ATMOSPHERIC CONDITIONS IN YELLOW AND RED VARIABLES

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ABSTRACT. Pulsation occurs in late-type giant and supergiant stars under a wide range of atmospheric conditions and evolutionary stages. Long observational baselines are necessary to distinguish pulsation behaviors. Spectrographic and photometric observations of a variety of late-type pulsators are considered in the context of light-curve taxonomy and changing atmospheric conditions.

Key Words: stars: late-type giants and supergiants, variables, pulsations

1. INTRODUCTION

A great number of pulsating variables of late type fall into one of the semiregular categories, for which amplitude and period may vary by as much as a few percent from cycle to cycle. These include SRa variables (red, low-amplitude counterparts to Miras), SRc variables (red supergiants of moderate amplitude), SRd variables (yellow Halo stars with P ~ 100 days), and RV Tauri stars (yellow giants and supergiants of the young to old disk).

The light curves show a wide range of shapes, amplitudes and types of instability, including mode switching, overtone pulsation (observed for Miras and probably some RV Tauris as well as for Cepheids and RR Lyraes), alternation of regular and irregular variations, and nonradial oscillations. It should also be mentioned that many of these variables show a Blazhko effect.
Many of the later yellow variables are near the so-called Dividing Line (cf. Haisch and Schmitt 1996) between strong stellar coronae and strong stellar winds. See Wahlgren 1992 for an excellent review of the taxonomy of RV Tau and SRd variables, and Percy et al. (1996) for light curves of many of the others.

2. OBSERVATIONS

I have obtained photometry (primarily UBV or UBVRI) for a sample of semiregular variables chosen primarily on the basis of period (20 days < P < 150 days) at the Cerro Tololo Inter-American Observatory (0.6 m and 0.9 m telescopes), the National Undergraduate Research Observatory in Flagstaff (0.78 m telescope; with students from Western: e.g., Herrero and Dawson (1993), and the Mount Laguna Observatory of San Diego State University (0.6 m telescope), since the middle 1980s. Image tube and CCD spectra were also obtained (the former by Scott Baird, on the 1.5 m CTIO telescope; the latter by Dawson at Mount Laguna) to better relate the variables' changing color indices to details of the pulsation such as Balmer line emission or the formation of molecular bands. The image tube spectra cover the range 3850 - 5100 Å.

3. LIGHT CURVE TAXONOMY

The most complete data set in the current research is from observations of southern variables at Cerro Tololo; preliminary results were reported by Dawson and Baird (1988). The SAAO system (Cousins) was used.

Variables were categorized on the bases of light and color amplitudes, by phase differences between light and color variations, and by a simple V skewness parameter

\[ S = \frac{t(\text{fall})-t(\text{rise})}{t(\text{fall})+t(\text{rise})} \]

measured at mean light (S = 0 for symmetric variation and S > 0 for a more rapid rise). This was done without knowledge of the pulsation type; indeed, the type of variation was unknown for many of the program stars.

Phase variations between V and the color indices have not proved to be sensitive discriminants among RV Tauri and SRd variables in particular, nor between those groups and a few other variables (mostly SRc) included in the CTIO study. The Table lists the phase shifts (in the sense “color index minus
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V") when the variations are compared at light maxima (1) and light minima (2). Since the number of identified SRd variables studied was small, I have added data on four northern variables (AG Aur, SX Her, AB Leo and SV UMa) from Kameny (1956) and Preston et al. (1963).

TABLE 1. Phase shifts

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>ΔΦ(U-B)1</th>
<th>ΔΦ(U-B)2</th>
<th>ΔΦ(B-V)1</th>
<th>ΔΦ(B-V)2</th>
</tr>
</thead>
<tbody>
<tr>
<td>RV Tauri stars</td>
<td>24</td>
<td>-0.14</td>
<td>-0.19</td>
<td>-0.12</td>
<td>-0.15</td>
</tr>
<tr>
<td>SRd variables</td>
<td>3</td>
<td>-0.08</td>
<td>-0.08</td>
<td>-0.06</td>
<td>-0.07</td>
</tr>
<tr>
<td>Northern SRd</td>
<td>4</td>
<td>-0.03</td>
<td>-0.13</td>
<td>-0.01</td>
<td>-0.10</td>
</tr>
<tr>
<td>All other SRs</td>
<td>6</td>
<td>-0.14</td>
<td>-0.14</td>
<td>-0.12</td>
<td>-0.12</td>
</tr>
</tbody>
</table>

TX Oph, BR Tel, V820 Cen, AI Sco, EN TrA and V385 CrA showed unusually large phase shifts. Of these, TX Oph and V820 Cen have known Balmer emission; spectra are not yet available for the others. EN TrA, probably a 36-day Cepheid, may also show such emission.

Fig. 1 displays two interesting variables which illustrate light and color variations encountered among semiregular pulsators. The SRd variable V3955 Sagittarii was first studied by Hector Alvarez on objective-prism plates (Alvarez 1979). A spectrum taken by Baird 37 days past V maximum shows moderately strong TiO bands and very conspicuous emission in Hβ through Hδ. In the photometry, the effects of the emission are evident in the large U-B amplitude. The relatively large amplitude in R-I compared to that in V-R points up the influence of the TiO bands, which affect flux through the R filter most strongly and the V filter somewhat but hardly affect the I band.

The other star is the remarkable variable SY Circini, which displays the alternating deep and shallow minima characteristic of RV Tauri stars but has a much greater V amplitude, more like that of a Mira variable. However, its average B-V (uncorrected for reddening) is only 1.34. SY Cir certainly deserves further study, especially spectrographically.

4. NORTHERN VARIABLES

I have been monitoring around two dozen northern semiregular variables, in particular those in the RV Tauri and SRd categories, with interspersed
photoelectric UBVRcI photometry and spectra, since 1991. The Mount Laguna

Fig. 1. Light curves in U, B, V, Rc and I for V3955 Sgr and SY Cir.

CCD spectra were obtained at the 1.0 m telescope and cover the 3950 - 4450 Å range with 42 Åmm dispersion at Hγ. Spectra were classified against MK standard stars as listed in the revised-MK catalog of Kennan and McNeil (1989), using the methods described in Keenan and McNeil (1976). While not as extensive as the CTIO observations, the photoelectric photometry allows one to place the spectra into an approximate phase context. Reduction of the photometry and spectra is continuing.

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REFERENCES

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