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PHOTOMETRY OF GSC 3408-0735: A W UMa SYSTEM NEAR THE SHORT-PERIOD LIMIT

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The W UMa stars are short-period overcontact binary systems of main sequence F, G, and K stars. The peak in their period distribution is at about 0.27 days (Rucinski, 2007), with a rapid dropoff in number at shorter periods. Given the small number of known systems with periods less than 0.22 days, any such system that can be well characterized will play an important role in understanding the nature of the short-period limit. In a recent analysis of 143 W UMa candidates with periods less than 0.22 days identified by Lohr et al. (2013) in SuperWASP data (Pollacco et al., 2006), Terrell (2014) found that 25 objects could be ruled out as W UMa systems and 16 were very likely to be W UMa systems, based on their colors from the AAVSO Photometric All-Sky Survey (hereafter, APASS; Henden et al., 2012). Of the remaining systems, the APASS observations are not yet sufficient in number or quality to classify them. In that group, the system GSC 3408-0735 (SuperWASP J080150.03+471433.8) has been observed once by APASS, with a $B-V$ value of 1.06 ± 0.02. Terrell (2014) required at least two observations of a system for inclusion in his analysis, but inspection of the SuperWASP light curve showed deep, potentially complete (total/annular), eclipses (see Figure 1), so it was selected for further photometric observation with the 0.5m telescope of the Sonoita Research Observatory (SRO).

The SRO 0.5m telescope is equipped with a Santa Barbara Instrument Group STL-6303E CCD camera with Johnson-Cousins filters. GSC 3408-0735 was observed on eight nights in February and March of 2014 in the B, V, and I_C passbands. Reduction of the images was performed in the usual manner by subtracting bias and dark frames and flatfielding. GSC 3408-1475 and GSC 3408-1827 were chosen as the comparison and check stars for differential photometry, and no variability greater than 0.01 magnitudes was detected in either star.

The instrumental differential magnitudes were analysed with the 2013 version of the Wilson-Devinney program (hereafter, WD; Wilson & Devinney, 1971; Wilson, 1979). The mean surface temperature of star 1 (T_1) was fixed at 4500 K based on the APASS $B-V$ value and the relatively low interstellar reddening in the field (maximum $E(B-V) = 0.06\pm0.01$) as estimated with the NASA/IPAC Infrared Science Archive's Galactic Dust

Reddening and Extinction tool at `http://irsa.ipac.caltech.edu/applications/DUST/` which uses the Schlafly and Finkbeiner (2011) reddening measurements.

Initial fits to the light curves resulted in an overcontact configuration for the system, and subsequent iterations were done in WD mode 1 which enforces various constraints appropriate for overcontact binaries (Wilson & Van Hamme, 2013), such as equal surface potentials for the stars, and a smooth variation of surface brightness over the common envelope (hence T_2 is computed from other parameters rather than being adjusted). The adjusted parameters were orbital inclination (i), surface potential of the common envelope (Ω_1), mass ratio ($q = M_2/M_1$), orbital period zero point (HJD_0), orbital period (P), primary star bandpass luminosities (L_1) and third light (l_3). The third light values were always very small compared to their errors, consistent with there being no third light in the system, and in the final solution, third light values were fixed at zero. Local surface computation of limb darkening coefficients (as functions of $T_{\rm eff}$ and $\log g$) was performed as described in Wilson & Van Hamme (2013).

The solution confirms that the eclipses are indeed complete, with a total secondary eclipse, making this an A-type system. While the SuperWASP light curve shows a mild asymmetry between the two maxima, our light curves do not, indicating that spot phenomena may be variable in size and/or location. Table 1 lists the parameters from the solution and Figure 2 shows the fits to the light curves. Figure 3 shows the system at the center of the primary eclipse. The instrumental differential magnitudes are available from the IBVS web site as file 6104-t1.txt.

GSC 3408-0735 is an important system because the eclipses are complete, thus resulting in a more accurate determination of the parameters of the system. The mass ratio, for example, is accurately recovered from the analysis of the photometry, as demonstrated by Terrell & Wilson (2005). With a period of 0.2175 days, it is the shortest-period overcontact binary known to show complete eclipses. The system is faint, V=13.48±0.01 at phase 0.67 for the APASS observation, so measuring accurate radial velocities will be challenging on all but the largest telescopes. But given the small number of systems near the short-period cutoff, and the ability to measure its absolute dimensions very accurately, GSC 3408-0735 is certainly worthy of study on larger instruments.

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Table 1. Parameters for GSC 3408-0735.

