 - STT 6 - ADS 293

The orbits of Van Biesbroeck (1954) and Muller (1954) are by now obsolete and have no longer represented observations for over 30 years. Thus we have recalculated the orbital elements of STT 6 obtaining:

node	=	151.0	(2000)
omega	=	184.0	
i	=	102.0	A = 0.43273
e	=	0.835	B = -0.24816
T	=	1923.0	F = -0.08078
P	=	400.0	G = -0.07379
n	=	0.900	
a	=	0.500	

As Muller has already emphasized the orbit is very eccentric and very inclined. Our geometrical elements do not differ much from those found, in their time, by Van Biesbroeck and Muller. Our orbit is however more eccentric and a double period (fig. 4). The parallax measured by Hipparcos is $0''.00491 \pm 0''.00126$; the corresponding sum of the masses is $6.6 M_{\odot}$, overestimated for a binary system of a spectral type B8.5V (C.D.S. gives A0). The semi-major axis is 101.8 A.U.. The dynamical parallax is $0''.0054$, in reasonable agreement with the measured one.

Ephemerides

1	2	3	1	2	3
2001.0	0.332	134.5	2006.0	0.265	115.4
2002.0	0.319	131.3	2007.0	0.251	110.4
2003.0	0.306	127.9	2008.0	0.237	104.7
2004.0	0.293	124.1	2009.0	0.222	98.3
2005.0	0.279	120.0	2010.0	0.208	91.0

O-C

1	2	3	4	5	6	7
1979.790	0.460	-0.051	157.7	1.2	3	HEI
1980.167	0.470	-0.044	158.7	2.2	3	WOR
1980.892	0.480	-0.038	151.3	-5.1	1	ZUL
1982.680	0.490	-0.040	158.6	2.4	3	HEI
1984.810	0.440	-0.104	155.8	-0.3	3	HEI
1987.760	0.561	-0.002	154.8	-1.0	1	MCA
1987.760	0.670	0.107	158.1	2.3	4	MLR
1988.655	0.567	-0.001	155.2	-0.5	1	MCA
1988.732	0.750	0.181	156.1	0.4	1	DOC
1988.732	0.760	0.191	158.0	2.3	1	ELI
1988.790	0.540	-0.029	157.2	1.5	2	HEI
1990.770	0.440	-0.141	155.7	0.1	3	HEI
1990.832	0.570	-0.011	158.1	2.5	3	PRI
1991.250	0.580	-0.004	155.0	-0.5	1	HIP
1994.940	0.520	-0.085	151.6	-3.7	2	HEI
1996.820	0.670	0.055	158.4	3.3	1	ALZ
1997.820	0.580	-0.041	154.8	-0.3	2	ALZ
1998.665	0.618	-0.007	154.6	-0.4	1	PIC
1999.809	0.590	-0.042	156.6	1.6	1	WSI

6 WDS 00487 +1841 - BU 495 - ADS 673

The orbits of Worley (1973), Heintz (1979) and Starikova (1983) have not represented observations for a long time. Couteau's orbit (1989), calculated only on the basis of visual observations, has a period which is too long and not completely satisfactory. For these reasons we recalculated the orbital elements of BU 495 obtaining:

node	=	31.3	+/-	5.6	(2000)
omega	=	338.1	"	12.4	
i	=	107.4	"	4.6	A = 0.42828
e	=	0.500	"	0.010	B = 0.33690
T	=	1979.856	"	0.27	F = 0.26984
P	=	143.628	"	4.0	G = -0.02464
n	=	2.83573	"	0.061	
a	=	0.317	"	0.026	

The parallax measured by Hipparcos is $0''.01628 \pm 0''.00121$; the sum of the masses of the system, corresponding to such a value, is $2.14 M_{\odot}$, with an

uncertainty of 28%, agreeing well with the values foreseen for a system of spectral type G0. The semi-major axis is 35.3 A.U.. The dynamical parallax is $0''.0149$, in reasonable agreement with the measured one (fig. 5).

