The Astronomical Journal, 138:664–679, 2009 August doi:10.1088/0004-6256/138/2/664

A CATALOG OF VISUAL DOUBLE AND MULTIPLE STARS WITH ECLIPSING COMPONENTS

P. Zasche[1,2], M. Wolf[1], W. I. Hartkopf[3], P. Svoboda[4], R. Uhlař[5], A. Liakos[6], and K. Gazeas[6]
[1] Astronomical Institute, Faculty of Mathematics and Physics, Charles University of Prague, CZ-180 00 Praha 8, V Holešovičkách 2, Czech Republic
[2] Instituto de Astronomía, Universidad Nacional Autónoma de México, A.P. 70-264, México, DF 04510, Mexico
[3] U.S. Naval Observatory, 3450 Massachusetts Avenue, Washington, DC 20392, USA
[4] Private Observatory, CZ-614 00 Brno, Výpustky 5, Czech Republic
[5] Private Observatory, Pohoří 71, CZ-25401, Jílové u Prahy, Czech Republic
[6] Department of Astrophysics, Astronomy and Mechanics, Faculty of Physics, University of Athens, GR-15784 Zografos, Athens, Greece
Received 2008 September 9; accepted 2009 May 17; published 2009 July 15

ABSTRACT

A new catalog of visual double systems containing eclipsing binaries as one component is presented. The main purpose of this catalog is to compile a complete list of all known multiples of this variety, both for current analysis and to highlight those in need of additional observations. All available photometric and astrometric data were analyzed, resulting in new orbits for eight systems and new times of minimum light for a number of the eclipsing binaries. Some of the systems in the catalog have acceptable solutions for their visual orbits, although in most cases their orbital periods are too long for simultaneous analysis. Also included, however, are a number of systems which currently lack an orbital solution but which may be suitable for simultaneous analysis in the future.

Key words: binaries: close – binaries: eclipsing – binaries: visual – catalogs – stars: fundamental parameters

1. INTRODUCTION

Binary stars are essential objects for determining precise physical properties of stars, especially masses, through a combined analysis of photometric, astrometric, and spectroscopic data. If the stars comprise an eclipsing binary (hereafter EB), radii, distance and, in favorable cases, effective temperatures also may be determined from a combined analysis of light and radial velocity (hereafter RV) curves. Moreover, masses and distances for visual binaries may be determined from a combined analysis of astrometric and RV measurements. Additional components often may be revealed through these analyses; one especially productive source is the study of the long-time behavior of the period of an EB. As might be expected, the longer the time span of conjunction time measurements, or times of minimum light, the greater the chance of detecting a long-period orbit due to an additional member of the system under study.

There are currently more than 2000 systems with known visual orbits (see the USNO Sixth Orbit Catalog[7]). Among these systems, at least 34 have been found to include an EB as one of their components. About 100 other EBs were found to be members of visual pairs or multiples, the orbit of which has not been computed yet. Collecting and investigating this fraction of the visual doubles is the purpose of this catalog.

The systems presented here were found through searches in the "Washington Double Star Catalog"[8] (WDS; Mason et al. 2001), identifying systems with EBs amongst their components. This catalog differs slightly from the one published by Chambliss (1992), where all of the multiple-star systems containing EBs known by the author were collected. Chambliss mentioned that 80 EBs were known to be components of multiple-star systems and presented 37 of them in detail. The present catalog is restricted to reasonably well observed visual binaries which contain EBs as a component (the qualifier "reasonably well observed" being described below). The number of known EBs amongst visual pairs is growing rapidly; we felt this justified collecting them into a separate catalog.

The $O - C$ diagrams constructed against the EBs linear ephemeris frequently display variations in their orbital periods (see, for example, a catalog of $O - C$ diagrams of such systems by Kreiner et al. 2001). For a discussion of the details and limitations of $O - C$ diagram analysis, see Sterken (2005). A periodic oscillation in an $O - C$ diagram may be explained as a light–time effect (hereafter LITE) caused by a distant companion orbiting around a common center of mass with the EB; see Irwin (1959), or Mayer (1990) for details. In favorable cases, this component may be identified as a distant member of the system, directly detectable astrometrically as a visual or interferometric companion. Despite the large number of EBs in our Galaxy (estimated at about 10^8, according to Kopal 1978 and Cooper & Hughes 1994), there are still only a few dozen systems known where the EBs are members of spatially resolvable pairs. A few of the most well known systems are V505 Sgr (see Mayer 1997), V819 Her (Muterspaugh et al. 2006), and VW Cep (Zasche & Wolf 2007, hereafter ZW, and Zasche 2008). Decades' worth of data are available for all these systems, making possible an analysis of period variations and also a solution of the visual orbits (fortunately the visual orbital periods in these examples are rather short). Despite this fact, until now the results from different techniques have been in contradiction with each other. A typical example of such a discrepancy is the system V505 Sgr, where Chochol et al. (2006) presented the period of the third body about 44.6 or 38.6 yr from period analysis, while Cvetković et al. (2008) derived the third-body period about 60.1 yr from the visual orbit. To the best of our knowledge, the system VW Cep is presently the most suitable for a combined analysis of variation of minima timings; the combination of available photometric and interferometric data can even be used to determine the distance to the system. The distance derived by this method is more precise than any previously derived value; see ZW for details. Such a combined approach is potentially very powerful, especially anticipating the high-quality data expected to come from planned astrometric and photometric space missions. The most serious weakness in this combined method seems to be due to the period of the distant component, which in most cases is

[7] http://ad.usno.navy.mil/wds/orb6.html
[8] http://ad.usno.navy.mil/wds/

extremely long (typically decades to centuries or longer). As a result, the data frequently cover only a small arc of the orbit, and this very incomplete coverage obviously degrades the precision of the results. For a detailed description of the method, including algorithms, limitations, and results, see ZW and Zasche (2008).

2. THE CATALOG

The selection criteria used during the compilation of this catalog were (1) the existence of more than 10 astrometric measurements, (2) a variation of position angles of the astrometric observations of more than 10°, and (3) the presence of an EB as one of its components.

A total of 44 systems which met these criteria were found; these are presented in Table 1 and commented upon in more detail in the following subsections. In a few cases, it was rather difficult to identify which component in the wide system comprised the EB. Other interesting systems, which contain an EB as one component but which do not satisfy the other selection criteria, were also included in Section 2.45. In Section 2.46, we discuss those systems which were difficult to classify. These include, for example, systems where the eclipsing nature is questionable, etc. In many systems, the only information about their distance is that by *Hipparcos* (Perryman & ESA 1997; see Column 9 in Table 1). However, the value of *Hipparcos* distance could be affected by a relatively large error due to the fact that the star is not a single target, but a binary.

The entire catalog is also available online.[9] This web site will be updated as new observations become available and as new systems meeting our selection criteria are discovered.

Notes on individual systems follow.

2.1. *V640 Cas*

V640 Cas (HD 123, HR 5, HIP 518, STF 3062AB) is listed as an EB. Only two photometric decreases were observed (Brettman et al. 1983), and no photometric analysis has been published. This system was observed over 16 nights from 2007 July to 2008 November in *B*, *V*, and *R* filters, but no minima were observed. From our new photometric observations, we can conclude that there is no variability above a level of 0.02 mag with periods in interval 1.02–1.1 days. Griffin (1999) discussed the plausibility of the photometric variations observed by Brettman et al. (1983), and also noted that no such variability is observable from the *Hipparcos* satellite (see Perryman & ESA 1997), concluding that the system is not variable at all. Therefore, the classification of V640 Cas as an eclipsing system is questionable. However, the system could be more complicated, and due to the presence of the third body the eclipses could turn on and off, similarly to V907 Sco (Lacy et al. 1999), SS Lac (Torres 2001), or V699 Cyg (Lippky & Marx 1994). The visual orbit is well observed, with some 572 data points obtained over 170 yr. Söderhjelm (1999) computed the most recently published orbital parameters, finding a period of about 107 yr and an angular semimajor axis of about 1.″4.

2.2. *V348 And*

V348 And (HD 1082, HIP 1233, A 1256AB) is an Algol-type EB. Its situation is similar to that of V640 Cas, as neither times of minima nor a photometric analysis have been found in the literature. The single available time of minimum was based on *Hipparcos* measurements, but is only poorly covered. Our new observations of the system, obtained during 19 nights, were summarized in Zasche & Svoboda (2008). The visual orbit is defined by data obtained over 93 yr and covering the range from 4° to 223° in position angle. Two rather different orbital solutions have been published: Olević (2002) derived values $p_3 = 138$ yr and $a = 150$ mas, while Seymour et al. (2002) found a period of about 330 yr and a semimajor axis 290 mas. Both solutions appear to fit the limited arc of observations equally well. The mass sums derived from these two different fits are not able to decide which solution is the more plausible, because the light-curve analysis has not yet been performed and the individual spectral types are not known. If we assume the spectral types of each of the components to be the same as the spectrum of the system as a whole (B9IV), the resulting mass sum should be much higher than predicted by either orbital solution—2.8 $M_\odot$ for Olević (2002) and 3.4 $M_\odot$ for Seymour et al. (2002).

2.3. *V355 And*

V355 And (HD 4134, HIP 3454, STF 52AB) is also an Algol-type EB, with a spectral classification of the whole system as F6V. The only published complete light curve is that of Tikkanen (2002), who also determined nine times of minima (unpublished, see the author's Web site).[10] Observations of the visual pair have been obtained during the past 170 yr, but cover a range in position angles of only about 20°. No visual orbit has yet been computed, but the orbital coverage to date suggests a period of order 3000 yr.

2.4. *ζ Phe*

ζ Phe (HD 6882, HR 338, HIP 5348) is an eccentric EB of Algol type, its spectral types were determined as B6V + B8V (according to Andersen 1983). It is a visual triple and double-lined spectroscopic binary. A detailed analysis using a combined solution of astrometry and times of minima was presented by ZW. This analysis yields a period for the visual orbit of about 221 yr. The mass of the predicted third body was derived to be $M_3 = 1.73\ M_\odot$, which is in excellent agreement with earlier photometric analyses by Clausen et al. (1976) and Andersen (1983). In addition to the long-term variation seen in the $O - C$ diagram caused by the LITE, apsidal motion is also detectable, with a period of ∼60 yr.

2.5. *BB Scl*

BB Scl (HD 9770, HIP 7372, GJ 60) is an EB and also the B component of a visual triple; we therefore deal with a quadruple system. Orbits of both the visual pairs have been derived. The wider AB–C pair (1.″42) revolves on its 112 year orbit (Newburg 1969), while the closer AB pair (0.″17) with period of 4.6 years was derived by Mason & Hartkopf (1999). The most detailed analysis is that by Watson et al. (2001), who analyzed this chromospherically active EB using spectroscopic and photometric techniques.

2.6. *V773 Cas*

V773 Cas (HD 10543, HR 499, HIP 8115, BU 870AB) is an Algol-type EB. One time of minimum light was derived from the *Hipparcos* observations, and three new minima were observed by the authors (see Table 2). The astrometry covers about 80° in position angle, from observations obtained during the last

