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Photometric solutions of some contact ASAS binaries

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HIGHLIGHTS

- The light curves of six ASAS targets are analyzed.
- The photometric elements are derived and the absolute parameters are estimated.
- The locations of the systems on the HR diagram and mass–radius plane are discussed.

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ABSTRACT

We present the first light curve solution of 6 contact binary systems which are chosen from the ASAS catalog. The photometric elements and the estimated absolute parameters of all systems are obtained with the light curve analyses. We calculated the values of degree of contact for the systems. The location of the targets on the Hertzsprung–Russell diagram and the mass–radius plane is compared to the other well-known contact binaries and the evolutionary status of the systems are also discussed.

1. Introduction

ASAS (All Sky Automated Survey, Pojmanski, 1997) is a project which aims to detect any kind of photometric variability by monitoring the large area of the sky with fully automated instruments. One of the main objectives of ASAS is to find and catalog variable stars. Through the project, approximately 10^7 stars which are brighter than 14^m have been observed so far. The prototype of the project was first operated in 1996 at the Warsaw University Astronomical Observatory. Now, it carries on with three full automatic instruments having V and I filters attached to CCD cameras at Las Campanas Observatory in Chile and at Mt. Haleakala Observatory in Maui, Hawaii. The categorized stars are relatively located in the southern hemisphere ($\delta < +28^\circ$) and many of them are newly discovered. The public domain data of the ASAS also ease the achievement and investigation of the systems in detail. ASAS apparent magnitudes were transformed into the standard 'I' and 'V' systems using Landolt (1992) and Hipparcos (Perryman et al., 1997). The photometric accuracy is given about 0.05 mag in most cases.

Pojmanski (2000) published the first results of observations obtained by the prototype ASAS camera and gave a catalog containing 3800 variable stars. According to Paczyński et al. (2006) 11,076 eclipsing binaries (including 5384 contact systems) were discovered. They presented the preliminary results of the analysis for thousands of binary systems. They also emphasized that their statistical investigation supports the hypothesis in which the thermal relaxation oscillation states of contact binaries (Flannery, 1976; Lucy, 1976).

The targets in our study were selected from the eclipsing binary list of Paczyński et al. (2006). We chose our targets according to the criteria that no detailed investigation can be found in literature. The main properties of the targets are listed in Table 1. In the next section we present the temperature determination method for primary components and the details of the light curve analyses. In Section 3, we give detailed information about the targets and some crucial parameters obtained by the light curve solutions. We conclude the results and compare the evolutionary status of the targets to known contact binaries in the last section.

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Table 1
Properties of the selected targets. RA, DEC and T_0 refer to the right ascension, the declination and the time of minimum light, respectively. V_{max} and V_{amp} denote the maximum brightness and the amplitude of variation in V filter.

ASAS number	Other ID	RA(^{hms})	DEC($^{\circ ms}$)	T_0(HJD-2450000)	Period(^{d})	V_{max}(^{m})	V_{amp}(^{m})
002821–1453.3	TYC 5268-1013-1	00 28 21	−14 53 18	1869.060	0.402660	11.54	0.44
012450–3241.4	TYC 7002-320-1	01 24 50	−32 41 24	1869.099	0.308971	11.45	0.58
024155+2507.8	TYC 1772-674-1	02 41 55	25 07 48	2621.660	0.400889	11.73	0.61
050334–2521.9	TYC 6477-224-1	05 03 34	−25 21 54	1868.980	0.414060	11.09	0.31
051353–1701.2	TYC 5906-87-1	05 13 53	−17 01 12	1869.140	0.341836	11.66	0.55
063546+1928.6	TYC 1337-1137-1	06 35 46	19 28 36	2621.780	0.475511	9.95	0.43

Table 2
The extinction ratios of different photometric systems given by Ramírez and Meléndez (2005).

Color	Photometric system	k[a]
$(V - J_2)$	Johnson-2MASS	2.16
$(V - H_2)$	Johnson-2MASS	2.51
$(V - K_2)$	Johnson-2MASS	2.70
$(B_T - V_T)$	Tycho	1.02
$(V_T - K_2)$	Tycho-2MASS	2.87

[a] $k = E(color)/E(B-V)$.

Table 3
Results of the light curve analysis of the systems. Formal error estimates are given in parenthesis.

