A&A 416, 1097–1105 (2004)
DOI: 10.1051/0004-6361:20034578

Astronomy
&
Astrophysics

Key parameters of W UMa-type contact binaries discovered by *HIPPARCOS*[⋆]

S. O. Selam[⋆⋆]

Ankara University, Faculty of Science, Dept. of Astronomy & Space Sciences, 06100 Ankara, Turkey

Received 25 October 2003 / Accepted 10 December 2003

Abstract. A sample of W UMa-type binaries which were discovered by the *HIPPARCOS* satellite was constructed with the aid of well defined selection criteria described in this work. The selection process showed up that several systems of which the variability types have been assigned as EB in *HIPPARCOS* catalogue are genuine contact binaries of W UMa-type. The light curves of the 64 selected systems based on *HIPPARCOS* photometry were analyzed with the aid of light curve synthesis method by Rucinski and their geometric elements (namely mass ratio q, degree of contact f, and orbital inclination i) were determined. The solutions were obtained for the first time for many of the systems in the sample and would be a good source for their future light curve analyses based on more precise follow-up observations.

Key words. stars: binaries: close – stars: binaries: eclipsing

1. Introduction

W UMa-type systems are eclipsing binaries with orbital periods between about 5 and 20 h showing continuous light variations. They consist of two solar-type component stars surrounded by a common envelope. There is a large scale energy transfer from larger, more massive component to the smaller, less massive one, roughly equalizing surface temperatures over the entire system. The equality of the effective temperatures of both components is one of the discriminating characteristics of the contact binaries of W UMa-type; it was initially one of the most difficult properties to explain and led to development of the successful *"contact model"* by Lucy (1968). The components of W UMa-type systems are rotating relatively fast (equatorial velocities of 100–200 km s^{-1}) in spite of their old ages. This is the natural consequence of spin-orbit synchronization due to strong tidal interactions between the components. W UMa-type systems have the least amount of angular momentum that binary stars can have and therefore they attract special attention as laboratories to test the angular momentum evolution of binary stars. Several reviews have discussed properties of W UMa-type systems; the recent ones, concentrating respectively on theoretical and observational issues, have been published by Eggleton (1996) and by Rucinski (1993a). A very recent catalogue of field contact binaries which have been compiled by Pribulla et al. (2003) is a good source for their physical parameters.

This paper is concentrating on the determination of essential (key) parameters (namely mass ratio q, degree of contact f, and orbital inclination i) of W UMa-type systems discovered photometrically by *HIPPARCOS* satellite. The main aim of this work is to provide preliminary set of parameters of these system which can be used as input parameters in their analyses of future more precise light curves based on follow-up observations.

Initially 79 such systems were extracted from the *HIPPARCOS* Catalogue (ESA 1997, hereafter HIP) according to the selection criteria described in Sect. 2 and their numbers have been reduced to 64 genuine contact binaries of W UMa-type after excluding the detached and semi-detached systems according to the "Fourier filter" described in Sect. 2. The light curves of these 64 systems based on *HIPPARCOS* photometry (data extracted from the Epoch Photometry Annex of HIP[1]) were analyzed with the aid of simplified light curve synthesis method by Rucinski (1993b). Section 3 of the paper describes the application of the Rucinski's method and analysis of the selected systems, and finally Sect. 4 is devoted to the summary and discussion.

2. Selection of the systems

W UMa-type systems discovered photometrically by *HIPPARCOS* satellite were extracted from the Variability Annex of HIP (hereafter HIPVA) according to the selection criteria itemized below:

- variability types EW (W UMa-type systems), EB (β Lyr-type systems), E, EW?, EB? and E? in the field P5 of HIPVA,
- having * flag in the field P2 of the HIPVA indicates that the object has been newly-classified as variable during the *HIPPARCOS* mission,

---

[⋆] Based on observations made with the ESA *HIPPARCOS* astrometry satellite.

[⋆⋆] e-mail: `selim@astro1.science.ankara.edu.tr`

[1] `http://astro.estec.esa.nl/Hipparcos/apps/PlotCurve.html`

- spectral type between A5 and K9 in the field P3 of HIPVA,
- variability period less than 1 day in the field P11 of HIPVA.

The systems filtered with the above criteria are listed in Table 1. The columns are explained at the bottom of Table 1 which their entries for the first six were mostly extracted from HIPVA. The systems, CC Lyn, FH Cam and CU CVn which are fullfilling the above described criteria have been identified in HIP as EB type systems, but Rucinski and his collaborators have shown that they are pulsating variables (Rucinski 2002) and therefore they were excluded form the current sample list. On the contrary, 7 systems, incluled to the current sample list have been identified as pulsating variables in HIP and later have been proven by different authors that they are genuine contact binaries. These systems are FI Boo (Lu et al. 2001), HI Dra and V351 Peg (Gomez-Forrellad et al. 1999), ET Leo (Rucinski et al. 2002), V2357 Oph (Rucinski et al. 2003), HH UMa (Pribulla et al. 2003), and NN Vir (Rucinski & Lu 1999). Their light elements (namely T_0 and P) and variability types were updated accordingly and marked with an explanatory $^{\rm b}$ footnote in Table 1. Two exceptions, DN Cam and IS CMa which are not being *HIPPARCOS* project discoveries were also included to the current sample, because they are neglected systems after their photometric discoveries (DN Cam by Strohmeier 1959 and IS CMa by Strohmeier & Knigge 1974). Several systems in the current sample were already observed and analysed spectroscopically or photometrically by different authors (see the references in last column in Table 1). These systems were also kept in the sample list for comparing their results with the parameters obtained in this study.

There is a number of low-amplitude short-period ($P <$ 1 day) variables of which their variability types are unknown and denoted only by "*P*" in HIPVA. These objects might be pulsating variables of low amplitude of types RRC, DSCT/DSCTC, or BCEP, as well as close binaries of types EW, EB, or EA seen at very low inclination angles (i.e., ELL-type). Duerbeck (1997) presented a method to discriminate the possible contact binaries among them based on the known period-colour relation for W UMa-type systems by Rucinski (1993a) and Rucinski & Duerbeck (1997). He showed that a polygon through the bluest confirmed contact binaries on $\log P-(B-V)$ plane could be used as the borderline between bluer pulsating variables and redder contact binaries for a given period. However, he noted that the sample of contact binary candidates separated in that way still may be contaminated by pulsating stars, since the RRC-type stars extend to relatively redder colours and longer periods. The working list of contact binary candidates of Duerbeck (1997) still waiting for spectroscopic or photometric verification (except FI Boo, ET Leo, V2357 Oph, and HH UMa as explained above) and therefore not considered in this study.

The literature on several systems in the current sample have shown that the HIP variability types are rather unreliable especially for the type EB. This was particularly so for the large number of small-amplitude systems called EB in HIP, most probably by some sort of an automated classifier. Of course, these could in fact be EW or EB binaries seen at small orbital inclination angles, but the tendency to call all variables EB seemed to increase for small amplitudes, exactly in the case where nothing can be said just from the shape of the light curve. On the other hand some EB-type system in HIP with deep unequal eclipses could be semi-detached or even detached systems. The most frequently occuring short-period EB objects appear to be binaries either just before establishing contact or in one of the broken-contact semi-detached stages, in any case, prior to the mass ratio reversal, with the more massive component close to or at its critical Roche surface. The distinction between EW and EB class in individual cases is frequently difficult and both types are evolutionary related to each other. This is the reason why EB systems in HIP were also included to the sample by the first selection criterion given above. So the filtered sample according to the above selection criteria should be clarified for variability type ambiguitiy.

