Light Curves and Analyses of the Eclipsing Binaries MT Her and DO And

The Bradstreet Observatory at Eastern University

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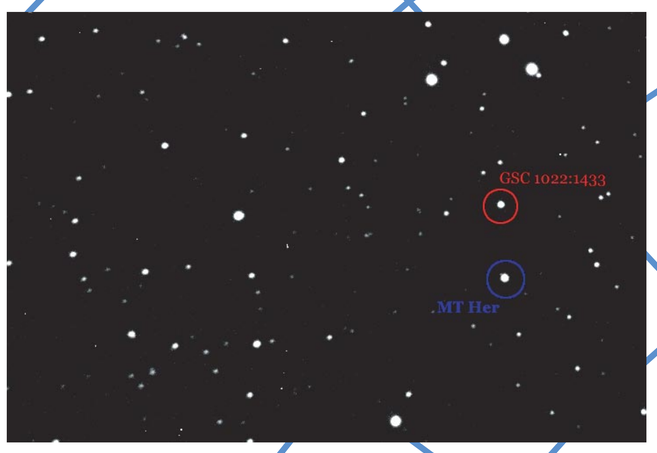


As a by-product of the ongoing work with the **C**atalog and **A**t**L**as of **E**clipsing **B**inaries (***CALEB***; Bradstreet et al. 2004), hundreds of eclipsing binaries have been identified that have either unpublished, incomplete or poor quality light curves. MT Her and DO And are two systems that were flagged as systems that would reward further study because of the reported large excursions in light variation. New precision V & R_c light curves of these binaries have been obtained using the 41-cm telescopes at the Eastern University Observatory equipped with SBIG ST-10XME CCD's.

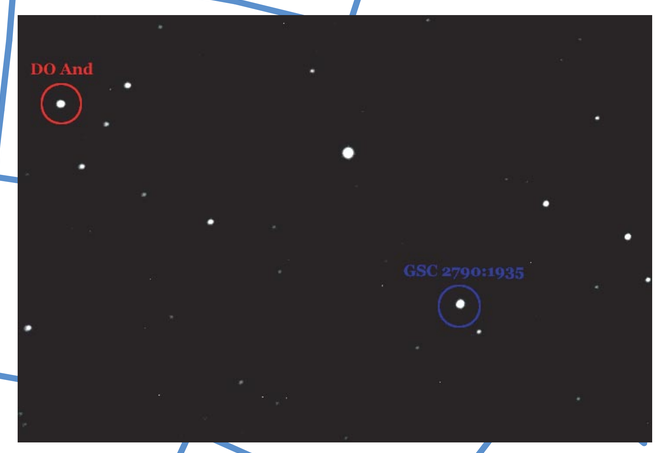
MT Her (P = 0.4877 days, m = 11.8) has only one other published light curve (Budding & Murad 1989) and their coverage was scanty and incomplete. We observed MT Her on 12 nights from 16 May – 2 Jul 2005, accumulating approximately 890 observations in both V and R_c. Five new times of minimum light were obtained and combined with all published timings resulting in the O-C diagram given below. The period of the system is shown to be increasing at the rate of dP/dt = +3.878 x 10^{-3} sec/yr as shown from the quadratic fit to the O-C residuals. The new ephemeris used to phase the data is 2453536.67090 + 0.48771779E.

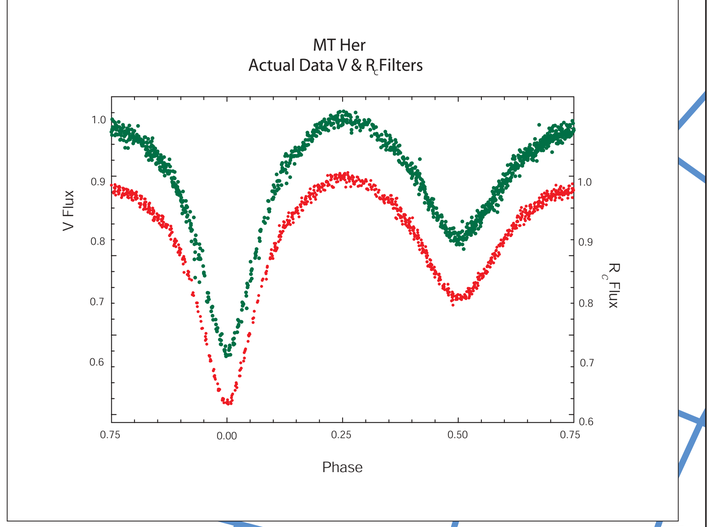
The light curves give the appearance of a near-contact system as evidenced by the significant difference in eclipse depths. Budding & Murad (1989) modeled their light curve as such. However, the significant out of eclipse light variations constrained the system to be overcontact for the various mass ratios modeled. The data of both filters were binned into 200 normal points and converted to flux units and then analyzed using the ***Binary Maker 3*** (Bradstreet & Steelman 2002) and Wilson-Devinney (1971, 1979, 1992) light curve analysis codes. The resulting analysis is shown in detail below, revealing that MT Her is an A-type overcontact binary (the hotter star is the larger, more massive component). The light curves exhibit slightly asymmetric maxima which are modeled well with a single cool spot on the more massive star. The computed mass ratio of q = 0.673 yields a small fillout of 0.0796. MT Her does indeed exhibit a large temperature difference of 1500 K between the two components, the average value for overcontact systems being ~200 K.

