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THE NEW CONTACT BINARY GSC 2414-0797

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Contact binary stars are of great interest since it is not obvious how they came to be or what they will evolve to become. Because many of these interesting stars are bright enough to be observed with small telescopes from bright locations, they make an ideal project for amateur-professional collaboration. The star GSC 2414-0797 was suspected of variability in brightness from the IPHAS survey (Drew et al., 2005) data. GSC 2414-0797 can be found in the NOMAD catalog (Zacharias et al., 2004) which lists $B = 13.96$ mag, $V = 13.41$ mag, $R = 12.58$ mag and 2MASS measurements reveal that $J = 11.77$ mag, $H = 11.33$ mag and $K = 11.18$ mag with an uncertainty of approximately ± 0.15 due to brightness variations of the star.

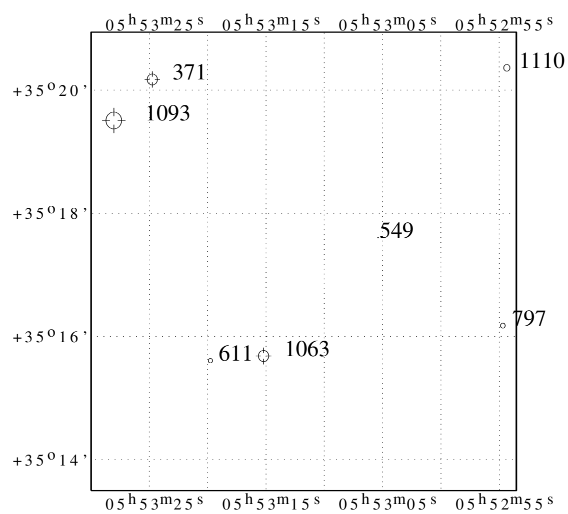

Figure 1. Finder chart labelled with the GSC identification numbers from region 2414.

The University of Victoria (UVic) observations were made with our automated 0.5 m telescope, Star I CCD and reduced in a fashion similar to that described in Robb and

Table 1: Stars observed in the field of GSC 2414-0797

GSC Id	R.A. J2000	Dec. J2000	GSC Mag.	ΔR Mag	σ Nights	σ Hours	ΔI Mag.	σ Nights	σ Hours
0797	$05^h52^m55^s$	$35°16'11''$	13.7	2.390	0.016	0.131	2.153	0.017	0.122
1093	$05^h53^m28^s$	$35°19'30''$	10.7	-	-	-	-	-	-
0371	$05^h53^m25^s$	$35°20'10''$	12.2	0.983	0.002	0.008	0.551	0.002	0.007
0611	$05^h53^m20^s$	$35°15'37''$	13.8	2.622	0.007	0.027	2.593	0.003	0.026
1063	$05^h53^m15^s$	$35°15'41''$	12.2	1.274	0.012	0.013	1.285	0.010	0.013
0549	$05^h53^m05^s$	$35°17'36''$	14.8	3.022	0.010	0.046	2.811	0.024	0.030
1110	$05^h52^m54^s$	$35°20'22''$	13.3	1.618	0.014	0.013	0.949	0.002	0.007

Greimel (1999). All UVic observations were made using 120 second exposures and Cousins R and I filters. The field of stars, seen in Figure 1, was observed during the years 2005, 2006 and 2008 and Julian Dates of observation (-2450000) were 3385, 3409, 3411, 3416, 3776, 3777, 3780, 4487-4489, and 4514. Table 1 lists the stars' identification numbers and magnitudes from the Hubble Space Telescope Guide Star Catalogue (GSC) (Jenkner et al., 1990).