Several among the systems in the sample have speckle interferometry, close visual or spectroscopic companions which are listed with their CCDM (Catalogue of Components of Double and Multiple Stars, Dommanget & Nys 2002) identifiers in Table 1. The observations of these systems maybe contaminated by the third light, due to the rather large instantaneous field of view of the detector of *HIPPARCOS* satellite (see Fig. 1.4.2 of HIP, Vol. 1, p. 78). This information can be easily retrieved by checking H48 field entry of HIP for an individual system. According to the entries in this field, the *HIPPARCOS* photometry of V410 Aur, ET Boo, V776 Cas, CT Cet, EE Cet, KR Com, V2150 Cyg, QW Gem, CN Hyi, V592 Per, BL Phe, VW Pic, V1055 Sco, V1123 Tau, HX UMa, II UMa, and LV Vir are contaminated by the light from their close companions. The H48 field in HIP for the systems HI Dra, IR Lib and V2388 Oph is empty and probably they can not be resolved or identified as multiple systems by the *HIPPARCOS* satellite. By looking at their astrometric data (separations between the visual components) in the CCDM catalog it was decided that their *HIPPARCOS* photometry are also contaminated by the third light, because, mostly the combined photometry of the components have been given in the HIP for the doubles with separations up to about $10''$. PU Peg, V1128 Tau and QW Tel are far enough from their visual companions and therefore it was assumed that their *HIPPARCOS* photometry was not affected by the third light. The separate $H_{\rm p}$ magnitudes of the visual components were taken from the *HIPPARCOS* Double and Multiple System Annex and the third light parameter L_3 in light units were calculated for the most of contaminated systems. Separate $H_{\rm p}$ magnitudes for HI Dra and IR Lib is absent in the *HIPPARCOS* Double and Multiple System Annex and their relevant data were taken from CCDM Catalog. For some systems the L_3 parameter were prefered to be taken from the recent literature which are mostly based on more precise spectroscopic determinations. These systems are EE Cet, KR Com, V2388 Oph and II UMa (Rucinski et al. 2002), V899 Her (Özdemir et al. 2002), and VW Pic (Rucinski 2002). The calculated or collected L_3 parameters for the contaminated systems were also listed in Table 1. The *HIPPARCOS* photometry of the contaminated systems have been corrected for the third light contribution by using these L_3 parameters, before any attempt to analyse their light curves.

Table 1. Systems filtered from *HIPPARCOS* Catalog with the first selection criteria described in Sect. 2.

Var Name (1)	HIP (2)	P(days) (3)	T_0-2 400 000 (4)	Type (5)	Sp (6)	CCDM no (7)	$\rho('')$ (8)	L_3 (9)	a_1 (10)	a_2 (11)	a_4 (12)	$\Sigma(\mathrm{O-C})^2$ (13)	EX (14)	Ref.* (15)
V851 Ara	083802	0.617372	48500.2098	EB	A7III				−0.007(1)	−0.021(1)	−0.000(1)	0.002		1
V870 Ara	088853	0.39978	48500.1840	EW	F8				−0.017(6)	−0.153(6)	−0.017(5)	0.058		1
V410 Aur	023337	0.36634	48500.1760	EW^{a}	G0/2V^{a}	J05012+3430A	1.699	0.277	−0.015(5)	−0.187(5)	−0.025(5)	0.025		1, 33
EF Boo	071107	0.420512	48500.3018	EW^{a}	F5+lateG:^{a}				−0.011(3)	−0.180(3)	−0.044(3)	0.034		1, 5, 9, 10, 11
ET Boo	073346	0.645046	48500.4420	EB	F8	J14593+4649A	0.22	0.311	−0.025(3)	−0.137(4)	−0.066(3)	0.054	EA	1, 36
FI Boo	075203	0.389998^{b}	51718.3951^{b}	EW^{a}	G3V^{a}				−0.012(1)	−0.047(1)	−0.002(1)	0.063		1, 7
FP Boo	076970	0.640487	48500.4780	EB	A5				−0.001(3)	−0.090(3)	−0.014(3)	0.022		1
RT Cae	020665	0.640604	48500.3581	EB?	F2V				−0.006(2)	−0.080(2)	−0.009(2)	0.027		1
DN Cam	021913	0.498312	48500.4880	EW^{a}	F2V:^{a}				−0.014(2)	−0.174(2)	−0.027(2)	0.047		5, 29, 30
FN Cam	046005	0.677128	48500.4270	EW	A9,F2^{a}				+0.005(2)	−0.162(2)	−0.015(2)	0.023		1, 5, 6
BF Cap	100107	0.532676	48500.0260	EB	F0V				−0.020(2)	−0.116(2)	−0.013(2)	0.010	EB	1
V776 Cas	008821	0.440413	48500.0775	EW^{a}	F2V^{a}	J01534+7003A	5.383	0.136	+0.000(2)	−0.073(2)	−0.001(2)	0.028		1, 3, 5, 35
V901 Cen	054865	0.354929	48500.1555	EW?	Fp				+0.008(4)	−0.151(6)	−0.024(5)	0.053		1
CK Cet	001808	0.767323	48500.5220	EB	A8/A9V				−0.044(3)	−0.082(3)	−0.027(3)	0.010	EA	1
CT Cet	005452	0.2564863	48500.1847	EW	G8/K0V	J01098-2013A	3.576	0.325	−0.010(5)	−0.108(5)	−0.011(4)	0.009		1
DY Cet	012311	0.440794	48500.2510	EW	F5V				+0.000(4)	−0.190(4)	−0.043(4)	0.014		1
EE Cet	013199	0.379917	48500.1940	EW	F8V^{a}	J02499+0856B	5.656	0.517	−0.003(8)	−0.194(9)	−0.046(8)	0.047		1, 25
IQ CMa	029474	0.731384	48500.1684	EB	A8V				−0.055(1)	−0.077(1)	−0.038(1)	0.052	EA	1
IS CMa	030174	0.616982	48500.3590	EW	F3V				+0.005(1)	−0.170(1)	−0.029(1)	0.015		1, 32
KR Com	065069	0.407968	48500.2121	EW^{a}	G0IV^{a}	J13203+1746A	0.136	0.359	+0.000(3)	−0.048(3)	−0.005(3)	0.022		1, 25
V711 CrA	088517	0.700892	48500.5170	EB	F3V				−0.006(2)	−0.121(2)	−0.019(2)	0.020		1
YY CrB	077598	0.376565	48500.2960	EW	F8V^{a}				−0.000(2)	−0.181(2)	−0.039(2)	0.035		1, 4, 12, 14, 15, 16, 17, 26
V2150 Cyg	105162	0.591856	48500.4340	EW	A6V^{a}	J21182+3035A	3.677	0.044	−0.001(1)	−0.054(1)	+0.002(1)	0.013		1, 7, 31
AP Dor	023793	0.427187	48500.3200	EW	F8III				−0.004(3)	−0.090(3)	−0.006(3)	0.015		1, 2
FU Dra	076272	0.306718	48500.2630	EW	F8V^{a}				−0.019(3)	−0.170(3)	−0.047(3)	0.028		1, 4, 13
GM Dra	084837	0.338736	48500.1791	EW^{a}	F5V^{a}				−0.006(3)	−0.097(3)	−0.003(3)	0.015		1, 20, 25
HI Dra	090972	0.597417^{b}	48500.3186^{b}	EW^{a}	F8	J18334+5842A	10.5	0.006	−0.008(2)	−0.072(2)	−0.003(2)	0.017		1, 3
HL Dra	091052	0.944276	48500.1890	EB	A5				−0.041(1)	−0.079(1)	−0.022(1)	0.004	EA	1
FP Eri	013475	0.335270	48500.1470	EB?	G0				+0.001(2)	−0.050(2)	−0.015(2)	0.020	EA	1
FX Eri	016864	0.292345	48500.1130	EW	-				−0.003(4)	−0.088(4)	−0.009(4)	0.081		1
QW Gem	032845	0.358127	48500.3060	EW^{a}	F8V^{a}	J06508+2927A	6.377	0.256	−0.014(4)	−0.187(6)	−0.034(5)	0.005		1, 33
V899 Her	081191	0.421173	48500.1360	EW^{a}	F5^{a}	Sp-triple		0.663	−0.004(1)	−0.163(1)	−0.025(1)	0.154		1, 7, 18, 19
V921 Her	082344	0.877366	48500.1250	EW^{a}	A7IV^{a}				−0.001(2)	−0.125(2)	−0.021(2)	0.024		1, 33
V972 Her	087958	0.443094	48500.0640	EW^{a}	F4V^{a}				−0.003(1)	−0.031(1)	−0.002(1)	0.004		1, 17, 25
WY Hor	011934	0.398940	48500.2210	EW	G2IV/V				−0.012(3)	−0.069(3)	+0.008(3)	0.025		1
QY Hya	059259	0.292339	48500.2490	EB	K2V				−0.023(4)	−0.102(4)	−0.028(4)	0.031	EA	1
V356 Hya	071077	0.911834	48500.0361	EB	A6IV				−0.007(1)	−0.036(1)	−0.015(1)	0.001	EA	1
CN Hyi	012884	0.456107	48500.0950	EW	F6V	J02456-7114A	0.512	0.030	−0.002(1)	−0.102(1)	−0.007(1)	0.006		1
CP Hyi	013999	0.479406	48500.2256	EW	F0V				−0.002(3)	−0.065(3)	−0.010(3)	0.007		1
BS Ind	105404	0.435338	48500.2625	EB	K0V				−0.041(4)	−0.056(4)	−0.031(4)	0.078	EA	1
ET Leo	051667	0.346503^{b}	51990.9912^{b}	EW^{a}	G8V^{a}				+0.001(2)	−0.048(2)	−0.003(2)	0.059		1, 3, 25, 35
EX Leo	052580	0.408604	48500.0080	EW^{a}	F6V^{a}				−0.002(3)	−0.094(3)	−0.007(2)	0.011		1, 6, 7
IR Lib	075836	0.2743688	48500.2223	EB	K0IV:+(G)	J15294-2851A	1.0	0.025	−0.004(2)	−0.048(3)	+0.002(2)	0.005		1
VW LMi	054003	0.477547	48500.1960	EW	F3V				+0.005(4)	−0.145(4)	−0.024(4)	0.027		1, 8
CW Lyn	042554	0.812389	48500.4570	EB	F2				−0.001(3)	−0.097(3)	−0.013(3)	0.015		1
V753 Mon	034684	0.677049	48500.2213	EW	A8V^{a}				−0.002(2)	−0.169(3)	−0.047(2)	0.014		1, 4

