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PHOTOMETRIC AND SPECTROSCOPIC STUDY OF THE W-TYPE, W UMa BINARY, TYC 2853-18-1

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TYC 2853-18-1 (GSC 2853 0018, $\alpha(2000)=02^h47^m07^s.996$, $\delta(2000)=+41°22'32''.80$) was recently discovered by TYCHO-2 as an eclipsing binary (Nicholson, Varley, 2006). The V magnitude range is $10.8 - 11.5$ and the variable was identified as an EW-Type with the following ephemeris:

$$\text{HJD Tmin I} = 2451370.87525 + 0.2949\text{d} \times \text{E}. \quad (1)$$

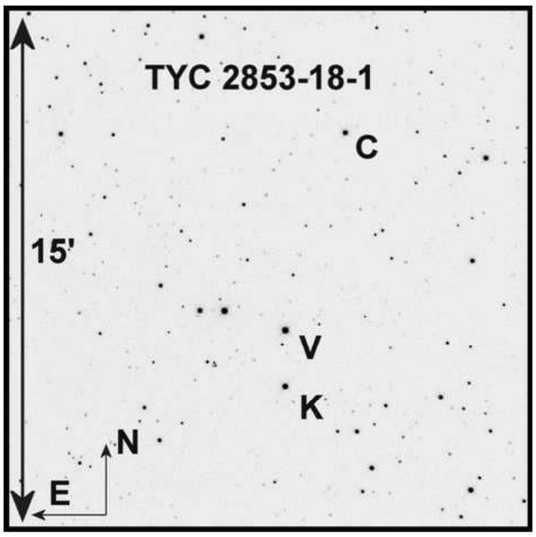

Figure 1. Finding Chart, TYC 2853-18-1 Variable (V), Comparison (C) and Check (K).

The LSPM North Catalog (Lépine and Shara, 2005) gives a Vmag of 11.05 and a $V - J$ of 1.61 for the variable, and TYCHO-2 gives an estimated $B - V$ of 0.799. These color indices all confirm that the variable is of spectral type ~K0V. Finally, the spectra of TYC 2853-18-1 and 54 Piscium were observed with the Dominion Astrophysical Observatory's (DAO) 1.8m telescope at 60Å/mm and are shown in Figure 2. The midtime of observation was 09:00 22 November 08, 2008 UT, which corresponds to a phase of approximately zero. The strength of the G band, Calcium H&K lines and the Calcium I 4227Å line and the H γ to Fe I 4384Å line all indicate a K0V±1 spectral class or $T = 5150 \pm 150$ for the effective temperature at phase zero where the primary, more massive component is eclipsing the hotter less massive secondary.

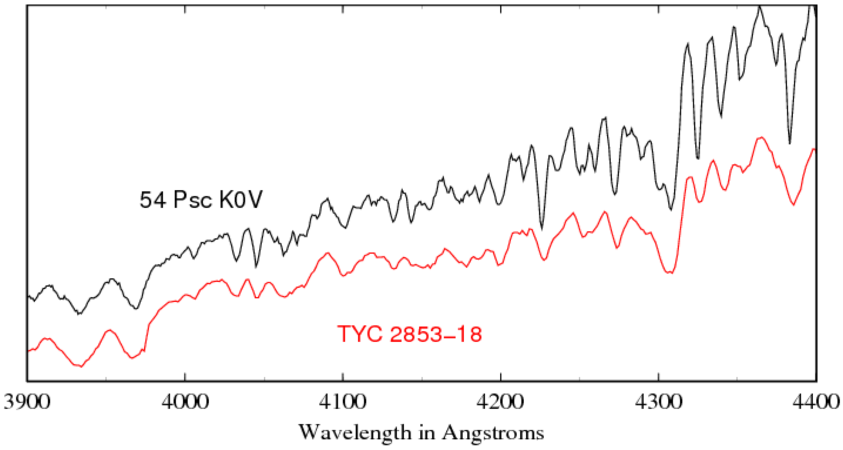

Figure 2. Optical Spectra of TYC 2853-18-1 at phase zero.

Our U, B, V, R_C, I_C light curves were taken at Lowell Observatory with the 0.81-m reflector with NURO time on 20 and 27 December, 2007 and via remote observing to Kitt Peak from South Carolina with the SARA 25 November, 3 December, 2007 and 19 February, 2008. NURO observations were take with the thermoelectrically cooled (< -100°C) 2K×2K CCD NASACAM. Ninety-five observations were taken in U, 217 observations were taken in B, 207 in V, 194 in R and 214 in I. Photometric precision was better than 1% in all filters. Our observations are given in Table 1, in delta magnitudes, variable minus comparison star. (The table is available through the IBVS website as `5901-t1.tex`.)

