COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS

Number 5547

Konkoly Observatory
Budapest
30 July 2004

*HU ISSN 0374 – 0676*

# PRELIMINARY SOLUTIONS FOR THE ECLIPSING BINARIES ROTSE1 J180616.31+280109.1, V883 Her, V507 Lyr, MQ Peg, AND MX Peg

WETTERER, C. J.[1]; BLOOMER, R. H.[2]; CARLSON, E.[1]; DOUGHERTY, M. S.[1]; OLIVE, D.[3]; CRAWFORD, B.[2]; COX, S.[4]; FLETCHER, K.[5]; KUNKLE, R.[6]

[1] United States Air Force Academy, USAF Academy, CO 80840, USA, e-mail: charles.wetterer@usafa.edu

[2] King College, Bristol, TN 37620, USA, e-mail: rhbloome@king.edu

[3] Carson Newman College, Jefferson City, TN 37760, USA, e-mail: olivejr@cn.edu

[4] Warren Wilson College, Ashville, NC 28815, USA

[5] Emory and Henry College, Emory ,VA 24327, USA

[6] Albuquerque Technical Vocational Institute, Albuquerque, NM 87109, USA, e-mail: jkunkle@tvi.edu

| **Observed star(s):** | | | | |
|---|---|---|---|---|
| Star name | GCVS type | Coordinates (J2000) RA | Dec | Comp./check star(s) |
| ROTSE1 J180616.31+280109.1 | EW | $18^h06^m16\overset{s}{.}3$ | $+28^\circ01'09''$ | CTI catalog |
| V883 Her | EW | $17^h50^m46\overset{s}{.}5$ | $+28^\circ00'49''$ | CTI catalog |
| V507 Lyr | EW | $18^h40^m48\overset{s}{.}5$ | $+28^\circ01'38''$ | CTI catalog |
| MQ Peg | EW | $22^h48^m10\overset{s}{.}4$ | $+28^\circ05'19''$ | CTI catalog |
| MX Peg | EW | $23^h22^m15\overset{s}{.}0$ | $+28^\circ05'33''$ | CTI catalog |

| **Observatory and telescope:** |
|---|
| CCD Transit Instrument (CTI), 1.8-m f/2.2 meridian pointing telescope |
| Capilla Peak Observatory (CAP), 0.61-m f/15.2 Cassegrain telescope |
| US Air Force Academy Observatory (AFA), 0.61-m f/15.6 Cassegrain telescope |

| | |
|---|---|
| **Detector:** | CTI: RCA LN2-cooled CCD, 320 × 512 pixels, $8\overset{'}{.}3$ wide strip, CAP: RCA LN2-cooled CCD, 320 × 512 pixels, $3\overset{'}{.}6 \times 5\overset{'}{.}2$ FOV, AFA: Photometrics LN2-cooled CCD, 512 × 512 pixels, $3\overset{'}{.}6 \times 3\overset{'}{.}6$ FOV. |

| | |
|---|---|
| **Filter(s):** | CTI: $BVR$, CAP: $V$, AFA: $BVR$ |

| **Date(s) of the observation(s):** |
|---|
| CTI: 1987.10–1991.05, CAP: 1994.06–1996.10, AFA: 2003.06–2003.09 |

ROTSE1 J180616.31+280109.1 (hereafter J180616) previously discovered in the ROTSE test field (Akerlof et al. 2000) and recently identified during a new search for variable stars in the CCD/Transit Instrument (CTI) databases, along with four other W UMa stars identified by Wetterer et al. 1996 (hereafter W96) in the CTI survey (V883 Her,

V507 Lyr, MQ Peg, and MX Peg) were chosen for observations as part of a Consortium for Astronomy Research and Teaching (CART) summer project at the US Air Force Academy (AFA) Observatory and follow-up independent cadet study of modeling W UMa eclipsing systems. The CTI data and 1994 CAP data for V883 Her, V507 Lyr, MQ Peg, and MX Peg were previously used in the photometric analysis in W96.

