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RECENT LIGHT CURVES AND PERIOD STUDY OF THE CONTACT BINARY W URSAE MAJORIS

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W Ursae Majoris (HD 83950) is a well-known F8V+F8V eclipsing binary system and is the prototype for W UMa-type contact binaries. A recent determination and discussion of its properties is given by Linnell (1991). W UMa was recently observed at the Villanova Observatory by J. DePasquale, C. Henry, I. Nadalin, and M. Stump on the nights of 30, 31 March, and 06, 13, 14, 15 and 25 April UT, 1999. The observations were obtained by using the same equipment and filters as described in Morgan et al. (1997). Over 800 new observations were recorded. The comparison star was HD 83728 ($V = +8.89$; $B-V = +1.07$; K2) and HD 83784 ($V = +8.88$; $B-V = +0.90$; K0) served as the check star. These were the same stars used previously at Villanova (since 1982) and found to be constant in brightness. The observations were reduced in the usual way with corrections for differential atmospheric extinction applied. However, because of the angular proximity of the comparison and variable stars, the extinction corrections were very small. Also, the UT times were converted to heliocentric Julian Day number.

The yellow and red observations were formed into light curves and are shown in Figure 1. In the figure the differential magnitudes, in the sense of variable *minus* comparison star (V − C), are plotted against orbital phase. The phases were computed using updated light elements so that recent primary minima occur at 0.0 phase:

$$T(\min \mathrm{I}) = \mathrm{HJD}\ 2451268.7233 + 0.33363808 \times E. \tag{1}$$

As can be seen in the figure, the light curves are well defined and show the characteristic continuous light variations that are typical for W UMa-type binaries. The light variations arise from the mutual eclipses of the component stars as well as from chiefly tidal distortion and reflection effects. The light curves are similar (but not identical) to the ones reported earlier by Morgan et al. (1997) using the same equipment and filters. As is usually the case for W UMa, the light curves show small asymmetries that change with time. The maximum at 0.25 phase is about 0.031 mag fainter than the maximum at 0.75 phase in the y-bandpass and about 0.015 mag fainter in the red bandpass. As shown in Fig. 1, there is also a noticeable distortion in the light curve near the bottom of primary eclipse. These asymmetries and photometric anomalies most likely arise from the presence of starspots on one or both stars of the system (see e.g., Guinan & Bradstreet 1988). W UMa, and typically most W UMa-type stars with cool components, display the manifestations of strong magnetic-dynamo activity such as: enhanced chromospheric emissions, strong coronal X-ray emission, and photometric anomalies in their light curves

