Period Analysis of AAVSO Visual Observations of 55 Semiregular (SR/SRa/SRb) Variable Stars

John R. Percy
Paul Jx Tan
Department of Astronomy and Astrophysics, University of Toronto. Toronto, ON M5S 3H4, Canada; john.percy@utoronto.ca

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Abstract We have used AAVSO visual data, and Fourier analysis and self-correlation analysis, to study the periodicity of 55 semiregular (SR) variables—21 SRa and 34 SRb. According to the standard system of variable star classification, these are pulsating red giants, with visual amplitudes less than 2.5 magnitudes, which show noticeable periodicity (SRa) or less-obvious periodicity (SRb). We find that their behavior ranges from highly periodic to irregular; some are not significantly variable. We have used a simple index, based on self-correlation analysis, to show that, on average, the SRa variables have a larger component of periodicity than the SRb variables, as expected. The distributions of this index for the two groups, however, overlap considerably. Of our 55 stars, 11 definitely or possibly show two radial periods, and at least 16 definitely or possibly show a long secondary period. We also analyzed three non-SR stars: T Cet is a double-mode SRc star; T Cen is an RVa star which should be reclassified as RVb; V930 Cyg is an irregular (Lb) star with a strong 250-day period.

1. Introduction

Pulsating red giants are classified in the *General Catalogue of Variable Stars* (GCVS; Kholopov *et al.* 1985) as Mira (M) stars if their visual amplitude is greater than 2.5 magnitudes, and semiregular (SR) or irregular (L) variables if their visual amplitude is less than that value. See Kiss and Percy (2012) for a brief review of SR variables. SR variables are subdivided into SRa and SRb (both giants), where SRb have less obvious periodicity than SRa, and SRc (supergiants). There are also SRs variables which are SR variables with "short" periods (generally 30 days or less); about 100 stars are placed in this (arbitrary) class.

These types are defined thus: SR: "...giants or supergiants of intermediate and late spectral types showing noticeable periodicity in their light changes, accompanied or sometimes interrupted by various irregularities...." L: "Slow irregular variables. The light variations of these stars show no evidence of periodicity, or any periodicity present is very poorly defined, and appears only occasionally...." Clearly these definitions are qualitative at best, but they were reasonable in the early days of variable star astronomy, especially if they were based on dense, long-term visual or photographic light curves.

Kiss *et al.* (1999) carried out an important study of a large sample of SR variables, also using AAVSO visual observations. They found that many of these stars had two or more periods, some identified with low-order radial pulsation modes, and some being "long secondary periods" whose nature and cause is unknown (Nicholls *et al.* 2009). And at least one star, R Dor, is known to switch between two periods (Bedding *et al.* 1998).

SR variables obey a series of period-luminosity relationships, corresponding to different radial modes. These P-L relationships were first observed in the MACHO and OGLE large-scale surveys of the Magellanic Clouds (Wood 2000), and later in a large sample of nearby variables with Hipparcos parallaxes (Tabur *et al.* 2009).

In a series of earlier papers (Percy and Terziev 2011 and references therein), we analyzed AAVSO visual observations of a large number of "irregular" (L-type) pulsating red giants. We found some to be slightly periodic, some to be irregular, and many to be not significantly variable (or microvariable at best).

In the present study, we analyzed 55 SRa and SRb variables which were not studied by Kiss *et al.* (1999), for the purpose of examining the periodicity of the stars in these two groups, and determining whether there are any differences in the periodicity. We used both Fourier analysis and self-correlation analysis to look for periods, including long secondary periods. An important subsidiary purpose was to provide feedback to AAVSO observers on how their thousands of measurements are used in astronomical research. Another purpose was to demonstrate how undergraduate students (such as co-author Tan) can carry out meaningful astronomical research using archival variable star data.

