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DY PEGASI - A DOUBLE MODE DWARF CEPHEID ?

Many of the variables in the lower instability strip pulsate with more than one period. Among them there are about fifteen stars which can be identified as radial pulsators with two successive modes excited (Breger 1979, Table III). Usually,these are fundamental and first overtone modes and the amplitude of weakly excited mode amounts a considerable fraction of the greatest one (Broglia and Conconi 1975, Table 5). Additionally, several large amplitude δ Scuti (or dwarf cepheid) variables show non-repetitiveness from cycle to cycle exceeding the observational error. The star DY Peg was reported by Masani and Broglia (1954) and by Hardie and Geilker (1958) as showing such a behaviour. The variation of amplitude of brightness of DY Peg is clearly seen from observations of Hardie and Geilker (1958). An example of their V magnitude observations is shown in Fig. 1.

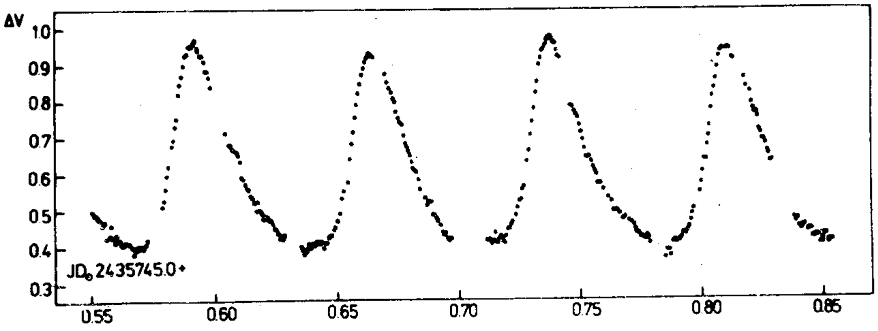

Fig. 1. A part (one night) of V magnitude observations of DY Peg plotted from the data contained in the Table 3 of Hardie and Geilker (1958).

We can see from this figure that the variation of the height of the maxima amounts to about $0\overset{m}{.}03$. The variation of the minima is not so clearly pronounced.

In an attempt to search for the nature of this non-repetitiveness we decided to carry out an analysis of photoelectric brightness observations of DY Peg. The method used was the periodogram method (Wehlau and Leung 1964). The photoelectric observations suitably distributed in time for a periodogram calculation are those of Masani and Broglia (1954), although their measurements are not so time-dense as those of Hardie and Geilker (1958).

Masani and Broglia observed the star DY Pegasi during 9 nights in October and November, 1953. They obtained a total of 573 measurements designated as "bleu" and 523 measurements designated as "giallo". We chose for our analysis 7 nights in the interval of JD 2434689-2434696 because these nights constitute compact block of observations (only the night JD 2434694 was missed by the authors). Such data set produces uncomplicated spectral window pattern (only the 1 cycle/day side lobes are present), and allow to use a relatively great frequency increment efficiently speeding up the computations. First, we analyses the "giallo" observations. As a check, we re-determined the principal period. The highest peak on the periodogram appeared for the frequency of $\omega_0=86.159\pm0.002$ radians/day. The corresponding period $P_0=0\overset{d}{.}072926\pm0\overset{d}{.}0000017$ agrees well with the more accurate previously known value, $P_0=0\overset{d}{.}072926355$ (Hardie and Geilker, 1958). The next step of our analysis was the fitting to the observations the trigonometric polynomial of the form:

$$m(t) = \langle m\rangle + \sum_{i=1}^{6} A_{0i}\cos(i\omega_0 t + \varphi_{0i}) \qquad (1),$$

where for ω_0 we used our value quoted above. Having the coefficients of Eq.1 determined we then subtracted from the analysed data the polynomial (1) and computed a periodogram of so prewhitened measurements. It was calculated in the range from 0.0 rad/d to 400.0 rad/d with the frequency increment of 0.2 rad/d. On this periodogram we can identify a spectral window structure with the highest peak placed at about 113 rad/d. This situation is shown in the upper part of Fig.2. A detailed computation gives the value ω_1=112.8±0.1 rad/d, which corresponds to the new period $P_1=0^d.05570\pm0^d.000049$. Finally, we obtained the least squares solution for the expression

$$m(t)=\langle m\rangle + \sum_{i=1}^{6} A_{0i}\cos(i\omega_0 t + \varphi_{0i}) + A_1\cos(\omega_1 t+\varphi_1) \qquad (2),$$

fitted to the "giallo" magnitude observations. The results are listed in Table I. The arbitrary initial epoch we denoted by T, N is the number of observations, $\langle m_g\rangle$ - the mean "giallo" magnitude, and s.d. is the standard deviation as determined by residuals from the solution. The first column contains the identi-