Ephemerides

1	2	3	1	2	3
2001.0	0.159	300.4	2006.0	0.212	266.9
2002.0	0.165	292.2	2007.0	0.227	262.4
2003.0	0.173	284.6	2008.0	0.243	258.5
2004.0	0.184	277.9	2009.0	0.260	255.1
2005.0	0.197	272.0	2010.0	0.277	252.1

O-C

1	2	3	4	5	6	7
1978.600	0.230	-0.018	42.7	0.5	3	WOR
1978.860	0.220	-0.032	43.5	2.2	3	HEI
1979.609	0.260	-0.005	36.6	-2.3	3	WAK
1979.896	0.270	0.001	34.2	-3.8	3	WOR
1980.800	0.280	-0.001	33.8	-1.7	3	HEI
1980.850	0.420	0.138	32.2	-3.1	3	MRL
1981.837	0.280	-0.011	34.3	1.6	3	WOR
1982.770	0.300	0.004	33.2	2.8	2	COU
1982.939	0.320	0.023	27.4	-2.6	2	MSS
1983.680	0.340	0.041	29.2	1.0	3	HEI
1983.990	0.300	0.001	28.8	1.3	2	LBU
1984.053	0.270	-0.029	29.7	2.4	4	SCA
1984.910	0.310	0.013	24.4	-0.9	2	LBU
1985.800	0.300	0.006	21.7	-1.4	3	HEI
1986.883	0.290	0.004	22.5	2.2	4	WOR
1986.910	0.340	0.054	26.1	5.9	1	LIN
1987.780	0.280	0.002	20.9	3.0	3	HEI
1988.724	0.320	0.052	11.4	-3.8	1	LIN
1988.730	0.340	0.072	7.5	-7.7	1	COU
1988.732	0.360	0.092	11.0	-4.2	1	DOC
1988.773	0.190	-0.078	14.5	-0.5	2	GII
1988.810	0.290	0.023	17.0	2.1	1	ISO
1988.840	0.270	0.003	15.9	1.1	4	WOR
1988.940	0.310	0.044	14.9	0.4	2	COU

1989.636	0.320	0.063	8.9	-3.4	2	DOC
1989.636	0.320	0.063	10.8	-1.5	2	LIN
1989.690	0.240	-0.017	16.6	4.4	2	HEI
1989.720	0.297	0.041	9.9	-2.2	1	COU
1989.840	0.240	-0.015	16.1	4.4	2	GII
1989.938	0.250	-0.003	10.5	-0.9	3	WOR
1990.790	0.230	-0.012	10.1	1.7	3	HEI
1990.835	0.230	-0.012	15.1	6.9	2	PRI
1991.250	0.235	-0.001	3.0	-3.7	1	HIP
1991.731	-	-	3.4	-1.3	1	LIN
1991.731	0.202	-0.028	4.4	-0.3	1	COU
1991.854	0.200	-0.028	4.0	-0.2	2	COU
1992.692	0.220	0.003	359.0	-1.6	1	MIU
1992.714	0.190	-0.026	0.3	-0.2	1	COU
1993.940	0.220	0.020	1.1	6.7	3	HEI
1995.910	0.190	0.013	351.7	9.4	2	HEI
1995.921	0.175	-0.002	340.3	-2.0	1	HRT
1998.663	0.153	-0.005	321.7	0.9	1	PIC

