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A CCD photometric study of the newly discovered contact binary ASAS 134738+0410.1

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Abstract. We present a CCD photometric study of the star with ASAS ID 134738+ 0410.1 using V band observations obtained from the *IUCAA* Girawali Observatory (IGO) 2-metre telescope, India. The star was selected from the δ Scuti database of All Sky Automated Survey (ASAS) (Pojmanski 2002). Our analysis reveals that the star is not a δ Scuti variable but is in fact a W UMa type contact binary with an orbital period of 0.2853067 day. Two new times of primary and secondary minima were determined from the observed data. A preliminary solution obtained using the Wilson-Devinney light curve modelling technique indicates that the star is more likely a partially-eclipsing W UMa type contact binary. However, the determination of actual subtype of this binary is quite impossible from the photometry alone, as the observed light curve can be fitted for both A- and W-type solutions. The exact classification of this binary needs to be determined from high resolution spectroscopy.

Keywords : binaries: close - stars : individual ASAS 134738+0410.1 - stars: magnetic fields

1. Introduction

In the ASAS[1] database, the star has maximum V magnitude of 13.47 mag and is located at $\alpha = 13^{\rm h}\,47^{\rm m}\,38^{\rm s}.0$ and $\delta = 04^{\rm o}\,10'\,05''.9$ (Epoch J2000). The star has been classified as δ

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[1]http://www.astrouw.edu.pl/asas/

Table 1. Basic information of ASAS 134738+0410.1, the comparison star and the check star.

Star	RA (J2000)	DEC (J2000)	J [mag]	H [mag]	K [mag]
ASAS 134738+0410.1 (Target)	$13^h 47^m 38^s.00$	$04^o 10' 06''.00$	11.894	11.472	11.407
2MASS 13473475+0408167 (Comparison)	$13^h 47^m 34^s.76$	$04^o 08' 16''.72$	12.408	12.026	11.951
2MASS 13472306+0413420 (Check)	$13^h 47^m 23^s.06$	$04^o 13' 42''.10$	12.213	11.870	11.789

Scuti/Contact/ Semi-Detached binary with a period of P_{ASAS} = 0.142654 day. The classification is thus ambiguous. In order to know the true nature of this object, we have obtained high precision CCD photometric data from new observations. The new data indicates that the star is a W UMa contact binary with an orbital period of P_{IGO} = 0.2853067 day which is nearly twice the period P_{ASAS} = 0.142654 day.

The V band CCD photometric observations of the star were carried out with the IGO 2-m telescope, located about 80 km from Pune, India during two nights on March 31 and April 02 in 2009. The IUCAA Faint Object Spectrograph Camera (IFOSC) equipped with EEV 2 K× 2 K thinned, back-illuminated CCD with 13.5 μm pixels was used. The CCD used for imaging provides an effective field of view of $\sim 10.5' \times 10.5'$ on the sky corresponding to a plate scale of 0.3 arcsec pixel^{-1}. The gain and read out noise of the CCD camera are 1.5 e^-/ADU and 4 e^- respectively. The FWHM of the stellar image varied from 3 to 5 pixels during the observations. We took a total of 153 frames in the V band with the exposure times varied between 100 s and 180 s for a good photometric accuracy.

The co-ordinates of the variable, comparison star and the check star along with the infrared JHK magnitudes taken from the 2MASS catalogue (Cutri et al. 2003) are listed in Table 1. The comparison and the check star are so close to the variable that they are in the same field during the observations. Image pre-processing and data reduction was carried out using IRAF[2] and MIDAS softwares. Instrumental magnitudes were obtained using the DAOPHOT package (Stetson 1987, 1992). The various tasks, e.g., *find*, *phot*, *daogrow*, *daomatch* and *daomaster* were applied in order to obtain the instrumental magnitudes of stars in all the frames. Extinction corrections were ignored as the target star is very close to the comparison star. In Fig. 1, we show the plots of the differential V band magnitude of (Variable - Comparison), (Comparison - Check) versus Heliocentric Julian Day (HJD) in the left, right upper and lower panels respectively for observations on March 31 and April 02, 2009. The reduced results show that the difference between the magnitude of the check star and that of the comparison star was constant with a probable error of ±0.004 mag in the V band [3].

