Eclipsing Binary Systems
AN TAU, V506 OPH, V609 AQL, and RV TRI

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Abstract

Almost complete light curves for AN TAU, V506 OPH, V609 AQL, and RV TRI, six new times of minimum (Tmin) for AN TAU, an EB/DW system, 14 new Tmin for V506 OPH, an EB/DW system, 4 new Tmin for V609 AQL, an EB/DW system, and 9 new Tmin for RV TRI, an EA/SD system are included. O-C1 and O-C2 values, linear and polynomial curves are displayed.

1. Introduction

During the last half of 2006, four (4) eclipsing binary systems were chosen for observation designed to optimize for long sessions with the target rising at an early evening hour, at a declination convenient to the mechanical limitations of the optical train. Selected systems were V506 OPH, an EB/DM type, V609 AQL, an EB/DW type, AN TAU, an EB/DM type and RV TRI, an EA/SD type (VizieR). Additional selection criteria beyond positioning included 7-13 magnitude range, and a period of 2 to .2 days. Beyond these basic criteria there was no specific agenda. There was a goal to attempt collecting enough data to create a complete light curve and resulting times of minima (Tmin) determined.
Each star was worked as many nights as possible, resulting in enough data points to create a light curve on each star system. Tmin were determined as were O-C calculations.

2. Observations

The Paradise View Observatory utilizes a Meade 14" LX200GPS with attached STL-1301 SBIG camera with a resulting 2007mm (79") focal length and an effective field of view of 1.49 arcsec/pixel (Figure 1). The Kings Canyon Observatory uses a Meade 12" LX200 classic with attached SBIG ST-9XE yielding a 1920mm (75.6") focal length and an effective field of view of 2.18 arcsec/pixel (Figure 2).

Star systems surveyed with associated information (VizieR) are displayed in Table 1. Table 2 lists database websites accessed in determining suitable star systems to observe and also provided additional information for various calculations. Times of minimum were obtained in the VR color system approximating the standard Johnson photometric system. Software used for reductions, charting and computations are listed in Table 3. Thirty-three (33) times of minimum were determined and are listed in Table 4.

A typical session starts days or weeks prior to the actual observation with a target selection. Using the AAVSO VSX query engine found at the AAVSO website (AAVSO VSX), potential candidates are selected and reviewed. TheSky6 software gives a visual feel for the candidates so local star densities can be seen, close neighbor systems that might make the target more challenging and actual rising, setting and air-mass 2.0 times. Once a star system is selected an observing and data collection script is created to coordinate the telescope and camera system for imaging through the night ending with a system shutdown and parking. Both observatories have standardized on the MPO software program "Connections" for scripting.

These observatories are not automated beyond the telescope and camera, so each night protective covers need to be removed and each morning replaced. Power and initiation procedures for the telescope and camera are manual as is the focus proce-

dure. Since an automated script is used, weather or the potential for foul weather, clouds, adverse winds and certain periods of the moon are factored into whether an observing session is prudent.

The following morning the equipment is secured and usually data reduction begins. The Software Bisque program "CCDSoft5" and MPO's "Canopus" are used to combine the images with flats, darks and bias which are collected most nights. The images are then run through Canopus to reduce the images for the data points and to graph the portion of the light curve for the night. These light curves are combined in Canopus to yield the corresponding more complete light curve for that system. The data is further analyzed using "PSI-Plot", "Peranso" and "Excel" at a later date.

Figure 1. Paradise View Observatory

Figure 2. Kings Canyon Observatory

System	Type	Spectral Type	Mag V	AML sec/year Observed
V506 OPH	EB/DM	A/F	11.20	+0.00579
V609 AQL	EB/DW	F8/-	11.70	-0.00990
AN TAU	EB/DM	A3/-	10.30	-0.04239
RV TRI	EA/SD	F9/K2	11.40	+0.01667

Table 1. List of Eclipsing Binary Systems Observed. AML=Angular Momentum Loss

Bob Nelson's O-C files	http://www.aavso.org/observing/programs/eclipser/omc/nelson_omc.shtml
SIMBAD	http://simbad.u-strasbg.fr/simbad/
VizieR	http://vizier.u-strasbg.fr/viz-bin/VizieR
AAVSO VSX	http://www.aavso.org/vsx/

