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THE REDDENED W UMa SYSTEM: GSC 1851-0320

KOFF, R.A.[1]; ROBB, R.M.[2,3,4]; THANJAVUR, K.[2,3,4]; HENDEN, A.A.[5]; KAISER, D.H.[6]; KUEBLER, J.P.[7]

[1] 1915 West 101st Avenue, Denver, CO 80260, USA, e-mail: Bob.Koff@worldnet.att.net

[2] Guest User, Canadian Astronomy Data Centre, which is operated by the Herzberg Institute of Astrophysics, National Research Council of Canada

[3] Guest Observer, Dominion Astrophysical Observatory, which is operated by the Herzberg Institute of Astrophysics, National Research Council of Canada

[4] Dept. of Physics and Astronomy, University of Victoria, Victoria, BC, Canada, V8W 3P6, e-mail: robb@uvic.ca

[5] Universities Space Research Association/U.S. Naval Observatory, P.O. Box 1149, Flagstaff, AZ 86002-1149, USA, e-mail: aah@nofs.navy.mil

[6] 2631 Washington Street, Columbus, IN 47201, USA, e-mail: dhkaiser@sprynet.com

[7] 1550 Blackstone Drive, Columbus, OH 43235, e-mail: PKUEB@aol.com

While engaged in a search for rotation rates of asteroids, Koff discovered light variations in the background star GSC 1851-0320. He used his 0.20-m SCT+unfiltered ST-6 CCD. Alerted by Koff, Kaiser used his 0.35-m SCT+ST-9E CCD+V filter to determine times of minimum light, the period and the light curve shape. Kuebler also started observations using a Celestron 14 and a Finger Lakes Instrumentation IMG512 camera. Henden used the USNO 1.0m telescope, a SITe 1024×1024 thinned, backside illuminated CCD and standard Johnson-Cousins filters. He found standardized BVR_CI_C magnitudes for the field using Landolt (1992) standard stars. The University of Victoria observations were made with our automated 0.5m telescope, Star I CCD, Johnson-Cousins filters and reduced in a fashion similar to that described in Robb and Greimel (1999). The field of stars observed is shown in Figure 1.

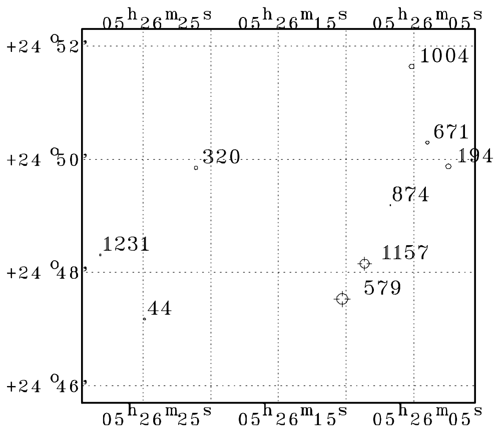

Figure 1. Finder chart labeled with the GSC identification numbers from region 1851.

Table 1: Stars observed in the field of GSC 1851-0320

Star GSC Id	R.A. J2000	Dec. J2000	GSC Mag.	ΔC Mag.	Std Dev Between	Std Dev Within
0320	$05^h26^m21\overset{s}{.}125$	$24°49'51''.78$	13.8	2.625	0.009	0.055
0579	$05^h26^m10\overset{s}{.}294$	$24°47'32''.57$	11.9	–	–	–
1157	$05^h26^m08\overset{s}{.}646$	$24°48'09''.70$	12.4	1.654	0.007	0.008
0194	$05^h26^m02\overset{s}{.}426$	$24°49'52''.60$	13.4	2.692	0.004	0.015
0671	$05^h26^m03\overset{s}{.}992$	$24°50'18''.16$	13.9	2.383	0.004	0.012
1004	$05^h26^m05\overset{s}{.}150$	$24°51'38''.85$	13.5	2.704	0.006	0.011
0044	$05^h26^m24\overset{s}{.}902$	$24°47'11''.16$	14.3	3.374	0.012	0.014
1231	$05^h26^m28\overset{s}{.}204$	$24°48'19''.49$	14.3	3.560	0.013	0.022

