BVR photometry of the star TU UMi

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Abstract. The paper presents BVR photometry of the variable star TU UMi obtained by observations with 60-cm telescope of Rozhen NAO in the autumn of 2009. We established a continuous increase of the (O-C) values with time. The obtained light curves are asymmetric with unequal maxima and steeper decreasing branches. Some of the peculiarities of the TU UMi variability can be attributed to the third bright companion.
Key words: stars, eclipsing stars, TU UMi

BVR крива на блясъка на звездата TU UMi

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Представена е BVR фотометрия на звездата TU UMi, получена през есента на 2009 с 60-см телескоп на НАО Рожен. Установено е нарастване на стойностите на (O-C) с времето. Получените криви на блясъка са асиметрични с по-стръмни намаляващи клонове и с нееднакви максимуми. Някои от особеностите на променливостта на TU UMi вероятно се дължат на нейния ярък спътник.

Introduction

The photometric variability of the star BD+76 544 (SAO 8123, HIP 73047, $V \simeq 8.8^m$) with a period of 0.188546 days was discovered by the Hipparcos mission. This F2 star was named TU UMi. Its type of variability was difficult to determine due to the small light amplitude of 0.06^m.

Duerbeck (1997) concluded that the star is a contact binary or a pulsating star with doubled period. Kazarovets et al. (1999) and Rodriguez et al. (2000) catalogued TU UMi as a δ Sct-type variable. On the basis on the Stromgren photometry Rolland et al. (2002) confirmed the original period of 0.188544 days and concluded that the position of TU UMi is outside the instability strip borders of the δ Sct stars in the H-R diagram.

The spectral observations of Pych & Rucinski (2004) showed that TU UMi is a triple system containing a close binary with orbital period of 0.377088 days and bright companion star ($L_3/(L_1 + L_2) = 1.25$). The spectral lines of the close binary TU UMi are very broad and masked by the strong sharp spectrum of the companion. This makes the determination of the individual radial velocities of the TU UMi components quite difficult. Rucinski et al. (2005) derived raw estimation of the mass ratio $q = 0.16$.

The triplety of TU UMi is a new confirmation of the conclusion of Pribula & Rucinski (2006) that the most close binaries exist in multiple system. This explained the least amount of their angular momenta by the distant companions that acquire and/or absorb angular momentum during the evolution of multiple systems making possible the formation of close binaries as TU UMi.

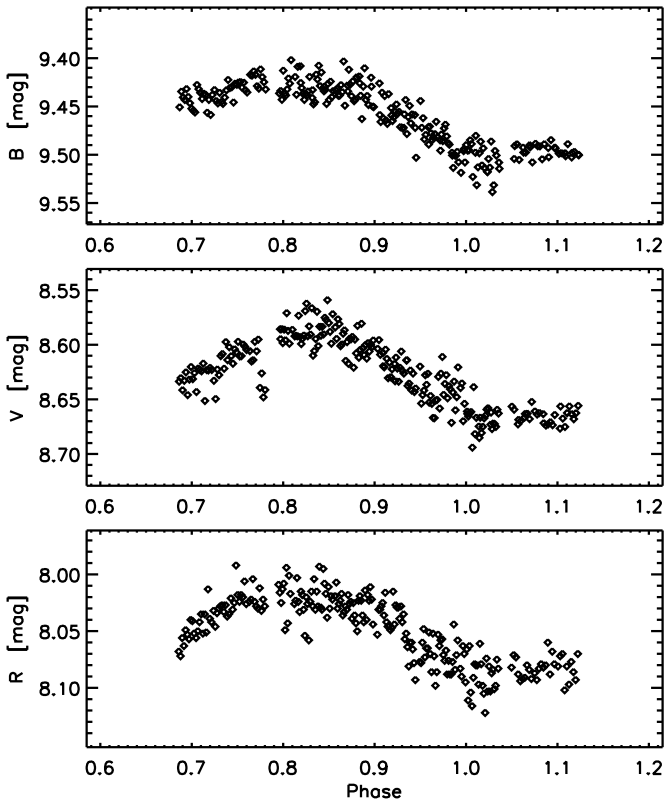

Fig. 1. BVR light curves of TU UMi on Oct 8 2009

1 Observations

The BVR photometry of TU UMi was carried out on 3 consecutive nights (8–10) in October 2009 (total time 13 hours) with the 60-cm Cassegrain telescope at Rozhen National Astronomical Observatory, using the FLI PL09000 CCD camera (3056 x 3056 pixels, $12\mu m$ pixel, field of 17.1 x 17.1 arcmin). The exposure times were respectively 9 s in R, 12 s in V and 35 in B color. We used TYC 4550-2457-1 as a comparison star. Its colors are $B = 12.47^m \pm 0.16^m$ and $V = 11.51^m \pm 0.09^m$.