Table 1: Photometric Characteristics

| | J180616 | V883 Her | V507 Lyr | MQ Peg | MX Peg |
|---|---|---|---|---|---|
| $V_{Max}$ | 12.737(2) | 13.146(3) | 14.266(3) | 13.434(4) | 16.326(13) |
| $V_{MinP}$ | 13.151(1) | 13.355(6) | 14.720(6) | 13.694(5) | 16.611(6) |
| $V_{MinS}$ | 13.039(1) | 13.323(5) | 14.689(7) | 13.685(8) | 16.587(8) |
| $V_{Mean}$ | 12.875(1) | 13.224(1) | 14.422(1) | 13.539(1) | 16.056(10) |
| $(B-V)$ | 0.414(12) | 0.412(10) | 0.57(6) | 0.502(5) | 0.63(5) |
| $(V-R)$ | 0.255(3) | 0.257(6) | 0.379(21) | 0.314(3) | 0.44(6) |
| $E(B-V)$ | 0.100 | 0.061 | 0.181 | 0.061 | 0.063 |
| period | 0.6600655(20) | 0.695016(3) | 0.3669098(10) | 0.3793826(15) | 0.3943902(20) |
| epoch | 52906.674(4) | 52843.788(7) | 52865.694(5) | 52901.8527(23) | 52872.955(8) |

Photometric characteristics for these stars are listed in Table 1: $V_{Max}$, $V_{MinP}$, and $V_{MinS}$ are the average standard V magnitudes at maximum, primary minimum, and secondary minimum light (CAP and AFA magnitudes transformed to CTI instrumental magnitudes via differential photometry with nearby stars in CTI database and then to standard magnitudes as detailed in W96); $V_{Mean}$ is the flux averaged standard V magnitude; $(B-V)$ and $(V-R)$ are the standard colors (recalculated from all available CTI and AFA data); $E(B-V)$ is reddening (as estimated from HI maps in Burstein and Heiles 1982); period is in days (using V photometry and employing Lafler and Kinman's period finding algorithm (Lafler and Kinman 1965)); and epoch is HJD - 2400000 of latest primary minima measured. Observations of all stars were planned to fill in the light curve and not necessarily measure a minimum timing. For those nights where a minimum was adequately observed, however, the Kwee and Van Woerden method (Kwee and Van Woerden 1956) was used to measure the minimum's timing. This is not possible for the CTI data because CTI observed each star only once per night, however, approximate minima timings can be listed for CTI data (and poorly covered CAP data) by listing the most prominent darkenings (within 10 percent of the known minimum magnitude and given a standard 0.02 day uncertainty). All these minima timings are listed in Table 3.

We used the Binary Star Maker 2.0 software and reference manual (Bradstreet 1993) to obtain preliminary solutions for these eclipsing binaries. By examining the most precise photometry (CAP 1996) V507 Lyr appears to undergo a total eclipse with a broadened secondary eclipse and a rounded and slightly deeper primary eclipse. For this system, we used the measured $B-V$ color to determine surface temperature, and assumed identical temperatures for the primary and secondary. The uncertainty in temperature was determined from the uncertainty in $B-V$ color. We simultaneously adjusted the mass ratio, fillout factor, and inclination to reproduce the observed light curve and list the best fit values and ranges qualitatively estimated by examining model fits. The other four systems appear to have rounded and smoothly varying light curves characteristic of W UMa eclipsing binaries undergoing partial eclipses. For these systems, we used the measured $B-V$ color and eclipse depths to estimate surface temperatures and calculated mass ratios consistent with equivalent temperature stars on the Main Sequence. This is probably a good assumption for MQ Peg and MX Peg whose light curve, color, and period are consistent with a contact system with stellar radii approximately equal to the equivalent Main Sequence stars. The observed colors and longer periods of J180636 and V883 Her, however, suggest that one or both components in these systems are extended stars (radii 40-50 percent greater than Main Sequence equivalents). Given the above assumptions, two uncertainties in temperature were determined: the first from the uncertainties in eclipse depths and the second from the uncertainty in the corrected $B-V$ color. Again, given the above assumptions, the uncertainty in mass ratio was determined from the uncertainties in eclipse depths only (the effect of the uncertainty in the $B-V$ color on the mass ratio is negligible). We simultaneously adjusted the fillout factor and inclination to reproduce the observed light curve and list the best fit value and ranges qualitatively estimated by examining model fits. We modeled all stars using standard values for gravity darkening coefficients (1.00 for radiative stars of T > 7200 K and 0.32 for convective stars), limb darkening coefficients (from Appendix III in Bradstreet 1993) and reflection coefficients (1.0 for radiative stars and 0.5 for convective stars) and assumed there was no third light contribution. Table 2 summarizes the results.