Table 2: Times of Minimum Light

HJD	Uncertainty	Observer	HJD	Uncertainty	Observer
2452177.9151	0.0004	RAK	2452267.0264	0.0010	RMR
2452183.9556	0.0007	RAK	2452267.8884	0.0003	RMR
2452184.9591	0.0007	RAK	2452268.0324	0.0005	RMR
2452199.9048	0.0004	RAK	2452268.7495	0.0005	RMR
2452207.9543	0.0008	RAK	2452268.8918	0.0005	RMR
2452225.7748	0.0003	DHK	2452296.6327	0.0016	RMR
2452250.7832	0.0008	RAK	2452317.6169	0.0010	KT
2452265.7334	0.0008	PK	2452317.7594	0.0006	KT
2452250.7850	0.0005	RMR	2452317.9040	0.0005	KT
2452266.7395	0.0004	RMR	2452320.7794	0.0006	KT
2452266.8810	0.0005	RMR	2452321.7829	0.0013	KT

Some observations were also made unfiltered (centered at $\sim$ 6500Å) designated C. The Julian Dates of observation (-2450000) are 2250R, 2266-2268C, 2296C, 2317C, 2320I, 2321V, 2322I, and 2334I. 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).

Our differential ΔC magnitudes are calculated in the sense of the star minus GSC 1851-0579. 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". 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. The smallest "Std Dev Between" is 0.004 magnitudes and 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 and a "Std Dev Within" one night of 0.008 sets an upper limit on variations of an hourly timescale.

The star GSC 1851-0320 had obvious variations during each night and most nights covered more than one cycle, causing the means for all nights to be similar. Times of minimum brightness of the star found using the method of Kwee and van Woerden (1956) are listed in Table 2. From these times of minimum light we find the ephemeris to be:

$$\text{HJD of Minimum Brightness} = 2452250^{\rm d}.7845(6) + 0^{\rm d}.287449(3) \times {\rm E}.$$

where the uncertainties in the final digit are given in brackets and the RMS error of the fit is less than 0.0013 days. In Figure 2 the differential ΔC magnitudes phased at this period are plotted. The light curve is typical of W UMa systems.

All-sky photometry by Henden yeilds V=14$^{\rm m}$.03 ± 0$^{\rm m}$.06, $B-V$=1$^{\rm m}$.39 ± 0$^{\rm m}$.04, $V-R$=0$^{\rm m}$.86 ± $0fmm01$, and $R-I$=0$^{\rm m}$.88 ± 0$^{\rm m}$.01 (available on the IBVS website: 5271-t3.txt) and 2MASS measurements yield J=11$^{\rm m}$.04, H=10$^{\rm m}$.41, and K=10$^{\rm m}$.24. These all indicate an approximately M0 spectral type for GSC 1851-0320, apparently making it the coolest W UMa known and deserving of further investigation. Therefore we observed the star with the DAO/HIA 1.8m telescope and obtained the spectrum shown in Figure 3.

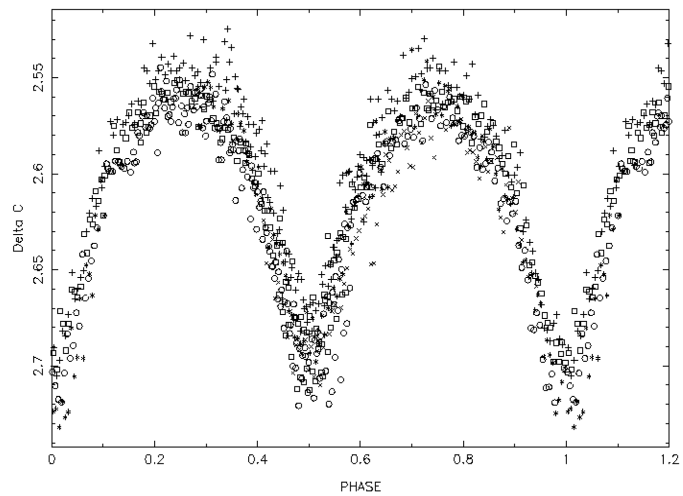

Figure 2. Unfiltered light curve of GSC 1851-0320 with different symbols for different nights.

