

ON PERIODS OF OSCILLATIONS IN  $\delta$  SCUTI TYPE STARS

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**ABSTRACT.** In considering both commensurability spectra of oscillation frequencies for  $\delta$  Sct stars and the distribution of periods for these variables from Kotov's (1987) data, frequencies  $f_F$ ,  $f_{1H}$ ,  $f_{2H}$ ,  $5/4f_F$  and  $3/2f_F$  are found, as well as their linear combinations. For 13 stars with two known periods identifications are carried out.

**Key words:** Stars:  $\delta$  Sct, RR Lyrae, mode identifications

In the work by Kotov (1987) in analyzing commensurability spectra of oscillation frequencies for  $\delta$  Sct stars a statistically significant tendency has been found for stars' number excess with frequencies multiple to that of  $f_0$  or with frequencies for which  $f_0$  is multiple to:

$$f_i \approx \begin{cases} z f_0, & \text{if } f_i \geq f_0, \\ f_0/z, & \text{if } f_i < f_0, \end{cases} \quad (1)$$

where  $z=1,2,3$ , and the period  $f_0^{-1} = 162.2$  min  $\pm$  2.8 min within the limits of error is in good agreement with the value by Stellingwerf (1979), 161 min, for a typical  $\delta$  Sct Star, and with a famous period of global pulsations of the Sun ( see Kotov (1987) and references therein).

In the commensurability spectrum, the second in significance peak ( $P_2=96$  min = 0.0663 days) is seen. Kotov (1987) considers it to be "artifact" associated with the maximum in distributing periods of  $\delta$  Sct stars in this range. However, we assume this peak to be real (Fig.1), and hence the period corresponding to it as well. The ratio of  $P_2/P_0 = 0.592$  is very close to  $3/5$  which is characteristic of the second overtone of pulsations. Hence,  $P_2$  is  $P_{2H}$ . In addition to these statistically significant two peaks, three less powerful peaks are seen: 77, 44 and 236 MHz (see Table 1).

Their identifications are likely to be:  $3/4f_0$ ,  $f_{2H}/4$  and  $f_{4H}$  (last - from observed period ratio  $P_{4H}/P_0=0.436$  close to the theoretical value 0.437 obtained by us according to Petersen's data (1990) for standard models of multimodal Population I pulsators).

With Fourier analysis of periods of RRc star AE Boo performed (see in the same volume) two frequencies  $f_E=5/4f_F$  and  $f_G=3/2f_F$  were introduced which were found in the power spectrum as well as their linear combinations with  $f_F$  and  $f_{1H}$ . As is seen these are present in  $\delta$  Sct type stars too:  $f_{4H} \approx f_0 + f_E$  and  $3/4f_0 \approx f_G/2$ .

Peaks in distributing periods can be noticed from Figure 1:  $P_{2H}/3=0.022$ ,  $P_0/3=0.038$ ,  $P_{4H}=0.049$ ,  $P_0/2=P_{3H}=0.056$ ,  $P_{2H}=0.066$ ,  $P_G=0.075$ ,  $P_{1H}=0.084$ ,  $P_E=0.090$ ,  $P_0=0.1126$ ,  $2P_{2H}=0.135$ ,  $3P_{4H}=0.148$ ,  $2P_G=4/3P_0=0.151$ ,  $3P_{3H}=0.169$ ,  $2P_E=8/5P_0=0.180$ ,  $4P_{4H}=0.197$ ,  $3P_{2H}=0.199$ ,  $2P_0=3P_G=0.225$ ,  $3P_{1H}=0.253$ ,  $4P_{2H}=0.265$ ,  $3P_E=0.270$  days and others.

Thus, the histogram of period distribution supports the data given in Table 1: frequencies  $f_0$ ,  $f_{2H}$ ,  $f_{4H}$ ,  $f_E$  and  $f_G$  are related with multiplicity ratios. In the commensurability spectra (Kotov, 1987) the frequencies  $f_{1H}$ ,  $f_E$  and  $f_G$ , besides the above, are noticed too in the wings of two basic peaks as humps.

In Table 2 are represented data for two periods of 13 particular stars of  $\delta$  Sct type from the Kotov's list (1987) and their probable identifications. In 10 cases of 13 the period ratios observed are different from those of their multiplicity within 0.02, in two stars the difference being equal to 0.03 and in LT Vul to 0.05. Taking into account some possible errors to appear when determining the periods, as well as the diversities of masses and chemical compositions in the stars, the fit would seem to be

