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A TIME OF MINIMUM AND ROTATIONAL VELOCITY FOR TT HYDRAE

TT Hya is a totally eclipsing Algol binary (B9.5 V + G9-K1 III-IV) with a seven-day period (Etzel 1988). Its spectrum shows prominent shell absorptions throughout the ultraviolet, which are probably formed in an accretion disk, and emission lines from an extended shell or wind during total eclipse (Plavec 1988). The existing ephemeris of Kulkarni and Abhyankar (1980),

$$\mathrm{HJD(Obs.)} \;=\; 2{,}424{,}615.388 + 6.95342913 \cdot \mathrm{E} \qquad (1)$$

is not especially well determined (see Etzel 1988). So, in preparation for making further IUE observations of TT Hya, we have observed it both photometrically and spectroscopically in the optical with the view of getting a more precise time of minimum.

Photometric observations in B and V were obtained on two nights in late April, 1992, with the 16-inch Vanderbilt-Tennessee State robotic telescope. Neither night was especially good photometrically, but data on the second clearly caught the star going through second contact into total eclipse, as shown in Figure 1. Since we have no observations of the rising branch of the eclipse, we have estimated the time of minimum by fitting a light curve calculated for the elements of Etzel (1988; Table IV with q=0.184 and the cool star filling its Roche lobe) to the observations. The resulting times are HJD 2,448,743.826 ± 0.004 for V and HJD 2,448,743.823 ± 0.004 for B, about one hour later than predicted by equation (1). We can use our time of minimum to obtain a slightly better ephemeris

$$\mathrm{HJD(Obs.)} \;=\; 2{,}448{,}743.825 + 6.9534414 \cdot \mathrm{E} \qquad (2)$$

which incorporates the time of minimum of Kulkarni and Abhyankar and Etzel's -0.0045-

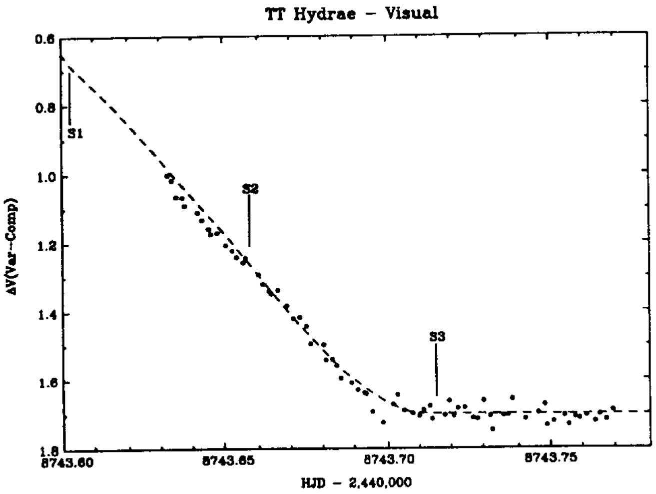

Figure 1. Observations of second contact of TT Hya made with the Vanderbilt-TSU robotic telescope. Magnitude differences are measured with respect to HD 97111, the same comparison star used by Kulkarni and Abhyankar. The dashed curve is the theoretically calculated light curve used to estimate the time of minimum. Phases of the three spectra taken in eclipse one orbit earlier are shown as vertical bars.

day correction to it. Observations for our first night were centered at phase 0.84. They can be used to determine the full amplitude of the light variation in the two colors: 1.77 mag in V and 2.58 mag in B. These are essentially the same as given by Etzel.

We also obtained spectra in the 6400-6480 Å range on three nights with the McMath Solar Telescope at the US National Solar Observatory. These had a dispersion of 0.09 Å/pixel and a resolution of about 1.5 pixels. Spectra were taken at phases 0.55 and 0.68 outside eclipse and at phases 0.968, 0.976, and 0.984 in primary eclipse. The last of these observations, shown in Figure 2, was made just after total eclipse had started, and it therefore records the light of the K star alone. The line broadening gives a rotational velocity of $v \sin i = 43 \pm 3$ km/s for a spherical star. Changes in equivalent widths of strong metallic lines over the phase range 0.68–0.984 are consistent with the changes in the fraction of the binary's light contributed by the K star.

