A Backyard CCD Photometric Study of the Neglected W UMa Binary EQ Tauri

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Abstract Analysis of CCD data collected in V- and R-band between Dec 2005 and March 2006 has been used to calculate an updated ephemeris and orbital period for EQ Tau. A Roche-type model invoking a hot spot in the neck region of the primary component produced a theoretical fit of light curve data in V that largely accounts for the peak asymmetry observed approaching Max I.

1. Introduction

The variability of EQ Tauri was first described by Tsesevich (1954). It took nearly two decades before a reliable orbital period was reported (Whitney 1972). Although included in the AAVSO list of eclipsing binaries, there have been relatively few publications which include full light curves for this neglected binary system. A CCD photometric analysis in R was first reported by Benbow and Mutel (1995). This was followed with more robust multi-color CCD (BV) investigations by Yang and Liu (2002) and photoelectric (UBV) studies by Pribulla *et al* (2001) and Vaňko *et al* (2004). A period study of EQ Tau was conducted by Qian and Ma (2001) who comprehensively analyzed times of minimum light over a 23 year period from 1973 to 1996.

EQ Tauri is spectral type G2 and changes in visual magnitude from 10.3 to 11 just under three times a day (Period = 0.341348 d). EQ Tau belongs to the A-type subclass of W UMa binaries since the most massive (1.217 $M_\odot$) and hotter primary star is occulted (annular eclipse) by the less massive (0.537 $M_\odot$) but cooler secondary constituent during primary minimum (Binnendijk 1984). Our view of this system is nearly edge on with an orbital inclination approximating 84°. Well suited for study by astronomy students and amateurs alike, this relatively bright variable is well within the light grasp of a modest aperture telescope coupled with a consumer-grade CCD camera. Located very near but not a member the Pleiades cluster, EQ Tau is favorably positioned for mid-latitude observers in the Northern Hemisphere during the fall and winter months.

2. Observations and Data Reduction

2.1 Astrometry

Images of EQ Tau were matched against the standard star fields provided in MPO CANOPUS (V7.6.4.6 Bdw Publishing, Inc.). The *MPO Star Catalog* is a mixture of the *Tycho 2* and *USNO A2.0* catalogs assembled using all *Tycho 2* stars brighter than mag 11 and *USNO A2.0* stars brighter than mag 15.3 also possessing a B-R magnitude in the range of 0.50 to 1.50.

2.2 Photometry

Visual (V) and red (R) filtered CCD photometric readings began on December 20, 2005 with the intent of generating light curves which could be used to potentially refine the orbital period for EQ Tau and calculate an updated ephemeris. Equipment included a 0.2-m Celestron Nexstar 8 GPS (f/6.3) or 0.2-m Vixen VC200L catadioptric (f/6.4) with an SBIG ST-402ME CCD camera mounted at the primary focus. V- or R-band imaging was carried out in separate sessions through Schüler photometric filters (1.25") based upon the Johnson-Cousins Bessell prescription. Each exposure was captured (unbinned) over a 10 to 15 second period with thermoelectric cooling regulated to maintain the CCD chip 20°C below the initial ambient temperature. For both instruments, the field of view (FOV) produced by this configuration was 12.3 x 18.5 arcmin (1.45 arcsec/pix). A typical session which was centered around the tabulated minima listings provided at the AAVSO website for eclipsing binaries, lasted from 2 to 4 hours with images taken every 40-45 seconds. Clock time was updated via the Internet Time Server immediately prior to each session. Image acquisition (raw lights, darks and flats) was performed using SBIG CCDSOFT 5 while calibration and registration was accomplished with AIP4WIN (V2.1.0: Willmann-Bell, Inc). Further photometric reduction (circular aperture) with MPO CANOPUS was achieved using 3 non-varying comparison stars to ultimately generate light curves for calculating ephemerides and orbital period. Instrumental readings were not reduced to standard magnitudes.

2.3 Light Curve Analyses

Preliminary light curve fits and three-dimensional renderings showing the orbital progress of EQ Tau and location of putative starspot(s) were produced by BINARY MAKER 3.0 (Bradstreet and Steelman 2002). The synthetic light curves produced by the program are essentially identical to those produced by the Wilson-Devinney program but with a much friendlier user interface. Final light curve analyses were performed using the 2003 version of the Wilson-Devinney (W-D) code (Wilson and Devinney 1971; Wilson 1979). WDwint54c (Nelson 2005b) provided a more convenient user interface to the W-D code. Each model fit incorporated all individual observations assigned an equal weight of 1 and not binned to normal points.

3. Results and Discussion

3.1 Astrometry

The position determined for EQ Tau was RA (2000.0) 03:48:13.51 and Dec. (2000.0) +22:18:50.7 based upon reference coordinates in the *MPO Star Catalog*. This agrees within 0.3 arcsec of either computed position generated from the SIMBAD website (ICRS 2000.0 coordinates: 03:48:13.4, +22:18:51). A representative exposure (15 sec) taken in V-band showing EQ Tau along with 3 comparison stars from the *Tycho 2* catalog is reproduced in Figure 1.

