Long Secondary Periods in Pulsating Red Giants: A Century of Investigation

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Abstract Red giants (RGs) are unstable to radial pulsation. About a third of them also show a long secondary period (LSP), 5-10 times the pulsation period. The LSPs were recently ascribed to eclipses of the RG by a low-mass dust-enshrouded companion. LSPs have been known for over a century. In this paper, I use primarily AAVSO visual and photoelectric observations to look for evidence of LSPs in 103 red giant stars listed by Nancy Houk in 1963 as having LSPs, based mostly on photographic photometry. I have determined LSPs in 37 stars, and upper limits (some of them not very stringent) in 25. In the former, the ratio of LSP to pulsation period peaks strongly at 10, which suggests that most of the stars are pulsating in the first overtone. The LSPs are consistent with Houk’s in 33 of the 37 stars. I have identified 16 stars as bimodal pulsators; their period ratios are consistent with previous observational and theoretical results. For 14 stars, the periods in the General Catalogue of Variable Stars are incorrect or absent.

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

1. Introduction

Red giants (RGs) are unstable to pulsation in one or more radial modes. In general, the larger and brighter the star, the longer the pulsation period (P) and the larger the amplitude (A). About a third of RGs also have a long secondary period (LSP), 5 to 10 times longer than the dominant pulsation period, depending on whether the pulsation period is the fundamental or first overtone (e.g. Wood 2000). Until recently, the cause of the LSP was uncertain, but Soszyński et al. (2021) have made a strong case for a binary mechanism: the companion was initially a planet, which later accreted material from the RG wind, and grew into a brown dwarf or low-mass star, which produces the observed LSP velocity variations in the RG. The dust-enshrouded companion eclipses the RG periodically, producing the LSP.

LSPs have been known for almost a century; a series of three papers helped to bring them to attention (O’Connell 1933, Payne-Gaposchkin 1954, and Houk 1963). These papers use photographic photometry, some of it extending back to the late 19th century. O’Connell (1933) pointed out that the ratio of LSP/P was about 10, but only four of his stars were actually red giants, and his result depends strongly on one star – V Hya. Payne-Gaposchkin (1954) collected information on many more red giants, of various types, (but even included RR Lyrae stars showing the Blazhko Effect, which is a totally different phenomenon). Houk (1963), in her Table III, lists 103 PRGs with LSPs.

I was interested in how effective the photographic photometry was in identifying and measuring LSPs, and whether the LSPs would stand up with time. Therefore, in the present paper, I use visual and photoelectric V observations from the American Association of Variable Star Observers (AAVSO) International Database, and V observations from the All-Sky Automated
Survey for Supernovae (ASAS-SN) to investigate the primary and secondary periods, and to compare them with the periods listed in Houk (1963). Previous studies of LSPs in RGs have been carried out on selected stars, using the same databases. These include Percy and Deibert (2016) and Percy and Leung (2017), who studied RGs with long and dense AAVSO data, and Percy and Fenaux (2019), who carried out a pilot study of RGs using the much-shorter ASAS-SN data.

2. Data and Analysis

For the 103 stars listed in Table III of Houk (1963), I analyzed visual (v) and photoelectric (V) data from the AAVSO International Database (AID), and V data from the ASAS-SN variable star database and catalog (Shappee et al. 2014, Jayasinghe et al. 2018, 2019), using light-curve analysis and time-series analysis using the AAVSO VSTAR software package (Benn 2013). Note that VSTAR provides the semi-amplitude SA, not the full amplitude or range. The ASAS-SN data and light curves are freely available on-line (asas-sn.osu.edu/variables) as are the AID data and light curves, and the VSTAR package (aavso.org). The AAVSO v observations are limited by their low precision – typically 0.2 to 0.3 mag – but are very numerous for many of the stars. The AAVSO V observations tend to be sparse. The ASAS-SN observations extend over only a few years.

In some cases, a strategy which was helpful for determining the LSP was to bin the visual observations, in bins equal in length to the pulsation period. This strategy was less-useful when the SA was less than 0.1 mag, or when the star was a bimodal pulsator, or when the data were sparse and/or had unusually long seasonal or other gaps.