[2]IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

[3]The observational data presented in this paper can be obtained from the authors on request.

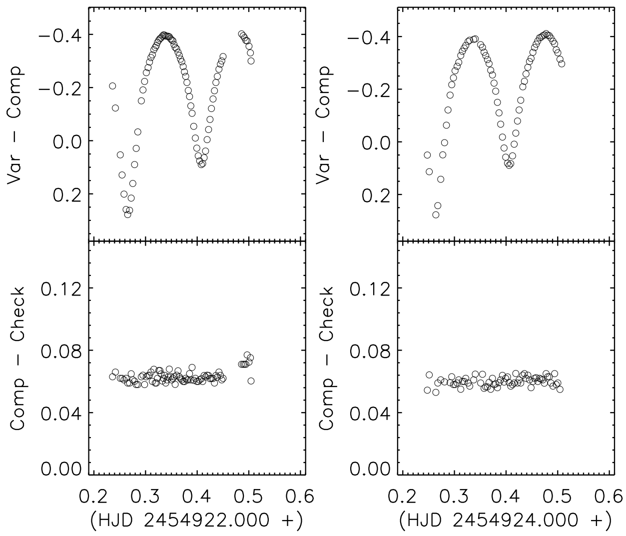

Figure 1. Left upper and lower panels show the differential magnitude versus time (in HJD) of the variable star (Var) with respect to the comparison star (Comp) and comparison star with respect to the check star (Check) respectively for March 31, 2009. The right upper and lower panels show the corresponding plots for April 02, 2009.

2. Period analysis and determination of times of minima

A period analysis was carried out using multi-harmonic ANOVA algorithm technique developed by Schwarzenberg-Czerny (1996, hereafter SC96) to find out the period of ASAS 134738+0410.1. The method computes periodogram by fitting multi-harmonic Fourier series to the time series data. It is very efficient and robust for non-sinusoidal signals. The various statistical properties and advantages of this method are described in SC96. The following times of minima were determined from the data using the Kwee & van Woerden's method (1956).

$$\text{Min I [Primary Minimum]} = 2454922.27125(5), 2454924.26926(28)$$

$$\text{Min II [Secondary Minimum]} = 2454922.41364(5), 2454924.41099(8)$$

The numbers given in parentheses represent the probable errors and are expressed in terms of the last quoted digits. For example, 2454922.27125(5) should be interpreted as 2454922.27125 ± 0.00005. We use the following ephemeris to derive the phased light curve.

$$\text{Min I} = \text{HJD}\, 2454922.27125(5) + 0^{\text{d}}.2853076 \times \text{E}\,, \quad (1)$$

where E is the epoch in days. We plot the phased light curve of the star in Fig. 2. The phased light curve of the star is defined as an array of phase (Φ) and differential V band magnitude (ΔV).

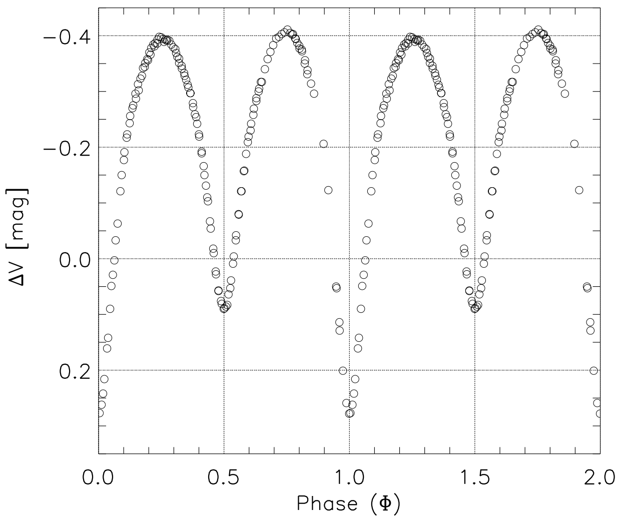

Figure 2. Phased light curve of ASAS 134738+0410.1. The light curve is plotted in the range [0, 2] for a clear visualisation of the primary and the secondary minimum. Open circles denote the observational data points.

