HISTOGRAMS OF PERIODS DISTRIBUTION AND MODE IDENTIFICATIONS OF RRc LYR STARS

Vladimir P. Bezdenezhnyi
Department of Astronomy, Odessa National University
T.G.Shevchenko Park Odessa 65014 Ukraine
astro@paco.odessa.ua

ABSTRACT. On the base of GCVS (General Catalogue of Variable Stars) sampling (381 stars with the known periods) has been carried out the analysis of periods of RRc Lyr stars. It has been given an interpretation of the histogram of periods distribution of these stars. All the peaks in the histogram were identified as radial overtones and their harmonics. It was proposed a new classification of these variable stars according to their mode identifications. The comparisons with the distributions of periods of δ Sct and other pulsating stars are carried out.

Key words: Stars: δ Scuti, RR Lyrae, RV Tau, classical Cepheids, bimodal Cepheids, β Cep stars, histogram of periods distribution, mode identifications

RR Lyrae stars have been studied for over a century now, and play an important role in astrophysics. They served as standard candles to fix the cosmological distance scale, these stars were considered to be prototypes of radially pulsating stars. They are radially pulsating giant A-F stars having amplitudes from 0.2 to 2 mag in V, belong to the galactic halo (Population II); often found in globular clusters. These pulsating variables have periods of 0.2-1.2 days. Some of these stars exhibit the Blazhko Effect - periodic variations in period and lightcurve.

Depending on their light curves and pulsation characteristics RR Lyrae stars are divided into different subclasses (Bailey classification). Three subtypes are recognized: RRab - the RRab stars, with high-amplitude non-sinusoidal light curves, pulsate in the fundamental radial mode. They have periods from 0.3 to 1.2 days, and amplitudes from 0.5 to 2 mag in V. RRc - RR Lyrae variables with nearly symmetric, sometimes sinusoidal, light curves, periods from 0.2 to 0.5 days, and smaller amplitudes not greater than 0.8 mag in V. They pulsate in the radial first overtone. RRd or RR(B) - bimodal (or double - mode) RR Lyrae variables showing two simultaneously operating pulsation modes (fundamental F and the first overtone 1H). RRe - Variables of the RR Lyrae type, which are the second overtone radial pulsators, are discussed recently.

In present work we analyzed GCVS IV sample of periods of RRc Lyr stars (381 variables with the known periods) for searching for the regularities in their periods distribution and identifications of peaks of their periods. Three histograms have been constructed for three different intervals of periods with three steps dP: 0.02, 0.01 and 0.005 days for control. The first histogram of periods distribution (for dP=0.02 days) shows two broad peaks at periods P_0=0.33 and P_1=0.29 days. The ratio of these periods is equal to 0.88. The theoretical ratio for periods P_g and P_{1H} is 0.(8). Overtone P_g was introduced by author (Bezdenezhnyi, 1994a,b) earlier. For this rough step of period fragmentation we have small precision of period determination. Therefore, two more histograms of period distribution (for dP=0.01 and 0.005 days) were constructed. The latter one is present in Figure 1.

In the network of workable by author (see Bezdenezhnyi, 1994a,b; 1997a,b,c,d,e; 2001a,b,; 2004) harmonic analysis we cannot present all the peaks of periods in one consistent sequence. We can see three harmonic sequencies respective to three splite primary (fundamental) periods: P_α =0.1081, P_β=0.1126 and P_γ=0.1042 days. At that P_β coincide with radial fundamental period of the Sun oscillation. Periods P_α and P_β and their sequences are found in β Cep stars too (Bezdenezhnyi, 2001a). We can transform periods into respective frequencies (which are additive): 9.25, 8.88 and 9.60 $\frac{c}{d}$. Mean difference between central and side frequencies is 0.36 $\frac{c}{d}$ that gives spliting period of 2.8 days or 11.1 days, taking into account that we have periods four-multiple to fundamental ones. Thus, we have three groups of periods, inside of which multiple relations take place. In periods distridutios are present the following periods of α-sequence: $4P_s$=0.230, $4P_{2H}$=0.258, $4P_g$=0.288, $4P_{1H}$=0.328, $4P_e$=0.345, $4P_r$=0.388, $4P_f$=0.428, $8P_s$=0.462 days. The solar or β- sequence is present with periods: $2P_f$=0.222, $4P_s$=0.238, $4P_{2H}$=0.270, $4P_g$=0.298, $4P_{1H}$=0.338, $4P_e$=0.358, $4P_r$=0.398, $4P_f$=0.451, $8P_s$=0.475, $8P_{2H}$= 0.532, $8P_g$=0.598, $9P_{2H}$=0.608 days. These two sequencies are present rather enough.

Two more remaining periods of 0.308 and 0.368 days belong to the third sequence. The ratio of these periods is equal to 0.834, that is nearly to the ratio $\frac{5}{6}$=0.833. For the ratio of periods P_f and P_{2H} is $\frac{5}{3}$, than $\frac{5}{6}$ is the ratio P_f to $2P_{2H}$. The ratio of period of 0.308 days to the fundamental one (0.1042 days) of γ-sequence is 2.96 - nearly to integer 3.We take period of 0.308 days for $4P_{1H}$ of this sequence, than period of 0.368 days may be identified with $4P_r$ of γ-sequence. This period evidently is observed in RS Boo (P=0.377 days). RW Dra has period of 0.443 days that is multiple with fundamental one (0.1126 days) of β-sequence. Their ratio is 3.934, that is nearly to integer 4. Period of 0.522 days for Y Leo Minor gives ratio 5.01 to P_f=0.1042 days - the fundamental period of γ-sequence. Period of 0.567 days of RR Lyr is multiple to the fundamental period of β-sequence. This ratio is 5.04 - nearly coinside with integer 5.

