

# A Study of the Spectroscopic Variability of Select RV Tauri and Semiregular Stars

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## ABSTRACT

The periodicity of RV Tauri and Semiregular types is not as well behaved as other variables such as Cepheids, and they take months to go through a single cycle. These constraints make it difficult to study these objects. While they lie between the Cepheids and the Miras on the HR Diagram and are believed to be in transition from the AGB to white dwarf phase, their evolution is not well understood.

We have acquired spectra for the years 2003-2012 using the Coude Feed Telescope at KPNO of three RV Tauri stars (AC Her, V Vul and R Sct) and four Semiregular types (SX Her, EU Del, g Her and Z UMa). We have fit their light curves using AAVSO photometry to more accurately determine their phase as a function of Julian Date over this long time span. This has allowed us to phase-fold the dates of our spectral observations and obtain a clearer picture of their behavior over a single cycle. We have found that some of these objects (e.g. SX Her) vary only 500 K while others (e.g. V Vul) change as much as 2000 K. The luminosity of some members of this sample varies as little as 50% while the light output of others changes by as much as 500%. We also present our results that show the cyclic movement on the HR Diagram of these objects over the course of their period.

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 variables are yellow supergiants that display light curves that alternate between deep and shallow minima over a single pulsation cycle, possibly due to multiple pulsations of different frequency. Semiregular stars are pulsating red giants that vary in light output with some degree of regularity but are not fully regular in amplitude or period. These objects are important because their position between the Cepheids and the Miras on the HR diagram make them a possible evolutionary stage from the asymptotic giant branch (AGB) to white dwarfs.

This work is part of a larger, multiyear study in which we are attempting to parameterize the changes in the stellar properties (L, T and R) of these objects as a function of the phase, similar to what has been done with Cepheids.

## DATA SET

Our photometric data were taken from the AAVSO database. We have acquired our own high signal-to-noise spectra of these stars since 2003 using the Coude Feed Telescope at Kitt Peak National Observatory (KPNO).

## DATA ANALYSIS

> Spectral types and luminosity classes were determined by comparing our spectra to standards in Jacoby et. al. (1984).

> The effective temperature (T) was derived from the spectral type using Gray & Corbally's (2009) standards.

> Apparent magnitude (m) and the pulsation phase for each date were taken from the AAVSO light curves.

> Stellar distance (d) was calculated using parallax values in the Hipparcos-Tyco database for all of the stars except V Vul.

> The absolute magnitude (M) was calculated using "d" and the distance modulus:  $m - M = 5\log(d) - 5$ .

> V Vul's parallax has not been measured, so we used its spectroscopic parallax to determine "M".

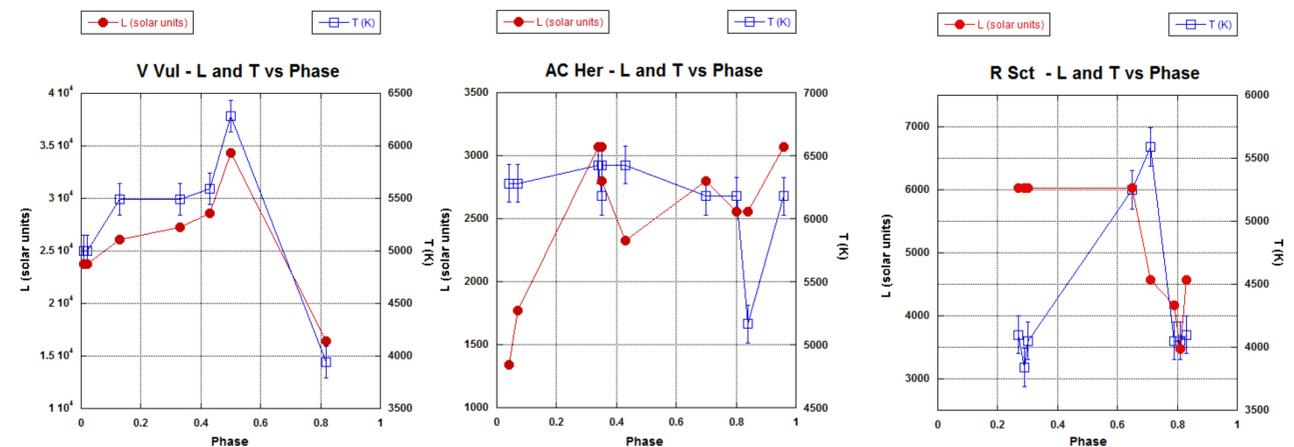
> The luminosity (L) was then calculated from:  
 $M(\text{star}) - M(\text{sun}) = -2.5\log[L(\text{star})/L(\text{sun})]$

## Phase Dependence Of L and T

As discussed in the Background Section, we are looking for an empirical relationship between changes in the stellar properties and the pulsation phase.

