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GSC 1419 0091, AN EXTREME MASS RATIO CONTACT BINARY

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As a part of our study of solar-type eclipsing binaries with extreme mass ratios (EMRB), we observed the variable GSC 1419 0091 [Brh V132, $\alpha(2000)= 10^{\rm h}11^{\rm m}59\overset{\rm s}{.}15$, $\delta(2000)= +16°52'30\overset{''}{.}28$]. This binary was discovered by Bernhard (2003, 2004) and identified as GSC 1419 0091. An unfiltered CCD light curve taken by Frank (2005) shows that the variable is unmistakably a low amplitude short period totally eclipsing system. That is the light curve character of an EMRB sometimes referred to as an AW UMa-type star. He gave the ephemeris:

$$\text{HJD Tmin I} = 2452754.4602 \pm 0.266727\text{d} \times \text{E} \qquad (1)$$

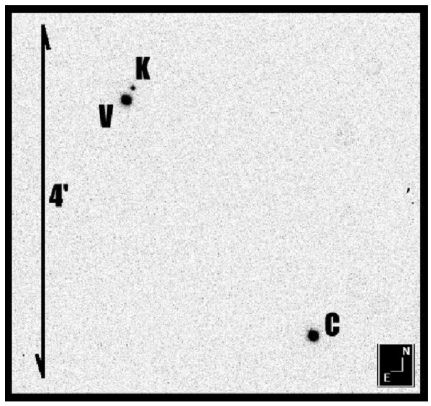

Figure 1.

Our B, V, R_c, I_c light curves were taken with the Lowell 31 inch reflector in Flagstaff with the LN cooled CCD camera and a metachrome coated TEK 512 × 512 chip and standard BVR_cI_c filters. The light curves were taken on 7, 11 and 12, March 2005 by NCH , RGS, and DRF. The individual observations included 59 B, 63 V, 59 R and 59 in I. The stars [GSC 1419 0805, $\alpha(2000)= 10^{\rm h}11^{\rm m}51\overset{\rm s}{.}30$, $\delta(2000)= +16°50'13\overset{''}{.}1$], and [$\alpha(2000) = 10^{\rm h}11^{\rm m}58\overset{\rm s}{.}88$, $\delta(2000)= +16°52'40\overset{''}{.}1$] were used as the comparison and check stars, respectively. The delta magnitudes are given in electronic Table 1 available on the IBVS website as `5697-t1.txt`. A finding chart of GSC 1419 0091 (V), the comparison

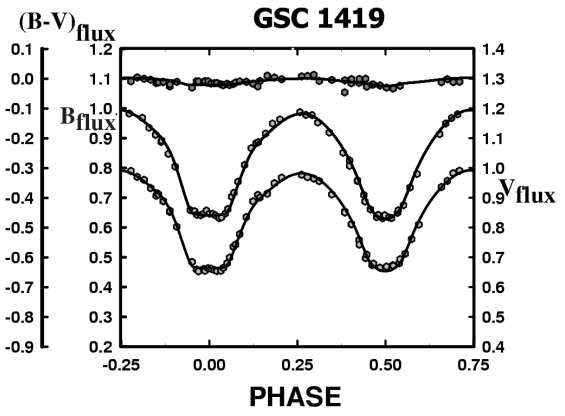

Figure 2.

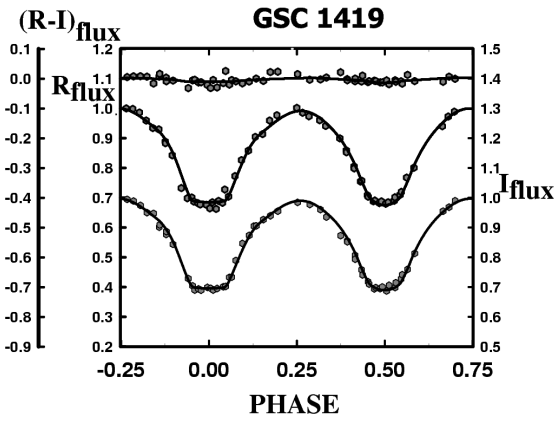

Figure 3.

star (C), and check star (K) is given in Figure 1. The light curves are displayed in Figure 2 and 3, as normalized flux versus phase.

Three precision mean epochs of minimum light were determined from eclipse timings in B, V, R_c, I_c using parabola fits: HJD Tmin I = 2453437.8293 d $\pm$ 0.0003, 2453441.8291d $\pm$ 0.0019 and HJD Tmin II = 2453437.6973 $\pm$ 0.0012. Other times of minimum light were determined by Hübscher (2005) and by Frank (Bernhard 2003, 2004). We also took times of low light from Rotse observations to extend the observational history for our period study.

A linear fit to all available timings of minimum light gives:

$$\text{HJD TMin I} = 2453437.8207\ (\pm 0.0024) + 0.2667249\ (\pm 0.0000007)\text{d} \times \text{E} \qquad (2)$$

A quadratic trend is apparent so we also calculated the following ephemeris:

$$\text{HJD TMin I} = 53437.82924\ (\pm 0.00079) + 0.26673640\ (\pm 000000059)\text{d} \times \text{E} \qquad (3)$$
$$+0.00000000153\text{d} \times \text{E}^2\ (\pm 0.00000000007)$$

In addition, we used the Wilson code to calculate a linear ephemeris using our present observations for the purpose of phasing the light curves (van Hamme and Wilson 1998):

$$\text{HJDTminI} = 2453437.82835 \pm 0.00029 + 0.266749 \pm 0.000010\text{d} \times \text{E} \qquad (4)$$

The $O - C$'s for the linear and quadratic fit are given in electronic Table 2 (available on the IBVS website as `5697-t2.txt`) and the plot of $O - C$ residuals for Equation 2 and overlaid by a quadratic fit is given as Figure 4.