Thus, individual values of periods of RRc Lyr stars confirm their commensurability with these three primary periods of above sequencies. One of this periods (0.1126 days) coincide with fundamental radial period of the Sun oscillation. But, apparently, this period is not the main one. It appears (as well as the period of 0.1042 days) because of splitting of period of 0.1081 days thanks to the influence of disturbing period of 11.1 days. Histograms of periods distribution of radial pulsating stars of different types: (RR Lyr, RV Tau, β Cep, δ Sct, classical and bimodal Cepheids and other ones, and even for pulsars (Bezdenezhnyi, 1994a,b; 1997a,b,c,d,e; 2001a,b; 2004, 2005a,b) only reflect this commensurability. At that, for different types of radial pulsating stars the ratios of their periods to one of above three fundamental periods change in rather large ranges, reflecting big differences in their periods. At that point of view a lot of periods may be identify with radial ones without attracting non-radial oscillations. Our Sun is a variable star with radial oscillations of small amplitude, it follows the same law. The ratio of its period to the fundamental one is just equal 1! For different RR_c Lyr stars these ratios are equal from 2 to 5, for β Cep stars - from 0.25 to 6, for δ Sct stars - from 0.1 to 2, for RV Tau stars they are in the range 260-3330 (Bezdenezhnyi, 2005a in this volume). For bimodal Cepheids (using periods data from Berdnikov (1993)) ratios are in range 13-37. So for bimodal Cepheids individual ratios are equal 18.999 for P_0 of TU Cas and 19.002 for P_1 of VX Pup! Our analysis (Bezdenezhnyi, 1997a) has given more detailed subdivision of bimodal Cepheids, pulsating in the frequencies f_{1H} and f_s, into two subgroups. The average ratios of periods P1/P0 for two samples are equal to 0.703 and 0.711. This follows also from Berdnikov's data (1993) for 13 bimodal Cepheids.

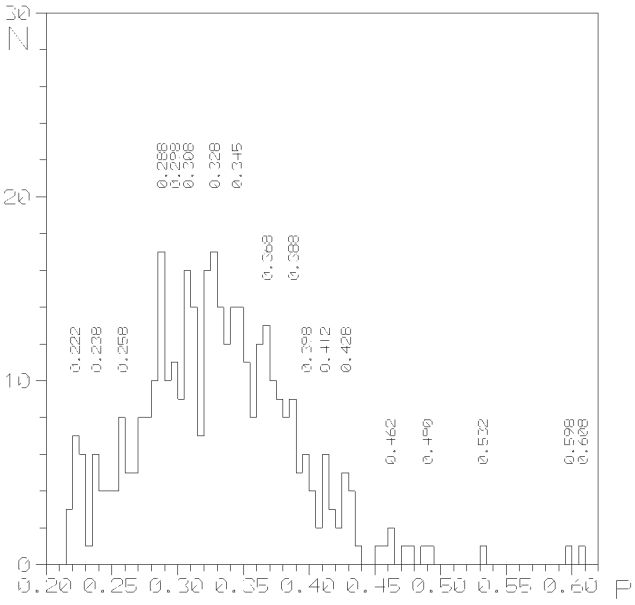

Figure 1: The distribution of RRc Lyr stars' periods based on the data of the sampling according to GCVS (dP=0.005 d).

References

Berdnikov L.N.: 1993, *Pis'ma A. Zh.*, **19**, no. 7, 619.

Bezdenezhnyi V.P.: 1994a, *Odessa Astron. Publ.*, **7**, 55.

Bezdenezhnyi V.P.: 1994b, *Odessa Astron. Publ.*, **7**, 57.

Bezdenezhnyi V.P.: 1997a, *Odessa Astron. Publ.*, **10**, 89.

Bezdenezhnyi V.P.: 1997b, *Odessa Astron. Publ.*, **10**, 92.

Bezdenezhnyi V.P.: 1997c, *Odessa Astron. Publ.*, **10**, 93.

Bezdenezhnyi V.P.: 1997d, *Odessa Astron. Publ.*, **10**, 95.

Bezdenezhnyi V.P.: 1997e, *Odessa Astron. Publ.*, **10**, 96.

Bezdenezhnyi V.P.: 2001a, *Odessa Astron. Publ.*, **14**, 118.

Bezdenezhnyi V.P.: 2001b, *Odessa Astron. Publ.*, **14**, 122.

Bezdenezhnyi V.P.: 2004, *Odessa Astron. Publ.*, **17**, 8.

Bezdenezhnyi V.P.: 2005a, *Odessa Astron. Publ.*, **18**, in this volume.

Bezdenezhnyi V.P.: 2004b, *Odessa Astron. Publ.*, **18**, this article.

Kholopov P.N. (ed.): 1985a, 1985b, 1987, General Catalogue of Variable Stars (Volumes 1-3, abbr. GCVS), Nauka, Moscow.