Table 2: Preliminary Solutions

| | J180616 | V883 Her | V507 Lyr | MQ Peg | MX Peg |
|---|---|---|---|---|---|
| $T_P$ (K) | 7390 ± 40,70 | 7110 ± 130,60 | 6800 ± 260 | 6535 ± 60,20 | 6130 ± 80,180 |
| $T_S$ (K) | 5900 ± 40,60 | 6720 ± 130,60 | 6800 ± 260 | 6480 ± 60,20 | 5990 ± 80,180 |
| *massratio* | 0.621 ± 0.007 | 0.876 ± 0.033 | 0.24 ± 0.01 | 0.984 ± 0.017 | 0.959 ± 0.022 |
| *fillout* | 0.1 (0.0 - 0.3) | 0.1 (0.0 - 0.15) | 0.2 (0.1 - 0.4) | 0.1 (0.0 - 0.35) | 0.0 (0.0 - 0.1) |
| *inclination* | 66°(68°- 64°) | 54°(56°- 53°) | 80°(84°- 76°) | 59°(61°- 51°) | 62°(62°- 60°) |

Notes on individual stars:

**J180616** is listed in Akerlof et al. 2000 as a W UMa eclipsing system with a period of 0.65998(23) days. The best period determined using the CTI and AFA V data is 0.6600655(20) days. There is evidence of possible star spot activity in the AFA photometry (see phases 0.6 to 0.9 in Figure 1) where a single night of V observations was approximately 0.05 magnitudes fainter than during other observations.

**V883 Her**'s period is listed in W96 (using previously reported CTI and CAP (1994) V data) as 0.695000(3) days (uncertainty originally not published). The new CAP (1996) V data slightly modifies this period to 0.695002(3) days. The new AFA V data, however, is systematically shifted later by about 1.1 hours. The best period determined using the new CAP (1996) and AFA V data is 0.695016(3) days with now the CTI data offset. No systematic timing error is known in any of the data, and so this may indicate that V883 Her's period is changing. If real, this implies a period increase of about 8.6 ± 2.3 seconds/century. This is extraordinarily large, but of the same order of magnitude as some other W UMa stars (see Molik and Wolf 1998). Clearly further more precise observations are warranted. Using the latter period and the minima listed in Table 3, the $O-C$ plot in Figure 6a illustrates this possible period increase.

**V507 Lyr**'s period is listed in W96 as 0.366912(1) days. The new CAP (1996) V data fits this period well while the new AFA V data is systematically shifted, this time earlier by about 15 minutes. The best period determined by CAP and AFA V data is 0.3669098(10) days. Again, if real, this implies a period decrease of about 1.0 ± 0.8 seconds/century. Using the latter period and the minima listed in Table 3, the $O-C$ plot in Figure 6b illustrates this possible period decrease.

**MQ Peg**'s period is listed in W96 as 0.379380(3) days. The new CAP (1995) V data refines this slightly to 0.3793785(15) days. The new AFA V data is again systematically shifted, this time later by about 30 minutes. The best period determined by CAP and AFA V data is 0.3793826(15) days. Again, if real, this implies a possible period increase of about 2.2 ± 1.1 seconds/century. Using the latter period and the minima listed in Table 3, the $O-C$ plot in Figure 6c illustrates this possible period increase.

**MX Peg**'s period is listed in W96 as 0.394387(3) days. The new CAP (1996) V data and AFA V data refined this slightly to 0.3943902(20) days.

