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.

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 range 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 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: Pojmański 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 are 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, 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 (Figure 2), RU Leo, 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.

Another important development is the ASAS-SN (All-Sky Automated Survey for Supernovae) project, based at Ohio State University. In the near future, it will have pre-computed light curves for all the stars in the VSX catalog at https://asas-sn.osu.edu/variables.

Thus, the management of the AAVSO observing programs will have to be done in the context of ASAS-SN and other large all-sky surveys.

6. Acknowledgements

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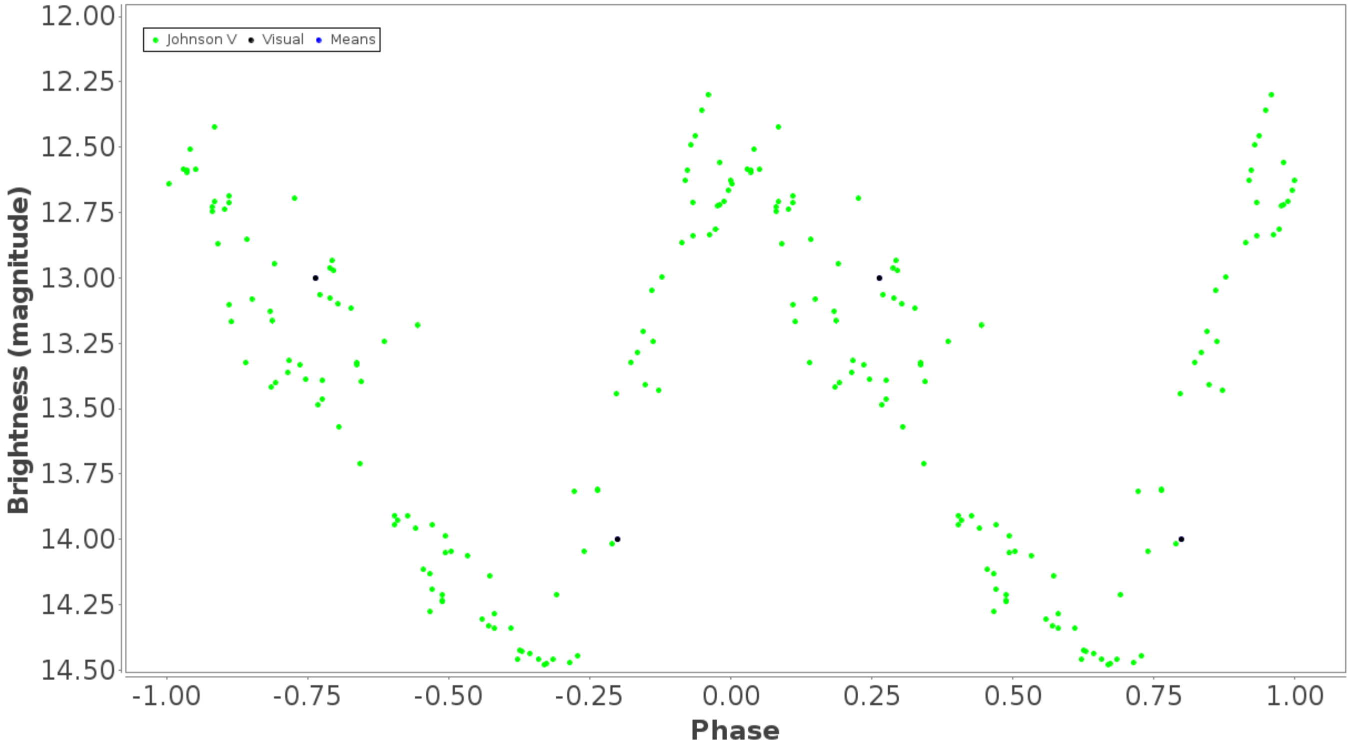

Figure 1. Phase plot for EQ And, 13 Jun 2018 (database). EQ And is classified as SR. The phase diagram using mostly Johnson V observations (green), a period of 270.48 days, and epoch 2454781.925, shown here, is quite satisfactory. The period in VSX, 211: days, does not produce a good phase diagram.

