Physical parameters of components in close binary systems: V

by

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ABSTRACT

The paper presents combined spectroscopic and photometric orbital solutions for ten close binary systems: CN And, V776 Cas, FU Dra, UV Lyn, BB Peg, V592 Per, OU Ser, EQ Tau, HN UMa and HT Vir. The photometric data consist of new multicolor light curves, while the spectroscopy has been recently obtained within the radial velocity programme at the David Dunlap Observatory (DDO). Absolute parameters of the components for these binary systems are derived. Our results confirm that CN And is not a contact system. Its configuration is semi-detached with the secondary component filling its Roche lobe. The configuration of nine other systems is contact. Three systems (V776 Cas, V592 Per and OU Ser) have high (44-77%) and six (FU Dra, UV Lyn, BB Peg, EQ Tau, HN UMa and HT Vir) low or intermediate (8-32%) fill-out factors. The absolute physical parameters are derived.

Key words: binaries: eclipsing–binaries: close–binaries: contact–stars: fundamental parameters

1. Introduction

This paper is a continuation of a series of papers (Kreiner et al. 2003 (Paper I), Baran et al. 2004 (Paper II), Zola et al. 2004 (Paper III), Gazeas et al. 2005 (Paper IV) aimed at derivation of the physical parameters of the components in contact and close binary systems with the ultimate goal of rediscussing the properties of components (including their evolutionary status) based on a sample of few dozen such binaries, the parameters of which were determined in a uniform way. As has been shown (see DDO series of papers - Rucinski et al. 2005 and references therein), determination of absolute parameters of contact systems only from light curve modeling, without knowing the spectroscopic mass ratio, can often result in spurious solutions thus leading to unreliable physical parameters of components.

The solutions based on recently obtained spectroscopic and multicolor photometric data for the next ten binary stars: CN And, V776 Cas, FU Dra, UV Lyn, BB Peg, V592 Per, OU Ser, EQ Tau, HN UMa and HT Vir are described in sections 2-4. The results derived are briefly discussed in Section 5.

2. The targets

2.1. CN And

CN And (BD+39°0059, GSC 02787-01815, V=9.76^m) was discovered by Hoffmeister (1949) as a short-period eclipsing binary. Photometric observations of CN And have been carried out by Bozkurt et al. (1976), Seeds and Abernethy (1982), Michaels et al. (1984), Rafert et al. (1985), Keskin (1989), Samec et al. (1998). The orbital period and light curve changes have been investigated by Evren et al. (1987) and Keskin (1989). Samec et al. (1998) interpreted the decreasing orbital period during the past 50 yr as being due to the mass transfer from the primary to the secondary component and/or caused by magnetic breaking as a result of strong system activity. Van Hamme et al. (2001) determined the rate of the mass transfer as 1.4 x 10^{-7} $M_\odot$/yr.

CN And is an active solar type binary with components of spectral type in the F5 to G5 range. Flare events with an amplitude of 0.11 mag at phases 0.21-0.24 (Yang and Liu 1985) and moderately strong X-ray emission (Shaw et al. 1996) from this star have been detected. Rucinski et al. (2000) obtained radial velocity curves of both components and determined the following spectroscopic elements of the orbit: γ=-24.9 km/s; K_1=87.5 km/s; K_2=224.3 km/s; $(M_1+M_2)\sin^3 i$=1.46 $M_\odot$; q=0.39. This value of mass ratio differs considerably from the

Table 1: Journal of photometric observations

object	observatory	dates
CN And	Mt. Suhora	19/20, 25/26, 29/30 Aug, 31 Aug/1 Sep, 3/4 Sep 2002
V776 Cas	Mt. Suhora	19/20, 24/25 Oct 2005
FU Dra	Jagiell. Univ.	27/28 Feb, 1/2, 4/5, 13/14 Mar 2002
UV Lyn	Mt. Suhora	5/6, 6/7 Feb 2005
BB Peg	Mt. Suhora	10/11 Aug, 5/6, 6/7 Oct 2004
V592 Per	Mt. Suhora	2/3, 4/5, 9/10, 10/11 Dec 2004, 16/17, 28/29 Jan 2005
OU Ser	Mt. Suhora	4/5, 5/6, 6/7 May 2003
EQ Tau	Mt. Suhora	15/16 Dec 2004, 8/9, 9/10 Jan 2005
HN UMa	Mt. Suhora	27/28 Feb 2003
HT Vir	Mt. Suhora	18/19, 19/20, 20/21, 21/22, 22/23, 23/24, April 14/15, 20/21 May 2004

photometric estimates ($0.5<q<0.8$) of Kaluzny (1983) and Rafert et al. (1985). Rucinski et al. (2000) concluded that CN And looks either like a typical contact binary of A sub-type or it could be a very close semidetached binary. Recently, Çiçek, et al. (2005) obtained new BVR light curves and computed absolute elements of the components. They concluded that CN And is almost a contact binary and the components fill about 99% of their Roche lobes.

According to Kaluzny (1983) CN And is a promising candidate for identification as a W UMa-type system caught in a phase of poor thermal contact, a phase predicted by the thermal relaxation oscillation theory (Lucy and Wilson 1979).

2.2. V776 Cas

V776 Cas (BD+69°0121, HIP 8821, V=9.00^m) is the brighter member of the visual binary ADS 1485. The companion, at separation of 5.38 arcsec, is 2 mag fainter than the contact binary. V776 Cas was discovered as an eclipsing binary with a small amplitude by the Hipparcos mission (ESA, 1997). It appeared in Duerbeck (1997) as V778 Cas with twice the actual period, spectral type F0, B-V=0.525 and variability range of 8.94-9.09 mag in V. The star was observed photometrically by Gomez-Forrellad et al. (1999) who assumed the star to be an EW-type binary undergoing marginal eclipses or an ellipsoidal variable. Their V light curve showed the primary minimum being deeper than the secondary by 0.04 mag, two almost equal in height maxima and the amplitude of variability of about 0.19 mag. Rucinski et al. (2001) obtained the first spectroscopic orbit of V776 Cas: γ=-24.7 km/s; K_1=32 km/s; K_2=245.3 km/s; $q=m_c/m_h=0.13$; $(M_1+M_2)\sin^3 i=0.975$ $M_\odot$. They found that the spectral type of the system is F2V and that it belongs to the A sub-class of the contact binaries. A photometric study of this system was published by Djurašević et al. (2004).