**Acknowledgements:**
We thank the Appalachian College Association for their support of this research. This research made use of the SIMBAD database, operated at CDS, Strasbourg, France.

References:

Akerlof, C. et al., 2000, *AJ*, **119**, 1901.
Bradstreet, 1993, *Binary Star Maker 2.0*, Contact Software.
Burstein, D., and Heiles, C., 1982, *AJ*, **87**, 1165.
Kwee, K. and Van Woerden, H., 1956, *BAN*, **12**, 327.
Lafler, J. and Kinman, T. 1965, *ApJ Sup.*, **11**, 216.
Molik, P. and Wolf, M. 1998, *IBVS*, No. 4640.
Wetterer, C.J., McGraw, J.T., Hess T.R., and Grashuis, R., 1996, *AJ*, **112**, 742.

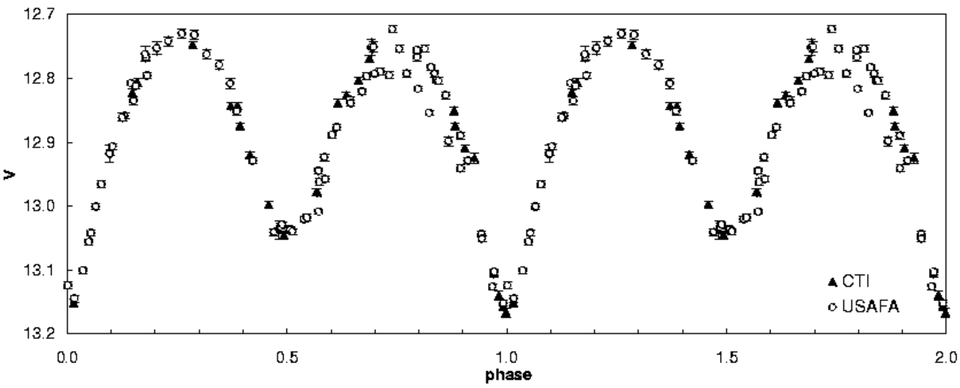


**Figure 1.** Light curve for J180616: P = 0.6600655 days, epoch = 2452906.674 HJD

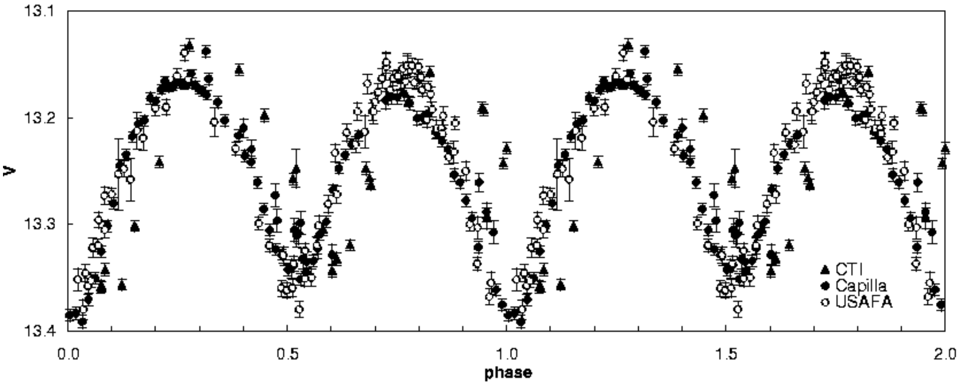


**Figure 2.** Light curve for V883 Her: P = 0.695016 days, epoch = 2452843.788 HJD

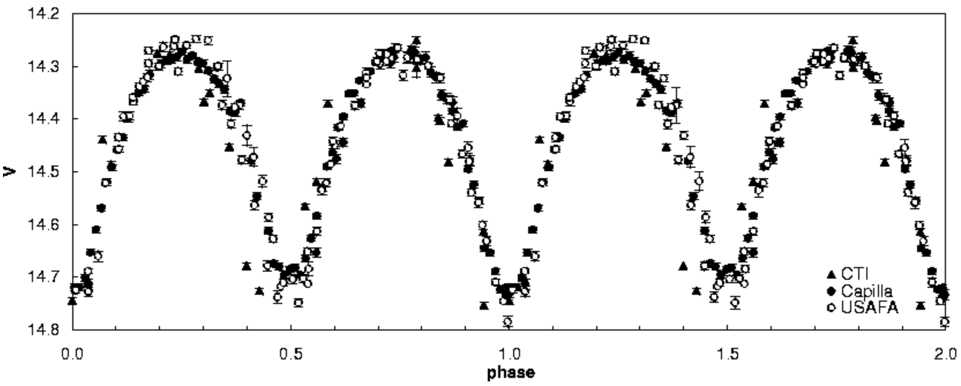


**Figure 3.** Light curve for V507 Lyr: P = 0.3669098 days, epoch = 2452865.694 HJD

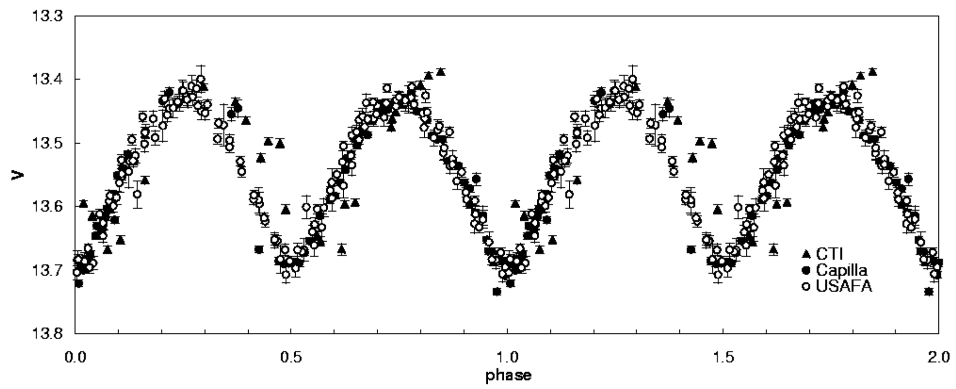


**Figure 4.** Light curve for MQ Peg: P = 0.3793826 days, epoch = 2452901.8527 HJD

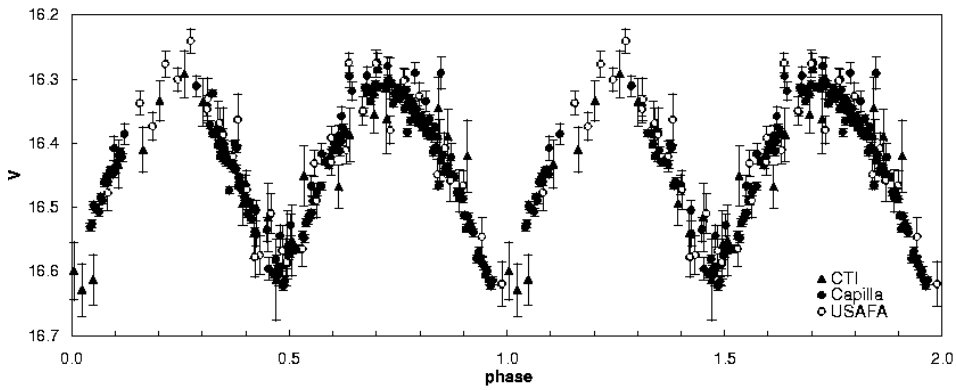


**Figure 5.** Light curve for MX Peg: P = 0.3943902 days, epoch = 2452872.955 HJD

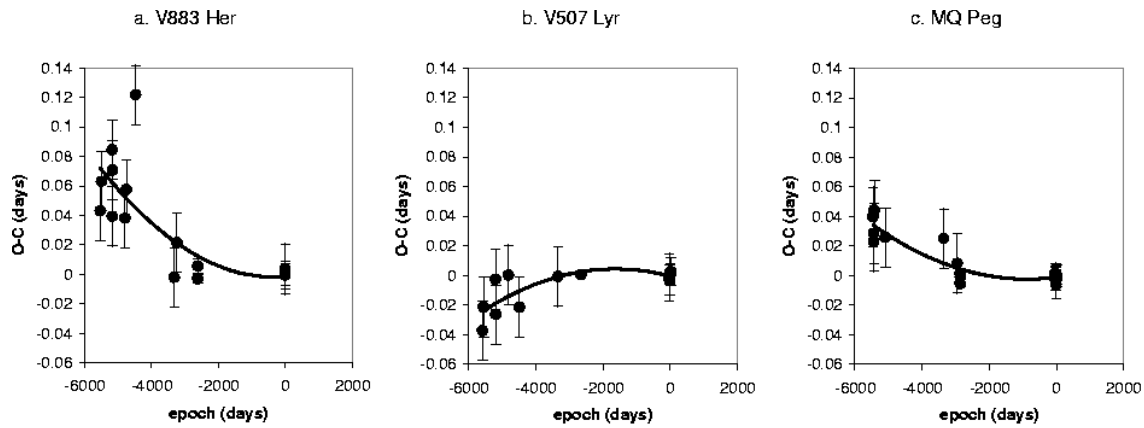


