CCD PHOTOMETRIC STUDY OF THE OVERCONTACT ECLIPSING BINARY SYSTEM V1363 Ori

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Abstract.

New BVRI light curves of the eclipsing binary system V1363 Ori, based on CCD observations made at the University of Athens Observatory, are analyzed using the Wilson-Devinney light curve synthesis code and new geometric and photometric elements are derived. These elements are used together with the available spectroscopic data to compute the absolute elements of the system. The evolutionary status of the system is also discussed.

1. Introduction

The eclipsing binary V1363 Ori (GSC 4904:0531) was first was discovered by Hipparcos satellite mission (ESA, 1997). It was listed in the 74th special name-list of variable stars (Kazarovets et al. 1999) as an EW type eclipsing binary with a period of 0.431915 days. The Hipparcos observations of the system were analyzed by Selam (2004), in order to determine the mass ratio, the degree of contact and the orbital inclination. The spectroscopic mass ratio is q=0.205 and the spectral type is estimated to be early to mid F-type Main Sequence system (Pych et al. 2004). An O’Connell effect in the light curves of V1363 Ori was present from the day of its discovery (Gomez-Forrellad et al. 1999) and confirmed by our observations.

2. Observations

The ground-based observations of V1363 Ori were made on 7, 9, 24 February and on 6, 11, 26 March 2004. The instruments used were the 0.40 m Cassegrain reflector at the University of Athens Observatory, Greece, and a ST-8 CCD camera. The CCD camera uses a Kodak KAF-1600 CCD chip, cooled by a two-stage Peltier element, which provides a CCD working temperature of -30° C below ambient. The CCD chip has 1536×1024 useful pixels of 9×9 microns, covering an area of approximately 15×10 arcmin.

The CCD camera is equipped with a set U, B, V, R and I Bessell filters. The scale on the chip is 1.24 arcsec/pixel in 2×2 binning mode.

A total number of 724 frames were obtained in all filters. The images were processed with the AIP4WIN program of Berry & Burnell (2000). Differential magnitudes were used to determine the standard deviation of our measurements, which is 0.005 mag on average in all bands used (B, V, R, I). From the light curves it is clear that V1363 Ori is a contact eclipsing binary of W UMa type.

3. Light curve analysis

3.1. Times of minima

Although we succeeded to observe complete light curves, it was not possible to compute the period of the system, since only one primary minimum was observed. The time of this minimum was computed by the method of Kwee & van Woerden (1956) and its value (the mean value in the four filters B, V, R and I) is: Min I (HJD) = 2452705.2281 ± 0.0008. For the phase diagrams we have used the following ephemeris, where the time of minimum is the one calculated from our observations and the period is from Gomez-Forrellad et al. (1999):

$$\text{Min I (HJD)} = 2452705.2281 + 0^{d}.431921 \times E \qquad (1)$$

3.2. Unspotted solution

Our light curves were analyzed with the Wilson-Devinney DC program, running in Mode 3. One hundred normal points were formed from our observations for each filter. Due to the profound asymmetries in the light curves, we had to assume the existence of at least one cool spot on the primary component of the system, since the temperatures of both components are almost the same. In the beginning of our solution it was assumed that no spots were present on the surface of the stars, and we performed the unspotted solution by omitting the observations around the asymmetrical part of the light curve, between phases of 0.75 and 0.95.

The spectroscopic mass ratio q=0.205±0.007 (Pych et al. 2004) was used as a fixed parameter. The free parameters to be determined by the program were the following: the phase of conjunction φ, the inclination i, the temperature of the secondary star T_2, the surface potentials Ω (both Ω_1 and Ω_2) and the non-normalized monochromatic luminosities of the primary (L_1) for the four filters. The temperature T_1 had a fixed value (from spectroscopic observations). The usual values from the theory were used for the coefficients of gravity darkening. The limb darkening coefficients were taken from the new tables of Claret (2000) (bolometric values) and Claret, Díaz-Cordovés & Giménez (1995), according to the spectral type and the wavelength of observation. The third light was assumed equal to zero. The results are given in the second column of Table 1. The errors given are standard deviations.

3.3. Spotted solution

Cool Spot model

In the second step of our analysis we used all the data, assuming that there is a cool spot in the primary component (spotted solution). The results are given in the third column of Table 1. The spot latitude is counted from the north pole, while the spot longitude from the line between the two components, counterclockwise.

The errors given are standard deviations. The derived parameters were used to construct the theoretical light curves which are shown along with the observed ones in Figure 1.

Hot Spot model

Since the position of the cool spot is around the neck region it was difficult to give a physical explanation. For this reason we tried to model the system with a hot spot on each of the two component. We obtained a satisfactory solution by placing the hot spot on the secondary component. But the position of this hot spot is far away from the neck region and again it was difficult to explain it physically.

The spot latitude was assumed to be 90° and the rest spot parameters were found to be: spot longitude = 57.3° ± 0.2°, spot radius = 13.9° ± 0.1° and temp. factor = 1.262 ± 0.001.

Table 1. Light curve solutions for V1363 Ori.