2.3. FU Dra

The contact binary FU Dra (HIP 076272, GSC 04181-00673, V=10.55^m) was discovered by the Hipparcos mission. The system has a large proper motion. Rucinski et al. (2000) found that FU Dra belongs to the W-type subgroup with spectral type F8V and obtained the following spectroscopic elements of the orbit of FU Dra: γ=-11.4 km/s; K_1=70.4 km/s; K_2=280.8 km/s; q=0.251; $(M_1+M_2)\sin^3 i=1.38$ $M_\odot$. Vaňko et al. (2001) obtained new photoelectric and CCD observations and determined the absolute parameters of the system.

2.4. UV Lyn

UV Lyn (BD+38°1992, HIP 44455, V=9.58^m) was discovered to be variable by Kippenhahn (Geier et al. 1955). Kuklin (1961) and Strohmeier et al. (1964) found 1.2 day periodicity, but later Strohmeier suspected the period to be incorrect. Bossen (1973) classified UV Lyn as a W UMa type binary with a period of 0.415 day and maxima of unequal brightness. On the basis of the light curve analysis Markworth and Michaels (1982) found that the star is a contact system with an inclination i=68° and a mass ratio q=0.526. Zhang et al. (1995) found a slow increase of the orbital period (confirmed later by Vaňko et al. 2001). They explained the change of the period by mass transfer from the secondary to the primary component. Lu and Rucinski (1999) obtained the first spectroscopic orbit of UV Lyn: γ=-0.3 km/s; K_1=86.5 km/s; K_2=235.7 km/s; q=0.367; $(M_1+M_2)\sin^3 i=1.44$ $M_\odot$.

2.5. BB Peg

BB Peg (HIP 110493, GSC 01682-01542, V=11.6^m) was discovered by Hoffmeister (1931). Its period was re-

Table 2: Linear ephemerides used for phase calculation and comparison stars used in our observations

star	reference epoch (HJD)	period (days)	comparison star
CN And	2452500.1210	0.4627899	GSC 02786-01556
V776 Cas	2452932.4339	0.44041574	GSC 04314-00449
FU Dra	2452338.5183	0.3067171	GSC 04181-01726
UV Lyn	2453407.3606	0.41498402	GSC 02983-01770
BB Peg	2453228.4574	0.361501	GSC 01682-01444
V592 Per	2453399.3400	0.715722	GSC 02897-00882
OU Ser	2452500.0710	0.296759	GSC 01487-00941
EQ Tau	2453354.5303	0.341348	GSC 01800-02137
HN UMa	2452698.3008	0.382525367	GSC 02522-00553
HT Vir	2453117.4702	0.407671	GSC 00311-01613

Table 3: Search ranges of the adjusted parameters

System	i(deg)	T_2(K)	Ω_1=Ω_2	L_1
CN And	60-90	4800-6400	2.00-4.00	6.0-13.5
V776 Cas	30-70	5000-7200	1.80-2.50	2.0-12.5
FU Dra	60-90	5000-6500	7.00-8.50	0.1-8.5
UV Lyn	50-90	5000-6500	5.40-7.50	2.5-7.0
BB Peg	60-90	4500-6600	5.00-8.00	2.0-8.0
V592 Per	80-90	5800-6800	2.20-2.90	4.0-8.0
OU Ser	40-70	5000-7000	2.06-2.50	5.0-12.0
EQ Tau	60-90	5000-6000	2.10-3.30	5.5-12.5
HN UMa	40-60	5700-6500	2.00-2.20	5.0-13.5
HT Vir	50-90	5000-6500	3.30-6.00	3.0-12.5

vised by Whitney (1959) to be 0.3515 day. The BV observations of Cerruti-Sola et al. (1981) revealed a variable degree of asymmetry from the yellow to the blue light curve and a phase shift of the secondary minimum. They classified BB Peg as a contact system of the W sub-type with the fill-out parameter of 37%. Leung et al. (1985) solved their light curves and derived a photometric mass ratio of 0.356 and the fill-out factor of 12%. The UBV data of Awadalla (1988) showed variable depth of the primary eclipse that is a total occultation and an increase of the orbital period. These features were explained by the existence of dark spots on the secondary star near the L_1 point. Hrivnak (1990) obtained the first spectroscopic value of the mass ratio q=0.34, later re-determined to be q=0.36 by Lu and Rucinski (1999). Other orbital elements were: γ=29.9 km/s; K_1=59.5 km/s; K_2=263.3 km/s; $(M_1+M_2)\sin^3 i=1.86\ M_\odot$.

2.6. V592 Per

The variability of V592 Per (BD+39°1054, HIP 022050, V=8.37^m) was discovered by Hipparcos. The star has been known to posses a near visual companion (Heintz 1990). Grenier et al. (1999) estimated the spectral type as F2IV, in agreement with the value (B-V)=0.35 from the Tycho-2 data (Hog et al. 2000). Douglas et al. (2000) and Prieur et al. (2001) obtained specle observations of the triple system. Rucinski et al. (2005) re-discovered the visual companion spectroscopically. Although it is fainter than the close binary, its spectral features are well defined due to their sharpness. The contribution of the companion to the total light of the system was estimated to be about 40%. Rucinski et al. (2005) obtained the first spectroscopic orbit of V592 Per: γ=27.9 km/s; K_1=93.7 km/s; K_2=230 km/s; q=0.408; $(M_1+M_2)\sin^3 i=2.52\ M_\odot$. The new spectroscopic mass ratio value differs considerably from that (q=0.25) derived from the light curve modeling by Selam (2004).

