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# PERIODS OF 25 PULSATING RED GIANTS

PERCY, JOHN R.[1]; DUNLOP, HEATHER[1]; KASSIM, LOLA[1]; THOMPSON, RAYMOND R.[2]

[1] Department of Astronomy, University of Toronto, Toronto ON Canada M5S 3H8,
e-mail: jpercy@erin.utoronto.ca

[2] Maple Observatory, 7 Welton St., Maple ON Canada L6A 1R8, e-mail: rayt@interlog.com

As stars expand and cool as red giants, they become pulsationally unstable. Initially, the amplitudes are a few hundredths to a few tenths of a magnitude, and the periods are days to weeks or more; these small-amplitude red variables (SARVs) are the subject of this paper. Later, the amplitude and period become much greater, and the star becomes a Mira star. This is one of a series of papers dealing with the search for, and study of SARVs; see Percy (1997) for a brief review.

**Observations.** The observations were obtained by the American Association of Variable Star Observers (AAVSO) photoelectric photometry program (Landis et al. 1992, Landis 2000). The results reported here are for two groups of stars: (i) those in Table 1 are stars in the general AAVSO PEP program which did not have sufficient measurements to be included in Percy et al. (1996); the data tend to be sparse at first, and then denser, as observers responded to the plea for more observations; (ii) those in Table 2 which are primarily stars which were assigned to specific observers (mostly RRT) as part of "Project SARV" (Percy et al. 1994). For both groups of stars, the measurements are made differentially in $V$ only, relative to the comparison and check stars listed in the tables. They are corrected for differential extinction, and reduced to the standard $V$ system using the catalogue values of the $B-V$ colors. The observations are available from the AAVSO: 25 Birch Street, Cambridge MA 02138, USA; e-mail: aavso@aavso.org

**Analysis.** The measurements were analyzed using light curves, power spectra, and autocorrelation diagrams, as described by Percy et al. (1996), who showed that these three techniques are useful and complementary in the analysis of stars like these. Analysis of the stars in Table 1 was done by LK; that of the stars in Table 2 was done by HD.

**Results.** The results are summarized in Table 1 and 2, which list the various designations of each star, the spectral type (from either the *Hipparcos Catalogue* (Perryman et al. 1997; hereinafter P97) or the *Bright Star Catalogue*), the amplitude $\Delta V$, the time span of the data $\Delta t$ in days (ending about JD 2451000), and the period of variability: more certain periods are given in bold-face type; less certain periods are denoted by a colon. A few of the stars were observed independently with an Automatic Photometric Telescope (Percy et al. 2000). Further notes are given below:

Table 1: Program stars and results

| Name | HD | SpT | Comp and Check (HD) | $\Delta V$ | $\Delta t$ (days) | Period (days) |
|---|---|---|---|---|---|---|
| T Cet | 1760 | M5/6Ib-II | 2475, 1343 | 0.80 | 3800 | 110:, 280: |
| EG And | 4174 | M2e | 3765, 4479 | 0.27 | 5550 | **29, 240** |
| AK Hya | 73844 | M6III | 73603, 74991 | 1.16 | 3100 | 50:: |
| TV UMa | 102159 | M4III | 101978, 102941 | 0.72 | 5800 | 600 |
| GK Com | 104207 | M4III | 104290, 102715 | 0.32 | 5300 | — |
| SW Vir | 114961 | M7III | 114866, 114783 | 1.85 | 5700 | **155** |
| FH Vir | 115322 | M6III | 115885, 114174 | 1.19 | 5650 | 72, 280 |
| EV Vir | 124304 | M3III | 124401, 124106 | 0.52 | 5550 | **19.5, 57** |
| $\tau^4$ Ser | 139216 | M5II-III | 140027, 139074 | 1.08 | 5750 | **110** + long |
| AZ Dra | 151481 | M2III | 150010, 151541 | 0.55 | 1020 | **352** |
| V973 Cyg | 186776 | M3III | 187523, 186619 | 0.40 | 1950 | **35, 376** |
| V1070 Cyg | 203712 | M7III | 203713, 203857 | 0.83 | 4200 | 110, 470 |

