THE CLASSICAL CEPHEIDS' HISTOGRAMS OF PERIODS DISTRIBUTION

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ABSTRACT. On the base of GCVS sampling has been carried out the analysis of periods of classical Cepheids. We have studied the histograms of periods distributions for the stars with small amplitudes (DCEPS) and large ones (DCEP) separately. These two histograms have different sight (amplitudes of the peaks), but their peaks follow to general sequence. We have given the modal interpretation of the histograms on the base of mode identifications.
Key words: Stars: classical Cepheids, histograms of periods distribution, mode identifications

On the base of the sampling (473 classical Cepheids with the known periods) taken from the fourth edition of the General Catalogue of Variable Stars (volumes 1-3, 1985 a, 1985 b, 1987, hereafter GCVS) we have constructed two preliminary histograms of periods distribution of these variable stars. The intervals of periods in these two histograms are 5 and 2 days respectively. It lets us to distinguish positions and realities of peaks. The most distinct peaks of periods distribution are at periods: 3.25, 4.25, 5.25, 7.25, 9.75, 12.75 and 15.5 days in these two histograms.

However we take into account that all classical Cepheids subdivide into two subclasses. And so, we have constructed two histograms (see Tab.1, Tab.2 and Fig.1, Fig.2) of periods distribution of these variable stars with small amplitudes (DCEPS) and large ones (DCEP) separately. The intervals of periods in these two histograms are 2 days. We have studied the histograms of periods distribution for two subclasses (435 and 38 stars respectively) of these variable stars with the purpose of detection their common characteristics and particular features.

Comparison of two histograms in Fig.1 and Fig.2 confirms that DCEP and DCEPS stars are different objects. As we can see (Tab.2 and Fig.2), the main peak of periods distribution for DCEPS stars is at the mean period about 3.3 days, and two more clear peaks are present at 4.4 and 5.5-5.6 days. Less reliable peaks with small amplitudes are also present at: 1.9, 2.7, 3.1, 6.5, 7.5, 8.4, 9.6, 13.7 and 17.1 days.

Experience shows, that identifications of periods among possible alternatives are easier and more reliable, if we begin analysis with big periods, even they have peaks with small amplitudes. At that, a key to identification is an analysis of periods commensurability (or multiplicity) relations. We take as hypothesis, that period of 17.1 days is Pg-overtone and 13.7 days is period Ps. The latter has found by us in frequency analysis of bimodal Cepheids and RR Lyrae - type stars (Bezdenezhnyi, 1997a, 1997b). And a peak at 9.6 days is a half period $P_{1H}/2$. So we have periods relations 9.6/13.7=0.701 and 13.7/17.1=0.801, near to theoretical values 0.703 and 0.8. It allows to explain all the set of DCEPS stars' periods.

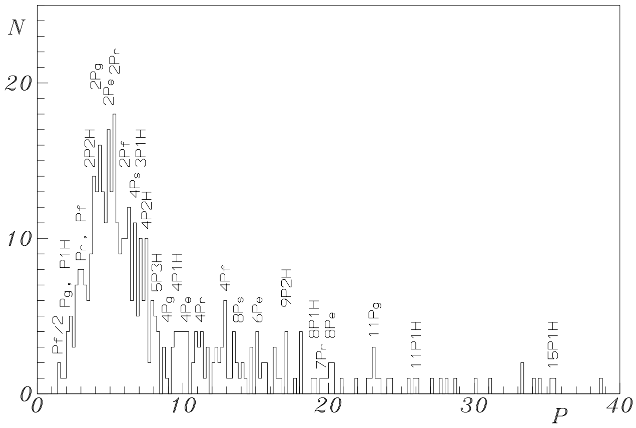

Figure 1: Periods distribution (dP=0.2 days) of large amplitude classical Cepheids (DCEP)

Then the rest of periods from the set of DCEPS stars' periods will be identified as: 1.9 days = $P_{2H}/4$, 5.6 days = $P_r/4$, 2.8 days = $P_r/8$, 8.4 days = $P_g/2$, 6.5 d = $P_s/2$, 3.3 d = $P_s/4$, 4.3 d = $P_g/4$, 7.5 d = $P_{2H}/2$, 3.1 d = $P_f/8$. Period 3.1 days with the largest amplitude is the basic one. We adopt it as fundamental period P_f, then new identification will be obtained from previous by means of multiplication by a factor of eight. 1.9 d = $2P_{2H}$, 2.8 d = P_r, 3.1 d = P_f, 3.3 d = $2P_s$, 4.3 d = $2P_g$, 5.6 d = $2P_r$, 6.5 d = $4P_s$, 7.5 d = $4P_{2H}$, 8.4 d = $4P_g$, 9.6 d = $4P_{1H}$, 13.7 d

Table 1: The histogram of large amplitude classical Cepheids' (DCEP) periods distribution (dP=0.2 days, n=435 stars)

