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GSC 4153-0634 - A NEW ECLIPSING BINARY

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Continuing our effort to discover the variability and period of photometric variations of X-ray sources found by the ROSAT satellite (Voges et al. 1999), we observed RXJ 114302+603436 (= GSC 4153-0634 = SAO 15610 = BD+61 1260). We made the photometric observations with our automated 0.5m telescope, Star I CCD and Johnson-Cousins VRI filters, and reduced them in a fashion similar to that described in Robb and Greimel (1999). The field of stars observed is shown in Figure 1.

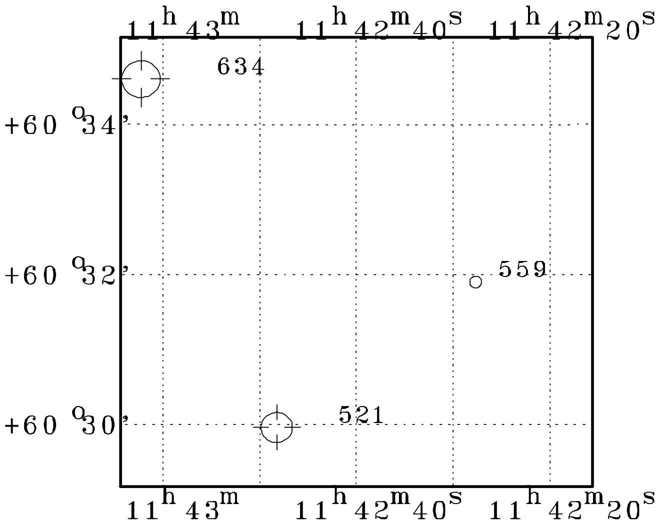

Figure 1. Finder chart labeled with the GSC identification numbers from region 4153.

Table 1 lists the stars' identification numbers and magnitudes from the Hubble Space Telescope Guide Star Catalog (GSC) (Jenkner et al., 1990) and positions from the USNO-A 2.0 catalog (Monet et al., 1998). The Julian Dates of observations (−2450000) and photometric bands used on those nights are 2402−05R, 2410R, 2433VI, 2435−39VRI, 2445−48VRI, 2459−61VRI, 2464−67VRI, and 2478VRI. The first nights of observations were marred by a dust particle on the CCD window and are used only for times of

Table 1: Stars observed in the field of GSC 4153-0634

Type	Star's GSC Id	R.A. J2000	Dec. J2000	GSC Mag.	ΔV Mag.	ΔR Mag.	ΔI Mag.
Variable	0634	$11^{h}43^{m}02.30^{s}$	$60°34'36.1''$	9.5	-0.953	-0.915	-0.866
Comparison	0521	$11^{h}42^{m}48.25^{s}$	$60°29'57.5''$	10.5	–	–	–
Check	0559	$11^{h}42^{m}27.58^{s}$	$60°31'54.4''$	13.2	2.621	2.602	2.567

Table 2: Times of Minimum Light -2450000

HJD	Error	Band	HJD	Error	Band
2402.9425	0.0004	R	2436.8993	0.0013	V, I
2404.7983	0.0002	R	2465.9166	0.0005	V, R, I
2410.9721	0.0004	R	2467.7683	0.0002	V, R, I
2433.8139	0.0011	V, I	2478.8799	0.0002	V, R, I

minimum light. The last seven nights were observed after the CCD window was cleaned and the data had reduced photometric uncertainties.

Our differential magnitudes are calculated in the sense of the star minus GSC 4153-0521. Brightness variations during a night were measured by the standard deviation of the differential magnitudes and for the best night are 0.004 between the variable and comparison stars (not during an eclipse) and 0.016 between the comparison and check stars. For each star the mean of the nightly means is shown as Δ magnitude in Table 1. The standard deviation of the nightly means is a measure of the night to night variations and for the check–comparison stars is 0.004 magnitudes. This excellent photometry shows that night to night variations in either of these stars must be less than a few millimagnitudes. We observed no significant variations in these stars in plots of the individual nights' data.

The star GSC 4153-0634 had obvious variations during some nights and both secondary and primary eclipses were seen. Times of minimum brightness of the star found using the method of Kwee and van Woerden (1956) from data within ± 0.04 days are listed in Table 2. From these times of minimum light we find the ephemeris to be:

$$\text{HJD of Minimum Brightness} = 2452402\overset{d}{.}3278(7) + 1\overset{d}{.}23472(3) \times \text{E}.$$

where the uncertainties in the final digit are given in brackets and the RMS error of the fit is less than 0.0011 days. In Figure 2 the differential ΔR_c magnitudes phased at this period are plotted.

A spectrum obtained with the 1.8m telescope of the Herzberg Institute of Astrophysics is shown in Figure 3. Although it is not in the best region or dispersion for spectral classification the Hδ/CaI lines show that the star is late F type. This spectrum was observed at a time close to primary minimum. For GSC 4153-0634 the 2MASS[1] photometry catalog gives J=8.56, H=8.38 and K=8.32, all with uncertainty of about ± 0.03 and the possibility that they were observed during an eclipse. Using Landolt (1992) standard stars, we found standardised magnitudes for GSC 4153-0634 to be V=9.57 $\pm$ 0.01, $B-V$=0.53 $\pm$ 0.01, $V-R$=0.31$\pm$0.01, and $R-I$=0.36$\pm$0.01 for phase=0.9. From the $V-K$ index we can esti-

[1] This publication makes use of data products from the Two Micron All Sky Survey, which is a joint project of the University of Massachusetts and the Infrared Processing and Analysis Center/California Institute of Technology, funded by the National Aeronautics and Space Administration and the National Science Foundation.

