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HR 4684: A POSSIBLE EXAMPLE OF RESONANCE IN DELTA SCUTI STARS.

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ABSTRACT. The light curve analysis of HR 4684, a delta Scuti star observed in 1976 at the Brera - Merate observatory, is presented. The results show three significant periodicities probably bound by a simple relation: the highest frequency seems to be the sum of the other ones. This fact represents an observational indication for the actuality of the parametric resonance mechanism suggested by Dziembowski for the pulsating dwarf stars. Another possible resonance was observed in KW 207.

1 - INTRODUCTION.

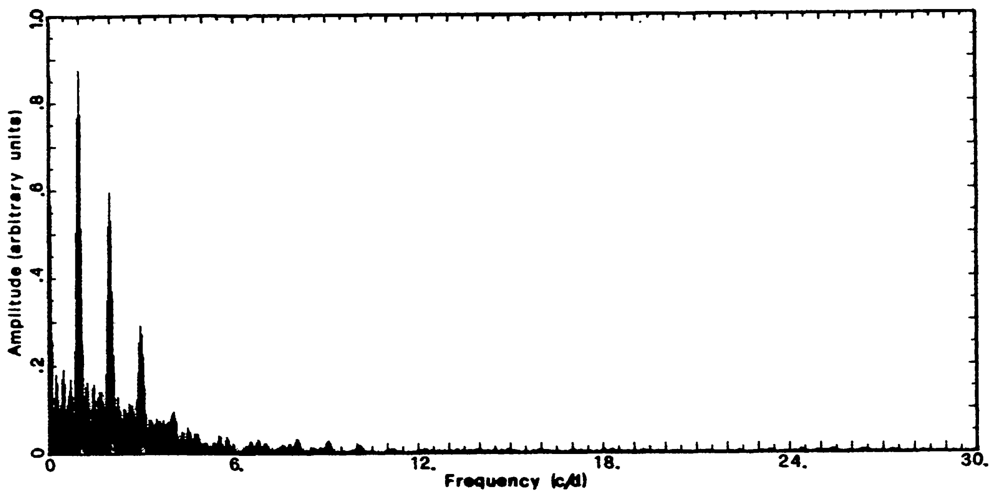
The member of the Coma cluster HR 4684 is a delta Scuti star which lies near the blue edge of the instability strip. Elliot (1974) measured its light curve for few nights in 1970 determining a tentative period P = $0^d.0551$. In the framework of our research program on the variability of the delta Scuti stars, we observed this object in 1976 during 11 nights (Guerrero and Mantegazza, 1976). Here we present the analisys of our light curve. The results have some interest, in that they show the presence of three periodicities, which seem to be linked by a parametric resonance mechanism.

2 - DATA ANALYSIS.

The data analysed for the search of periodicities consists of 177 Δm_V normal points distributed over two series of consecutive nights. For description of the instrumental equipment and of the reduction procedure, see Bossi et al. (1977).

Two analysis methods were adopted: the least squares power spectrum proposed by Vaníček (1971) and the non linear least squares period determination routine PERDET (Breger, 1982) in connection with the Fourier trans-

Fig.1 - The spectral window.



form for unequally spaced data (Deeming, 1975).

The results obtained by means of both methods are very similar: we found three sinusoidal components of comparable amplitudes. However, there is an indetermination about the exact values of their frequencies, because of the data spacing with the time, which, as one can see from the spectral window (Fig.1), produces two strong aliases at ±1 cycle/day of the central peak. The problem is entangled by the presence of some power at low frequency, mainly due to the different mean levels in the observations of the different nights. So, we have several sets of frequencies that in the least squares sense are equivalent:

10.25, 15.02 and 25.23 c/d;

9.25, 15.02 and 24.27 c/d;

10.25, 16.02 and 25.23 c/d;

9.25, 16.02 and 25.23 c/d;

9.31, 14.98 and 24.27 c/d;

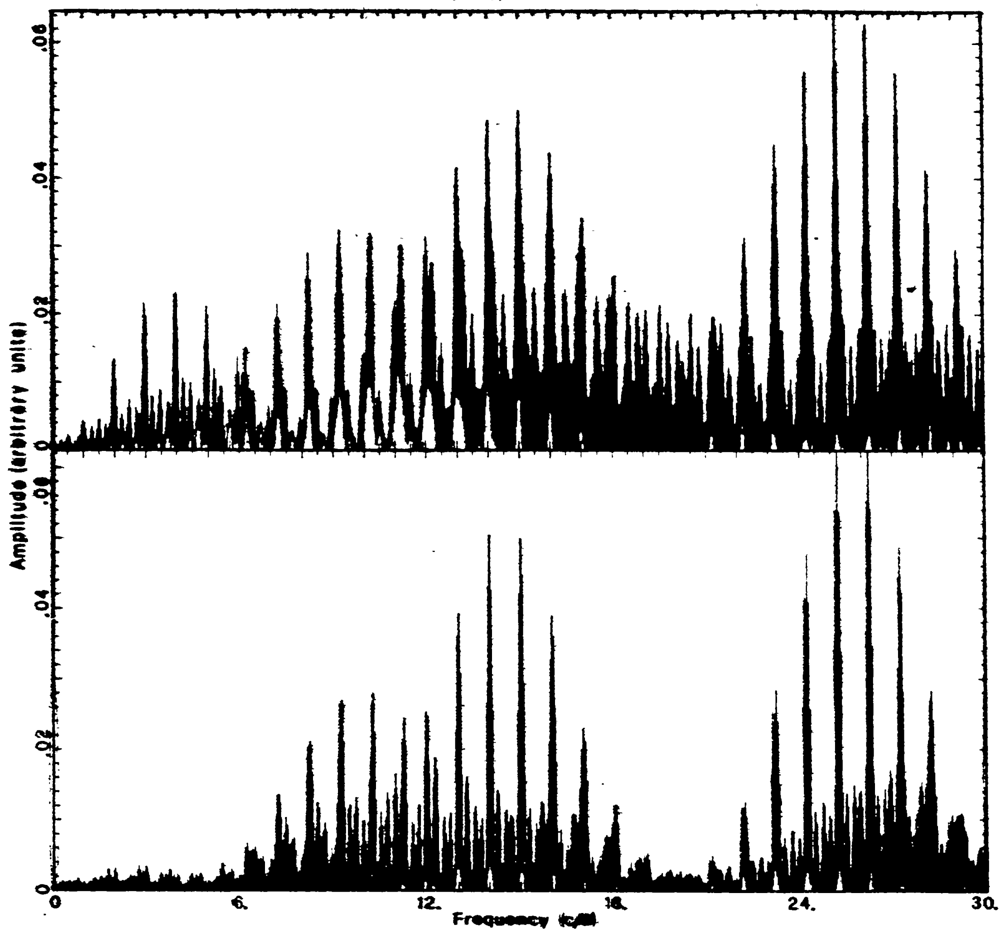
etc..

