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A NEW ECLIPSING BINARY IN THE FIELD OF LHS 2176 AND 2178

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The nearby stars LHS 2178 = GJ 362 = GSC 4386_1592 and LHS 2176 = GJ 360 = = GSC 4386_1705 have had their properties summarized by Hünsch et al. (1999), including their visual and X-ray brightnesses, colors, spectral types, and distances. Panagi and Mathioudakis (1993) report Hα emission in LHS 2178. We observed these stars in a continuing search for photometric variations in active stars.

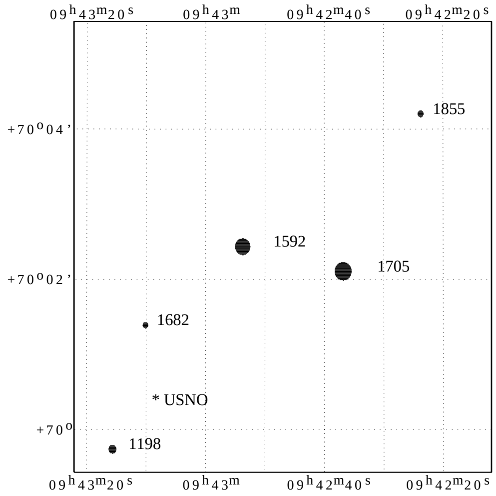

Figure 1. Finder chart labeled with the GSC numbers and an ∗ to denote USNO1575–03003814.

Figure 1 shows the field of stars observed with the automated 0.5m telescope of the Climenhaga Observatory at the University of Victoria and reduced in a fashion similar to that described in Robb and Greimel (1999). Table 1 lists the stars' identification numbers, coordinates (J2000) and magnitudes from the Hubble Space Telescope Guide

Table 1: Stars observed in the field of LHS2178

GSC No.	R.A. J2000	Dec. J2000	GSC Mag.	ΔC Mag.	Std Dev Between	Std Dev Within
4386_1592	$09^h42^m54^s$	$+70°02'26''$	10.8	-	-	-
4386_1705	$09^h42^m37^s$	$+70°02'06''$	10.2	−0.539	0.016	0.002
4383_1198	$09^h43^m16^s$	$+69°59'44''$	13.8	3.875	0.031	0.011
USNO1575–03003814	$09^h43^m09^s$	$+70°00'09''$	15.4	5.159	0.130	-
4386_1682	$09^h43^m10^s$	$+70°01'23''$	14.6	4.867	0.098	0.029
4386_1855	$09^h42^m24^s$	$+70°04'12''$	14.5	5.020	0.090	0.035

Star Catalog (GSC) (Jenkner et al. 1990). Initially observations were made in R_c and I_c, but to increase the signal to noise ratio we were forced to observe with no filter, which we designate with a "C". From standard star observations we found that our system with no filter had a very wide passband with a center wavelength close to that of Cousins R, but with 3.5 times the flux. Our differential ΔC magnitudes are calculated in the sense of the star minus LHS2178. For each star the mean of the nightly means is shown as ΔC in Table 1. The standard deviation of the nightly means is a measure of the night to night variations and is called "Std Dev Between" in Table 1. Brightness variations during a night were measured by the standard deviation of the differential magnitudes and are listed for the most photometric night in the last column as "Std Dev Within".

From the plots of individual night's data we observed no significant variations in LHS 2178 or LHS 2176. From night to night there were variations larger than we would have expected, however the comparison stars are so faint that we cannot claim to have seen photometric variations on a daily time scale.

The star USNO1575–03003814 (Monet et al. 1996) had obvious variations during a night and is a new eclipsing binary star. There is no ambiguity in the determination of its orbital period, since two of the nights contain more than one minimum. Using data points within $0\overset{d}{.}04$ of the minimum, and the method of Kwee and van Woerden (1956), the heliocentric Julian Dates of minimum brightness were found and are listed in Table 2 with a letter indicating the filter used.

Table 2: Times of Minimum (HJD – 2451000) of USNO1575–03003814

Primary	643.7333R	651.8163C	652.7902I	653.7574C	671.8686C	672.8403C
Secondary	643.8984R	652.9475I	677.8507C	680.7647C		

Assuming the secondary minima are at phase 0.5, a fit to these times gives the ephemeris:

$$\text{HJD of Primary Minimum} = 2451643\overset{d}{.}7333(10) + 0\overset{d}{.}32340(3) \times E.$$

where the uncertainties in the final digit are given in brackets and the root mean square error of the fit is $0\overset{d}{.}0021$. The 947 differential (LHS 2178 − USNO1575–03003814) unfiltered magnitudes phased at this period are plotted in Figure 2 with different symbols for each of the nights. The large scatter is attributable to the faintness of the object.

To ascertain the temperature and brightness of the variable star, CCD frames of the field were obtained with B, V, R_c and I_c filters. The stars LHS 2178 and LHS 2176 have

B, V, R_c and I_c magnitudes measured by Weis (1996), thus allowing us to transform our observed magnitudes to the standard Cousins system. For USNO1575–03003814 this yields values of $V = 15.43 \pm .10$ and $B-V = 1.04 \pm .10$, $V-R = 0.53 \pm .10$, $V-I = 0.86 \pm .10$ at maximum light. The reddening would be $E_{B-V} = 0.132$, $E_{V-I} = 0.182$ with an extinction of about $A_v = 0.439$ (Schlegel et al. 1998). From the dereddened colors we estimate the spectral class of USNO1575–03003814 to be approximately K0V (Cousins 1981).

