

# Spectral Variations of Three RV Tauri Stars

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## ABSTRACT

UZ Oph, TT Oph and AD Aql are classified as RV Tauri stars in the General Catalog of Variable Stars (GCVS). We present preliminary results of our study of the spectral variations of these stars including observations from 2003 to the present. Changes on the order of several spectral types and luminosity classes are observed. We discuss each object's shift in position on the L vs. T diagram as a function of the phase of their light curve. Our photometric data is taken from the AAVSO International Database and our spectra come from a long term observing program organized by S. Howell using the Coude Feed Telescope at Kitt Peak National Observatory.

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.

## DATA SET

Our photometric data was taken from AAVSO. We have acquired high signal-to-noise spectra of these stars since 2003 using the Coude Feed Telescope at KPNO. Variable type and period come from GCVS except as noted.

Star	Variable Type	Period (days)	# of Spectra	Dates of Spectral Coverage
UZ Oph	RVA	88.5‡	10	6/10/03 – 6/28/07
TT Oph	RVA†	30.33‡	6	6/10/03 – 6/27/04
AD Aql	RVA	65.40	4	6/10/03 – 6/28/04

† the GCVS variable type is questioned by Cash *et. al.* 2011  
‡ the period comes from Cash *et. al.* 2011

## DATA ANALYSIS

➤ Spectral types and luminosity classes were determined by comparing our spectra to standards in the Jacoby Spectral Atlas.

➤ The effective temperature (T) was derived from the spectral type.

➤ Photometric data were taken from the AAVSO dataset to determine the apparent magnitude (m) on each date for UZ Oph and TT Oph. No such data was available for AD Aql.

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

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

➤ The luminosity (L) was then calculated from:

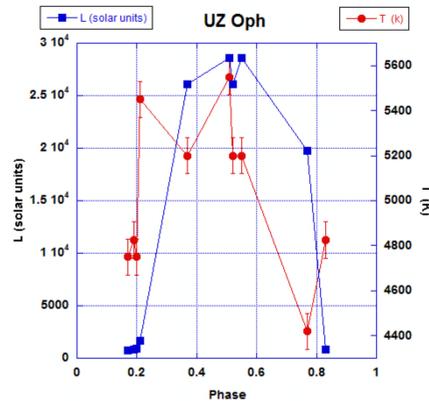
$$M(\text{star}) - M(\text{sun}) = -2.5\log[L(\text{star})/L(\text{sun})]$$

➤ For AD Aql, T and Mv were derived using our spectra, but other quantities could not be calculated because of the lack of available photometry on the dates our spectra were taken.

➤ Conversion of JD to pulsation phase values was possible for UZ Oph and TT Oph based on the fits from Cash *et. al.* 2011 (this conference).

## GRAPHICAL RESULTS and DISCUSSION

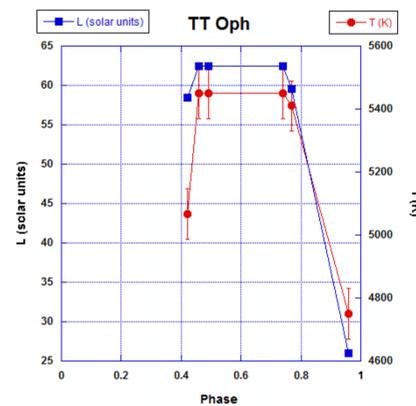
In all of the plots below the error bars for temperature assume an error of one spectral subtype during classification.



### UZ Oph

The plot on left shows the variation of luminosity (blue) and temperature (red) as a function of the phase within the pulsation cycle.

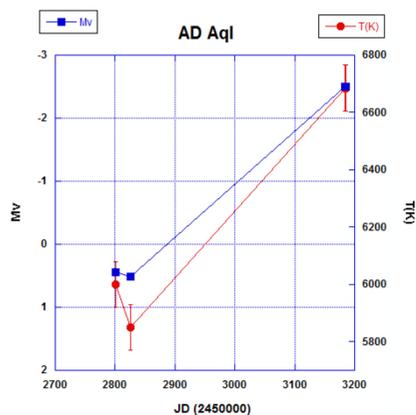
Both L and T show a symmetric rise to a maximum at mid-cycle and return to a minimum at the end of the period. Future analysis of other stellar quantities such as radius and surface velocity should prove enlightening.