Our comparison star (marked C on the finder chart given as Figure 1) was GSC 2853 0765 [$\alpha(2000) = 02^h46^m58^s.481$, $\delta(2000) = +41°28'26''.69$, TYCHO $B - V = 0.741$, ~G8V]. The check star was GSC 2853 0312 (K) [$\alpha(2000) = 02^h47^m08^s.413$, $\delta(2000) = +41°20'49''.71$ TYCHO $B - V = 0.591$, ~G0V]. The variable is given as V.

We determined five times of minimum light from our present observations using parabola fits, which are given in Table 2.

We calculated the following ephemeris from all the available times of minimum light including the epoch given in Table 3.

$$\text{HJD Tmin I} = 2451370.875 \pm 0.001 + 0.2949039 \pm 0.0000001\text{d} \times \text{E} \qquad (2)$$

Our $O - C$ residuals calculated from Equation 2 are given in Table 2.

Table 2. $O - C$ Linear Residuals, Eq. 2

	Epochs	Errors	Cycles	Linear residuals	Reference
1	2451370.8753		0.0	0.0000	IBVS 5700 (2006)
2	2454455.7199	0.0006	10460.5	0.0028	This paper
3	2454516.6131	0.0005	10667.0	−0.0016	This paper
4	2454438.7605	0.0001	10403.0	0.0004	This paper
5	2454440.5298	0.0005	10409.0	0.0002	This paper
6	2454462.6464	0.0003	10484.0	−0.0009	This paper
7	2454462.7943	0.0002	10484.5	−0.0005	This paper

Our $UBVRI$ phased light curves, Phase versus Delta Magnitudes, in the sense of $V - K$, are given as Figures 6–8. (Available through the IBVS website as `5901-f6.eps -- 5901-f8.eps`.)

The $V - C$ curves in V showed scatter whose source is unknown, so we switched to the $V - K$ for modeling purposes. The light curves show some intrinsic effects of variability possibly due to magnetic spots. A brief total eclipse occurred in the primary eclipse

(∼8.5 m) shows this is a W-Type W UMa. The angularity in the shoulder at ∼phase 0.12 reveals that this is a very shallow fill-out contact binary.

Table 3. Synthetic Curve Parameters for TYC 2853-180-1

Parameters	*BVRI* Solution	*U* Solution
$\delta B, \delta V, \delta R, \delta I$ (nm)	440, 550, 640, 790	360
$x\text{bol}_{1,2}, y\text{bol}_{1,2}$	0.645, 0.645 0.17, 0.17	0.647, 0.647 0.176, 0.176
$x_{1I,2I}, y_{1I,2I}$	0.637, 0.637 0.208, 0.208	–
$x_{1R,2R}, y_{1R,2R}$	0.724, 0.724 0.200, 0.200	–
$x_{1V,2V}, y_{1V,2V}$	0.790, 0.790 0.159, 0.159	–
$x_{1B,2B}, y_{1B,2B}$	0.851, 0.851 0.044, 0.044	–
$x_{1B,2B}, y_{1B,2B}$	0.870, 0.870, −0.117, −0.117	–
$g_1 = g_2$	0.32	0.32
$A_1 = A_2$	0.50	0.50
Inclination (°)	81.63±0.09	85 ±2
T_1, T_2 (K)	5150±150*, 5023±5	5250±150*, 5219±14
Potentials, ω_1, ω_2	6.057±0.025	6.16±0.04
$q(m2/m1)$	2.62±0.02	2.69±0.03
fill-out	5.5±4%	6±6%
$L_1/(L_1+L_2)_I$	0.31±0.06	–
$L_1/(L_1+L_2)_R$	0.32±0.04	–
$L_1/(L_1+L_2)_V$	0.32±0.02	–
$L_1/(L_1+L_2)_B$	0.32±0.04	–
$L_1/(L_1+L_2)_U$	–	0.30±0.03
JD_0 (days)	2454440.5298±0.0005	
Period (days)	0.29489998±0.0000005	
r_1, r_2 (pole)	0.282±0.001, 0.440±0.001	0.280±0.004, 0.441±0.003
r_1, r_2 (side)	0.295±0.002, 0.471±0.001	0.292±0.004, 0.472±0.004
r_1, r_2 (back)	0.326±0.007, 0.499±0.005	0.326±0.007, 0.499±0.005
Sum of square res	3.7554	

*Estimated from the spectroscopy. The Wilson code period shows formal errors that are calculated from the variability of differentially corrected parameters as listed in the table. These have little to do with observational scatter. For example, while the Wilson code assigns an error to T2 of only 5K. However, the observational scatter would suggest about 150K from the spectral observations. All the other uncertainties, including the phasing period should be regarded the same way. Actual observational errors can be 10 times or more greater than those found from numerical calculations in such a synthetic code. I have exaggerated the errors by listing errors from the full set of corrections and not from the subsets in order to minimize this effect.