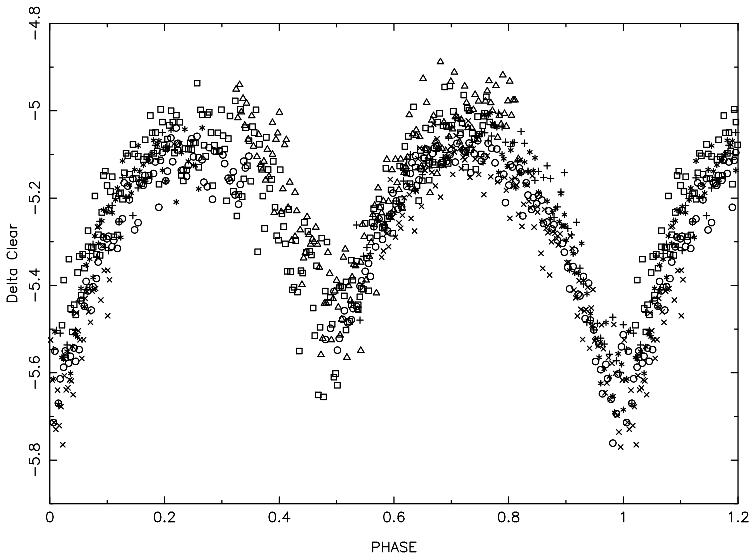

Figure 2. Unfiltered light curve of USNO1575–03003814 for spring 2000

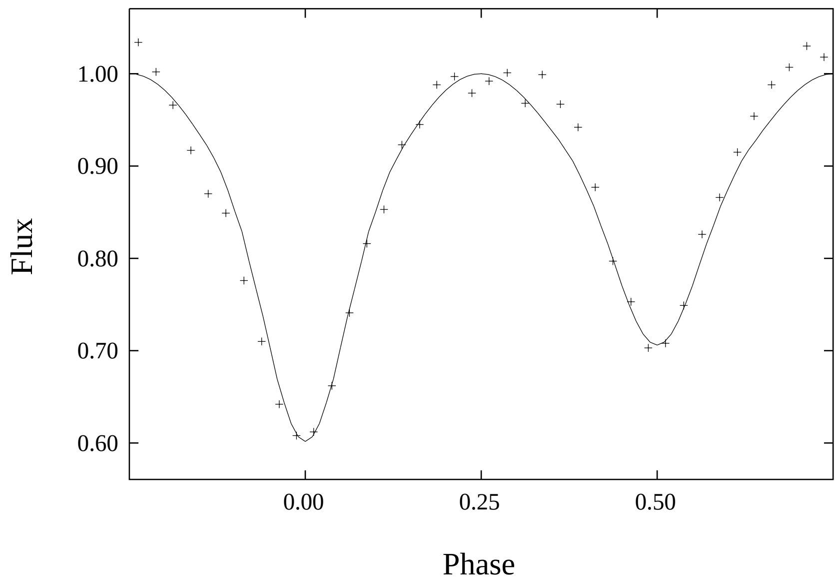

Figure 3. Unfiltered normal points with curve from an example model of the eclipsing system

While the true nature of this system cannot be determined from these data, a model can be found using reasonable parameters. The light curve leads us to expect this to be a near-contact system. Using Binmaker 2.0 (Bradstreet 1993), the model light curve as shown in Figure 3 was made. We assumed a temperature of 4900K for the primary and a mass ratio of 0.95. A satisfactory fit to the data was found with an inclination of 71.5° and a temperature of the secondary star 500K cooler than the primary star. Two main-sequence stars of this temperature difference would have a mass ratio of 0.95. The eclipses are then well fit with the stars just touching the inner critical surface of the Roche Lobe (fillout = 0.0). The uncertainty in the inclination is about ±2° and the difference in temperature is known to about ±10% both dependent on the assumed mass ratio.

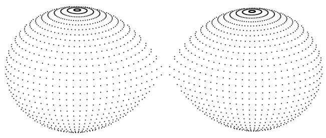

Figure 4. Three-dimensional model of the near-contact system at phase 0.25

The relative sizes and shapes of the components of the system are shown in Figure 4, again using Binmaker 2.0 (Bradstreet 1993).

The absolute magnitude can be estimated from the period and $(B-V)_0 = 0.91$ (Rucinski and Duerbeck 1997) and $(V-I)_0 = 0.68$ (Rucinski 2000) to be $M_V = 4.7 \pm .3$ giving a distance of 1140 ± 150 pc. The dependence of the absolute magnitude on the color through Rucinski's formula is nearly equal to the relationship of extinction and the reddening making the distance determination almost independent of the extinction.

The star USNO1575–03003814 is therefore a near-contact eclipsing system with late-type components. Photometric observations should be continued to monitor light curve changes due to spot migration, flares, and period changes. Spectroscopic observations will be valuable to determine a precise spectral class for the system and to measure radial velocities to determine the masses and the scale of the system.

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