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IMPROVED ORBITAL EPHEMERIS OF GT URSAE MAJORIS

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GT UMa (= HIP 51876, $\alpha_{2000} = 10^{\rm h}35^{\rm m}55\overset{\rm s}{.}7$, $\delta_{2000} = +63°35'32''$) is an eclipsing binary with an orbital period of 1.16472 days as quoted in the Hipparcos Catalogue Variability Annex. The star has no other photometric monitoring reported in the literature. So we embarked on a thorough photometric study conducted at the Črni Vrh observatory, Slovenia in the observing seasons of 2002 and 2003. The results show that the orbital period needs to be improved.

We obtained 3713 pairs of Johnson B and V photometric measurements of GT UMa during 17 useful nights between 2002 Jan 3 and 2003 Jan 29. The observations were obtained with a 19-cm, f/4 flat field S-C telescope and Wright Instruments Peltier cooled system with an EEV CCD02-06-1-206 backside illuminated CCD with 574×385 pixels of 22 μm each. Exposure time was 30 sec in B and 15 sec in V band. Measurements have been reduced by the DAOPHOT (Stetson, 1987) package based on 4 comparison stars with colour coefficients calculated each night. Table 1 quotes names, magnitudes and standard deviations of comparison stars. All comparison stars are from the Tycho II catalogue with their Johnson magnitudes calculated from the Tycho ones using the relations $V = V_T - 0.090(B_T - V_T)$, $B - V = 0.850(B_T - V_T)$ (ESA, 1997). We can infer that median error of individual measurements of GT UMa is 0.015 in V and 0.011 in B band. This is in agreement with the dispersion of the light curve of GT UMa measured outside of photometric eclipses.

The determination of eclipse minima has been done with the algorithm proposed by Kwee & Van Woerden (1956); the results are presented in Table 2. We also report some minima from Hipparcos $\rm H_p$ measurements. Their accuracy is lower because of the substantially smaller number of points and because individual points are separated by at least one rotational period of the satellite.

The original ephemeris based on Hipparcos data

$$\mathrm{HJD_{min}} = 2448500.22 + 1.16472\mathrm{E} \qquad (1)$$

is not consistent with our observations, as timings of our minima are displaced for ~ 0.05 days. A new ephemeris consistent with the whole body of Hipparcos and our measurements is:

$$\mathrm{HJD_{min}} = 2452278.522(2) + 1.164708(2)\mathrm{E} \qquad (2)$$

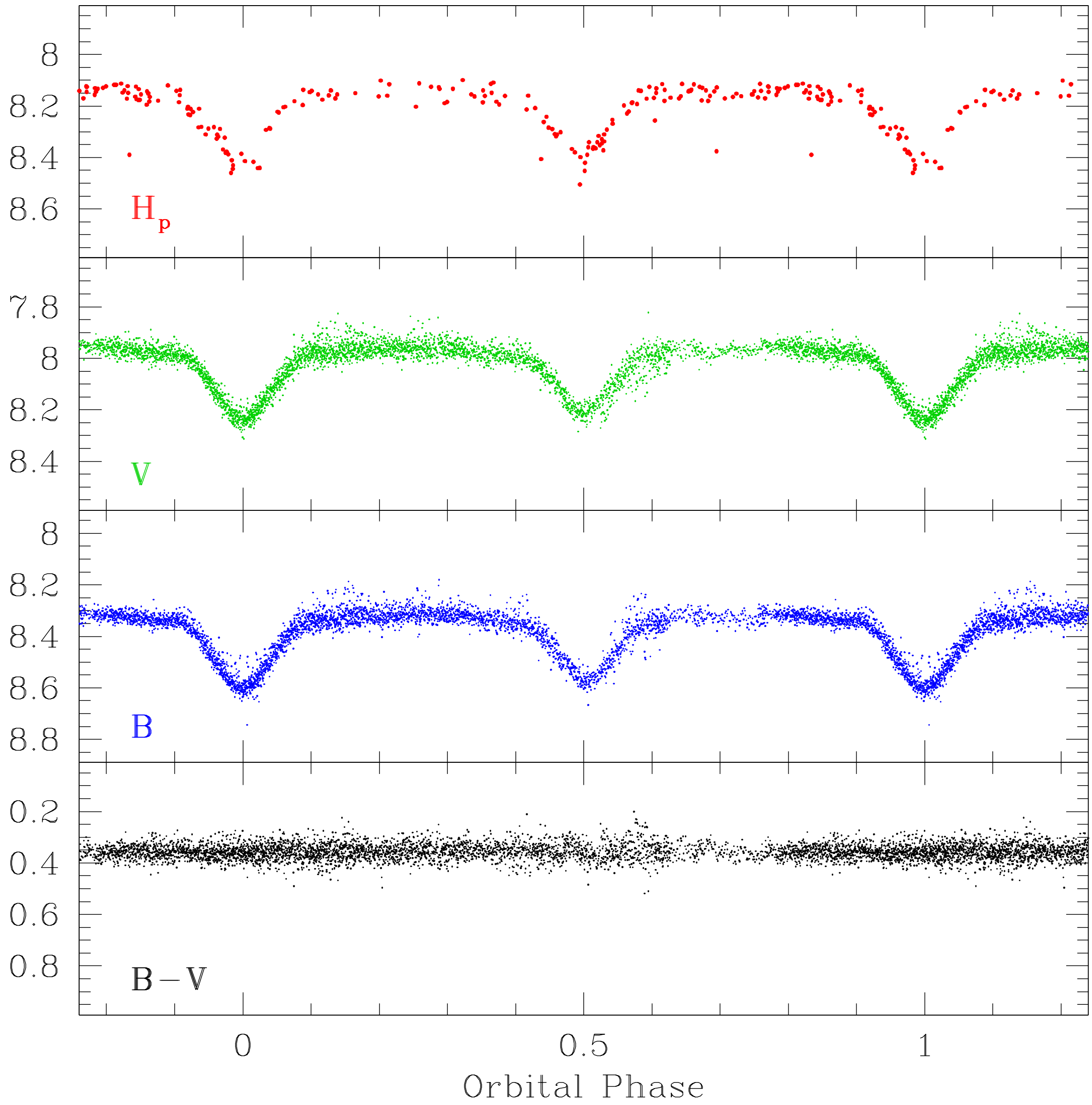

Figure 1. Hipparcos and our photometry with orbital phase calculated from improved orbital ephemeris (eq. 2).

Table 1: Comparison stars, average magnitudes and typical errors of individual measurements. Each star was measured on 3931 (V) or 3934 (B) frames.

star	B	V	B-V	σ(B)	σ(V)
TYC 4147 164 1	10.755	10.326	0.429	0.021	0.036
TYC 4147 600 1	11.774	11.031	0.743	0.027	0.030
TYC 4147 267 1	11.764	10.978	0.786	0.035	0.067
TYC 4147 646 1	11.637	11.051	0.586	0.050	0.080

Table 2: Times of eclipse minima from Hipparcos and our data.

type	HJD	error	filter
primary	2448474.60	0.02	H_p
primary	2448738.97	0.02	H_p
secondary	2449003.92	0.02	H_p
primary	2452278.52	0.005	B and V
primary	2452279.69	0.008	B and V
secondary	2452282.60	0.005	B and V
primary	2452285.51	0.005	B and V
secondary	2452287.255	0.006	B and V
primary	2452652.396	0.004	B and V
primary	2452654.72	0.008	B and V

Numbers in brackets give errors on the last decimal place. This ephemeris is used for the photometry plot (Fig. 1). Clearly the improved orbital period satisfactorily joins photometric observations by Hipparcos and our new photometry. Note that it does not require any secular change of orbital period during the time spanned by Hipparcos and our observations.

The light curves are flat-topped with partial eclipses centered on 0.0 and 0.5 in orbital phase. This indicates that GT UMa is a detached binary and that photometric data are consistent with a circular orbit. The constancy of the B-V index during eclipses indicates that the two stars have an equal temperature. The average value of B-V = $0\overset{m}{.}36$ corresponds to the spectral type F2 on the main sequence which agrees with the spectral type from the literature.

Hipparcos recognizes GT UMa as a visual binary with another component at a separation of 17.570 arcsec, position angle $266\overset{\circ}{.}4$, and with the same parallax (8.18 mas). The companion star is $\sim$ 2.6-mags fainter than the eclipsing binary and of a late F or an early G spectral type. The separation of the components is smaller than the width of the Hipparcos star mapper slits (34 arcsec), so light from the visual companion could slightly contaminate the measured Tycho magnitudes of the eclipsing binary. Halbwachs et al. (1997, their Figure 1) showed that this effect is smaller than 0.02 mags for the V_T filter. Since the eclipses were sampled at random orientations of the star mapper slit, the influence on the derived relative depth of the eclipses is much smaller, in our case below the statistical error of individual H_p measurements. Visual binary is wide enough that it has no influence on the results of our CCD photometry. We note that components of the GT UMa visual binary have a very different size and direction of their proper motion. The implied relative velocity projected on the plane of the sky is $\gtrsim$ 200 km s^{-1}. At a projected separation of 2150 a.u. this implies that GT UMa's visual binary is clearly not a bound system, so it can have no influence on timing of eclipses and so on orbital ephemeris of the eclipsing pair.

We note that a faint ROSAT X-ray source 1RXS J103554.9+633533 (Voges et al., 2000) lies very close to the GT UMa visual binary. At the time of ROSAT observations (21-24 Oct 1990) the component A (i.e. the eclipsing binary) of GT UMa was only 5 arcsec and the component B only 13 arcsec from the reported position of the X-ray source. But we note that the positional error for ~ 15 photons detected by ROSAT is 16 arcsec, so the X-ray source may correspond to either of the two components or to a completely unrelated source. A relatively small proper motion of the A component of GT UMa will keep it within the ROSAT positional errorbox for the foreseeable future, so the best chance to resolve the issue is a repeated X-ray imaging with superior angular resolution capabilities aboard the Chandra satellite.

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