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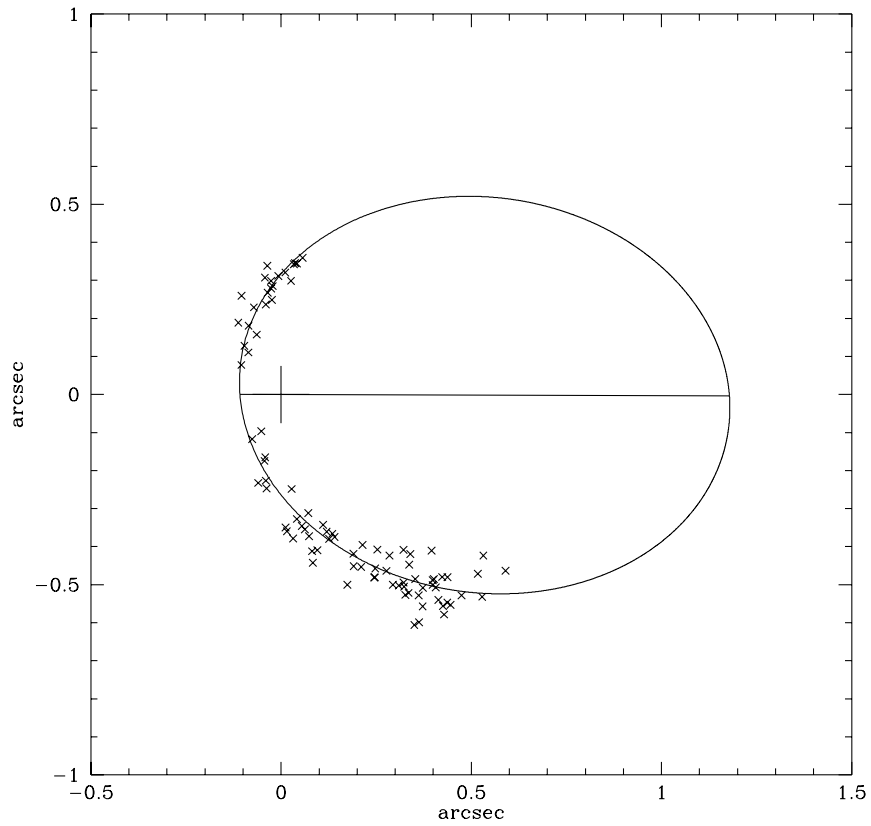