Because our estimate of the rotational velocity is about twenty percent bigger than

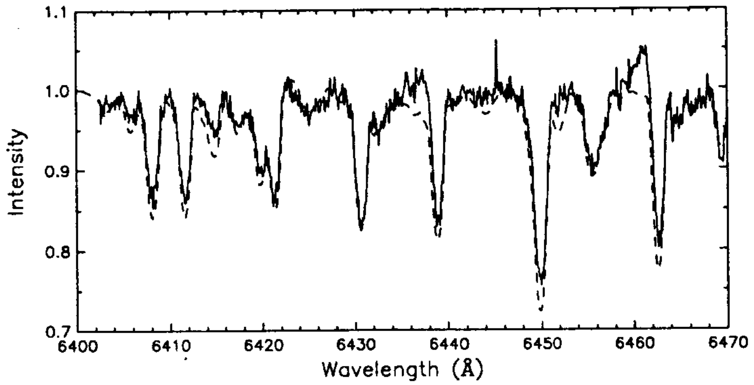

Figure 2. A spectrum of TT Hya made at phase 0.984 (solid line). This shows only the light of the K star, since the B star is totally eclipsed. The dashed curve is a spectrum of κ CrB broadened to simulate the velocity structure of the lobe-filling component of TT Hya; it has been shifted by +40 km/s to account for the difference in velocities of the two stars.

expected for synchronous rotation of a Roche lobe-filling component with the properties derived by Etzel, we decided to analyze the system more fully. To get a better idea of the geometry of the system, we have used a scheme previously applied to UU Cnc (Eaton, Hall, and Honeycutt 1991) to calculate the spectrum of the rotating, distorted lobe-filling component of TT Hya. In applying it, we took κ CrB (K1 IVa, $v\sin i < 5$ km/s, RV = -17 km/s) as the comparison star. When properly broadened for rotation, the stronger lines in κ CrB have equivalent widths about seven percent greater than in the K component of TT Hya. A comparison is given in Figure 2. Properties of the TT Hya system in total eclipse are especially simple. The only light detected comes from the K-giant component, which surely must be in contact with its Roche lobe. Thus the rotational velocity would depend uniquely on the mass ratio, the velocity amplitude of the cool, lobe-filling star, and the inclination. Because of the shell spectrum of the B star and its high rotational velocity, the amplitude of the hotter component's velocity curve, hence the mass ratio, has not been accurately determined. Popper (1982), however, has measured a velocity amplitude for the cool star, K_c = 130 km/s. Calculations in which the spectrum of κ CrB is broadened to simulate TT Hya show we do not get the observed rotational broadening for this velocity amplitude if we use the mass ratio (q=0.184) derived by Etzel for a lobe-filling component. Instead, we must raise the mass ratio to $q=0.25 \pm 0.02$ at $K_c = 130$ or increase the the velocity amplitude to $K_c = 145 \pm 5$ km/s (about 10%) at q = 0.184. For both of these cases the mass of the B star is increased slightly over the 2.25 $M_\odot$ found by Etzel and Popper, specifically to 2.5-3.1 $M_\odot$. Likewise, the radius of the K star would be about 5.6 $R_\odot$ in both cases. Some combination of these changes is indicated, although an increase in the velocity amplitude is favored slightly by the shift of the lines between the spectra in eclipse and the one for phase 0.68.

We also took an Hα spectrum at phase 0.11. It shows a broad, double-peaked emission component close to the velocity of the B star along with the weak rotationally broadened and redshifted spectrum of the K star. The emission component is 18 Å wide at its base and has a central reversal broad enough to be the the rotationally broadened absorption line of the B star.

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