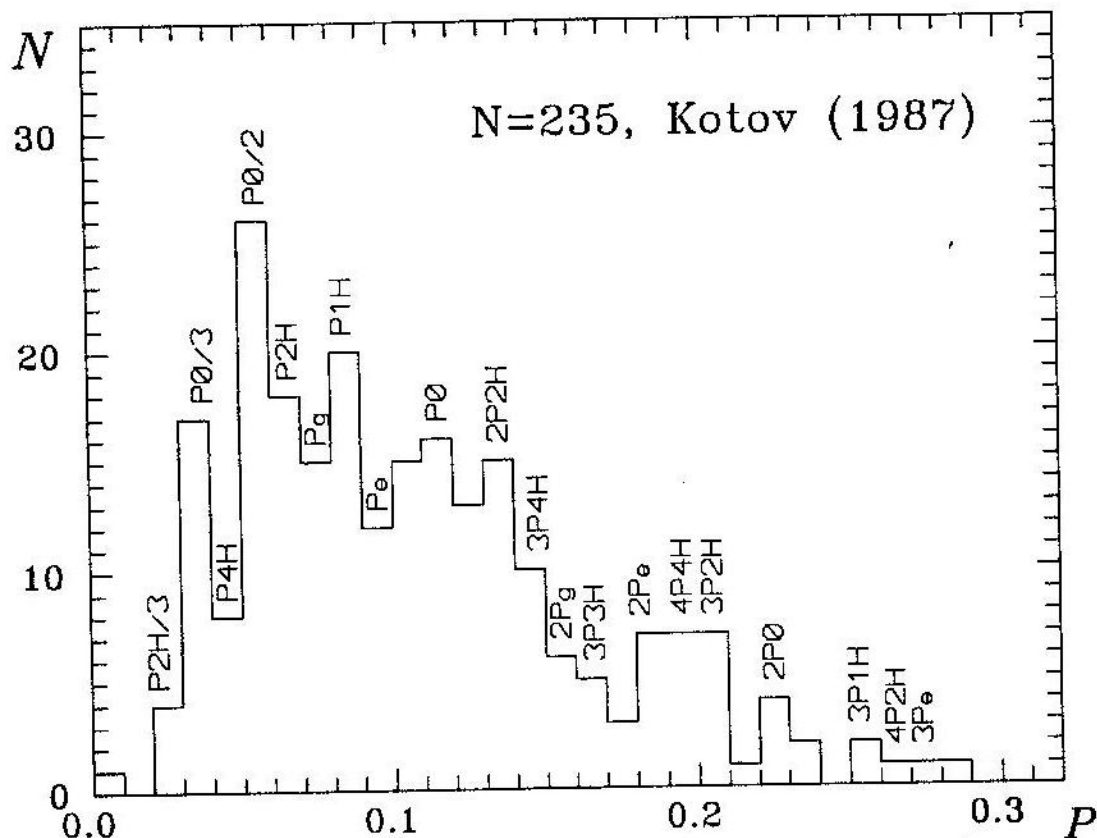


Figure 1. The distribution of oscillation periods from data of sampling according to Kotov (1987).

Table 1.

$f_i$ (MHz)	$f_i$ (1/days)	$P_i$ (days)	$P_i$ (min)	$k_i = P_i/P_0$	identifications
103	8.881	0.1126	162	1	$f_F$
175	15.079	0.0663	96	0.592	$f_{2H}$
77	6.637	0.1507	217	1.338	$3/4 f_F = f_G/2$
44	3.793	0.2637	380	2.341	$f_{2H}/4$
236	20.342	0.0492	71	0.436	$f_{4H} = f_F = f_E$

Table 2.

star	$P_1$	$P_2$	$k = P_2/P_1$	$k_{theor}$	$\Delta k$	identifications
EM Aqr	0.095	0.068	0.72	0.75	0.03	$P_E$ and $P_{2H}$
UV Ari	0.06	0.037	0.62	0.60	0.02	$P_F/2$ and $P_{2H}/2$
VV Ari	0.76	0.063	0.83	0.83	0.00	$P_{2H}$ and $P_{3H}$
AI CVn	0.209	0.139	0.67	0.67	0.00	$2P_F$ and $2P_G$
AO CVn	0.135	0.1218	0.90	0.90	0.00	$2P_G$ and $2P_{2H}$
UU Com	0.028	0.021	0.75	0.75	0.00	$P_F/4$ and $P_{1H}/4$
S Eri	0.1558	0.1188	0.76	0.75	0.01	$2P_G$ and $P_F$
HQ Hya	0.097	0.076	0.78	0.80	0.02	$P_F$ and $P_E$
V465 Per	0.070	0.030	0.43	0.44	0.01	$P_{2H}$ and $P_E/3$
VY Psc	0.219	0.163	0.74	0.75	0.01	$2P_F$ and $2P_{1H}$
IM Tau	0.1449	0.1120	0.77	0.75	0.02	$2P_G$ and $P_F$
LT Vul	0.1096	0.0935	0.85	0.80	0.05	$P_F$ and $P_E$
10 NGC6871	0.1082	0.0903	0.83	0.80	0.03	$P_F$ and $P_E$

fairly well.

Similarly to multimodal RR Lyrae type stars, the periods of  $\delta$  Sct stars are close to those of  $P_F$ ,  $P_E$ ,  $P_{1H}$ ,  $P_G$ ,  $P_{2H}$  and their combinations.

#### References

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## SEARCH FOR LONG-TERM VARIATIONS OF dKe-dMe STARS

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**ABSTRACT.** Measurements of brightness of 29 red dwarf stars and 3 stars of other types were made on time scales of 5 – 90 years using plates archives of Sternberg State Astronomical Institute (Moscow), Astronomical Observatory of Odessa State University and Sonneberg Observatory (Germany). The sensitivity of plates are close to B band. The long-term changes in yearly mean magnitude have been detected or suspected for 10 dKe-dMe objects. Two stars, V833 Tau and PZ Mon, show high amplitude of variability up to 0.6 – 1.0 mag. The range of variability in mean light of the other eight stars is of 0.2 – 0.5 mag. The light curves show typical times of long-term variability of about 30–60 years. Changes of the mean light of the remained dKe-dMe stars and three other stars of other types – FK Com, V654 Her, AE Aqr – do not exceed 0.2 mag. Complete paper is to be published in: *Izvestija Krymskoy Astrofizicheskoy Observatorii*, v.91.

**Key words:** Stars: Variable