The data were reduced in a standard way using the software package MaxIm DL by dark substraction and flat-field division.

They are phased according to the spectroscopic ephemeris of Rucinski et al. (2005)

$$HJD(MinI) = 2452725.6262 + 0.377088 * E \quad (1)$$

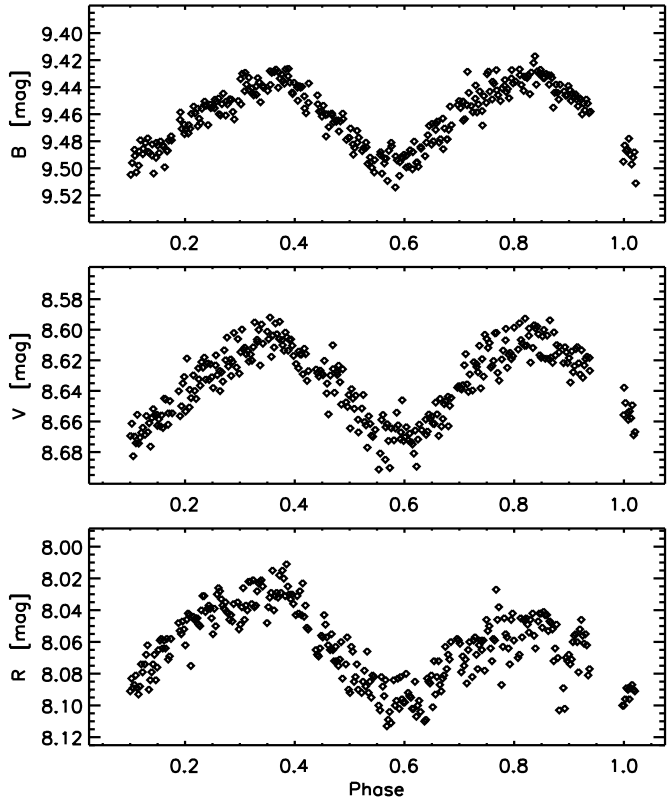

Fig. 2. BVR light curves of TU UMi on Oct 10 2009

and Figures 1 - 2 show the light variability of the star during two of the nights.

2 Analysis of the data

The observed light variability of TU UMi leaded to several conclusions.

(1) Its amplitudes are around 0.07^m in the three colors. These small values probably due to the low orbital inclination as well as to the big light contribution of the tertiary of TU UMi.

(2) The light curves from Oct 8 in all colors show slight light dip at phase 0.03.

(3) The observations from Oct 10 covering almost whole cycle show opposite levels of the light maxima at B color from one hand and V and R colors on the other hand: the B maximum at phase 0.37 is higher than that

Table 1. O-C values

HJD	Type	Phase	O-C [days]	Reference
2452725.62620	Min I	0.000	0.00000 ±0.00000	Rucinski et al. (2005)
2453713.50846	Max II	0.766	0.00597 ±0.00045	Klingenberg et al. (2006)
2454513.41998	Min I	0.052	0.01957 ±0.00060	Brat et al. (2008)
2454513.61237	Min II	0.562	0.02342 ±0.00080	Brat et al. (2008)
2455115.45469	Min II	0.588	0.03329 ±0.00048	our data (10.10.2009)

at phase 0.82 while the V and R maxima at phase 0.37 are lower than those at phase 0.82. Such a behavior may be explained by O'Connell effect, i.e. by cool spot visible around second quadrature.