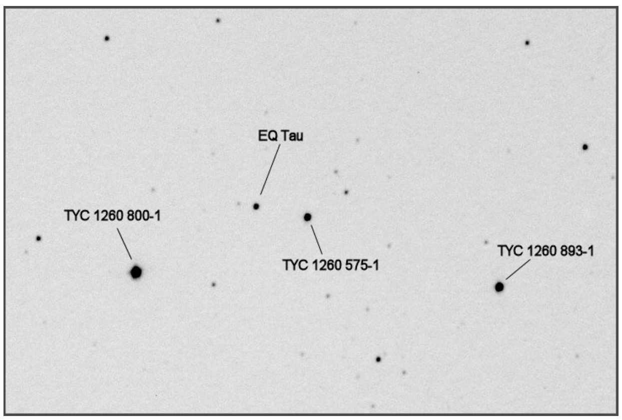

Figure 1. Exposure (15 sec) in V-band taken on March 2, 2006 showing EQ Tau and three comparison stars from the *Tycho 2* catalog.

3.2 Ensemble Photometry

All three comparison stars were not variable at least over the observation time span; this was verified prior to accepting data from each session. The airmass for all observations over the entire campaign ranged from 1.00 to 1.97. Plotting the averaged magnitude (C_{Avg}) for all comparisons yielded a narrow range of values with no obvious trend. A representative example is shown for a dataset in R in which acquisition started on January 12, 2006 (Figure 2). Collectively, C_{Avg} in V or R did not exhibit a pattern that would otherwise suggest variability beyond experimental error.

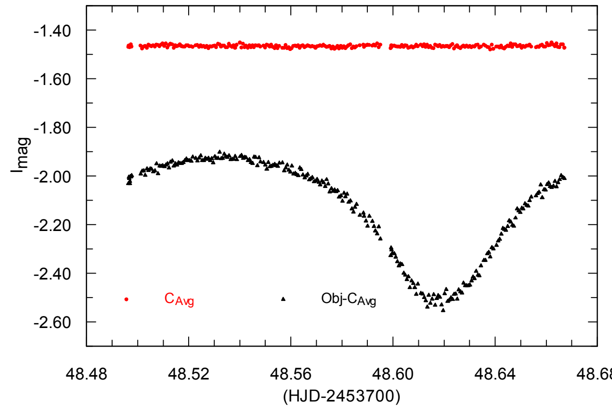

Figure 2. R-band instrumental magnitude (I_{mag}) vs. time (HJD) for EQ Tau (Obj-C_{Avg}) and the average magnitude (C_{Avg}) from all three comparison stars. Discontinuities in data arise from rejected readings due to the sporadic appearance of clouds.

3.3 Folded Lightcurve and Ephemeris

A total of 683 individual photometric readings in V and 571 in R were combined to produce light curves that spanned 10 weeks of data collection. These included 7 times of minima (ToM) which were captured during 8 viewing sessions between December 20, 2005 and March 2, 2006 (Table 1). MPO CANOPUS provided a period solution for the folded datasets using Fourier analysis. The time of minimum for the first primary epoch was estimated by *Canopus* using the Hertzsprung method as detailed by Henden and Kaitchuck (1990). Using this limited set of data, the linear ephemeris equation (1) for the Heliocentric Primary Minimum (HPM) was initially determined to be:

$$HPM = 2{,}453{,}724.55563 + 0.34134(1)\ d \cdot E \qquad (1)$$

and in excellent accordance with previously published orbital periods for EQ Tau. A periodogram (Figure 3), produced using PERANSO (v 2.1 CBA Belgium Observatory) by applying periodic orthogonals (Schwarzenberg-Czerny 1996) to fit observations and analysis of variance (ANOVA) to evaluate fit quality, confirmed the period determination. ToM values for all

Table 1. Journal of Light Curve Minima Captured from EQ Tauri

Observed Time of Minima (HJD-2400000.0)	UT Date	Color	No. of Observations	Type of Minima
53724.5539 ±0.00008	20Dec2005	R	203	I
53748.6186 ±0.00021	13Jan2006	R	263	II
53762.6141 ±0.00008	27Jan2006	V	219	II
53776.6097 ±0.00013	10Feb2006	V	143	II
53788.5552 ±0.00110	22Feb2006	R	105	II
53795.5542 ±0.00002	01Mar2006	V	116	I
53796.5779 ±0.00015	02Mar2006	V	87	I

