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UBVRI ANALYSIS OF THE ECLIPSING BINARY V1128 TAURI

HAWKINS, NATHAN C.[1,2]; SAMEC, RONALD G.[1,2]; VAN HAMME, WALTER[4]; FAULKNER, DANNY R.[2,3]

[1] Astronomy program, Department of Physics Bob Jones University, Greenville, SC 29614, USA

[2] Visiting Astronomer, SARA Observatory, Kitt Peak, AZ

[3] U of South Carolina, Lancaster, SC

[4] Florida International University, Miami, Fl

As a part of our study for solar-type eclipsing binaries, we observed the variable V1128 Tauri [GSC 664 694, HIP 17878; $\alpha(2000)= 03^{\rm h}49^{\rm m}27\overset{\rm s}{.}8$, $\delta(2000)= +12^\circ54'44''$]. The variability of V1128 Tau was discovered by HIPPARCOS (ESA 1997). According to the TYCHO catalog (ESA 1997), V1128 Tau is a solar-type binary, with a spectral type of G0. Our preliminary standard star work has confirmed this. We obtained a $B-V = 0.606 \pm 0.039$. Timings of minimum light have been published by Hegedüs et al. (2003), and Tas et al. (2003). Tas et al. give the following ephemeris:

$$\text{HJD Tmin I} = 2452236.060963 \pm 0.000014 + (0.30537332 \pm 0.00000002\text{d}) \times \text{E}. \quad (1)$$

Our observations were made with the Southeastern Association for Research in Astronomy (SARA) 0.9-m reflector and AP7 CCD at Kitt Peak, on 24-27 December, 2003, by RGS, DRF, and NCH. Standard $UBVR_CI_C$ filters were used. Between 70 and 100 high precision observations were taken in each pass band. The stars [GSC 664 1304, HIP 17876, $\alpha(2000)= 03^{\rm h}49^{\rm m}27\overset{\rm s}{.}5$, $\delta(2000)= +12^\circ54'32''$, $B-V = 0.726 \pm 0.052$] and [GSC 666 710, $\alpha(2000) = 03^{\rm h}49^{\rm m}38\overset{\rm s}{.}7$, $\delta(2000)= +12^\circ54'01''$, $B-V = 0.854 \pm 0.072$] were used as the comparison and check stars, respectively. A finding chart for V1128 Tau, the comparison star, and check star is given as Figure 1. The light curves are given in Figure 2, as normalized flux versus phase.

Three precision mean epochs of minimum light were determined from eclipse timings in all five pass bands, using parabola fits: HJD Tmin I = 2453000.6523 ± 0.0002 and HJD Tmin II = 2452998.6665 ± 0.0002 and 2453000.8044 ± 0.0003. From our observations, we calculated the following linear ephemeris, which we then used to phase our data:

$$\text{HJD TMin I} = 2453000.6522 \pm 0.0004 + 0.30530 \pm 0.00009 \times \text{E} \quad (2)$$

A linear fit to all available timings of minimum light gives:

$$\text{HJD TMin I} = 2453000.6533 \pm 0.0001 + 0.305373219 \pm 0.000000037 \times \text{E} \quad (3)$$

Due to the fact that the $O-C$ plot seemed to indicate a period change, we also calculated a quadratic fit to all available timings:

$$\text{HJD Tmin I} = 2453000.6525 \pm 0.0002 + 0.30537273 \pm 0.00000011 \times \text{E} \quad (4)$$
$$-0.000000000034(\pm 0.000000000007) \times \text{E}^2$$

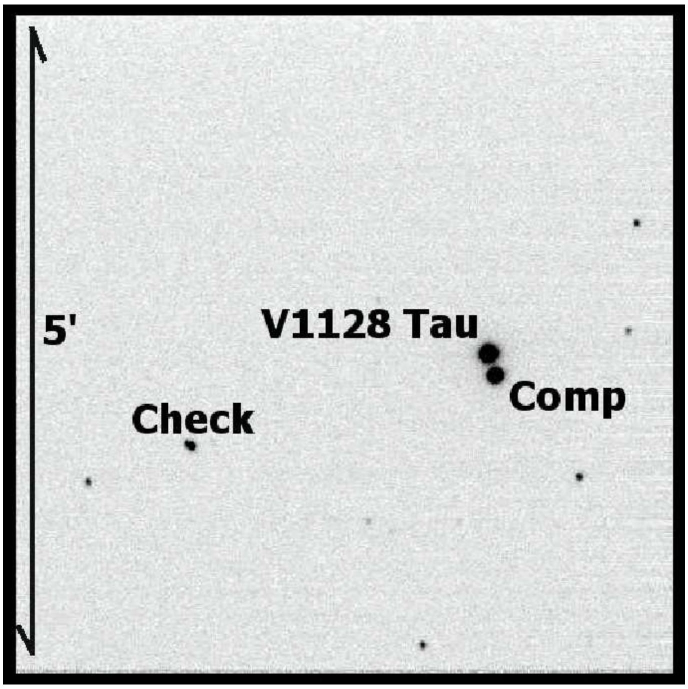

Figure 1.

