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UBVRI CCD OBSERVATIONS OF HM MONOCEROTIS AND SIXTY TWO YEAR PERIOD STUDY

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As a part of our search for solar type binaries with gas streams we observed the neglected variable, HM Monocerotis (GSC 162 265, $\alpha(2000) = 07^h03^m2\overset{s}{.}89$, $\delta(2000) = -00°13'49\overset{''}{.}1$). Wachmann (1968) gave 48 times of minimum light and a starting ephemeris (recalculated by us),

$$\text{HJD Tmin I} = 2430110.195\ (\pm 0.004) + 0.4076573\ (\pm 0.0000005)\text{d} \times \text{E}. \qquad (1)$$

His photographic light curves show a large difference in minima, yet a smoothly changing slope in the out-of-eclipse portion, both marks of a near contact system.

Our present UBVRI light curves of HM Mon were taken at CTIO in Chile with the 0.9-m reflector on 18, 19, 20, 23 May 2001, by RGS and DRF. The CFIM 2K×2K T2K CCD camera operating in a 1K×1K quad amplifier mode for fast readouts. Standard UBVR_cI_c Johnson-Cousins filters were used. Over 180 observations were taken in each pass band. The stars (GSC 162 1551, $\alpha(2000) = 07^h02^m59\overset{s}{.}60$, $\delta(2000) = 0°14'32\overset{''}{.}8$) and (GSC 162 1709, $\alpha(2000) = 07^h03^m12\overset{s}{.}16$, $\delta(2000) = 00°14'31\overset{''}{.}1$) were used as comparison and check stars, respectively. A finding chart of HM Mon (V), the comparison (C) and check star (K) are given in Figure 1. The light curves and color curves of the variable are given in Figure 2 as normalized flux versus phase.

We were able to perform a period study with 89 times of minimum light spanning an amazing 62 years (Kreiner, Kim and Nah, 1999; BBSAG 1994, 1995, 1997). Our three mean epochs of minimum light were determined from U,B,V,R,I eclipse timings:

$$\begin{aligned}\text{HJD MIN I} &= 2452632.7926 \pm 0.0004\\ &= 2452637.6842 \pm 0.0005\\ \text{HJD MIN II} &= 2452636.6638 \pm 0.0008\end{aligned}$$

using parabola fits. We calculated the following linear ephemeris from recent epochs (after JD 2444500) which we used to phase our data:

$$\text{HJD Tmin I} = 2452632.7895\text{d}(0.0041) + 0.40765554(0.00000037)\text{d} \times \text{E}. \qquad (2)$$

A weighted quadratic fit was applied to all available timings of minimum light gave:

$$\begin{aligned}\text{HJD Tmin I} = {} & 2452632.7888 + 0.40765508\text{d} \times \text{E} - 0.000000000018 \times \text{E}^2. \qquad (3)\\ & \pm 0.0013 \quad \pm 0.00000014 \qquad \pm 0.000000000002\end{aligned}$$

Figure 3 shows the $O - C$'s calculated from the linear part of equation 3 overlain by the quadratic fit (the last term). This demonstrates that equation 3 provides a good representation of the period behavior of the system. The steady period decrease it indicates is not unusual for solar type binaries undergoing magnetic breaking via stellar winds. Our $U - B$, $B - V$, $V - I$, $R - I$ color indices indicated a spectral type of about G2V $\pm$ 2 for the system, so solar type activity is expected. The check star was found to be F8V with a Vmag of 13.03 and the comp star a K2V star with V = 12.25.

In modeling the light curve we first used Binary Maker 2.0 (Bradstreet, 1992) to fit the light curves. We tried contact and near contact models. None provided satisfactory fits even with a spot. Later, I tried a V1010 Oph type with a stream spot near the L1 point on the smaller star with a large dark spot facing it on the larger component. This immediately provided an excellent fit to these otherwise difficult curves.

Using averaged starting values from Binary Maker as our input values, we calculated complete simultaneous 5 color synthetic light curve solutions with the Wilson Code (Wilson & Devinney, 1971; Wilson, 1990, 1994). Our best solution indicates that the secondary component is slightly under-filling its Roche lobe (fill-out = 99.39$\pm$0.03%) while the secondary component is filling. Other values calculated include the temperature difference, δT = 2345 K, mass ratio m_2/m_1 = 0.590 and an inclination of 75.4 degrees. The two modelled spots are as follows: a stream spot with a temperature factor of 1.46 and a radius of 13.1 degrees very near the L1 point of the secondary component and a solar-type dark spot of radius 33.1 degrees with a T factor of 0.92. Another solution was obtained in a contact mode (presented at the January 2004 AAS meeting, Dudles et al. 2003) with a cool third light. But the goodness of fit parameters were about 3 times worse and the fit was questionable.

