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A photometric study of the W UMa-type eclipsing binary system 1SWASP J160156.04 + 202821.6

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HIGHLIGHTS

- We present the first B, V, R, and I light curves of the system J1601.
- The photometric mass ratio is estimated to be around 0.7.
- The analysis suggests the system J1601 to be in an overcontact configuration.

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ABSTRACT

B, V, R and I light curves of the eclipsing binary system 1SWASP J160156.04 + 202821.6 (J1601) have been constructed, for the first time, based on the CCD observations obtained using the 1.88 m telescope of Kottamia Astronomical Observatory (KAO), Egypt, during June, 2013. Twenty new times of minima (8 primary and 12 secondary) have been derived from the presented photometry, and a new ephemeris has been determined. The analysis of the corresponding light curves is made using Djurašević's inverse problem method. The light-curve asymmetry is explained using a Roche model with spots on system components. The analysis showed that the system is in an overcontact configuration ($f_{\rm over} \sim 13\%$) with a small temperature difference between the components ($\Delta T = T_{\rm h} - T_c \sim 120$ K), indicating a good thermal contact. The analysis suggests that J1601 is an A-subtype of W UMa-type eclipsing systems, where the primary component is the hotter and more massive one.

1. Introduction

Eclipsing binary systems are significant in general, because they can give us basic stellar parameters, and precise distances. In the special case of close, active systems we are able to study the tidal interactions, mass loss, and mass transfer (accretion disks, circumbinary shells). That is why every individual system can contribute to a better understanding of these processes.

The eclipsing binary system 1SWASP J160156.04 + 202821.6 (α_{2000}=16^{h}01^{m}56^s.04, δ_{2000} =+20°28′21″.52) was discovered as a variable star by Norton et al. (2011) during the analysis of the data from the SuperWASP project (Pollacco et al., 2006), whose primary aim is searching for transiting extra-solar planets. They published a list of 53 candidates for short period eclipsing binary stars observed by SuperWASP. The list includes 48 newly identified objects with periods ~0.23 days. Norton et al. (2011) reported that the orbital period of the system J1601 is 0.22653 days, with maximum $V_{mag} = 14.07$, and amplitudes of 0.70 and 0.57 mag for the depths of the primary and secondary minima. Lohr et al. (2012) chose a short name for the system: J1601, and made a more precise study of the orbital periods in Norton's list, where they found that the orbital period of J1601 is the same as previously estimated by Norton et al. (2011).

Until now there was no information about the spectral type of the system.

2. Observational data and light curves

Photometric observations of J1601 have been obtained in B, V, R and I wide pass-bands (whose effective wavelengths, $\lambda_{\rm eff}$, are 433 nm, 514 nm, 586 nm and 766 nm), during three nights, on 3rd, 4th and 5th of June, 2013, using the EEV CCD 42–40 camera, with 2048×2048 pixels, cooled by liquid nitrogen to −125 C°,

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attached to the Newtonian focus of the 1.88 m telescope of Kottamia Astronomical Observatory (KAO), Egypt. The B, V, R and I light curves are presented here for the first time.

Standard basic data reduction of the raw CCD images was carried out.

Differential photometry was performed with respect to GSC 0151100135 and GSC 0151100096 as a comparison and check stars, respectively. The basic information on the variable, comparison, and check stars was obtained from the UCAC4 Catalogue (see Zacharias et al., 2012), and is listed in Table 1.

The variable *(V)*, the comparison (C), and the check (K) star are shown in one of the V-band frames of our observations as shown in Fig. 1.

The observational data is given in the supplementary table S1.

3. Epochs of photometric minima

Twenty new times of minima of J1601 (8 primary and 12 secondary) have been derived from the observations. The moments of these minima were calculated using the software package AVE (Barbera, 1996), which uses the method of Kwee and van Woerden (1956). Table 2 gives the following parameters: the deduced heliocentric times of minima (HJD), the probable errors in the heliocentric time (P.E.), types of filter (Band), and type of minima (Min.). We used the new times of minima to calculate new ephemeris according to the following equation:

$$HJDMinI = 2456448.36291 + 0.226593 \times E, \quad (1)$$

where E is the integer cycle.

The light curves folded according to this ephemeris and normalized to the first light curve maximum, are shown in Fig. 2.

4. Light curve analysis

To analyse the asymmetric light curves (the secondary maximum is slightly higher than that of the primary one), probably deformed by the presence of spotted areas on the components, we used Djurašević's (Djurasevic, 1992a) program generalised to the case of an overcontact configuration (Djurasevic et al., 1998). The program is based on the Roche model and the principles arising from the paper by Wilson and Devinney (1971). The light curve analysis was made by applying the inverse problem method Djurasevic (1992b), which is based on Marquardt's (Marquardt, 1963) algorithm.

