Sparsely-Observed Pulsating Red Giants in the AAVSO Observing Program

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Abstract This paper reports on time-series analysis of 156 pulsating red giants (21 SRa, 52 SRb, 33 SR, 50 Lb) in the AAVSO observing program for which there are no more than 150-250 observations in total. Some results were obtained for 68 of these stars: 17 SRa, 14 SRb, 20 SR, and 17 Lb. These results generally include only an average period and amplitude. Many, if not most of the stars are undoubtedly more complex; pulsating red giants are known to have wandering periods, variable amplitudes, and often multiple periods including “long secondary periods” of unknown origin. These results (or lack thereof) raise the question of how the AAVSO should best manage the observation of these and other sparsely-observed pulsating red giants.

AAVSO keywords = AAVSO International Database; photometry, visual; pulsating variables; giants, red; period analysis; amplitude analysis

ADS keywords = stars; stars: late-type; techniques: photometric; methods: statistical; stars: variable; stars: oscillations

1. Introduction

Red giants are unstable to radial pulsation. As they expand and cool, the period and amplitude of pulsation increase. Pulsating red giants (PRGs) are classified as Mira if they have well-pronounced periodicity and visual amplitude greater than 2.5, as SRa if they have smaller amplitudes and persistent periodicity, as SRb if the periodicity is poorly expressed, and Lb if the variability is irregular. These classes are arbitrary; there is a spectrum of behavior from strictly periodic to completely irregular, and of amplitudes from millimagnitudes up to 10 magnitudes.

The AAVSO International Database contains observations of thousands of PRGs. Some are well-studied, especially the brighter Miras; see Templeton et al. (2005) for a study of the periods and period changes in 547 of them. There are many, however, which have not been studied, often because the number of observations is insufficient. A few years ago, my students and I undertook a study of some PRGs for which there were only a few hundred observations: SRa/SRb/SR stars (Percy and Tan 2013, Percy and Kojar 2013) and Lb stars (Percy and Long 2010, Percy and Terziev 2011).

The present paper describes a study of several dozen more SR and Lb stars for which there were a total of 150-250 observations, and for which analysis might be possible. I thank Elizabeth Waagen, at AAVSO HQ, for compiling lists of these sparsely-observed SRa, SRb, SR, and Lb stars. Although the primary purpose of this study was to determine the basic variability parameters of as many of these stars as possible, an equally-important purpose was, more generally, to determine whether sparsely-observed PRGs can yield any meaningful results.

2. Data and Analysis

Observations were taken from the AAVSO International Database (Kafka 2018). They ranged from all visual for some stars, to all Johnson V (photoelectric or CCD) for others. Periods
Figure 1: EQ And is classified as SR. The phase diagram using visual observations and a period of 270.48 days, shown here, is quite satisfactory. The period in VSX, 211: days, does not produce a good phase diagram.

were determined (or searched for) using the Fourier routine in the VSTAR software package (Benn 2013). Some of the stars had been studied with the All-Sky Automated Survey (ASAS: Pojmanski 1997), and a period had been derived. In many cases, the ASAS light curve showed that the variability was complex, and occurred on two or more periods or time scales. This may be true for most of our stars.

3. Results

Tables 1-4 list results for the stars classified as SRa, SRb, SR, and Lb, respectively. Columns list: the star; the period in the VSX catalog (PVSX); the mean period and semi-amplitude obtained in the present study; and notes about the star. Visual amplitudes are denoted v; Johnson V amplitudes as V. The notes are as follows: 1: new period gives a better phase curve than PVSX; 2: new period and PVSX give equally good phase curves; 3: PVSX gives a poor phase curve; 4: neither new period or PVSX gives a good phase curve; *: see note in section 3.1. Figure 1 gives one example: of an SR star (EQ And) which shows a quite acceptable phase curve.

Many of the Lb stars in Table 4 were observed primarily in Johnson V, and produce acceptable results with only a few dozen observations.

The following are the number of stars analyzed, and the number and percent which produced results, and which appear in Tables 1-4: SRa: 21, 17, 81%; SRb: 52, 14, 27%; SR: 33, 20, 61%; Lb: 50, 17, 34%.

3.1 Notes on Individual Stars

These notes on individual SRa, SRb, SR, and Lb stars are combined, and listed in order of constellation. Many of the 156 stars in the input list also have observations from other sources, such as ASAS, Hipparcos, DIRBE (Smith et al. 2002), AFOEV etc. but, unless they helped in the analysis or interpretation of the AAVSO data, they are not discussed here.

KW Cep: the Fourier spectrum is complex; the dominant cycle lengths are about 150 days.

UZ Cet: the ASAS period is 80.9 days, but the average cycle length is about 117 days. PVSX,
Figure 2: RU Leo is classified as Lb (irregular). The phase diagram using Johnson V observations and a period of 161 days, shown here, is quite satisfactory.

the new period, and the ASAS period produce equally unsatisfactory phase curves, but PVSX is probably the best.

**RU CrB**: the V observations show cycle lengths of about 60 days, but the early visual observations give a period of 436 days, which may possibly be a long secondary period.