Parameter	Mode 3 (no spot)	Mode 3 (cool spot)
φ	-0.0041 ± 0.0002	-0.0008 ± 0.0002
i (deg)	53.84 ± 0.01	56.59 ± 0.11
T_1 (K)	6750*	6750*
T_2 (K)	6342 ± 1	6789 ± 12
$\Omega_1 = \Omega_2$	2.1191 ± 0.0001	2.1569 ± 0.0015
$q = m_2/m_1$	0.205*	0.205*
$g_1 = g_2$	0.32*	0.32*
$A_1 = A_2$	0.50*	0.50*
% overcontact	96%	73%
$L_1/(L_1+L_2)$ (B)	0.8238 ± 0.0021	0.7628 ± 0.0031
$L_1/(L_1+L_2)$ (V)	0.8147 ± 0.0018	0.7657 ± 0.0019
$L_1/(L_1+L_2)$ (R)	0.8088 ± 0.0011	0.7678 ± 0.0013
$L_1/(L_1+L_2)$ (I)	0.8015 ± 0.0011	0.7707 ± 0.0012
$X_1 = X_2$ (B)	0.706*	0.706*
$X_1 = X_2$ (V)	0.602*	0.602*
$X_1 = X_2$ (R)	0.497*	0.497*
$X_1 = X_2$ (I)	0.417*	0.417*
r_1 (vol)	0.5661 ± 0.0008	0.5540 ± 0.0012
r_2 (vol)	0.3218 ± 0.0008	0.2948 ± 0.0012
Spot Parameters		
Spot Latitude (deg)	-	127.3 ± 1.4
Spot Longitude (deg)	-	6.1 ± 0.4
Spot Radius (deg)	-	41.5 ± 0.9
Temper. Factor	-	0.77 ± 0.01
Σ w(res)^2	0.0303	0.0358

* assumed

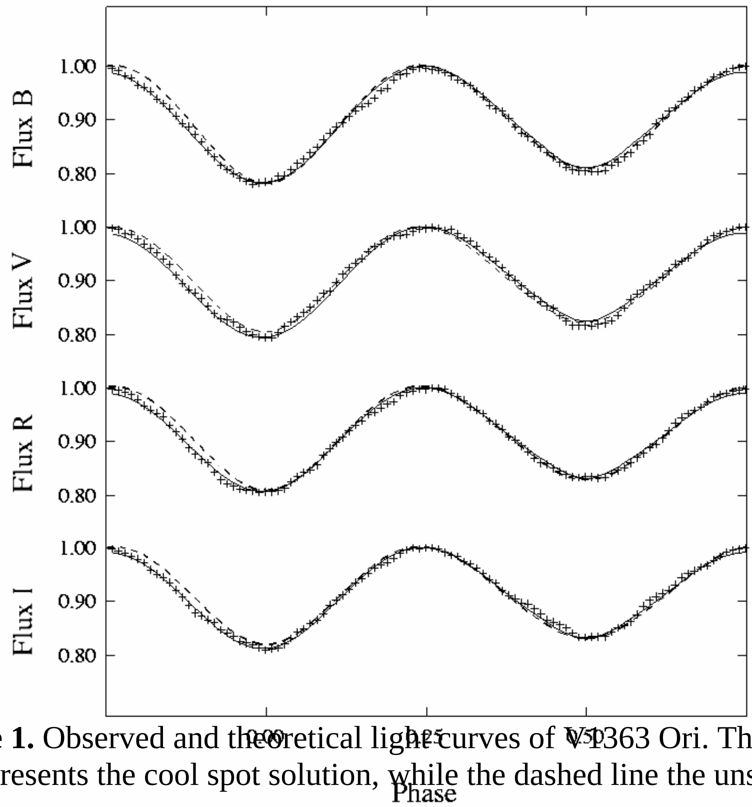

Figure 1. Observed and theoretical light curves of V1363 Ori. The solid line represents the cool spot solution, while the dashed line the unspotted.

5. Summary and conclusions

It is clear from Figure 1 that the observed light curves of V1363 Ori are rather symmetrical with some small parts of asymmetry, explained by spot activity on the stellar surfaces. There is a small difference in the depths of the two minima indicating different surface temperatures of the two components. Such a light curve is typical for W-type contact systems of W UMa type. The light curve analysis shows a highly contact configuration with a fill-out factor 73%.

The elements derived from the cool spot model of Table 1 are combined with the available spectroscopic data to compute the following absolute physical parameters in solar units (radii, masses and luminosities) of V1363 Ori: R_1=1.665±0.087, R_2=0.886±0.046, M_1=1.314±0.599, M_2=0.269±0.123,

L_1=5.193±0.026, L_2=1.505±0.032 and the absolute bolometric magnitudes of the components are: $M_{(bol)1}$=2.960, $M_{(bol)2}$=4.305.

By using the absolute elements of the system we tried to get a picture of its evolutionary status. By means of the M-R diagram we see that the primary component lies on the TAMS line, an indication that is not yet evolved. On the other hand, the less massive secondary, seems to be evolved, as it is well above the TAMS line.

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