Light Curve Analysis Of TT Oph And UZ Oph

J. Cash, B. Pugh, E. Maina (South Carolina State University)

Abstract:

TT Oph and UZ Oph are both classified in the GCVS as RV Tauri stars, pulsating variables with alternating deep and shallow minima. The literature indicates that the RV Tauri nature of these two stars is questionable. We have examined the AAVSO light curves of these objects for the eight year period of 2002-2010. We will present our analysis of the light curves and discuss how their recent behavior compares with past behavior as presented in the literature. Support for this work was provided by the NSF PAARE program to South Carolina State University under award AST-0750814.

Background:

RV Tauri (RV) and Semi-Regular (SR) variables are two related classes of pulsating variable stars. There may be a continuum of behavior between the groups and cross-identification may occur (Percy and Mohammed 2004). The tables below summarize the basic light curve properties of each group (Samus et al. 2009)

RV:
- formal periods of 30 – 150 days
- alternating deep and shallow minima
- depths of minima can vary and interchange

SR:
- periods of 20-2000 days
- noticeable periodicity
- accompanying irregularities

We are examining two stars TT Oph and UZ Oph that are classified as RV by the General Catalog of Variable Stars (GCVS) but which may be SR stars. The main features that we are looking for will be the alternating deep and shallow minima caused by two dominate periods in the light curve: the formal period (from one deep minima to the next) and the half period (from one minima to the next minima regardless of depth). For an RV star these two periods are typically near a 2:1 ratio. Figure 1 below shows an example of a synthetic, idealized light curve expected for an RV star.

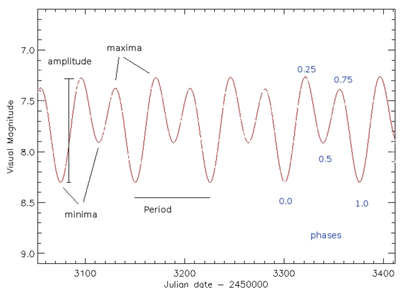

Figure 1: Ideal Light Curve

Analysis Methods:

We used two programs from American Association of Variable Star Observers (AAVSO) to aid our analysis: the Weighted Wavelet Z Analysis (WWZ) program and the Time Series Analysis (TS1.2) program. The WWZ program was used to identify the dominate periods in the light curves for each star and examine how those periods changed over time. The Fourier analysis tools within TS1.2 were used to refine the estimates of the dominate periods and then perform least squares fitting to the light curves using those periods. The light curves were examined on a year to year basis to look for the characteristic two periods, alternating minima, as well as irregularities and variations in the light curves.

AAVSO Data:

Our light curve data comes from the American Association of Variable Star Observers (AAVSO) for the time period from Jan 1, 2002 through Jun 1, 2010. This date range was chosen as it covered the time span for our existing spectroscopic database (see related posters 342.12 and 342.13). We included only Visual magnitudes and averaged the raw light curve data in four day bins. Typical error bars for AAVSO data points are in the range of 0.2-0.3 magnitudes and we estimate that the typical standard error of the mean for the averaged data is around 0.2 magnitudes.

TT Oph:

GCVS Listing:
Type: RVa, Period: 61.08 days, Magnitude Range: 9.45 – 10.84 (Samus et al. 2009)

Past Behavior (non exhaustive listing)
- (Gerasimovic 1927) published light curve shows clear alternation of deep and shallow minima
- (Horowitz 1987) published light curve shows alternation of deep and shallow minima but irregularities in pattern, Fourier analysis indicates half period amplitude dominates
- (Percy and Mohammed 2004) self-correlation study shows great regularity but little evidence of alternating deep and shallow minima, RVa classification questioned

Current Findings
The WWZ and Fourier analysis of the eight year span are dominated by a single frequency at 0.0328 cycles/day (see figures 2 and 3 below). This corresponds to the expected half period at 30.49 days. The in no indication of the expected formal period at 61.08 days. The light curves for individual years show some variation in the depth of the minima but no pattern of alternating deep and shallow minima (see figure 4 below). Fourier analysis on individual years show no clear indication of the expected formal period. Light curve fits using just the half period produce reasonable fits for most years (see figure 5 below) although some data points indicate an occasional deeper minima depth. We attempted to create fits where the expected formal period was included, but fits were not improved significantly and never yielded significant amplitudes for the formal period component.

Our Conclusion...
The current behavior of TT Oph is not consistent with the alternating pattern expected for RV Tauri stars. It may be in a stage of more intense irregularities or it may currently be better classified as a Semi-regular star.