**VY Eri**: the ASAS light curve is very complex; irregular or multiperiodic star?

**TZ Hor**: there is also a peak at 23.41 days, but the cycle lengths are 35 days.

**DV Lac**: the Fourier spectrum is complex, with cycle lengths in the range of 150 to 180 days.

**RS LMi**: complex; cycle lengths about 110 days; there may be a long secondary period.

**V360 Peg**: the *General Catalogue of Variable Stars* (Samus et al. 2017) classifies this star as possibly RV Tauri type, but we find no evidence for this.

**SW Pic**: the V observations show periods of about 25 and 35 days.

**TW Ret**: the *General Catalogue of Variable Stars* (Samus et al. 2017) classifies this star as possibly RV Tauri type, but we find no evidence for this.

**BN Ser**: there are several peaks of comparable height in the Fourier spectrum. There appears to be a long secondary period.

4. Discussion

In the AAVSO observing program, there are 155 PRGs which are designated as “legacy stars”, and recommended for regular observation. Over the last decade, they have averaged about 375 observations per year (Pearce 2018). These dense, sustained observations enable astronomers to follow their wandering periods, variable amplitudes, multiperiodicity, and long secondary periods (LSPs).

For the 156 stars in the present study, there are less than 250 observations in total. As a result, less than half the stars yield any meaningful result, that usually being only an estimate of the average period and amplitude. There are some stars which have only a few dozen V observations obtained on a single night (!). For others, sparse observations are spread over many decades. For others, the Fourier spectra showed many comparable peaks, with none of them prominent.
Some PRGs are known to pulsate in both the fundamental and first-overtone modes. There may be some stars for which the derived period is actually an LSP, with the shorter pulsation period hidden in the noise. Some stars, especially the Lb stars, may be truly irregular.

A few of the Lb stars in Table 4 had only one or two cycles of V observations, so it was not possible to say whether they showed any strict periodicity. A few others had more V observations, but not enough to say whether they were multiperiodic or irregular. A few, such as OR Cep, RU Leo (Figure 2), and Z LMi, showed good phase curves, and may be SR. Some of the stars in Tables 1-4 may, of course, have been misclassified as to variable star type because of limited observations.

5. Conclusions

Of the 156 stars that were examined, less than half yielded any useful information, that being an average period and amplitude. In many cases, that information was uncertain. It is noteworthy, however, that about a third of the Lb (irregular) variables showed some periodicity.

It is not clear that continued sparse observation of the stars in this study will yield better results. And there are many more PRGs in the AAVSO observing program with less than 150 observations in total, and which were therefore not included in the present study. AAVSO might wish to think seriously about how to manage these PRGs in its observing program. If it is decided that these stars should continue to be observed, then it might be best if observers “adopted” stars for a year or two (or three), to ensure that they were observed sufficiently regularly.

6. Acknowledgements

I thank the AAVSO observers who made the observations on which this project is based, the AAVSO staff who archived them and made them publicly available, and the developers of the VSTAR package which was used in the analysis. Special thanks to Elizabeth Waagen. This project made use of the SIMBAD database, maintained in Strasbourg, France. The Dunlap Institute is funded through an endowment established by the David Dunlap family, and the University of Toronto.

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### Table 1: Variability Properties of Some SRa Stars

| Star    | PVSX (days) | P(days) | Amp (mag) | Notes                                      |
|---------|-------------|---------|-----------|--------------------------------------------|
| UV Aql  | 385.5       | 350±30  | 0.17v     | many peaks                                 |
| LQ Ara  | 183.7       | 179.73  | 0.34v     | 1: data consistent with PVSX               |
| FX Cas  | 289         | 292.4   | 1.44v     |                                            |
| V533 Cas| 305         | 303.67  | 1.04v     |                                            |
| V864 Cas| –           | 344     | 1.00V     | P(vis) = 368 days                          |
| AL Cen  | 125         | 128.7   | 0.69v     | 1, ASAS P = 126.64 days                   |
| V343 Cep| 525         | 482.9   | 0.93v     |                                            |
| UZ Cet  | 121.74      | 203.34  | 0.14V     | *, 1, multiperiodic?                       |
| V577 Cyg| 479         | 478.5   | 0.32v     | 1, P(V) = 460.8 days                      |
| V659 Cyg| 514         | 509.68  | 0.73v     |                                            |
| V1059 Cyg| 372        | 380±10  | 0.18v     | poor phase curve; period spurious?         |
| AY Her  | 129.75      | 127.58  | 1.05v     | 2                                          |
| IV Peg  | 214.0       | 213.8   | 0.95v     | 1, ASAS P = 210.387 days                  |
| TW Ret  | 217.6       | 225.99  | –         | *, 2, RVT according to SIMBAD             |
| VV Tel  | 138.8       | 137.6   | 0.73v     |                                            |
| UZ Vel  | 354         | 390.6   | 0.16v     | 1; ASAS P = 353 days                      |
| AAVSO 0705+29 | 106.2 | 106.64  | 0.43v     | 3                                          |