Figure 3 gives the $O-C$'s calculated from the linear portion of equation (4), with the quadratic term shown overlaying. The plot shows indications of a variable, decreasing period, just as one would expect in the case solar-type binaries due to magnetic braking. Although the timings cover only about 15000 orbits, the quadratic term is already very significant. A complete table of minima and linear and quadratic residuals are given as Table 1. The linear residuals are calculated from equation (3) and the quadratic ones are calculated from equation (4). Further observations, as well as archival searches for photographic minima, are needed to confirm this behavior.

To arrive at an independent solution, we first pre-modeled with Binary Maker 2.0 (Bradstreet 1992) and obtained preliminary solutions in all five pass bands independently. Both detached and semi-detached configurations were tested. Parameters derived from the initial Binary Maker solutions were then used as the starting values for a simultaneous 5-color synthetic light curve solution using the Wilson Code (Wilson & Devinney 1971, Wilson 1990, 1994).

Our solution indicates that the system is a W-type W UMa system; the cooler star is almost twice the mass of the hotter component ($m2/m1 = 1.944 \pm 0.004$). The mass ratio is constrained by the totality of the primary eclipse. The W-type phenomena is indicative of strong (saturated) magnetic activity on the primary component, which masks the true temperature of the star. The components fill their Roche lobe to only 18.5%. Other parameters include the temperatures, $T_1 = 6000$ K (fixed) and $T_2 = 5830$ K, and orbital inclination of 85°.

The observed O'Connell effect is more evidence for magnetic spot activity; our model includes a single large magnetic region on the surface of the secondary, less massive component, with a mean temperature factor of 0.89 of the surface temperature (5220 K). The position and size of the region is given by the parameters: co-latitude = 125°, longitude = 266°, and radius = 25°.