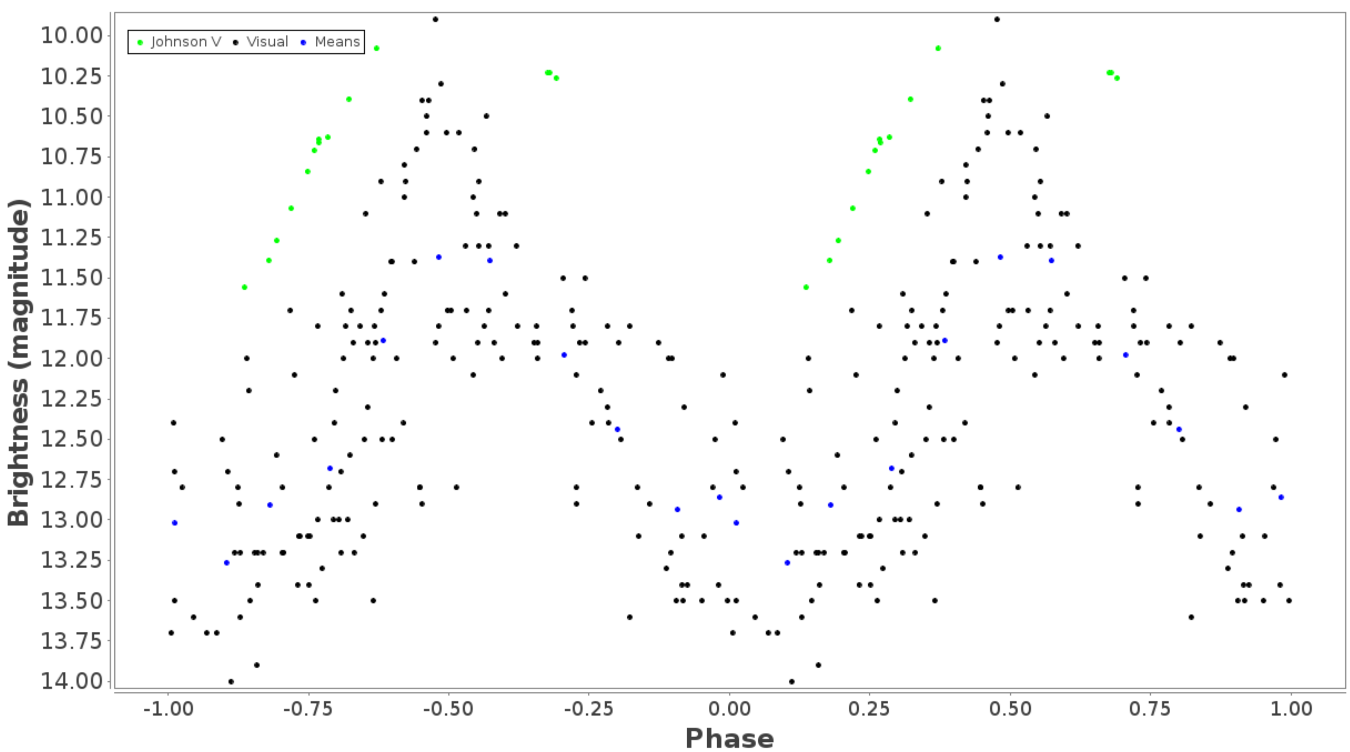

Figure 2. Phase plot for OR Cep, 13 Jun 2018 (database). OR Cep is classified as Lb (irregular). The phase diagram using mostly visual (black) and a few Johnson V (green) observations, a period of 348.5 days, and an epoch of 2454651.51, shown here, is quite satisfactory.

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:
FX Cas	289	292.4	1.44v	data consistent with PVSX
V533 Cas	305	303.67	1.04v	1
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	1
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	1
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	0.70V	1
UZ Vel	354	390.6	0.16v	1:, ASAS P = 353 days
NSVS J0712062+293744	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	1
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	*; 2, 436 days may be an LSP
V1673 Cyg	115.5	116.5	0.15v	
AE Del	260	152.5	0.67v	PVSX is an alias
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
OGLE-BLG-LPV-062772	78.09	same	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; Figure 2
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; $\Delta V = 0.50$