2.7. OU Ser

OU Ser (BD+16°2773, HIP 075269, V=8.25^m) belongs to the W UMa stars discovered by the Hipparcos mission. It also belongs to the group of high-velocity stars (V_{sp}=124.0±4.4 km/s). The large proper motion of OU Ser had been the reason for its inclusion in the survey by Carney et al. (1994) who noted also the broad lines indicating a short-period and the possibility of light variations. Pribulla and Vaň(2002) published the first ground-based BV photometry of the system. They found that the second maximum was fainter than the first one. This effect was

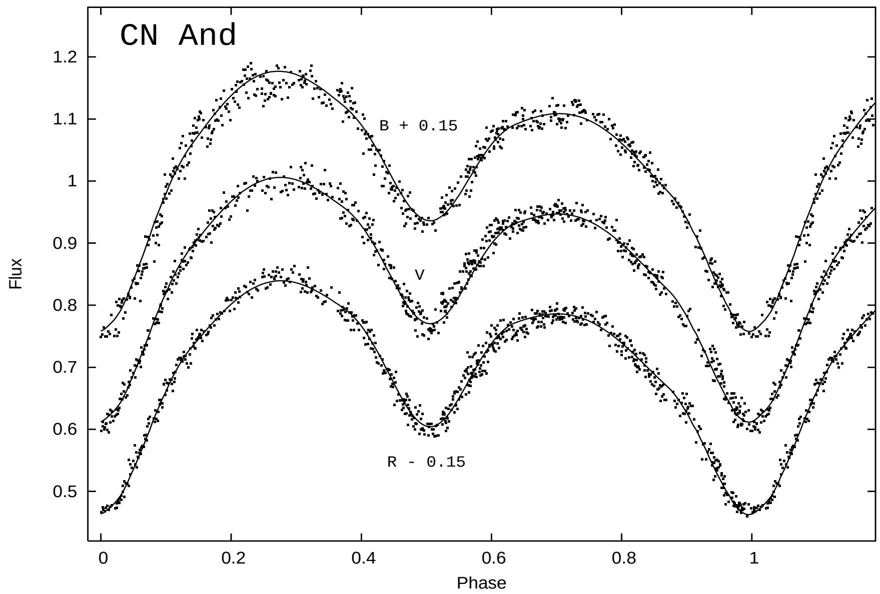

Figure 1: Comparison between theoretical and observed light curves of CN And. Individual observations are shown by dots while lines represent the theoretical light curves.

more pronounced in the B filter. Yesilyaprak (2002) observed OU Ser in the V filter and determined several times of minima. Olsen (1994) obtained Stromgren photometry of the star and derived the spectral type of OU Ser to be G1/G2V. Rucinski et al. (2000) classified the star as F9/G0 and obtained the following spectroscopic elements of the orbit: γ=-64 km/s; K_1=40.6 km/s; K_2=234.2 km/s; q=0.173; $(M_1+M_2)\sin^3 i$=0.64 $M_\odot$.

2.8. EQ Tau

The variability of EQ Tau (GSC 01260-00909, V=10.45^m) was discovered by Tsesevitch (1954). New photometric observations were gathered by Benbow and Mutel (1995) and Buckner et al. (1998). The light curves of EQ Tau published by Yang and Liu (2002) showed a typical O'Connell effect. They also claimed a variable period for this system and classified it as a contact binary of sub-type A. The asymmetry of the light curve was explained by a cool spot. The most recent photometry in UBV filters was obtained by Vaňko et al. (2004). Due to low brightness, EQ Tau was not included as a target in the Hipparcos mission. In the Tycho 2 catalogue it appears with V=11.3 mag and B-V=0.98. Qian and Ma (2001) found that the orbital period of EQ Tau was decreasing and explained it by the mass transfer between components. On the basis of the fact that its parameters do not agree with the mass-radius relation, they suspected that EQ Tau has a near contact confguration. Rucinski et al. (2001) obtained the following parameters of the spectroscopic orbit: γ=72 km/s; K_1=112.4 km/s; K_2=254.4 km/s; q=m_c/m_h=0.442; $(M_1+M_2)\sin^3 i$=1.75 $M_\odot$.

2.9. HN UMa

HN UMa (BD+38°2220, HIP 055030, V=9.82^m) is another eclipsing binary discovered by the Hipparcos mission. The times of minima were determined by Dvorak (2005) but no ground-based photometry of the system has been published yet. Using the Hipparcos photometry Selam (2004) computed q=0.10, the fill-out factor of 20 % and inclination i=52.5°. The spectroscopic orbit of the star was determined by Rucinski et al. (2003). They found the system mass ratio q=0.14 and classified the spectrum as F8V. The orbital parameters were: γ=-37.1 km/s; K_1=29.6 km/s; K_2=212.2 km/s; $(M_1+M_2)\sin^3 i$=0.562 $M_\odot$.

2.10. HT Vir

During observations of the very close visual binary ADS 9019 Walker (1984) discovered variability of HT Vir (BD+5°2794, HIP67186, V=7.162^m). The light curves indicated presence of a contact binary of W UMa-type with a period of 0.4077 days. From analysis of their UBV photometric observations Walker and Chamblis (1985) concluded that the components of the eclipsing pair are identical, they are in contact configuration and the third component contributes at the maximum as much light as the eclipsing system itself. Lu et al. (2001)