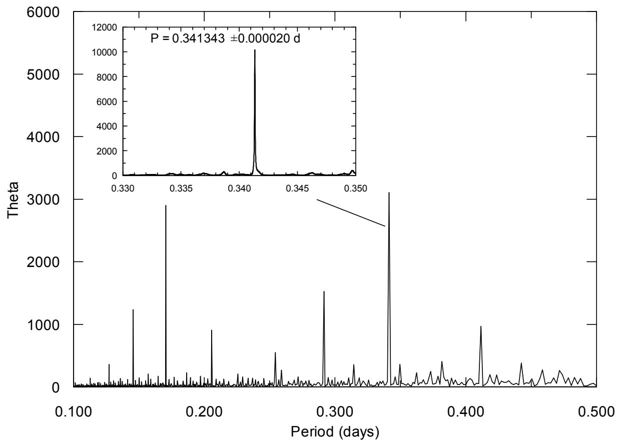

Figure 3. Periodogram for EQ Tau using the Schwarzenberg-Czerny (1996) method to search for periodicity in unevenly sampled observations. Inset figure shows higher resolution analysis of the most dominant period (P= 0.341343± 0.00002d)

seven epochs were estimated by the program Minima v24d (Nelson 2005a) using the simple mean from a suite of six different methods including parabolic fit, tracing paper, bisecting chords, Kwee and van Woerden (1956), Fourier fit and sliding integrations (Ghedini 1981). These new minima along with values from Pribulla *et al* (2002), Yang and Liu (2002), and additional IBVS readings published between 2001-2003 were used to calculate (Microsoft®Excel) residual values (Table 2) based upon the GCVS reference epoch (Kholopov *et al.* 1985) defined by the ephemeris (2):

$$\text{HPM} = 2{,}440{,}213.3250 + 0.34134848\ \text{d}\cdot\text{E} \qquad (2)$$

Due to the curvilinear nature of the O-C residuals observed for at least a decade, two separate regression analyses were performed. A revised equation (3) based upon a linear least squares fit (Figure 4) of near term $(O\text{-}C)_1$ data from November 13, 2002 to March 2, 2006 was calculated from:

$$\text{O-C} = a + bE \qquad (3)$$

where:
a = -2.5112432E-02 ±4.015631E-03
b = -5.3243936E-08 ±1.058481E-07

Recalculated residuals $(O\text{-}C)_L$ from the derived ephemeris equation (4) are provided in Table 2 and plotted in Figure 5.

$$\text{HPM} = 2{,}440{,}213.0739\ (40) + 0.34134843\ (11)\ \text{d}\cdot\text{E} \qquad (4)$$

Expanding the analysis to include O-C data from the past ten years revealed a parabolic relationship (Figure 6) between residuals $(O\text{-}C)_1$ and time (Cycle Number) that can be fit by the quadratic expression (5):

$$\text{O-C} = a + bE + cE^2 \qquad (5)$$

where:
a = 0.13665221 ±0.01904
b = -8.5151347E-06 ±1.0735212E-06
c = 1.1054448E-10 ±0.1509161E-10

which leads to the following ephemeris (6):

$$\text{HPM} = 2{,}440{,}213.4617\ (190) + 0.34133996\ (107)\ \text{d}\cdot\text{E} + 1.105(0.15)\times 10^{-10}\cdot\text{E}^2 \qquad (6)$$

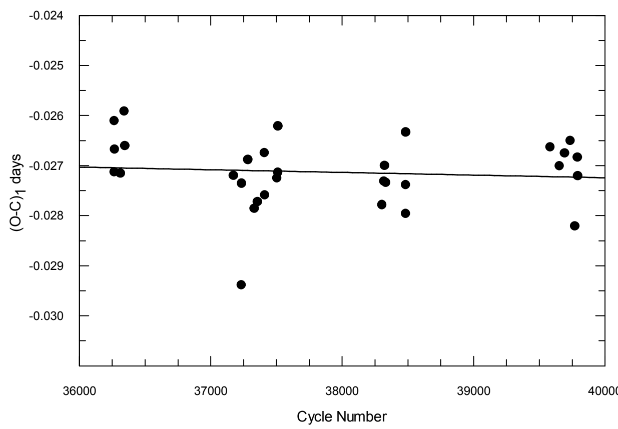

Figure 4. Linear least squares fit of residuals $(O\text{-}C)_1$ vs time of minima (Cycle Number) for EQ Tau observed between November 13, 2002 and March 2, 2006.

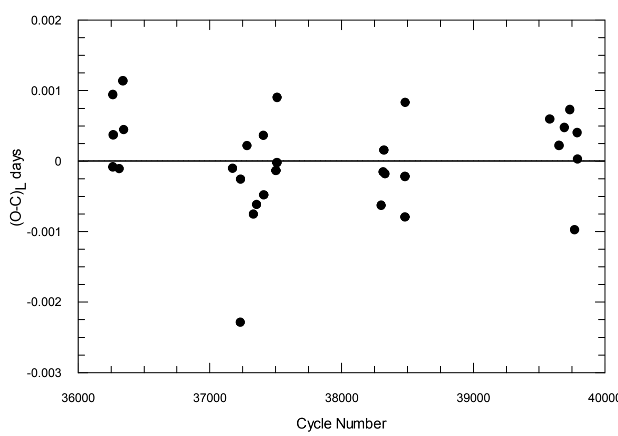

Figure 5. Recalculated residuals $(O\text{-}C)_L$ following linear fit of $(O\text{-}C)_1$ and time of minima values (Cycle Number) for EQ Tau between November 13, 2002 and March 2, 2006.