The photometric observations (H_p magnitudes) along with their standard errors (σ_{H_p}) for these system were taken from the Epoch Photometry Annex of HIP (hereafter HIPEPA) and the relevant light curves are constructed using the light elements (T_0, P) given in Table 1. Only the H_p magnitudes having 0 (zero) and 1 (one) quality flag in the field HT4 of HIPEPA were used in this study. The final classification and selection (namely clarifiying the variability type ambiguity) of the objects listed in Table 1 have been done by performing the Fourier analysis of their *HIPPARCOS* light curves in the same way as described originally by Rucinski (1997a, 1997b, 2002). This "Fourier filter" technique is depending on relations between some Fourier coefficients obtained by least-squares fits to the light curves which were normalized to unity at orbital quadratures (i.e., phases $\theta_{\mathrm{maxI}} = 0.25$ or $\theta_{\mathrm{maxII}} = 0.75$) and eliminated from the third light contribution if it is necessary. Normalization of the light curves were always made to the higher maxima in this study as suggested by Rucinski (1993b). The fit function;

$$l(\theta) = \sum_{i=0}^{10} a_i \cos(2\pi i\theta) \tag{1}$$

is a cosine series with 11 coefficients where a_i, θ and $l(\theta)$ are denoting the Fourier coefficients, the orbital phase and normalized light in light units, respectively. This is the same fit function forming the basis of the Rucinski's simplified light curve synthesis method (Rucinski 1993b) which was used during the light curve analysis in this work. Figure 1 illustrates a typical Fourier fit for the system V2388 Oph. Only the resulting Fourier coefficients a_1, a_2 and a_4 were listed in Table 1 which are necessary for "Fourier filter" and light curve analyses. Their

Table 1. continued.