Table 2. Database Websites Accessed

Software Bisque – CCDSoft5	Image Processing and CCD Camera Control
Software Bisque – TheSky6	Planetarium
Microsoft – Excel	Spreadsheet
MPO Software – Canopus/PhotoRed	Data Processing
MPO Software – Connections	Telescope and Camera Control
PERANSO	Period Analysis
PSI-Plot	Technical Plotting and Data Processing

Table 3. Software Used in Observation and Data Reduction

OBJECT	HJD +2,400,000	Sd	Filter	Type		OBJECT	HJD +2,400,000	Sd	Filter	Type
V506 OPH	53886.760500	0.00002	V	II		AN TAU	54035.737200	0.00003	V	I
V506 OPH	53886.763320	0.00006	R	II		AN TAU	54035.737000	0.00003	R	I
V506 OPH	53887.817538	0.00007	V	II		AN TAU	54038.964255	0.00001	V	I
V506 OPH	53887.822400	0.00006	R	II		AN TAU	54038.963245	0.00004	R	I
V506 OPH	53948.794500	0.00004	V	I		AN TAU	54039.775000	0.00007	V	II
V506 OPH	53948.793310	0.00005	R	I		AN TAU	54039.800846	0.00005	R	II
V506 OPH	53956.748960	0.00003	V	I		RV TRI	54077.919194	0.0003	R	I
V506 OPH	53956.748400	0.00005	R	I		RV TRI	54077.920690	0.0001	V	I
V506 OPH	53957.808500	0.00008	V	II		RV TRI	54076.785953	0.0003	R	II
V506 OPH	53957.799667	0.00007	R	II		RV TRI	54087.717593	0.0001	R	I
V506 OPH	53964.702818	0.00002	V	I		RV TRI	54088.857158	0.0002	R	II
V506 OPH	53964.704480	0.00005	R	I		RV TRI	54076.793463	0.0006	V	II
V506 OPH	53965.763161	0.00002	V	I		RV TRI	54087.718074	0.00004	V	I
V506 OPH	53965.762308	0.00004	R	I		RV TRI	54089.606204	0.0004	V	II
V609 AQL	53966.801237	0.00002	V	I		RV TRI	54088.850000	0.0002	V	II
V609 AQL	53966.800236	0.00004	R	I						
V609 AQL	53968.793472	0.00003	V	II						
V609 AQL	53968.761756	0.02000	R	II						

Table 4. Target Stars with New Times of Minima. Type I = Primary Type II = Secondary

3. Systems

3. 1. V506 OPH

V506 OPH, located at RA 17 41 04.2 hours, Dec +07 47 04 degrees is considered to be an EB/DM variable ranging in brightness from 11.2 to 12 magnitude and a period of 1.0604, Epoch of 2428543.603. VizieR describes an EB/DM as EB are "Beta Lyrae-type eclipsing systems. These are eclipsing systems having ellipsoidal components and light curves for which it is impossible to specify the exact times of onset and end of eclipses because of a continuous change of a system's apparent combined brightness between eclipses; secondary minimum is observed in all cases, its depth usually being considerably smaller than that of the primary minimum; periods are mainly longer than 1 day. The components generally belong to early spectral types (B-A). Light amplitudes are usually <2 mag in V. DM - Detached main-sequence systems. Both components are main-sequence stars and do not fill their inner Roche lobes." (SIMBAD, VizieR)

Bob Nelson's O-C chart contains 50 times of min between 1974 and 2004 (Nelson). Further searching of the literature revealed 12 more in 2005 (IBVSa). We were able to determine 14 more times of minimum in 2006 from our own imaging sessions.

O-C1 calculations were done on the times of minimum to determine what changes have been occurring since discovery. Further O-C2 calculations were accomplished using the PSI-Plot software to determine if there were any regular patterns of change. See Figures 3 and 4 for O-C curves and Figure 5 for the light curve created from 2006 sessions.