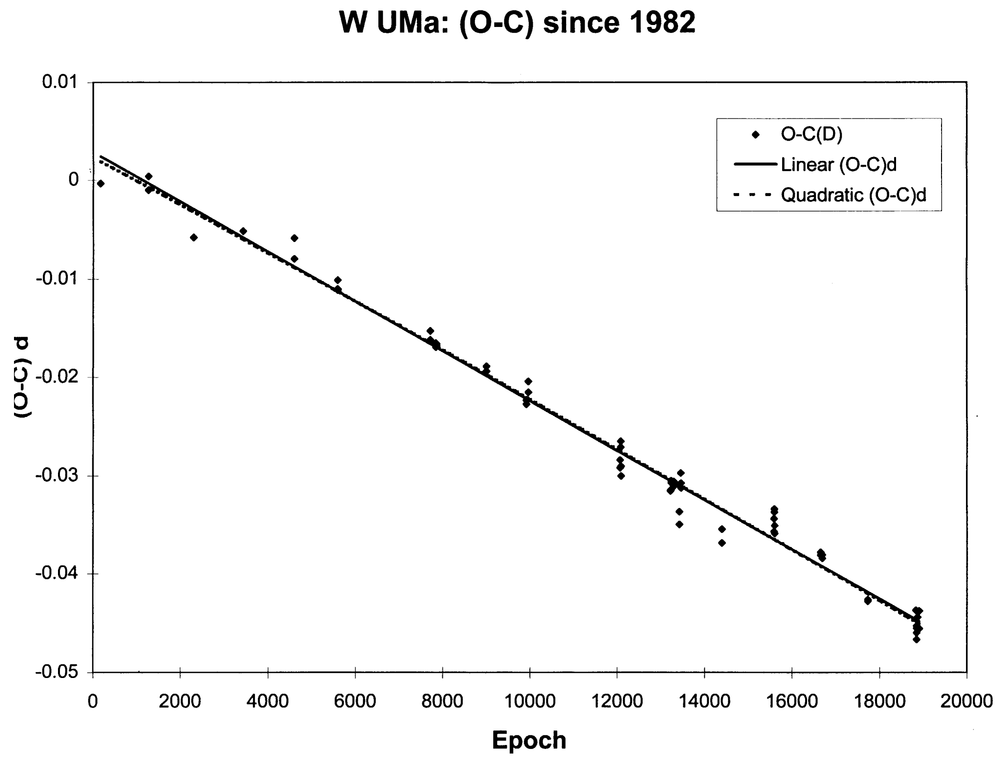

Figure 1.

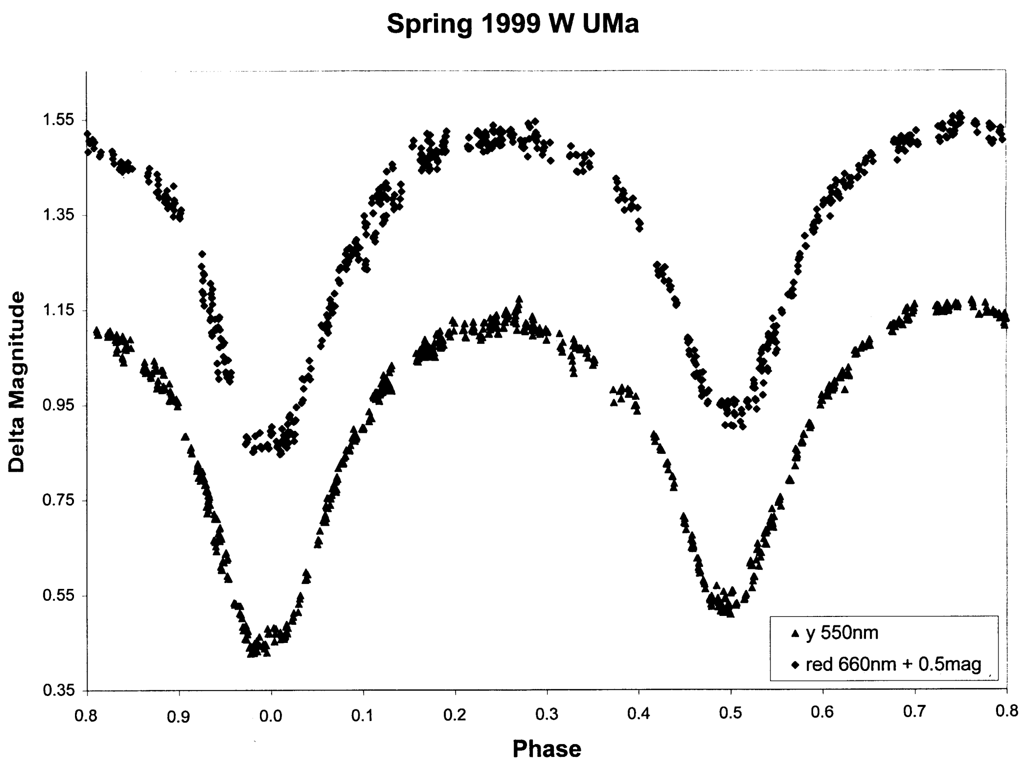

Figure 2.

produced by large starspots (see e.g., Guinan & Giménez 1993). Preliminary analyses of the March-April 1999 light curves indicate the presence of at least two spot regions on the stars. One extended spotted region is most visible near 0.20–0.30 phase and produces the small depression in the light curves seen during the quadrature near 0.25 phase.