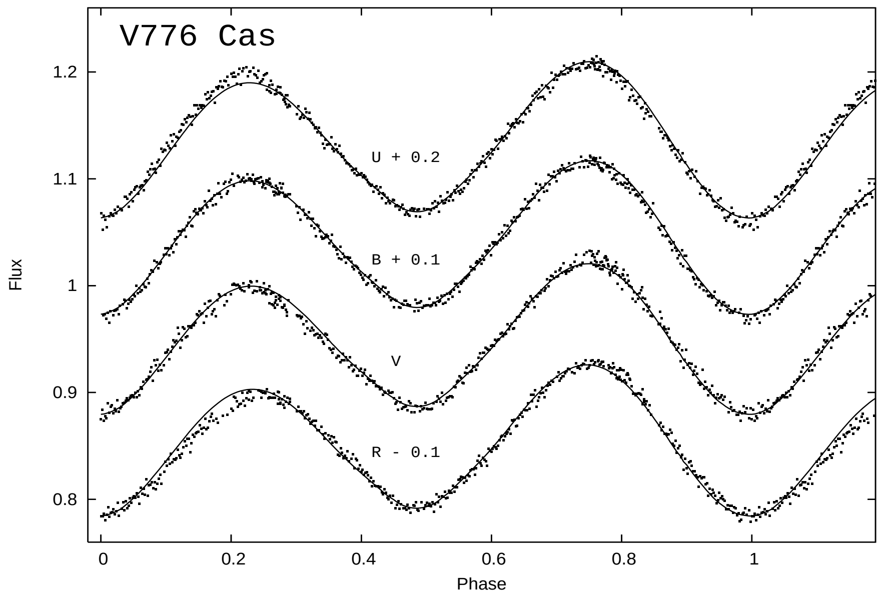

Figure 2: Comparison between theoretical and observed light curves of V776 Cas

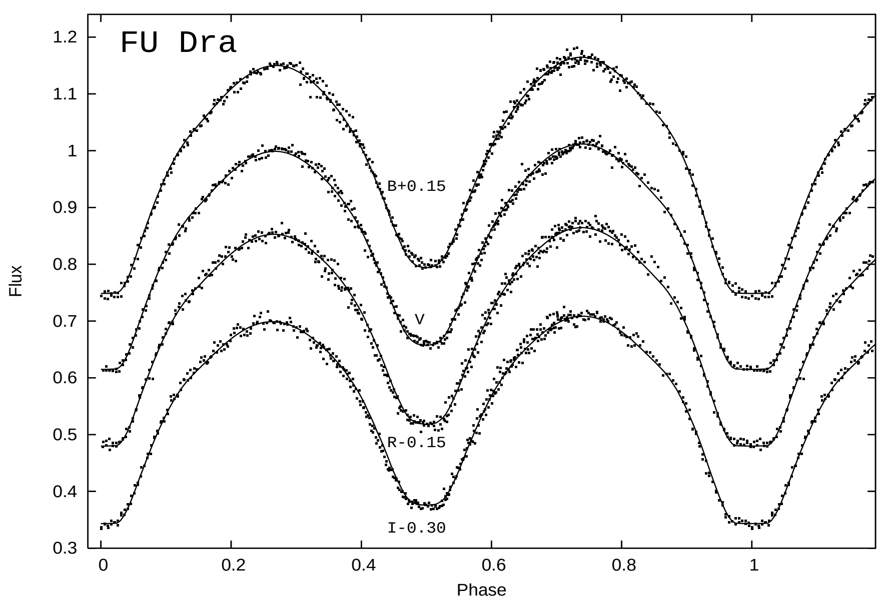

Figure 3: Comparison between theoretical and observed light curves of FU Dra

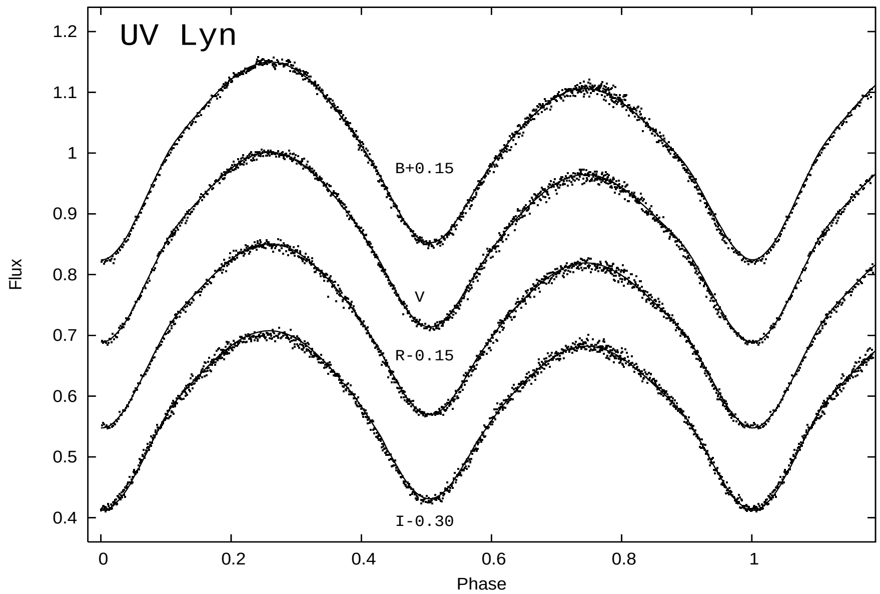

Figure 4: Comparison between theoretical and observed light curves of UV Lyn

determined the following spectroscopic elements for the close binary: γ=-23.4 km/s; K_1=169.4 km/s; K_2=208.5 km/s; $(M_1+M_2)\sin^3 i$=2.285 $M_\odot$; q=0.812. They found that the third component is also a radial velocity variable with a period of 32.45 days that makes HT Vir a quadruple system. Based on the broadening function results Lu et al. (2001) estimated that the companion(s) were about twice fainter than the contact binary at its maximum.

3. Photometric observations

The stars analyzed in this paper were observed at 2 observatories, but we were careful to use only one instrument to obtain a complete light curve of each system. The light curve of FU Dra was obtained at the Astronomical Observatory of the Jagiellonian University with the 50 cm telescope and a Photometrics S300 CCD camera equipped with wide-band BVRI filters. We chose GSC 04181-01726 as the comparison star, whose constancy was confirmed against GSC 04181-01721. The photometric data for nine targets were gathered at Mt. Suhora Observatory using the two-channel (for CN And only) and three-channel photometers (for eight other systems) attached to the 60-cm Cassegrain telescope. Both photometers are equipped with sets of wide-band, close to the Johnson-Morgan system filters and Hamamatsu PMTs. V592 Peg and UV Lyn were observed through the BVRI filters while V776 Cas and HN UMa through UBVR filters. For five targets: CN And, BB Peg, OU Ser, EQ Tau and HT Vir the light curves were collected in BVR filters. We applied a standard reduction procedure, accounting for dead time, different sensitivities of channels, and differential extinction. Table 1 presents the journal of observations for objects analyzed in this paper. The single data points were phased using the epoch of the primary minimum derived from our observations and a recently corrected period (Kreiner 2004). The ephemerides are given in Table 2 along with name of the comparison star we used for observations of each system.