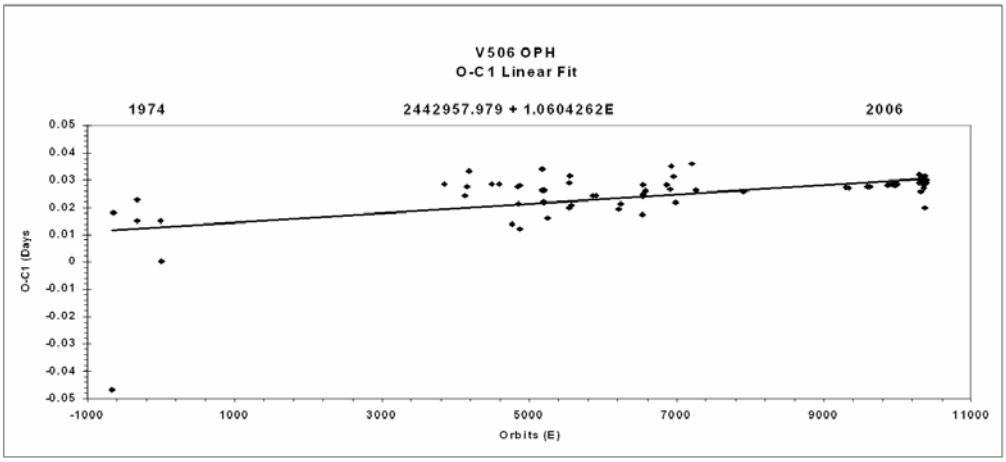

Figure 3. V506 OPH O-C1

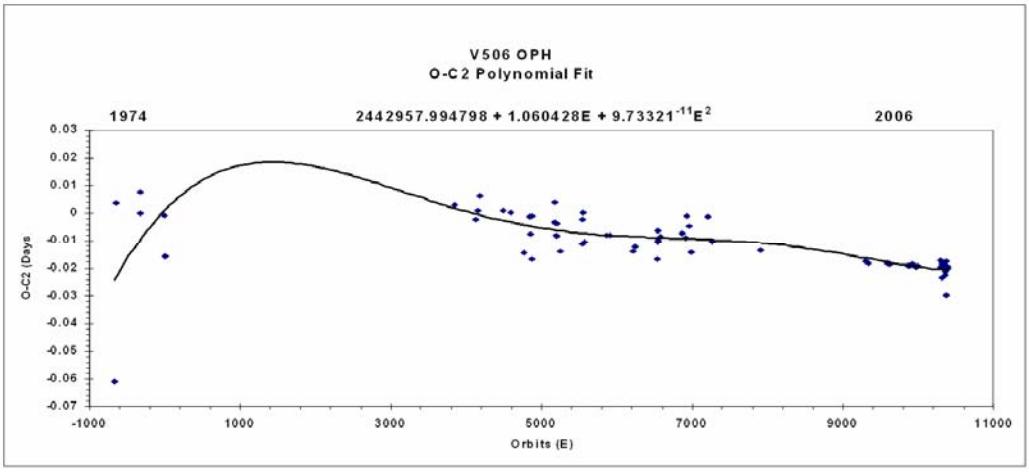

Figure 4. V506 OPH O-C2

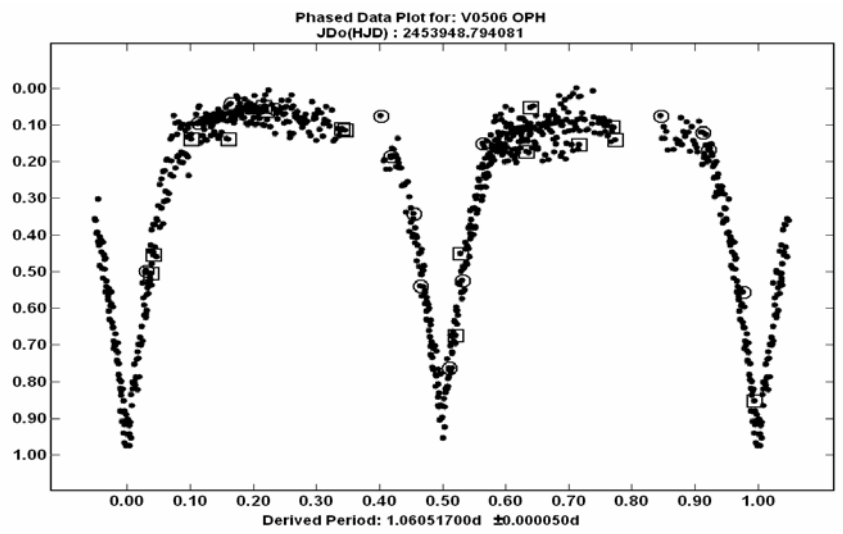

Figure 5. V506 OPH Light Curve

3. 2. V609 OPH

V506 OPH, located at RA 17 41 04.2 hours, Dec +07 47 04 degrees is considered to be an EB/DM variable ranging in brightness from 11.2 to 12 magnitude and a period of 1.0604, Epoch of 2428543.603. VizieR describes an EB/DM as EB are “Beta Lyrae-type eclipsing systems. These are eclipsing systems having ellipsoidal components and light curves for which it is impossible to specify the exact times