Binary Maker 3.0 (Bradstreet, 2002) was used to find initial fits for modeling. Representative values were then entered into the 2004 version of the Wilson Code (Wilson and Devinney, 1971 (WD); Wilson, 1990, 1994; Van Hamme and Wilson, 1998; Wilson, and Van Hamme 2003). We ran a full *UBVRI* simultaneous solution. However, the *U* solution did not fit the data well so a *BVRI* synthetic simultaneous solution was calculated. The T2 is an estimate from our spectroscopic observations. Following our first solution, we ran 23 additional solutions with q fixed and spanning the mass ratio range of 0.3 to 3.25. This "q-search" was used to determine the best q value for our *BVRI* light curves. See Figure 3. Our best synthetic light curve solution is seen overlaying the normalized flux curves are shown as Figure 4 and 5. The complete solution table is given as Table 3. A Roche-lobe model for the binary is shown as Figure 9 (Available through the IBVS website as `5901-f9.eps`.) We decided to run a *U* curve solution separately just to see how different it was. The *U* solution is found to be very similar (See Table 3.) to the *BVRI* with a 3 degree increase in inclination, while other values are overlapping or nearly overlapping the earlier ones. So we see no major differences to further comment on.

TYC 2853-18-1 is found to be among the W-type W UMa contact binaries. (Our solution reveals that the less massive, slightly hotter component is eclipsed at phase zero.) The mass ratio has reached 2.6 (m_1/m_2) and is likely tending toward larger mass ratios as the secondary component is consumed by the primary. Thus, TYC 2853-18-1 may be a prototype of an AW UMa-type system. The driving mechanism for this supposed process is the torque supplied by out flowing winds along 'stiff' field lines originating from the solar-type stars.

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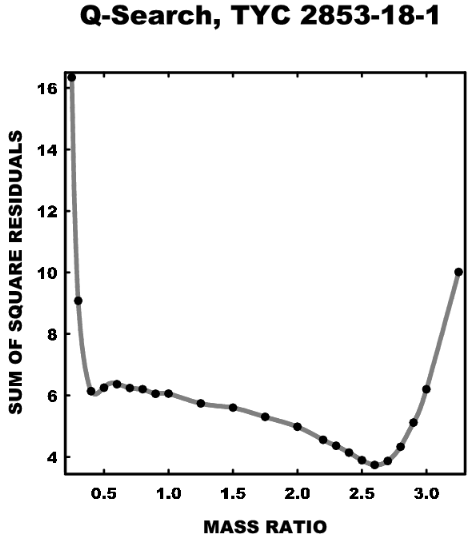

Figure 3. Plot of the results of our q-search for the best fiting mass ratio.

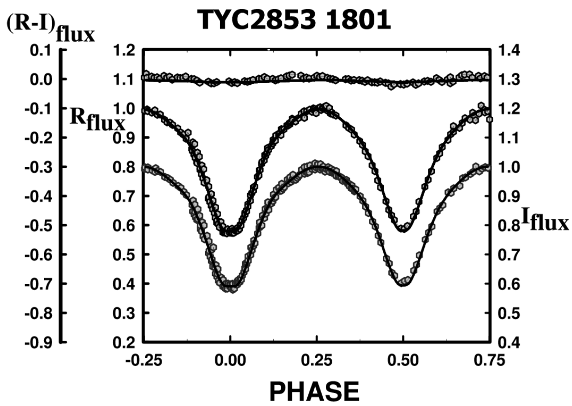

Figure 4. B,V,R,I synthetic light curve solutions overlaying the normalized flux curves.

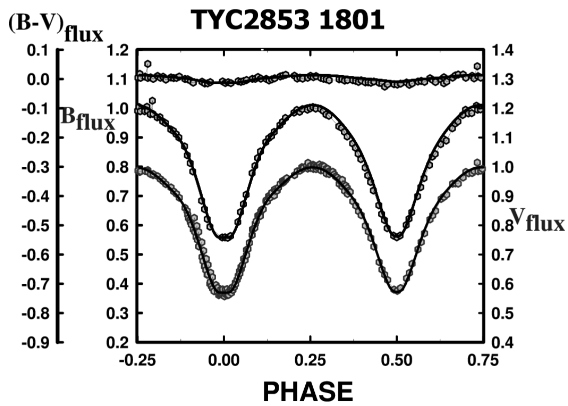

Figure 5. B,V,R,I synthetic light curve solutions overlaying the normalized flux curves.

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