DO And (P = 1.3487 days, m = 12.5) is listed in the GCVS as having a period of 0.672 days. Haussler (1988) discovered that the actual period is twice that value and published the only existing light curve prior to our work. Haussler's light curve, although covering the entire cycle, contains significant scatter and no meaningful analysis could be carried out on his data. DO And was observed on more than 20 nights through Sep - Nov 2005, accumulating more than 1200 observations in both V and R_c. The large number of observations was required for good phase coverage because of the relatively long period of the system coupled with weather and an aggravating phasing cadence which seemed to fight against obtaining eclipse coverage. Three new times of minimum light were secured and when combined with all published timings yielded the O-C diagram shown below. The O-C residuals indicate that the period of the binary has remained constant over nearly 13000 Keplerian cycles, and the new ephemeris generated from this study is 2453632.60160 + 1.3487069E.

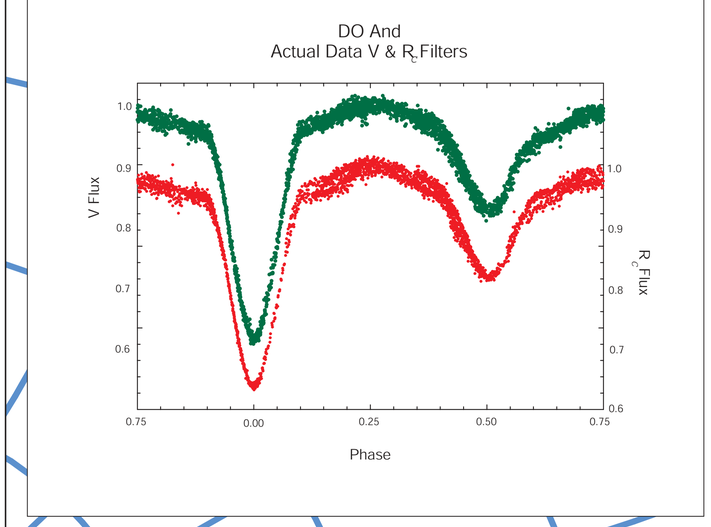
The light curves in both bandpasses were averaged into 200 normal points in flux units and analyzed as with MT Her. There was also an asymmetry in the maximum light levels in both filters which was modeled with a cool starspot on the cooler secondary star. The larger star, modeled at 9000 K, would not be expected to have spots because its atmosphere would be mostly radiative. The complete results of the light curve analysis are shown below. DO And is a detached system with a temperature difference of 2500 K between the two components. Although detached, the stars are both in close proximity to their respective Roche surfaces (see figure below) and hence are both significantly distorted from spheres. The significant scatter in the observations is believed to be intrinsic to the binary, perhaps not surprising for a spotted star in such close proximity to its hot companion.

We wish to thank Dr. Jerzy Kreiner for very kindly providing us with all the previously published timings of minimum light for these binaries.





Individual V (green dots) and R_C (red dots) observations of MT Her



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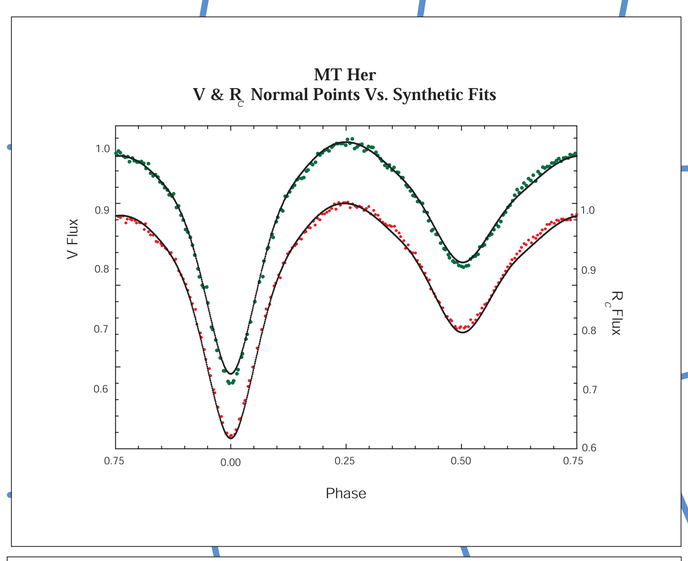