9 http://sirrah.troja.mff.cuni.cz/∼zasche/Catalog.html

10 http://www.student.oulu.fi/∼ktikkane/AST/V355AND.html

Table 1
The Catalog

HD (1)	Star Designation (2)	Spectral Types 1 (3)	2 (4)	3 (5)	V (mag) (6)	P (days) (7)	p_3 (yr) (8)	π (mas) (9)	Comp (10)	Min Pri (11)	Min Sec (12)	M Astr. (13)	Depth MinP (14)	Depth MinS (15)	Orbit (16)	References (17)
123	V640 Cas	G3V	M2-3	G9V	5.93	1.026	106.7	49.30 ± 1.05	3	2	0	572	0.066 V		y	1,2,3,4,5
1082	V348 And		B9IV		6.76	5.539	137.9/330	4.05 ± 0.76	3	1	0	61	0.150 Hp		y	1,2,6,7,8
4134	V355 And		F6V		7.69	4.7184	...	8.22 ± 1.74	3	7	2	51	0.310 V	0.21 V	n	1,2,9
6882	ζ Phe	B6V	B8V	A7V	3.97	1.66978	220.9	11.66 ± 0.77	3	25	17	11	0.510 V	0.31 V	y	1,2,11,12,13
9770	BB Scl	K3-4V	K4-5V	K1-2V+M2V	7.14	0.47653	4.56+111.8	42.29 ± 1.47	4	2	0	88+44	0.220 Hp	0.22 Hp	y	1,2,14,15,16,17
10543	V773 Cas	A3V		F0-5	6.21	1.29367	304.04	12.63 ± 0.77	3	4	0	79	0.090 Hp		y	1,2,18,19,20
12180	AA Cet	F2V	F2V	F5	7.22	0.53617	...	4.63 ± 2.36	4	160	80	33	0.500 p	0.50 p	n	1,2,21,76
14817	V559 Cas	B9V	B9V	B9V	7.02	1.5806	836	4.43 ± 1.51	3	9	6	101	0.220 V	0.20 V	y	1,2,22,21
19356	β Per	B8V	G8IV	A7m	2.12	2.86731	1.862	35.14 ± 0.90	3	≈1400	9	37	1.270 V	0.05 V	y	1,2,23,24
25833	AG Per	B3Vn	B3	B	6.69	2.02873	...	3.89 ± 1.31	3	51	52	39	0.310 V	0.31 V	n	1,2,25
29911	V592 Per	F2IV		G0V	8.37	0.71572	115.32	5.12 ± 1.55	3	11	15	19	0.350 Hp	0.27 Hp	Y	1,2,26,27
35411	η Ori	B1V	B3V	B2V	3.38	7.9904	9.44	3.62 ± 0.88	4	1	0	19	0.290 V	0.26 V	y	1,2,21,28
36486	δ Ori A	09.5II	B0.5III	B	2.23	5.73248	704.8	3.56 ± 0.83	3	6	3	38	0.120 V	0.06 V	Y	1,2,29
38735	V1031 Ori	A8III-IV	A5IV-V	A6IV-V	6.06	3.40556	92.66	4.99 ± 1.04	3	8	5	20	0.410 V	0.30 V	Y	1,2,21,30
57061	τ CMa	O9II		O	4.39	1.28212	...	1.02 ± 0.71	4	2	0	32	0.050 Hp	0.04 Hp	n	1,2,31
60179	YY Gem	dM1e	dM1e	A1V	9.07	0.81428	...	63.27 ± 1.23	6	97	85	140	0.690 V	0.68 V	n	1,2,32
66094	V635 Mon	G9III-IV	A2.5	F5	7.31	1.80781	257	3.06 ± 1.04	3	113	2	24	0.500 p		y	1,2,33,34,35
71487	NO Pup	B9V	A7V	A3V+A3V	6.7	1.25688	...	5.32 ± 0.87	5	10	5	29	0.450 V	0.13 V	n	1,2,21,36
71581	VV Pyx	A1V		A5-A7	6.58	4.59618	...	4.51 ± 1.00	3	6	5	11	0.520 V	0.50 V	n	1,2,37
71663	LO Hya	F0V	G0V	A5V+F5V	6.42	2.49963	54.70	11.73 ± 0.94	5	3	3	69	0.240 V	0.10 V	y	1,2,21,38
74956	δ Vel	A0V	A1V	F	1.95	45.150	142.00	40.90 ± 0.38	3	5	5	38	0.400 V		y	1,2,39,40
...	AC UMa	A2		G0	10.3	6.85469	1199.2		3	80	0	10	3.700 V		Y	1,41
82780	DI Lyn	F2V	F3V	G3V	6.76	1.68154	64.257	11.80 ± 2.50	5	3	2	12	0.080 V	0.05 V	y	1,2,42,43,44
91636	TX Leo	A2V		B	5.67	2.44507	...	7.05 ± 0.99	3	8	0	140	0.090 V	0.03 V	n	1,2,45,46
101205	V871 Cen		O7IIIn		6.49	2.0842	1715.8	−1.44 ± 1.42	5	1	0	17	0.080 V	0.08 V	Y	1,2,47
101379	GT Mus	A0V	A2V	K4III+dF/G	5.17	2.7546	90.7	5.81 ± 0.64	4	0	0	13	0.130 V		y	1,2,48,49
103483	DN UMa	A3V	A3V	A8-9	6.54	1.73043	136.538	4.07 ± 1.24	5	11	8	34	0.100 B	0.10 B	y	1,2,50,51
110317	VV Crv		F5IV		5.27	3.145	...	11.72 ± 1.90	5	1	0	156	0.150 Hp		n	1,2,52,53
114529	V831 Cen	B8V		B9V	4.58	0.64252	27.0	9.42 ± 1.52	5	1	0	40	0.170 V	0.15 V	y	1,2,54,55
119931	HT Vir	F8V	F8V	F	7.16	0.40764	260.7	15.39 ± 2.72	4	21	22	277	0.420 V	0.42 V	y	1,2,13,56,57
...	ET Boo		F8		9.09	0.64504	113.32	5.85 ± 1.40	4	18	13	20	0.300 Hp	0.20 Hp	y	1,2,58,59
133640	i Boo	K0V	K4V	G2V	4.76	0.26782	206	78.39 ± 1.03	3	358	241	753	0.600 V	0.49 V	y	1,2,5,60
148121	V1055 Sco		G3V		8.64	0.36367	...	11.45 ± 1.25	3	4	3	12	0.250 V	0.25 V	n	1,2,61
157482	V819 Her	F2V	F8V	G7III-IV	5.57	2.22964	5.530	15.53 ± 1.16	3	63	34	34	0.085 V	0.05 V	y	1,2,62,63
162724	V906 Sco	B9V	B9V	B9	5.96	2.78595	34.71	3.23 ± 0.83	3	6	1	14	0.270 V	0.25 V	Y	1,2,64
163151	V2388 Oph	F3V		F	6.26	0.80230	8.925	14.72 ± 0.81	3	21	10	35	0.280 Hp	0.23 Hp	y	1,2,65,66
163708	V1647 Sgr	A1V	A2V	F0-1V	6.8	3.28279	1219.7	8.70 ± 1.40	3	9	11	15	0.630 V	0.49 V	Y	1,2,67
165590	V772 Her	G1V	K6V	K7V+M0V	7.10	0.87950	20.08	26.51 ± 1.35	5	29	0	256	0.100 V		y	1,2,68,69
184242	V2083 Cyg		A3		6.88	1.86749	372	3.98 ± 0.79	3	5	2	58	0.240 Hp	0.24 Hp	y	1,2,7,9

Table 1
(Continued)

HD	Star	Spectral Types			V	P	p_3	π	Comp	Min	Min	M	Depth	Depth	Orbit	References
(1)	Designation	1	2	3	(mag)	(days)	(yr)	(mas)		Pri	Sec	Astr.	MinP	MinS		
	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
185936	QS Aql	B5V	F3	B4	5.99	2.51331	61.72	1.98 ± 0.82	3	21	3	76	0.130 V	0.04 V	y	1,2,70,71
187949	V505 Sgr	A2V	G5IV	F7-8V	6.49	1.18287	60.14	8.58 ± 1.38	3	316	6	17	1.050 V	0.17 V	y	1,2,72,73
195434	MR Del	K2	K6	K2	11.01	0.52169	1996.6	22.53 ± 5.13	3	16	11	37	0.310 V	0.17 V	Y	1,2,17
197433	VW Cep	K1	G5	K3	7.3	0.27832	29.79	36.16 ± 0.97	3	1093	821	17	0.450 V	0.33 V	y	1,2,13,74
201427	BR Ind		F8V		7.1	0.89277	167	20.47 ± 2.08	3	1	0	37	0.140 Hp		y	1,2,69

Notes. Columns 3–5 give the individual spectral types of primary, secondary, and tertiary components, V denotes the magnitude in V filter, P stands for the orbital period of the eclipsing pair, p_3 gives the period of the third body, π quotes the *Hipparcos* parallax, Column 10 gives the total number of known components in the system, Columns 11 and 12 stand for the number of times of primary and secondary minima observed (including our new ones), M denotes the number of astrometric observations, Columns 14 and 15 give the depths of primary and secondary minima. In Column 16 "y/n" indicates if there is (or not) an orbital solution for the system. The upper case "Y" denotes the orbital solution presented here for the first time. Column 17 lists the references for the particular system, respectively. The orbital periods p_3 are adopted from the published papers, or as determined in the present analysis., References: (1) Samus et al. 2004; (2) Perryman & ESA 1997; (3) Brettman et al. 1983; (4) Griffin 1999; (5) Söderhjelm 1999; (6) Olević 2002; (7) Seymour et al. 2002; (8) Abt 1981; (9) Abt 1985; (10) Tikkanen 2002; (11) Andersen 1983; (12) Clausen et al. 1976; (13) Zasche & Wolf 2007; (14) Newburg 1969; (15) Mason & Hartkopf 1999; (16) Watson et al. 2001; (17) Cutispoto et al. 1997; (18) Appenzeller 1967; (19) Schröder & Schmitt 2007; (20) Popović & Pavlović 1995; (21) Chambliss 1992; (22) Zaera 1985; (23) Pan et al. 1993; (24) Lestrade et al. 1993; (25) Gimenez & Clausen 1994; (26) Rucinski et al. 2007; (27) Grenier et al. 1999; (28) Balega et al. 1999; (29) Harvin et al. 2002; (30) Andersen et al. 1990; (31) van Leeuwen & van Genderen 1997; (32) Leung & Schneider 1978; (33) Docobo & Ling 2008; (34) Ginestet & Carquillat 2002; (35) Malkov et al. 2006; (36) Wolf et al. 2008; (37) Andersen et al. 1984; (38) Docobo & Ling 2007; (39) Otero et al. 2000; (40) Argyle et al. 2002; (41) Strohmeier 1959; (42) Wolf & Caffey 1998; (43) Tokovinin et al. 2006; (44) Tokovinin 1998; (45) Chamberlin & McNamara 1957; (46) Roberts et al. 2005; (47) Walborn 1973a; (48) Murdoch et al. 1995; (49) Parsons 2004; (50) Popper 1986; (51) Aristidi et al. 1999; (52) Massarotti et al. 2008; (53) Malaroda 1975; (54) Finsen 1964; (55) Edwards 1976; (56) Walker & Chambliss 1985; (57) Lu et al. 2001; (58) Seymour 2001; (59) Bartkevičius & Gudas 2002; (60) Docobo & Andrade 2006; (61) Houk 1982; (62) van Hamme et al. 1994; (63) Muterspaugh et al. 2006; (64) Alencar et al. 1997; (65) Yakut et al. 2004; (66) Hartkopf et al. 1996; (67) Andersen & Gimenez 1985; (68) Reglero et al. 1991; (69) Fekel et al. 1994; (70) Holmgren 1987; (71) Zasche 2008; (72) Tomkin 1992; (73) Cvetković et al. 2008; (74) Kaszas et al. 1998; (75) Houk 1978; (76) Duerbeck & Rucinski 2007.

Table 2
New Minima Timings of Selected Systems Based on CCD and Photoelectric Observations, the Kwee-van Woerden (1956) Method was Used

Star	HJD-2400000	Error	Type	Filter	Obs.
V773 Cas	54507.4103	0.0005	Pri	R	[1]
V773 Cas	54533.2864	0.0007	Pri	R	[1]
V773 Cas	54776.4933	0.0003	Pri	I	[4]
AA Cet	53687.4389	0.0002	Pri	R	[2]
V559 Cas	54433.3446	0.0004	Sec	BVR	[1]
V559 Cas	54505.2635	0.0004	Pri	R	[1]
V559 Cas	54535.2957	0.0007	Pri	R	[1]
V559 Cas	54738.4053	0.0009	Sec	BVRI	[4]
V559 Cas	54810.3245	0.0025	Pri	BVRI	[4]
V592 Per	54432.4787	0.0003	Sec	R	[1]
V592 Per	54491.5237	0.0003	Pri	R	[1]
V592 Per	54517.2911	0.0003	Pri	R	[1]
V592 Per	54523.3741	0.0005	Sec	R	[1]
V592 Per	54774.5904	0.0003	Sec	R	[4]
V592 Per	54798.5679	0.0003	Pri	R	[4]
V592 Per	54826.4795	0.0005	Pri	R	[4]
V1031 Ori	54831.3964	0.0003	Sec	R	[4]
V1031 Ori	54860.3377	0.0004	Pri	R	[4]
V635 Mon	54539.2564	0.0014	Pri	BV	[2]
V635 Mon	54857.4412	0.0019	Pri	R	[4]
AC UMa	54620.4612	0.0003	Pri	R	[3]
DI Lyn	54585.3703	0.0015	Sec	R	[1]
DI Lyn	54591.2478	0.0020	Pri	R	[1]
DI Lyn	54912.4254	0.0017	Pri	VRI	[4]
DI Lyn	54933.4489	0.0025	Sec	BVR	[1]
TX Leo	54595.4140	0.0021	Pri	R	[4]
DN UMa	52381.7956	0.0003	Sec	BV	[5]
DN UMa	54508.4873	0.0012	Sec	R	[1]
DN UMa	54521.4630	0.0009	Pri	R	[1]
DN UMa	54834.6816	0.0012	Pri	R	[1]
HT Vir	54539.4315	0.0003	Pri	VR	[2]
HT Vir	54539.6368	0.0005	Sec	VR	[2]
ET Boo	54524.4746	0.0002	Pri	VRI	[3]
i Boo	54499.4495	0.0003	Pri	R	[1]
i Boo	54499.5855	0.0001	Sec	R	[1]
i Boo	54499.7179	0.0001	Pri	R	[1]
V1055 Sco	53090.1272	0.0025	Pri	V	[6]
V1055 Sco	53090.3076	0.0031	Sec	V	[6]
V819 Her	54564.3794	0.0040	Pri	R	[1]
V819 Her	54585.5559	0.0020	Sec	R	[1]
V819 Her	54594.4766	0.0010	Sec	R	[4]
V819 Her	54623.4631	0.0010	Sec	BVR	[1]
V819 Her	54642.4133	0.0030	Pri	BVR	[4]
V819 Her	54738.2917	0.0021	Pri	R	[1]
V2388 Oph	54534.6075	0.0030	Sec	R	[2]
V2388 Oph	54583.5470	0.0003	Sec	R	[4]
V2388 Oph	54593.5738	0.0002	Pri	R	[4]
V2388 Oph	54614.4372	0.0006	Pri	R	[4]
V2388 Oph	54620.4524	0.0005	Sec	R	[4]
V2388 Oph	54675.4117	0.0004	Pri	R	[1]
V2388 Oph	54718.3351	0.0004	Sec	R	[1]
V772 Her	54540.5504	0.0021	Pri	R	[4]
V772 Her	54584.5230	0.0008	Pri	R	[4]
V772 Her	54628.5031	0.0009	Pri	R	[1]
V772 Her	54713.8093	0.0010	Pri	R	[1]
V2083 Cyg	54583.5507	0.0003	Pri	R	[1]
V2083 Cyg	54598.4903	0.0007	Pri	BVR	[1]
V2083 Cyg	54683.4603	0.0008	Sec	BVR	[1]
V2083 Cyg	54684.3951	0.0006	Pri	BVR	[1]
V2083 Cyg	54698.4014	0.0005	Sec	BVR	[1]
V2083 Cyg	54712.4065	0.0005	Pri	BVR	[1]
QS Aql	54309.4160	0.0030	Pri	R	[1]
QS Aql	54383.5446	0.0005	Sec	R	[1]
QS Aql	54696.4583	0.0020	Pri	R	[4]
QS Aql	54726.6177	0.0005	Pri	R	[1]

