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A NEW ORBIT OF THE BINARY RR LYRAE STAR TU UMa

The RRab-type light variation (V=9.26-10.24 mag, A8-F8) of TU UMa (= $BD + 30^o2162$ = $SAO\,62578$ = $HIC56088$) was discovered by Guthnick & Prager (1929).

The period change was discussed by Szeidl et al. (1986). They fitted the O−C diagram with a negative parabola and found a 23 year-long cyclic variation superimposed on it. They concluded that this could be explained by the duplicity of the star.

Saha & White (1990) analysed the radial velocity and O−C curve of TU UMa, and determined a very eccentric orbit (P=7374.5 day, e=0.97, $a\,sin\,i$=2590 million km). Wade et al. (1992) used a special point on the rising branch to construct the O−C diagram.

The aim of our measurement was to obtain new data on the O−C diagram in order to determine the recent period variation.

We carried out photoelectric photometry (through Johnson UBV filters) of TU UMa on six nights: 1, 8, 21, 28 March and 21, 22 April 1995 with the 40 cm Cassegrain telescope and SSP-5A photometer of Szeged Observatory, Hungary. The comparison star was GSC 1984.0145 (V=9.2 mag, marked with B on chart of Quester, 1993).

The phase diagram of the light curve is plotted in Figure 1 (P=0.557702 day, T_0 =2449699.9600). The period was determined with the Phase Dispersion Method.

The moments of maxima are listed in Table 1, where the O−C residuals have been obtained from the ephemeris (Saha & White 1990):

$$Hel.JD\,max = 2425760.4364 + 0.5576581097 \times E$$

Table 1 continues the similar table in Szeidl et al. (1986). The O−C diagram can be seen in Figure 2 without the visual data with weight=0. First we fitted a parabola using only the visual normal, photographic and photoelectric data (weight=1,2,3) and derived the following formulae

$$-1.57398 \times 10^{-10} \times (HJD)^2 + 1.1334 \times 10^{-5} \times HJD - 0.1744,$$

which corresponds to a period decrease of $-3.148\,10^{-10}\,d/d = -1.755\,10^{-10}\,d/cycle = -9.9\,ms/yr$. This value is about double the reported one in Szeidl et al. (1986).

Then we calculated a light-time effect curve (only the photoelectric data were used with weight=3) supposing a cyclic period variation due to orbital motion in binary system. The parameters of the fit and their estimated errors are in Table 2. We note that the χ^2-function around the minimum is very flat, therefore a lot of parameter series give similarly good fit.

Accepting $M_1 = 0.55 \pm 0.05\,M_\odot$ mass for the pulsating component (Fernley 1993), we can calculate the semi-major axis of the orbit of the secondary and its mass with iteration (Table 3). The errors are from the uncertainty of the P and M_1. The results suggest a red or white dwarf companion which is probably not detectable in the spectrum of TU UMa

Table 1. Times of maxima

Hel.JD	weight	O−C (day)	source
46848.858	3	+0.0225	Liu and Janes (1989a)
47219.689	3	+0.0109	Barnes et al. (1992)
47255.386	0	+0.0178	BAV Mitt.50 (1988)
47255.398	0	+0.0298	BAV Mitt.50 (1988)
47265.416	0	+0.0099	BAV Mitt.50 (1988)
47265.443	0	+0.0369	BAV Mitt.50 (1988)
47270.451	0	+0.0260	BAV Mitt.50 (1988)
47275.466	0	+0.0221	BAV Mitt.50 (1988)
47294.418	0	+0.0137	BAV Mitt.50 (1988)
47609.494	0	+0.0129	BAV Mitt.52 (1989)
47613.388	0	+0.0033	BAV Mitt.52 (1989)
47613.389	0	+0.0043	BAV Mitt.52 (1989)
47618.961	3	−0.0003	Saha and White (1990)
47943.531	0	+0.0126	BAV Mitt.56 (1990)
47966.364	0	−0.0183	BAV Mitt.56 (1990)
47995.387	0	+0.0065	BAV Mitt.56 (1990)
48024.382	0	+0.0032	BAV Mitt.56 (1990)
48319.385	0	+0.0051	BAV Mitt.59 (1991)
48329.407	0	−0.0108	BAV Mitt.59 (1991)
48358.436	0	+0.0200	BAV Mitt.59 (1991)
48387.411	0	−0.0032	BAV Mitt.59 (1991)
48745.433	0	+0.0023	BAV Mitt.60 (1992)
49059.402	0	+0.0098	BAV Mitt.62 (1993)
49108.462	0	−0.0041	BAV Mitt.62 (1993)
49137.459	0	−0.0054	BAV Mitt.68 (1994)
49785.455	3	−0.0081	present paper
49798.282	3	−0.0072	present paper
49805.5315	3	−0.0073	present paper