Parameter	Value
$T_1(K)$	4500 (assumed)
$T_2(K)$	4477 (computed)
i (°)	85.2±0.3
Ω_1	2.715±0.006
q	0.440±0.003
HJD_0	2453383.949±0.006
P (days)	0.2175137±0.0000004
$L_1/(L_1+L_2)_B$	0.686±0.002
$L_1/(L_1+L_2)_V$	0.684±0.002
$L_1/(L_1+L_2)_{I_C}$	0.682±0.001

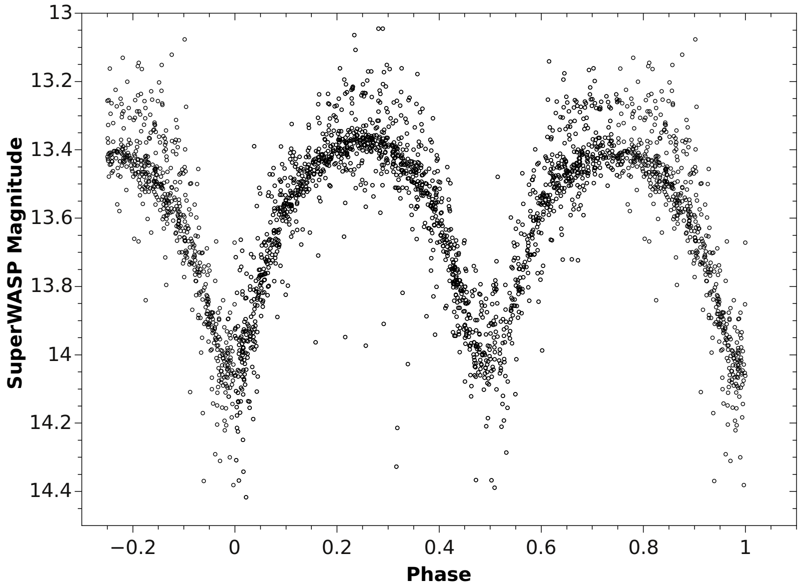

Figure 1. The SuperWASP (data release 1) light curve of GSC 3408-0735.

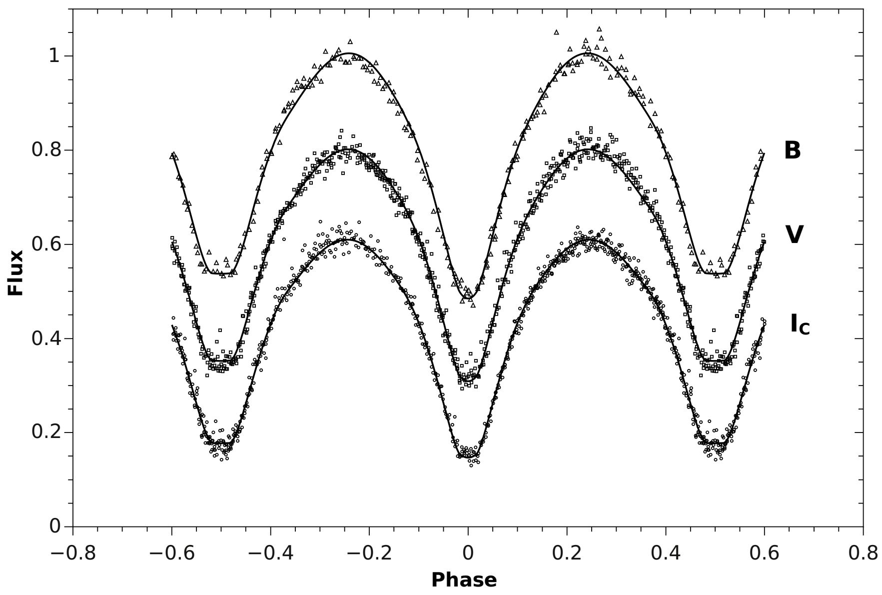

Figure 2. The SRO B, V and I_C light curves of GSC 3408-0735 and the photometric solution using the Wilson-Devinney program.

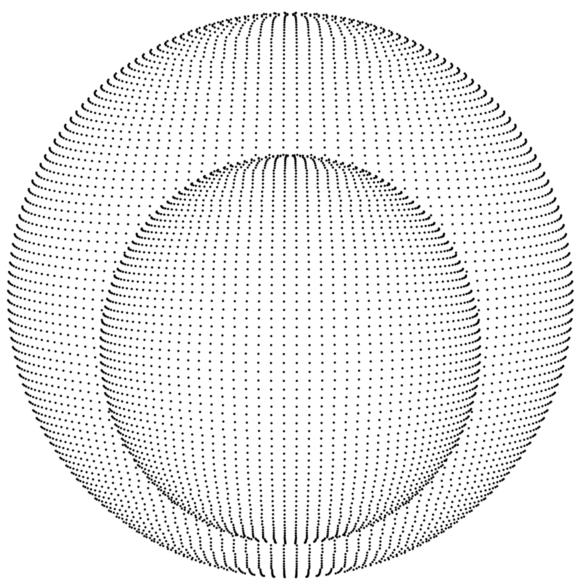

Figure 3. The GSC 3408-0735 system at primary eclipse.