3. Results

Table 1 lists the 37 stars for which I found good evidence for an LSP; Table 2 lists 25 stars for which I found some evidence that an LSP is not present; we include a rough upper limit to the semi-amplitude that I could detect. In some cases, the upper limit was too large to be of much significance. Table 3 lists 16 stars which may be bimodal. Table 4 lists 15 stars for which the period in the General Catalogue of Variable Stars (Samus et al. 2017) is probably not correct, or is absent. Note that, for some stars in the sample, the GCVS period is the LSP, not the pulsation period.

For the following stars, I obtained no significant results about possible bimodal pulsation, or about LSPs, but there may be other useful information in the Notes, in the Appendix: SS And, V Aql, RX Boo, ST Cam, RS Cap, BZ Car, μ Cep, CV Cep, T Crt, RV Cyg, CH Cyg, V539 Cyg, EI Del, S Dra, UU Dra, V Eri, SU Hya, U Lac, WY Lac, KP Lyr, Y Mic, RV Mon, SX Mon, W Nor, TW Oph, V521 Oph, V574 Oph, RT Ori, V Pav, RT Pav, TT Per, BU Per, SY Vel.

4. Discussion

The stars in Table 1 have LSP SAs which tend to be small; for almost half, they are 0.1 mag or less. This is consistent with previous results in which the SAs are 0.5 mag or less. Three stars stand out, however: V Hya, with visual SA = 1.11, BU Lac, with visual SA = 0.88, and SV And with visual SA = 1.98. V Hya is a famous variable in which the deep minima are believed to be due to obscuration by a cloud associated with a companion passing in front of the red giant – an extreme example of the process proposed by Soszyński et al. (2021). SV And also has deep minima; my data are extensive enough to show that the amplitude of the LSP does not vary significantly over 100 years. It would be interesting to see whether the SA correlated with any other properties of the star.

The ratios LSP/P peak strongly at 9-10, which suggests that most of the stars pulsate in
the first overtone. This is to be expected, since most of the stars in the table are shorter-period pulsators, rather than large-amplitude Mira stars which tend to pulsate in the fundamental mode.

In 33 of the 37 stars in Table 1, my LSP is consistent with Houk’s. The ones that disagree are SV And, S Dra, RY Lac, and TW Oph.

There are a few stars for which I could find LSPs, but not pulsation periods. According to the Soszyński et al. (2021) hypothesis, there is no reason why a non-pulsating star could not have an LSP, though there would have to be some mechanism by which the companion could become dust-shrouded.

Table 2 lists stars which had adequate data, but in which I was not able to identify an LSP. For some of them, the upper limit to the SA was well below 0.1 mag. For others, the upper limit was sufficiently high that I cannot rule out an LSP.

Table 3 lists bimodal stars, and their pulsation period ratios. These cluster around 0.5, and are consistent with previous observed (Percy and Huang 2015) and theoretical values. There is more scatter than found by Percy and Huang (2015), but the trend of decreasing $P(\text{short})/P(\text{long})$ with increasing $P(\text{long})$ is present in our data.

One star had a second period which did not fit either the LSP or the bimodal classification: RW Psc with periods of 65 and 154 days. The former could be a second overtone and the latter a fundamental mode.

Note that Houk (1963) did not include possible bimodal pulsators in her list of stars – with one exception: RV Cyg, for which she proposed periods of 300 and 470 days. I was not able to obtain results on this star.

5. Conclusions

Of the 103 red giants listed by Houk (1963) as possibly having LSPs, I have found evidence for an LSP in 37 of them. In 33, the LSP that I have found is consistent with the value given by Houk (1963). For a few other stars, I have put stringent upper limits on the the amplitude of any LSP. For the rest, I do not have results, or cannot rule out an LSP. I conclude that the photographic photometrists of the past were rather successful in detecting and measuring LSPs in pulsating red giants, even when the amplitudes were small.

There are still many unanswered questions about this phenomenon, which occurs in a large fraction of RGs. The Soszyński et al. (2021) mechanism for producing LSPs is a fascinating and important one, and suggests that studies of LSPs should continue. A combination of long-term photographic and visual photometry, along with more modern techniques has the potential to answer some of the unanswered questions.