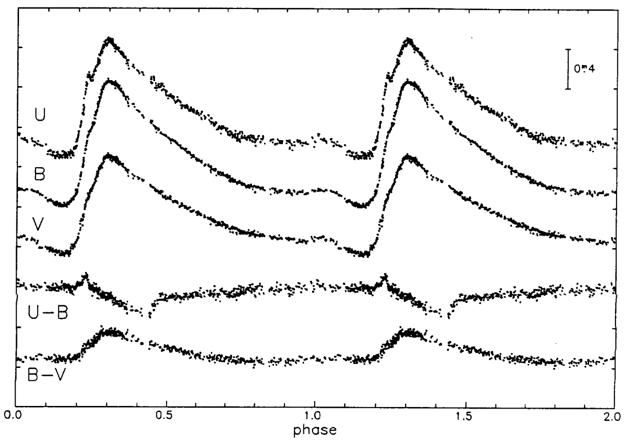

Figure 1. Phase diagram of TU UMa

Table 2. Parameters of the light-time curve

$P_{orb} = 8800 \pm 100\ day$
$a_1 sin\ i = 600 \pm 100 \times 10^6\ km$
$e = 0.9 \pm 0.05$
$\omega = 178^o \pm 3^o$
$\tau = 2447200 \pm 50$
$t_0(O - C = 0) = 2447200 \pm 50$
$K = 11.4 \pm 0.5\ km/s$
$f(M_2) = 0.11 \pm 0.01\ M_\odot$
$A_{O-C} = 0.01 \pm 0.002\ day$

Table 3. Inclination, semi-major axis of the orbit and mass of the companion

$i(deg)$	$a(AU)$ ± 0.2	$M_2(M_\odot)$ ± 0.02
10	12.11	2.54
30	8.18	0.40
50	7.65	0.23
70	7.48	0.18
90	7.44	0.17

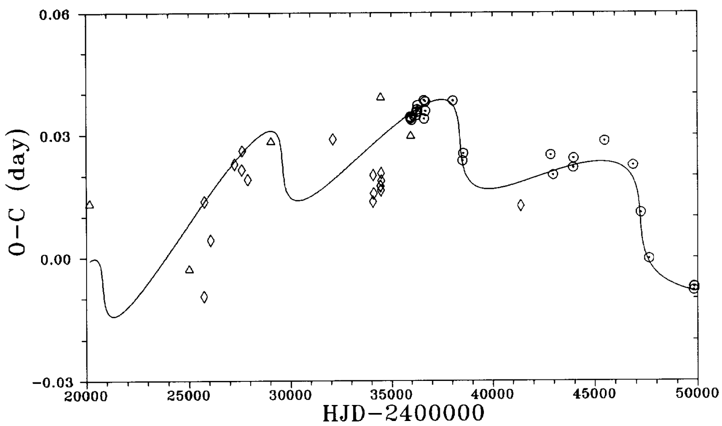

Figure 2. O−C diagram of TU UMa. The fit is the sum of the parabola and the light-time curve. Circles, triangles and diamonds represent photoelectric, photographic and visual (normal) observations respectively.

due to its low brightness. The calculated orbital radial velocity amplitude (K) of the RR Lyrae star is large enough, but the rare spectroscopic measurements for gamma-velocity cannot help to confirm the binary nature.

We can estimate the distance of TU UMa from $M_V = 0.75 \pm 0.05\, mag$ (Fernley 1994) and $< m_V >= 9.75\, mag$: $d = 630 \pm 100\, pc$. If the semi-major axis is $8\, AU$ then the largest distance of the secondary component is 0.01–0.015 arcsec from TU UMa.

Liu & Janes (1989b) reported $[Fe/H] = -1.30$, E(B−V)=0.004, $< R/R_\odot >= 4.95$, $< log\ g >= 2.73$, $< T_{eff} >= 6352\ K$, d=621 pc, $< M_V >= 0.85\, mag$.

We conclude that TU UMa may have a low mass companion. Of course, the binary hypothesis can be confirmed only a few years later. Recently the binary nature is only suspected for a few RR Lyrae stars (e.g. Prosser 1989, Szatmáry 1990).

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