MULTIPLE PERIODICITIES IN δ SCUTI STARS

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Abstract. Four δ Scuti stars (θ Tuc, ϱ Phe, 1 Mon and 21 Mon) have been observed intensively in an effort to understand the periodicities present in these stars. The stars selected were known to be of variable amplitude and relatively large light range. The data of each star was Fourier analysed. In no case did the period ratios have values consistent with the period ratios of low order radial modes. The most interesting result appears in the analysis of 1 Mon. The three principal periodicities present occur at $P_1 = 0.13612$, $P_2 = 0.13378$ and $P_3 = 0.13855$ days. To within the errors these periods form an equal frequency split, i.e. $1/P_2 - 1/P_1 = 1/P_1 - 1/P_3$.

DISCUSSION

Cox: I do not understand how you get these periods, I assume it's by some Fourier analysis?

Stobie: Yes, it is by Fourier analysis.

Cox: Therefore it assumes that these pulsations in all the modes are sinusoidal. Now if they are not sinusoidal, what does that do to them?

Stobie: For a start, you calculate your mean curve and see just how sinusoidal it comes out, and if it does not look sinusoidal, you'd expect a significant power to appear in one of the harmonics of this frequency at exactly half that period or one third that period, whatever it is. In fact, in this star we just looked at some results that Bob Shobbrook brought from Sydney and it turned out that for this star which is of large amplitude, there was evidence that there was a component I think at $0\overset{d}{.}06$ which has a very small amplitude. Most of these stars, the lower amplitude ones, have really sinusoidal curves when you look at them.

Schatzman: What is the meaning of a Fourier analysis for a saw toothed oscillation?

Stobie: Once you've got what you think is the main period, even if the thing is completely non-linear in shape, you can pick out a mean sine wave out of that.

Schatzman: I do not mean that you cannot do the calculation, I'm asking about the physical meaning of a Fourier analysis on a non-linear oscillation.

Stobie: But the assumption is that it's a combination of modes.

Schatzman: But this is not. This is a non-linear oscillation; not a superposition of linear modes.

Kemp: In physical systems, one can certainly have non-linear oscillators which can have a rigorously periodic behaviour, such that the oscillation waveform can be represented by a discrete Fourier series. (An ordinary pendulum for example is a non-linear oscillator, for finite amplitudes, yet is still strictly periodic, actually multiply periodic, if dissipation is negligible).

Rodgers: Can I ask Dr Cox or Iben about the linear combination of various modes? Has anyone done anything like this and is there anything physically in the numbers game that is indulged in, in s distortions and ϕ distortions of dwarf Cepheid light curves, like AI Velorum? What does the non-linear pulsation calculation say about them?

Cox: I don't know. I looked at that recently and I was quite appalled, I didn't think it really was legal doing that and I sort of feel that way here but your amplitudes are lower and therefore more sinusoidal.

Stobie: This would not add anything that had any physical meaning, it was a purely mathematical device to reduce this non-sinusoidal wave by phase distortion.

Ledoux et al. (eds.), Stellar Instability and Evolution, 67–68.

Cox: That is correct, I don't know the answer really.

Schatzman: You have observed for 59 nights one of the stars, the question is whether with this analysis you can predict something concerning the phase one year ahead, and I think you can not.

Shobbrook: The process is merely to look at the frequency spectrum of the observations and pick out sine curves, but we also of course look at the harmonics. Three have very small first harmonics, half the main period, and they are the three highest peaks in the frequency spectrum.

Savedoff: Is it correct to say that out of 10^4 data points, by taking out 6 parameters you have extracted most of the information and the residuals have dropped from 16/100ths mag. to 2/100ths mag.?

Stobie: Yes.

Schatzman: Are these periods just the result of the combination of non-linear oscillations, the periods of which *have* some physical significance? You're going to have harmonics of these non-linear oscillations of large amplitude and these harmonic periods will have no physical significance. For example, the harmonics you obtain will not describe the number of nodes from the centre to the surface of the star.

Rodgers: But in beat Cepheids you can analyse the harmonic periods and obtain period ratios which do have physical significance.

Sinvhal: We observed a δ Scuti star in two runs separated by two years and found the periods of the major Fourier components to be unchanged over the 2 year interval.

Stobie: Yes, this is the sort of thing that Fitch has done with similar results.

Warner: The equal spacing in this frequency domain is exactly what you would expect from non-radial pulsation involving a rotational perturbation and I have done a quick calculation which shows the rotation period to be 1 day or 2 days generating 3 modes, either 0 ± 1 or 0 ± 2 and a distinguished friend here tells me that $v \sin i$ is about 25 km s^{-1} which would give a rotation period of 1 day.

Stobie: I would have thought that the distortion required to produce this effect would have been quite large and would require rapid rotation.

Shobbrook (added in press): There is some confusion in the foregoing discussion regarding *harmonics* and *overtones*. The Fourier components of a non-sinusoidal periodic wave are *harmonics*, or *integer* multiples of the fundamental frequency which merely define the (constant) shape and amplitude of the wave. *Overtones* are other possible modes of vibration of the star, having a non-integer relationship with the fundamental, and whose interaction with the fundamental will produce a beat phenomenon.

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