V & R_C synthetic Wilson-Devinney fits (solid curves) to normal points of MT Her

Light Curve Parameters for MT Her

(Probable errors given in parentheses)

mass ratio	= 0.673 (5)
$\Omega_1 = \Omega_2$	= 3.1645 (98)
fillout	= 0.0796
inclination	= 80.°10 (16)
mean density$_1$	= 0.645 g/cm^3
mean density$_2$	= 0.745 g/cm^3
T_1	= 6500°K (assumed)
T_2	= 5012°K (8)
albedo$_1$ = albedo$_2$	= 0.5 (assumed)
luminosity$_1$ = L_1 (5500 Å)	= 0.7811 (14)
luminosity$_2$ = L_2 (5500 Å)	= 0.2189
limb darkening $x_1 = x_2$ = (5500 Å)	= 0.527 (assumed)
luminosity$_1$ = L_1 (6400 Å)	= 0.7640 (15)
luminosity$_2$ = L_2 (6400 Å)	= 0.2360
limb darkening $x_1 = x_2$ = (6400 Å)	= 0.723 (assumed)
gravity brightening $g_1 = g_2$	= 0.32 (assumed)

Stellar Radii

r_1 back	= 0.44847 (444)	r_2 back	= 0.37873 (303)
r_1 side	= 0.41704 (302)	r_2 side	= 0.34400 (172)
r_1 pole	= 0.39396 (233)	r_2 pole	= 0.32816 (135)

Spot Parameters on Star 1

Latitude	Longitude	Radius	Temperature Factor
45°0	120°0	18°0	0.80

Light Curve Parameters for DO And

(Probable errors given in parentheses)

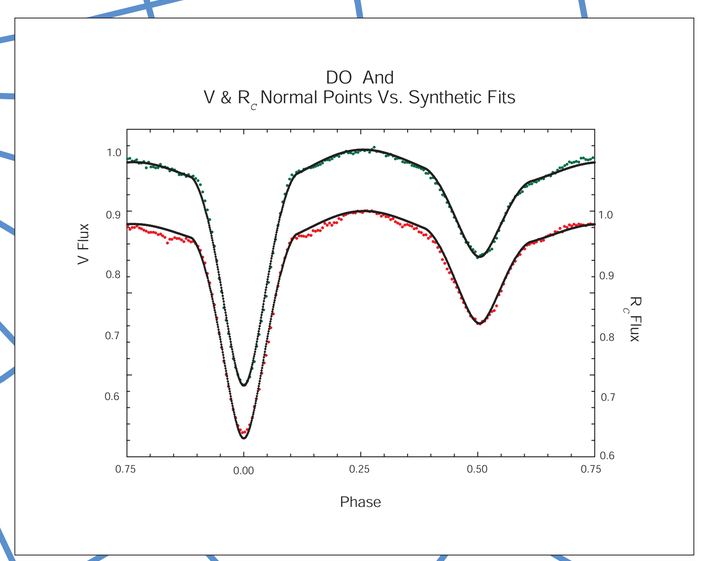
mass ratio	= 0.786 (5)
Ω_1	= 3.9116 (assumed)
Ω_2	= 3.6150 (183)
fillout 1	= -0.1270
fillout 2	= -0.0586
inclination	= 81.52 (7)
T_1	= 9000 °K (assumed)
T_2	= 6463 °K (12)
albedo A_1	= 1.0 (assumed)
albedo A_2	= 0.5 (assumed)
luminosity 1 = L_1 (5500 Å)	= 0.7497 (21)
luminosity 2 = L_2 (5500 Å)	= 0.2503
limb darkening 1 = x_1 (5500 Å)	= 0.456 (assumed)
limb darkening 2 = x_2 (5500 Å)	= 0.527 (assumed)
luminosity 1 = L_1 (6400 Å)	= 0.7209 (22)
luminosity 2 = L_2 (6400 Å)	= 0.2791
limb darkening 1 = x_1 (6400 Å)	= 0.379 (assumed)
limb darkening 2 = x_2 (6400 Å)	= 0.447 (assumed)
gravity brightening 1 = g_1	= 1.00 (assumed)
gravity brightening 1 = g_2	= 0.32 (assumed)

Stellar Radii

r_1 back	= 0.33827 (72)	r_2 back	= 0.33883 (391)
r_1 side	= 0.32579 (55)	r_2 side	= 0.31894 (294)
r_1 pole	= 0.31624 (46)	r_2 pole	= 0.30796 (252)
r_1 point	= 0.34832 (94)	r_2 point	= 0.35840 (576)