Our differential magnitudes are calculated in the sense of the star minus GSC 2414-1093. For each star the mean of the nightly means is shown as ΔR and ΔI in Table 1. Brightness variations on an hourly timescale were measured by the standard deviation of the differential magnitudes and are listed for the most photometric night in the column labelled "σ Hours". A "σ Hours" one night of 0.007 sets an upper limit on variations of an hourly timescale. The standard deviation of the means of each night is a measure of the night to night variations and is called "σ Nights" in Table 1. The smallest "σ Nights" is 0.002 magnitudes. This excellent photometry shows that night to night variations in GSC 2414-1093 and GSC 2414-0371 must be less than a few millimagnitudes. Only the 2008 data are included in the table since the mean values for the other years were different by a few hundredths of a magnitude due to slight differences in the flat fields. If we assume the flat fields are perfect the standard deviation of the ΔR nightly means for all 11 nights would be 0.011 magnitudes for the stars GSC 2414-1093 and GSC 2414-0371, so these stars remained constant at that level on the nights we observed them.

The star GSC 2414-0797 showed brightness variations during a night typical of a contact binary star. During the night 2454487 more than one orbit was observed allowing an unambiguous estimate of the period to be 0.340 ± 0.002 days. Times of minimum brightness listed in Table 2 were found using the method of Kwee and van Woerden (1956) on the data within 0.04 days of the minimum. The 2008 times of minima are the average of the times of minima determined from the R and I filtered data.

Table 2: Times of Minimum Light HJD-2450000

Year	HJD	(O-C)	Type	HJD	(O-C)	Type
2005	3385.7698(06)	-0.0010	II	3411.6583(06)	+0.0006	II
	3416.7659(04)	-0.0011	II			
2006	3777.6528(16)	+0.0014	I	3777.8226(03)	+0.0009	II
2008	4487.6677(07)	-0.0012	II	4487.8400(08)	+0.0008	I
	4488.0071(23)	-0.0024	II	4488.6905(11)	-0.0003	II
	4489.7126(16)	+0.0000	II	4489.8852(12)	+0.0023	I

From these times of minima our best estimate of the ephemeris is:

$$\text{HJD of Primary Minimum} = 2453385^{\rm d}\!.6005(7) + 0^{\rm d}\!.3406176(6) \times \mathrm{E}.$$

where the uncertainty in each final digit is given in brackets and the RMS deviation was 0.0014 days. There is no evidence for a changing orbital period.

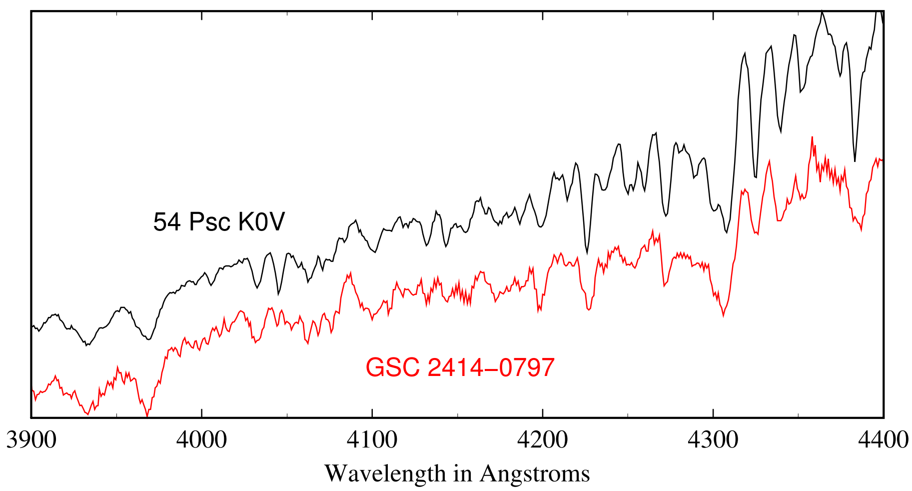

Figure 2. Spectra of GSC 2414-0797 and the MK K0V spectral class standard star 54 Piscium

Spectra of GSC2414-0797 and 54 Piscium observed with the Dominion Astrophysical Observatory's 1.8 m telescope at 60 Å/mm are shown in Figure 2. The time of observation was 4:22 UT 18 Feb 2006, which corresponds to a phase of approximately 0.16. The strength of the G band, Calcium H&K lines and the Calcium I 4227 Å line are typical of a late G or early K spectrum and the H γ 4340 Å and Fe I 4326 Å lines indicate a K0V±1 spectral classification. All the catalog colour measurements listed in the first paragraph are consistent with a spectral class of K0V±3, if the V measurement is assumed to be too faint by 0.3 magnitudes, so henceforth we will assume that at maximum brightness $V = 13.1$ mag.

