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1999 OBSERVATIONS OF THE SOLAR TYPE ECLIPSING BINARY, TY URSAE MAJORIS

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TY Ursae Majoris [GSC 3837-135, SVS 366, RA(2000) = $12^{\rm h}9^{\rm m}2\overset{\rm s}{.}656$, DEC(2000) = $56°01'53\overset{''}{.}54$] was observed as a part of our program to detect solar type, eclipsing binaries coming into contact through the use of precision multi-band photometry. Broglia & Conconi (1983) had modeled TY UMa in both near contact and a shallow contact configurations, so we added this binary to our list of program stars. TY UMa was discovered by Beljawsky (1933). Broglia & Conconi (1983) presented 2 complete light curves from 1981 and 1982 as well as a partial one from 1967. They found moderate asymmetries in the light curves and calculated the following light elements:

$$\text{J.D. Hel Min I} = 2439532\overset{\rm d}{.}4965 + 0.354538609 \times E. \qquad (1)$$

Their Wilson Code contact solution gave a marginal fill-out of 12% and a mass ratio of 0.4. Similarly, their near contact solution gave a mass ratio of 0.42. Later, Lister et al. (2000) reported V and I light curves from 1993 observations. Lister et al.'s (2000) curves are similar in characteristics to the 1981 curves of Broglia & Conconi (1983). Their models, calculated with the LIGHT2 synthesis code gave a similar inclination and mass ratio with an unusually large fill-out, 27.5%. Such a rapid of change in the degree of contact is difficult to explain especially for a system there describe as undergoing thermal relaxation oscillations about shallow contact. We suggest that spot activity is played a role in their results. The present observations were taken with the 0.79-m Lowell telescope, Flagstaff, Arizona on April 9–11, 1999. Standard Johnson UBV filters were used in conjunction with a thermo-electrically cooled, blue-enhanced PMT. The comparison and check star are given as Comp, and Chk in Figure!1 along with the variable Var. Our photometry revealed that the comparison star [HD 105859, GSC 3837-122, $V = 10.226(11)$, $B-V = 0.609(13)$, $U-B = 0.085(14)$] is of spectral type G0V and the check star, [GSC 3837-157, $V = 9.085(20)$, $B-V = 0.286$, $U-B = 0.068(12)$] is of spectral type A9V. TY UMa, at phase zero had magnitudes $V = 12.077(19)$, $B-V = 0.627(21)$, and $U-B = 0.102(7)$. Here, standard errors accompany the values given in parentheses. All three stars show no evidence of reddening, but lie on the main sequence $U-B$ vs. $B-V$ color-color diagram. We took 666 individual observations in U,

Table 1: Epochs of minimum light of TY UMa

JD Hel. 2400000 +	Epoch	$(O-C)_1$	$(O-C)_2$	Source
40714.7018	−26735.5	−0.0037	0.0002	Walker
40714.8788	−26735.0	−0.0040	−0.0000	Walker
40717.7163	−26727.0	−0.0028	0.0011	Walker
40717.8951	−26726.5	−0.0013	0.0027	Walker
40718.7796	−26724.0	−0.0032	0.0008	Walker
41395.7701	−24814.5	−0.0117	−0.0002	Walker
41395.9483	−24814.0	−0.0107	0.0007	Walker
50193.5894	0.0	0.0109	0.0001	BAV 102
51278.8626(2)	3061.0	0.0293	−0.0041	PO
51279.7495(1)	3063.5	0.0299	−0.0036	PO
51279.9267(1)	3064.0	0.0298	−0.0036	PO
51280.8124(8)	3066.5	0.0291	−0.0055	PO

PO: Present Observations

671 in B, and 669 in V. Four mean epochs of minimum light were determined from two primary and two secondary eclipses using bisection of chords method. Observations taken in 5, 8, 11 and 12 of May 1970, and 19 March 1972 at the Naval Observatory, Flagstaff station by Walker, yielded nine additional timings of minimum light which we present here. Walker used the tracing paper method to find these. These precision epochs of minimum light are given in Table 1 along with the standard errors of the last digits in parentheses.

A linear ephemeris was calculated using 198 epochs of minimum light:

$$\text{J.D. Hel Min I} = 2450193\overset{\text{d}}{.}5785(50) + 0.35454257(26) \times E. \tag{2}$$

The residuals are shown in Figure 2 and as $(O-C)_1$ in Table 1. The residuals in Figure 2 show a continuous period increase.