Table 1: Epochs of Minimum Light, V1128 Tau

Epochs 2400000+	Cycles	Linear Residuals	Quadratic Residuals	Weight	Reference
48500.0620	−14738.0	−0.0008	0.0001	1.0	ESA 1997
51822.5237	−3858.0	0.0002	−0.0003	1.0	Hegedüs et al. 2003
51830.4633	−3832.0	0.0001	−0.0004	1.0	Hegedüs et al. 2003
51830.6165	−3831.5	0.0007	0.0001	1.0	Hegedüs et al. 2003
52236.4578	−2502.5	0.0009	0.0008	1.0	Tas et al. 2003
52236.4578	−2502.5	0.0010	0.0008	1.0	Tas et al. 2003
52236.6096	−2502.0	0.0000	−0.0002	1.0	Tas et al. 2003
52236.6101	−2502.0	0.0005	0.0004	1.0	Tas et al. 2003
52240.4271	−2489.5	0.0004	0.0002	1.0	Tas et al. 2003
52240.4274	−2489.5	0.0007	0.0005	1.0	Tas et al. 2003
52248.3670	−2463.5	0.0006	0.0004	1.0	Tas et al. 2003
52248.3672	−2463.5	0.0008	0.0006	1.0	Tas et al. 2003
52254.3201	−2444.0	−0.0011	−0.0013	1.0	Tas et al. 2003
52254.3205	−2444.0	−0.0007	−0.0008	1.0	Tas et al. 2003
52258.2906	−2431.0	−0.0005	−0.0006	1.0	Tas et al. 2003
52258.2906	−2431.0	−0.0004	−0.0006	1.0	Tas et al. 2003
52258.4440	−2430.5	0.0003	0.0001	1.0	Tas et al. 2003
52258.4444	−2430.5	0.0006	0.0005	1.0	Tas et al. 2003
52263.3298	−2414.5	0.0001	0.0000	1.0	Tas et al. 2003
52263.3301	−2414.5	0.0004	0.0002	1.0	Tas et al. 2003
52263.4819	−2414.0	−0.0005	−0.0007	1.0	Tas et al. 2003
52263.4819	−2414.0	−0.0005	−0.0006	1.0	Tas et al. 2003
52277.2233	−2369.0	−0.0009	−0.0011	1.0	Tas et al. 2003
52277.2235	−2369.0	−0.0007	−0.0009	1.0	Tas et al. 2003
52277.3762	−2368.5	−0.0007	−0.0008	1.0	Tas et al. 2003
52277.3771	−2368.5	0.0002	0.0000	1.0	Tas et al. 2003
52277.3772	−2368.5	0.0003	0.0001	1.0	Tas et al. 2003
52313.2582	−2251.0	−0.0001	−0.0002	1.0	Tas et al. 2003
52314.3272	−2247.5	0.0001	0.0000	1.0	Tas et al. 2003
52315.2437	−2244.5	0.0006	0.0005	1.0	Tas et al. 2003
52536.4871	−1520.0	0.0011	0.0012	1.0	Tas et al. 2003
52536.4872	−1520.0	0.0011	0.0013	1.0	Tas et al. 2003
52563.5116	−1431.5	0.0000	0.0002	1.0	Tas et al. 2003
52563.5119	−1431.5	0.0003	0.0005	1.0	Tas et al. 2003
52565.3429	−1425.5	−0.0010	−0.0008	1.0	Tas et al. 2003
52565.3435	−1425.5	−0.0003	−0.0001	1.0	Tas et al. 2003
52565.4967	−1425.0	0.0002	0.0003	1.0	Tas et al. 2003
52565.4968	−1425.0	0.0003	0.0005	1.0	Tas et al. 2003
52565.4976	−1425.0	0.0011	0.0013	1.0	Tas et al. 2003
52565.4977	−1425.0	0.0012	0.0014	1.0	Tas et al. 2003
52608.2474	−1285.0	−0.0013	−0.0011	0.5	Tas et al. 2003
52608.2484	−1285.0	−0.0003	−0.0001	0.5	Tas et al. 2003
52608.4011	−1284.5	−0.0004	−0.0001	1.0	Tas et al. 2003
52608.4013	−1284.5	−0.0001	0.0001	0.5	Tas et al. 2003
52998.6665	−6.5	−0.0019	−0.0011	1.0	Present Observations
53000.6523	0.0	−0.0010	−0.0002	1.0	Present Observations
53000.8044	0.5	−0.0016	−0.0008	1.0	Present Observations

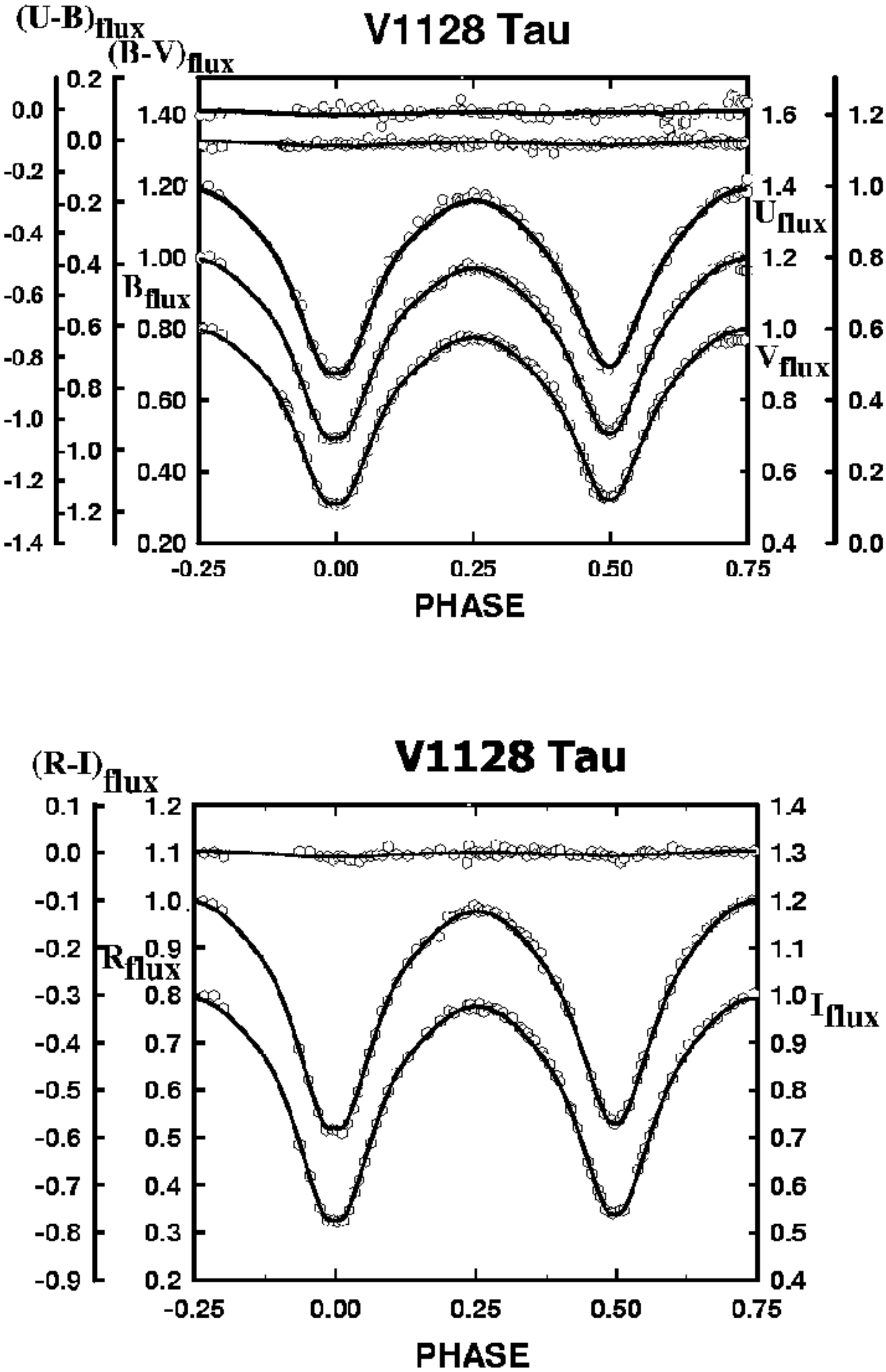
V1128 Tau
(U-B)flux
(B-V)flux
Bflux
Uflux
Vflux
PHASE
V1128 Tau
(R-I)flux
Rflux
Iflux
PHASE