**Notes on Stars in Table 1: T Cet:** unsolved, literature period 158.9 days (P97). **EG And:** unsolved (P97); periods 29 and 242 days (Percy et al. 2000). **AK Hya:** unsolved, literature period 75 days (P97). **TV UMa:** unsolved, literature period 42 days (P97). **GK Com:** unsolved, literature period 50 days (P97). **SW Vir:** period 153.6 days, literature period 150 days (P97); period 153.8 days (Percy et al. 2000). **FH Vir:** unsolved, literature period 70 days (P97). **EV Vir:** unsolved, literature period 120 days (P97). **$\tau^4$ Ser:** unsolved, literature period 100 days (P97). **AZ Dra:** unsolved, no literature period (P97). **V973 Cyg:** unsolved, literature period 40 days (P97). **V1070 Cyg:** unsolved, literature period 73.5 days; complex variability with possible period of 60 days (Percy et al. 2000).

Table 2: Program stars and results

| HR | Name | SpT | Comp and Check (HR) | $\Delta V$ | $\Delta t$ (days) | Period (days) |
|---|---|---|---|---|---|---|
| 211 | NSV 00293 | M4III | 225, 213 | 0.22 | 1950 | 12? 32? 40? |
| 284 | WW Psc | M2III | 294, 307 | 0.23 | 1900 | **25**, 300 |
| 648 | CSV 100168 | M0III | 624, 609 | 0.14 | 1950 | 32:, 275: |
| 2286 | $\mu$ Gem | M3III | 2230, 2185 | 0.23 | 2400 | **29** |
| 2999 | NSV 03721 | M3III | 3522, 3540 | 0.13 | 2400 | 22:, 360 |
| 3521 | BO Cnc | M3III | 3522, 3540 | 0.26 | 1950 | **27**, 270 |
| 4267 | VY Leo | M5III | 4207, 4201 | 0.75 | 2650 | 48, 500 |
| 4483 | $\omega$ Vir | M4III | 4559, 4515 | 0.28 | 2250 | **30**, 275 |
| 5331 | FS Vir | M4III | 5283, 5307 | 0.18 | 1850 | 20, 250 |
| 5352 | CY Boo | M3III | 5254, 5243 | 0.10 | 1800 | **23**, 350: |
| 6543 | V642 Her | M4III | 6542, 6577 | 0.29 | 2650 | 26 and/or 32 |
| 6815 | V669 Her | M3III | 6768, 6775 | 0.17 | 2650 | **27** |
| 7009 | XY Lyr | M4.5II | 7017, 7019 | 0.55 | 1575 | **120** |

**Notes on Stars in Table 2:** These were classified as "unsolved" by P97 unless otherwise noted. **HR 211:** very poor distribution of observations; Thompson (1999) found a time scale of about a month from a subset of these data, and from *Hipparcos* epoch photometry. **HR 648:** very sparse observations; no obvious time scale. **HR 2286:**

period 27 days plus long period (Percy et al. 2000). **HR 2999:** no obvious short period. **HR 4267:** period 46.34 days (P97). **HR 6543:** period 25.6 days, plus 500-1500 days (Percy et al. 2000); period 25 days (Percy et al. 1994); literature period 12 days (P97). **HR 6815:** period about 20 days (Percy et al. 1994); Thompson (1997) found a time scale of just over 20 days from a subset of these data.

**Discussion.** Previous papers in this series (see Percy 1997 for a list and review of these) have revealed both short (20–200 days) and long (hundreds or thousands of days) periods in SARVs. Note that most of the stars in Tables 1 and 2 have a period in the range of 20–50 days; these short periods are apparently radial pulsation periods (Percy & Parkes 1998). The nature of the long periods is unclear; two recent suggestions have been (i) the rotation of a non-uniform star (Cummings 1999) and (ii) a convectively induced oscillatory thermal mode (Wood 2000). The present results add to our database of periods of SARVs, which will be used to study the nature and systematics of both long and short periods.

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