COMPARISON OF THE PULSATION PROPERTIES OF THE RR LYRAE STARS IN ω CENTAURI WITH THOSE OF CLASSICAL CEPHEIDS

J.O. Petersen
Copenhagen University Observatory, Øster Voldgade 3
DK-1350 Copenhagen K, Denmark

INTRODUCTION

In the last few years several studies have shown that Fourier decomposition technique is a powerful method for quantitative description of light curves of pulsation variables. This technique was introduced by Simon & Lee (1981), who showed that amplitude ratios and phase differences provide a very useful description of the Hertzsprung progression for classical Cepheids. Recently, Simon & Teays (1982) discussed 70 RR Lyrae field stars.

In the present study I analyse 130 photographic mean light curves of RR Lyrae variables in ω Centauri taken from Martin (1938). I wish (i) to compare the Fourier decomposition parameters of the ω Cen RR Lyrae stars with those of the field variables as studied by Simon & Teays, (ii) to discuss the evidence for progression sequences among the ω Cen variables and (iii) to compare the basic pulsation properties of the RRab variables in ω Cen with those of classical Cepheids.

THE FUNDAMENTAL MODE RR LYRAE VARIABLES

I calculate the Fourier decomposition parameters defined by Simon & Lee (1981) by the method described in Petersen & Hansen (1984). Here I only present the analyses of the lowest order phase difference, φ_{21}, and amplitude ratio, R_{21}. The higher order Fourier parameters give results that are rather similar; they will be discussed in more detail elsewhere (Petersen, 1984).

Fig. 1 shows φ_{21} and R_{21} as functions of the pulsation period. These distributions can be compared with the corresponding distributions for field RRab stars as given by Simon & Teays (1982). About half the field stars have periods below 0.50 d compared to only two of the ω Cen variables. But for periods 0.50 - 0.75 d a close agreement is found both for φ_{21} and R_{21}. Within about ±0.10 for the phase difference and ±0.03 for the amplitude ratio no systematic differences are seen.

In the period interval 0.75 - 0.90 d I find smooth variations in φ_{21} and R_{21} rather than a drastic change at a period of about 0.80 d as indicated by XZ Ceti. This result also holds for higher order Fourier parameters (Petersen, 1984).

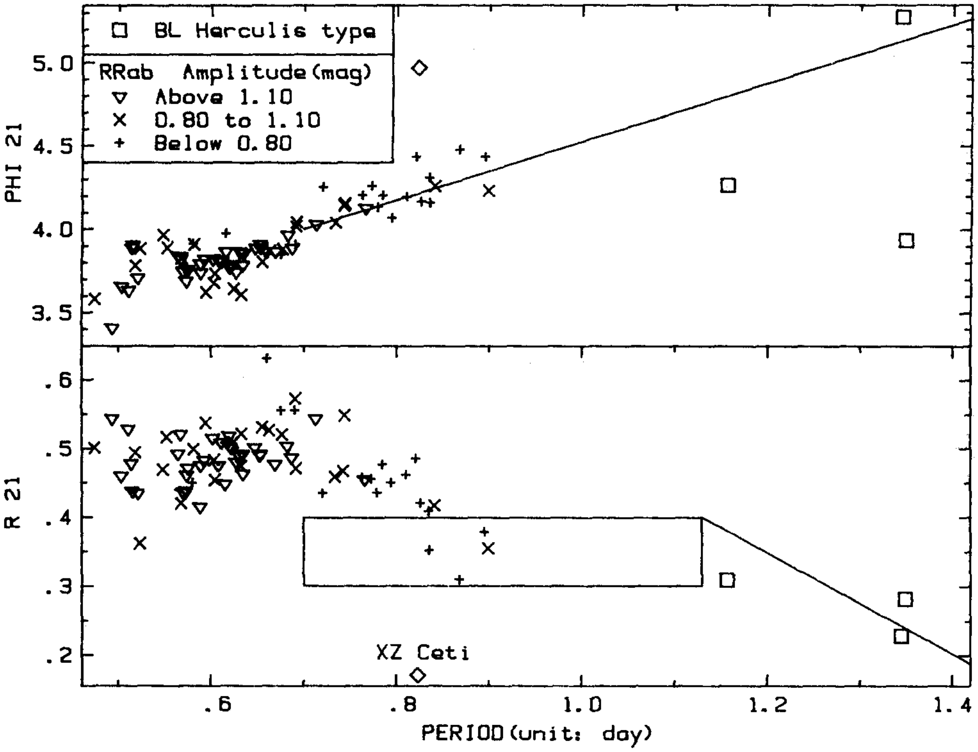
For the field stars Simon & Teays noted some evidence for a Cepheid-like progression for periods 0.55 - 0.75 - 0.82 d. In particular they pointed out that XZ Ceti might be associated with the fundamental mode - second overtone resonance in the bump progression sequence.

However, I can now safely follow the sequence to 0.90 d and find no indication of a close resonance. Clearly, the long period RRab stars in ω Cen do not resemble XZ Ceti.

To me it is reassuring that the resonance, after all, does not occur in RRab stars at a period of about 0.80 d. Firstly, the BL Herculis variables probably form a simple continuation of the RRab stars toward higher periods. And several investigations (e.g. Petersen & Hansen, 1984; and references therein) agree that this resonance occur at a period 1.5 - 1.6 d. Secondly, comparing with Simon & Lee's (1981) Fourier description of the well established bump progression for the classical Cepheids, one should expect a rise in φ_{21} to about 5.4 (and a decrease in R_{21} to about 0.1) before the resonance appears. And the RRab stars in ω Cen show a rise to only about 4.2 at a period of 0.80 d.