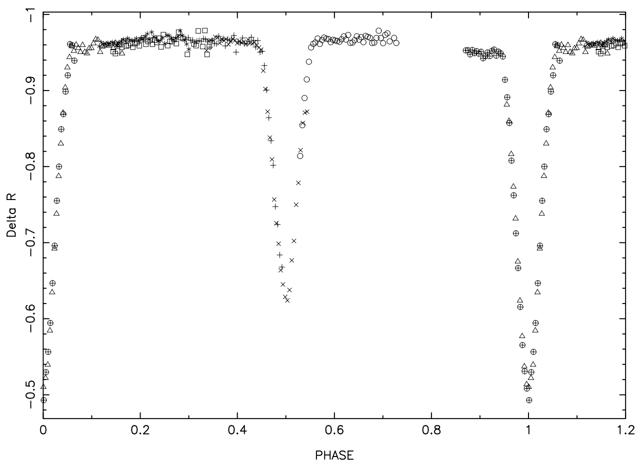

Figure 2. R_c filtered light curve of GSC 4153-0634 with different symbols for different nights.

mate a spectral type of F6V and thus a $E(B-V)$ of 0.06±0.03. From $E(B-V)$=0.06±0.03 a V extinction of 0.19 ± 0.09 follows, and the dereddened colors are consistent with our F-type spectral classification. These all indicate an approximately F6V spectral type for GSC 4153-0634 and a distance of approximately 200 parsecs.

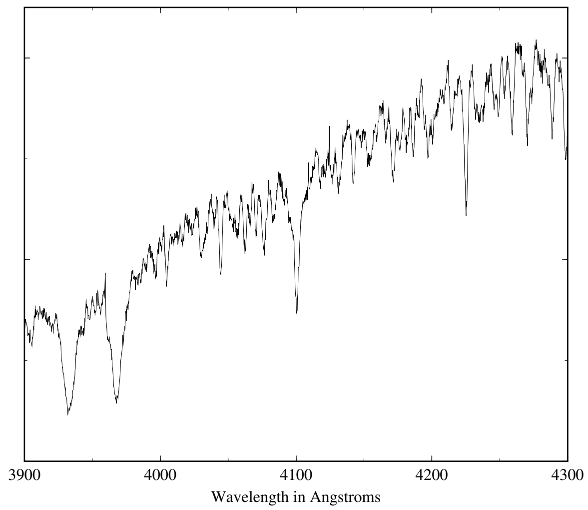

Figure 3. Spectrum of GSC 4153-0634 showing the Hδ absorption line at 4101$\AA$ and CaI at 4226$\AA$

While a definitive solution to the light curve is not attempted with this data set, there exist physically plausible parameters which fit the data. Our light curve model, synthesised using Binmaker2 (Bradstreet, 1993) is plotted with the binned data points in Figure 4. From the spectral class we assume a temperature for the hot star of 6400K and appropriate limb darkening, gravity darkening (g=0.32) and reflection (R=0.5) coefficients. The set of parameters we found were: radius of hot star of 0.21 ± 0.03, radius of cool star of 0.18 ± 0.03 as fractions of the orbit diameter, temperature of the cool star of 6000K and an orbital inclination of $83^\circ \pm 2^\circ$. The uncertainty in the temperature difference of the two stars is $\sim$ 100K. The well separated stars make the mass ratio indeterminate, so we assumed a value of 0.85, consistent with the temperature difference. We needed

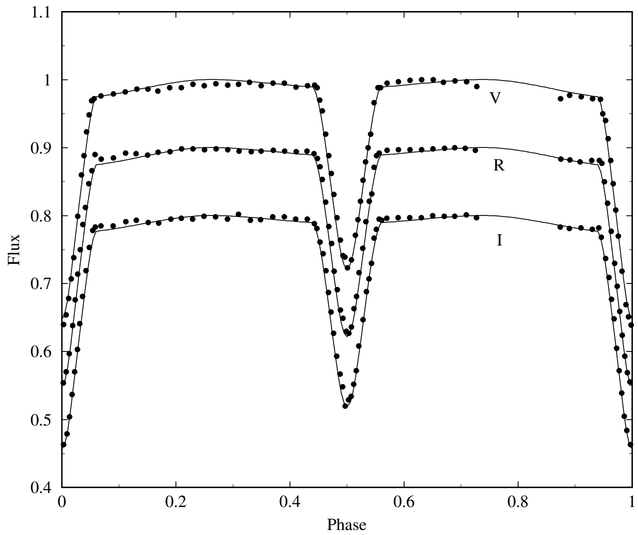

Figure 4. Model lines and light curve points of GSC 4153-0634

to include a cool spot of radius 10° on the cooler star's equator at 0° longitude to model the difference in maximum light. This well separated model is consistent in temperature difference, mass ratio and ratio of the radii with a F6V+F9V eclipsing binary star.

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