Table 2
(Continued)

Star	HJD-2400000	Error	Type	Filter	Obs.
QS Aql	54726.6177	0.0006	Pri	R	[1]
V505 Sgr	52837.4766	0.0030	Pri	BVRI	[2]
V505 Sgr	52843.3892	0.0029	Pri	VRI	[2]
V505 Sgr	53263.3029	0.0002	Pri	R	[2]
V505 Sgr	54267.5470	0.0002	Pri	VI	[2]
V505 Sgr	54270.5016	0.0040	Sec	I	[2]
V505 Sgr	54648.4260	0.0005	Pri	R	[4]
V505 Sgr	54655.5233	0.0003	Pri	R	[4]
V505 Sgr	54658.4817	0.0005	Sec	R	[4]
V505 Sgr	54706.3869	0.0002	Pri	R	[4]
MR Del	54278.4913	0.0005	Sec	R	[3]
MR Del	54676.5415	0.0010	Sec	R	[4]
MR Del	54682.5395	0.0010	Pri	BVR	[4]
MR Del	54706.5374	0.0003	Pri	R	[4]
VW Cep	54521.2597	0.0002	Sec	R	[1]
VW Cep	54522.3723	0.0003	Sec	R	[1]
VW Cep	54522.5128	0.0003	Pri	R	[1]
VW Cep	54536.2892	0.0003	Sec	R	[1]
VW Cep	54536.4282	0.0002	Pri	R	[1]
VW Cep	54536.5670	0.0002	Sec	R	[1]

Note. [Obs.]: [1] P. Svoboda, Brno; [2] Athens Observatory; [3] Ondřejov Observatory; [4] R.Uhlař, Jílové u Prahy; [5] San Pedro Mártir Observatory; [6] OMC *INTEGRAL* satellite.

120 years. The most recent preliminary visual orbit calculation by Popović & Pavlović (1995) derives a period of about 304 yr and a semimajor axis about 1″.

2.7. AA Cet

AA Cet (HD 12180, HIP 9258, ADS 1581 A) is a W UMa-type EB. There have been more than 200 times of minima obtained during the last 40 years, but no significant LITE variation has been detected. Astrometric observations of the visual pair have shown no significant change since its discovery by William Herschel in 1782; hence no orbital solution has been attempted. One new minimum of light was observed at Athens Observatory (see Table 2). Recently, Duerbeck & Rucinski (2007) discovered the visual component to be also a binary.

2.8. V559 Cas

V559 Cas (HD 14817, HIP 11318, STF 257AB) is an Algol-type eclipsing and spectroscopic binary. There have been only 14 observed times of minima since 1971, including our latest ones (see Table 2). Due to its very long orbital period (about 836 years, according to Zaera 1985), only about 100° of the orbit has been observed since 1830. Periastron passage occurred in 1932 and was well covered; regrettably, no minima times were determined during that era.

2.9. β Per

Algol (β Per, HD 19356, HR 936, HIP 14576, LAB 2Aa,Ab) is the well known prototype of this class of binaries. With its 2.12 mag in V, it is the second brightest system in the catalog. The time of minimum brightness was first measured by Montanari on 1670 November 8 (although the variability of the "Demon star" had been known from much earlier times). The current set of times of minima is very large, with about 1400 observations covering the past three centuries, and photoelectric measurements dating as far back as 1910 (Stebbins 1910). In spite of this, a detailed description of period variations in the $O-C$ diagram is still missing. The system is rather complicated, but the distant component (orbital period ~1.8 yr) originally discovered on the basis of RV variations, was first resolved by speckle interferometry in 1973 (Labeyrie et al. 1974). The orbit of this component is now well established ($a = 94.6$ mas and $e = 0.23$, according to Pan et al. 1993). Several distant companions are listed in the WDS, but these are probably optical.

2.10. AG Per

AG Per (HD 25833, HIP 19201, STT 71AB) is an Algol-type EB. Over 100 times of minima, obtained from the 1920s up to the present, have been collected from the published literature. AG Per is one of the most typical apsidal-motion systems, and has been analyzed several times (see, e.g., Wolf et al. 2006). Data are sufficient for combining the apsidal motion and LITE into one joint solution (similar to the ζ Phe case). Precise light curves have also been measured and analyzed (see Woodward & Koch 1987). On the other hand, although astrometric observations have been obtained 39 times since 1846, the change in position angle has been too small to permit an orbital solution.

2.11. V592 Per

V592 Per (HD 29911, HIP 22050, COU 1524) is a β-Lyrae EB system. There have been 25 times of minima published to date, six of them observed for this paper (see Table 2). Astrometric data cover only about 20°, with 19 data points obtained over 28 years. A preliminary orbit has been computed (using standard methods, see, e.g., Batten 1973), yielding a period of about 115 years and a semimajor axis of about 220 mas. The derived elements are given in Table 3 and plotted in Figure 1, together with all observations used in the solution. Due to the fact that the orbit is only a preliminary one, the resulting derived mass of the system is unreliable. In this case, the mass derived from the visual orbit (about 6 $M_\odot$) is considerably higher than would be expected according to the estimated spectral types. New observations are needed.

Table 3
Orbital Elements for the Newly Derived Solutions and the Total Masses of the Systems According to These Orbital Solutions

WDS Designation $\alpha\delta$(2000)	Variable Star Designation	Period p_3 (yr)	Epoch of Periastron T_0 (yr)	Semimajor Axis a ($''$)	Inclination i (deg)	Longitude of Periastron ω (deg)	Eccentricity e	Longitude of Node Ω (deg)	Total Mass ($M_\odot$)
04445+3953	V592 Per	115.3	1903.9	0.223	79.1	98.5	0.498	210.0	6.21
		±7.1	±6.4	±0.030	±8.4	±9.7	±0.006	±9.0	±4.08
05320-0018	δ Ori A	704.8	1972.8	0.970	96.9	95.2	0.914	325.3	40.7
		±127.7	±145.2	±0.331	±13.8	±9.6	±0.165	±17.3 :	±32.2
05474-1032	V1031 Ori	92.66	1942.6	0.176	76.3	0.3	0.001	111.9	5.11
		±6.61	±7.8	±0.007	±8.2	±28.5 :	±0.001	±9.4	±1.13
08558+6458	AC UMa	1199.2	1349.0	30.15	106.5	102.7	0.790	62.9	$5\cdot10^6$
		±341.8	±280.5	±0.52	±7.8	±8.9	±0.047	±6.8	$\pm4\cdot10^6$
11383-6322	V871 Cen	1715.8	909.2	1.316	81.9	73.8	0.730	234.8	3390
		±285.4	±230.1	±0.445	±13.0	±14.8 :	±0.106	±8.8	±2860
17539-3445	V906 Sco	34.71	1974.1	0.172	80.5	183.0	0.001	103.0	125.2
		±1.13	±1.2	±0.015	±6.8	±9.7	±0.002	±9.7	±46.7
17592-3656	V1647 Sgr	1219.7	1778.4	14.36	94.7	269.4	0.841	113.8	3021
		± 83.4	±76.2	±6.08	±8.5	±21.2	±0.027	±12.7	±468
20312+0513	MR Del	1996.6	1945.9	3.763	74.2	0.0	0.493	61.2	1.17
		±170.5	±130.3	±0.156	±8.4	±7.4	±0.051	±8.0	±0.40

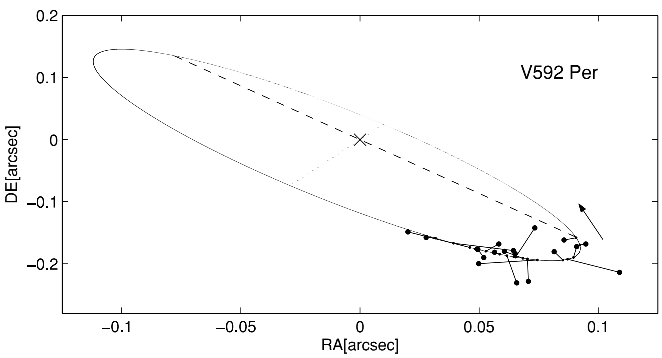

Figure 1. Relative orbit of V592 Per on the plane of the sky. Individual measurements are plotted as dots, and straight "$O - C$" lines connect the these observations to their predicted positions on the fitted orbit. The cross indicates the position of the eclipsing binary on the sky, the dotted line represents the line of apsides, and the dashed line the line of nodes.

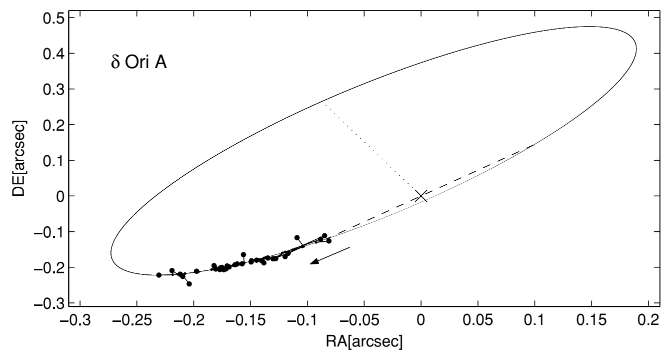

Figure 2. Relative orbit of δ Ori A on the plane of the sky.

2.12. η Ori

η Ori (HD 35411, HR 1788, HIP 25281, MCA 18Aa,Ab + DA 5AB) is a quadruple system with three resolvable components. The primary is an eclipsing and also a double-lined spectroscopic triple (periods 8 days and 9.2 years). One of the components also has a pulsation period of ∼8 hr. There has been only one published time of minimum, derived from the *Hipparcos* observations. The orbit of the interferometric pair (MCA 18Aa,Ab) derived by Balega et al. (1999) finds an orbital period of about 9.44 yr, in reasonable agreement with the spectroscopic period.

2.13. δ Ori A

δ Ori A (HD 36486, HR 1852, HIP 25930, HEI 42Aa,Ab) is a massive EB with an orbital period 5.7 days. Only nine times of minima were found in the literature, and these minima do not show any significant LITE variation (more probably apsidal motion). On the other hand, there is a fair amount of motion on the plane of the sky seen in the 38 measurements obtained since the visual pair was first observed in 1978. The preliminary orbit listed in Table 3 and shown in Figure 2 predicts a period of about 705 years and a semimajor axis of 1$''$. From the orbital parameters, the total mass of the system is about 40 $M_\odot$. For a detailed discussion about the masses of the binary components, see Harvin et al. (2002). There appears to be a problem with the derived masses of primary and secondary, which are substantially below the expected masses for stars of their luminosity. On the other hand, the evolutionary tracks of stars with the measured values of [log $T_{\rm eff}$, log L] predict much higher masses for both components. If we accept the masses derived by Harvin et al., the mass of the third component should be about 20 $M_\odot$. Single stars of such a mass should be observable via a UV flux contribution, which has not happened. A plausible conclusion is that the distant component is probably also a binary.