2. Data and analysis

We have used visual observations of 55 SR variables in the AAVSO International Database (AID), as listed in Tables 1 and 2. We chose stars which had a sufficient number of measurements, but which had not been studied by Kiss *et al.* (1999). AI Cyg, GY Cyg, RS Gem, RX UMa, and V930 Cyg (see below) were classified as "uncertain" by Kiss *et al.* (1999), so we re-analyzed them here. There were more SRb stars that obeyed these criteria than SRa stars. Our methodology was very similar to that used in our studies of L-type variables (Percy and Terziev 2011): we use Fourier analysis and self-correlation analysis. The latter shows the cycle-to-cycle behavior of the star, averaged over the dataset (Percy and Sen 1991; Percy and Mohammed 2004). We initially called this method *autocorrelation*, because it is a simple version of that well-established technique. Laurent Eyer then pointed out that it was actually a form of *variogram* analysis (Eyer and Genton 1999). We have since used the name *self-correlation* to avoid any confusion. Fourier analysis is much better for analyzing multiperiodic variables, unless the periods are an order of magnitude different, as in the case of the "long secondary periods." In that case, self-correlation is certainly valid and useful.

The self-correlation diagram (Figures 1–4) allows us to define a simple measure of the fraction of the stars' variability which is periodic. Let A be the intercept on the vertical axis; it is a measure of the average observational error in the data (because, if two measurements are independently made, a short time apart, they will on average differ by the average observational error). Let B be the level of the first maximum in the diagram, and let C be the level of the first deep minimum. Then define k = (B–C)/(B–A). If k = 1, the star is periodic; if k = 0, the star is irregular. The values of k are given in the Tables. For RW Sgr (Figure 2), for instance: A = 0.30, B = 0.76, C = 0.36, and k = 0.87.

3. Results

The results are summarized in Tables 1 and 2 for the SRa and SRb stars, respectively. The tables list the stars, their range and period from the *Variable Star Index* (VSX; Watson *et al.* 2012), the intercept on the vertical axis of the self-correlation diagram (which, as mentioned, is a measure of the average observational error in the data), the period and amplitude determined from Fourier analysis, the period and amplitude determined from self-correlation analysis, the index k, and the presence or absence of a long secondary period. VSX is located on the AAVSO website. Many of the SRb variables had VSX periods that were uncertain or unknown. The VSX periods come from various sources, including the GCVS "living" version maintained by the Sternberg Astronomical Institute.

As mentioned: self-correlation analysis is not useful for determining multiple periods, unless they are of different orders of magnitude. The self-correlation periods marked with an asterisk (*) were not independently determined by self-correlation but, for these stars, the forms of the self-correlation diagrams are consistent with the Fourier periods. The periods that we would prefer are in bold face.

For the ten stars which clearly have two radial periods, the period ratios are tightly clustered between 0.499 (AY Dra) and 0.598 (RV Mon); in fact, 9 stars have ratios between 0.499 and 0.544. This is consistent with the result of Kiss *et al.* (1999). The identification of these two radial periods is important, because it indicates which radial modes the periods correspond to, and which P-L relationship these stars would obey.

The long secondary periods in Tables 1 and 2 are typically an order of magnitude longer than the radial periods, as has been found in other pulsating red giants. The median ratio is 9.3, with a tendency for a higher ratio in stars with longer periods. There may be other LSPs which eluded us; Houk (1963), for a few stars, gives LSPs which we did not find (see sections 3.1 and 3.2).

The mean k values were 0.67 for the SRa variables, and 0.52 for the SRb variables. This indicates that the SRa variables have a slightly greater component of periodicity than the SRb variables, as might be expected. But there is considerable overlap between the two distributions of k values; each group contains some stars that are highly periodic, and some that are irregular.