Parameter	002821–1453.3	012450–3241.4	024155+2507.8
i (°)	78.2(6)	81.8(6)	80.8(3)
q	0.173(7)	0.377(8)	0.45(1)
T_1 (K)	6540	5186	5746
T_2 (K)	6593(79)	5164(25)	5537(61)
$\Omega_1 = \Omega_2$	2.12(2)	2.60(2)	2.76(3)
f(%)	40	13	7
$\frac{L_1}{L_1+L_2}$	0.82(1)	0.71(1)	0.72(2)
$\overline{r_1}$	0.549(9)	0.472(7)	0.44(1)
$\overline{r_2}$	0.26(3)	0.30(1)	0.31(2)
T_0 (HJD-2450000)	2080.8634(6)	4740.6713(2)	4409.6264(6)
P (d)	0.4026640(1)	0.30897005(2)	0.40088802(5)
	050334–2521.9	051353–1701.2	063546–1928.6
i (°)	83.3(2)	70.3(7)	85.4(1)
q	0.133(3)	0.52(4)	0.173(4)
T_1 (K)	6347	5419	6229
T_2 (K)	5925(40)	5086(53)	6072(29)
$\Omega_1 = \Omega_2$	2.01(1)	2.81(8)	2.10(1)
f(%)	53	34	58
$\frac{L_1}{L_1+L_2}$	0.885(5)	0.71(3)	0.834(4)
$\overline{r_1}$	0.572(5)	0.46(3)	0.557(4)
$\overline{r_2}$	0.24(3)	0.35(4)	0.27(2)
T_0 (HJD-2450000)	3630.8372(4)	1914.6192(5)	3705.7085(3)
P (d)	0.41406990(4)	0.34183617(8)	0.47551487(3)

2. Light curve analyses of program stars

2.1. Temperature determination

Since the light curve analysis of an eclipsing binary system requires the effective temperature of at least one of the components, the accurate determination of the effective temperature is a critical step in the solution. Our program stars do not have any detailed spectroscopic or photometric study in the literature, however, their Johnson, 2MASS and Tycho magnitudes are given in several data archives. In this case the only way to determine their temperature is to use different colors and temperature calibrations. We used the calibrations given by Ramírez and Meléndez (2005) who listed the adopted extinction ratios for various photometric systems. For the reddening correction, we used calibrations given in Table 2 (Ramírez and Meléndez, 2005) and $E(B-V)$ values which are obtained from Kurucz models (Castelli and Kurucz, 2003). The $(V-K)$ color was decided to use in the light curve solution because of its relatively low dependence on the metallicity. We then determined the effective temperatures of primary components for derived intrinsic color indices by using the appropriate table (Table 11) of Ramírez and Meléndez (2005). During our calculations, we assumed that the primary component is a main-sequence star and its metallicity value is equal to solar metallicity, [Fe/H] = + 0.0. Finally, the average values of two calculated temperatures corresponding to $(V-K_2)$ and (V_T-K_2) colors of each target adopted as the effective temperature values for primary components.

2.2. Analyses

The V–band light curves of selected contact binary systems were collected from the ASAS database. We analyzed all light curves by using the PHOEBE (Prša and Zwitter, 2005) software, which is based on the Wilson–Devinney code (Wilson and Devinney, 1971). The unmeasured and grade D (noted as useless) data were not included to our analyses. The gravitational darkening coefficients of the primary and secondary components, g_1 and g_2, were chosen from Ruciński (1969) while the albedo values, A_1 and A_2, were taken from van Hamme (1993). The following parameters were set as adjustable during the light curve analysis: The inclination of the orbit, i, mass ratio $q = M_2/M_1$, temperature of the secondary component, T_2, dimensionless surface potentials of the primary and secondary components, $\Omega_1 = \Omega_2$, unnormalized monochromatic luminosity of the primary component, L_1, the time of primary minimum, T_0, and the orbital period of the binary, P. Additionally, we calculated the fillout factor of each system by using the following equation (Lucy and Wilson, 1979),

$$f = \frac{\Omega_i - \Omega}{\Omega_i - \Omega_o}, \quad (1)$$

where Ω_i is the inner and Ω_o is the outer Lagrangian potentials. As a first step, we tried to find a solution for all light curves including all observational points (including those with large scattered ones) from the ASAS database. When we reach a reasonable solution, we calculated the differences between the theoretical and observational light curves points for this initial solution. In order to extract the useless scattered points we calculated the standard deviations, σ, of these differences and we removed the points located beyond the 3σ. Then we run the code again to find the final solution. The resulting parameters yielded by analysis of 6 systems including output errors of PHOEBE code are presented in Table 3 and the theoretical light curves among the observational points are also shown in Fig. 1. At the bottom of the figures we also present the differences between computed and observational light curves in the final solution. In the following subsections, we give them some details of the systems based on our analyses.