Table 2. Recalculated Residuals Following Linear and Quadratic Fit of $(O\text{-}C)_1$ and Times of Minima (ToM) (November 9, 1996–March 02, 2006) Data for EQ Tauri

ToM	Type	Cycle Number	$(O\text{-}C)^a_1$	$(O\text{-}C)_L$	$(O\text{-}C)_Q$	Reference
50396.9250	II	29833.5	-0.01988	0.006823	-0.00088277	IBVS 4559
51166.3224	II	32087.5	-0.02195	0.004869	0.00080773	Sirrah[a]
51166.4931	I	32088	-0.02193	0.004895	0.00083420	Sirrah
51183.903	I	32139	-0.02080	0.006025	0.00203390	Rucinski (2001)
51184.2423	I	32140	-0.02285	0.003976	-0.00001317	Sirrah
51822.9035	I	34011	-0.02465	0.002270	0.00043064	IBVS 5040
51896.2932	I	34226	-0.02488	0.002058	0.00041640	IBVS 5056
51896.29324	I	34226	-0.02484	0.002098	0.00045640	IBVS 5056
51899.3656	I	34235	-0.02461	0.002322	0.00068860	IBVS 5296
51911.3122	I	34270	-0.02521	0.001728	0.00012478	IBVS 5056
51911.31279	I	34270	-0.02462	0.002318	0.00071478	IBVS 5056
51930.2550	II	34325.5	-0.02725	-0.000310	-0.00186411	IBVS 5056
51930.2565	II	34325.5	-0.02575	0.001190	-0.00036411	IBVS 5056
52185.4141	I	35073	-0.02614	0.000841	-0.00012239	Sirrah
52185.58167	II	35073.5	-0.02924	-0.002263	-0.00322625	IBVS 5594
52185.5855	II	35073.5	-0.02541	0.001567	0.00060375	Sirrah
52219.5491	I	35173	-0.02599	0.000998	0.00010459	Sirrah
52225.3522	I	35190	-0.02581	0.001175	0.00029296	IBVS 5296
52225.5235	II	35190.5	-0.02519	0.001801	0.00091909	IBVS 5296
52230.1305	I	35204	-0.02639	0.000597	-0.00027549	Yang and Liu (2002)
52232.3484	II	35210.5	-0.02726	-0.000268	-0.00113586	IBVS 5230
52232.5192	I	35211	-0.02713	-0.000142	-0.00100973	IBVS 5230
52247.3679	II	35254.5	-0.02709	-0.000099	-0.00093705	IBVS 5230
52250.1002	II	35262.5	-0.02558	0.001414	0.00058087	Yang and Liu (2002)
52250.2708	I	35263	-0.02565	0.001340	0.00050699	Yang and Liu (2002)
52252.3180	I	35269	-0.02654	0.000449	-0.00037958	IBVS 5296
52338.3396	I	35521	-0.02476	0.002246	0.00157726	IBVS 5484
52592.3005	I	36265	-0.02713	-0.000084	-0.00036065	IBVS 5463
52592.4722	II	36265.5	-0.02610	0.000942	0.00066536	IBVS 5463
52593.3250	I	36268	-0.02667	0.000371	0.00009541	IBVS 5463
52608.6852	I	36313	-0.02715	-0.000108	-0.00036407	IBVS 5371
52618.2442	I	36341	-0.02591	0.001136	0.00089203	IBVS 5643
52620.2916	I	36347	-0.02660	0.000445	0.00020403	IBVS 5484
52902.5862	I	37174	-0.02720	-0.000104	-0.00006822	IBVS 5668
52922.5529	II	37232.5	-0.02938	-0.002287	-0.00223734	IBVS 5579
52923.4083	I	37235	-0.02735	-0.000258	-0.00020783	IBVS 5592
52939.7935	I	37283	-0.02688	0.000218	0.00027845	IBVS 5636
52956.5186	I	37332	-0.02786	-0.000755	-0.00068399	IBVS 5643
52964.7111	I	37356	-0.02772	-0.000617	-0.00054130	IBVS 5493
52982.4622	I	37408	-0.02674	0.000364	0.00045076	IBVS 5643
52983.4854	I	37411	-0.02759	-0.000481	-0.00039395	IBVS 5643
53014.8898	I	37503	-0.02725	-0.000136	-0.00003260	IBVS 5636
53017.6207	I	37511	-0.02713	-0.000024	0.00008134	IBVS 5636
53017.7923	II	37511.5	-0.02621	0.000902	0.00100721	IBVS 5636
53287.6267	I	38302	-0.02778	-0.000629	-0.00046001	IBVS 5657
53292.7474	I	38317	-0.02731	-0.000156	0.00001347	IBVS 5636
53294.7958	I	38323	-0.02700	0.000154	0.00032285	IBVS 5636
53297.8676	I	38332	-0.02734	-0.000182	-0.00001310	IBVS 5636
53349.2405	II	38482.5	-0.02738	-0.000220	-0.00005577	IBVS 5657
53349.4106	I	38483	-0.02796	-0.000794	-0.00063000	IBVS 5657
53349.5829	II	38483.5	-0.02633	0.000831	0.00099576	IBVS 5657
53724.5539	I	39582	-0.02663	0.000595	0.00057462	Present Study
53748.6186	II	39652.5	-0.02700	0.000220	0.00017959	Present Study
53762.6141	II	39693.5	-0.02675	0.000475	0.00042141	Present Study
53776.6097	II	39734.5	-0.02650	0.000729	0.00066286	Present Study
53788.5552	II	39769.5	-0.02821	-0.000975	-0.00105352	Present Study
53795.5542	I	39790	-0.02683	0.000402	0.00031691	Present Study
53796.5779	I	39793	-0.02720	0.000027	-0.00005938	Present Study

