

A Spectroscopic Study of the RV Tauri Stars TT Oph and UZ Oph

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ABSTRACT

TT and UZ Orphiuchus are listed as RV Tauri types in the *General Catalog of Variable Stars*, although Percy and Mohammed (2004, JAAVSO, 32, 9) question this classification. We have acquired spectra of these objects with the Coude Feed Telescope at KPNO over the past decade. In this study we have phase folded the dates of our spectral observations from 2003 to 2012 in order to examine the variation of luminosity and temperature as a function of phase. The luminosity of TT Oph changes by a factor of 3 or more while its temperature varies as much as 1000 K over its 61 day period. UZ Oph varies by nearly an order of magnitude in luminosity and up to 1200 K during its 87 day oscillation. The cyclic behavior of these variations and the change in position on the HR Diagram is demonstrated.

Support for this work was provided by the NSF PAARE program to South Carolina State University under award AST-0750814. We thank the director of KPNO for his generous allocation of telescope time to this project over the years.

BACKGROUND

RV Tauri stars are a small class of pulsating, luminous, yellow supergiants whose light curves are characterized by alternating deep and shallow minima. The time from one deep minima to the next deep minima is known as the formal period, while the time from one deep minima to the next shallow minima is referred to as the half period. The formal periods are typically in the range of 30 to 150 days.

RV Tauri stars are old, low mass supergiants that lie between the Cepheid and Mira-type variables on the HR diagram. These stars may be executing blue loops around the asymptotic giant branch (AGB); or they may be in transition from the AGB to white dwarfs. Since this transition is not well understood, RV Tauri types stand as a potential bridge across this evolutionary gap and are objects of interest.

The work presented herein is part of our larger study of RV Tauri and Semiregular variables. We hope to gain a better understanding of how their stellar properties (L, T and R) change over the course of a pulsation cycle.

TT Oph and UZ Oph are classified as RV Tauri variables; however, Percy and Mohammed (2009) question this. In our own fit to the AAVSO light curve of TT Oph, the defining pattern of alternating deep and shallow minima is not evident. Therefore, we have used the half period for TT Oph in this study and indicated in the table below.

DATA SET

We have acquired high signal-to-noise spectra of these stars since 2003 using the Coude Feed Telescope at KPNO. The spectra we have analyzed up to this point are listed in the table below. They represent approximately half of the total number of our spectra for each star. Our photometric data was taken from AAVSO and used to determine the phase values for each date on which we have spectra.

Star	Period This study (days)	Period GCVS (days)	# of Spectra this study	Dates of Spectral Coverage
UZ Oph	89.48	87.44	10	6/10/03 – 6/28/07
TT Oph	30.47	61.08	10	6/10/03 – 5/18/11

DATA ANALYSIS

➤ Spectral types and luminosity classes were determined from our spectra by comparing them to Jacoby et. al., 1984.

➤ The effective temperature (T) was derived from the spectral type using Gray & Corbally (2009) standards.

➤ Photometric data were taken from the AAVSO dataset to determine the apparent magnitude (m) on each date.

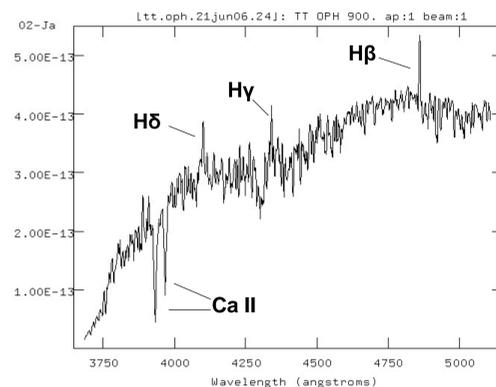
➤ Stellar distance (d) was derived from the Hipparcos-Tyco parallax database for TT Oph.

➤ The absolute magnitude (M) for TT Oph was calculated using “d” and the distance modulus: $m - M = 5\log(d) - 5$.

➤ For UZ Oph, “M” was determined from the spectroscopic parallax using Gray & Corbally (2009) standards.

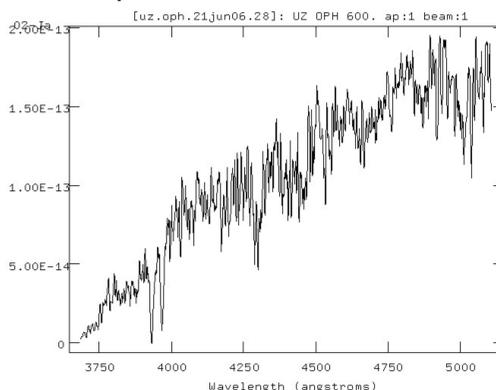
➤ The luminosity (L) was then calculated from:
 $M(\text{star}) - M(\text{sun}) = -2.5\log[L(\text{star})/L(\text{sun})]$

➤ Phase values were calculated for the dates of our spectroscopic observations using our fit to the AAVSO data.