Although a quadratic fit seems suggested by the curve, it did not represent the data well so a cubic was attempted. This ephemeris fits the residuals surprisingly well. Such a fit is shown in Figure 2 overlaying the O-C residuals. The cubic ephemeris is:

$$\begin{aligned}\text{J.D. Hel Min I} = 2450193\overset{\text{d}}{.}5893(16) + 0.35454911(33) \times E + \\ + 2.70(15) \times 10^{-10} \times E^2 + 1.74(17) \times 10^{-15} \times E^3.\end{aligned} \tag{3}$$

The residuals of this fit are shown in Table 1 as the $(O-C)_2$. Physically this could mean that there is an accelerating period increase. In the case of conservative mass transfer, this would be caused by a continuous but increasing mass flow from the smaller to the larger component of the binary. The UBV light curves and the $B-V$ and $U-B$ color curves of the variable are shown in Figure 3 as differential standard magnitudes (variable − comparison) versus phase. We note that a sinusoidal curve fits the data with an equally good fit with an oscillation of 100 years. This is a rather short time interval for a TRO oscillation and is too long for an invisible third component orbital period unless it is a neutron star. The probable error of a single observation was 1.3% in B, 1.2% in V, and 1.3% in U. At present, we have calculated a contact solution using the Wilson Code (Wilson 1994, 1990, Wilson & Devinney 1971). Tests for a third light gave a null result. The results show that TY UMa consists of solar-type G0 and G2V spectral type

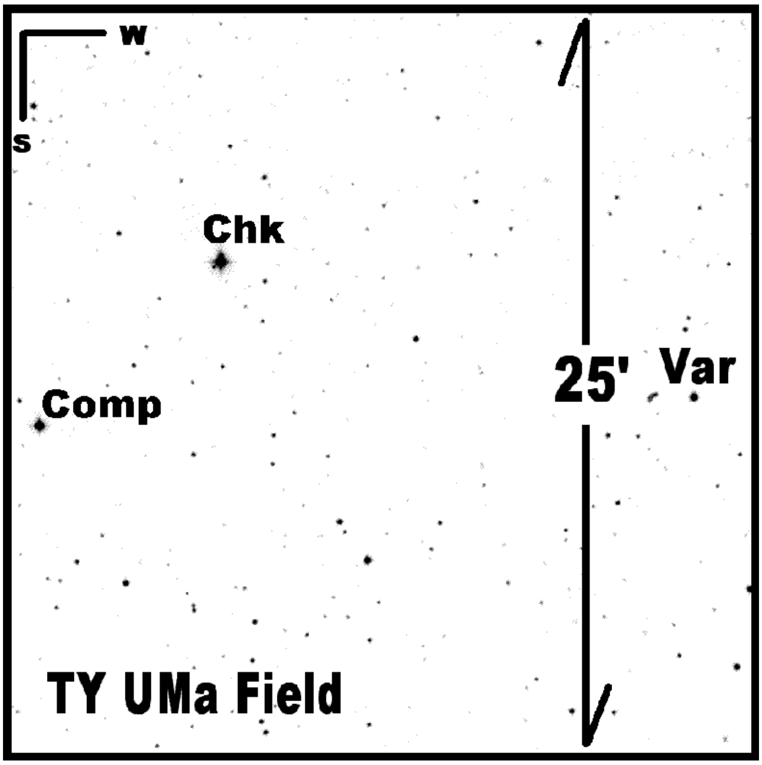

Figure 1. Finding chart of TY UMa, Var, the comparison, Comp, and the check star, Chk