a: http://sirrah.troja.mff.cuni.cz/~mira/variables/lightcurves/lc.cgi?tbl=2

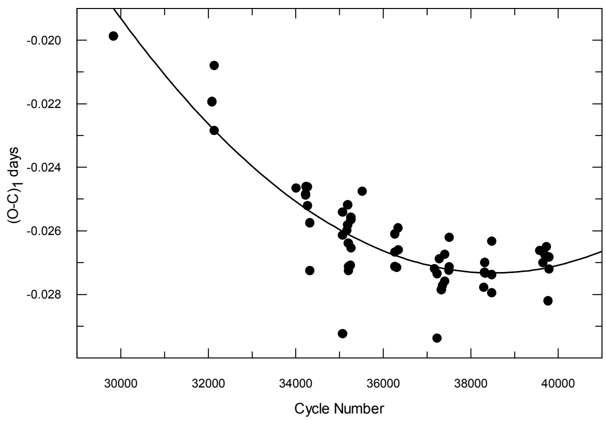

Figure 6. Quadratic least squares fit of residuals $(O\text{-}C)_1$ vs time of minima (Cycle Number) for EQ Tau observed between November 9, 1996 and March 2, 2006.

Recalculated residuals $(O\text{-}C)_Q$ resulting from this quadratic expression are listed in Table 2 and plotted in Figure 7.

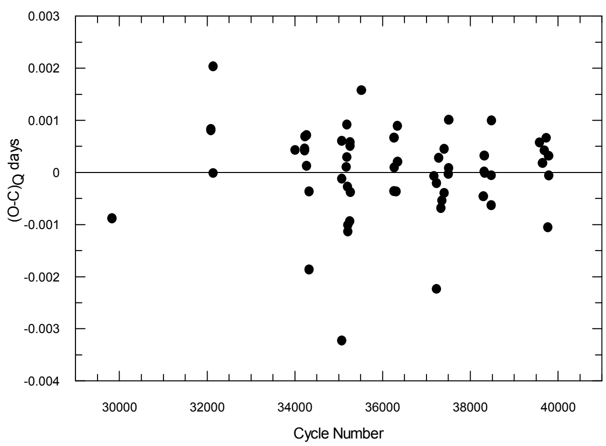

Figure 7. Recalculated residuals $(O\text{-}C)_Q$ following quadratic fit of $(O\text{-}C)_1$ and time of minima (Cycle Number) values for EQ Tau between November 9, 1996 and March 2, 2006.

Since at least late-1996, EQ Tau has apparently undergone a very slow orbital period rate increase as defined by the equation (7) below:

$$dP/dt = 2\times(1.105\cdot10^{-10})(1/0.34133996)(86400)(365.25) = 0.02044 \text{sec/yr} \quad (7)$$

This may foreshadow a reversal in behavior for EQ Tau since Qian and Ma (2001) had reported a negative parabolic fit for the previous 23 years which corresponded to a secular decrease in the orbital period ($dP/dt = -0.016$ sec/yr).

The folded light curves (Figure 8) comprised of all observations in V- and R-band, show that both minima are separated by ~0.5 phase and consistent with a circular orbit. Light curve data in R-band are incomplete due to poor photometric conditions that persisted throughout the

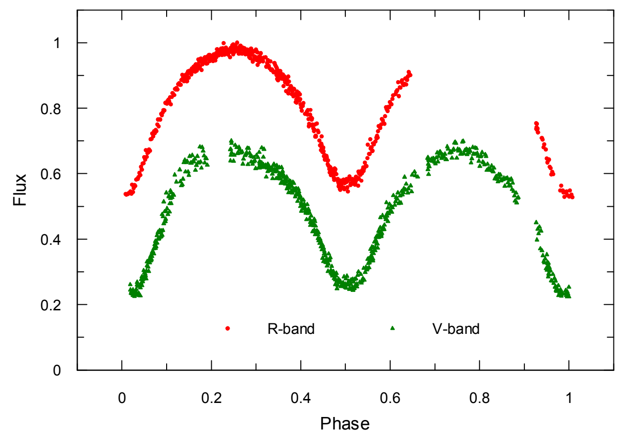

Figure 8. Folded CCD light curve for EQ Tauri captured in V- and R band (December 2005-March 2006). Curves from each filter are intentionally offset for clarity.

2005-2006 winter in north central New Jersey (USA). Unlike the light curves published by Yang and Liu (2002) and Pribulla *et al* (2002), this season did not exhibit an O'Connell effect which was nearly as obvious. This asymmetry common to many light curves from overcontact binaries showed greater variability in V-band, most notably near Max I. A plausible explanation for this intrinsic variability might involve the presence of starspot(s) on one or more binary components and is further discussed in §3.4.1.