Var Name (1)	HIP (2)	P(days) (3)	T_0-2 400 000 (4)	Type (5)	Sp (6)	CCDM no (7)	$\rho('')$ (8)	L_3 (9)	a_1 (10)	a_2 (11)	a_4 (12)	$\Sigma(\mathrm{O-C})^2$ (13)	EX (14)	Ref.* (15)
V2357 Oph	082967	0.415568^b	52050.2364^b	EW^a	G5V^a				+0.005(4)	−0.053(4)	−0.001(4)	0.021		1, 33
V2377 Oph	085944	0.425401	48500.0316	EW^a	G0/1V^a				−0.011(2)	−0.055(2)	+0.001(1)	0.010		1, 7
V2388 Oph	087655	0.802298	48500.1200	EW^a	F3V^a	J17542+1108A	0.088	0.167	−0.011(1)	−0.126(1)	−0.016(1)	0.010		1, 21, 23, 25
V1363 Ori	023809	0.431915	48500.0343	EW?	F8				+0.007(5)	−0.076(4)	−0.003(4)	0.019		1, 3
V386 Pav	103320	0.551841	48500.2722	EW	A9V				−0.006(1)	−0.049(1)	−0.000(1)	0.042		1
PU Peg	110464	0.862023	48500.0487	EB	F0	J22226+0956A	91	−−	−0.008(1)	−0.041(1)	+0.003(1)	0.013		1, 3
V335 Peg	112960	0.810746	48500.3591	E	F5				−0.010(1)	−0.014(1)	−0.001(1)	0.004		1
V351 Peg	115627	0.593297^b	48500.4930^b	EW^a	A8V^a				−0.008(2)	−0.122(2)	−0.015(2)	0.004		1, 3, 5
V357 Peg	117185	0.578452	48500.3159	EW	F5				+0.006(2)	−0.163(2)	−0.030(2)	0.012		1, 17, 22, 24, 35
V592 Per	022050	0.715722	48500.2430	EB	F2	J04445+3953A	0.206	0.314	−0.009(9)	−0.174(8)	−0.028(9)	0.026		1
BL Phe	000883	0.810352	48500.3370	EB	F6IV/V	J00108-5729A	3.21	0.336	−0.064(2)	−0.134(2)	−0.044(2)	0.032	EA	1
BM Phe	001507	0.413627	48500.2010	EW	F3/F5V				−0.002(2)	−0.103(3)	−0.010(3)	0.036		1
VW Pic	023196	0.4257631	48500.0070	EB	F3V	J04595-4928A	9.887	0.138	+0.000(1)	−0.046(1)	−0.010(1)	0.010	EA	1
XY Pic	027170	0.2972608	48500.1131	EB?	F0III/IV				+0.000(1)	−0.021(1)	+0.002(1)	0.005		1
CP Psc	004593	0.684014	48500.4656	EB?	–				−0.029(5)	−0.064(5)	−0.036(5)	0.042	EA	1
VY PsA	109884	0.633889	48500.5510	EB	F3V				−0.019(1)	−0.059(2)	−0.011(2)	0.005	EA	1
BD Scl	002550	0.566287	48500.5040	EB	F2				−0.048(4)	−0.090(4)	−0.007(4)	0.013	EB	1
BE Scl	006350	0.422901	48500.2670	EW	F8				−0.010(3)	−0.149(3)	−0.026(3)	0.054		1
V1055 Sco	080603	0.363673	48500.2734	EB	G3V	J16274-3729A	0.2	0.420	−0.028(4)	−0.176(3)	−0.050(4)	0.034	EB	1
OU Ser	075269	0.2967645	48500.2780	EW	F9/G0V$^{\mathrm{a}}$				−0.002(2)	−0.076(2)	−0.007(2)	0.030		1, 4, 12, 31
V1123 Tau	016706	0.399957	48500.3570	EB	G0	J03350+1743A	4.268	0.169	−0.010(3)	−0.161(3)	−0.032(4)	0.030		1
V1128 Tau	017878	0.3053732	48500.0620	EB	G0	J03495+1255A	12.09	−−	−0.015(5)	−0.173(4)	−0.038(5)	0.035		1
QW Tel	090026	0.411928	48500.1940	EB	F8/G0	J18222-5534A	31.1	−−	−0.010(3)	−0.061(3)	−0.003(3)	0.012		1
DX Tuc	118096	0.377111	48500.2540	EW	F7IV/V				−0.003(4)	−0.112(4)	−0.019(4)	0.097		1
HH UMa	054165	0.3754937^b	52368.3979^b	EW^a	F8				+0.003(3)	−0.075(4)	−0.006(4)	0.024		1, 37
HN UMa	055030	0.382608	48500.0781	EW^a	F8V^a				−0.000(2)	−0.047(2)	−0.004(2)	0.008		1, 33
HX UMa	058648	0.379156	48500.3720	EW^a	F4V^a	J12021+4304A	0.626	0.045	−0.003(2)	−0.076(2)	−0.004(2)	0.042		1, 33
II UMa	061237	0.82522	48500.0830	EW	F5III^a	J12329+5448A	0.872	0.145	−0.001(2)	−0.139(2)	−0.013(2)	0.042		1, 25
TV UMi	073474	0.415546	48500.2744	EB	F8				−0.006(1)	−0.034(1)	−0.002(1)	0.003		1, 34
V362 Vel	054112	0.445177	48500.2560	EB	F3V				−0.002(2)	−0.104(2)	−0.015(2)	0.100		1
LV Vir	066078	0.409439	48500.1744	EB	F6V	J13328-1746A	1.181	0.413	−0.001(3)	−0.121(3)	−0.002(3)	0.012		1
MS Vir	068881	0.312440	48500.1960	EB	K0/K1III/IV				−0.020(7)	−0.095(6)	−0.002(6)	0.042		1
NN Vir	070020	0.480690^b	50595.3452^b	EW^a	F0/1V^a				+0.004(5)	−0.147(4)	−0.011(4)	0.024		1, 27, 28
DX Tuc	118096	0.377111	48500.2540	EW	F7IV/V				−0.003(4)	−0.112(4)	−0.019(4)	0.097		1
HH UMa	054165	0.3754937^b	52368.3979^b	EW^a	F8				+0.003(3)	−0.075(4)	−0.006(4)	0.024		1, 37
HN UMa	055030	0.382608	48500.0781	EW^a	F8V^a				−0.000(2)	−0.047(2)	−0.004(2)	0.008		1, 33
HX UMa	058648	0.379156	48500.3720	EW^a	F4V^a	J12021+4304A	0.626	0.045	−0.003(2)	−0.076(2)	−0.004(2)	0.042		1, 33
II UMa	061237	0.82522	48500.0830	EW	F5III^a	J12329+5448A	0.872	0.145	−0.001(2)	−0.139(2)	−0.013(2)	0.042		1, 25
TV UMi	073474	0.415546	48500.2744	EB	F8				−0.006(1)	−0.034(1)	−0.002(1)	0.003		1, 34
V362 Vel	054112	0.445177	48500.2560	EB	F3V				−0.002(2)	−0.104(2)	−0.015(2)	0.100		1
LV Vir	066078	0.409439	48500.1744	EB	F6V	J13328-1746A	1.181	0.413	−0.001(3)	−0.121(3)	−0.002(3)	0.012		1
MS Vir	068881	0.312440	48500.1960	EB	K0/K1III/IV				−0.020(7)	−0.095(6)	−0.002(6)	0.042		1
NN Vir	070020	0.480690^b	50595.3452^b	EW^a	F0/1V^a				+0.004(5)	−0.147(4)	−0.011(4)	0.024		1, 27, 28

Note : Columns: (1) Name of the variable; (2) *HIPPARCOS* identifier; (3) variability period in days; (4) Epoch in HJD for the systems marked with ^{b} and in BJD for the remaining; (5) variability type; (6) spectral type; (7) CCDM identifier for systems with close visual or spectroscopic companions (Catalogue of Components of Double and Multiple Stars, Dommanget & Nys 2002); (8) separation between the visual or spectroscopic components in arcseconds; (9) third light contribution from the visual or spectroscopic component in light units; (10)–(12) the Fourier cosine coefficients in light units obtained by Fourier decomposition of the light curves, the numbers in parentheses are standard errors in units of last decimal places; (13) Sum of squared residuals for the Fourier fits as a goodness of fit parameter; (14) Systems excluded among the genuine W UMa-type systems by "Fourier filter" as described in text, EA = detached systems eliminated by $a_2 - a_4$ filter, EB = β Lyr-type systems eliminated by $a_2 - a_1$ filter; (15) coded key references on the literature for the corresponding system.

[*] 1. Kazarovets et al. (1999), 2. Eggen (1980), 3. Gomez-Forrellad et al. (1999), 4. Rucinski et al. (2000), 5. Rucinski et al. (2001), 6. Pribulla et al. (2002), 7. Lu et al. (2001), 8. Dumitrescu (2000), 9. Özdemir et al. (2001a), 10. Gothard et al. (2000), 11. Samec et al. (1999), 12. Pribulla & Vanko (2002), 13. Vanko et al. (2001), 14. Erdem et al. (2001), 15. Pribulla et al. (2001), 16. Sipahi et al. (2000), 17. Keskin et al. (2000), 18. Özdemir et al. (2002), 19. Özdemir et al. (2001b), 20. Çiçek et al. (2001), 21. Yakut & İbanoğlu (2000), 22. Yaşarsoy et al. (2000), 23. Rodriguez et al. (1998), 24. Aliş et al. (2002), 25. Rucinski et al. (2002), 26. Soydugan et al. (2001), 27. Gomez-Forrellad & Garcia-Melendo (1997), 28. Rucinski & Lu (1999), 29. Vanko & Pribulla (2001), 30. Strohmeier (1959), 31. Yeşilyaprak C. (2002), 32. Strohmeier & Knigge (1974), 33. Rucinski et al. (2003), 34. Değirmenci et al. (2003), 35. Tanrıverdi et al. (2003), 36. Karska & Maciejewski (2003), 37. Pribulla et al. (2003).

[a] Values are changed according to the literature.

[b] Type of variability was changed from pulsating to EW in the literature and light elements are updated accordingly.