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Table 1: Stars with long secondary periods. The columns list: the star name, the periods given by Houk (1963), the pulsation period P, the LSP, the LSP SA, and LSP/P – the last four determined in the present paper.

| Star      | Houk Periods (d) | P (d) | LSP (d) | SA(LSP) | LSP/P |
|-----------|------------------|-------|---------|---------|-------|
| SV And    | 315.96, 930      | 314   | 2283    | 0.84    | 7.3   |
| TW Aur    | 150, 1370        | 144   | 1353    | 0.18    | 9.4   |
| U Cam     | 400, 3000        | 215   | 3000±200| 0.13    | 14.0  |
| RS Cam    | 88.6, 960        | 90.5  | 999 0.15| 11.0    |       |
| RS Cnc    | 120, 1700        | 239   | 2050±100| 0.07    | 8.6   |
| RT Cnc    | 90±542           | 93±3  | 650±100 | 0.06    | 7.0   |
| Y CVn     | 158, 2000-2200   | 160   | 2009    | 0.06    | 12.6  |
| TZ Car    | 69, 1183         | 70    | 1213    | 0.25    | 17.3  |
| VY Cas    | 100, 600         | 93.4  | 800±200 | 0.09    | 8.6   |
| AA Cas    | 115, 850         | 75±5  | 870     | 0.05    | 11.6  |
| SS Cep    | 90, 950          | 101.1 | 955     | 0.11    | 9.4   |
| RS CrB    | 69.5, 331        | 70    | 332     | 0.24    | 4.7   |
| AF Cyg    | 94.1, 960        | 93    | 913     | 0.08    | 9.8   |
| AW Cyg    | 220, 2200        | 205   | 2290    | 0.08    | 11.2  |
| S Dra     | 136, 1319        | 181.7 | 1000    | 0.08    | 5.5   |
| TX Dra    | 78, 654          | 77    | 700±15  | 0.14    | 9.1   |
| Z Eri     | 80, 746          | 78    | 710±20  | 0.10    | 9.1   |
| X Her     | 95.0, 746        | 100   | 700     | 0.08    | 7.0   |
| 30 g Her  | 70, 900          | 88    | 875     | 0.16    | 9.9   |
| V Hya     | 533, 6500        | 531   | 6500±500| 1.11    | 12.2  |
| RV Lac    | 67, 550-700      | 70    | 625±8   | 0.32    | 8.9   |
| RY Lac    | 38-91, 300-420   | 80    | 700±100 | 0.05    | 8.8   |
| BU Lac    | 200, 2000        | 250   | 2200±200| 0.88    | 8.8   |
| S Lep     | 90, 875-900      | 90    | 867±10  | 0.23    | 9.6   |
| T Mus     | 93, 1021         | 93    | 1020    | 0.23    | 11.6  |
| TW Oph    | 165, 2000        | 376.1 | 3225    | 0.23    | 8.6   |
| W Ori     | 212, 2450        | 211   | 2400±50 | 0.20    | 11.4  |
| RX Peg    | 110, 629         | 110   | 650     | 0.12    | 5.9   |
| TW Peg    | 90, 956.4        | 100   | 952±4   | 0.11    | 9.5   |
| rho Per   | 33-55, 1100      | 54.65 | 1000±300| 0.04    | 18.3  |
| T Per     | 326, 2800        | 340   | 2500±500| 0.06    | 7.4   |
| U Per     | 320.63, 2500     | 320   | 2500±100| 0.31    | 7.8   |
| UZ Per    | 91, 927          | 90    | 895     | 0.29    | 9.9   |
| RT Psc    | 70, 533          | 70    | 515±5   | 0.08    | 7.4   |
| Y Tau     | 240.9, 1750      | 245   | 1733    | 0.04    | 7.1   |
| ST UMa    | 81, 590          | 90    | 610±10  | 0.06    | 6.8   |
| V UMi     | 72.0, 760        | 72    | 750±20  | 0.08    | 10.4  |
Table 2: Stars possibly lacking long secondary periods. The columns list: the star name, the periods given by Houk (1963), the pulsation period P, in days, and an estimate of the maximum semi-amplitude of the LSP – the last two determined in the present paper.