of onset and end of eclipses because of a continuous change of a system's apparent combined brightness between eclipses; secondary minimum is observed in all cases, its depth usually being considerably smaller than that of the primary minimum; periods are mainly longer than 1 day. The components generally belong to early spectral types (B-A). Light amplitudes are usually <2 mag in V. DM - Detached main-sequence systems. Both components are main-sequence stars and do not fill their inner Roche lobes.” (SIMBAD, VizieR).

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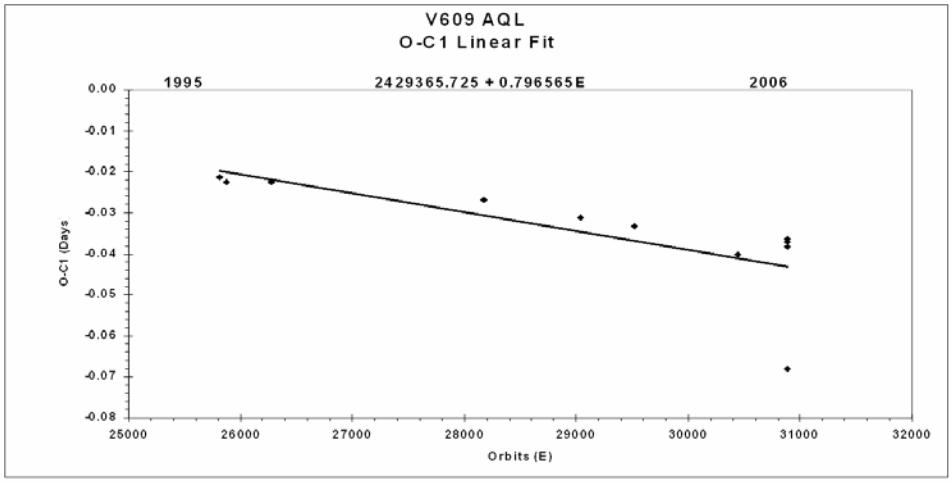