The stellar sizes in the model are described by the filling factors for the critical Roche lobes, $F_{h,c}$ of the primary (hotter, h) and secondary (cooler, c) component. This tells us to what degree the stars fill their corresponding critical lobes. For synchronous rotation of the components, these factors are expressed as the ratio of the stellar polar radii, $R_{h,c}$, and the corresponding polar radii of the critical Roche lobes: $F_{h,c} = R_{h,c}/R_{Roche_{h,c}}$. In the case of an overcontact configuration, the potential ($\Omega_{h,c}$), characterising the common photosphere, is derived with the filling factor of the critical Roche lobe

Table 1
The catalogue data for variable J1601, comparison and check stars.

		Comparison	Check
GCS	0151100479	0151100135	0151100096
UCAC4	553–054948	553–054947	553–054940
α_{2000}	$16^h01^m56^s.04$	$16^h01^m55^s.36$	$16^h01^m44^s.25$
δ_{2000}	+20°28′21″.52	+20°27′33″.00	+20°26′27″.26
B	$15^m.119$	$15^m.905$	$15^m.508$
V	$13^m.99$	$15^m.24$	$14^m.82$
R	$13^m.615$	$14^m.99$	$14^m.69$

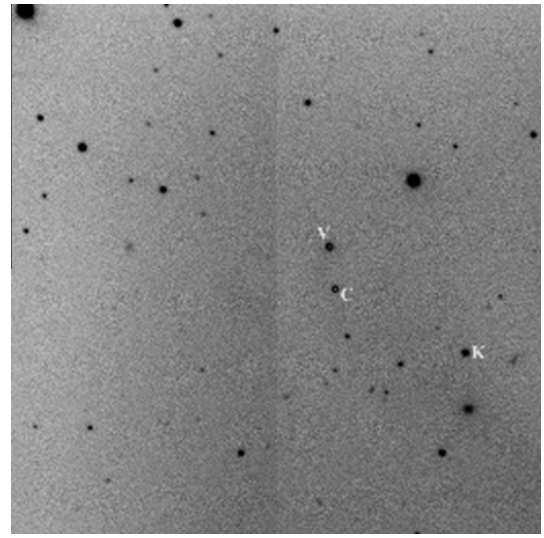

Fig. 1. One of the V-band CCD images of J1601. V, C, and K in the image refer to the variable, comparison, and check stars, respectively.

Table 2
Epochs of minimum light of the system J1601.

Time of min. (HJD)	P.E.	Band	Min.
2456447.3433210	0.000394	B	II
2456447.3430740	0.000126	V	II
2456447.3435940	0.000538	R	II
2456447.3443190	0.000471	I	II
2456448.3631140	0.000661	B	I
2456448.3630860	0.000273	V	I
2456448.3629890	0.000370	R	I
2456448.3624580	0.000445	I	I
2456448.4760110	0.000552	B	II
2456448.4758860	0.000550	V	II
2456448.4758130	0.000296	R	II
2456448.4758940	0.000630	I	II
2456449.4956140	0.000560	B	I
2456449.4957340	0.000602	V	I
2456449.4958280	0.000613	R	I
2456449.4953350	0.000580	I	I
2456449.3821600	0.000326	B	II
2456449.3822000	0.000320	V	II
2456449.3815750	0.000710	R	II
2456449.3821670	0.000362	I	II

$F_{h>1}$ of the primary, while F_c may be excluded from further consideration. The degree of overcontact is defined in the classical way (Lucy and Wilson, 1979) as:

$$f_{over}[\%] = 100 \cdot (\Omega_{h,c} - \Omega_i)/(\Omega_o - \Omega_i), \quad (2)$$

where $\Omega_{h,c}$, Ω_i, and Ω_o are the potentials of the common photosphere and of the inner and outer contact surfaces. To achieve more reliable estimates of the model parameters in the light curve analysis program, we used a dense coordinate grid, having $72 \times 144 = 10368$ elementary cells per star. The intensity and angular distribution of radiation of elementary cells are determined by the stellar effective temperature, limb darkening, gravity darkening and by the reflection effect.

The presence of spotted areas (dark or bright) enables us to explain the asymmetries and the light curve anomalies. In the program, these active regions are approximated by circular spots, characterised by the temperature contrast of the spot with respect to the surrounding photosphere ($A_S = T_S/T_*$), by the angular dimension (radius) of the spot (θ_S) and by the longitude (λ_S) and latitude (φ_S) of the spot centre. The longitude (λ_S) is measured