We analyzed three stars which were on our original list of SR variables, but which are actually of other types. T Cet is an SRc star; it has periods of 160.8 and 287.7 days. T Cen is an RVa star with a period of 90.5 days (Fourier) or 91 days (self-correlation) and an amplitude of 0.59 magnitude. It also has an LSP of 900 days, so it should be reclassified as an RVb star. V930 Cyg (classified by Kiss *et al.* (1999) as "uncertain") is an Lb star with a period of 252.3 days (Fourier) or 248 days (self-correlation) and an amplitude of 0.41 magnitude, so it should probably be re-classified as SR.

As in our studies of L-type variables using visual observations, a few stars show low-level signals at periods of a year (TV And, TX Tau, V380 Sco, BR Eri, RR Eri, RT Ori, RV Mon, TT Per, and TU Gem), or a month (V380 Sco), which we ascribe to the Ceraski effect, which is an artifact of the visual observation process.

3.1. Notes on individual SRa stars

AK Peg: our results support the VSX period of 193.6 days.

AO Dra: we find a period of 143.5 days, which is not consistent with the VSX period of 103 days.

AY Dra: in addition to the VSX period of 262.5 days, we find a period of 130.8 days.

AY Her: we find a period of 127.3 days, which is close to the VSX period of 129.75 days.

BD Peg: we do not find the VSX period of 78 days in our data, with an amplitude greater than 0.02 mag.

DX Peg: the VSX period of 80.66 days is not present in our data.

EP Vel: we find a period of 259 days, which is close to the VSX period of 240 days; we find an additional period of 515 days. Both periods are strong and coherent.

RS Dra: we find a period of 278.2 days, which is close to the VSX period of 282.72 days; we find an additional period of 143 days. The 278.2-day period is strongest in the first half of the data, the 143.4-day period in the second half.

RT Cas: our results support the VSX period of 399.8 days.

RW Eri: our results support the VSX period of 91.4 days; we also find a long secondary period of 950 days.

RW Sgr: we find a period of 188.4 days, which is close to the VSX period of 186.82 days.

SZ Lyr: we find a period of 143.7 days, which is close to the VSX period of 133.1 days; we also find a weak period of 74 days.

TV And: we find a period of 111.7 days; the VSX period is 110 days.

TV Tau: we find no evidence for the VSX period of 120 days.

TX Tau: we find no evidence for the VSX period of 40.1 days, with an amplitude greater than 0.02 magnitude.

TY Cep: we find a period of 344.1 days, which is close to the VSX period of 330 days.

V380 Sco: we find no evidence for the VSX period of 187.17 days; the star appears irregular.

V577 Cyg: our results support the VSX period of 479 days.

V927 Cyg: we find no evidence for the VSX period of 229 days.

VY Aps: we find a period of 164.7 days, which is close to the VSX period of 152 days.

X Oct: we find a period of 200.8 days, which is consistent with the VSX period of 200 days.

3.2. Notes on individual SRb stars

AI Cyg: we find periods of 142 and 273 days, which are not consistent with the VSX period of 197.3 days.

BG Mon: we find no evidence for the VSX period of 30: days, with an amplitude greater than 0.02 mag; the star appears irregular.

BR Eri: the VSX period of 73.3 days is weakly present in our data, but is uncertain; otherwise, the star appears irregular.

DP Ori: we find periods of 246.1 and 127: days; the VSX period of 90: days is not present in our data.

FX Ori: we find a period of 692.2 days, which is close to the VSX period of 720 days.

GY Cyg: we find a period of 250 days which is not inconsistent with the VSX period of 300: days.

R Dor: we find periods of 176.3 and 329.8 days, the former being close to the VSX period of 172 days. This star has been extensively studied by Bedding *et al.* (1998), who found mode-switching between the 176- and 330-day periods.

RR Eri: we find a period of 93: or 90 days, which supports the VSX period of 94.6 days.

RS Gem: we find periods of 270.3 and 147: days, the latter being consistent with the VSX period of 140: days.

RT Ori: we do not find strong evidence for the VSX period of 321 days, or for any other period. Houk (1963) gives an LSP of 3200 days.

RT Psc: we find a period of 515.7 days, but no evidence for the VSX period of 70 days.

