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Photometric elements, absolute dimensions and evolutionary status of the eclipsing binary HU Tauri

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Abstract. The photometric elements of HU Tauri are derived from an analysis of it's *B* and *V* light curves using the Wilson and Devinney (1971) light curve synthesis method. The photometric elements suggest that HU Tauri is a semi-detached system and the primary minimum in it's light curve is due to an occultation.

Combining the photometric elements and spectroscopic orbital elements the absolute dimensions of the system are derived. The cool and less massive secondary has over filled its Roche-lobe and it is over luminous for its mass. HU Tau is found to be a semi-detached system similar to Algol and δ Lib.

Key words : stellar evolution—binaries

1. Light curves

The *B* and *V* observations of HU Tauri by Parthasarathy & Sarma (1980) were grouped into 96 normal points in the *V* passband and 101 points in the *B* passband. These normal points were analysed for elements with Wilson-Devinney (W-D) (1971) light curve synthesis programme.

2. Light curve analysis

As the nature of the primary eclipse—transit or occultation—was not well established, we obtained a combined solution for the *B* and *V* light curves for both these possibilities using code-2 of W-D method meant for detached systems. Firstly, we obtained a converged solution for the case of the primary eclipse being a transit and the resulting system being detached. However, we also obtained a converged solution for the other case i.e., primary eclipse being an occultation. The fractional radius of the cool star r_c was found to be 0.277 and mass ratio to be 0.301. For this mass ratio the radius of the Roche-lobe for the cooler star is found to be 0.272 (Plavec & Kratochvil 1964). The result indicates that HU Tau is a semi-detached system. Hence a combined solution for *B* and *V* light curves was obtained using code-5 of W-D method meant for a semi-detached system. The photometric elements derived from our present analysis for Case I (transit) and Case II (occultation) are given in table 1.

Table 1. HU Tau : photometric elements

Element	Case I (transit)	Case II (occultation)
T_h(°K)	12000 ± 70	13598 ± 89
T_c(°K)	4904 ± 92	5744 ± 16
i	90° ± 1°	77°.99 ± 0°.06
r_h	0.301 ± 0.001	0.218 ± 0.001
r_c	0.215 ± 0.001	0.336 ± 0.001
q	0.296 ± 0.002	0.282 ± 0.018
L_h^V	0.973 ± 0.025	0.847 ± 0.001
L_c^V	0.027	0.153
L_h^B	0.988 ± 0.022	0.891 ± 0.001
L_c^B	0.012	0.109
$R_h/R_\odot$	3.65 ± 0.1	2.69 ± 0.04
$R_c/R_\odot$	2.68 ± 0.08	4.15 ± 0.05
Log $L_h/L_\odot$	2.394 ± 0.060	2.346 ± 0.054
Log $L_c/L_\odot$	0.571 ± 0.090	1.224 ± 0.037
$M_{h,bol}$	−1.30 ± 0.15	−1.17 ± 0.14
$M_{c,bol}$	+3.26 ± 0.22	+1.63 ± 0.09
$M_{h,v}$	−0.58 ± 0.15	−0.11 ± 0.14
$M_{c,v}$	+3.57 ± 0.22	+1.77 ± 0.09

3. Spectral types of components

From the fractional luminosities of the hotter and cooler stars and from the magnitude and $(B - V)$ colours outside the eclipse, we find the spectral types of the primary (hotter) star to be B8 V or B9 V which is consistent with its MK spectral type of B8 V. The secondary (cooler) star is found to be a late F or early G subgiant or giant.

4. Absolute dimensions

The spectroscopic orbital elements of HU Tau were derived by Mammano and Margoni (1967) and Parthasarathy (1979). Parthasarathy detected the spectrum of the secondary component and derived the radial velocities. Combining the spectroscopic and photometric elements (Russell-Merrill method) obtained by him he derived the absolute dimensions of the system (Parthasarathy 1979). He concluded that HU Tauri is a semi-detached system and the primary minimum is due to an occultation. We report here a slightly revised absolute dimensions based on the spectroscopic orbit obtained by Parthasarathy (1979) and the photometric elements derived now using the W-D light curve synthesis method for the semi-detached system with the primary minimum due to an occultation. These absolute dimensions are given in table 2.