2.14. V1031 Ori

V1031 Ori (HD 38735, HR 2001, HIP 27341, MCA 22) is an Algol-type detached system. Twelve times of minima have been found in the literature. A new circular orbit of the interferometric binary is shown in Figure 3. Based on only 20 observations obtained from 1980 to 1997, the solution is obviously very preliminary. The derived orbital period is about 93 yr and the semimajor axis about 0$''$.18 (see Table 3 for the parameters). From our new orbital solution, we derive a mass of $M_{123} = (5.1 \pm 1.1)$ $M_\odot$ for all three components.

Based on the RV measurements and a few speckle observations, Andersen et al. (1990) concluded that the orbit

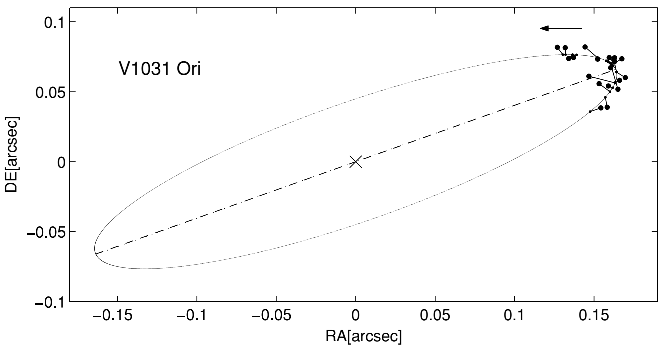

Figure 3. Relative orbit of V1031 Ori on the plane of the sky.

should be much larger, with a period of about 3700 years. Third-component lines were observed in the spectra of V1031 Ori and RVs for the 93 year orbit would be much larger than measured. Andersen et al. (1990) also derived the physical parameters of both eclipsing components, resulting in $M_{12} = (4.76 \pm 0.04)\, M_{\odot}$. However, they assumed that the wide orbit is coplanar with the EB orbit, which is not necessary true in multiple systems. Because the orbital coverage is so poor, only further interferometric observations, as well as precise RV investigation will reveal the true nature of the system. New times of minima are also needed.

2.15. τ CMa

τ CMa (HD 57061, HR 2782, HIP 35415, FIN 313Aa,Ab) is the brightest star in the open cluster NGC 2362. It is a β-Lyrae-type EB, with a period about 1.28 days. τ CMa is also a spectroscopic binary with an orbital period of about 154.9 days; the EB is probably the visual secondary (Stickland et al. 1998). This interesting system therefore contains both the longest period spectroscopic binary and the shortest period EB known among the O-type stars. The system was precisely analyzed by van Leeuwen & van Genderen (1997). This triple system is one member of the visual binary FIN 313Aa,Ab, which has been measured astrometrically 32 times since 1951. The change in position angle is still quite small, however, so no orbital solution has yet been attempted.

2.16. YY Gem

YY Gem (Castor C, α Gem C, HD 60178J, HIP 36850, STF 1110AB) is an EB and also the C component of the Castor multiple system. The three visual components are all doubles: A and B are spectroscopic binaries, while C is the EB YY Gem; we therefore are dealing with a sextuple system. (A fourth visual companion is also listed in the WDS; however, the D component shows a very different proper motion and is likely an optical rather than physical companion.) About 180 times of minima have been published for YY Gem. With 1341 observations covering nearly two centuries, the orbit of the AB pair (p_3 = 467 yr, a = 6$''$.8) is well defined now. However, no significant change in position angle has been seen in the orbit of component C around the AB pair, despite data spanning 180 years.

2.17. V635 Mon

V635 Mon (HD 66094, HIP 39264, A 1580AB) is an Algol-type EB. It is well observed, with over 100 times of minima published to date; however, these data points follow the linear ephemeris without any indication of a LITE. A total of 24 astrometric measurements have been made over the past century, spanning about 150° (although phase coverage was very sparse through most of that time). The most recent analysis by Docobo & Ling (2008) gives a period of 257 years, with a semimajor axis of about 313 mas.

2.18. NO Pup

NO Pup (HD 71487, HR 3327, HIP 41361, B 1605Ba,Bb) is an eccentric EB of Algol type. There have been 15 times of minima observed and the apsidal motion of the system has been studied a few times, resulting in an apsidal period of about 37 years (Giménez et al. 1986). Altogether there are four visible components in this multiple system, with the eclipsing system probably comprising the primary. Chambliss (1992) has estimated that the close Ba,Bb pair orbit with a period of about 32 years, but no orbital analysis has yet been published. The relative separation and angle between A and the pair comprising B has remained essentially unchanged over the past 160 years. A fourth component was discovered in 1997, using adaptive optics, by Tokovinin et al. (1999), but has not yet been confirmed.

2.19. VV Pyx

VV Pyx (V596 Pup, HD 71581, HR 3335, HIP 41475, B 2179AB) is an Algol-type EB and also a double-lined spectroscopic binary. Andersen et al. (1984) analyzed the light curve and also the RV curves of the system, deriving a precise set of physical parameters. There were 11 times of minima found in the literature (1976–2005), but these data show very slow apsidal motion (on the order of centuries). The visual orbit is also covered only very poorly, with 11 observations obtained over the course of 38 years showing a change in position angle of about 13°; no orbital analysis is yet possible. Andersen et al. (1984) speculate that the visual companion could also be a binary; speckle interferometric observations have ruled out any companions with separations greater than ∼30 mas and magnitude difference less than about 3 mag, but only further precise observations could prove or disprove the existence of closer and/or fainter companions.

2.20. LO Hya

LO Hya (HD 71663, HR 3337, HIP 41564, A 551AB) is another Algol-type EB. A detailed analysis of this system was performed by Bakos (1985). Both the A and B components are spectroscopic binaries, while the distant C component also appears to be a physical companion. We therefore deal with at least a quintuple system. One spectroscopic component is also the EB LO Hya, with an orbital period of about 2.5 days. Six times of minima have been found in the literature. Some 69 astrometric measurements obtained during the last century reveal a visual orbit with a 55 year period (see Docobo & Ling 2007).

2.21. δ Vel

δ Vel (HD 74956, HR 3485, HIP 42913, I 10AB) is an Algol-type EB classified as A1V spectral type; at V = 1.95 mag it is the brightest system in the catalog. The star was discovered to be photometrically variable in 1997 (see Otero et al. 2000 for details); the period of such variation is about 45 days. Altogether 10 times of minima were obtained, but these observations indicate very slow apsidal motion (on the timescale of centuries). The visual A and B components orbit with a period of about 142 years and a semimajor axis of about 2$''$ (according

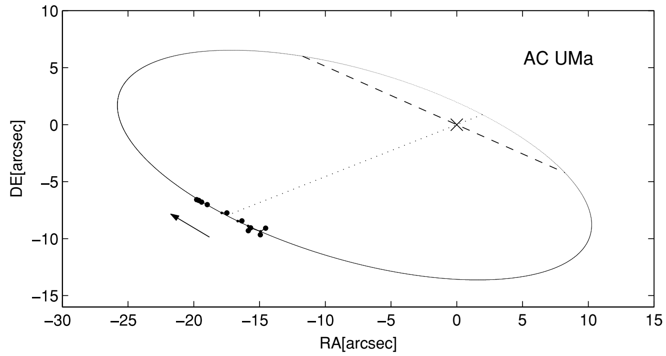

Figure 4. Relative orbit of AC UMa on the plane of the sky.

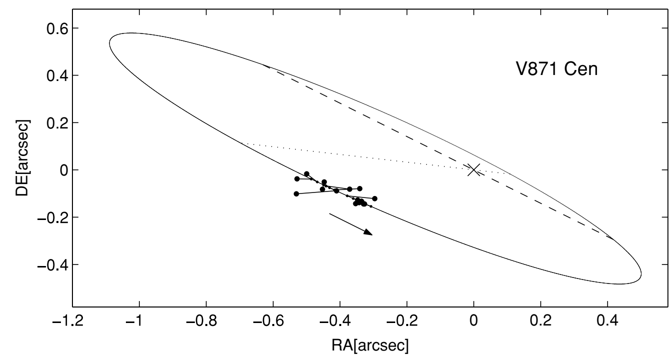

Figure 5. Relative orbit of V871 Cen on the plane of the sky.

to Alzner & Argyle 2000). The whole system is, however, more complicated, consisting of two proper-motion pairs (with separations of 2″ and 6″, respectively), separated in the sky by 72″. The primary component was additionally resolved into a 15 mas pair by long-baseline interferometry. We therefore appear to be dealing with a system of at least six components. However, thanks to the interferometric observations and detailed analysis by Kellerer et al. (2007), the picture of the system has been simplified somewhat. According to these authors, the two distant components C and D do not belong to the system. Furthermore, the 45 day period interferometric orbit appears to correspond to that of the eclipsing pair.

2.22. AC UMa

AC UMa (ARG 21AB) is an Algol-type EB, and at $V = 10.3$ mag is one of the faintest systems studied here. The orbital period is about 6.85 days. The 80 times of minima found in the literature suggest a possible variation in orbital period on the timescale of decades, but this finding is inconclusive and a larger data set is needed. The visual orbit shown in Figure 4 is based on only 10 observations obtained during the past 106 years. As one can see, only a short arc of the orbit is covered by data, so one cannot derive the parameters of the orbit precisely. This solution gives an extremely long period of about 1200 years, although this value could be even longer (see Table 3). Another possible explanation is that the distant component is only an optical companion and not physically associated with the EB system. The different proper motions of the two visual components suggest this latter interpretation to be the more probable one (see the Catalog of Rectilinear Elements[11] for details). Another argument that the component is probably not gravitationally bound with the EB is the fact that the total mass computed from the visual orbit is unacceptably high, see Table 3.

2.23. DI Lyn

DI Lyn (A Hya, HD 82780, HR 3811, HIP 47053, COU 2084Aa,Ab) is an Algol-type EB. There is only one time of minimum available in the literature, see Wolf & Caffey (1998); however, four additional minima were measured for this paper (see Table 2). This hierarchical system is rather complicated, and contains at least five physical components, see Tokovinin et al. (2006), component C seems to be only an optical one. Two components are spectroscopic binaries (periods 28 days and 1.7 days), one of them is also the EB DI Lyn. Tokovinin (1997) estimated the period of the close visual Aa,Ab pair at ∼64 yr. However, any orbital solution has been published, and this estimation of period was based only on the relative motion of these stars—only about 28° in 22 years—and the Kepler's third law, so this may be an underestimate.

2.24. TX Leo

TX Leo (HD 91636, HR 4148, HIP 51802, STF 1450AB) is an Algol-type EB and its apparent brightness is about $V = 5.67$ mag. There have been eight times of minima observed since 1930. The astrometric data set is much larger, about 140 measurements secured over the last 180 years, but the relative motion has been minimal.

2.25. V871 Cen

V871 Cen (HD 101205, HIP 56769, I 422AB) is a β-Lyrae-type EB. There is a brief paper on the photometric observations of V871 Cen, together with one minimum time derived (see Mayer et al. 1992). Confirmation of the period of its photometric variability is based on analysis of *Hipparcos* and ASAS data, see Otero (2007). The system includes four visual components; astrometric measurements of the closest pair secured during the last 104 years reveal a change in position angle of only about 20°, so our 1700 year period orbital solution is not very convincing (see Table 3 and Figure 5 for details). Also a derived total mass of the system more than 3000 $M_\odot$ indicates an unacceptable solution with the current data.

2.26. GT Mus

GT Mus (HD 101379, HR 4492, HIP 56862, B 1705AB) is one component of a quadruple system, as each member of this close visual pair is itself a close binary (see Murdoch et al. 1994). One of them is a spectroscopic binary with period about 61 days, which is also an RS CVn-type binary, while the other one is an EB with orbital period about 2.75 days. No minima have been published. Astrometric data obtained during 76 years and cover about 110° of the orbit. The estimated period of the AB pair is about 91 years (Parsons 2004). The visual pair has two faint wide companions; the physical/optical nature of these is unknown.