Figure 2.

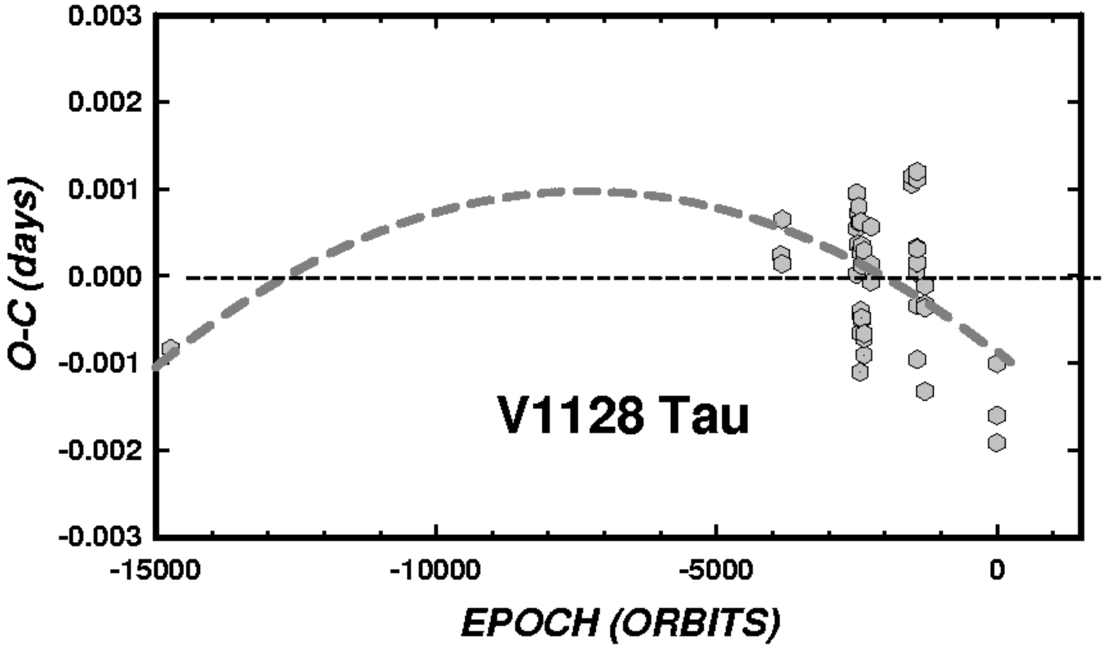

Figure 3.