Spot Parameters on Star 1

Latitude	Longitude	Radius	Temperature Factor
60°0	300°0	25°0	0.70



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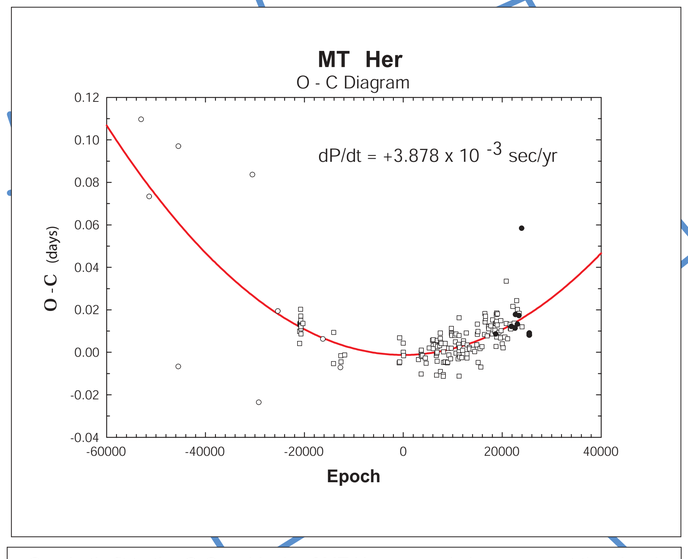
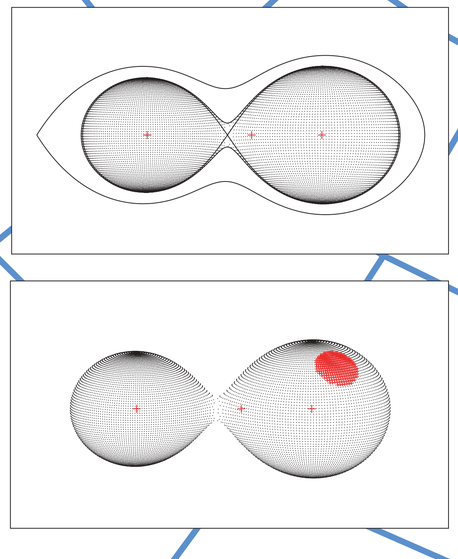
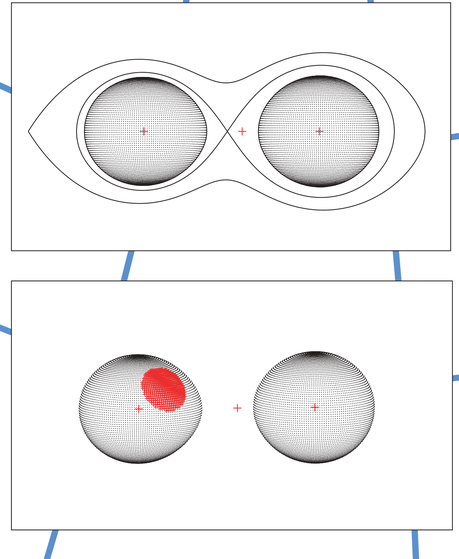
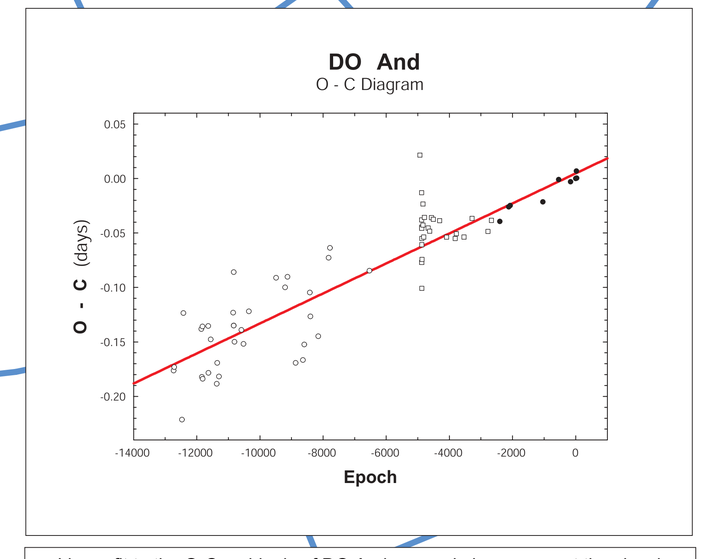


Quadratic fit to the O-C residuals of MT Her; open circles represent the visual timings, open squares the photographic timings and solid circles the CCD timings.







Linear fit to the O-C residuals of DO And; open circles represent the visual timings, open squares the photographic timings and solid circles the CCD timings.