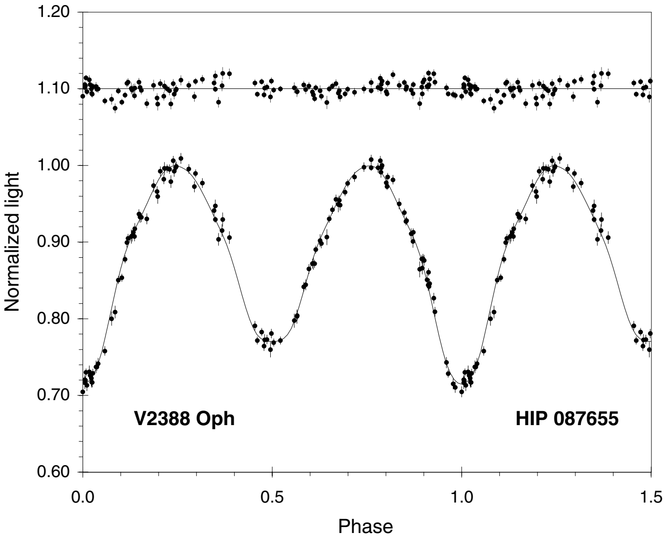

Fig. 1. A typical Fourier fit illustrated for the system V2388 Oph as an example. The residuals from the fit are also displayed at top shifted by 1.1 light units.

standard estimation errors were given in parentheses after each value which are in units of last decimal places. Sum of squared residuals $\Sigma(O-C)^2$ for the fits were also listed in Table 1 as a goodness of fit parameter.

During the construction of an automated variability-type classifier for the very large OGLE sample of eclipsing binaries Rucinski (1997a, 1997b) explained in detail that detached binaries (EA) can be simply discriminated from the EW and EB-type binaries on the a_2–a_4 plane by the boundary condition $a_4 < a_2(0.125 - a_2)$. On equality this expression corresponds to the theoretical position of systems at marginal (inner) contact. He also showed that EB-type binaries can be discriminated from the real EW-type binaries by the boundary condition $a_1 < -0.02$. On equality this expression corresponds to the statistical upper-limit position of the systems having acceptable amount of difference between the eclipse depths (and thus temperature difference between the components) for being a contact binary. Although this boundary condition related only with a_1 coefficient it was preferred to display the corresponding filtering results on a_2–a_1 plane just for visualization purposes. The results for our sample are shown in Fig. 2 on a_2–a_4 plane and in Fig. 3 on a_2–a_1 plane. The solid thick curve in Fig. 2 and the solid thick line in Fig. 3 illustrates the relevant boundary conditions described above. 12 systems; ET Boo, CK Cet, IQ CMa, HL Dra, FP Eri, QY Hya, V356 Hya, BS Ind, BL Phe, VW Pic, CP Psc and VY PsA were clearly separated as EA-type binaries by the "Fourier filter" on a_2–a_4 plane and 3 systems; BF Cap, BD Scl and V1055 Sco were separated as EB-type binaries by the "Fourier filter" on a_2–a_1 plane. In that way the number of genuine contact binaries in the sample has been reduced to 64 after removing these EA and EB-type systems and only the light curves of the 64 remaining systems were analysed in the next section. The removed EA and EB type systems are indicated by their new variability types at Col. 14 in Table 1. The variability types of all the remaining 64 systems should be assigned as EW.

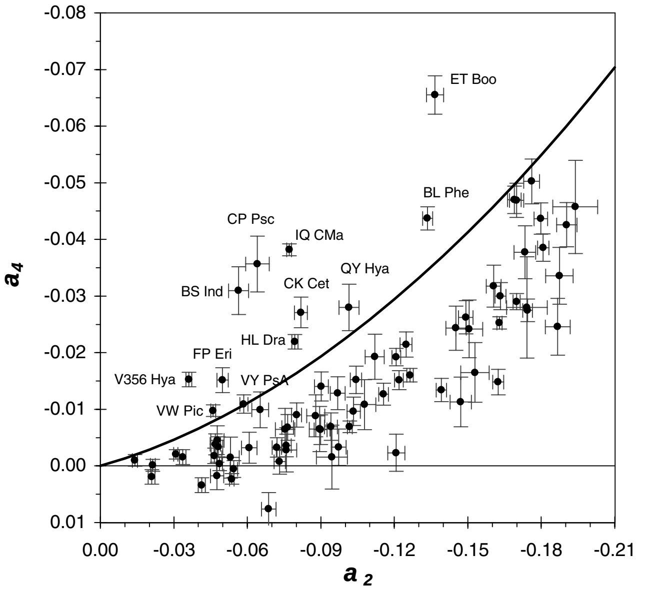

Fig. 2. Fourier coefficients a_2 and a_4 have been used to separate detached binaries from EW and EB binaries. The error bars are representing the standard estimation errors of the Fourier coefficients obtained during the least-square fits to the normalized light curves. The solid thick curve illustrates the "Fourier filter" boundary $a_4 = a_2(0.125 - a_2)$ which corresponds to the theoretical position of systems at marginal contact and separates the detached binaries (located above that curve) from real EW and EB binaries (located below that curve). The detached system which were filtered on a_2–a_4 plane are labeled by their variable-star names.

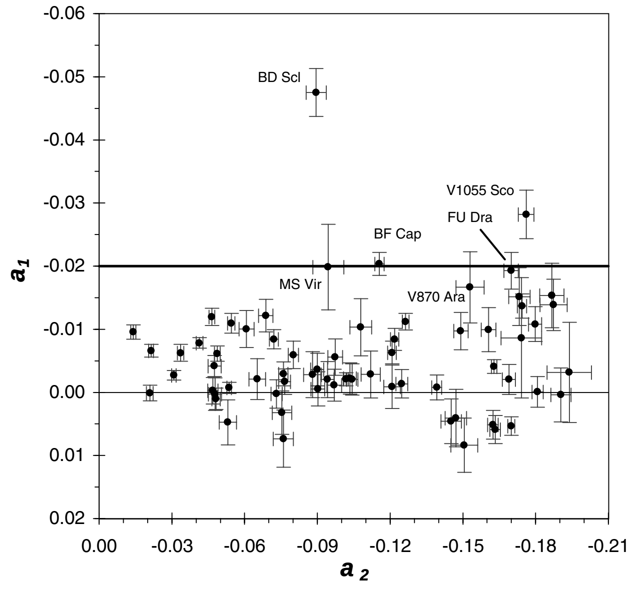

Fig. 3. Fourier coefficients a_1 and a_2 have been used to separate EB binaries from genuine EW binaries. The error bars are representing the standard estimation errors of the Fourier coefficients obtained during the least-square fits to the normalized light curves. The solid thick line illustrates the "Fourier filter" boundary $a_1 = -0.02$ which separates the EB binaries (located above that line) from EW binaries (located below that line) as suggested by Rucinski (1997a,b). The EB system which were filtered on a_2–a_1 plane are labeled by their variable-star names. The systems which passed the filter but very close to the boundary are also labeled by their variable-star names.