2.27. DN UMa

DN UMa (HD 103483, HR 4560, HIP 58112, A 1777AB) is another Algol-type EB, which comprises the primary component of the visual quadruple system ADS 8347. The D component of this system is over 1 arcmin in separation from the primary; however, the similarity in parallax indicates the wide pair is probably physical. A detailed light-curve analysis was published by Garcia & Gimenez (1986) and an RV curve analysis by Popper (1986). There have been 16 observed times of

[11] http://ad.usno.navy.mil/wds/lin1.html

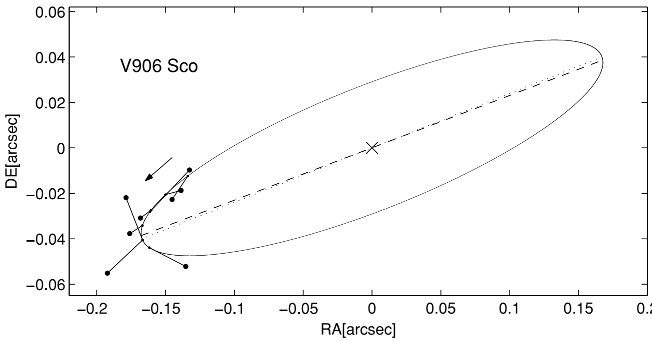

Figure 6. Relative orbit of V906 Sco on the plane of the sky.

minima from 1979 until our recent measurements (see Table 2). The visual orbit is defined reasonably well, with a century's worth of data covering nearly a full revolution. The most recent orbit was by Aristidi et al. (1999), who derived $p_3 = 136.5$ yr and $a = 230$ mas.

2.28. VV Crv

VV Crv (HD 110317, HIP 61910, STF 1669AB) is a system consisting of two spectroscopic binaries (periods 44.51 days and 1.46 days; see Massarotti et al. 2008). The eclipsing nature of one of its components was discovered from *Hipparcos* data (Perryman & ESA 1997); this gave an orbital period of about 3.14 days, suggesting that the system might be quintuple. *Hipparcos* data have also provided the only time of minimum found thus far in the literature. Astrometric data have been obtained over the past 180 years, but have described a change in position angle of about only 14°. Due to this short arc, no orbit has been calculated; however, Tokovinin et al. (2006) have estimated the period of AB pair to be about 4500 years.

2.29. V831 Cen

V831 Cen (HD 114529, HR 4975, HIP 64425, SEE 170AB) is a β-Lyrae system and also a spectroscopic binary, with an orbital period of about 0.64 days. The only published minimum is that measured by the *Hipparcos* satellite. The close AB pair of this visual quadruple system has been observed for over 100 years, with a single attempt at an orbital solution by Finsen (1964) yielding $p_3 = 27$ yr and $a = 185$ mas. $O - C$ errors are quite large, however; this is due primarily to the small separation of the AB pair, but perhaps also in part to the presence of the nearby C component (separation $< 2''$) further complicating the early measurements.

2.30. HT Vir

HT Vir (HD 119931, HIP 67186, STF 1781) is a contact W UMa system. Although only a visual binary, the system is in fact quadruple, with three components visible in the spectra. The spectroscopic single-lined binary (period 32.5 days) constitutes component A, while the EB (period 0.41 days) is the B component. Astrometric measurements have been made regularly since Struve's discovery of the visual pair in 1830, defining the orbit quite precisely. On the other hand, times of minima have been measured only a few times since discovery of the eclipsing variable. A detailed analysis of this system, combining the angular position measurements and period variation, was presented in ZW.

2.31. ET Boo

ET Boo (HIP 73346, COU 1760) is a ninth magnitude β-Lyrae EB. The system has been found to be quadruple, according to Pribulla et al. (2006). There have been 31 times of minima published to date, including one new value published here (see Table 2). It is also a close visual binary, discovered in 1978 (Couteau 1981). Astrometric measurements obtained between 1978 and 1999 have shown a change in position angle of about 40°; unfortunately it has not been observed in nearly a decade. A very preliminary orbit was derived by Seymour (2001), giving a period of about 113 years and an angular semimajor axis of 261 mas. Variation of the orbital period is hardly detectable with available data; therefore, new observations of minima and also astrometry are needed.

2.32. i Boo

i Boo (HD 133640, HR 5618, HIP 73695, STF 1909AB) is a well known EB of the W UMa type and, at a distance about 13 pc, also the nearest system in the catalog. Many times of minima have been observed over the last 90 years, including three new values listed in Table 2, but a satisfactory explanation of the period changes is still lacking. It is an X-ray binary and has also been found to exhibit flares. There is quite a large set of astrometric measurements of the visual binary, dating back to its discovery by William Herschel in 1781, and most phases of the orbit are quite well defined. The most recent orbital analysis finds a period of about 206 years and a semimajor axis of 3$''$.8 (Söderhjelm 1999).

2.33. V1055 Sco

V1055 Sco (HD 148121, HIP 80603, B 872AB) is a β-Lyrae EB. There have been only seven times of minima published in the literature, two of them derived from photometric data obtained by the Optical Monitoring Camera (OMC) onboard the *International Gamma-Ray Astrophysics Laboratory* (*INTEGRAL*) satellite (see Table 2). Astrometric measurements obtained during the last 70 years cover only about 15° in position angle, making it much too premature to attempt a solution to the visual orbit.

2.34. V819 Her

V819 Her (HD 157482, HR 6469, HIP 84949, MCA 47) is an Algol-type EB, orbiting about a common center of mass with a third component in a 5.5 year period orbit. Eccentricity is about 0.67, and LITE is evident. The wider pair was discovered by speckle interferometry in 1980 (McAlister et al. 1983) and has been extensively observed by this technique and also more recently with the Palomar Testbed Interferometer (Muterspaugh et al. 2008). In this system, LITE was analyzed together with the interferometry and RV data (see Muterspaugh et al. 2006).

2.35. V906 Sco

V906 Sco (HD 162724, HR 6662, HIP 87616, B 1871AB) is a detached triple-lined EB. A detailed photometric and spectroscopic analysis of this system was made by Alencar et al. (1997), who also included a discussion about possible apsidal motion. A new visual orbit has been derived (see Figure 6 and Table 3); in this solution only the more precise interferometric measurements from the astrometric data set were used, due to the much larger scatter in the earlier micrometry data. The last astrometric observations of any type were obtained more than

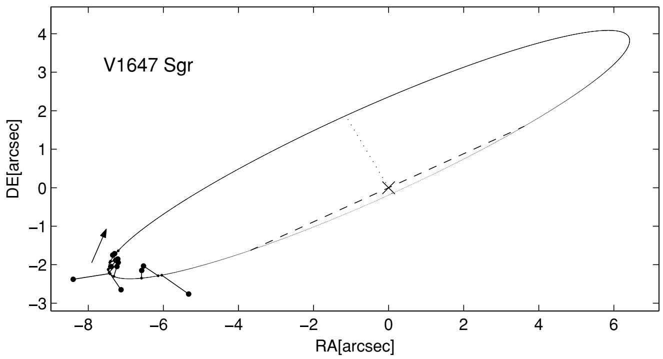

Figure 7. Relative orbit of V1647 Sgr on the plane of the sky.

15 years ago, so new measurements are needed to improve upon this solution. Also a total mass about 100 $M_\odot$ indicates this orbit to be a preliminary one.

2.36. V2388 Oph

V2388 Oph (HD 163151, HR 6676, HIP 87655, FIN 381) is a contact EB of W UMa type. A detailed analysis of *ubvy* light curves was performed by Yakut et al. (2004) and an RV analysis by Rucinski et al. (2002). A preliminary solution for the visual orbit was made by Hartkopf et al. (1996), finding a period of about 9 years. Unfortunately, there have been only a few observations published of times of minima; due to the poor sampling afforded by these data, no variation in the $O - C$ diagram for minima times is evident.

2.37. V1647 Sgr

V1647 Sgr (HD 163708, HIP 88069, HJ 5000) is an Algol-type EB. A few dozen times of minima are available; these data indicate a slow apsidal motion with a period about 530 years (see Wolf 2000). Andersen & Gimenez (1985) published the most detailed study of the whole system to date, including into their analysis also the visual component. Astrometric measurements of the visual pair obtained over the past 170 years cover only about 14° in position angle, as shown in Figure 7. A preliminary orbit was computed for the first time, but the results are not very convincing due to the limited phase coverage. The period derived here is about 1200 years (see Table 3 for the orbital parameters); the total mass which results in more than 3000 $M_\odot$ makes this solution unrealistic.

2.38. V772 Her

V772 Her (HD 165590, HIP 88637, STT 341AB) is an EB as well as an RS CVn variable star. This is the A component of a close visual triple and spectroscopic binary of very high eccentricity; Heintz (1982) derived values of $p_3 = 20$ yr and $e = 0.956$. See also Batten et al. (1979) for details on the spectroscopic orbit. The C component is physically connected to the system and was also found to be a spectroscopic variable (period is about 25 days, according to Fekel et al. 1994). We therefore deal with at least a quintuple system (the WDS lists four additional wide companions, but these are probably optical due to their fast relative motion; see Tokovinin 1997). There have been more than 20 times of minima published to date. Bruton et al. (1989) published an $O - C$ diagram with 16 minima times, fitted with a LITE curve based on parameters derived from the visual orbit.

2.39. V2083 Cyg

V2083 Cyg (HD 184242, HIP 96011, A 713) is an Algol-type EB. There has been only one time of minimum (based on *Hipparcos* data) published, our six new observations are in Table 2. Astrometry of the close visual pair during the last century covers about 70° of the orbit. A preliminary orbital solution by Seymour et al. (2002) gives a period of about 372 years and an angular semimajor axis about 498 mas.

2.40. QS Aql

QS Aql (HD 185936, HR 7486, HIP 96840, KUI 93) is an Algol-type eclipsing, and also spectroscopic, binary. The 24 available minima observations (four of which are new; see Table 2), allow the period variation to be clearly visible. The close visual binary has been observed for over 70 years; the recent orbit by Docobo & Ling (2007) finds an extremely large eccentricity ($e = 0.966$), but many of the observations show large residuals to this 62 year period solution. Combined analysis is still problematic (see Mayer 2004) due to poor coverage of the system by both methods.

2.41. V505 Sgr

V505 Sgr (HD 187949, HR 7571, HIP 97849, CHR 90) is an Algol-type eclipsing (and also spectroscopic) binary. Since its discovery as a variable, several light-curve measurements and analyses have been attempted, the latest by İbanoğlu et al. (2000). A detailed spectral analysis of the system was published by Tomkin (1992), who also noted discovery of a third component in the spectrum of the system, as well as a slow change in the RV of this component. Solution of the visual orbit is still uncertain: Tomkin (1992) estimated a period of about 100 years, while Mayer (1997) derived an orbit with a period of about 38 years; the recent orbit by Cvetković et al. (2008) found a period of 60 years. The problems of the visual orbit and the LITE solution were discussed in Zasche (2008). The set of times of minima is quite large (more than 300 observations), but a detailed explanation of the period changes is still lacking (see Chochol et al. 2006). Nine new minima observations were obtained, see Table 2.

2.42. MR Del

MR Del (HD 195434, HIP 101236, AG 257AB) is an Algol-type EB; at $V = 11.01$ it is the faintest object in the catalog. There have only been a few times of minima observed during the last 15 years; four additional new measurements are given in Table 2. Although the visual pair has been observed for a century, the position angle has changed by only about 15°. Such a small change suggests an orbital period of order 2000 years; our preliminary solution is given in Table 3 and illustrated in Figure 8. The resulting total mass results in about 1.2 $M_\odot$.

2.43. VW Cep

VW Cep (HD 197433, HIP 101750, HEI 7) is a W UMa-type system, whose primary and secondary are both chromospherically active. There have been numerous LITE studies made of this system; Herczeg & Schmidt (1960) proposed the presence of a third body with an orbital period of 29 years and an angular separation between 0."5 and 1."2. In 1974, the first successful visual observation of the third component was obtained by Heintz (1975). The visual orbit is fairly well defined, and the parameters of this orbit (see Docobo & Andrade 2005) are in agreement

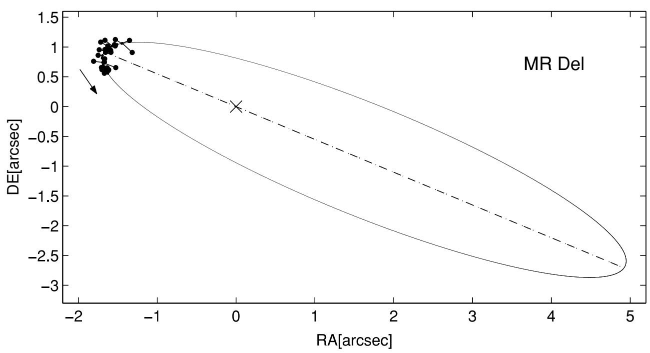

Figure 8. Relative orbit of MR Del on the plane of the sky.

with the LITE variation in the $O - C$ diagram of minima timings (see ZW for details). This system seems to be perhaps the most suitable one for simultaneous analysis of both the period variation and the visual orbit; this technique could also derive the distance to the system. Six new minima observations were obtained for this paper; see Table 2.