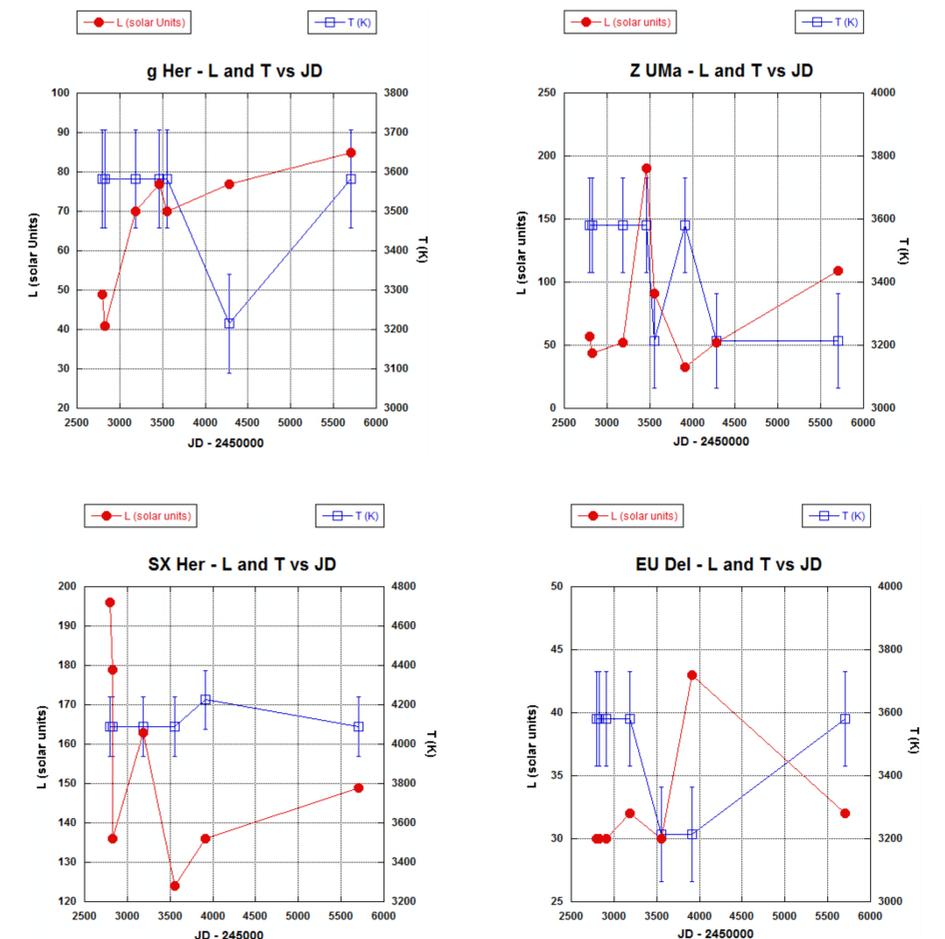
To the right are plots for each of the 3 RV Tauri stars that show how the luminosity of each star (red data points) and the temperature (blue data points) vary with the phase. Error bars for the temperature correspond to a possible error of one spectral subtype in our classification.

V Vul shows a nice trend, symmetric around the midpoint of the phase, despite the paucity of points between 0.5 and 1.0. This will be addressed when the rest of our spectra are examined. AC Her and R Sct do not show such a trend; but the number of data points currently is small. A trend may emerge once the other spectra are included.



## Variation of L and T When the Phase Values are Not Known

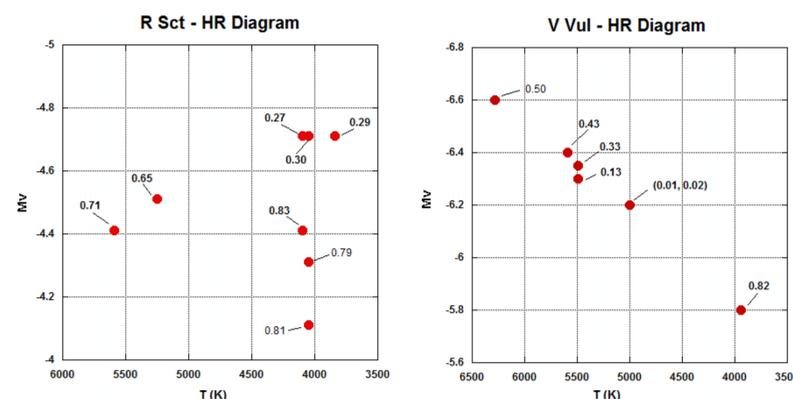
We have not completed the phase calculations for the Semiregular variables shown below; g Her, Z Uma, SX Her and EU Del. Instead we have plotted the change in L (red data points) and T (blue data points) as a function of the Julian date. Error bars for the temperature correspond to a possible error of one spectral subtype in our classification. We anticipate useful results once we have completed the analysis of all the spectra and the determination of the corresponding phase values from the AAVSO photometry.



## Cyclic Movement in the HR Diagram

Shown below are the HR diagrams for R Sct and V Vul. These were constructed from the quantities derived as described elsewhere. The numerical quantity next to each point is the corresponding phase value.

As expected, each star moves along a path in HR diagram during a single phase cycle and returns to its starting point for the next cycle. R Sct appears to move in a closed loop, while V Vul slides back and forth along the supergiant branch in the figure. More data points will further clarify this.



## 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.
- Gray, R. O. and Corbally, C. J.; 2009, *Stellar Spectral Classification*; (Princeton: Princeton University Press)

## FUTURE WORK

We have additional spectroscopic data for the time period 2007 to 2012 that is not included in the above work. Once that data is reduced we will have better phase coverage and anticipate being able to make more definitive statements about the variation of these quantities over the course of a single pulsation cycle. Stellar radii calculations will also be carried out.

## ACKNOWLEDGEMENTS

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