Table I

Synthetic light curve of DY Peg

T = JD⊙2434689.0
N = 417
$\langle m_g\rangle=0^m.5322 \pm 0^m.0007$*
s.d.=0.0162

Interpretation	ω(rad/d)		A		φ(rad)	
ω_0	86.159	±0.002	0.286	±0.001	6.31	±0.01
$2\omega_0$	172.315	0.006	0.118	0.001	4.05	0.02
$3\omega_0$	258.48	0.02	0.045	0.001	1.91	0.07
$4\omega_0$	344.61	0.03	0.021	0.001	6.26	0.1
$5\omega_0$	430.75	0.08	0.008	0.001	4.7	0.3
$6\omega_0$	517.0	0.2	0.003	0.001	2.6	0.7
ω_1	112.8	±0.1	0.005	±0.001	5.2	±0.5

*This is the mean value as determined directly from the observations of Masani and Broglia (1954), Table III. It was substracted from the data before periodogram calculation. All the further analysis was performed on an intensity scale, assuming for $\langle m_g\rangle$I=1.0.

fication of the frequencies of all revealed sinusoidal components, second column - the frequencies expressed in radians/day, the third - the amplituds, and the fourth - the initial phases in radians.

It can be seen from this Table that the light variation of DY Peg is strongly non-sinusoidal. The harmonics up to $6\omega_0$ are present. The secondary variation ω_1 is very weakly excited. Its amplitude is placed between the amplitudes of $5\omega_0$ and $6\omega_0$ harmonics of the principal variation.

In order to check our results concerning the presence of ω_1 component we analysed in a similar manner the simultaneous "bleu" magnitude observations of Masani and Broglia (1954). It

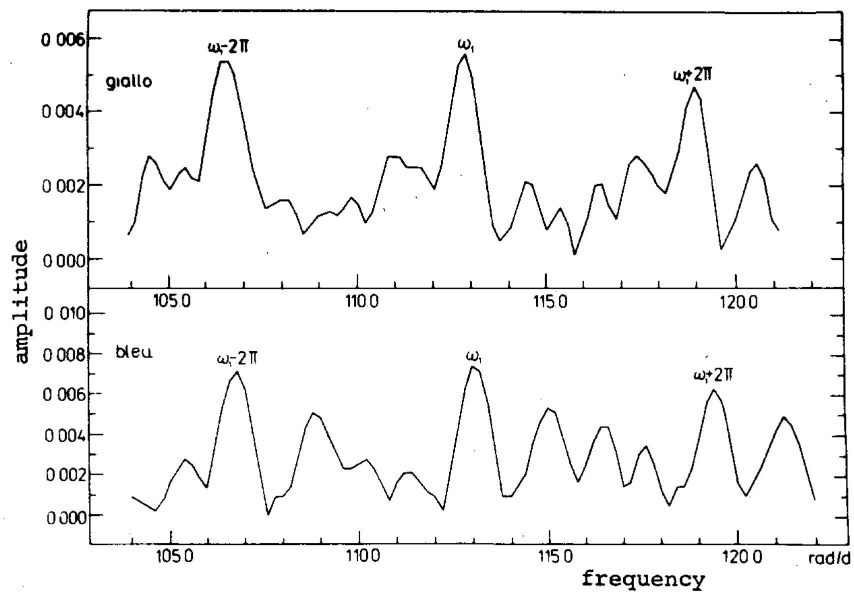

Figure 2. The secondary (ω_1) light variation component visible on the DY Peg periodograms.

has been found that the ω_1 component occurred on the relevant periodogram in the same place as previously (see bottom part of Fig.2). Finally, the same procedure adopted to the V magnitude observations od Hardie and Geilker (1958) presented in Fig.1, yielded two peaks on the periodogram. They are located at about 116 rad/d and 208 rad/d, respectively. Their amplitudes equal to about 0.01 in an intensity scale. Taking into account the fact, that the frequency error for these components as estimated from least squares solution amounts to about 4 rad/d, it can be concluded that the appearance of both the peaks is caused by the presence of ω_1, and even $2\omega_1$, components, respectively.

All the above results say us that the existence of the ω_1 component is not accidental, though the relevant amplitudes exceed the periodogram noise level not very much. The other fact strengthening our conclusion is that the ratio $\omega_0/\omega_1 = 0.764$ is quite similar to the period ratios for other double mode stars in the δ Scuti region. Thus, DY Peg is very likely a double mode (or dwarf cepheid) star with fundamental and first overtone radial modes of pulsation excited. The reason we have used the word "likely is that the synthetic light curve of the form of expression (2) does not reproduce satisfactorily the cycle amplitude variation of the observations analysed. Generally speaking, in order to improve this situation one should use more components in an expression like (2) with more accurately determined coefficients. This in turn requires more accurate, and possibly time denser, data points to be available. Thus, further photometric observations of DY Peg are badly needed.

In contrast to the other double mode δ Scuti stars with large amplitude light variations (of the order of $0^{m}.5$), the secondary pulsation in DY Peg seems to be very weakly excited (cf. Table 5 in Broglia and Conconi, 1975).

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