4. Light curve modeling

The light curves of all the systems were analyzed by means of the Wilson-Devinney code (Wilson 1979, 1993) supplemented with the Monte Carlo search method. This method does not require any assumption regarding the system configuration, which is concluded from the results. The light curve modeling was done simultanously in all filters. The procedure we applied was in detail described in Papers I and II.

The effective temperature of star No. 1 (the W-D notation: the star eclipsed at phase 0) was fixed and its value was assumed according to the spectral type obtained by the DDO group and making use of the spectral type versus temperature calibration published by Harmanec (1988). Only the spectral type of V592 Per was taken from Grenier et al. (1999). Albedos and gravity darkening coefficients were adopted according to the theory: A=1.0, g=1.0 for stars with radiative envelopes and A=0.5, g=0.32 for these with convective envelopes. The limb darkening coefficients were taken from the tables by Díaz-Cordovés et al. (1995) and Claret et al. (1995). The inclination, the temperature of the secondary star, potential(s), phase shift and the luminosity of the primary were adjusted. In case of an O'Connell effect, clearly seen in the light curve, a spot(s) was added to our solution and the whole

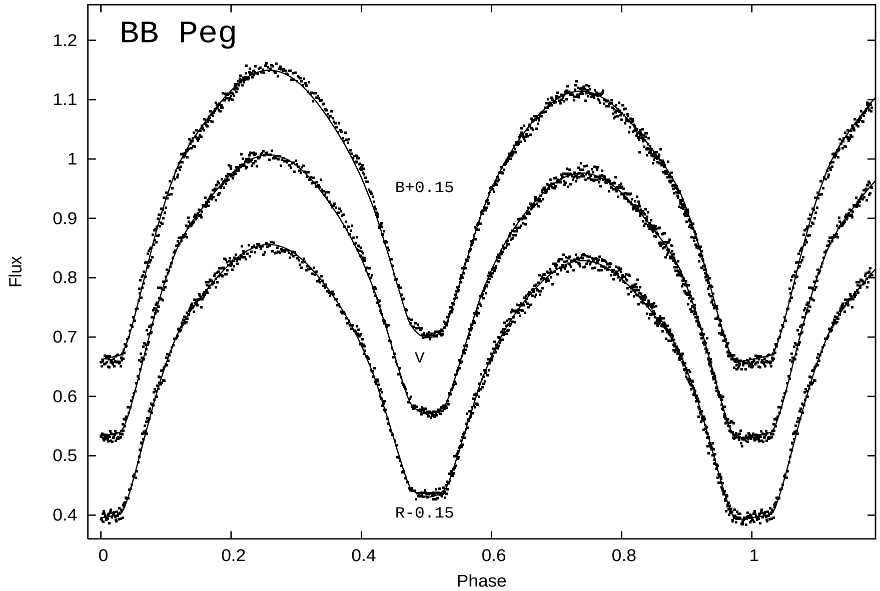

Figure 5: Comparison between theoretical and observed light curves of BB Peg

Table 4: Results from the light curve modeling for CN And, V776 Cas, FU Dra, UV Lyn and BB Peg

parameter	CN And	V776 Cas	FU Dra	UV Lyn	BB Peg
configuration	near-contact	contact	contact	contact	contact
fill-out factor	-	77%	15%	18%	21%
phase shift	0.0054±0.0004	-0.0123±0.0014	-0.0006±0.0002	0.0033±0.0002	0.0028±0.0001
i (degrees)	75.1±0.1	52.5±0.9	81.0±0.2	67.6±0.1	88.5±0.2
T_1(K)	*6450	*6700	*6100	*6000	*6100
T_2(K)	5375±14	6725±90	5670±5	5770±5	5780±7
Ω_1	2.794±0.013	2.001±0.008	7.508±0.005	6.080±0.001	5.936±0.003
Ω_2	2.619±0.001	**2.001	**7.508	**6.080	**5.936
$q_{corr}(M_2/M_1)$	*0.371	*0.138	*3.756	*2.685	*2.589
L_1^s (U)		9.355±0.366			
L_1^s (B)	10.274±0.039	8.993±0.390	3.730±0.012	3.889±0.011	4.249±0.016
L_1^s (V)	9.947±0.037	9.224±0.385	3.598±0.010	3.843±0.009	4.194±0.014
L_1^s (R)	9.634±0.035	9.520±0.365	3.510±0.009	3.797±0.008	4.116±0.012
L_1^s (I)			3.361±0.007	3.772±0.007	
L_2^s (U)		**1.800			
L_2^s (B)	**1.977	**1.738	**8.501	**7.766	**7.586
L_2^s (V)	**2.161	**1.770	**8.632	**7.887	**7.767
L_2^s (R)	**2.322	**1.824	**8.778	**7.964	**7.864
L_2^s (I)			**8.891	**8.116	
l_3^s (U)		0.080±0.035			
l_3^s (B)		0.080±0.035			
l_3^s (V)		0.068±0.037			
l_3^s (R)		0.047±0.035			
l_3^s (I)					
r_1 ^{side}	0.42975±0.00026	0.5947±0.0036	0.26968±0.00037	0.2991 ±0.0009	0.30363±0.00028
r_2 ^{side}	0.28846±0.00002	0.2443±0.0035	0.50908±0.00041	0.4797 ±0.0010	0.47778±0.00030

$*$ - not adjusted, $**$ - computed, L_1^s, L_2^s: W-D program input values – the subscripts 1 and 2 refer to the star being eclipsed at primary and secondary minimum, respectively.