Our best solution is shown overlaying the data in Figure 1. A geometrical representation of HM Mon with the two spots is given in Figure 4 as viewed from the pole.

Only after many trails did we understand the correct modeling configuration. The difficulties in the modeling undoubtedly arose from the dominating character of the spots. The stream spot persisted through the entire set of differential corrections iterations (hundreds) and is undoubtedly real. This system is probably undergoing rapid evolution into contact. Good quality spectroscopic data is need to verify this these important results.

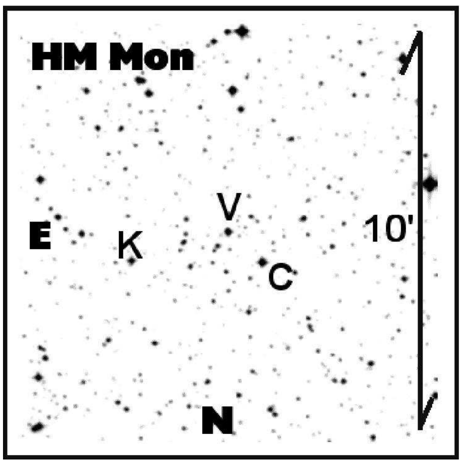

Figure 1.

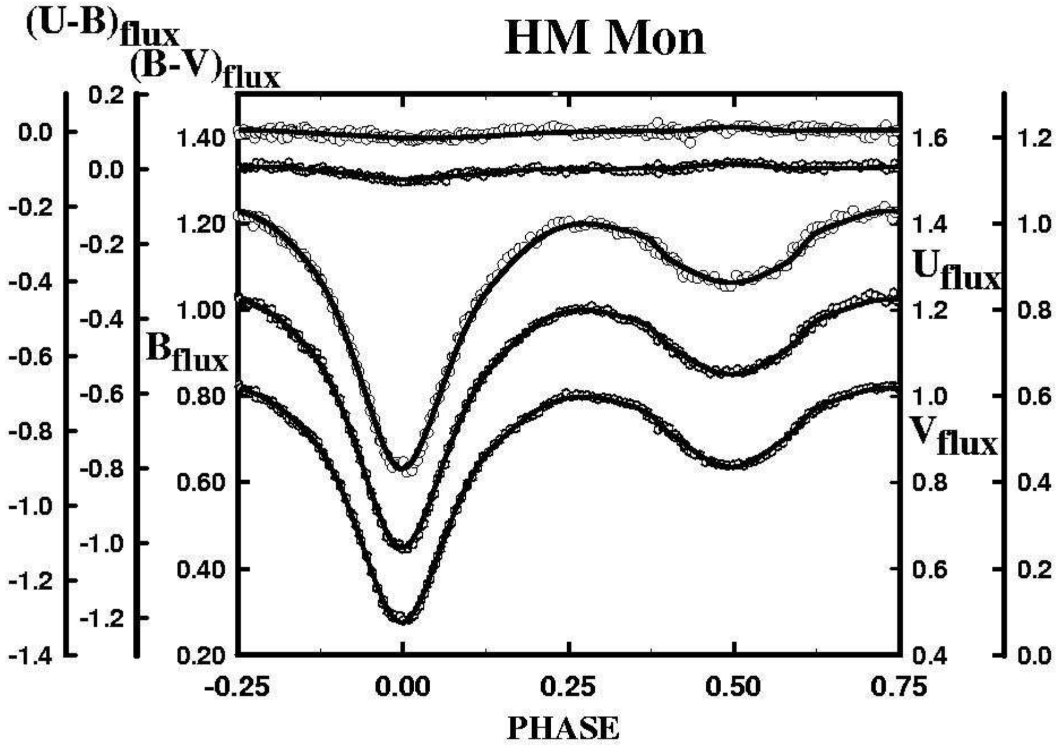

Figure 2.