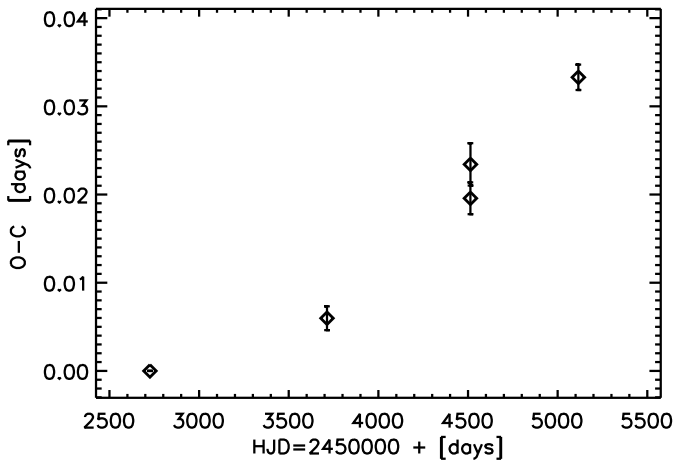

Fig. 3. Increasing of the (O-C) values which error bars correspond to 3σ

(4) The phase of the Min II from Oct 10 (Fig. 2) is 0.588, i.e. there is a delay in respect to the expected time. That is why we gathered all known characteristic times of TU UMi (Table 1), calculated their phases according to the spectroscopic ephemeris of Rucinski et al. (2005) and built the corresponding (O-C) diagram (Fig. 3). It reveals that the O-C values show some linear (or parabolic?) increase with time. The reason for this course of the (O-C) diagram may be the low precision of the determined period of TU UMi or its slow shortening during the last years.

(5) The folded light curves (Fig. 4) reveal asymmetric shape (most asymmetric in B color) with steeper decreasing branches. Their characteristic phases are: almost flat primary minimum at phases 0.0-0.1 (longest in B color), secondary minimum around phase 0.6 (longest in R color), primary sharp maximum at phase 0.37 and secondary maximum at phase 0.82. One may note a feature seeming as "standstill" at phase range 0.2-0.3 causing the big light curve asymmetry.

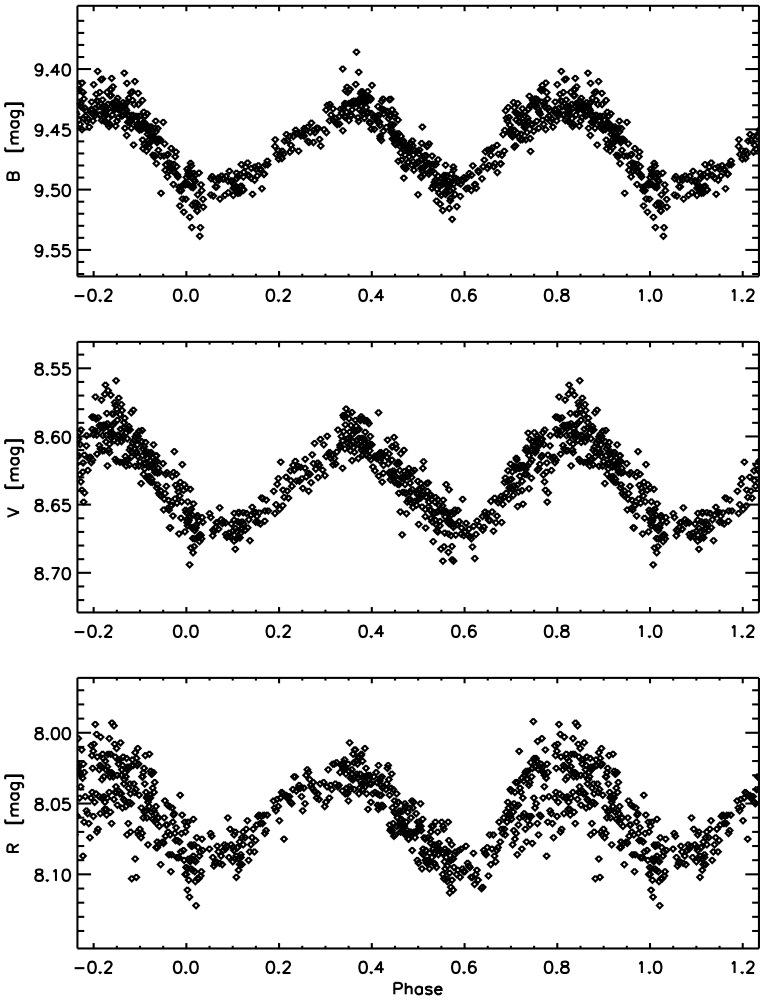

Fig. 4. BVR folded curves of TU UMi

3 Conclusion

Our BVR observations showed that the light curves of TU UMi are asymmetric with steeper decreasing branches and unequal maxima. We established that the (O-C) values of its characteristic phases (minima and maxima) increase continuously with time. Probably most of the peculiarities of the light variability of TU UMi due to the third bright companion.

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