3. Analyses of the light curves

The analyses of the *HIPPARCOS* light curves of the sample systems have been performed with the aid of the Rucinski's simplified light curve synthesis method (Rucinski 1993b). Basically the method can be described as a nomographic version of his well known *WUMA* code (see Rucinski 1973, 1974, 1976; Hill & Rucinski 1993) based on the original *"contact model"* by Lucy (1968). His basic idea during construction of the nomogram tables was that the brightness variations of contact binaries of the W UMa-type are totally dominated by geometrical causes and he showed that the light curves of EW-type systems depend practically only on three key parameters, the mass ratio $q = m_2/m_1$, orbital inclination i and degree of contact f (see Rucinski 1993b and references therein). The parameter f is defined through the Jacobi equipotentials C as

$$f = (C_1 - C)/(C_2 - C) \tag{2}$$

where C_1 and C_2 are, respectively, for the inner ($f = 0$) and outer ($f = 1$) critical equipotentials. Using his *WUMA* code, he generated a series of theoretical light curves by systematically sampling the parameter space (f, q, i) for three values of f; 0.0, 0.5 and 1.0 with steps $\Delta q = 0.05$ and $\Delta i = 2\overset{\circ}{.}5$ between $0.05 \leq q \leq 1$ and $30° \leq i \leq 90°$. During the calculations he adopted a representative solar case for the radiative parameters in photometric V-band by taking $T_{\rm eff} = 5770$ °K, with the gravity brightening exponent $\beta = 0.32$ and the bolometric albedo $A = 0.5$. He also confirmed that this specific selection of radiative parameters is not too restrictive as the orbital variations are strongly dominated by the geometrical effects and valid through the bracketing atmospheres $[T_{\rm eff}, u]$ between [5900, 0.57] and [5660, 0.61], where u is the linear limb darkening coefficient. Then he has constructed the nomograms consisting of the Fourier coefficients a_i ($i = 0, 1, ..., 10$) obtained by the Fourier decomposition of these theoretical light curves as described in the previous section. He also generated nomograms for theoretical eclipse depths $d_{\rm minI-t} = 1 - l(0°)$ and $d_{\rm minII-t} = 1 - l(180°)$ in light units for the same parameter space which are very useful to decide the validity of the solution for a particular system.

The nomograms (for Fourier coefficients and eclipse depths) were retrieved electronically from Rucinski's anonymous FTP site[2] and interpolated in f with steps $\Delta f = 0.1$ to obtain a finer grid in degree of contact parameter. The application of the solution method using these nomograms is very easy. As described in Rucinski (1993b) just comparing the theoretical and observational values of the Fourier coefficients a_2 and a_4 on the a_2–a_4 plane and constraining the theoretical points near to observational one with their corresponding eclipse depths values would be enough to obtain an approximate solution for a particular system. More distinctly, one should find a theoretical point on a_2–a_4 plane close to the observationally determined point with its corresponding values of minima depths are also similar to the observational ones. The uniqueness of the solution obtained in that way is an important issue as any other method of solving light curves of contact systems and discussed in the final section of this paper.

The effective wavelengths of Johnson V-band and *HIPPARCOS* $H_{\rm p}$-band are more or less the same. These bands only differ by a colour-dependent offset (see HIP, Vol. 13, p. 275), but basically identical when one considers the variability. Thus the V-band theoretical predictions in nomograms were directly used for $H_{\rm p}$ variability without applying any transformation to the observational data.

Observational values of the eclipse depths in light units for 64 genuine EW-type system in the final sample were calculated using the Fourier descriptions of their *HIPPARCOS* light curves. Using these observational eclipse depths along with the Fourier coefficients obtained in the previous section, approximate solutions were obtained for each of the 64 systems and listed in Table 2. Corresponding literature data for those systems subjected to spectroscopic or photometric analysis were also listed in this table for comparison. The columns were explained at bottom of the table.

4. Summary and discussion

A sample of W UMa-type contact binaries which were discovered by the *HIPPARCOS* satellite was constructed by well defined selection criteria and "Fourier filter" described in Sect. 2 of this work. Through these selection processes all the *HIPPARCOS* discoveries of genuine W UMa-type contact binaries having orbital periods shorter than 1 day with spectral type later than A5 were covered by the sample. The *HIPPARCOS* light curves of 64 system in the current sample were analised with the aid of Rucinski's simplified light curve synthesis method (Rucinski 1993b) and their essential geometric parameters, namely the degree of contact f, mass ratio $q = m_1/m_2$ and orbital inclination i were obtained. As already discussed by Rucinski (1997a) the solution method used in this study is rather convinient if one takes in account the large databases of variables observed with moderate accuracy as in the case of the *HIPPARCOS* mission photometry. Therefore there wasn't any attempt to use more sophisticated light curve solution methods in this study.

As one compare the results in Table 2 reasonably consistent solutions were reached for those systems that are already subjected to photometric or spectroscopic analysis. This situation proven that the simplified light curve synthesis method by Rucinski (1993b) is a very powerful tool to find first approximations to the parameters of the W UMa-type systems. The observed inconsistency between the parameters obtained here and in the literature for some of these systems are mainly due to the bad phase coverage, large scatter, erroneous observations or relatively large asymmetries between the maxima (so called O'Connell effect) in their *HIPPARCOS* light curves. As can be seen from Eq. (1) the light curve synthesis method by Rucinski (1993b) uses only the cosine terms during the Fourier decomposition of the light curves. Cosine terms are insensitive to the asymmetrical features in the light curves and therefore the solutions for the systems showing O'Connell effect in their light curves became more uncertain according to the amount of the

---

[2] `http://www.astro.utoronto.ca/~rucinski/fourier_depth.html`

Table 2. The results of the light curve solutions for the 64 genuine EW-type systems.