Figure 6. V609 AQL O-C1

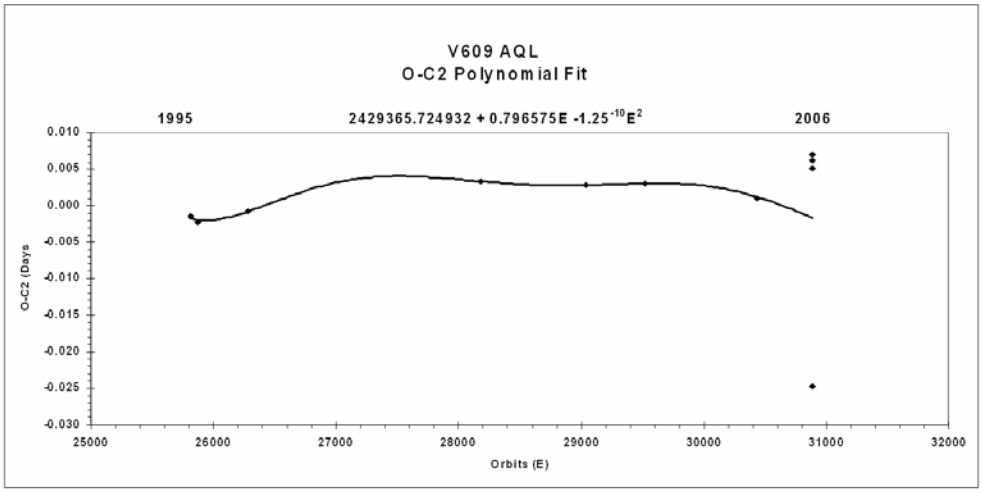

Figure 7. V609 AQL O-C2

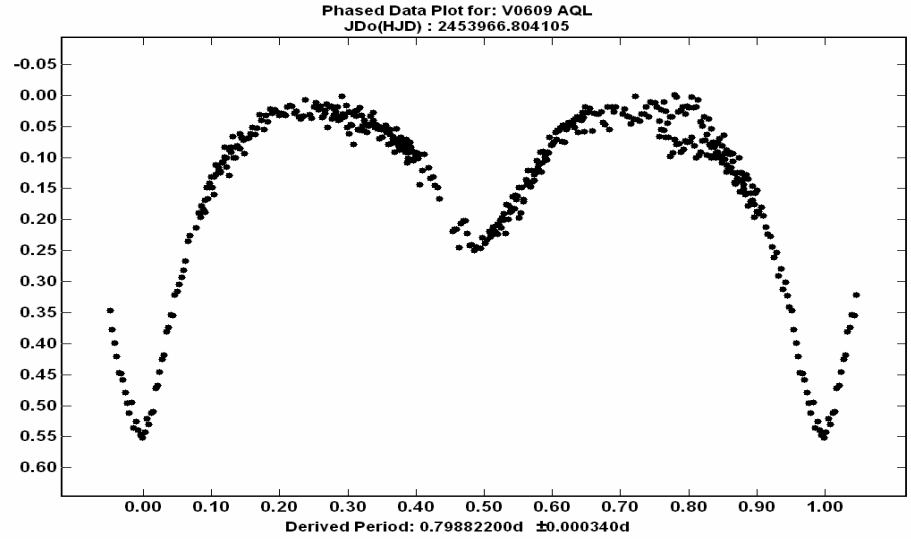

Figure 8. V609 AQL Light Curve

3. 3. AN TAU

AN TAU, located at RA 03 56 11.4 hours, Dec +29 31 23 degrees is considered to be an EB/DM like V 506 OPH described in section 3.1. The system ranges in brightness from 10.3 to 11.15 mag and has a period of 1.614640, Epoch of 2428181.3880 (SIMBAD, VizieR).

Bob Nelson's O-C charts contain 14 times of minimum (Nelson) and a reference search turned up 2 more times of minimum (IBVSd). Our observations produced another 6 times of minimum. Nelson describes the O-C relationship as "Very Uncertain". As such we haven't added any curves to the charted O-C1 data as seen in Figure 9.

O-C1 calculations were done on the times of minimum to determine what changes have been occurring since discovery. Further O-C2 calculations were accomplished using the PSI-Plot software to determine if there were any regular patterns of change. Figure 10 displays the polynomial fit for the O-C2 data. Figure 11 is the light curve from this year's observations.