2.44. BR Ind

BR Ind (HD 201427, HIP 104604, HU 1626AB) is an Algol-type EB. The position angle of the visual binary changed by $\sim 80^\circ$ between 1914 and 2001; this was sufficient to define a preliminary orbit of $p_3 = 167$ yr and $a = 894$ mas (Seymour et al. 2002). The only published time of minimum was derived from *Hipparcos* data.

2.45. Other Systems

There are also numerous other cases where the strict conditions introduced in the beginning of Section 2 are not satisfied. Some of the more interesting systems are presented in Table 4. Their visual orbits have not yet been derived, due to insufficient phase coverage. In most of these systems the change of position angle is too slow, or there are still only a few measurements available. One could expect that during the next decades some of these systems will move to that ones in chapter 2.

2.46. Special Cases

There are also a number of "special cases" which were not included in the catalog due to their more complicated or uncertain nature. A few examples are described below.

1. In all systems included in the catalog, the close EB comprises one component of a much wider visual interferometric pair. However, in a few rare cases the components of the EB also comprise the components of the visual pair. The systems β Aur, β Cap, γ Per, and V695 Cyg are eclipsing pairs which have also been resolved by interferometry (another possible example of such a system is α Com). The chances of an orbit being sufficiently edge-on to produce eclipses are of course greater for systems with smaller separations; it is therefore expected that the number of such "visual–eclipsing" binaries will increase as more EBs are observed by long-baseline interferometers. However, these systems do not meet the criteria for inclusion in this catalog.
2. Another class of objects not included in the catalog is that of the so-called ellipsoidal variables. Systems such as HD 178125 (18 Aql, Y Aql) or HD 22124 (IX Per) are also sometimes classified as EBs and a few "minima" have been published, as well.
3. The system HD 217675 (o And, 1 And) is sometimes classified as an EB. In fact, this quadruple system (Hill et al. 1988) is photometrically variable (Olsen 1972), but, according to (Pavlovski et al. 1997), it is not an EB.

3. DISCUSSIONS AND CONCLUSION

More than 13,000 systems in the WDS had sufficiently large astrometric data sets to allow potential analysis and were, therefore, checked for the presence of EB components. Many stars which were suspected to be variables were found in this large set, but only a very limited number of these systems had ever been given detailed spectroscopic or photometric analysis. Systems chosen for inclusion in this catalog were selected on the basis of EB designations in the SIMBAD database and notes in the WDS.[12] However, in many cases identification of a star as an eclipsing variable is a rather difficult task; because of this, many such systems are designated in SIMBAD only as "variable stars." Although the current number of known visual doubles containing eclipsing variables as components is still quite limited, this number is expected to increase substantially as the true nature of more of these "variable stars" is determined through further photometric observation.

A long-term goal is to increase the size of this catalog to the point where reliable statistical analysis of this class of systems may be attempted. The subset of visual multiple systems including EB components could be another area of potential interest. If one has information about the various orbits in these systems, the ratio of periods or the mutual inclinations of the long and the short orbits could prove an interesting probe into the mechanisms for formation of these objects. Also a frequency of quadruple or quintuple systems among multiples could be studied. The main catalog in the present paper includes seven quadruple systems, eight quintuples, and one sextuple. However, there are still many cases, where the membership of a star to the system is questionable, so this fraction of multiples is expected to increase.

Regrettably, many of the systems in the catalog lack recent observations. Ironically, this is due in part to the fact that many of these systems are too bright for modern photometric equipment. Some of the earliest known EBs are now neglected, since they can easily saturate a CCD detector mounted on even a modest telescope. Phase coverage of most visual binary orbits is insufficient, due largely to the exceedingly long orbital periods of these pairs. Astrometry of closer interferometric pairs is also lacking, as shifting priorities of telescope allocation committees has made it difficult for observers to get time on the large telescopes needed for obtained these data. As a result, analysis is complicated, and newly derived orbital elements are affected by relatively large errors due to small arcs of the orbit covered and/or sparse phase coverage.

In conclusion, although a few of the systems in the catalog presented here (e.g., V505 Sgr, QS Aql, V2388 Oph) are suitable for simultaneous analysis of period variation and astrometry, in most cases the time span of observations is still too short and more data are needed. The highest priority systems for which interferometric observations are desired include V1031 Ori, ET Boo, and V906 Sco. Systems especially in need of additional photometric observations for minima determinations are V1031 Ori, LO Hya, V906 Sco, and V2388 Oph.

[12] http://ad.usno.navy.mil/wds/wdsnewnotes_main.txt

Table 4
Other Eclipsing-Visual Systems

HD	Star	Spectral Types			EB Type	V	P	Min	Min	M	Depth	Depth	$\Delta\Theta/\Delta T$	References
	Designation	1	2	3		(mag)	(days)	Pri	Sec	Astr.	MinP	MinS	(°)/(yr)	
1061	UU Psc		F0IV		EW	6.01	0.84168	1	0	145	0.05 V	0.05 V	1/225	1,2,3
4161	YZ Cas	A2IV	F2V		EA	5.65	4.46722	32	3	11	0.41 B	0.07 B	0/103	4,5
4502	ζ And	K1III	F		EW	4.10	17.7695	3	2	4	0.22 V	0.10 V	40/91	4,6
5679	U Cep	B7V	G8III–IV	G8III	EA	6.92	2.49291	1268	1	8	2.49 V	0.18 V	1/119	4,7
8152	AQ Psc		F8V		EW	8.67	0.47561	11	11	4	0.36 V	0.36 V	6/81	1,8,9
	RS Tri		A5V		EA	10.26	1.90892	85	1	9	0.73 V	0.13 V	1/110	4,10
13078	BX And	F2V	K		EB	8.98	0.61011	257	42	22	0.67 b	0.25 b	2/176	4,11
	GZ And	G5V	G5V	M3V	EW	10.89	0.30502	99	118	9	0.78 V	0.75 V	4/170	4,12,13
	EX Per	A1			EA	12.00	8.47595	8	2	10	0.80 V	0.50 V	2/96	4
18541	ST Per	A3	K1-2IV		EA	9.61	2.64836	341	2	4	1.88 V	0.10 V	0/70	4,14
24909	IQ Per	B8V	A6V	A3	EA	7.73	1.74356	125	15	18	0.55 V	0.16 V	0/132	4,15,16
25638	SZ Cam	O9IV	B0.5V	B0	EB	6.93	2.69847	77	14	78	0.29 B	0.24 B	2/177	4,17
34335	CD Tau	F7V	F5IV	K2	EA	6.77	3.43514	51	40	29	0.57 V	0.54 V	1/178	4,18
35921	LY Aur	O9III	O9.5III	B0V	EB	6.85	4.00250	32	17	31	0.69 V	0.60 V	4/105	4,19
37020	θ Ori	B3V	A7IV	O7V	EA	7.96	6.47053	19	0	112	0.75 V	0.08 V	0/176	4,20
					+ EA	+ 6.73	+ 65.4329	+ 24	+0		0.93 V			4,20
62863	PV Pup	A8V	A8V	A2V	EA	6.93	1.66073	2	3	59	0.44 V	0.43 V	1/225	4,21
65818	V Pup	B1V	B3IV		EB	4.45	1.45449	16	4	6	0.57 V	0.47 V	1/119	4,22
74307	S Cnc	B9V	G8IV	G0V	EA	8.35	9.48454	234	0	5	1.96 V	0.10 V	0/120	4,16,23
75821	KX Vel		B0III		EA	5.09	26.30624	0	0	8	0.08 B		4/65	4,24
83950	W UMa	F8V	F8V		EA	7.96	0.33363	1176	284	4	0.73 V	0.68 V	7/80	4,25
89714	HP Car		B0.5III		EA	8.93	1.60045	1	0	4	0.45 V	0.45 V	18/59	4,26
93206	QZ Car	O9.7I	B0I	O9V	EB	6.24	5.9991	5	1	4	0.33 V	0.27 V	0/85	4,27,28
	AM Leo		F8V		EW	9.31	0.36580	194	139	41	0.58 V	0.58 V	0/175	4,29
99769	MN Cen		B2-3V		EA	8.8	3.48901	7	4	10	0.40 b	0.10 b	0/117	4,30
99946	AW UMa	A8Vn		G5	EW	6.92	0.43873	103	72	21	0.30 V	0.25 V	0/131	4,31
106400	AH Vir	G8V	G8V	K1V	EW	9.33	0.40753	261	169	7	0.60 V	0.53 V	2/93	4,32
114911	η Mus		B8V		EA	4.77	2.3963	2	0	17	0.05 V		3/176	4,33
117408	SS Hya	A0V		A0	EA	7.86	8.2	1	0	4	0.22 B		6/108	4,34
132742	δ Lib	A0V	K0IV	F	EA	4.95	2.32735	200	0	4	0.99 V		3/94	4,35
134646		F4III		G8	EA	6.82	2.44405	1	0	11	0.13 V	0.06 V	2/102	36,37
135421	BV Dra	F9V	F8V		EW	8.04	0.35007	53	61	39	0.60 V		1/167	4,38
	+ BW Dra	+G3V	+G0V		+EW	+ 8.74	+ 0.29217	+ 53	+ 42		+ 0.47 *V*	+ 0.41 *V*		4,38
138672	EI Lib	A3-7	F5-8	Am	EA	9.50	1.98691	4	0	7	1.00 b		3/79	4,16,34
139319	TW Dra	A5V	K0III		EA	7.43	2.80685	499	5	36	2.50 b		4/157	4,39
139966	HH Nor	F0		F0IV	EA	10.2	8.58313	1	0	9	1.20 b		0/164	4,30,40
149730	R Ara		B9IV		EA	6.65	4.42509	6	0	21	0.90 b	0.20 b	8/164	4,30
150708	WW Dra	G2IV	K0IV	F2V	EA	8.59	4.62972	84	10	23	0.65 V	0.08 V	1/175	4,20
153751	ϵ UMi	G1	A-F		EA	4.22	39.4809	1	0	6	0.04 V	0.02 V	4/80	4,41
155937	AK Her	F2V	F6V	K2V	EW	8.51	0.42152	460	161	14	0.48 V	0.35 V	0/104	4,12,20
156247	U Oph	B5V	B5V	B5	EA	5.90	1.67735	431	257	13	0.72 V	0.62 V	3/123	4,42
156633	u Her	B2IV	B8III	B	EB	4.80	2.05103	222	36	28	0.68 V	0.24 V	2/158	4,43
161321	V624 Her	A4	A7		EA	6.20	3.89498	3	1	7	0.18 V	0.17 V	0/98	4,44
161783	V539 Ara	B3V	B4V	A0-1V	EA	5.92	3.16913	17	12	16	0.52 V	0.43 V	2/166	4,45
163181	V453 Sco		B0I		EB	6.61	12.00597	4	1	5	0.37 V	0.34 V	3/89	4,33
165814	V3792 Sgr	B4IV		B9IV	EB	6.71	2.24808	2	0	10	0.45 V	0.38 V	1/130	4,34,46
166937	μ Sgr	B8I	B1.5V	B9III	EA	3.84	180.55	1	0	18	0.08 V		5/177	1,42,47
	TZ Lyr		F5V		EB	10.77	0.52883	400	5	5	0.98 V	0.18 V	6/74	4,29
167647	RS Sgr	B5V	A2V	A1V	EA	6.03	2.41568	36	8	8	0.96 V	0.27 V	2/108	4,48,49
174638	β Lyr	B8II	B6.5	B5V	EB	3.52	12.93763	1475	923	93	1.11 V	0.60 V	6/129	4,50,51
178001	BH Dra	A2V	A7	Am	EA	8.43	1.81724	193	0	20	0.89 V	0.20 V	2/103	4,10,33
180639	V342 Aql	A4II	K0IV	K2II	EA	8.68	3.39088	121	0	41	3.40 b		1/160	4,52,53
181987	Z Vul	B4V	A3III		EA	7.33	2.45493	425	17	5	1.65 V	0.33 V	0/101	4,54
183794	V822 Aql	B3	B9		EA	7.12	5.29495	16	6	24	0.57 V	0.20 V	5/126	4,73
185507	σ Aql	B3V	B3V	G8V	EB	5.18	1.95026	6	3	6	0.20 V	0.10 V	3/170	4,16,42
191515	V346 Aql	A0V	G4IV		EA	9.08	1.10636	702	0	19	1.10 b	0.10 b	3/69	4,10
192909	V1488 Cyg	K3I	B4-5	A	EA	4.02	1147.4	1	0	10	0.24 V		2/178	4,55
	V1191 Cyg		F6V		EW	10.8	0.31338	23	19	5	0.33 V	0.29 V	2/107	4,56
198287	V367 Cyg	A7	B6-7		EB	7.04	18.59773	88	32	7	0.93 V	0.49 V	115/56	4,57
199005	KZ Pav	F6V	K4IV	F2	EA	7.75	0.94988	86	11	21	1.59 V		1/165	4,58
203069	RY Aqr	A8V	K1	K2V	EA	8.86	1.96658	161	4	4	1.30 V		1/101	4,59
204215	KP Peg		A2V		EB	7.28	0.72721	8	0	91	0.21 V		5/177	4,60
206155	EE Peg	A3V	F5V	K5V	EA	6.98	2.62821	77	2	5	0.58 V	0.13 V	123/24	4,20
208392	EM Cep	B0.5V	B1V	B1V	EW	7.03	0.80619	27	24	26	0.15 V	0.14 V	0/175	4,10,61