I will now consider the classical Cepheid sequences starting at a period of 3 d and ending at the resonance period 9 d. The φ_{21} sequence is well represented by a straight line from φ_{21} =4.0 to 5.4.

Figure 1. φ_{21} and R_{21} versus period for 75 RRab stars and 3 BL Herculis stars in ω Centauri and the field variable XZ Ceti. Full lines and the area shown on the lower panel represent mean sequences defined by the classical Cepheids transformed to the ω Cen variables (see text).



This sequence can be transformed into an equivalent *expected* sequence for the ω Cen variables using the plausible assumptions: (a) φ_{21} varies in the same way along the progression sequences and R/M is a good pulsation parameter determining φ_{21} (Cogan, 1970); (b) for the ω Cen variables the mass is about 0.5 solar masses, and (c) the relevant resonance period is 1.5 d corresponding to 9 d for the classical Cepheids; (d) well established properties of classical Cepheids. The resulting sequence is shown on Fig. 1 together with similar predictions for R_{21} also based upon (a) - (d) (see Petersen (1984) for details).

ω Cen contains three BL Herculis type variables with period 0.9 - 1.5 d. As they ought to follow the bump progression they are also plotted in Fig. 1.

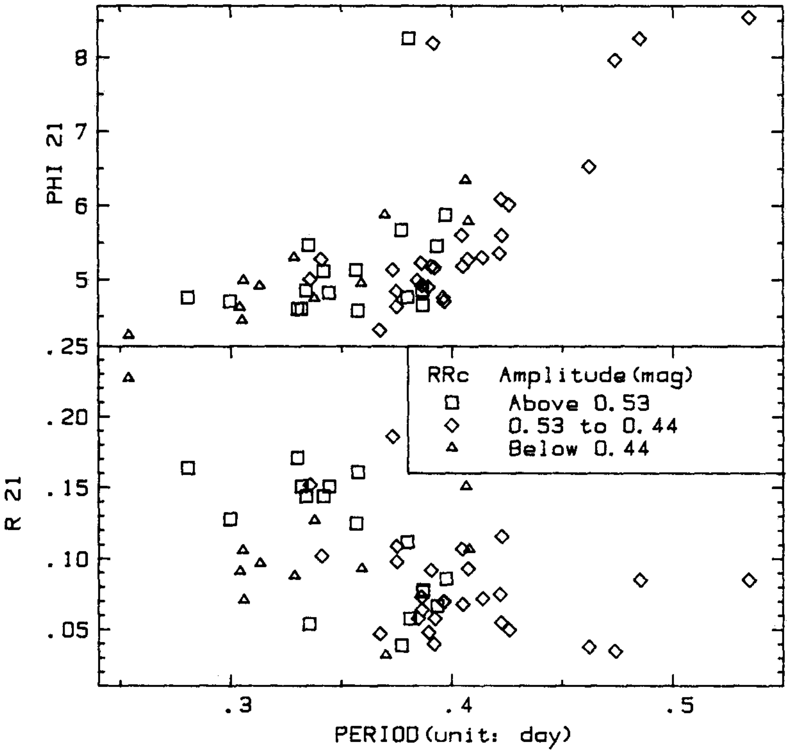
Fig. 1 shows a nice agreement between the observational data for ω Cen variables and the transformed schematical data for classical Cepheids. If we simply assume that the RRab sequences continue somewhat farther from the resonance than the corresponding Cepheid sequences, I assess the agreement to be very satisfactory. And also the BL Her stars follow the sequences reasonably well. From Fig. 1 I conclude that there is strong evidence for a bump progression sequence from a period of about 0.5 d through the RRab region and the BL Her variables to the resonance at about 1.5 d and that this sequence is essentially identical with the well established sequence for classical Cepheids from 3 d to 9 d.

This result seems to be confirmed by a study of theoretical RRab pulsation models by Stothers (1981). His standard model with period 0.529 d gives velocity curves for the various zones which very convincingly show the formation of a secondary bump by a Christy wave in the way that is well known from models of short period classical Cepheids.

THE FIRST OVERTONE RR LYRAE VARIABLES

The large number (55) of RRc variables in ω Cen combined with their relatively large period interval (0.25 - 0.53 d) makes it possible now to demonstrate systematic variations in φ_{21} and R_{21} also for them (Fig. 2; details in Petersen, 1984). It seems interesting that the systematics in many respects is the same as in the well studied case of the classical Cepheids, if we assume a resonance at about 0.45 d. However, since the RRc variables are first overtone pulsators, effects from the fundamental mode - second overtone resonance seems impossible. Therefore, it is tempting to propose the presence here of another resonance. I must emphasize that both the data base used and and the resonance explanation need confirmation from independent investigations. I think that further studies of the RRc variables could be important for the understanding of the bump mechanism.

Figure 2. φ_{21} and R_{21} vs. period for 55 RRc variables in ω Centauri.



REFERENCES

Cogan, B.C. (1970). Astrophys. J., *162*, 139.
Martin, W.C. (1938). Leiden Annalen, *Vol. XVII*, Part 2.
Petersen, J.O. (1984). Astron. Astrophys., submitted.
Petersen, J.O. & Hansen, L. (1984). Astron. Astrophys., in press.
Simon, N.R. & Lee, A.S. (1981). Astrophys. J., *248*, 291.
Simon, N.R. & Teays, T.J. (1982). Astrophys. J., *261*, 586.
Stothers, R. (1981). Astrophys. J., *247*, 941.