Above: One of our spectra of TT Oph. Note the Balmer emission lines as well as the Ca II H and K lines and others in absorption.

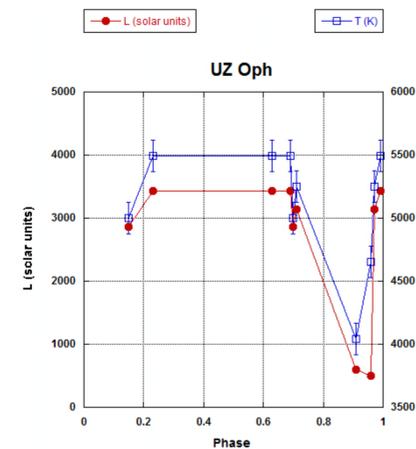
Below: One of our spectra of UZ Oph with the Ca II H and K lines and others in absorption.



REFERENCES

- AAVSO data: <http://www.aavso.org>
 Hipparcos/Tyco data: <http://simbad.u-strasbg.fr/Simbad>
 Jacoby, G.H. et. al., 1984, ApJS, 56, 257
 Percy and Mohammed 2004, JAAVSO, 22, 9
 Gray, R.O. & Corbally, C.J. 2009, “Stellar Spectral Classification”
 GCVS data: <http://www.sai.msu.su/gcvs/>

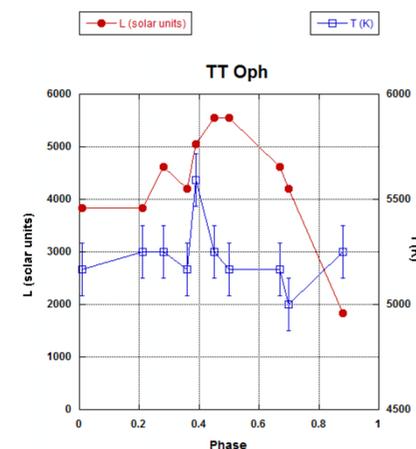
RESULTS and DISCUSSION



UZ Oph

The plot above and left shows the variation of luminosity (red circles) and temperature (blue squares) as a function of the phase. Error bars in temperature correspond to a possible classification error of one spectral subtype.

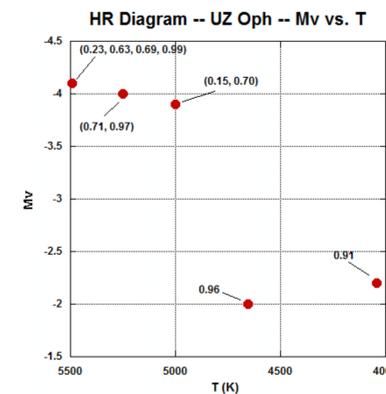
The behavior of L and T are uncertain at mid-cycle because of the absence of spectra. Data at phases 0.2 and 0.7 are symmetric around the mid-phase point, suggesting L and T peak near 0.5. The dip near 0.9 appears real. Once additional spectra are examined, it is likely that a well behaved dependence will be observed.



TT Oph

The plot above and left shows the variation of luminosity (red circles) and temperature (blue squares) as a function of phase. Error bars in temperature correspond to a possible classification error of one spectral subtype.

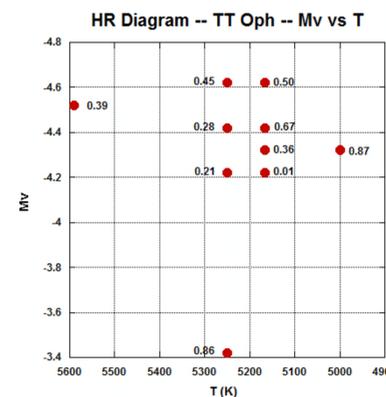
L varies as expected, peaking at mid-cycle. T is less well behaved and surprisingly shows little change over the course of the cycle. We will reexamine our classification of the spectra as well as examine additional spectra in our database to get a clearer picture of the phase dependence of T.



UZ Oph

The plot above and right tracks the movement of UZ Oph in the HR diagram as a function of the phase, whose numerical value is shown in black beside each data point.

The upper three points lie along the supergiant track while the lower two points are on the bright giant (II) track. While there is movement in the HR Diagram, a trend or closed loop cannot be inferred because of the limited number of data points. This may be clarified once all of our spectra are analyzed.



TT Oph

The plot above and right tracks the movement of TT Oph in the HR diagram as a function of phase, whose numerical value is shown in black beside each data point.

The vertical stratification of the data results from the star having the same spectral type at different phases but having a different apparent magnitude. Once magnitude errors are taken into account, some of the points will overlap in position. While there is movement in the HR diagram, a clearer understanding will have to await analysis of additional spectra.

FUTURE WORK

- Analyze additional spectra for the period 2008-2012
- Examine variations in stellar radius (R) as a function of phase space

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