| Star   | Houk Periods | P (d) | A(max) |
|--------|--------------|-------|--------|
| SS And | 152, 650     | 152:  | 0.15   |
| TZ And | 118, 974     | 114.7 | ...    |
| UX And | 400±, 7000   | 402   | 0.10   |
| V Aql  | 353, 2270    | 362   | 0.05   |
| UU Aur | 235, 3500    | 445   | 0.07   |
| RX Boo | 78: , 500    | 160   | 0.07   |
| ST Cam | 195, 2100    | 201   | 0.09   |
| RS Cap | 340, 3360    | 130   | 0.15   |
| WZ Cas | 186.0, 4000  | 192   | 0.04   |
| CQ Cas | 110-250, 2300| 204, 367 | 0.15 |
| CV Cep | 60, 2000     | 60:   | 0.18   |
| RR CrB | 60.8, 377    | 55    | 0.04   |
| AW Cyg | 220, 2200    | 204   | 0.04   |
| CH Cyg | 97, 4700     | —     | 0.30   |
| V Eri  | 97, 1209     | 300   | 0.30   |
| Y Hya  | 95, 302.8    | 363   | 0.10   |
| KP Lyr | 146, 1300    | 140   | 0.13   |
| Y Mic  | 182, 4650    | 181   | 0.20   |
| SX Mon | 100±, 1100   | 100:  | 0.10   |
| W Nor  | 134.7, 1300  | 147   | 0.20   |
| BQ Ori | 110, 795     | 247   | 0.08   |
| Y Per  | 252.3, 2400  | 253   | 0.03   |
| BU Per | 365, 2950    | —     | 0.10   |
| Z UMa  | 198, 1560    | 190   | 0.04   |
| TZ Vir | 134, 6900    | 168   | 0.04   |
Table 3: Stars which are bimodal. The columns list: the star name, the longer pulsation period Pa in days, the shorter pulsation period Pb in days, and the ratio Pb/Pa.

| Star     | Pa (d) | Pb (d) | Pb/Pa |
|----------|--------|--------|-------|
| UX And   | 402    | 218    | 0.54  |
| UU Aur   | 445    | 235    | 0.53  |
| RS Cam   | 159    | 89     | 0.56  |
| U Cam    | 400    | 215    | 0.54  |
| WZ Cas   | 370    | 192    | 0.52  |
| CQ Cas   | 367    | 204    | 0.56  |
| SS Cep   | 179    | 100    | 0.56  |
| AF Cyg   | 174    | 93     | 0.53  |
| RS Dra   | 276    | 142    | 0.51  |
| TX Dra   | 134    | 77     | 0.57  |
| RY Lac   | 80     | 46.5   | 0.58  |
| BQ Ori   | 247    | 120    | 0.49  |
| TW Oph   | 376    | 172    | 0.46  |
| W Ori    | 317    | 211    | 0.67  |
| RW Psc   | 154    | 65     | 0.42  |
| V UMi    | 123    | 72     | 0.59  |

Table 4: Stars with missing or inaccurate GCVS periods. The columns list: the star name, the GCVS period in days, and the suggested period, based on the present analysis.

| Star     | GCVS period (d) | suggested period (d) |
|----------|-----------------|----------------------|
| TZ And   | none            | 114.7                |
| TW Aur   | 104             | 144                  |
| RS Cnc   | 229.155         | 239                  |
| Y CVn    | 3000            | 160                  |
| TZ Car   | none            | 70                   |
| VY Cas   | 116             | 93.4                 |
| AA Cas   | none            | 75                   |
| SS Cep   | 340             | 100                  |
| CV Cep   | none            | 60                   |
| V539 Cyg | 160             | not 160              |
| X Her    | 95.0            | 101.5                |
| RY Lac   | none            | 80                   |
| BQ Ori   | 110             | 247                  |
| ST UMa   | 110             | 90                   |
| TZ Vir   | 134             | 168                  |
Appendix: Notes on Individual Stars

The following are notes on individual stars. The symbol v indicates results from AAVSO visual observations; V indicates results from AAVSO photoelectric observations; ASAS-SN indicates results from the All-Sky Automated Survey for Supernovae; PD and PL indicate results from Percy and Deibert (2016) and Percy and Leung (2017), respectively; GCVS indicates a period from the General Catalogue of Variable Stars (Samus et al. 2017); numbers in parentheses are the semi-amplitudes of the periods given; and a colon denotes uncertainty.