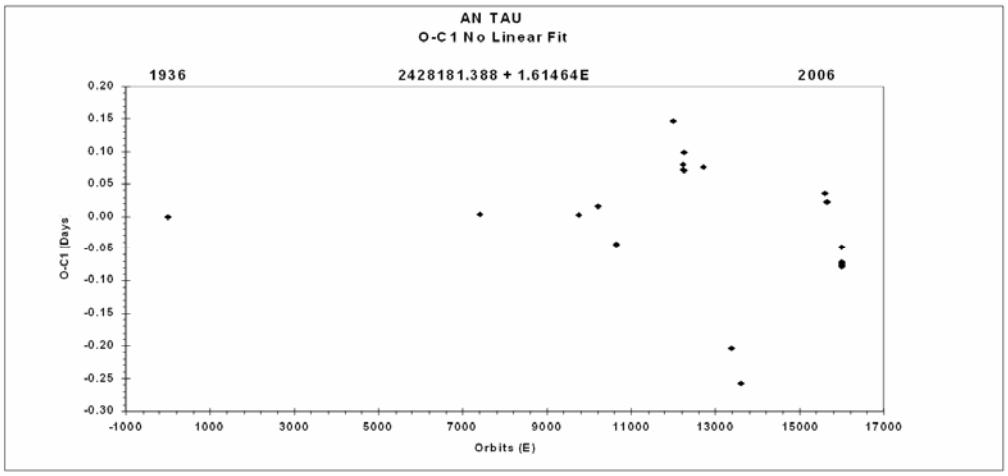

Figure 9. AN TAU O-C1

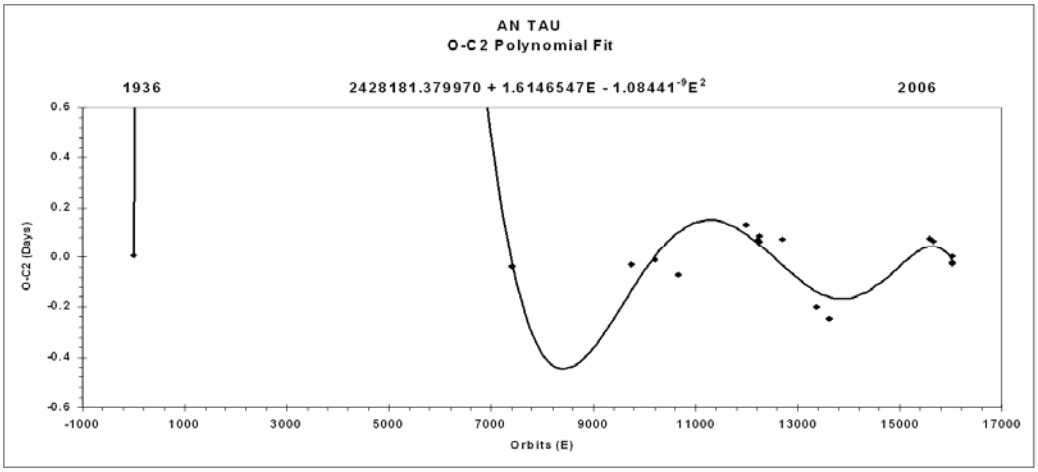

Figure 10. AN TAU O-C2

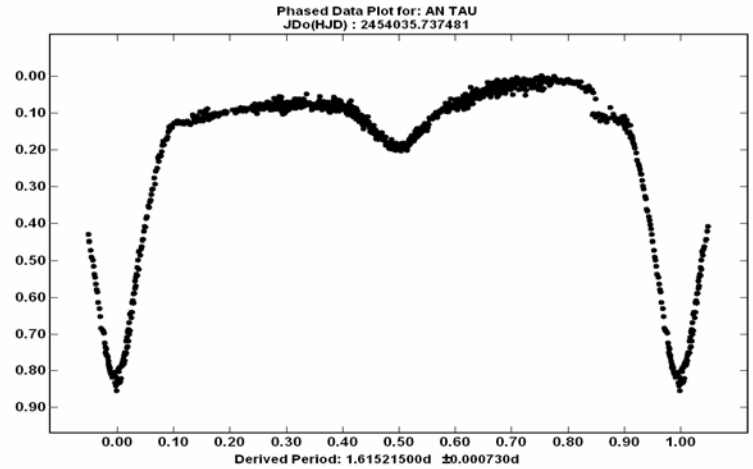

Figure 11. AN TAU Light Curve

3. 4. RV TRI

RV TRI, located at RA02 13 18.2 hours, Dec +37 01 01 degrees is listed as an EA/SD variable. This system ranges in brightness from 11.5 to 13.3, has a period of 0.753666480 and Epoch of 2446033.3080. VizieR describes the EA component as "Algol (beta Persei)-type eclipsing systems. Binaries with spherical or slightly ellipsoidal components. It is possible to specify, for their light curves, the moments of the beginning and end of the eclipses. Between eclipses the light remains almost constant or varies insignificantly because of reflection effects, slight ellipsoidality of components, or physical variations. Secondary minima may be absent. An extremely wide range of periods is observed, from 0.2 to >= 10000 days. Light amplitudes are also quite different and may reach several magnitudes." and SD as "Semidetached systems in which the surface of the less massive component is close to its inner Roche lobe." (SIMBAD, VizieR)

Bob Nelson's O-C file for RV TRI contains 198 times of minimum (Nelson), reference review discovered another 3 times of minimum (IBVSe, f) and for this paper we derived 9 more times of minimum.

O-C1 calculations were done on the times of minimum to determine what changes have been occurring since discovery. Further O-C2 calculations were accomplished using the PSI-Plot software to determine if there were any regular patterns of change. Figures 12 and 13 are the charts derived from the O-C1 and O-C2 calculation. Figure 14 is the light curve from this year's observations.