ΔP	N	ΔP	N	ΔP	N
0.0 - 1.0	0	9.6 - 9.8	4	18.4 - 18.6	0
1.0 - 1.2	0	9.8 - 10.0	4	18.6 - 18.8	0
1.2 - 1.4	0	10.0 - 10.2	4	18.8 - 19.0	1
1.4 - 1.6	2	10.2 - 10.4	4	19.0 - 19.2	1
1.6 - 1.8	1	10.4 - 10.6	0	19.2 - 19.4	0
1.8 - 2.0	1	10.6 - 10.8	2	19.4 - 19.6	1
2.0 - 2.2	4	10.8 - 11.0	4	19.6 - 19.8	1
2.2 - 2.4	5	11.0 - 11.2	3	19.8 - 20.0	1
2.4 - 2.6	3	11.2 - 11.4	4	20.0 - 20.2	2
2.6 - 2.8	7	11.4 - 11.6	1	20.2 - 20.4	2
2.8 - 3.0	8	11.6 - 11.8	3	20.4 - 20.6	0
3.0 - 3.2	8	11.8 - 12.0	0	20.6 - 20.8	0
3.2 - 3.4	7	12.0 - 12.2	2	20.8 - 21.0	1
3.4 - 3.6	6	12.2 - 12.4	3	21.8 - 22.0	1
3.6 - 3.8	9	12.4 - 12.6	2	22.6 - 22.8	1
3.8 - 4.0	14	12.6 - 12.8	3	22.8 - 23.0	1
4.0 - 4.2	13	12.8 - 13.0	6	23.0 - 23.2	3
4.2 - 4.4	16	13.0 - 13.2	1	23.2 - 23.4	1
4.4 - 4.6	13	13.2 - 13.4	1	23.4 - 23.6	1
4.6 - 4.8	11	13.4 - 13.6	4	24.0 - 24.2	1
4.8 - 5.0	17	13.6 - 13.8	2	24.2 - 24.4	1
5.0 - 5.2	13	13.8 - 14.0	1	25.4 - 25.6	1
5.2 - 5.4	18	14.0 - 14.2	2	25.8 - 26.0	1
5.4 - 5.6	11	14.2 - 14.4	1	26.0 - 26.2	1
5.6 - 5.8	9	14.4 - 14.6	0	27.0 - 27.2	1
5.8 - 6.0	10	14.6 - 14.8	3	27.6 - 27.8	1
6.0 - 6.2	10	14.8 - 15.0	0	28.0 - 28.2	1
6.2 - 6.4	12	15.0 - 15.2	4	28.6 - 28.8	1
6.4 - 6.6	6	15.2 - 15.4	1	30.0 - 30.2	1
6.6 - 6.8	11	15.4 - 15.6	2	31.0 - 31.2	1
6.8 - 7.0	5	15.6 - 15.8	2	33.2 - 33.4	2
7.0 - 7.2	10	15.8 - 16.0	0	34.0 - 34.2	1
7.2 - 7.4	6	16.0 - 16.2	0	34.4 - 34.6	1
7.4 - 7.6	10	16.2 - 16.4	3	35.2 - 35.4	1
7.6 - 7.8	2	16.4 - 16.6	1	35.4 - 35.6	1
7.8 - 8.0	6	16.6 - 16.8	1	38.6 - 38.8	1
8.0 - 8.2	5	16.8 - 17.0	0	41.2 - 41.4	1
8.2 - 8.4	4	17.0 - 17.2	4	45.0 - 45.2	1
8.4 - 8.6	0	17.2 - 17.4	0	48.6 - 48.8	1
8.6 - 8.8	3	17.4 - 17.6	0	49.4 - 49.6	1
8.8 - 9.0	1	17.6 - 17.8	1	49.6 - 49.8	1
9.0 - 9.2	0	17.8 - 18.0	0	51.0 - 51.2	1
9.2 - 9.4	3	18.0 - 18.2	4	64.2 - 64.4	1
9.4 - 9.6	4	18.2 - 18.4	0	68.4 - 68.6	1

Table 2: The histogram of small amplitude classical Cepheids' (DCEPS) periods distribution (dP=0.2 days, n=38 stars)

ΔP	N	ΔP	N	ΔP	N
1.8 - 2.0	1	3.8 - 4.0	1	5.8 - 6.0	0
2.0 - 2.2	0	4.0 - 4.2	1	6.0 - 6.2	0
2.2 - 2.4	1	4.2 - 4.4	3	6.2 - 6.4	0
2.4 - 2.6	1	4.4 - 4.6	2	6.4 - 6.6	1
2.6 - 2.8	2	4.6 - 4.8	0	6.6 - 7.4	0
2.8 - 3.0	1	4.8 - 5.0	0	7.4 - 7.6	1
3.0 - 3.2	4	5.0 - 5.2	0	8.2 - 8.4	1
3.2 - 3.4	6	5.2 - 5.4	1	9.4 - 9.6	1
3.4 - 3.6	1	5.4 - 5.6	3	13.6 - 13.8	1
3.6 - 3.8	1	5.6 - 5.8	3	17.0 - 17.2	1