SV And: Houk: 316d, 930d. v: 314.96d (1.98); no LSP present. ASAS-SN: 313.0d.

TZ And: Houk: 118d, 974d. v: 114.7d (0.07); no LSP. ASAS-SN: 120d plus very slow variation; no evidence for the 974d period. PD: 114.8d, 1355.1d. ASAS-SN: ~370d. Bimodal?

UX And: Houk: 400±d, 7000d. v: 219.5d (0.19), 7000-9000d (0.16). V: 215.8d (0.19), 401.8d (0.36). ASAS-SN: ∼370d. Bimodal?

V Aql: Houk: 353d, 2270d. v: 215.9d (0.06), 362.4d (0.09), LSP not visible. V: several possible LSPs; none stands out.

TW Aur: Houk: 150d, 1370d. v: 1353d (0.17). V: 143.6d (0.21). ASAS-SN suggests ∼120d, ~600d. 104d GCVS period not supported.

UU Aur: Houk: 235d, 3500d. v: 235.1d (0.08), 444.6d (0.13), no LSP visible.

RX Boo: Houk: 78d, 500d. v: 160.4d (0.07), LSP not clear. PD: 160.3d, 2205.1d.

UCAM: Houk: 400d, 3000d. v: 219.5d (0.09), 2941d (0.12). V: 212.8d (0.13), 2631d (0.23). ASAS-SN: 400d. PD: 219.4d, 2967.4d. Possibly bimodal.

RS Cam: Houk: 88.6d, 960d. v: 89.4d (0.19), 159.4d (0.10), 1019d (0.14). ASAS-SN: ∼90d. PD: 90.5d, 999d. Possibly bimodal.

ST Cam: Houk: 195d, 2100d. v: 201d (0.09), 363d (0.10), 1557d (0.09). ASAS-SN: 170d. Possibly bimodal.

RS Cnc: Houk: 120d, 1700d. v: 238.9d (0.13). V: 239.5d (0.21). PD: 240.8d, 2050d.

RT Cnc: Houk: 90d, 542d. v: 93±3d (0.06), 750±100d (0.06). V: 93±3d (0.17), 600±50d (weak). ASAS-SN: ∼100d. PD: 89.3d, 691.7d. Evidence for LSP is weak.

YCvn: Houk: 158d, 2000-2200d. v: 159.2d (0.05); there is an indistinct peak at 2008d. PD: 160d, 2008.9d.

TZ Car: Houk: 69d, 1183d. v: 1213d (0.24), shorter periods are noisy. ASAS-SN: ∼70d.

BZ Car: Houk: 97d, 1800d. v: 110.7d (0.09). ASAS-SN: ∼120d.

VY Cas: Houk: 100d, 600d. v: 93.4d (0.12), 1014d (0.15). ASAS-SN: ∼100d, ∼600d. LSP uncertain. 116d GCVS period probably needs adjusting.

WZ Cas: Houk: 186.0d, 4000d. v: 192.1d (0.06), 369.7d (0.15); LSP amplitude less than 0.04. V: 370d only. ASAS-SN: 200d. Possibly bimodal.

AA Cas: Houk: 70-115d, 850d. v: 74.3d (0.04), 870d (0.04). ASAS-SN: ∼75d. PD: 80.1d, 866.8d. LSP probably present. No GCVS period.

CQ Cas: Houk: 110-250d, 2300d. v: 204.8d (0.33), 367.4d (0.40), not aliases. V: 204d (0.59). Bimodal, no strong evidence for LSP.