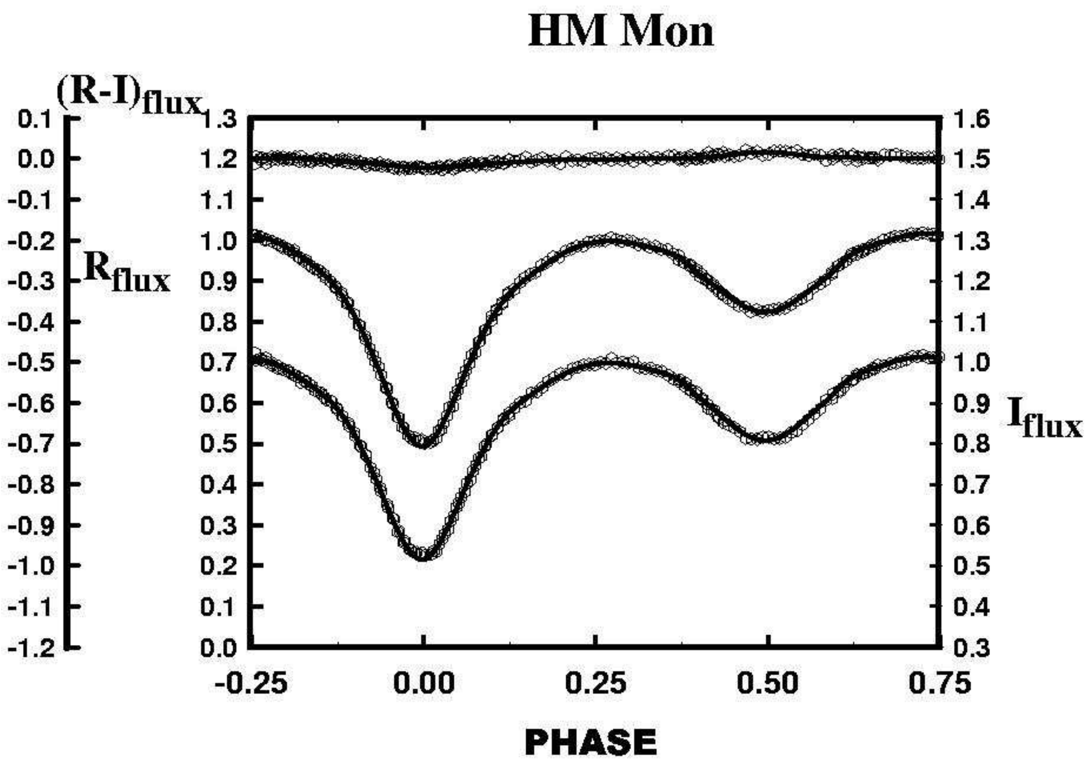

Figure 3.

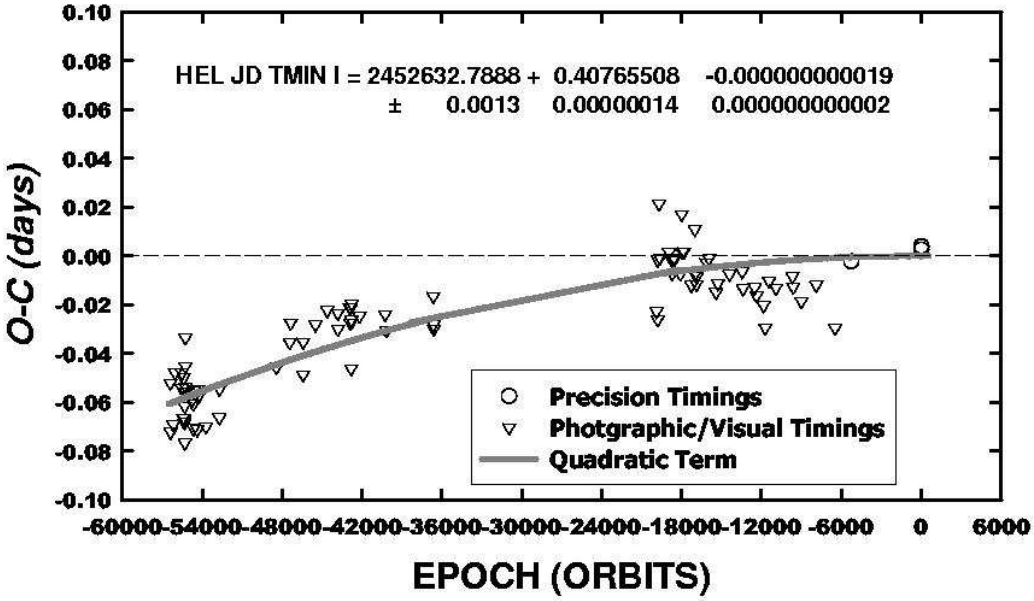

Figure 4.

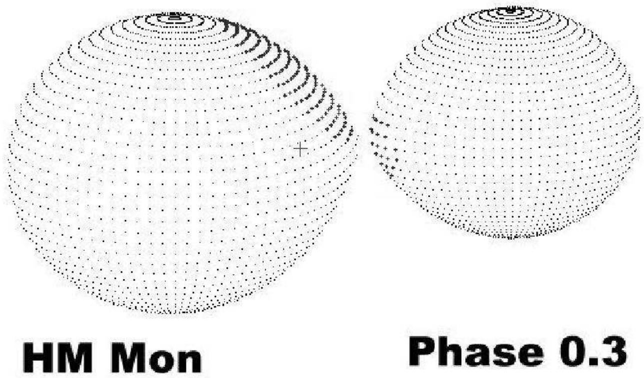

Figure 5.

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