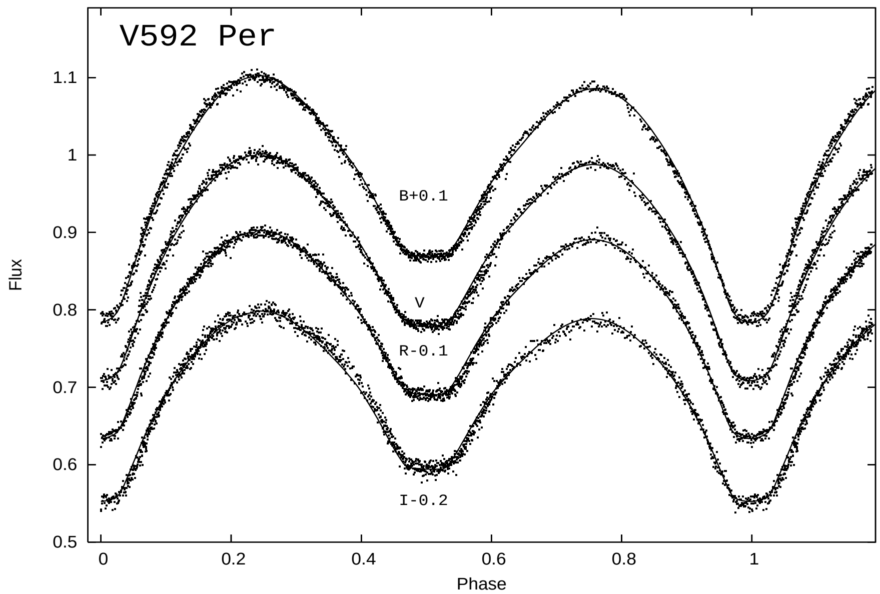

Figure 6: Comparison between theoretical and observed light curves of V592 Per

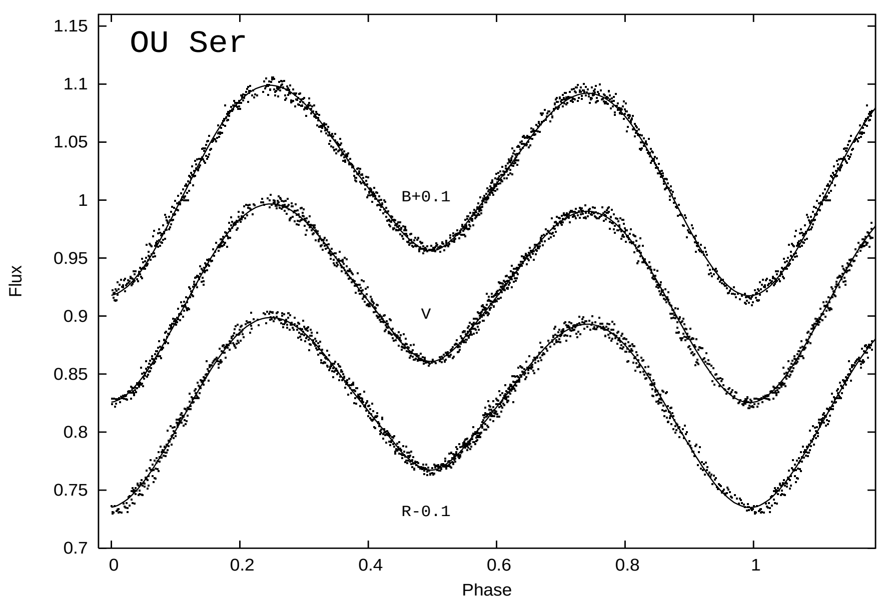

Figure 7: Comparison between theoretical and observed light curves of OU Ser

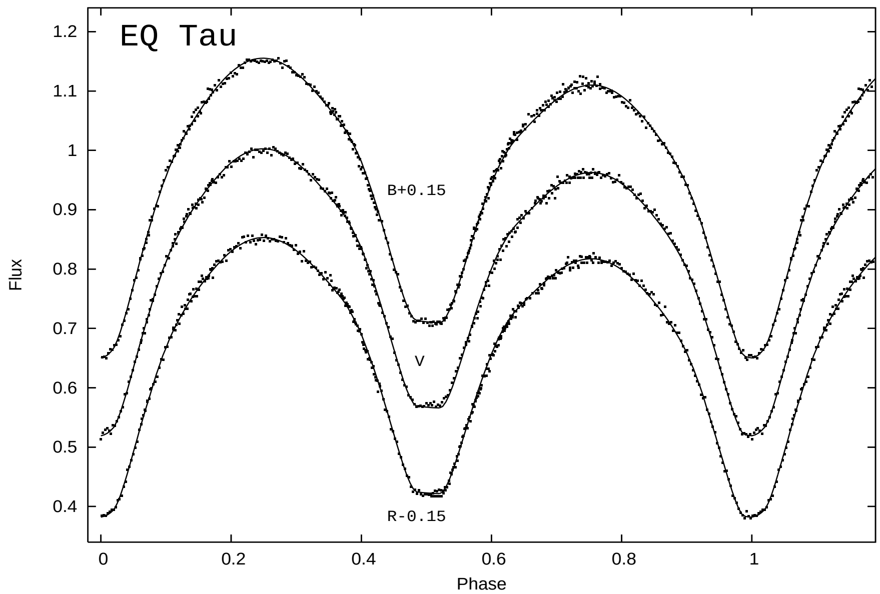

Figure 8: Comparison between theoretical and observed light curves of EQ Tau

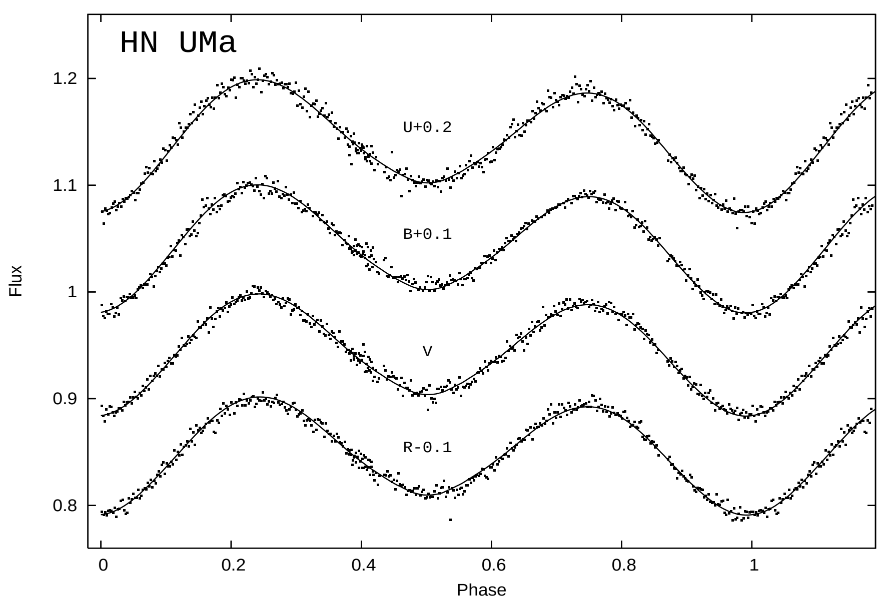

Figure 9: Comparison between theoretical and observed light curves of HN UMa

Table 5: Results from the light curve modeling for V592 Per, OU Ser, EQ Tau, HN UMa and HT Vir

parameter	V592 Per	OU Ser	EQ Tau	HN UMa	HT Vir
configuration	contact	contact	contact	contact	contact
fill-out factor	59%	44%	13%	32%	8%
phase shift	0.0010±0.0005	0.0025±0.0009	0.0029±0.0001	0.0024±0.0014	0.0011±0.0002
i (degrees)	89.6±0.8	52.1±0.8	85.5±0.1	46.7±0.9	84.3±0.5
T_1(K)	*6800	*5950	*5860	*6100	*6100
T_2(K)	6020±40	6226±73	5810±5	6082±77	6010±10
Ω_1	2.526±0.008	2.113±0.007	2.737±0.001	2.065±0.007	4.067±0.003
Ω_2	**2.526	**2.113	**2.737	**2.065	**4.067
$q_{corr}(M_2/M_1)$	*0.389	*0.172	*0.447	*0.147	*1.227
L_1^s (U)				9.656±0.117	
L_1^s (B)	5.868±0.073	9.087±0.123	8.209±0.018	9.641±0.119	3.553±0.054
L_1^s (V)	5.524±0.070	9.176±0.112	8.192±0.016	9.685±0.110	3.562±0.053
L_1^s (R)	5.162±0.069	9.297±0.104	8.200±0.015	9.772±0.100	3.544±0.053
L_1^s (I)	4.851±0.073				
L_2^s (U)				**1.755	
L_2^s (B)	**1.466	**2.462	**3.791	**1.758	**3.980
L_2^s (V)	**1.528	**2.418	**3.808	**1.770	**4.026
L_2^s (R)	**1.523	**2.377	**3.829	**1.788	**4.041
L_2^s (I)	**1.534				
l_3^s (B)	0.406±0.005				0.362±0.009
l_3^s (V)	0.426±0.005				0.360±0.009
l_3^s (R)	0.457±0.006				0.359±0.010
l_3^s (I)	0.475±0.007				
r_1 ^{side}	0.4985 ±0.0022	0.5624±0.0028	0.45900±0.00009	0.5713±0.0029	0.3613 ±0.0004
r_2 ^{side}	0.3250 ±0.0021	0.2483±0.0026	0.31131±0.00009	0.2320±0.0026	0.3991 ±0.0004

$*$ - not adjusted, $**$ - computed, L_1^s, L_2^s: W-D program input values – the subscripts 1 and 2 refer to the star being eclipsed at primary and secondary minimum, respectively.