SS Cep: Houk: 90d, 950d. v: 100.3d (0.04), 951.5d (0.10). V: 99.4d (0.10), 179d (0.12), 922.5d (0.33). ASAS-SN: ∼100d, ∼1000d. PD: 101.1d, 955.2d. Possibly bimodal.

CV Cep: Houk: 60d, 2000d. V: 731d (0.23). ASAS-SN: ∼60d and 1000+d.

RR CrB: Houk: 60.8d, 377d. v: 55.3d (0.04), 91.0d (0.03), 392.8d (0.04). ASAS-SN consistent with ∼60d and ∼400d. PL: 55.5d, 630d. LSP probably present. Low amplitudes!
RS CrB: Houk: 69.5d, 331d. v: 330.0d (0.24). ASAS-SN: ~70d, ~300d. 332.2d GCVS period is LSP.

T Crt: Houk: 70±, 1006. ASAS-SN: ~70d.

AF Cyg: Houk: 94.1d, 960d. v: 93.4±1d (0.10), 174±2d (0.08), 913d or 1439d (0.07). V: 92.8d (0.22), 174±2d (0.34), 92.8d (0.22). ASAS-SN: ~160d. PL: 94d, 1439d. Probably bimodal with probable LSP.

CH Cyg: Houk: 94.1d, 960d. v: 93.4±1d (0.10), 174±2d (0.08), 913d or 1439d (0.07). V: 92.8d (0.22), 174±2d (0.34), 92.8d (0.22). ASAS-SN: ~160d. PL: 94d, 1439d. Probably bimodal with probable LSP.

AW Cyg: Houk: 220d, 2200d. v: 357d (0.06); no sign of a 220d period or LSP. V: 203.8d (0.12), LSP, if present, is weak. ASAS-SN: ~190d. PD: 209d, 2289d.

CH Cyg: Houk: 97, 4700. The light curve of this famous variable is dominated by large irregular eruptions.

V539 Cyg: Houk: 160d, 1500d. ASAS-SN: ~190d. 160d GCVS period appears not correct.

S Dra: Houk: 136d, 1319d. The Houk and GCVS period of 136d does not seem to be present.

RS Dra: Houk: 141.15d, 280d. v: 142±1d (0.27), 276±2d; the first may be a harmonic. ASAS-SN: ~40d and 300d. Difficult to interpret; if the 40d ASAS-SN period is real, then one of the longer periods may be an LSP.

TX Dra: Houk: 78d, 654d. v: 77.0d (0.08), 136±1d (0.07), 712.8d (0.14). V: 77.5±1d (0.14), 132±2d (0.24), 868d (0.17). ASAS-SN: 75d. PD: 77.5d, 711.8d. Bimodal pulsator with LSP.

UU Dra: Houk: 120d, 960d. ASAS-SN: ~120d. No sign of LSP.

Z Eri: Houk: 80d, 746d. v: 78.4d (0.05), 724.6d (0.10). V: 78.5d (0.11), 730.5d (0.13). PD: 78.5d, 692.4d. PL: 118.4d, 725d. Longer period is an LSP. The 80d GCVS period needs refining.

V Hya: Houk: 533d, 6500d. v: 531.9d (0.53), 6329d (1.13). PD: 531.4d, 6907.4d.

Y Hya: Houk: 95d, 302.8d, 1200d. v: 363.0d (0.13), no conspicuous LSP.

SU Hya: Houk: 95±d, 780d. ASAS-SN: 90d, 500d.

U Lac: Houk: 150d, 550-690d. AAVSO data sparse. ASAS-SN: ~50d, 700d (dominant).

RV Lac: Houk: 67d, 550-700d. v: 632.9d (0.32). V: 70d (0.19), 98d (0.19), 617.3d (0.40). ASAS-SN: ~60d, 600d. PD: 70d, 632d. LSP present.

V Hyi: Houk: 533d, 6500d. v: 531.9d (0.53), 6329d (1.13). PD: 531.4d, 6907.4d.

Y Hyi: Houk: 95d, 302.8d, 1200d. v: 363.0d (0.13), no conspicuous LSP.

