AMPLITUDES AND FREQUENCIES OF δ SCUTI STARS: SYSTEMATICS

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1. PERIODS

Delta Scuti stars are short-period pulsating A/F stars situated on or above the main sequence. They often pulsate with two more excited modes. The knowledge of the period lengths and period ratios is very important to deduce the nature of the pulsation modes, e.g. is the pulsation radial or nonradial? Furthermore, these values provide valuable information on the interior structure of these stars.

The determination of the period ratios from the light curves is difficult, since only a few cycles can be covered during a night. The small amplitudes of about 0.01 mag in some variables also makes the multiperiod analysis difficult. While every star should be considered on its own merit, a rough estimate of about 5 nights per deduced period appears to be a minimum requirement. Even then different analyses can give different results. A recent example is the star 38 Cnc (=BT Cnc). An excellent set of observations by Guerrero, Mantegazza and Scardia (1979) gave three periods with nonradial period ratios and a good fit. Our subsequent analysis of the same data gave three radial periods with an even better fit!

The reported periods of δ Scuti stars can usually be assigned to three groups: (i) radial periods where the reported period ratios are near the theoretical values of $P_1/P_0 = 0.76$ and $P_2/P_1 = 0.81$. This large group of variables contains (among others) all the large-amplitude variables except 1 Mon, (ii) nonradial pulsators with period ratios different from the expected radial values. The best example here may be 14 Aur (Fitch 1979). It is possible that this group contains a few radial pulsators who also have excited nonradial modes or stars with observationally uncertain period ratios, (iii) stars which appear to change their periods with time, such as 21 Mon (Stobie, Pickup and Shobbrook 1977). More details on the multiple frequencies can be found in Fitch (1976) and Breger (1979).

Sufficient multiperiod analyses are now available to examine some systematics. Some of the conclusions must, however, be considered as preliminary at this stage. Let us first consider radial pulsators. The

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many model calculations have shown that for δ Scuti stars the value of the pulsation constant Q_o is $0^{\rm d}.033$ for the radial fundamental mode. This predicts that a period-gravity and a period-luminosity-color relation should exist. To avoid the T_{eff} term, the period-gravity relation will be examined (Figure 1).

The <u>radial</u> pulsators (open circles) follow a narrow band in Figure 1 with the width given by the observational uncertainties in determining log g. The slope indicates that Q_o is constant, as expected. The 12 stars with large amplitudes (RRs stars) show the same relation as the 11 smaller-amplitude variables. If we assume that δ Scuti stars have an average rotational velocity, the constant Q line indicates that $Q_o = 0^{\rm d}.039$, higher than the theoretical value of $0^{\rm d}.033$. However, the δ Scuti stars analyzed so far have considerably lower than average values of <u>v sin i</u>, and a correction needs to be applied. Inspection of the c_1 index (Balmer jump) calibration for A stars by Crawford (1979) leads to a reduction of the observed Q_o value to the $0^{\rm d}.030$ to $0^{\rm d}.035$ range. Exact quantitative corrections are regrettably not available. We conclude that the observed fundamental radial period length is in agreement with calculations.

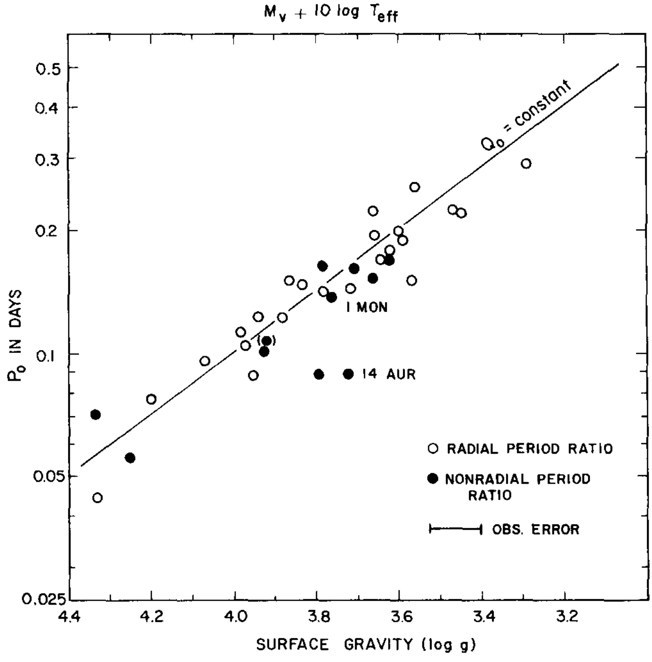

Figure 1 – Observed relationship between period and gravity for radial and nonradial δ Scuti pulsators.