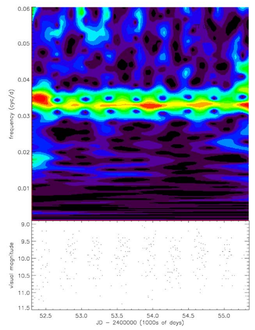

Figure 2: WWZ output for TT Oph

Figure 3: Fourier Spectrum for TT Oph

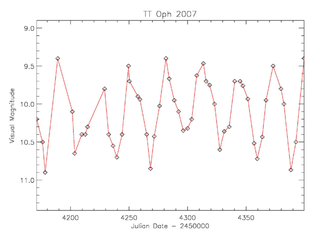

Figure 4: Light Curve Data

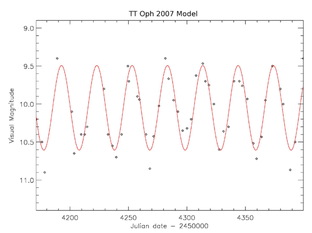

Figure 5: Light Curve Fit

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- We acknowledge with thanks the variable star observations from the AAVSO International Database contributed by observers worldwide and used in this research.
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Related posters at this conference
- 342.12 Walter et al., *Spectral Variations of Three RV Tauri Stars,*
- 342.13 Nesmith et al., *The Correlation Between the Photometric Variability and Spectra of Seven RV Tauri and Semi-Regular Stars*

UZ Oph:

GCVS Listing:
Type: RVa, Period: 87.44 days, Magnitude Range: 9.93 – 11.50 (Samus et al. 2009)

Past Behavior (non exhaustive listing)
- (Leiner 1922) published light curve shows alternating deep and shallow minima and cycle to cycle changes in the light curve shape
- (Horowitz 1987) published light curve shows regions of alternating minima and regions of irregularities
- (Percy and Mohammed 2004) self correlation study found no evidence of alternating deep and shallow minima, RVa classification questioned

Current Findings
The WWZ analysis shows a dominate frequency near the expected half period at 0.023 cycles/day and a weaker but still clear signal near the expected formal period at 0.011 cycles/day (see figure 6 below). The Fourier analysis of the eight year span (figure 7 below) shows the dominate half period signal near 0.023 cycles/day while the formal period near 0.011 cycles/day is split into several distinct spikes which is typical for a light curve with irregularities. The light curves for individual years mostly show the typical RV alternating deep and shallow minima as shown for year 2007 in figure 8 below. Fourier analysis on single years of the light curve show dominate peaks at both the formal and half period. The exception to this is year 2008 which seems to show a series of shallow minima with no obvious deep minima between them. For all years, we were able to fit the light curve with a two frequency model including both the formal and half period (see figure 9 below). Upon examining the locations of the deep minima, we also found that there appears to be an interchange of deep and shallow minima during the observing gap between 2002 and 2003.

Our Conclusion...
UZ Oph currently shows the alternating pattern of deep and shallow minima but also manifests irregularities. It should retain the RVa classification but is one of the more irregular members.

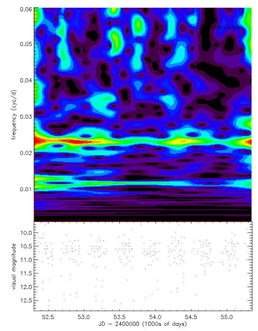

Figure 6: WWZ Output for UZ Oph

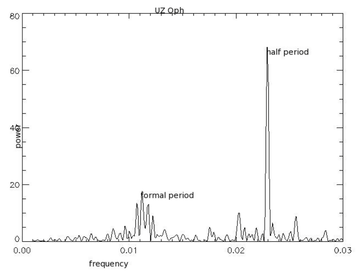

Figure 7: Fourier Spectrum for UZ Oph

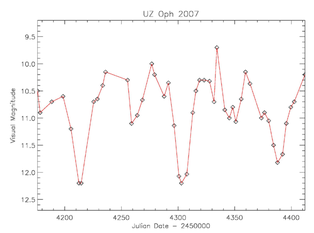

Figure 8: Light Curve Data

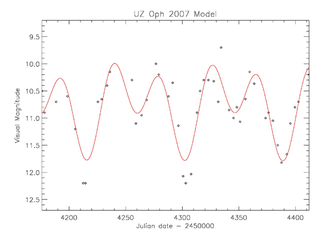

Figure 9: Light Curve Fit

Future Work:

- Continue monitoring of TT Oph and UZ Oph into future
- Correlation of photometric and spectroscopic behaviors
- Examination of other RV and SR light curves

References:

- Gerasimovic, B. P., 1927BHarO.847...17G
- Horowitz, D. H., 1987JAVSO..16...71H
- Leiner, E., 1922AN....216..295L
- Percy, J. R. and Mohammed, F., 2004JAVSO..32....9P
- Samus, N., et al. 2009yCat....102025S