Several primary and secondary minima were observed during 1999. Times of minimum light were determined from least squares parabolic fits to the eclipse data. Also, timing determinations were made by reflecting the ingress and egress branches of the eclipses to check the least squares fits. Both methods yielded consistent results when the observations in the lower half of the eclipses were used in the analyses. Times of minimum light were independently determined for the yellow and red data but no systematic differences were found. However, the yellow data had less scatter and yielded somewhat higher precisions to the timings. The new minima are given in Table 1. Additional eclipse timings were obtained from unpublished observations made at Villanova during 1996, 1997, 1998. These additional determinations are listed in Table 1 as well.

Table 1: Times of Primary and Secondary Eclipses of W UMa (1996–1999)

Filter	Type	JD Hel (2450000+)	Observer
r	I	0188.7466	S. Margheim
$b(n)$	I	0188.7453	"
r	I	0191.7487	S. West
$b(n)$	I	0191.7479	"
r	II	0191.5836	"
$b(n)$	II	0191.5832	"
y	II	0543.5673	R. Mittal
r	II	0543.5670	"
y	II	0554.5771	R. Slevinsky
r	II	0554.5767	"
y	I	0901.7228	P. Dituro
r	I	0901.7229	"
y	I	1268.7229	J. DePasquale
r	I	1268.7238	"
y	II	1274.5606	I. Nadalin
r	II	1274.5608	"
y	I	1274.7263	"
r	I	1274.7270	"
y	II	1281.5670	J. DePasquale
r	II	1281.5681	"
y	I	1293.7448	M. Stump
r	I	1293.7465	"

$r = 660$ nm; $b(n) = 453$ nm; $y = 550$ nm

Morgan et al. (1997) have carried out a period study of W UMa from observations collected at Villanova from 1982 to 1995 and found that the period has been relatively constant during that interval. In Figure 2, we extend this study to 1999 by combining the minima given here with those already published by Morgan et al. (1997). In the figure the $O-C$ values are plotted against the number of cycles elapsed (E). $O-C$ values were calculated with the ephemeris used previously by Morgan et al. (1997). Linear (solid line) and parabolic (dotted curve) least squares fits were made to the data, but as shown in the figure, there is little difference between them. Thus, for this interval of time we adopt a linear fit and the mean period during this time interval is $P_{(1982-1999)} = 0.33363554$ d. This is the same value found by Morgan et al. 1997. However, W UMa has a long history of complicated changes in apparent period over time (see e.g., Hamzaoğlu et al. (1982) and Morgan et al. (1997) and that the relatively *constant* period found over the last 15-20 years is probably transitory. However, the light elements given above may be used to predict eclipses over the next few years.

A closer examination of the Figure 2 also reveals possible small (~ 0.002 d) systematic residuals of the $O-C$ values from the linear or quadratic ephemeredes. These short-term variations could arise from asymmetries in the light curve caused by the presence of dark starspots that skew the shape of the minima and produce apparent shifts in the measured mid-eclipse times. The residuals also could be produced from dynamical effects either from small changes in the orbital period or from the light-time effect of a third body. However, if a third body were present then the resulting residuals would be periodic in nature. This does not appear to be the case from the present data. As pointed out by Morgan et al. (1997), the present period is about 22 sec shorter than previous values. The apparent decrease of the period with time could arise from angular momentum loss from magnetic braking or could be due to mass transfer between the components.

Additional photoelectric photometry of W UMa is planned at Villanova University Observatory. This research is supported in part from a NSF/RUI grant AST-9315365 to Villanova University, which we gratefully acknowledge. For this research, we utilized the SIMBAD database, operated by CDS, Strasbourg, France.

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