Figure 1: STT 2 - ADS 161

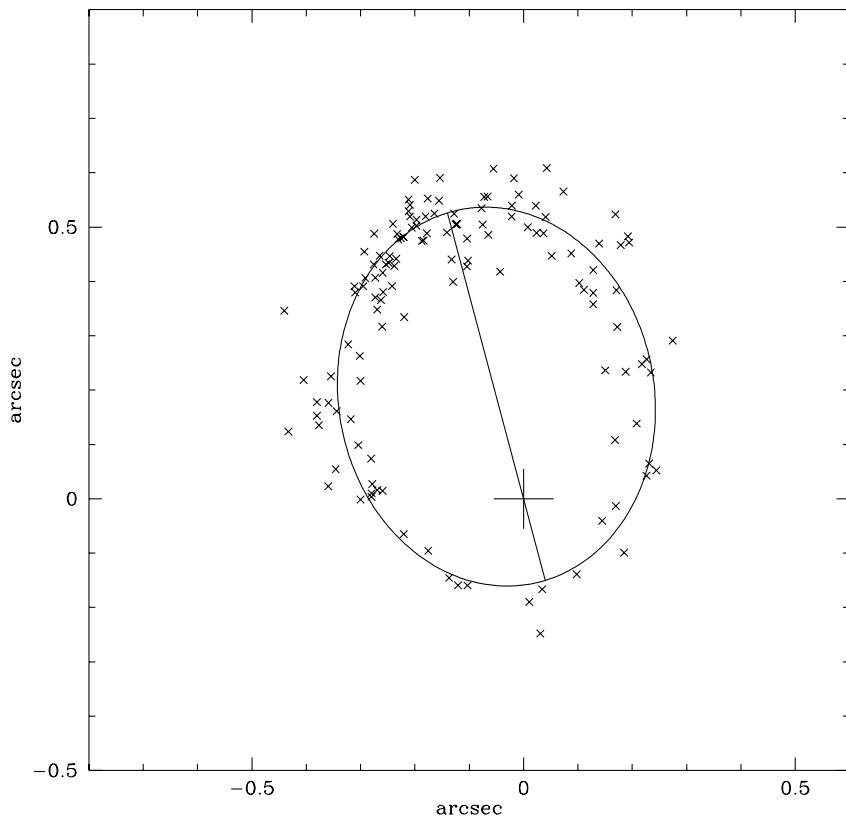


Figure 2: STT 4 - ADS 221

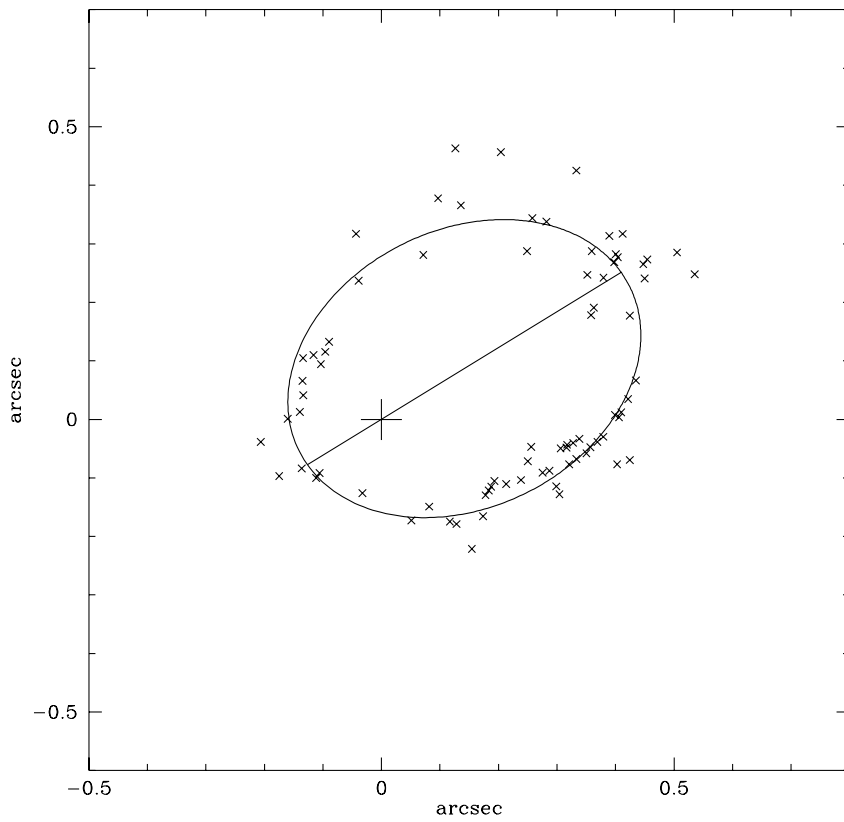