RU Per: we find periods of 93 and 602: days, but no evidence for the VSX period of 170: days.

RV Mon: we find periods of 585 and 979 days, but no evidence for the VSX period of 121.3 days. The long-term light curve is complex; there may be a 2700-day LSP. Houk (1963) gives a period of 132 days.

RX UMa: we find a period of 200.2 days, which is close to the VSX period of 195 days.

RY Cam: we find a period of 135.1 days, which is consistent with the VSX period of 135.75 days.

S Lep: we find a period of 855.5 days, and possibly 90 days with an amplitude of 0.02 or less; the VSX period is 97.3 days.

SW Mon: we find periods of 103.5 and 193.5 days; the VSX period is 112 days.

SY Eri: we find a possible period of 330: days with very low amplitude, but no evidence for the VSX period of 96: days.

SY For: we find a period of 151.3 days, but no evidence for the VSX period of 55: days.

TT Per: we find a long period of 2360 days, but no evidence for the VSX period of 82 days.

TT Tau: we find no evidence for the VSX period of 166.5 days, or for any other period.

TU Gem: we find periods of 215 and 2406 days; the former is close to the VSX period of 230 days.

TW Aur: we find periods of 1350 and possibly 285 days, but no evidence for the VSX period of 150: days.

UX And: we find a period of 218.7 days, which is close to the VSX period of 200 days.

V Hor: we find a period of 63 days; there is no period given in VSX.

V Lyn: we find a period of 87.2 days; there is no period given in VSX.

V Pav: we find a possible period of 324: days, but no evidence for the VSX period of 225.4 days; the star is essentially irregular. Houk (1963) gives an LSP of 3735 days.

V431 Ori: we find possible periods of 273: and 2400 days, but no evidence for the VSX period of 122: days; the variability is weak.

V465 Cas: we find periods of 97 and 898.4 days, but no evidence for the VSX period of 60 days.

VZ Tel: we find a period of 81.2 days, but no evidence for the VSX period of 117.8 days.

W Nor: we find a period of 147 days; the VSX period is 134.7 days. Houk (1963) gives an LSP of 1300 days.

XZ Aur: we find a possible period of 120: days, but no evidence for the VSX period of 250 days; the star is essentially irregular.

Z Eri: we find periods of 78 and 729.0 days; the former is close to the VSX period of 74.0 days.

Z Psc: we find a period of 155.9 days, which is consistent with the VSX period of 155.8 days.

4. Discussion

We found one or more periods in almost all of the 55 stars. Most were new periods, or ones which differed from those in VSX. In the Tables, we have marked our preferred periods in bold face. Generally we have preferred our own periods, since we know how they were derived, and we have confidence in them. In most cases, it is not obvious how the VSX periods were derived. Where our periods are uncertain, and the VSX period appears to be well-determined, we have preferred it.

We have not attempted to form P-L relationships for our sample. A few of the brightest stars have Hipparcos parallaxes good to 25%, but most are fainter stars without accurate parallaxes.

Using our k index, we have estimated the proportion of the stars' variability that is periodic. Within each sub-class (SRa and SRb), there is a wide range of k. It is not clear how the stars were initially classified—presumably from inspection of the light curve. One could possibly define stars with k greater than 0.5 as SRa and those with k less than 0.5 as SRb.

One of the purposes of this paper was to provide feedback to AAVSO observers. It is often felt that visual observations are obsolete. The study of red giants (and other variables) has certainly been revolutionized by the ultra-precise photometric monitoring by space missions such as MOST, CoRoT, and Kepler (for example, Hekker *et al.* 2011), as well as by CCD photometry from the ground (Tabur *et al.* 2009), but these have not yet amassed the long (decades) datasets such as those in the AID. It is definitely desirable to extract as much scientific information as possible from the AAVSO data, which were so diligently collected over so many years. In this paper, we have done so. These data have provided information on the stars' basic periodicity, and on their long-term behavior.