The term phase (Φ) is defined as :

$$\Phi = \frac{(t - t_0)}{P} - \mathrm{Int}\left(\frac{t - t_0}{P}\right). \quad (2)$$

The value of Φ is from 0 to 1, corresponding to a full cycle of the orbital period (P) and Int denotes the integer part of the quantity. The zero point of the phase corresponds to the time of primary eclipse (t_0).

A closer look at the light curve of ASAS 134738+0410.1 (Fig. 2) shows that the light curve exhibits O'Connell effect (O'Connell 1951), a phenomenon common to many W UMa type contact binaries due to the surface magnetic activities. To quantify the O'Connell effect, we do a parabolic least-square fitting around the two maxima. The result indicates that the phase at 0.75 (Max II) is ∼ 0.008 mag brighter than that at phase 0.25 (Max I). Also from the light curve, it is clearly seen that the Min I and Min II have different eclipse depths, which indicates that the effective temperatures of the two stars are different. Therefore, the star is a W UMa type eclipsing binary not in thermal contact.

The analysis of the light curve was performed by the software package PHOEBE (Prša & Zitter 2005). It is a modified package of the widely used Wilson-Devinney (hereafter, WD) program for eclipsing binary stars (Wilson & Devinney 1971; Wilson 1979; Wilson 1990).

The effective temperature of ASAS 134738+0410.1 can be calculated from the period-colour relation given by Rucinski (2000) who derived the following relation for contact binary systems.

$$(B - V) = 0.04\,P^{-2.25}, \tag{3}$$

where P is the period in days. With the above equation, the colour of ASAS 134738+0410.1 can be calculated as: $(B - V) = 0.672$. The interstellar extinction along the direction of the star is $E(B - V) = 0.023$ following Schlegel et al. (1998). Therefore, the intrinsic colour index of the star would be $(B - V)_0 = 0.649$. On the other hand, the infrared colour index for the star is $(J - K) = 0.487$ following Cutri et al. (2003). Both these colour indices suggest a spectral type nearly G5V for the binary system.

The adopted parameters are the temperature of the star 1 $T_1 = 5560$ K suitable for the spectral type G5V through the calibration of Cox (2000), the limb-darkening coefficients $x_1 = x_2$, $y_1 = y_2$ interpolated for square root law from Van Hamme (1993) tables, coefficients of gravity darkening $g_1 = g_2 = 0.32$ (Lucy 1967), the bolometric albedos $A_1 = A_2 = 0.5$ (Rucinski 1969) appropriate for convective envelopes.

The adjustable parameters are the orbital inclination i, mass ratio q_{ph}, the mean temperature of the star 2 T_2, the surface potentials of the components Ω_1 and Ω_2, the monochromatic luminosity of the star 1 L_1. Planck function was used to compute the luminosity of the star 1.

Since there is no spectroscopic mass ratio available presently, we try to find the photometric mass ratio q_{ph} using trial values in the range 0.3 to 3.80 in steps of 0.1. Assuming that initially the system is a detached system, the differential corrections were started from mode 2, the differential correction converged to a mode 3 solution (contact mode). We tried both A- and W-type solutions for the system. Both the solutions gave plausible fit to the observed light curve over a wide range of q_{ph} values due to its partial eclipsing nature. Therefore, it is impossible to reliably determine its actual subtype and other parameters from the photometric light curve alone, unless high resolution spectroscopic observations are obtained.

3. Summary and conclusions

We have discovered that the star having ASAS ID 134738+0410.1 identified by ASAS is a W UMa type overcontact binary. We have determined new period and times of minima from very accurate and precise CCD data. Based on the WD code as implemented in the software PHOEBE, we have done preliminary modelling of the light curve. However, unique value of the mass ratio could not be obtained from the modelling, due to its partial-eclipsing nature. Hence, the actual subtype of the system could not be determined. This star deserves high resolution spectroscopic time series radial velocity measurements to determine its true subtype and mass ratio which should be combined with the photometric light curve data to obtain various geometrical and physical parameters accurately.

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