3.4 Light Curve Synthesis

The Roche model founded on basic principles derived from the seminal Wilson and Devinney (1971) paper has been widely used to provide simulated light curve solutions which closely fit changes in flux arising from eclipsing binary star systems.

Mode 3 (overcontact), synchronous rotation and circular orbits were selected for modeling EQ Tau by W-D. Since this binary star system has a convective envelope (T_{eff} < 7500°K), values for bolometric albedo (0.5) and gravity darkening exponents (0.32) were based on theoretical values reported by Rucinski (1969) and Lucy (1967), respectively. Logarithmic limb darkening coefficients for both stars were interpolated according to Van Hamme (1993). The mean effective temperature of star 1 (the star eclipsed at primary minimum) was set equal to 5800°K based on its spectral type (G2). Initial attempts to obtain a light curve solution involved adjustment of parameters for the mean effective temperature of the secondary (T_2), orbital inclination (i), mass ratio (q), bandpass-specific luminosity of the primary (L_1), common envelope surface potential (Ω) as well as the size, location and relative temperature of putative starspot(s). Fortunately, since Rucinski *et al* (2001) performed radial velocity measurements on EQ Tau which resulted a spectroscopically determined mass ratio (q = 0.442) value, this greatly constrained the

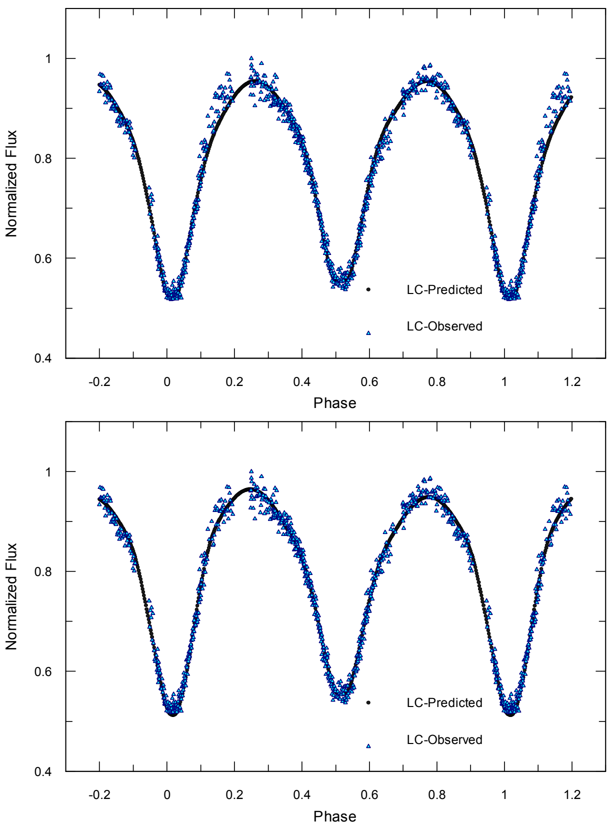

Figure 9. Unspotted (top) and spotted (bottom) W-D simulation of light curve for EQ Tau superimposed with CCD observations in V-band from the present study

search for a light curve solution. Once an approximate fit was obtained, differential corrections (DC) were applied separately to photometric data in both filters. To attenuate strong correlations, the method of multiple subsets (Wilson & Biermann, 1976) was used. The subsets consisted of non-spot parameters, the spot co-latitude and temperature factor, and the spot longitude and radius. Standard errors for the present study are those calculated by WDwint.

3.4.1 Unspotted and Spotted Models

The values for q, $\Omega_{1,2}$, T_1, T_2, and i reported by Yang and Liu (2001) were used as a starting point for an unspotted solution (Table 3). $A_{1,2}$, $g_{1,2}$, $x_{1,2}$, and T_1 were fixed whereas $\Omega_{1,2}$, T_2, q, and i were iteratively adjusted using DC to achieve a minimum residual fit of all V-band photometric observations. The W-D model error $[\Sigma(O\text{-}C)^2=0.24654]$ where O-C is the residual between the observed and synthetic light curve was generally unacceptable due to the poor coverage between 0.1 and 0.194P as the light curve approached Max I (Figure 9).

The secular change in orbital period (dP/dt = 0.02044 sec/yr) with attendant mass exchange between components, along with the excess light and high variability in flux prior to Max I suggested a starspot solution for the 2005-2006 epochs. Therefore, a strategy to build a model which further minimized the residual fit was based upon invoking the starspot parameters A_S, Θ, φ, and r_S. Yang and Liu (2001) were the first to reproduce the asymmetrical shape of EQ Tau light curves by employing the geometrical and physical elements of hot and dark starspots on each stellar component. At that time a case was made that the best model fit supported the putative appearance of a cool spot on the secondary star. The apparent asymmetry observed at Max I for EQ Tau this season may arise from a number of possibilities including 1) dark starspot(s) on either component facing the observer to decrease the depth of Max II or 2) hot starspot(s) on either star responsible for an increase in flux during Max I.