This paper also has an educational dimension. Co-author Paul Tan was in the third year of the Astronomy and Physics Program at the University of Toronto. This project enabled him to integrate and apply a wide range of science, math, and computing skills. Based in part on his success in this project, he was awarded a 2012 summer research assistantship in the prestigious Dunlap Institute of Astronomy and Astrophysics.

We did not analyze all of the SRb stars in the AID, nor did we analyze the stars which were classified as SR or SR:. Furthermore: there may be SRa and SRb stars which we did not analyze because of small numbers of observations, which could still yield useful results from our methods of analysis. This can be a project for yet another undergraduate student.

5. Conclusions

We have used Fourier and self-correlation analysis to study the periodicity of 55 semiregular (SRa/SRb) pulsating red giants. For most of them, we have determined new or improved periods. Of the 55 stars, 11 show evidence for two radial periods, and at least 16 show evidence for long secondary periods. We have used a simple index, based on self-correlation analysis, to measure the fraction of the stars' variability which is periodic. The SRa variables show a higher index of periodicity than the SRb stars, as would be expected from their classification. But the distributions of the index overlap and, in each group, there are some stars with strong periodicity, and others with little or no periodicity.

6. Acknowledgements

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Table 1. Periodicity analysis of AAVSO visual observations of SRa variables.

Star	*Range*	*P(d)*[1]	δv	*P(Δv)[F]'*[1]	*P(Δv)[SC]*[1]	*k*	*LSP*
AK Peg	8.6–10.24V	**193.6**	0.32	193.1/0.36	193/0.20; 2500:	0.70	Y:
AO Dra	11.0–12.5p	103	0.20	**143.5**/0.40	142.5/0.35	0.83	N
AY Dra	10.6–12.6p	262.5	0.2:	**130.8**/1.63; **262.2**/1.6	130*; 260*	0.96	N
AY Her	10.5–12.8V	129.75	0.15	**127.3**/1.14	127/1.0	0.67	N
BD Peg	9.4–10.3p	78	0.20	**3300**/0.18	3300/0.1	0.83:	Y
DX Peg	8.7–9.6V	80.66	0.24	**499.2**/0.11	500/0.02	0.60:	?
EP Vel	9.8–11.2p	240	0.33	**259**/0.5; **515**/0.58	260*; 517/0.5:	0.76	N
RS Dra	9–12V	282.72	0.26	**143**/0.5; **278.2**/0.94	140*; 280*	0.81	Y:
RT Cas	11.0–14.0p	**399.8**	0.42	393:	400/0.90	0.95	N
RW Eri	10.2–11.7p	91.4	0.09	**91.4**/0.16; **950**/0.15	88:/0.1; 950:	0.32	Y:
RW Sgr	9–11.7V	**186.82**	0.30	188.4/0.34	188/0.45	0.87	N
SZ Lyr	10.3–12.5V	133.1	0.42	74:/0.08; **143.7**/0.14	144/0.14	0.60	N
TV And	8.3–11.5V	110	0.33	**111.7**/0.21	113.1/0.20	0.71	N
TV Tau	9.3–12.2V	120	0.37	—	—	0.65	N
TX Tau	10.5–12.3V	40.1	0.37	—	—	0.72	N
TY Cep	9.7–13.3V	330	0.23	**344.1**/0.29	335/0.27	0.71	N
V380 Sco	9.16–10.6V	187.17	0.38	—	—	0.00	N
V577 Cyg	10.3–11V	479	0.30	**480**/0.26	450/0.1	0.67	Y:
V927 Cyg	10.5–12.0p	229	0.35	**2900**/0.25	3000/0.12	0.29:	Y
VY Aps	11–14.52B	152	0.29	**164.7**/0.27	164/0.15; 2000:/0.1	0.52	Y:
X Oct	6.8–10.9V	200	0.57	**200.8**/1.38	201/1.4	1.00	N

[1] *The self-correlation periods marked with an asterisk (*) in column 6 were not independently determined by self-correlation but, for these stars, the forms of the self-correlation diagrams are consistent with the Fourier periods. The periods that we would prefer are shown in bold face in columns 3 and 5.*

Table 2. Periodicity analysis of AAVSO visual observations of SRb variables.