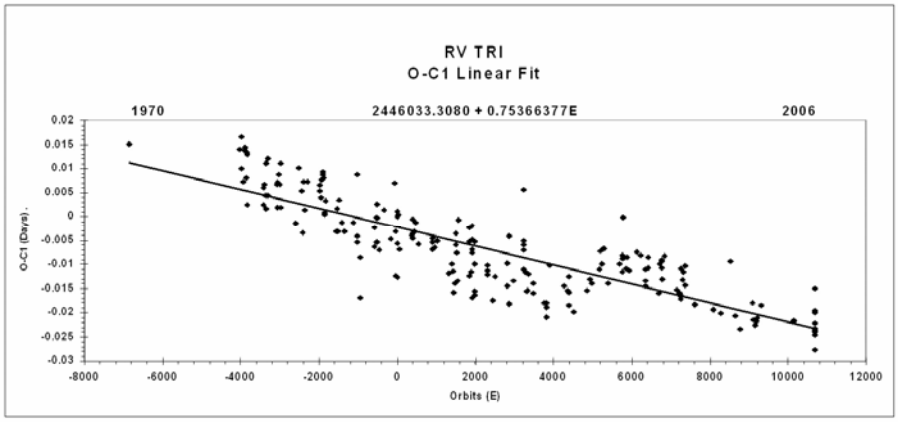

Figure 12. RV TRI O-C1

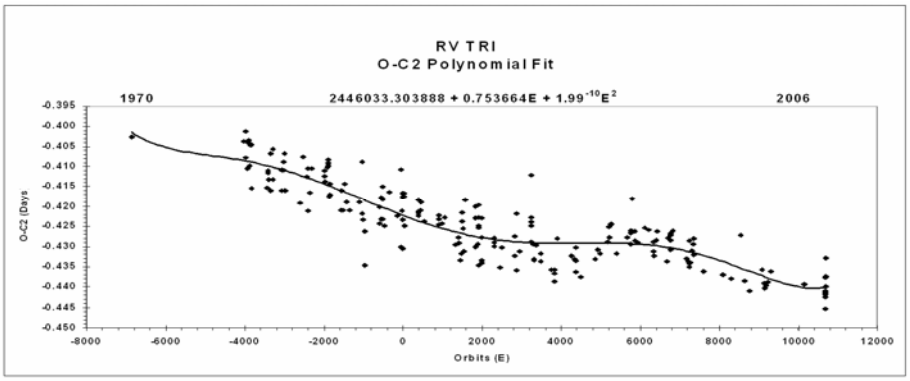

Figure 13. RV TRI O-C2

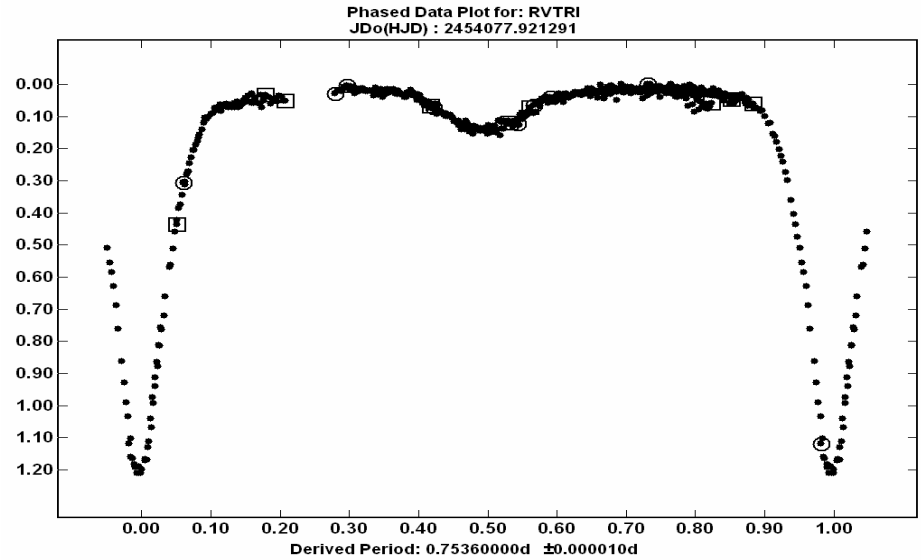

Figure 14. RV TRI Light Curve

4. Conclusion

Four eclipsing binary systems were observed in 42 sessions during the last half of 2006 with the intention of collecting enough data to provide a complete light curve for each system. As demonstrated we were able to produce high quality, almost complete light curves on each system, capturing enough primary and secondary eclipses to determine 33 new times of minimum. It was also shown that the new data fit nicely with O-C data and curves created in previous work.

The whole procedure has been a stimulating learning process that involved learning how to work with the hardware, integrating the software into the process, and doing on-line research to aid in selecting appropriate targets. This was all done with off the shelf equipment and relatively inexpensive software to produce high quality data comparable to previous research.

5. References

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http://vizier.u-strasbg.fr/viz-bin/VizieR