Var Name (1)	HIP (2)	f (3)	q (4)	$i(^\circ)$ (5)	$d_{\mathrm{minI}-t}$ (6)	$d_{\mathrm{minII}-t}$ (7)	$d_{\mathrm{minI}-o}$ (8)	$d_{\mathrm{minII}-o}$ (9)	f_l^b (10)	q_l^a (11)	$i_l(^\circ)^b$ (12)	Ref. (13)
V851 Ara	083802	0.4	0.20	30.0	0.053	0.042	0.053	0.042				
V870 Ara	088853	0.7	0.25	70.0	0.319	0.298	0.322	0.298				
V410 Aur	023337	0.5	0.25	87.5	0.387	0.341	0.387	0.348		0.144		33
EF Boo	071107	0.2	0.45	77.5	0.410	0.399	0.413	0.387	0.25	0.512		5, 11
FI Boo	075203	0.1	0.35	45.0	0.097	0.093	0.094	0.093		0.372		7
FP Boo	076970	0.0	0.10	80.0	0.200	0.184	0.201	0.179				
RT Cae	020665	0.8	0.10	60.0	0.172	0.159	0.177	0.154				
DN Cam	021913	0.4	0.45	72.5	0.372	0.362	0.376	0.364	0.50	0.421	71.9	5, 29
FN Cam	046005	0.9	0.25	70.0	0.358	0.311	0.356	0.336	0.88	0.222	71.2	5, 6
V776 Cas	008821	0.7	0.15	52.5	0.155	0.142	0.156	0.148		0.130		5
V901 Cen	054865	0.5	0.20	75.0	0.321	0.297	0.319	0.296				
CT Cet	005452	0.6	0.10	75.0	0.229	0.201	0.227	0.200				
DY Cet	012311	0.2	0.45	77.5	0.410	0.399	0.407	0.398				
EE Cet	013199	0.2	0.65	77.5	0.436	0.430	0.435	0.430		0.315		25
IS CMa	030174	0.5	0.30	75.0	0.372	0.351	0.375	0.349				
KR Com	065069	0.7	0.05	55.0	0.096	0.095	0.099	0.095		0.091		25
V711 CrA	088517	0.0	0.15	90.0	0.257	0.231	0.256	0.214				
YY CrB	077598	0.3	0.30	80.0	0.390	0.361	0.383	0.363	0.634	0.243	77.0	4, 12
V2150 Cyg	105162	0.9	0.80	32.5	0.113	0.109	0.113	0.110		0.802		7
AP Dor	023793	1.0	0.10	62.5	0.202	0.178	0.203	0.182				
FU Dra	076272	0.0	0.30	82.5	0.370	0.345	0.379	0.360	0.235	0.251	78.6	4, 13
GM Dra	084837	0.4	0.35	57.5	0.207	0.201	0.205	0.201		0.18		25
HI Dra	090972	0.7	0.15	52.5	0.148	0.139	0.150	0.140				
FX Eri	016864	0.9	0.10	65.0	0.212	0.189	0.216	0.186				
QW Gem	032845	0.5	0.30	85.0	0.419	0.374	0.420	0.370		0.334		33
V899 Her	081191	0.3	0.55	70.0	0.344	0.339	0.343	0.332	0.237	0.566	68.72	7, 18
V921 Her	082344	0.2	0.15	87.5	0.275	0.244	0.282	0.238		0.226		33
V972 Her	087958	0.0	0.15	42.5	0.063	0.055	0.063	0.059		0.167		25
WY Hor	011934	-	-	-	-	-	0.156	0.137				
CN Hyi	012884	0.6	0.23	60.0	0.221	0.208	0.220	0.207				
CP Hyi	013999	0.6	0.10	57.5	0.145	0.140	0.145	0.143				
ET Leo	051667	0.1	0.25	47.5	0.101	0.096	0.100	0.098		0.342		25
EX Leo	052580	0.3	0.35	57.5	0.195	0.192	0.195	0.191	0.31	0.199	61.1	6, 7
IR Lib	075836	0.3	0.45	40.0	0.101	0.095	0.102	0.094				
VW LMi	054003	0.4	0.25	72.5	0.320	0.307	0.320	0.303				
CW Lyn	042554	0.0	0.10	77.5	0.197	0.183	0.198	0.180				
V753 Mon	034684	0.0	0.95	74.0	0.377	0.377	0.379	0.378		0.97		4
V2357 Oph	082967	0.4	0.25	45.0	0.112	0.109	0.113	0.108		0.231		33
V2377 Oph	085944	0.8	0.10	50.0	0.120	0.111	0.122	0.105		0.395		7
V2388 Oph	087655	0.4	0.15	85.0	0.288	0.252	0.289	0.234	0.495	0.186	83.9	23, 25
V1363 Ori	023809	0.4	0.55	52.5	0.191	0.187	0.190	0.187				
V386 Pav	103320	0.9	0.10	47.5	0.107	0.101	0.105	0.093				
PU Peg	110464	0.1	0.45	40.0	0.082	0.076	0.087	0.071				
V335 Peg	112960	0.1	0.15	30.0	0.039	0.028	0.040	0.020				
V351 Peg	115627	0.4	0.35	62.5	0.245	0.251	0.248	0.251		0.36		5
V357 Peg	117185	0.4	0.30	75.0	0.362	0.345	0.368	0.341				
V592 Per	022050	0.6	0.25	85.0	0.397	0.345	0.399	0.325				
BM Phe	001507	0.7	0.15	62.5	0.217	0.200	0.215	0.204				
XY Pic	027170	0.0	0.40	30.0	0.045	0.037	0.045	0.038				
BE Scl	006350	0.5	0.25	75.0	0.350	0.328	0.351	0.320				
OU Ser	075269	0.4	0.15	57.5	0.157	0.156	0.163	0.164	0.307	0.173	54.23	4, 12
V1123 Tau	016706	0.4	0.25	77.5	0.358	0.332	0.360	0.331				
V1128 Tau	017878	0.3	0.45	75.0	0.391	0.380	0.406	0.379				
QW Tel	090026	0.1	0.05	80.0	0.138	0.123	0.139	0.114				
DX Tuc	118096	0.3	0.15	70.0	0.239	0.233	0.243	0.228				
HH UMa	054165	0.2	0.35	55.0	0.165	0.164	0.163	0.163	0.19	0.40	52.6	37
HN UMa	055030	0.2	0.10	52.5	0.101	0.095	0.102	0.096		0.14		33
HX UMa	058648	0.7	0.25	50.0	0.165	0.155	0.167	0.149		0.291		33
II UMa	061237	0.7	0.20	70.0	0.307	0.279	0.307	0.278		0.172		25
TV UMi	073474	0.1	0.10	47.5	0.075	0.069	0.081	0.067				
V362 Vel	054112	0.4	0.15	67.5	0.228	0.223	0.232	0.216				
LV Vir	066078	1.0	0.60	52.5	0.279	0.251	0.281	0.248				
MS Vir	068881	1.0	0.25	52.5	0.212	0.186	0.212	0.189				
NN Vir	070020	0.5	0.55	65.0	0.313	0.304	0.315	0.306		0.419		28

Note : Columns: (1) Name of the variable; (2) *HIPPARCOS* identifier; (3) Degree of contact; (4) Mass ratio; (5) Orbital inclination; (6) Theoretical depth of primary minimum in light units; (7) Theoretical depth of secondary minimum in light units; (8) Observational depth of primary minimum in light units; (9) Observational depth of secondary minimum in light units; (10)–(12) Same as Cols. 3–5 but for literature data; (13) Coded key references for the literature data. The Number codes are identical with those used in Table 1.

[a] All values except for HH UMa are spectroscopic determinations from the radial velocity curve solutions by Rucinski and his collaborators.

[b] All values except for EF Boo and HH UMa have been obtained with WD-code by different authors. The values of EF Boo are the results of a *Binary Maker* (Bradstreet 1993) approximation and those of HH UMa are obtained with the new light curve solution code *ROCHE* by Pribulla (2003). All the q values except for EF Boo, V2388 Oph and HH UMa were fixed to the spectroscopically determinated ones by the authors during the light curve solutions.

O'Connell effect. Due to that reason WY Hor is the only system in the sample, that no acceptable solution were found.

Another limitation of the solution method used in this study comes from the low amplitude systems. The a_2 and a_4 coefficients of the low amplitude W UMa-type systems are very close to zero and this would bring an uncertainity during the determination of the degree of contact f parameter as one can see from Fig. 6 of Rucinski's (1993b) paper. Therefore the obtained solutions for such systems (i.e., $|a_2| < 0.03$) like V335 Peg, XY Pic and V851 Ara are rather uncertain. The classification of several systems based on "Fourier filter" technique is also complicated due to the combined effect of the low amplitude and bad phase coverage with largely scattered or erroneous observations in their light curves. Visual inspection of their *HIPPARCOS* light curves does not support the classification obtained solely by the "Fourier filter". Such are the systems very close to the boundries on a_2–a_4 and a_2–a_1 planes; FP Eri, QY Hya, VW Pic, V1055 Sco, MS Vir, and V870 Ara.

The analysis method used in this study faces the same difficulty as any other method of solving light curves of contact systems. If we do not know q exactly (namely, spectroscopically determined mass ratio $q_{\rm sp}$), then we do not know which component (more or less massive) is eclipsed at each eclipse. However, even in this case the nomogram tables provide a means of determining the valid pairs of (q, i) parameters for an assumed f. If we see total eclipses, than we can hope for a full solution. The method by Mochnacki & Doughty (1972) permits to find another (q, i) dependence from the angles of the internal eclipse contacts. Intersection of the two relations will give correct q and i separately. Unfortunately the moderate accuracy of the *HIPPARCOS* mission photometry does not allow us to discriminate the systems showing total eclipses and prevent us to apply Mochnacki & Doughty's (1972) method in this study. It is believed that rather large deviations of the solution results obtained in this study from more precisely determined literature values in Table 2 are due to the above described uniqueness problem. Such are the systems EE Cet ($q = 0.65$ while $q_{\rm sp} = 0.315$), EX Leo ($q = 0.35$ while $q_{\rm sp} = 0.199$) and V2377 Oph ($q = 0.10$ while $q_{\rm sp} = 0.395$).