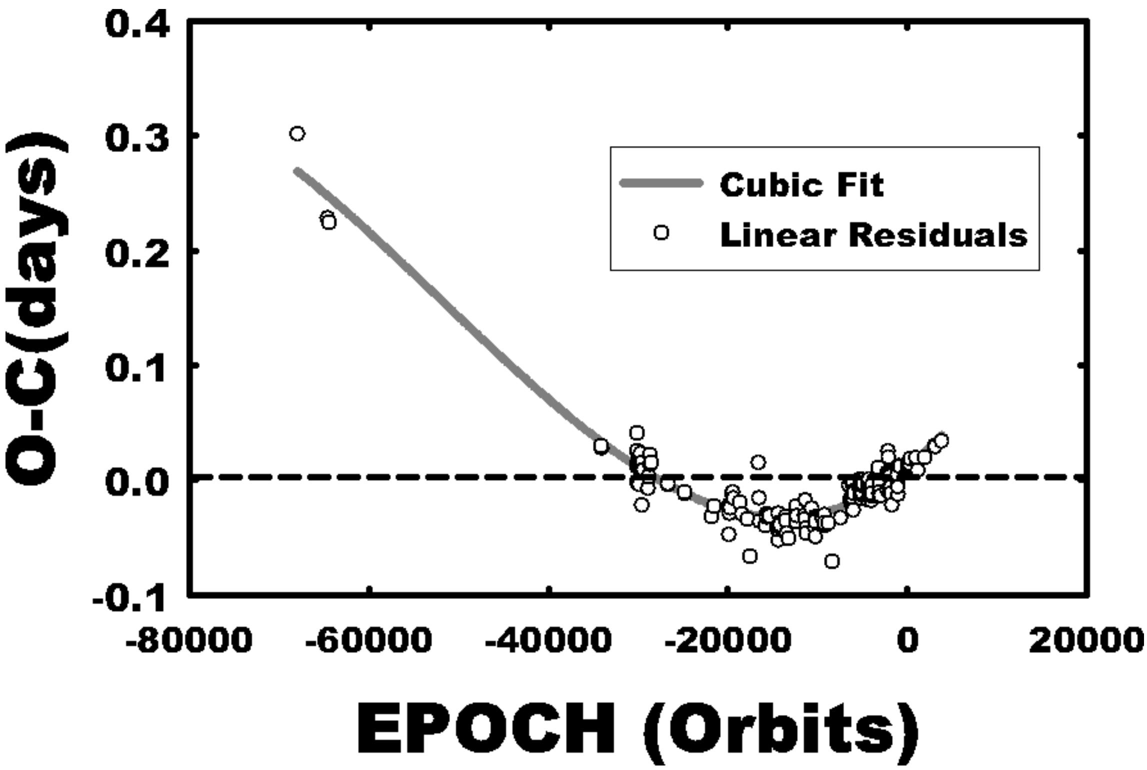

Figure 2. The $O-C$ linear residuals and the computed cubic ephemeris from Equation (3)

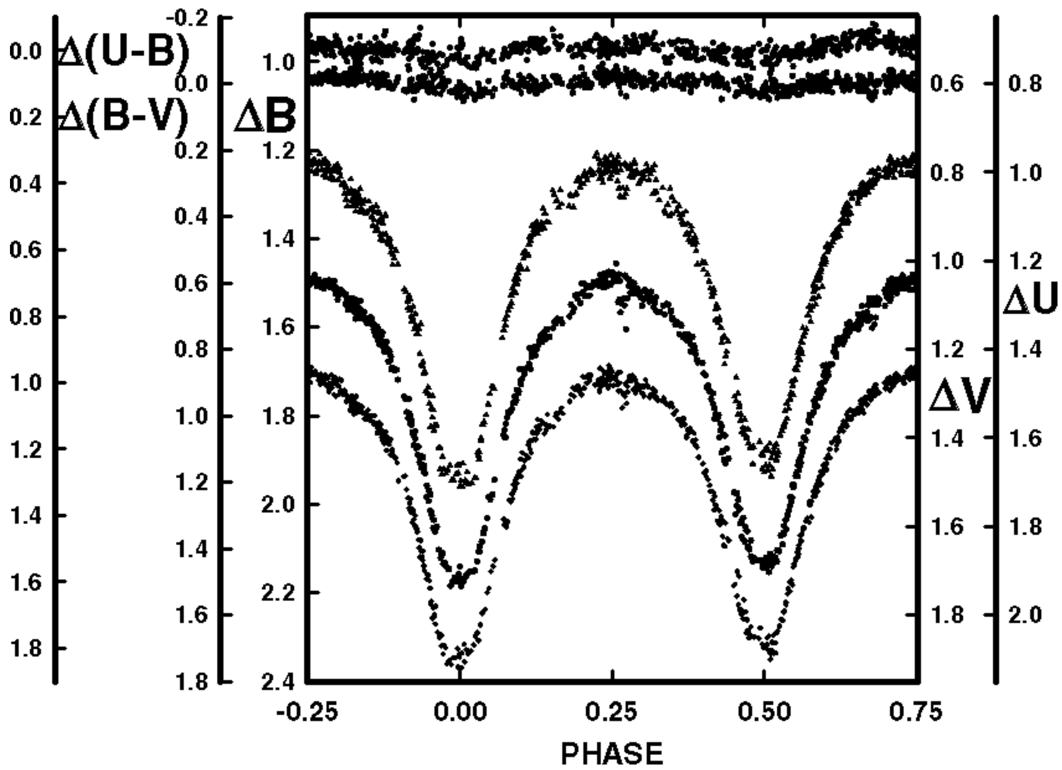

Figure 3. U, B, V standard magnitude light curves as defined by the individual observations

components with a mass ratio of 2.601(2) (or 0.38 for comparison to the previous mass ratios) and a very small fill-out factor of 9%. The model typical is for a W-type W UMa shallow contact system (massive star is slightly cooler). The W-type phenomena is due to wide spread cool spot activity on the hotter more massive star which makes its apparent temperature cooler (Hendry & Mochnacki 2000). This binary has been heavily patroled in the past and this work should be continued into the future. It is truly an astrophysically important close binary.

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