Table 4
(Continued)

HD	Star	Spectral Types			EB Type	V	P	Min	Min	M	Depth	Depth	$\Delta\Theta/\Delta T$	References
	Designation	1	2	3		(mag)	(days)	Pri	Sec	Astr.	MinP	MinS	(°)/(yr)	
209278	DX Aqr	A2V	K0III		EA	6.37	0.94501	164	5	81	0.41 V		2/184	4,62
209943	V376 Cep	F5		F6IV-V	EA	7.43	1.166	2	0	150	0.07 V		9/182	1,63
211853	GP Cep	WN6o/WCE	O3-6	B0:I	EB	9.03	6.6884	1	0	12	0.11 V		0/94	4,64
				+ B1:V-III	+ EB		+ 3.4696	+ 1	+ 0					
215661	ZZ Cep	B7	F0V	A2	EA	9.00	2.14180	240	0	23	0.95 V	0.14 V	1/155	4,10,65
216309	SU Aqr		A2IV		EB	9.95	1.04470	44	0	9	0.60 b	0.30 b	1/99	4,34
219113	SZ Psc	F8V-IV	K1IV		EA	7.44	3.96579	60	0	5	0.54 V	0.20 V	1/91	4,66,67
221253	AR Cas	B4.2IV		A6V	EA	4.88	6.06633	9	1	11	0.14 V	0.04 V	2/119	4,68
232121	SX Cas	B7	K3III		EA	9.05	36.56375	82	1	6	0.87 V	0.36 V	1/95	4,69
256320	FI Ori	F5	K2IV	F7V	EA	10.3	4.44815	40	1	10	0.90 b		7/95	4,70,71
261025	AK Aur	A1	F5III	F5	EA	10.20	4.76314	8	1	10	0.50 B		0/179	4,10
349425	AD Her	A4V	K2		EA	9.68	9.76661	26	0	17	1.47 V	0.09 V	0/107	4,72

Notes. For the explanation of the individual columns, see Table 1. In the column, the "EB types" are the following abbreviations: "EW" for W UMa type, "EB" for β Lyrae type, and "EA" for Algol-type eclipsing binaries, respectively. The column $\Delta\Theta/\Delta T$ denotes the mean rate of the position angle variation with time, which has been derived only from the first and the last measurements of the system. θ Ori, BV+BW Dra, and GP Cep constitute multiple systems with two eclipsing binaries. The system GP Cep is more complicated, its light curve is rather "eclipsing like" (see Demers et al. 2002). References: (1) Samus et al. 2004; (2) Cowley & Fraquelli 1974; (3) Shobbrook 2005; (4) Malkov et al. 2006; (5) Celikel & Eryurt-Ezer 1989; (6) Kővári et al. 2007; (7) Plavec 1983; (8) Djurašević et al. 2006; (9) Sarma & Radharkrishnan 1982; (10) Brancewicz & Dworak 1980; (11) Samec et al. 1989; (12) Rucinski et al. 2007; (13) Tokovinin 1997; (14) Olson 1982; (15) Lacy & Frueh 1985; (16) Halbedel 1985; (17) Lorenz et al. 1998; (18) Ribas et al. 1999; (19) Drechsel et al. 1989; (20) Chambliss 1992; (21) Vaz & Andersen 1984; (22) Frieboes 1962; (23) Etzel & Olson 1985; (24) Morgan et al. 1955; (25) Rucinski et al. 1993; (26) Proust et al. 1981; (27) Walborn 1973b; (28) Leung et al. 1979; (29) Hill et al. 1975; (30) Houk & Cowley 1975; (31) Abt 2004; (32) Lu & Rucinski 1993; (33) Levato 1975; (34) Houk & Smith-Moore 1988; (35) Bakiş et al. 2006; (36) Pagel 1960; (37) Otero 2007; (38) Batten et al. 1989; (39) Zejda et al. 2008; (40) Budding 1984; (41) Hinderer 1957; (42) Lindroos 1985; (43) Hilditch 2005; (44) Petrie 1950; (45) Andersen 1983; (46) Gray et al. 2006; (47) Polidan & Plavec 1984; (48) Ferrer & Sahade 1986; (49) Lindroos 1986; (50) Guetter 1968; (51) Harmanec & Scholz 1993; (52) Stephenson 1960; (53) Erdem et al. 2007; (54) Popper 1957; (55) Ginestet & Carquillat 2002; (56) Rucinski et al. 2008; (57) Pavlovski et al. 1992; (58) Svechnikov & Kuznetsova 1990; (59) Helt 1987; (60) Pych et al. 2004; (61) Simonson 1968; (62) Hoffleit & Jaschek 1982; (63) Grosheva 2006; (64) Demers et al. 2002; (65) Carrier et al. 2002; (66) Zhang & Gu 2008; (67) Eaton & Henry 2007; (68) Krylov et al. 2003; (69) Plavec et al. 1982; (70) Fehrenbach 1961; (71) Budding et al. 2004; (72) Batten & Fletcher 1978; (73) Popper 1981.

Some of this work was based on data from the OMC Archive at LAEFF, preprocessed by ISDC. We thank Dr.Miloš Zejda for kindly sending us the data. Dr. Andrei Tokovinin and also an anonymous referee are greatly acknowledged for their helpful and critical suggestions. This investigation was supported by the Czech Science Foundation, grants 205/06/0217 and 205/06/0304. We also acknowledge the support from the Research Program MSMT0021620860 of the Ministry of Education and also from the Mexican grant PAPIIT IN113308. This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France, and of NASA's Astrophysics Data System Bibliographic Services.

REFERENCES

Abt, H. A. 1981, ApJS, 45, 437
Abt, H. A. 1985, ApJS, 59, 95
Abt, H. A. 2004, ApJS, 155, 175
Alencar, S. H. P., Vaz, L. P. R., & Helt, B. E. 1997, A&A, 326, 709
Alzner, A., & Argyle, R. 2000, IAU Comm. 26 Inf. Circ., 142
Andersen, J. 1983, A&A, 118, 255
Andersen, J., Clausen, J. V., & Nordstrom, B. 1984, A&A, 134, 147
Andersen, J., & Gimenez, A. 1985, A&A, 145, 206
Andersen, J., Nordström, B., & Clausen, J. V. 1990, A&A, 228, 365
Appenzeller, I. 1967, PASP, 79, 102
Argyle, R. W., Alzner, A., & Horch, E. P. 2002, A&A, 384, 171
Aristidi, É., et al. 1999, A&AS, 134, 545
Bakiş, V., Budding, E., Erdem, A., Bakiş, H., Demircan, O., & Hadrava, P. 2006, MNRAS, 370, 1935
Bakos, G. A. 1985, J. R. Astron. Soc. Can., 79, 119
Balega, I. I., Balega, Yu. Yu., Hofmann, K.-H., Tokovinin, A. A., & Weigelt, G. 1999, SvAL, 25, 797
Bartkevičius, A., & Gudas, A. 2002, Baltic Astron., 11, 153
Batten, A. H. 1973, Binary and Multiple Systems of Stars (International Series of Monographs in Natural Philosophy, Vol. 51; Oxford: Pergamon)
Batten, A. H., & Fletcher, J. M. 1978, PASP, 90, 312
Batten, A. H., Fletcher, J. M., & MacCarthy, D. G. 1989, Publ. Dom. Astrophys. Obs. Victoria BC, 17, 1
Batten, A. H., Morbey, C. L., Fekel, F. C., & Tomkin, J. 1979, PASP, 91, 304
Brancewicz, H. K., & Dworak, T. Z. 1980, Acta Astron., 30, 501
Brettman, O. H., Fried, R. E., Duvall, W. M., Hall, D. S., Poe, C. H., & Shaw, J. S. 1983, Inf. Bull. Var. Stars, 2389, 1
Bruton, J. R., Hall, D. S., Boyd, L. J., Genet, R. M., & Lines, R. D. 1989, Ap&SS, 155, 27
Budding, E. 1984, Bull. Inf. Cent. Donnees Stellaires, 27, 91
Budding, E., Erdem, A., Çiçek, C., Bulut, I., Soydugan, F., Soydugan, E., Bakiş, V., & Demircan, O. 2004, A&A, 417, 263
Carrier, F., North, P., Udry, S., & Babel, J. 2002, A&A, 394, 151
Celikel, R., & Eryurt-Ezer, D. 1989, Ap&SS, 153, 213
Chamberlin, C., & McNamara, D. H. 1957, PASP, 69, 462
Chambliss, C. R. 1992, PASP, 104, 663
Chochol, D., et al. 2006, Ap&SS, 304, 93
Clausen, J. V., Gyldenkerne, K., & Gronbech, B. 1976, A&A, 46, 205
Cooper, H., & Hughes, D. W. 1994, Nature, 371, 30
Couteau, P. 1981, A&A, 43, 79
Cowley, A., & Fraquelli, D. 1974, PASP, 86, 70
Cutispoto, G., Kuerster, M., Messina, S., Rodono, M., & Tagliaferri, G. 1997, A&A, 320, 586
Cvetković, Z., Novaković, B., & Todorović, N. 2008, New Astron., 13, 125
Demers, H., Moffat, A. F. J., Marchenko, S. V., Gayley, K. G., & Morel, T. 2002, ApJ, 577, 409
Djurašević, G., Dimitrov, D., Arbutina, B., Albayrak, B., Selam, S. O., & Atanacković-Vukmanović, O. 2006, PASA, 23, 154
Docobo, J. A., & Andrade, M. 2005, IAU Comm. 26 Inf. Circ., 157
Docobo, J. A., & Andrade, M. 2006, ApJ, 652, 681
Docobo, J. A., & Ling, J. F. 2007, AJ, 133, 1209
Docobo, J. A., & Ling, J. F. 2008, IAU Comm. 26 Inf. Circ., 164
Drechsel, H., Lorenz, R., & Mayer, P. 1989, A&A, 221, 49
Duerbeck, H. W., & Rucinski, S. M. 2007, AJ, 133, 169
Eaton, J. A., & Henry, G. W. 2007, PASP, 119, 259
Edwards, T. W. 1976, AJ, 81, 245
Erdem, A., Soydugan, F., Doğru, S. S., Özkardeş, B., Doğru, D., Tüysüz, M., & Demircan, O. 2007, New Astron., 12, 613
Etzel, P. B., & Olson, E. C. 1985, AJ, 90, 504
Fehrenbach, C. 1961, J. Obs., 44, 233