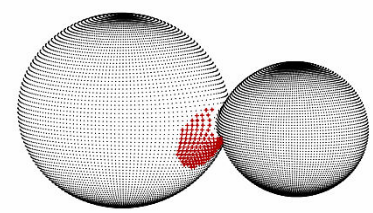

Figure 10. BinaryMaker3 generated rendering of EQ Tau showing the location of a hot starspot near the neck region on the primary component.

DC iterations of A_S, Θ, φ, and r_S yielded a best fit $[\Sigma(O\text{-}C)^2=0.04787]$ which supported placement of a hot starspot in the neck region of the primary constituent (Figure 10). The putative existence of a bright spot located in the neck region where mass and energy transfer occur (Vilhu 1992) was a important addition to the model. Furthermore, consistent with the ongoing increase in orbital period (dP/dt), the shock wave associated with mass transfer from the secondary would potentially create a hot spot near the neck of the recipient primary star and may correspond to greater flux variability during Max I.

R-band data were initially modeled using the optimized V-band parameters (Table 3) for a spotted solution. Convergence which minimized residuals $[\Sigma(O\text{-}C)^2=0.07244]$ was quickly obtained with minor changes to T_2, q, $\Omega_{1,2}$, and i. However, the large gap in data around Max II (Figure 11) would cast some doubt about the robustness of the model fit and for this reason no attempt was made to obtain a simultaneous solution for V- and R-band light curves.

Table 3. A Comparison of Selected Geometrical and Physical Elements of EQ Tauri Obtained Following Roche Model Curve Fitting

Parameter	V-band Present Study Unspotted	V-band Present Study Spotted	R-band Present Study Spotted	Pribulla *et al* 2001 Unspotted	Yang and Liu 2002		
					Unspotted	**Dark 2**	**Hot 1**
T_1 (°K)	5800	5800	5800	5860	5800	5800	5800
T_2 (°K)	5773 (10)[a]	5710 (25)	5747 (26)	5851	5726	5735	5722
$L_1/(L_1+L_2)$	0.6904	0.6997	0.6907	0.6784	0.6922	0.6846	0.6930
q (m_2/m_1)	0.4275 (0.0035)	0.4341 (0.0033)	0.4279 (0.0036)	0.442	0.4349	0.4357	0.4347
$A_{1,2}$	0.5	0.5	0.5	0.5	0.5	0.5	0.5
$g_{1,2}$	0.32	0.32	0.32	0.32	0.32	0.32	0.32
$x_{1,2}$, $y_{1,2}$	0.758, 0.237	0.758, 0.237	0.666, 0.254	0.65	0.64	0.64	0.64
$\Omega_{1,2}$	2.722 (0.007)	2.723 (0.003)	2.700 (0.006)	2.7303	2.7108	2.7192	2.7161
i	84.44 (0.65)	82.73 (0.59)	83.69 (0.45)	86.59	84.45	84.32	83.67
f (% overcontact)	4.4	8.94	13.3	12.0	14.3	18.8	12.1
$A_{S1} = T_{S1}/T_2$		1.25 (0.01)	1.06 (0.01)			0.80	1.10
Θ_{S1} (spot co-latitude)		98°	98°			95.8°	103.2°
φ_{S1} (spot longitude)		355° (8.5)	355° (44)			261.8°	260.9°
r_{S1} (angular radius)		15.45° (0.14)	15.45° (0.91)			18.6°	14.4°

a: error estimate from W-D code (2003)

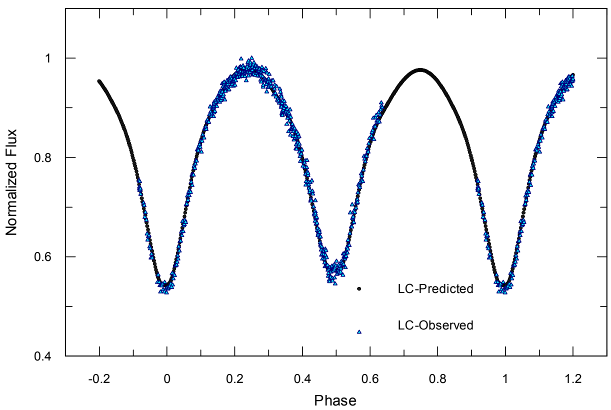

Figure 11. Spotted W-D simulation of light curve for EQ Tau superimposed with CCD observations in R-band from the present study.

4. Conclusions

CCD visual (V) and red (R) filter photometric readings have lead to the construction of light curves which were used to revise the orbital period for EQ Tau and calculate an updated ephemeris. The positive parabolic relationship between O-C residuals and cycle number suggests a secular rate increase in dP/dt over the past decade. A Roche-type model incorporating a hot spot in the neck region of the primary constituent has produced a theoretical fit of light curve data in V-band that largely accounts for the observed flux variability prior to Max I.

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6. References

Agerer, F. and Hübscher, J. 2002, *Inf. Bull. Var. Stars*, No. 5296.

Agerer, F. and Hübscher, J. 2003, *Inf. Bull. Var. Stars*, No. 5484.

Benbow, W.R. and Mutel, R.L. 1995, *Inf. Bull. Var. Stars*, No. 4187.