Figure 3: BU 1015 - ADS 281

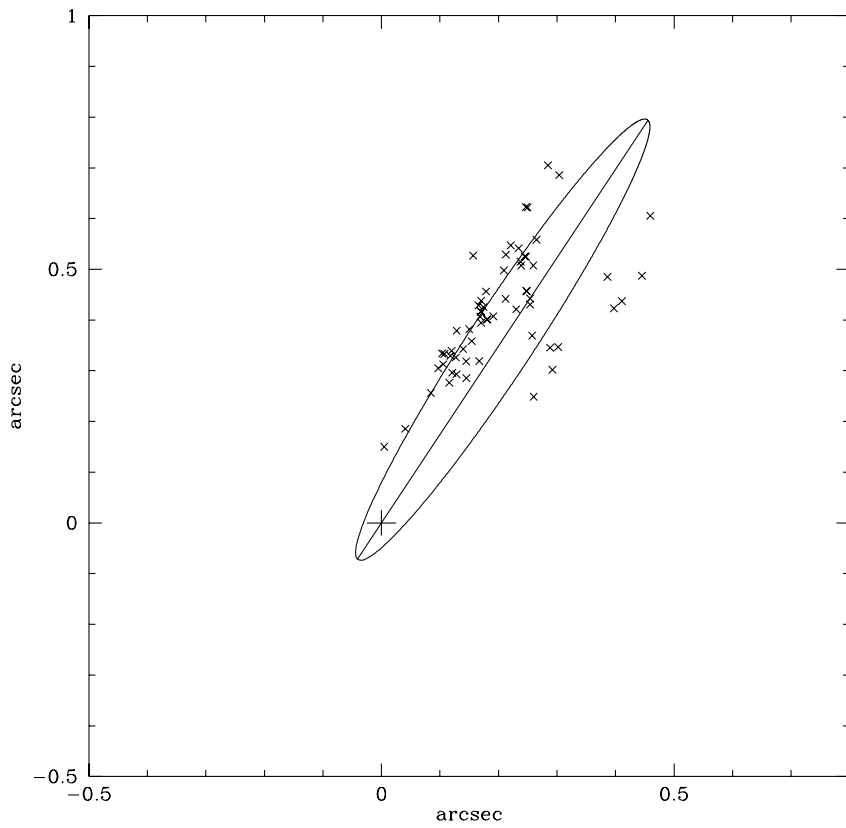


Figure 4: STT 6 - ADS 293

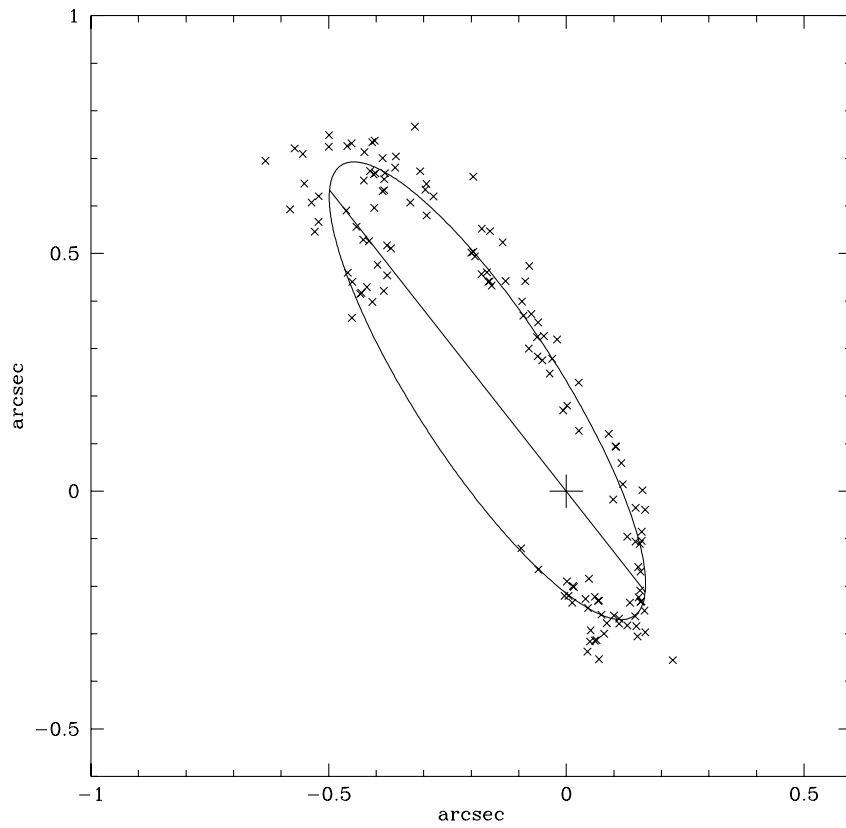


Figure 5: BU 495 - ADS 673