Our solution is shown overlaying the phased, flux-normalized data in Figure 2; while a geometrical representation of V1128 Tau is given in Figure 4. Out tabled solution is given in Table 2. Tas et al. (2003) has published a large collection of B,V data using 3 different telescopes and detectors over two observing seasons. A Wilson solution was calculated on the combined curves. Their solution is of W-type with an inclination of 85° and a mass ratio of $m1/m2 = 2.2$. They also showed asymmetries in the light curves indicating spot activity in the system. The differences between Tas et al. (2003) and the present solution arise due to a combination of the following factors. Tas et al.'s (2003) solutions are based only on B and V observations, while ours is based on $UBVR_CI_C$, thus giving a better fix on the parameters, especially those related to temperature. They used one dimensional limb darkening coefficients, while we used two dimensional coefficients as well as bolometric albedos. Tas et al.'s (2003) choice of coefficients was different from ours. We used Van Hamme's coefficients which are included with the Wilson code based on Kurucz atmospheres and the temperature of the primary component. Our primary component temperature was fixed at 6000 K, better reflecting its K0 spectral type. We also allowed our spot to adjust in latitude. Also, it is best not to combine light curves from different seasons for active W UMa binaries.

We wish to thank the Southeastern Association for Research in Astronomy (SARA) for their allocation of observing time, as well as NASA and the American Astronomical Society for their continued support of our undergraduate research programs through their small research grants.

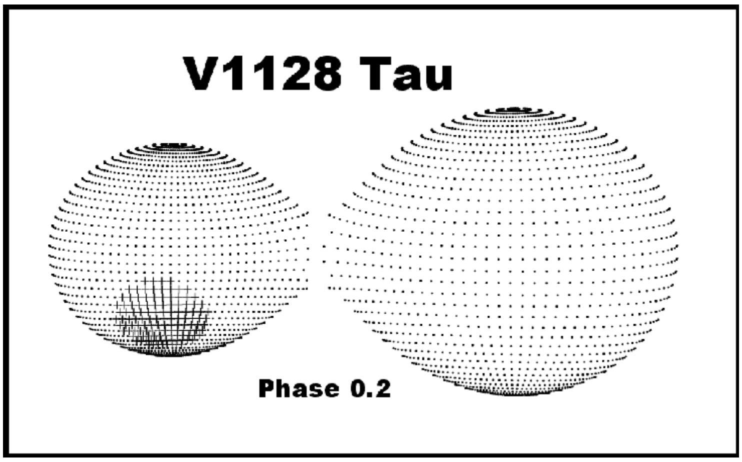

Figure 4.

Table 2: Synthetic light curve parameters for V1128 Tau

λ_B, λ_V, λ_R, λ_I (nm)	360, 440, 550, 640, 790
x_{1U}, x_{2U}, y_{1U}, y_{2U}	0.872, 0.872, 0.143,0.143
x_{1B}, x_{2B}, y_{1B}, y_{2B}	0.829, 0.829, 0.185,0.185
x_{1V}, x_{2V}, y_{1V}, y_{2V}	0.745, 0.745, 0.256,0.256
x_{1R}, x_{2R}, y_{1R}, y_{2R}	0.653, 0.653, 0.269,0.269
x_{1I}, x_{2I}, y_{1I}, y_{2I}	0.56, 0.56, 0.26, 0.26
g_1 , g_2	0.32, 0.32
A_1 , A_2	0.500, 0.500
$xbol_1$, $xbol_2$	0.647 , 0.647
$ybol_1$, $ybol_2$	0.221 , 0.221
Inclination	84°.92 ± 0°.06
T_1, T_2 (K)	6000, 5828 ± 1
ω_1,ω_2	5.061 ± 0.001
q (m_2/m_1)	1.944 ± 0.001
pshift	0.998 ± 0.001
$L_1/(L_1+L_2)U$	0.402 ± 0.009
$L_1/(L_1+L_2)B$	0.394 ± 0.008
$L_1/(L_1+L_2)V$	0.386 ± 0.009
$L_1/(L_1+L_2)R$	0.382 ± 0.007
$L_1/(L_1+L_2)I$	0.377 ± 0.009
r_1, r_2 (pole)	0.312 ± 0.001, 0.422 ± 0.001
r_1, r_2 (side)	0.327 ± 0.001, 0.450 ± 0.001
r_1, r_2 (back)	0.367 ± 0.005, 0.482 ± 0.002
fill-out	18.5 ± 0.1%
Spot Parameters:	Primary Component
Colatitude	125°± 1°
Longitude	266°± 1°
Spot radius	25°.0 ± 0°.3
Temperature factor	0.998 ± 0.001

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