Comparison of plots of the individual years' data reveal no systematic offsets as might be expected from flat fielding errors or changes in active regions. Therefore the 1152 individual ΔR observations were averaged into 100 normal points and plotted in Figure 3. Using the Light Curve Synthesis software Binary Maker 3.0 (Bradstreet 2004) various models were fit to the data. Because there are no known radial velocity data and the eclipses seem to be partial, the mass ratio / inclination / fillout factor degeneracy cannot be broken (Terrell and Wilson 2005). We can however put limits on the inclination, mass ratio and fillout factor and show that the system can be described by astronomically reasonable parameters. The (mass ratio, inclination, fillout factors) limits were (0.22, 75°, 0.20) to $(0.90, 66°, 0.05)$. Plotted in Figure 3 is the best fit found using a mass ratio of 0.3, an inclination of 71.3°, a fillout factor of 0.17, temperatures of 5150 and 5052 Kelvin. To model the difference in maxima a spot 90% of the photospheric temperature on the more massive star at colatitude of 55° and longitude of 275° and a radius of 13.5° was assumed. This fit gave mean residuals of 0.004. The 2008 data taken with both the I and R band filters were used to calculate 50 normal points and the differences are plotted in Figure 3 shifted by an arbitrary amount. As expected the color and thus temperature did not change as a function of phase.

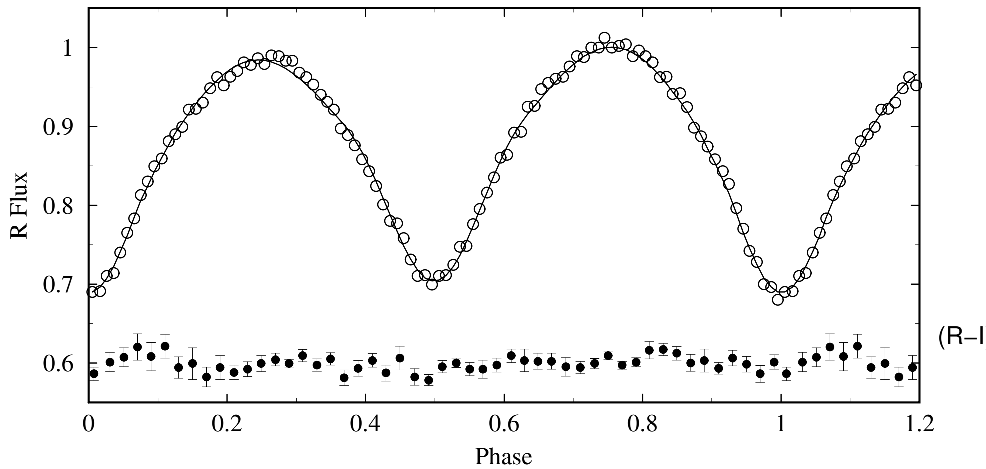

Figure 3. Model of GSC 2414-0797 with the parameters given in the text

Assuming a K0 star, the PLC relation by Rucinski (2004) implies an absolute magnitude of about $M_V = 4.75 \pm 0.25$, so with an apparent magnitude of $V = 13.1 \pm 0.1$ an estimate of the distance is 470 ± 100 parsecs. Since the star seems to have a dark spot it might be expected to be an X-ray source but it is not included in the ROSAT Bright Source catalog (Voges, et al. 1999). GSC 2414-0797 seems to be a rapidly rotating late type contact binary star with active regions covering a significant part of its surface.

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