surface of the brighter component was searched for a possible spot location. If there was any information about existence of a companion in a system also a third light parameter was added and adjusted. The ranges used for searching for the best solution are given in Table 3.

The results from the light curve modeling are presented in Tables 4 and 5, while the comparison of observations (points) and the best fit achieved (lines) for each system is shown in Figs. 1 - 10.

5. Discussion

The physical parameters for ten close binary systems have been obtained by combined solutions of new multicolor light curves and the radial velocity curves from the DDO spectroscopic program (Table 6). The absolute parameters of components of three systems: V592 Per, HN UMa and HT Vir have been determined for the first time. Our results generally agree with recent determinations based on spectroscopic values for the mass ratios for other systems (Vaňko et al. 2001, Djurašević et al. 2004, Pribulla and Vaňko 2002, Yang and Liu 2002).

Our new light curves of CN And show a strong asymmetry also noticed by other observers. The first quadrature is more than 0.05 mag brighter than the second one (see Fig. 1). In order to obtain a good fit to the BVR light curves we introduced two spots in our model and the whole surface of the brighter star was searched for their location. Due to intrinsic scatter and the distorsion of the light curve the exact configuration of this system is not well determined: van Hamme et al. (2001) obtained a semidetached configuration with the more massive component filling its Roche lobe while Çiçek et al. (2005) near-contact geometry with both components filling 99% of their Roche lobes. The final result may even depend on assumptions about spots location. Our best solution resulted in one hot and one cool spots at middle latitudes. The configuration of the best fit is semidetached with the secondary star filling it Roche lobe. The temperature difference between the components is about 1000 K, as indicated by the unequal depth of the minima, much higher than these obtained both by van Hamme et al. (2001) and Çiçek et al. (2005).