**Figure 6.** O-C plots for V883 Her, V507 Lyr, and MQ Peg (solid lines are non-weighted quadradic fits)

Table 3: Minima Timings

| HJD | type | HJD | type |
|---|---|---|---|
| **J180616** | | 2452842.7594(28) | secondary |
| 2447320.852(20) | secondary | 2452843.860(10) | secondary |
| 2447322.856(20) | secondary | 2452844.7772(27) | primary |
| 2447323.844(20) | primary | 2452864.779(5) | secondary |
| 2447643.965(20) | primary | 2452865.694(5) | primary |
| 2447688.845(20) | primary | 2452878.721(6) | secondary |
| 2447100.719(20) | primary | 2452884.776(9) | primary |
| 2448101.717(20) | secondary | **MQ Peg** | |
| 2452830.760(12) | primary | 2447443.715(20) | primary |
| 2452833.732(19) | secondary | 2447466.651(20) | secondary |
| 2452834.719(12) | primary | 2447470.640(20) | primary |
| 2452866.7340(25) | secondary | 2447482.606(20) | secondary |
| 2452906.674(4) | primary | 2447807.718(20) | secondary |
| **V883 Her** | | 2449545.859(20) | primary |
| 2447319.844(20) | primary | 2449952.920(20) | primary |
| 2447357.742(20) | secondary | 2450036.5601(15) | secondary |
| 2447678.861(20) | secondary | 2450036.7566(20) | primary |