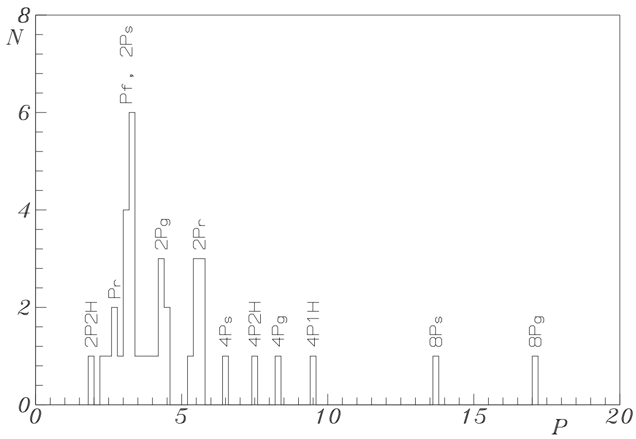

Figure 2: Periods distribution (dP=0.2 days) of small amplitude classical Cepheids (DCEPS)

= $8P_s$, 17.1 d = $8P_g$.

Period Pf specified from correlations of multipleness (equal 3.15 days) coincides with a value of 3.1528 = 28 P_{fund}, where P_{fund} = 0.1126 d is a fundamental period of radial pulsations of the Sun. Though the sampling of DCEPS stars with the known periods in GCVS is not large, we can identify the primary peaks in the histogram of periods distribution. The ratios of periods show that periods are commensurable (often - multiple ones), as in the case of other types of pulsating stars.

Overtones P_r, P_e, P_g and P_s were introduced into practice by the author (Bezdeneznyi, 1994 a, 1994 b, 1997 a, 1997 b) for variable stars RR Lyrae, δ Scuti types and bimodal Cepheids. Overtones P_s and P_e, P_g and P_f, are related like P_{3H} and P_{1H}: $P_{1H} = 3/2P_{3H}$, $P_f = 3/2P_g$, $P_e = 3/2P_s$. Similarly three pairs of overtones are related like P_{1H} and P_f: $P_f = 4/3P_{1H}$, $P_r = 4/3P_g$, $P_e = 4/3P_{2H}$, $P_g = 4/3P_{3H}$. And by analogy with above we have the following multiple relations: $P_{1H} = 5/4P_{2H}$, $P_f = 5/4P_e$, $P_g = 5/4P_s$. Hence two new multiple relations take place: $3P_r = 4P_g = 5P_s$, $4P_f = 5P_e = 6P_g$, besides relation known earlier: $3P_f = 4P_{1H} = 5P_{2H} = 6P_{3H}$. Two new relations may be combined into one: $8P_f = 9P_r = 10P_e = 12P_g = 15P_s$. This relation connects all new overtones with fundamental period P_f. And at last this relation may be combined with known earlier one into universal relation: $24P_f = 27P_r = 30P_e = 32P_{1H} = 36P_g = 40P_{2H} = 45P_s = 48P_{3H}$.

It appears that identification, made for DCEPS stars with small amplitudes, fits for large-amplitudes (DCEP) stars too. As we can see from Fig. 1 and Fig. 2, for every sub-group of variable stars we have its own distribution of periods, with different maxima of distribution and different main peaks. But all of these peaks follow to one general regularity (one general sequence, determined by $P_f = 3.15$ days). There is a distinct peak (see Fig. 1) in area of $P_f = 3.15$ day and a period $P_r = 2.8$ days in its left wing. To the left of these periods we find out the step with two periods coincident to the theoretical first overtone $P_{1H} = 2.36$ days and overtone $P_g = 2.1$ days. More to the right than these two peaks we have two main peaks, determining maxima of distribution: at 4.3 and 5.2 days. Each of these peaks consists of a few near periods: $2P_g = 4.2$ days, $2P_{2H} = 3.8$ days and $2P_e = 3P_s = 5.0$ days, $2P_r = 5.6$ days, $3P_{2H} = 5.7$ days.

Some more to the right is a peak $2P_f = 3P_g = 6.3$ days, a peak of a period $4P_s = 6.7$ days is next to this and two more peaks $3P_{1H} = 7.1$ days and $3P_e = 4P_{2H} = 7.6$ days are present. A wide peak is visible with a center about 9.8 days, formed by the periods $4P_{1H} = 5P_{2H} = 9.45$ days, $4P_e = 6P_s = 10.1$ days, $5P_g = 10.5$ days. Also a peak of periods $4P_r = 11.2$ days and $6P_{2H} = 11.3$ days is present. There are some peaks $6P_e = 9P_s = 15.1$ days, $9P_{2H} = 17.0$ days, $8P_e = 12P_s = 20.1$ days and $11P_g = 23.1$ days.

Thus, for two sub-groups of classical Cepheids different overtones and their harmonics of the same period Pf = 3.15 days, typical for all ensemble of these stars, are present. A period Pf is multiple to the fundamental period of radial oscillations of the Sun Pfund = 0.1126 days.

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