Fekel, F. C., Henry, G. W., Hampton, M. L., Fried, R., & Morton, M. D. 1994, AJ, 108, 694
Ferrer, O. E., & Sahade, J. 1986, PASP, 98, 1342
Finsen, W. 1964, Rep. Ob. Johannesburg Circ., 7, 123
Frieboes, H. O. 1962, ApJ, 135, 762
Garcia, J. M., & Gimenez, A. 1986, Ap&SS, 125, 181
Gimenez, A., & Clausen, J. V. 1994, A&A, 291, 795
Giménez, A., Clausen, J. V., & Jensen, K. S. 1986, A&A, 159, 157
Ginestet, N., & Carquillat, J. M. 2002, ApJS, 143, 513
Gray, R. O., Corbally, C. J., Garrison, R. F., McFadden, M. T., Bubar, E. J., McGahee, C. E., O'Donoghue, A. A., & Knox, E. R. 2006, AJ, 132, 161
Grenier, S., et al. 1999, A&AS, 137, 451
Griffin, R. F. 1999, Observatory, 119, 27
Grosheva, E. A. 2006, Astrophysics, 49, 397
Guetter, H. H. 1968, PASP, 80, 197
Halbedel, E. M. 1985, PASP, 97, 434
Harmanec, P., & Scholz, G. 1993, A&A, 279, 131
Hartkopf, W. I., Mason, B. D., & McAlister, H. A. 1996, AJ, 111, 1
Harvin, J. A., Gies, D. R., Bagnuolo, W. G., Jr., Penny, L. R., & Thaller, M. L. 2002, ApJ, 565, 1216
Heintz, W. D. 1975, ApJS, 29, 315
Heintz, W. D. 1982, PASP, 94, 705
Helt, B. E. 1987, A&A, 172, 155
Herczeg, T., & Schmidt, H. 1960, Veroeffentlichungen Astron. Inst. Univ. Bonn, 57, 1
Hilditch, R. W. 2005, Observatory, 125, 72
Hill, G., Hilditch, R. W., Younger, F., & Fisher, W. A. 1975, MNRAS, 79, 131
Hill, G. M., Walker, G. A. H., Dinshaw, N., Yang, S., & Harmance, P. 1988, PASP, 100, 243
Hinderer, F. 1957, Astron. Nachr., 284, 1
Hoffleit, D., & Jaschek, C. 1982, The Bright Star Catalogue (4th ed.; New Haven, CT: Yale Univ. Observatory)
Holmgren, D. 1987, BAAS, 19, 709
Houk, N. 1978, Michigan Catalogue of Two-Dimensional Spectral Types for the HD Stars, Vol. 2 (Ann Arbor, MI: Univ. Michigan)
Houk, N. 1982, Michigan Catalogue of Two-Dimensional Spectral Types for the HD Stars, Vol. 3 (Ann Arbor, MI: Univ. Michigan)
Houk, N., & Cowley, A. P. 1975, Michigan Catalogue of Two-Dimensional Spectral Types for the HD Stars, Vol. 1 (Ann Arbor, MI: Univ. Michigan)
Houk, N., & Smith-Moore, M. 1988, Michigan Catalogue of Two-Dimensional Spectral Types for the HD Stars, Vol. 4 (Ann Arbor, MI: Univ. Michigan)
İbanoğlu, C., Çakirli, Ö., Değirmenci, Ö., Saygan, S., Ulaş, B., & Erkan, N. 2000, A&A, 354, 188
Irwin, J. B. 1959, AJ, 64, 149
Kaszas, G., Vinko, J., Szatmary, K., Hegedus, T., Gal, J., Kiss, L. L., & Borkovits, T. 1998, A&A, 331, 231
Kellerer, A., Petr-Gotzens, M. G., Kervella, P., & Coudé Du Foresto, V. 2007, A&A, 469, 633
Kopal, Z. 1978, Astrophysics and Space Science Library, Vol. 68 (Dordrecht: Reidel), 524
Kővári, Z., Bartus, J., Strassmeier, K. G., Oláh, K., Weber, M., Rice, J. B., & Washuettl, A. 2007, A&A, 463, 1071
Kreiner, J. M., Kim, C.-H., & Nha, I.-S. 2001, An Atlas of O-C Diagrams of Eclipsing Binary Stars, ed. Jerzy M. Kreiner, Chun-Hwey Kim, & Il-Seong Nha (Cracow, Poland: Wydawnictwo Naukowe Akademii Pedagogicznej)
Krylov, A. V., Mossakovskaya, L. V., Khaliullin, K. F., & Khaliullina, A. I. 2003, Astron. Rep., 47, 551
Kwee, K. K., & van Woerden, H. 1956, Bull. Astron. Inst. Neth., 12, 327
Labeyrie, A., Bonneau, D., Stachnik, R. V., & Gezari, D. Y. 1974, ApJ, 194, L147
Lacy, C. H., & Frueh, M. L. 1985, ApJ, 295, 569
Lacy, C. H. S., Helt, B. E., & Vaz, L. P. R. 1999, AJ, 117, 541
Lestrade, J.-F., Phillips, R. B., Hodges, M. W., & Preston, R. A. 1993, ApJ, 410, 808
Leung, K.-C., Moffat, A. F. J., & Seggewiss, W. 1979, ApJ, 231, 742
Leung, K.-C., & Schneider, D. P. 1978, AJ, 83, 618
Levato, H. 1975, A&AS, 19, 91
Lindroos, K. P. 1985, A&AS, 60, 183
Lindroos, K. P. 1986, A&A, 156, 223
Lippky, B., & Marx, S. 1994, Astron. Ges., Abstr. Ser., 10, 151
Lorenz, R., Mayer, P., & Drechsel, H. 1998, A&A, 332, 909
Lu, W.-X., & Rucinski, S. M. 1993, AJ, 106, 361
Lu, W., Rucinski, S. M., & Ogłoza, W. 2001, AJ, 122, 402
Malaroda, S. 1975, AJ, 80, 637
Malkov, O. Y., Oblak, E., Snegireva, E. A., & Torra, J. 2006, A&A, 446, 785
Mason, B. D., & Hartkopf, W. I. 1999, IAU Comm. 26 Inf. Circ., 138
Mason, B. D., Wycoff, G. L., Hartkopf, W. I., Douglass, G. G., & Worley, C. E. 2001, AJ, 122, 3466
Massarotti, A., Latham, D. W., Stefanik, R. P., & Fogel, J. 2008, AJ, 135, 209
Mayer, P. 1990, Bull. Astron. Inst. Czech., 41, 231
Mayer, P. 1997, A&A, 324, 988
Mayer, P. 2004, in ASP Conf. Ser. 318, in Spectroscopically and Spatially Resolving the Components of the Close Binary Stars, ed. R. W. Hilditch, H. Hensberge, & K. Pavlovski (San Francisco, CA: ASP), 233
Mayer, P., Lorenz, R., & Drechsel, H. 1992, Inf. Bull. Var. Stars, 3765, 1
McAlister, H. A., Hendry, E. M., Hartkopf, W. I., Campbell, B. G., & Fekel, F. C. 1983, ApJS, 51, 309
Morgan, W. W., Code, A. D., & Whitford, A. E. 1955, ApJS, 2, 41
Murdoch, K. A., Hearnshaw, J. B., Kilmartin, P. M., & Gilmore, A. C. 1994, Exp. Astron., 5, 195
Murdoch, K. A., Hearnshaw, J. B., Kilmartin, P. M., & Gilmore, A. C. 1995, MNRAS, 276, 836
Muterspaugh, M. W., Lane, B. F., Konacki, M., Burke, B. F., Colavita, M. M., Kulkarni, S. R., & Shao, M. 2006, A&A, 446, 723
Muterspaugh, M. W., et al. 2008, AJ, 135, 766
Newburg, J. L. 1969, Rep. Obs. Johannesburg Circ., 7, 190
Olević, D. 2002, IAU Comm. 26 Inf. Circ., 147
Olsen, E. H. 1972, A&A, 20, 167
Olson, E. C. 1982, ApJ, 257, 198
Otero, S. A. 2007, Open Eur. J. Var. Stars, 72, 1
Otero, S. A., Fieseler, P. D., & Lloyd, C. 2000, Inf. Bull. Var. Stars, 4999, 1
Pagel, B. E. J. 1960, AJ, 65, 352
Pan, X., Shao, M., & Colavita, M. M. 1993, ApJ, 413, L129
Parsons, S. B. 2004, AJ, 127, 2915
Pavlovski, K., Harmanec, P., Bozic, H., Koubsky, P., Hadrava, P., Kriiz, S., Ruzic, Z., & Stefl, S. 1997, A&AS, 125, 75
Pavlovski, K., Schneider, H., & Akan, M. C. 1992, A&A, 258, 329
Perryman, M. A. C., ESA 1997, The *HIPPARCOS* and *TYCHO* catalogues, (Astrometric and Photometric Star Catalogues Derived from the ESA Hipparcos Space Astrometry Mission; ESA SP Series 1200; Noordwijk: ESA Publications)
Petrie, R. M. 1950, Publ. Dom. Astrophys. Obs. Victoria BC, 8, 319
Plavec, M. J. 1983, ApJ, 275, 251
Plavec, M. J., Weiland, J. L., & Koch, R. H. 1982, ApJ, 256, 206
Polidan, R. S., & Plavec, M. J. 1984, AJ, 89, 1721
Popović, G. M., & Pavlović, R. 1995, Bull. Astron. Belgrade, 151, 45
Popper, D. M. 1957, ApJ, 126, 53
Popper, D. M. 1981, PASP, 93, 318
Popper, D. M. 1986, PASP, 98, 1312
Pribulla, T., et al. 2006, AJ, 132, 769
Proust, D., Ochsenbein, F., & Pettersen, B. R. 1981, A&AS, 44, 179
Pych, W., et al. 2004, AJ, 127, 1712
Reglero, V., Fernandez-Figuerora, M. J., Gimenez, A., de Castro, E., Fabregat, J., Cornide, M., & Armentia, J. E. 1991, A&AS, 88, 545
Ribas, I., Jordi, C., & Torra, J. 1999, MNRAS, 309, 199
Roberts, L. C., Jr., et al. 2005, AJ, 130, 2262
Rucinski, S. M., Lu, W., Capobianco, C. C., Mochnacki, S. W., Blake, R. M., Thomson, J. R., Ogłoza, W., & Stachowski, G. 2002, AJ, 124, 1738
Rucinski, S. M., Lu, W.-X., & Shi, J. 1993, AJ, 106, 1174
Rucinski, S. M., Pribulla, T., & van Kerkwijk, M. H. 2007, AJ, 134, 2353
Rucinski, S. M., et al. 2008, AJ, 136, 586
Samec, R. G., Fuller, R. E., & Kaitchuck, R. H. 1989, AJ, 97, 1159
Samus, N. N., et al. 2004, VizieR Online Data Catalog, 2250, 0
Sarma, M. B. K., & Radharkrishnan, K. R. 1982, Inf. Bull. Var. Stars, 2073, 1
Schröder, C., & Schmitt, J. H. M. M. 2007, A&A, 475, 677
Seymour, D. 2001, IAU Comm. 26 Inf. Circ., 145
Seymour, D. M., Mason, B. D., Hartkopf, W. I., & Wycoff, G. L. 2002, AJ, 123, 1023
Shobbrook, R. R. 2005, J. Astron. Data, 11, 7
Simonson, S. C. I. 1968, ApJ, 154, 923
Söderhjelm, S. 1999, A&A, 341, 121
Stebbins, J. 1910, ApJ, 32, 185
Stephenson, C. B. 1960, AJ, 65, 60
Sterken, C. 2005, in ASP Conf. Ser. 335, The Light-Time Effect in Astrophysics: Causes and Cures of the $O - C$ Diagram, ed. C. Sterken (San Francisco, CA: ASP), 335
Stickland, D. J., Lloyd, C., & Sweet, I. 1998, Observatory, 118, 7
Strohmeier, W. 1959, Astron. Nachr., 285, 87
Svechnikov, M. A., & Kuznetsova, E. F. 1990, Katalog Priblizhennykh Fotometricheskikh i Absoliutnykh Elementov Zatmennykh Peremennykh Zvezd (Sverdlovsk: Izd-vo Ural'skogo Universiteta)
Tikkanen, K. 2002, BBSAG, 125, 1

Tokovinin, A. A. 1997, A&AS, 124, 75
Tokovinin, A. A. 1998, Astron. Lett., 24, 288
Tokovinin, A. A., Chalabaev, A., Shatsky, N. I., & Beuzit, J. L. 1999, A&A, 346, 481
Tokovinin, A. A., Thomas, S., Sterzik, M., & Udry, S. 2006, A&A, 450, 681
Tomkin, J. 1992, ApJ, 387, 631
Torres, G. 2001, AJ, 121, 2227
van Hamme, W. V., et al. 1994, AJ, 107, 1521
van Leeuwen, F., & van Genderen, A. M. 1997, A&A, 327, 1070
Vaz, L. P. R., & Andersen, J. 1984, A&A, 132, 219
Walborn, N. R. 1973a, AJ, 78, 1067
Walborn, N. R. 1973b, ApJ, 179, 517
Walker, R. L., & Chambliss, C. R. 1985, AJ, 90, 346
Watson, L. C., Pritchard, J. D., Hearnshaw, J. B., Kilmartin, P. M., & Gilmore, A. C. 2001, MNRAS, 325, 143
Wolf, M. 2000, A&A, 356, 134
Wolf, G. W., & Caffey, J. F. 1998, Inf. Bull. Var. Stars, 4649, 1
Wolf, M., Zejda, M., & de Villiers, S. N. 2008, MNRAS, 388, 1836
Wolf, M., et al. 2006, A&A, 456, 1077
Woodward, E. J., & Koch, R. H. 1987, Ap&SS, 129, 187
Yakut, K., Kalomeni, B., & İbanoğlu, C. 2004, A&A, 417, 725
Zaera, J. A. 1985, IAU Comm. 26 Inf. Circ., 96
Zasche, P. 2008, arXiv:0801.4258
Zasche, P., & Svoboda, P. 2008, Inf. Bull. Var. Stars, 5827, 1
Zasche, P., & Wolf, M. 2007, Astron. Nachr., 328, 928
Zejda, M., Mikulášek, Z., & Wolf, M. 2008, A&A, 489, 321
Zhang, L.-Y., & Gu, S.-H. 2008, A&A, 487, 709