It is typical for W UMa binaries to have continuously decreasing or increasing periods. In the stage of shallow contact, binaries may undergo thermal relaxation oscillations (TRO) so, theoretically, the period will alternately increase and decrease. (Cyclic changes can also result from stellar magnetic cycles or from a third body.) When binary components reach firm contact, after TRO cycles, the solar type binary will steadily lose angular momentum via stellar winds and its period will be characterized by a continuous decrease. We found from our light curve solution that the fill-out is still somewhat shallow so TRO may still be acting here. In that case, and the period can be on the increase as suggested by the quadratic ephemeris. Further observations are needed to confirm the trend suggested by our preliminary period study.

Standard magnitudes were determined from observations of Landolt standard stars SA 106 700, PG 1323 086, ,PG 1323 086B, PG 1323 086C, and PG 1407-013 on March 7,

2005. They indicate the variable is a 12th magnitude binary which varies from a $V = 11.78 \pm 0.03$ to 12.28 ± 0.07. The comparison and check stars have a V magnitude of 11.64 ± 0.08 and 15.28 ± 0.08, respectively. The color indices indicate that GSC 1419 091 is of late G to early K-type. The check is late F to early G while the comparison is late K to early M. Details are given in electronic Table 3, available on the IBVS website as `5697-t3.tex`.

We began by pre-modeling the binary in Binary Maker 3.0 (Bradstreet 2002) and then used Our results as starting values for the 5-color synthetic light curve solution in the newest 2004 Wilson Code.(Wilson & Devinney 1971, Wilson 1990, 1994).

Our solution indicates that GSC 1419 0091 is a short period AW UMa-type contact binary. The primary component is the more massive, slightly cooler star. The primary component is over five times the mass of the secondary component ($m_2/m_1 = 0.19$) the Roche lobe fillout is 23%. We would expect this to increase with time. Other parameters include the temperatures, $T_1 = 5000 \pm 300$K (fixed, error from photometry) and $T_2 = 5014 \pm 3$K (formal error, so the actual error is still about ± 300). The orbital inclination was $84\overset{\circ}{.}7 \pm 0\overset{\circ}{.}1$. The eclipses are total, so we believe our solution is definitive. We note here that errors given in the Table are formal errors.

The observed O'Connell effect is evidence for magnetic spot activity; our model includes two weak but broad magnetic regions. Both of the magnetic regions were of high latitude which is indicative of strong magnetic activity.

Our solution is given as electronic Table 4 (available on the IBVS website as `5697-t4.tex`) and the synthetic light curves are shown overlaying the phased, flux-normalized data in Figure 3. Our geometrical representation of GSC 1419 0091 is given in Figure 5.

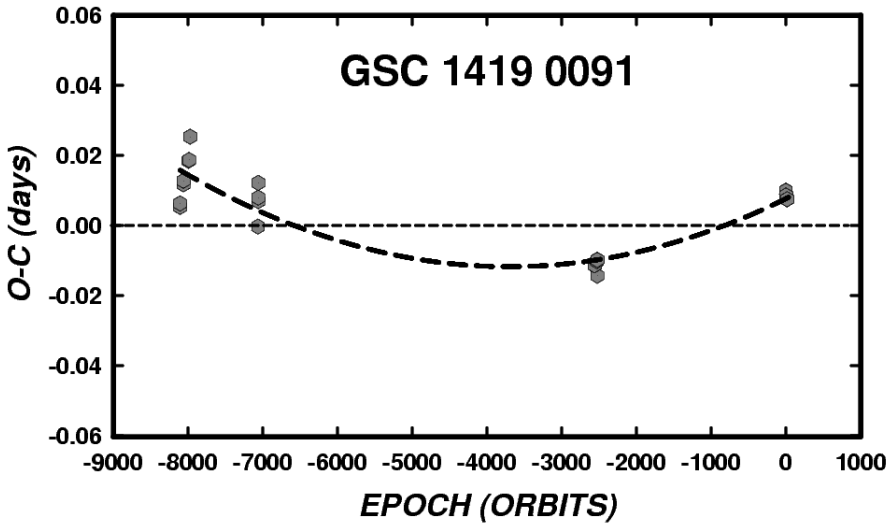

Figure 4.

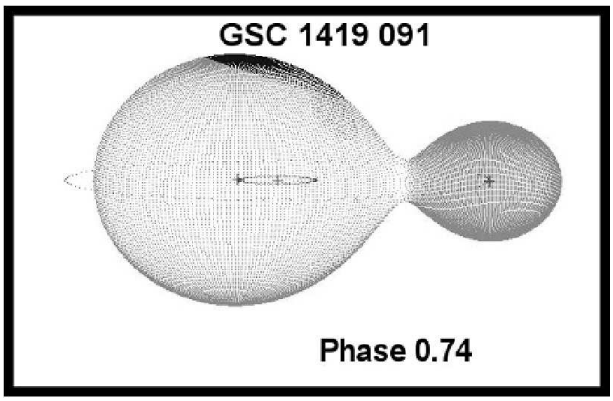

Figure 5.

We wish to thank the National Undergraduate Research Observatory (NURO) and Lowell Observatory for their allocation of observing time, as well as NASA and the American Astronomical Society for their continued support of our undergraduate research programs through their small research grants.

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