A certain amount of uncertainty in the solution results can also be expected for the systems of spectral types (i.e., surface temperatures) that are outside the defined limits of bracketing atmospheres (see Sect. 3). According to the effective temperature calibration of dwarf stars by Gray & Corbally (1994) the upper and lower limits of the bracketing atmospheres correspond to the spectral types F9 and G3, respectively. As one can see from Table 1, most of the systems have mainly mid to late F spectral types and lying outside but very close to the defined upper limit. Since the geometry is the dominant cause of the brightness variations of W UMa-type binaries, it is believed that the uncertainty due to the above described reason should be very small.

Preliminary photometric solutions were obtained for 53 systems in this study for the first time. It is believed that their approximate parameters determined from these solutions would be a good source for their future light curve analyses based on more precise follow-up observations. Especially 19 of them have spectroscopically determined mass ratios (see Table 2) in the literature and are urgently waiting for good photometric light curves for full solution.

Acknowledgements. The author would like to thank Dr. Slavek M. Rucinski for his useful comments on application the light curve analysis method and to the anonymous referee for his/her constructive comments. This research has made use of the SIMBAD database, operated at CDS, Strasbourg, France and NASA's Astrophysics Data System.

References

Aliş, S., Keskin, M. M., & Atay, M. E. 2002, IAU-IBVS, No. 5282

Bradstreet, D. H. 1993, Binary Maker 2.0, Dept. of Physics, Eastern College, St. Davis

Çiçek, C., Demircan, O., Erdem, A., et al. 2001, IAU-IBVS, No. 5144

Değirmenci, Ö. L., Bozkurt, Z., Yakut, K., et al. 2003, IAU-IBVS, No. 5379

Dommanget, J., & Nys, O. 2002, Observations et Travaux 54, 2 (VizieR On-Line Data Catalog: I/274)

Duerbeck, H. W. 1997, IAU-IBVS, No. 4513

Dumitrescu, A. 2000, IAU-IBVS, No. 4952

ESA 1997, The Hipparcos and Tycho Catalogues, ESA SP-1200

Eggen, O. J. 1980, IAU-IBVS, No. 1772

Eggleton, P. P. 1996, in The Origins, Evolution, and Destinies of Binary Stars in Clusters, ed. E. F. Milone, & J.-C. Mermilliod (San Francisco: ASP), ASP Conf. Proc., 90, 257

Erdem, A., Budding, E., Demircan, O., et al. 2001, IAU-IBVS, No. 5152

Gomez-Forrellad, J. M., & Garcia-Melendo, E. 1997, IAU-IBVS, No. 4469

Gomez-Forrellad, J. M., & Garcia-Melendo, E., Guarro-Flo, J., Nomen-Torres, J., & Vidal-Sainz, J. 1999, IAU-IBVS, No. 4702

Gothard, N. W., Van Hamme, W., & Samec, R. G. 2000, AAS, 197, 4803

Gray, R. O., & Corbally, C. J. 1994, AJ, 107, 742

Hill, G., & Rucinski, S. M. 1993, in Light Curve Modelling of Eclipsing Stars, ed. E. F. Milone (Springer), 135

Karska, A., & Maciejewski, G. 2003, IAU-IBVS, No. 5380

Kazarovets, A. V., Samus, N. N., Durlevich, O. V., et al. 1999, IAU-IBVS, No. 4659

Keskin, V., Yaşarsoy, B., & Sipahi, E. 2000, IAU-IBVS, No. 4855

Lu, W., Rucinski, S. M., & Ogloza, W. 2001, AJ, 122, 402

Lucy, L. B. 1968, ApJ, 151, 1123

Mochnacki, S. W., & Doughty, N. A. 1972, MNRAS, 156, 51

Özdemir, S., Demircan, O., Erdem, A., et al. 2001a, IAU-IBVS, No. 5033

Özdemir, S., Demircan, O., Erdem, A., et al. 2001b, IAU-IBVS, No. 5034

Özdemir, S., Demircan, O., Erdem, A., et al. 2002, A&A, 387, 240

Pribulla, T., Vanko, M., Parimucha, S., & Chochol, D. 2001, IAU-IBVS, No. 5056

Pribulla, T., & Vanko, M. 2002, CoSka, 32, 79

Pribulla, T., Chochol, D., Vanko, M., & Parimucha, S. 2002, IAU-IBVS, No. 5258

Pribulla, T. 2003, A&A, in preparation

Pribulla, T., Kreiner, J. M., & Tremko, J. 2003, CoSka, 33, 1

Pribulla, T., Parimucha, S., Chochol, D., & Vanko, M. 2003, IAU-IBVS, No. 5414

Rodriguez, E., Claret, A., Garcia, J. M., et al. 1998, A&A, 336, 920

Rucinski, S. M. 1973, AcA, 23, 79

Rucinski, S. M. 1974, AcA, 24, 119

Rucinski, S. M. 1976, PASP, 88, 777

Rucinski, S. M. 1993a, in The Realm of Interacting Binary Stars, ed. J. Sahade, G. E. McCluskey, & Y. Kondo (Dordrecht: Kluwer Acad. Publ.), 111
Rucinski, S. M. 1993b, PASP, 105, 1433
Rucinski, S. M. 1997a, AJ, 113, 407
Rucinski, S. M. 1997b, AJ, 113, 1112
Rucinski, S. M., & Duerbeck, H. W. 1997, PASP, 109, 1340
Rucinski, S. M., & Lu, W. 1999, AJ, 118, 2451
Rucinski, S. M., Lu, W., & Mochnacki, S. W. 2000, AJ, 120, 1133
Rucinski, S. M., Lu, W., Mochnacki, S. W., Ogloza, W., & Stachowski, G. 2001, AJ, 122, 1974
Rucinski, S. M. 2002, PASP, 114, 1124
Rucinski, S. M., Lu, W., Capobianco, C. C., et al. 2002, AJ, 124, 1738
Rucinski, S. M., Capobianco, C. C., Lu, W., et al. 2003, AJ, 125, 2358
Samec, R. G., Tuttle, J. P., Brougher, J. A., Moore, J. E., & Faulkner, D. R. 1999, IAU-IBVS, No. 4811
Sipahi, E., Keskin, V., & Yaşarsoy, B. 2000, IAU-IBVS, No. 4859
Soydugan, F., Erdem, A., Özdemir, S., et al. 2001, Proceedings of the XII. Turkish National Astronomy Meeting, ed. C. İbanoğlu, İzmir-Turkey, 129
Strohmeier, W. 1959, AN, 285, 87
Strohmeier, W., & Knigge, R. 1974, Bamberg Veröffentlichungen der Remeis-Sternwarte, 10, 110
Tanrıverdi, T., Kutdemir, E., Elmaslı, A., et al. 2003, IAU-IBVS, No. 5407
Vanko, M., & Pribulla, T. 2001, IAU-IBVS, No. 5200
Vanko, M., Pribulla, T., Chochol, D., et al. 2001, CoSka, 31, 129
Yakut, K., & İbanoğlu, C. 2000, IAU-IBVS, No. 5002
Yaşarsoy, B., Sipahi, E., & Keskin, V. 2000, IAU-IBVS, No. 4866
Yeşilyaprak, C. 2002, IAU-IBVS, No. 5330