Star	*Range*	*P(d)*[1]	δv	*P(d)/Δv[F]*[1]	*P(d)/Δv[SC]*[1]	*k*	*LSP*
AI Cyg	9.2–11.8p	197.3	0.15	**142**/0.13; **273**/0.13	142*; 273*	0.50	Y
BG Mon	9.2–10.4V	30:	0.25	—	—	0.33:	N
BR Eri	6.5–8.16V	73.3:	0.32	—	—	0.38	N:
DP Ori	10.5–12.5p	90:	0.21	**127:**/0.1; **246.1**/0.23	125*; 242/0.1	0.59	N
FX Ori	7.7–10.4V	720	0.26	**692.2**/0.34	680/0.22	0.81	N
GY Cyg	10.6–12.5p	300:	0.14	**250**/0.08	250/0.03	0.36	N
R Dor	4.78–6.32V	172	0.28	**176.3**/0.1; **329.8**/0.15	175*; 335*	0.68	N
RR Eri	6.80–7.62V	94.6	0.22	93:	90/0.02	0.33	N
RS Gem	9.1–12V	140:	0.27	**147:**; **270.3**/0.22	150*; 270/0.15	0.64	N
RT Ori	9.7–11.8p	321	0.34	351:	—	0.57	N:
RT Psc	8.2–10.4p	70	0.27	**515.7**/0.20	525/0.08	0.69	N
RU Per	10–12V	170:	0.22	**93**/0.05; **602:**	90/0.02; 600	0.33	N
RV Mon	6.88–7.7V	121.3	0.31	**585**/0.1:; **979**/0.15	500; 1000	0.50:	Y:
RX UMa	9.8–12.2V	195	0.25	**200.2**/0.35	200/0.35	0.63	N
RY Cam	7.7–8.7V	**135.75**	0.23	135.1/0.20	135/0.18	0.81	N
S Lep	6–7.58V	**97.3**	0.19	855.5/0.24	90:/0.02; 854/0.13	0.60	Y:
SW Mon	9.05–10.9V	112	0.37	**103.5**/0.13; **193.5**/0.14	100*; 190*	0.65	N
SY Eri	10.4–11.4p	96:	0.24	330:/0.02	—	0.75:	Y:
SY For	11–12.57B	55:	0.25	**151.3**/0.30	147/0.25	0.82	N
TT Per	9.2–10.6p	82	0.28	**2360**/0.08	2400:/0.03	0.43	Y
TT Tau	10.2–12.2p	166.5	0.22	—	—	0.00	N
TU Gem	9.4–12.5p	230	0.25	**215**/0.1:; **2406**/0.1	215/0.03; 2400/0.02	0.50	Y:

Table continued on next page

Table 2. Periodicity analysis of AAVSO visual observations of SRb variables, cont.