The trial period proposed by Elliot (1974) don't result confirmed.

If we try to evaluate, in addition to the goodness of the least squares fits, the structure of the frequency patterns, we obtain a slight preference for the first set (see Fig.2).

It is very interesting to observe that, if we label the three frequencies f1, f2 and f3 in order of increasing values, most of these solutions belong to the type:

Fig.2 – Frequency patterns: power spectrum of the observational data, cleared of low frequencies components (TOP) and power spectrum of a synthesized light curve (the first possible solution without noise) (BOTTOM).



f3 = f1 + f2.

This fact is strenghtened if we consider the decimal places of all the proposed solutions: for them the above sum is always verified within the uncertanties. In fact, it would be uncorrect to estimate the accuracy on the frequency determinations according to the whole time basis, whereas the 54% of the observations fall within six consecutive nights: it is more correct to evaluate it about 0.04 c/d.

As regards the semi-amplitudes of these components, they all result of about $0^{m}.004 \sim 0^{m}.005$, with a slight prevalence of f3.

3 - DISCUSSION.

Owing to the uncertanties in the periods, we cannot obtain reliable mode identifications.

In the hypothesis of radial pulsations, the period ratios $P2/P1 \simeq 0.7$, $P3/P2 \simeq 0.6$ and $P3/P1 \simeq 0.4$ would indicate the excitation of the fundamental mode, an intermediate overtone (1H or 2H) and an high overtone (5H). This would be an interesting result in the context of the linear non adiabatic theory (see e.g. Stellingwerf, 1979).

We can obtain other indications computing the Q values. From the photometric indices of this star (Hauck and Mermilliod, 1980) we derive, through Crawford's calibration (1979), $(b-y)_o = 0.098$, $(c_1)_o = 0.946$ and $M_V = 1.71$. Using Breger's calibration (1977), we get an effective temperature $T_e = 8350°K$ and, for the gravity, log g = 4.05. Moreover, we obtain from Hayes (1979) a bolometric correction of -0.03 mag, which yields a bolometric magnitude $M_{bol} = 1.68$. Consequently, the Q parameters result to be $Q1 \simeq 0.045$, $Q2 \simeq 0.031$ and $Q3 \simeq 0.018$. The high value of Q1 suggests a non radial g_1 mode (Fitch, 1981), Q2 the radial fundamental mode and Q3 a relatively high overtone (H3 or a non radial p_3^1, p_3^2 mode).

In any case, the period ratios and the Q values indicate the excitations of an high overtone, whose frequency is the sum of the frequencies of the two lower order modes. Moreover, there is a moderate evidence that also the highest amplitude belongs to the highest frequency component. Since the linear non adiabatic theory predicts just that high overtones are preferably excited (Stellingwerf, 1979; Dziembowski, 1980; see also Antonello, this workshop), we can interpret the highest order component as an unstable mode which decays in two lower order damped modes. In particular, one of these modes may be a g mode. This seems to be an important verification, in an observed delta Scuti star, of the Dziembowski's (1982) suggestion about the presence of parametric resonance mechanisms in pulsating dwarf stars.

In the past, we showed already a possible resonance in another delta Scuti star observed at the Brera - Merate observatory (Bossi et al., 1982). In fact, the analysis of the light curve of KW 207 (HD 73576) yielded the three possible periods $P1 = 0^d.0583$, $P2 = 0^d.0642$ and $P3 = 0^d.1175$. Here $P3 \simeq 2 \times P1$. The Q1 value ($\sim$0.019) suggests a relatively high overtone or an high order non radial p mode, Q2 ($\sim$0.021) a lower overtone or non radial p mode and Q3 ($\sim$0.038) the fundamental radial mode, a f mode or a g_1 (with $l \simeq 3$) mode. As in the preceding case, the component with the lowest period has the highest amplitude. So, we can interpret the P3 pulsation as a damped mode which is excited by the highest unstable one.

As a concluding remark, we recall that, according to Dziembowski (1982), this kind of resonance can occur also when the relation $f_1 = f_2 + f_3$ (or $f_1 = 2 \times f_2$) is nearly, and not exactly, verified.