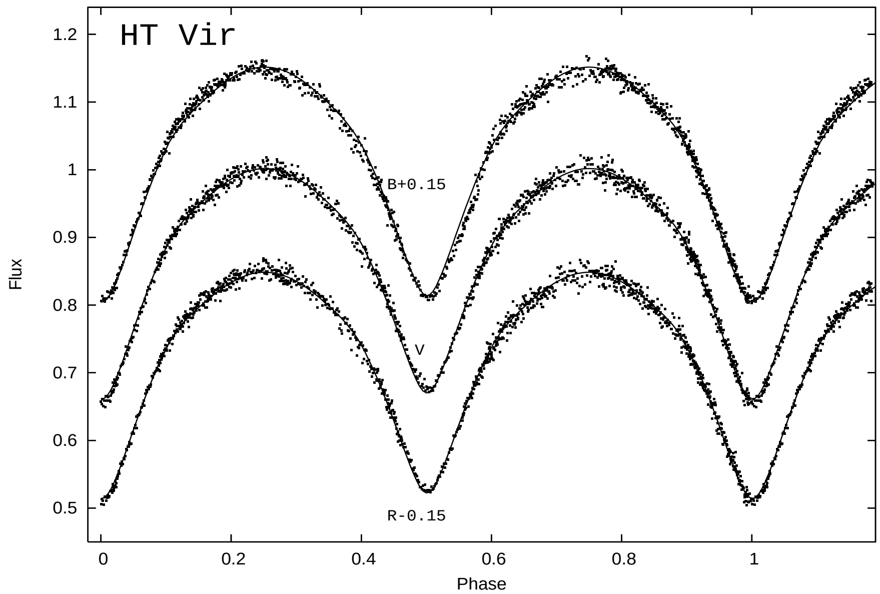

Figure 10: Comparison between theoretical and observed light curves of HT Vir

Table 6: Absolute parameters of the components

system	$\mathcal{M}_1$	$\mathcal{M}_2$	R_1	R_2	L_1	L_2
CN And	1.132±0.036	0.420±0.023	1.252±0.013	0.840±0.009	2.40±0.05	0.52±0.01
V776 Cas	1.750±0.040	0.242±0.017	1.821±0.017	0.748±0.012	5.90±0.11	1.01±0.06
FU Dra	0.312±0.012	1.173±0.023	0.588±0.005	1.110±0.009	0.42±0.01	1.13±0.02
UV Lyn	0.501±0.015	1.344±0.025	0.858±0.007	1.376±0.010	0.84±0.01	1.86±0.03
BB Peg	0.550±0.014	1.424±0.022	0.813±0.007	1.279±0.010	0.81±0.01	1.61±0.03
V592 Per	1.743±0.056	0.678±0.037	2.252±0.025	1.468±0.018	9.58±0.21	2.50±0.09
OU Ser	1.109±0.038	0.192±0.008	1.148±0.007	0.507±0.006	1.48±0.01	0.34±0.02
EQ Tau	1.233±0.030	0.551±0.020	1.143±0.009	0.775±0.006	1.36±0.02	0.61±0.01
HN UMa	1.279±0.060	0.179±0.011	1.435±0.010	0.583±0.007	2.55±0.03	0.41±0.03
HT Vir	1.046±0.013	1.284±0.015	1.107±0.004	1.223±0.005	1.50±0.01	1.72±0.02

The shape of the light curve of V776 Cas indicates low inclination. Additionally the contribution of a third light further decreases the amplitude of variations. Our solution resulted in an inclination of i=52.5° and the contribution of the visual companion in the range from 8% to about 5% in the U and R filters, respectively. The secondary star is slightly hotter than the primary. V776 Cas is in deep contact configuration with a fill-out factor of 77%. Considering the low inclination and influence of the third light this solution is not as reliable as these for high-inlination systems.

Due to its lower brightness observations of FU Dra show larger scatter, but the theoretical light curve describes them well. Because of a noticable O'Connel effect, not reduced after accounting for color term extinction, one cool spot was introduced in our model. We obtained a high inclination of i=81° for this system as indicated by deep eclipses. The configuration is contact with a fill-out factor of 15%.

A similar fill-out factor was obtained for UV Lyn (18%). Also this star shows a significant difference in brightness of the maxima and we had to add a spot into the model. The best fit was obtained for a big cool spot near the equator of the secondary star. We confirm the results by Vaňko et al. (2001) that the bigger component in this system is the cooler one.

BB Peg shows a flat bottom primary minimum. The secondary minimum is a little shallower. Our solution resulted in a high inclination of i=88.5° and a contact configuration with a fill-out factor of 21%. The bigger component is cooler and again, a cool spot was placed on the more luminous star as a noticable O'Connell effect is present in the light curve.

V592 Per is another high-inclination system (i=89.6°). Due to the contribution of a companion star, the amplitude variations are smaller than for BB Peg. We obtained a deep contact configuration with the contribution of the third star to the total light from about 40% in the B filter to about 48% in the I filter, in good agreement with estimates from broadening functions analysis (Rucinski et al. 2005).

Light curves of OU Ser and HN UMa are featurless, similar to that of V776 Cas, indicating low inclination. Indeed, inclination of 52° was derived for OU Ser while even lower i=47° for HN UMa. As there is no indication of the existence of a third light in these systems, their solution should be somewhat more reliable than that of V776 Cas. For both systems the contact configuration described observations the best. The fill-out factors are 48% and 32% for OU Ser and HN UMa, respectively.

The light curve of EQ Tau shows deep eclipses and an O'Connell effect. Therefore, a cool spot on the primary component surface was assumed. Our solution confirms the results by Yang and Liu (2002) and Pribulla and Vaňko (2002). The degree of contact is low with the fill-out factor of 13% and the components have almost the same temperatures.

The best fit we obtained for HT Vir resulted in a marginally contact configuration with a fill-out factor of 8%. The visual companion contributes about 36% to the total light, independently of the filter, a lower contribution than that derived by Lu et al. (2001), Walker and Chamblis (1985). Since the third light was introduced into the model, which is strongly correlated with many parameters, the configuration is not quite reliable. Only some independent companion brightness estimate (i.e. from specle measurements) can resolve the problem.

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