| 2447679.858(20) | primary | 2450041.6865(18) | primary |
| 2447686.840(20) | primary | 2452864.861(5) | secondary |
| 2448062.811(20) | primary | 2452865.813(4) | primary |
| 2448100.709(20) | secondary | 2452866.760(6) | secondary |
| 2448381.907(20) | secondary | 2452871.691(9) | secondary |
| 2449528.907(20) | secondary | 2452871.882(5) | primary |
| 2449611.637(20) | secondary | 2452878.710(4) | primary |
| 2450228.796(5) | secondary | 2452894.644(4) | primary |
| 2450229.8298(25) | primary | 2452894.828(9) | secondary |
| 2452842.745(9) | secondary | 2452901.6607(14) | secondary |
| 2452843.788(7) | primary | 2452901.8527(23) | primary |
| 2452844.834(17) | secondary | 2452907.733(7) | secondary |
| **V507 Lyr** | | **MX Peg** | |
| 2447293.948(20) | secondary | 2447466.673(20) | primary |
| 2447323.867(20) | primary | 2447482.630(20) | secondary |
| 2447680.889(20) | primary | 2447500.581(20) | primary |
| 2447682.883(20) | secondary | 2448126.865(20) | primary |
| 2448062.845(20) | primary | 2448212.631(20) | secondary |
| 2448391.941(20) | primary | 2449610.747(20) | secondary |
| 2449538.922(20) | primary | 2449634.804(9) | secondary |
| 2450218.8071(22) | primary | 2452872.758(8) | secondary |
| 2452838.725(16) | secondary | | |