### TT Oph

The plot on left shows the variation of luminosity (blue) and temperature (red) as a function of the phase in the pulsation cycle.

Coverage of the pulsation cycle is less complete than for UZ Oph. Nonetheless, there is a strong suggestion that L and T rise and fall around a maximum near the midpoint of the pulsation cycle. Recently acquired and future spectra will fill in some of the gaps in phase coverage and clarify the issue.



### AD Aql

On the left and in blue is a plot of absolute magnitude as a function of Julian Date (JD) for AD Aql. T as a function of JD is shown in red. The lack of photometric data on and near the dates of our spectroscopic observations limited us to use of the absolute magnitude based on the luminosity class from our spectra. The point in the upper right is actually two observations closely spaced in time and superimposed on one another.

The small number of spectra and the absence of a fit to the light curve for AD Aql limits our ability to draw conclusions about the behavior of this star. Recently acquired and future spectra will allow us to better examine this object.

## FUTURE WORK

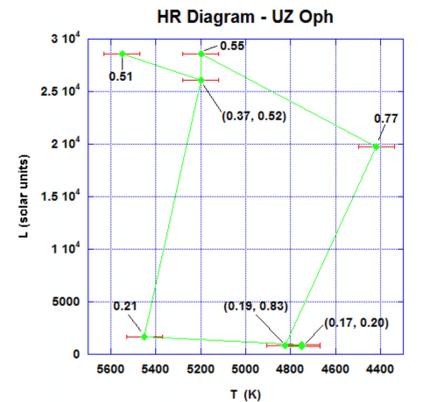
- Include additional spectra of all 3 stars acquired since 2008
- Combine results with stars in poster 342.13 by Nesmith, *et. al.*
- Examine variations in stellar properties in pulsation phase space

*The ultimate goal of our 5-year study is to determine the temporal change of the physical parameters for RV Tauri stars throughout their pulsation cycle in order to better understand the physical nature of these objects.*

### UZ Oph

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

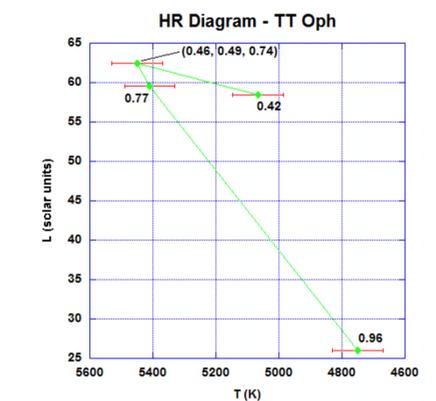
Some changes are rather significant despite the short time period (e.g. from 0.20 to 0.21 in the phase cycle). Such changes must be viewed with caution. Nonetheless, it is clear that UZ Oph completes a closed loop over the HR diagram during a single pulsation cycle.



### TT Oph

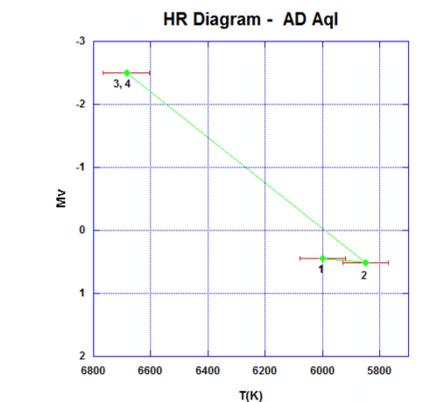
The HR diagram is shown on the right. Phase values are indicated as numbers in black next to the appropriate data points.

The data is not complete enough to draw conclusions other than to say that TT Oph moves around the HR diagram during its pulsation cycle. It may close the loop during the first part of the cycle (0 to 0.42) where there is currently a gap in the data. Future analysis of additional spectra should resolve this question.



### AD Aql

The HR diagram for AD Aql at the right shows our only data points to date. The black numerical values near each point represent the chronological sequence in which the observations were taken over the 12.5 months for which we have coverage. A better understanding of this object awaits additional spectroscopic and photometric data.



## 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.
- Cash *et. al.*, 2011, Poster 342.11, this conference
- Nesmith *et. al.*, 2011, Poster 342.13, this conference

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