### Table 2: Variability Properties of Some SRb Stars

| Star    | PVSX (days) | P(days) | Amp (mag) | Notes                                      |
|---------|-------------|---------|-----------|--------------------------------------------|
| W Ara   | 122         | 119.6   | 0.14v     | 1, ASAS P = 121.8 days                     |
| V505 Car| 26.5        | 20.266  | 0.02V     | and/or 26.408 days                         |
| V481 Cas| 158.4       | 159     | 0.07V     |                                            |
| R Cir   | 222         | 366.3?  | 0.24v     | 1, 3, ASAS P = 220 days                   |
| RU Crt  | 60.85       | 700     | 0.39v     | broad peak in Fourier spectrum            |
| AQ Del  | 71.9        | 71.6    | 0.16v     | 1, ASAS P = 73.61 days                    |
| VY Eri  | 102.5       | 189     | 0.23v     | *, 1, ASAS P = 191 days, one cycle in V   |
| V521 Ori| 221         | 225.17  | 0.36V     | 1                                          |
| X Pav   | 199.19      | 400.3   | 0.33v     | 1                                          |
| V443 Per| 69.5        | 69.9    | 0.17V     | 3, LSP ~ 400 days                         |
| RW Psc  | 154         | 154.2   | 0.15v     | 2                                          |
| Z Ser   | 88.2        | 88.3    | 0.18v     | P(ASAS) = 89.379 days                     |
| BN Ser  | 140.7       | same    | 0.17V     | *, ASAS P = 144.131 days                  |
| GK Vel  | 120:        | 182:    | 0.08v?    | 1, several peaks including 123.7 days     |
Table 3: Variability Properties of Some SR Stars

| Star     | PVSX (days) | P (days) | Amp (mag) | Notes                                      |
|----------|-------------|----------|-----------|--------------------------------------------|
| EQ And   | 211:        | 273.6    | 0.82v     | 1; see Figure 1                             |
| KQ Aql   | 164.2       | 417      | 0.50v     | 2, PVSX gives good phase curve              |
| V925 Aql | –           | 398.8    | 0.18v     | poor phase curve                            |
| SZ Ara   | 221.8       | 219.8    | 0.77v     |                                            |
| UW Cam   | 544         | 523.3    | 0.33v     | variable amplitude                          |
| AM Car   | 314         | 408      | 0.45v     | 1; also 50-day cycles                       |
| RU CrB   | 436         | 427      | 0.2V *    |                                            |
| V1673 Cyg| 115.5       | 116.5    | 0.15v     | PVSX is an alias                            |
| AE Del   | 260         | 152.5    | 0.67v     |                                            |
| V529 Her | 400         | 197.3    | 0.10v     | 2                                           |
| TZ Hor   | ???         | 35.52    | 0.02V *   | *; also 23.41 days                          |
| Y Mic    | 364:        | 180±2    | 0.18v     | 4                                           |
| V360 Peg | 44.9        | 45.28    | 0.09V *   | *; 1, RV Tau evidence weak                  |
| V Pic    | 180         | 173.3    | 0.62v     | 1                                           |
| SW Pic   | –           | 25.2±0.1 | 0.026V *  |                                            |
| γ Ret    | 25          | 29.87    | 0.034V    |                                            |
| DR Tuc   | –           | 23.59    | 0.028V    | Hipparcos $P = 23.87$ days                  |
| o Vir    | –           | 30.50    | 0.036V    |                                            |
| NSV11453 | 153         | 296.47   | 0.85v     | 1                                           |
| OOO-BLG-605| 78.09     |          | 0.21V     | 2                                           |

Table 4: Variability Properties of Some Lb Stars

| Star     | P (days) | Amp (mag) | Notes                                      |
|----------|----------|-----------|--------------------------------------------|
| KR Cep   | 50       | 0.13V     | one cycle in V                             |
| KT Cep   | 77       | 0.16V     | two cycles in V                            |
| KW Cep   | 170±10   | 0.15v     | *; complex; cycles 150 days long           |
| OR Cep   | 348.5    | 0.97v     | good phase curve                           |
| DV Lac   | 170±10   | 0.27V     | *; irregular; result uncertain             |
| PY Lac   | 95       | 0.19V     | one cycle in V; also short-period variability? |
| RU Leo   | 161      | 0.38V     | good phase curve                           |
| VX Leo   | 95.6     | 0.16V     | good phase curve, but complex, multiperiodic? |
| CP Leo   | 190:     | 0.07V     | poor phase curve; complex, multiperiodic?   |
| GK Leo   | 345±5    | 0.16V     |                                            |
| Z LMi    | 161:     | 0.31V     | good phase curve                           |
| RS LMi   | 90:      | 0.13V     | *; poor phase curve; complex                |
| CX Mon   | 385      | 0.35v     | fair phase curve                           |
| WW Psc   | 25±      | 0.03V     |                                            |
| FL Ser   | 390±2    | 0.16v     | fair phase curve                           |
| TT UMa   | 490±10   | 0.1v      | fair phase curve                           |
| NSV 623  | 74 ±2    | 0.25v     | uncertain; $\Delta V = 0.50$               |