5. Evolutionary status

The photometric solutions of the light curves of HU Tau using the W-D light curve synthesis method (table 1) show that if we consider the primary minimum as due to transit, the system

Table 2. HU Tau : Absolute dimensions based on orbital inclination i = 78° and primary eclipse occultation

m_h	$4.72 \pm 0.14 M_\odot$
m_c	$1.27 \pm 0.03 M_\odot$
A	$12.34 \pm 0.12 R_\odot$
R_h	$2.69 \pm 0.04 R_\odot$
R_c	$4.15 \pm 0.05 R_\odot$
Log $L_h/L_\odot$	2.346 ± 0.054
Log $L_c/L_\odot$	1.224 ± 0.037
$M_{h,bol}$	-1.17 ± 0.14
$M_{c,bol}$	$+1.63 \pm 0.09$
$M_{h,v}$	-0.11 ± 0.14
$M_{c,v}$	$+1.77 \pm 0.09$

is detached and the orbital inclination is 90°. If we consider the primary minimum as due to an occultation the system is semi-detached and the orbital inclination is 78°. The absence of totality phase and partial eclipse shape of the secondary minimum clearly indicates that the inclination is not 90°; therefore the solution obtained considering the primary minimum due to transit is not realistic. In order to understand the evolutionary status of the system we have considered the positions of the primary and secondary components in the Log L versus Log T_e diagram of the evolutionary tracks of Maeder & Meynet (1988) for stars of Population I composition with initial masses of 1.15 m$_\odot$, 1.3 m$_\odot$, 3.5 m$_\odot$ and 4.0 m$_\odot$ (figure 1). From the position of the less massive and cooler component in the Log L - Log T_e diagram, it is clear that this component is an evolved star while the primary, more massive hotter component is unevolved and is still close to the main sequence. In fact the solution obtained for the

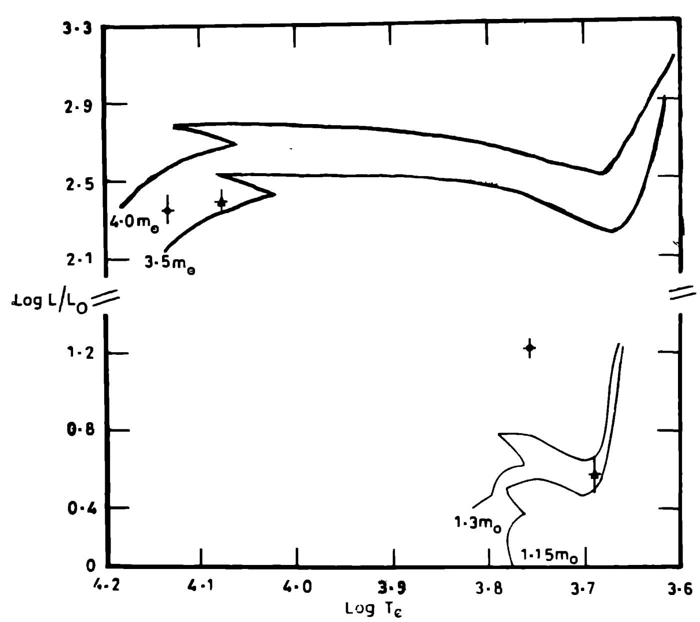

Figure 1. HU Tau : Evolutionary status of the two components. Solid, lines represent the evolutionary tracks of Maeder and Meynet (1988) for stars of Population I composition. Δ's represent Case I and ●'s represent Case II solutions with error bar.

semi-detached case with primary minimum as due to an occultation clearly shows that the cooler and less massive secondary has filled its Roche lobe and is overluminous for its mass.

6. Conclusions

From an analysis of the *B* and *V* light curves of HU Tau using the W-D light curve synthesis method we conclude that HU Tau is a semi-detached system and the primary minimum is due to occultation. The absolute dimensions derived from combining photometric and spectroscopic elements suggest that the less massive and cool secondary component has overfilled its Roche lobe and is also overluminous for its mass.

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