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The longest observed nonradial periods have also been plotted in Figure 1. We note that the lengths are similar to those of the observed fundamental radial period. Period length, therefore, does not distinguish radial from nonradial pulsators. Further conclusions must be speculative, since the actual modes have usually not been identified for the individual stars. Some calculations, such as the models by Dziembowski listed in Petersen (1976) are available. The ZAMS models listed for the p_1 mode with $l = 4$ give $Q = 0^d.024$, only slightly lower than the observed values near $0^d.03$. Two stars deviate from the others in Figure 1. One of these stars is the ellipsoidal δ Scuti star 14 Aur, in which p_5 global modes have been identified by Fitch (1979). These modes have low Q values and therefore a low position in the figure. We conclude that the modes of most other nonradial pulsators should have a lower k value (order) than 14 Aur.

2. AMPLITUDES

The amplitudes of δ Scuti stars are highly variable from star to star and range from zero (constant) or near-zero to 0.8 mag. A search among different observational parameters reveals that rotational velocity and the associated metallicism appear most important in determining the amplitude of pulsation.

To illustrate the importance of rotation, we have to separate the δ Scuti stars into two groups: main-sequence (short-period) stars, and evolved (long-period) stars. This division is necessary because of the observed exclusion between classical Am stars (which are only on the main-sequence and have systematically low rotational velocities) and pulsation. Consequently, we find that on the main sequence the slow rotators are constant in light. The rapid rotators pulsate with only very small amplitudes.

Among the evolved stars the exclusion between classical Am stars and pulsation does not apply and we can study what happens to amplitudes at low rotational velocities. The data in Table I has been calculated from various variability surveys. More information can be found in a review paper (Breger 1979). The variables with amplitudes greater than 0.3 mag are usually very faint and considerably more distant than the average small-amplitude pulsator. This is a consequence of the small

TABLE I

RELATION BETWEEN AMPLITUDES AND ROTATION AMONG EVOLVED STARS

Group of stars	Average v sin i (km/sec)
Constant	124 ± 10
Variable (all amplitudes)	77 ± 13
0.1 ≲ Amplitude ≲ 0.3 mag	35 ± 13
Amplitude ≳ 0.3 mag (RRs)	25:

number of large-amplitude pulsators and the increased probability of accidental discovery. Due to the faintness of these variables, rotational velocities have not been systematically measured. The available spectra, however, show that the large-amplitude variables are very sharp-lined. Since the pulsation of these variables is radial, the amplitudes of pulsation should be independent of aspect, sin i. Consequently, we can disregard the possibility that the observed large amplitudes among many sharp-lined stars are caused by a pole-on aspect.

Table I demonstrates the systematic decrease of rotational velocity with increasing amplitude. Rotational velocity, therefore, appears to be the most important (but not only) parameter determining the amplitude of pulsation of a δ Scuti star.

REFERENCES

Breger, M., 1979. Publ.Astron.Soc.Pacific, 91, 5.
Crawford, D.S., 1979. Preprint.
Fitch, W.S., 1976 in Multiple Periodic Variable Stars, I.A.U. Colloquium 29, W.S.Fitch,ed.(Budapest:Akademia i Kiado),p. 167.
Fitch, W.S., 1979. Astrophys. J., 231, 808.
Guerrero, G., Mantegazza, L., and Scardia, M., 1979. Preprint.
Petersen, J.O., 1976 in Multiple Periodic Variable Stars, I.A.U. Colloquium 29, W.S.Fitch,ed.(Budapest:Akademia i Kiado), p. 195.
Stobie, R.S., Pickup, D.A., and Shobbrook, R.R., 1977. Monthly Notices Roy. Astron. Soc. 170, 389.