Star	*Range*	*P(d)*[1]	δv	*P(d)/Δv[F]*[1]	*P(d)/Δv[SC]*[1]	*k*	*LSP*
TW Aur	9.1–10.6p	150:	0.20	**1350**/0.22	1333/0.08; 285;/0.03	0.40	Y:
UX And	8.2–9.9V	200	0.24	**218.7**/0.23	218/0.13	0.67	N
V Hor	8.7–9.8p	—	0.29	**63**/0.08	65/0.06	0.43:	N
V Lyn	9.5–12.0p	—	0.30	**87.2**/0.24	90/0.1	0.54	N
V Pav	9.3–11.2p	225.4	0.35	—	324:/0.05	0.40	N
V431 Ori	9.3–11.1V	122:	0.49	**273:**; **2400**/0.18	275:; 2400/0.03	0.33	Y
V465 Cas	6.1–7.2V	60	0.23	**97**/0.16; **898.4**/0.16	95/0.01; 900/0.04	0.40	Y
VZ Tel	12.7–14.0V	117.8	0.25	**81.2**/0.21	80/0.2	0.50	N
W Nor	10.3–11.6p	**134.7**	0.25	147/0.2	140:	0.75	N
XZ Aur	11.3–12.5V	250	0.36	—	120:	0.33	N
Z Eri	6.17–7.18V	**74.0**	0.26	78/0.06; **729.0**/0.15	75/0.02; 727/0.04	0.40	Y
Z Psc	6.37–7.49V	155.8	0.27	**155.9**/0.13	157/0.04; 260–300::	0.70	N

[1] *The self–correlation periods marked with an asterisk (*) in column 6 were not independently determined by self–correlation but, for these stars, the forms of the self–correlation diagrams are consistent with the Fourier periods. The periods that we would prefer are shown in bold face in columns 3 and 5.*

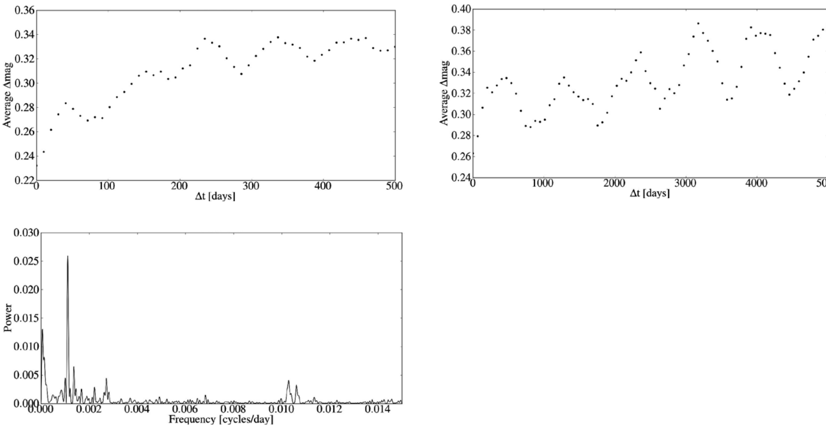

Figure 1. The self-correlation diagrams (top) and Fourier spectrum (bottom) for V465 Cas. The 90-day and 900-day periods show up as repeating minima in the self-correlation diagrams, and as peaks in the Fourier spectrum. The 900-day period is a "long secondary period" whose nature and cause are unknown.

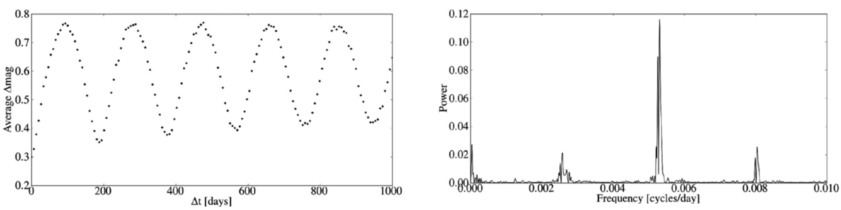

Figure 2. The self-correlation diagram (left) and Fourier spectrum (right) of RW Sgr. There is a single, strong period (and its one-cycle-per-year aliases in the Fourier spectrum).