RV Mon: Houk: 131.5d, 1047d. v: 360.0d (0.13), 982.3d (0.12). LSP is weak.

U Mus: Houk: 93d, 1021d. v: 1022.5d (0.23); 93d period not present in our data.

W Nor: Houk: 134.7d, 1300d. v: 147.2d (0.19); possible 823d or 2020d LSP. ASAS-SN is consistent with this pulsation period and an LSP ≥ 2000d.
**TW Oph**: Houk: 165d, 2000d. v: 171.9d (0.16), 376.1d (0.41). GCVS: 185d. Bimodal. PD: 210.7d, 2353.1d.

**W Ori**: Houk: 212d, 2450d. v: 210.7d (0.12), 316.2d (0.11), 2358d (0.20). V: 317.3d (0.25). ASAS-SN: ∼100-250d, irregular. PD: 246.6d, 2147.8d. Bimodal?

**BQ Ori**: Houk: 110d, 795d. v: 127.3d (0.10), 246.9d (0.17), possibly 709d. V: 118d (0.25), 248d (0.50). ASAS-SN: ∼100-250d, irregular. PD: 246.6d, 2147.8d. Bimodal?

**5774 Oph**: Houk: 71.5d, 500d. ASAS-SN: ∼100-250d. PD: 246.6d, 2147.8d. Bimodal?

**RX Peg**: Houk: 110d, 629d. V: ∼650d, shorter period possibly present. ASAS-SN: ∼110d, possible LSP ≥ 1500d.

**TW Peg**: Houk: 90d, 956.4d. v: 100.0d (0.04) weak, 948.8d (0.11). ASAS-SN: ∼100d, ∼750d. T Per: Houk: 326d, 2800d. v: 2488d (0.06), 326d not present. V: 342.9d (0.18), 1938d (0.17) uncertain. ASAS-SN: 318.7d, possible 2000-3000d. GCVS: 2430d.

**Y Per**: Houk: 252.3d, 2400d. v: 252.8d (0.41), LSP amplitude less than 0.04. V: 253.8d (0.37), possible LSP. ASAS-SN: ∼200d.

**U Per**: Houk: 320.63d, 2500d. v: 318.57d (1.07), 2531.6d (0.31). V: 2500±10d. ASAS-SN: 320.3d, slow (could be 2500d).

**TT Per**: Houk: 82d, 843d. v: nothing stands out. ASAS-SN: ∼90d.

**UX Per**: Houk: 91d, 927d. v: 896.9d (0.29), no sign of 91d. V: no sign of 91d. ASAS-SN: 90d, ∼1000d. PD: 186.3d, 893.4d.

**rho Per**: Houk: 33-55d, 1100d. V: 54.65d (0.05), 1169d (0.04). PL: 55d, 723d.

**RT Psc**: Houk: 70d, 533d. v: 511.2d (0.19), no sign of shorter period. V: 517.6d (0.27), shorter period signal is noisy.

**RW Psc**: Houk: 31-53d, 154d. v: 154.2d (0.15). ASAS-SN: 65±15d, 150d. Unusual period ratio.

**Y Tau**: Houk: 240.9d, 1750d. v: 244.7d (0.10), no LSP. V: 1733d (0.36). ASAS-SN: ∼250d. Z UMa: Houk: 198d, 1560d. v: 192±3d (0.38), no LSP. V: 188.5d (0.92), 4184d (0.30). ASAS-SN: ∼200d, no evidence for 1560d period.

**ST UMa**: Houk: 81d, 590d. v: 90.2d (0.04), 610.5d (0.06). V: 89.5d (0.13), 600d (0.14). ASAS-SN: 80±10d, ∼600d possibly present. PD: 90.3d, 623.1d.

**V UMi**: Houk: 72.0d, 760d. v: 72.88d (0.10), 121.1d (0.04), 754.7d (0.08). V: 71.2d (0.16), 124.8d (0.15), 730d (0.22). ASAS-SN: ∼75d. PD: 72.9d, 757.3d. Bimodal.

**TZ Vir**: Houk: 134d, 6900d. v: 167.7d (0.24), 8928d (0.25). ASAS-SN: consistent with 160d period.