Binnendijk, L. 1984, Pub. A.S.P., **96**, 646.

Bradstreet, D. H. and Steelman 2002, D. P. 2002, Bull. A.A.S., **34**, 1224.

Borkovits, T., Bíró, I.B., Csizmadia, S., Patkós, L., Hegedüs, T., Pál, A. Kóspál, Á., and Klagyivik, P. 2004, *Inf. Bull. Var. Stars*, No. 5579.

Buckner, M., Nellermoe, B. and Mutel, R. 1998, *Inf. Bull. Var. Stars*, No. 4559.

Cook, J.M., Divoky, M., Hofstrand, A., Lamb, J., and Quarderer, N. 2005, *Inf. Bull. Var. Stars*, No. 5636.

Csizmadia, Sz., Zhou, A.Y., Könyves, V., Varga, Z., and Sándor, Zs. 2002, *Inf. Bull. Var. Stars*, No. 5230.

Ghedini, S. 1981, Societa Astronomica Italiana, **52,** 633.

Henden, A.A., and Kaitchuck, R.H. 1990, *Astronomical Photometry: A Text and Handbook for the Advanced Amateur and Professional Astronomer*, Willmann-Bell, Richmond.

Hübscher, J. 2005, *Inf. Bull. Var. Stars*, No. 5643.

Hübscher, J., Paschke, A., and Walter, F. 2005, *Inf. Bull. Var. Stars*, No. 5657.

Kholopov, P.N. *et al.* 1985, General Catalogue of Variable Stars, Fourth Ed., Moscow (http://www.sai.msu.su/groups/cluster/gcvs/cgi-bin/search.htm).

Krajci, T. 2005, *Inf. Bull. Var. Stars*, No. 5592.

Kwee, K.K., and van Woerden, H. 1956, B.A.N., **12**, 327.

Lucy, L.B. 1967, Z. Astrophys., **65**, 89.

MPO Canopus ©1993-2003, MPO Canopus & PhotoRed Installation Guide and Reference Manual, Bdw Publishing, Colorado Springs, CO 80908.

Müyesseroglu, Z., Törün, E., Özdemir, T., Gürol, B., Özavci, I., Tunç, T., and Kaya, F. 2003, *Inf. Bull. Var. Stars*, No. 5463.

Nelson, R.H. 2001, *Inf. Bull. Var. Stars*, No. 5040.

Nelson, R.H. 2003, *Inf. Bull. Var. Stars*, No. 5371.

Nelson, R.H. 2004, *Inf. Bull. Var. Stars*, No. 5493.

Nelson, R.H. 2005a, "Minima©2002, 2003: "Astronomy Software by Bob Nelson" URL: http://members.shaw.ca/bob.nelson/software1.htm

Nelson, R.H. 2005b, "WDwint54c: "Astronomy Software by Bob Nelson" URL: http://members.shaw.ca/bob.nelson/software1.htm

Pribulla, T. and Vaňko, M. 2002, Astronomical Institute Slavic Academy of Sciences, **32**, 79.

Pribulla, T., Vaňko, M., Parimucha, Š., and Chochol, D. 2001, *Inf. Bull. Var. Stars*, No. 5056.

Pribulla, T., Baludansky, D., Chochol, D., Chrastina, M., Parimucha, S., Petrík, K., Szasz, G., Vaňko, M., and Zboril, M. 2005, *Inf. Bull. Var. Stars*, No. 5668.

Qian, S. and Ma, Y. 2001, Pub. Astron. Soc. Pacific, **113**, 754.

Rucinski, S.M. 1969, Acta Astron., **19,** 245.

Rucinski, S.M., Lu, W, Mochnacki, S.W., Ogloza, W. and Stachowski, G. 2001, Astron. J., **122**, 1974.

Rucinski, S.M., Pych, W., Ogloza, W., Conidis, G., and Rogoziecki, P. 2005, Astron. J., **130**, 767.

Sarounová, L. and Wolf, M. 2005, *Inf. Bull. Var. Stars*, No. 5594.

Schwarzenberg-Czerny, A. 1996, Astrophys J., **460**, L107.

Tsesevich, V.P. 1954, Izv. Astron. Obs. Odessa, **4**, No. 3.

Van Hamme, W. 1993, Astrophys. J., **106,** 2096.
Vaňko, M., Parimucha, Š., Pribulla, T. and Chocol, D. 2004, Baltic Astronomy, **13**, 151.
Vilhu, O. 1992, "W-Ursae-Majoris binaries. Evolutionary Processes in Interacting Binary Stars": International Astronomical Union Symposium 151, Ed. Y. Kondo et al. Dordrecht: Kluwer, p 61.
Whitney, B.S. 1972, *Inf. Bull. Var. Stars*, No. 633.
Wilson, R.E. and Devinney, E.J. 1971, Astrophys J., **166**, 605.
Wilson, R.E. and Biermann, P. 1976, Astron. and Astrophys. **48**, 349.
Wilson, R.E. 1979, Astrophys J., **234**, 1054.
Yang, Y. and Liu, Q. 2002, Astron. J., **124,** 3358.