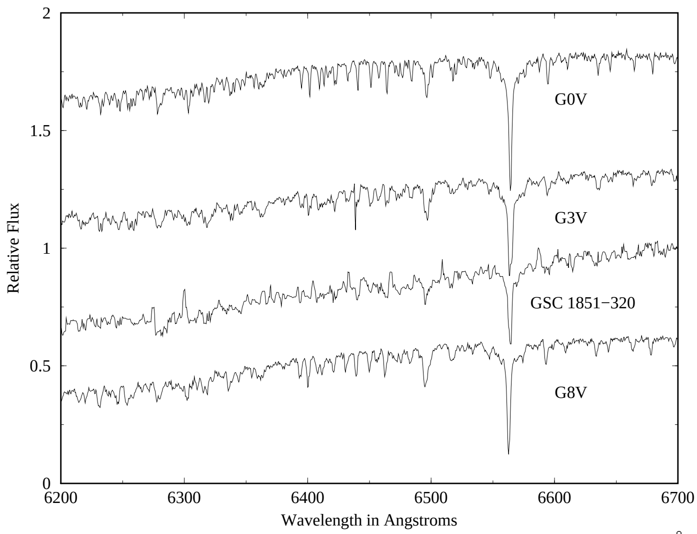

Figure 3. Spectrum of GSC 1851-0320 showing the Hα absorption line at 6563Å and FeI at 6497Å

Obviously the star's spectral type is not M but G. The reason for the discrepancy must be reddening, and in the Lick Observatory Sky Atlas (1967) we observe a dust cloud in the star's direction. Using the Java applet written by J. Köppen, found at `http://astro.u-strasbg.fr/~koppen/nebula/ExtCurv.html`, we find for an $E(B-V)$=0$^{\rm m}$.73 ± 0.$^{\rm m}$10 a V extinction of 2$^{\rm m}$.27 ± 0$^{\rm m}$.30, and dereddened colors consistent with our G-type spectral classification. The relation given by Rucinski (2000) between absolute magnitude, the intrinsic color and period of a W UMa system yields $M_V = 4.64$. Combined with extinction, we find a distance of 260 ± 80pc to this system. The distance to the Taurus Star Forming Region is ~ 140pc and therefore the dust cloud could be part of that region.

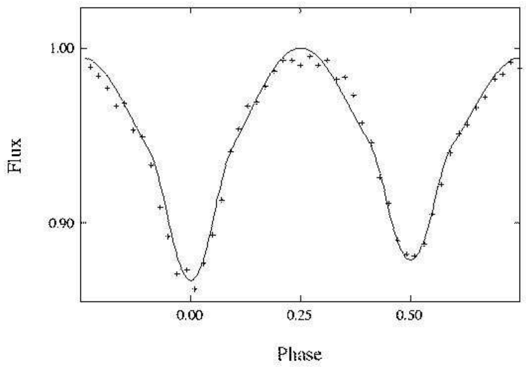

Figure 4. Model line and light curve points of GSC 1851-0320

While a definitive solution to the light curve is not possible with this data set, there exist physically plausible parameters, which fit the data fairly well. Our light curve model, synthesized 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 5600K and appropriate limb darkening (X=0.56), gravity darkening (g=0.32) and reflection (R=0.5) coefficients. The set of parameters we found were: radius of hot star of 0.37 ± 0.2, radius of cool star of 0.35 ± 0.2, temperature of the cool star of 5400K and an orbital inclination of $59^\circ \pm 2^\circ$. The uncertainty in the difference in temperature of the two stars is ~ 100K. The small inclination makes the mass ratio indeterminate but a value of 0.94 is consistent with the temperature difference. We needed to include a spot on the cooler star to model the difference in maximum light.

This near contact model is consistent in temperature difference, mass ratio and ratio of the radii with a G4V orbited by a G6V star. While the color of GSC 1851-0320 is very red for a contact binary, we are convinced that this is a consequence of an intervening dust cloud and the system has the temperature and spectral class expected for its period.

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