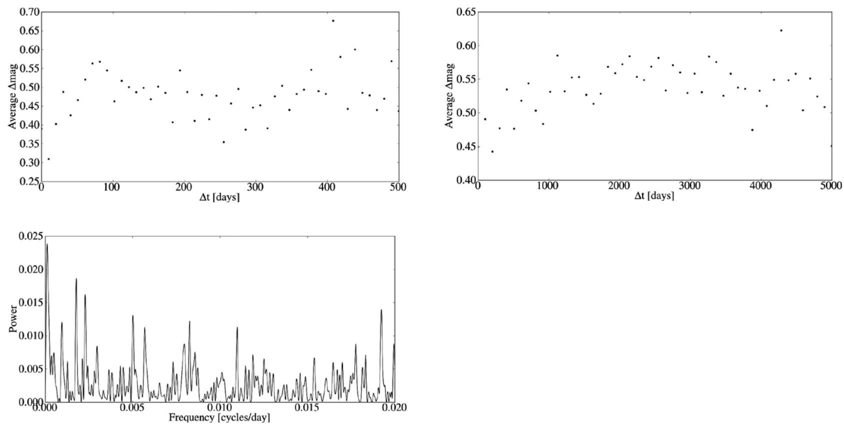

Figure 3. The self-correlation diagrams (top) and Fourier spectrum (bottom) for V Pav. There is no pattern of repeating minima in the self-correlation diagram, or conspicuous peaks in the Fourier spectrum. This star can be classified as irregular.

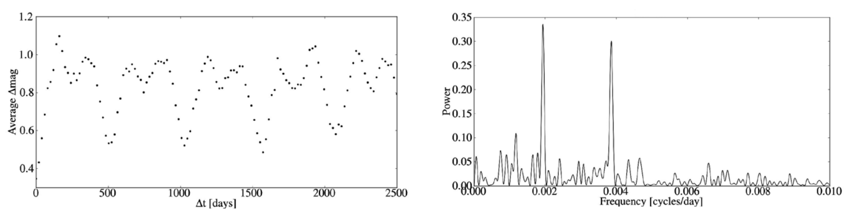

Figure 4. The self-correlation diagram (left) and Fourier spectrum (right) for EP Vel. They are consistent with the presence of two periods of 259 and 515 days, with approximately equal amplitudes.

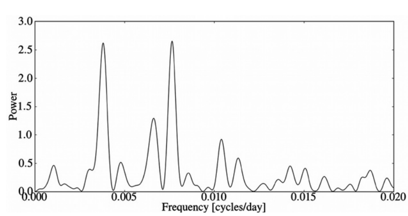

Figure 5. The Fourier spectrum for AY Dra, showing peaks corresponding to periods of 130.8 and 262.8 days, and aliases which are offset in frequency by 0.00274 cycle/day (a period of one year). There is no evidence of an LSP.

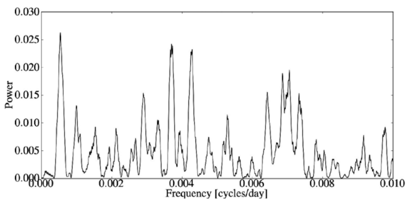

Figure 6. The Fourier spectrum for AI Cyg, showing peaks corresponding to periods of 142 and 273 days, and possibly an LSP. The input visual data are rather sparse.

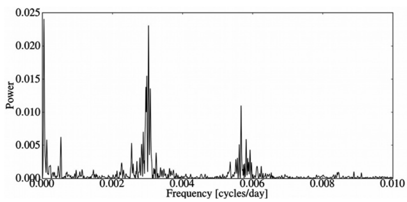

Figure 7. The Fourier spectrum for R Dor, showing peaks corresponding to periods of 176.3 and 329.8 days. The very low frequency signal presumably reflects the very slow, apparently-irregular variations in the mean magnitude of this star.

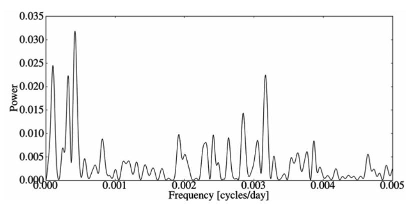

Figure 8. The Fourier spectrum for V431 Ori, showing peaks corresponding to low-amplitude periods of 273 and 2400 days, both visible in the self-correlation diagrams (not shown). The data are very noisy; the average error is 0.49 magnitude.