On the rapidly Oscillating Ap Stars

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ABSTRACT

Frequency separation $\Delta\nu$ between consecutive modes have been computed for A stars. It is shown that $\Delta\nu$ is a good indicator of the star's position in the main sequence band. Applications to HD101065, HD24712 and HD83368 are discussed.

I. INTRODUCTION

Kurtz (1980, 1982, 1983a, b) and Kurtz and Seeman (1983) have discovered rapid oscillations in cool Ap stars corresponding to high order p modes. For these modes the knowledge of a few periods brings no significant information concerning the structure of these stars. However if even only 2 successive such frequencies are observed their difference $\Delta\nu$ helps to locate the star in the H.R. diagram.

II. FREQUENCY SEPARATION IN THE HR DIAGRAM

We have computed frequencies and frequency separation $\Delta\nu$ for models of 1.5, 1.75 and 2 $M_\odot$. Their chemical composition is given by X = .7, Z = 0.02. A few properties of the models are given in table I. The models and the frequencies have been computed neglecting magnetic fields. Therefore this work rests in the hypothesis that the magnetic field of Ap stars does not introduce significant perturbations of the models and of their oscillation periods.

From the $\Delta\nu$ values, we drew curves of constant $\Delta\nu$ (in μHz) in the HR diagram which are shown in fig. 1. They are nearly parallel to the Z.A. M.S. Therefore $\Delta\nu$ gives no information concerning the mass of the observed stars but it is a good indicator of their position in the M.S. band.

We also computed the dimensionless values of $\Delta\nu$ defined as $\Delta\nu_{SD} = \Delta\nu(R^3/GM)^{1/2}$. We found that $\Delta\nu_{SD}$ is nearly constant for all the models studied. We obtained $\Delta\nu_{SD} = 0.2$ with an accuracy of 2.5%. For the sun $\Delta\nu_{SD} = 0.2246$. Therefore $\Delta\nu$ for Ap stars may be obtained from the solar value through a homologous transformation.

III. APPLICATIONS

a) HD101065

According to Kurtz (1980), this star has $T_{eff} = 7400$ K and is near the main sequence. It shows pulsations in 4 frequencies, a singlet at $\nu = 1315$ μHz and a triplet at the average frequency of 1370 μHz. Kurtz suggests that all the 4 modes are quadrupolar. Then $\Delta\nu = 55 \pm 4$ μHz and HD101065 is at the end or just after the main sequence phases. Its effective temperature suggests a mass of the order of 1.6 $M_\odot$.

For HD24712, Shibahashi (1984) has suggested on the basis of the rotational splitting that the oscillations should be associated with 2 values of ℓ differing by one. It seems natural for HD101065 to suppose that the singlet and the triplet are respectively $\ell = 0$ and 1 modes. Then $\Delta\nu = 110 \pm 4$ μHz and the star should be very close to the ZAMS and its mass should be $\lesssim 1.5$ M_0.

b) HD24712 (HR1217)

According to Bonsack (1979), this star has $7350 < T_{eff} < 7500$ K. Kurtz (1982) observed two triplets with $\Delta\nu = 68 \pm 4$ μHz. Kurtz and Seeman (1983) observed 6 frequencies with $\overline{\Delta\nu} = 34.7 \pm 4$ μHz that they interpret as 6 consecutive modes with the same ℓ.

A $\Delta\nu$ of about 35 μHz places the star outside the M.S. band, approximatively 1.5 magnitude above the ZAMS if $T_{eff} = 7400$ K, in a region where the star moves very rapidly in the HR diagram.

With Shibahashi's suggestion $\Delta\nu \simeq 69$ μHz. Then HD24712 can be interpreted as a star of about 1.5 $M_\odot$ just in the middle of the M.S. phases. Its radius is then 1.7 $R_\odot$ very close to the value of 1.8 $R_\odot$ derived by Kurtz with the oblique rotator model.

c) HD83368 (HR3831)

Kurtz (1982) has observed 2 triplets at 1428 μHz (11.67 min) and 2856 μHz. He claims that their ratio is equal to 2 with an accuracy of 3 10^{-5}.

Though the 2 lines are triplets, he suggests that the lowest frequency is a dipole mode and the other a quadrupole mode. His argumentation is based on the asymptotic formula $\nu = \nu_o(n + \ell/2)$ which predicts that $2\ \nu(n, \ell = 1) = \nu(2\ n, \ell = 2)$. It would however be surprising that the asymptotic formula reaches such a high accuracy at the frequencies given above. For the 13 models studied, we computed eigenvalues close to these frequencies. As could be expected, the asymptotic formula gives the best results for models at the end of the M.S. phases as for a given frequency the overtone number n increases when $\Delta\nu$ decreases. However the ratio $\nu(2\ n,\ell = 2)/\ \nu(n,\ell = 1)$ deviates always from 2 by more than $5\ 10^{-3}$. Therefore Kurtz's suggestion may not be accepted. Though Kurtz has raised objections to this idea, it seems to us that presently the best explanation to this ratio of 2 is that the higher frequency triplet is the first harmonic of the low frequency one.

TABLE I : Properties of the Models

$M/M_\odot$	N	$L/L_\odot$	$R/R_\odot$	T_{eff}	X_c	$\rho_c/\bar{\rho}$
2	1	20.00	1.533	9880	0.6465	87.57
	2	22.23	1.797	9368	0.4309	149.5
	3	24.46	2.297	8487	0.0602	475.7
	4	25.20	2.297	8553	0.0283	544.[illegible]
1.75	1	11.46	1.396	9008	0.6832	87.72
	2	12.81	1.626	8583	0.4592	149.1
	3	13.70	1.894	8090	0.2387	277.1
	4	14.12	2.092	7753	0.0914	459.4
	5	14.51	2.126	7741	0.0402	561.4
1.5	1	6.010	1.317	7893	0.6907	96.98
	2	6.909	1.513	7628	0.4319	173,6
	3	7.492	1.842	7035	0.1184	433.0
	4	7.697	1.897	6996	0.0512	554.8

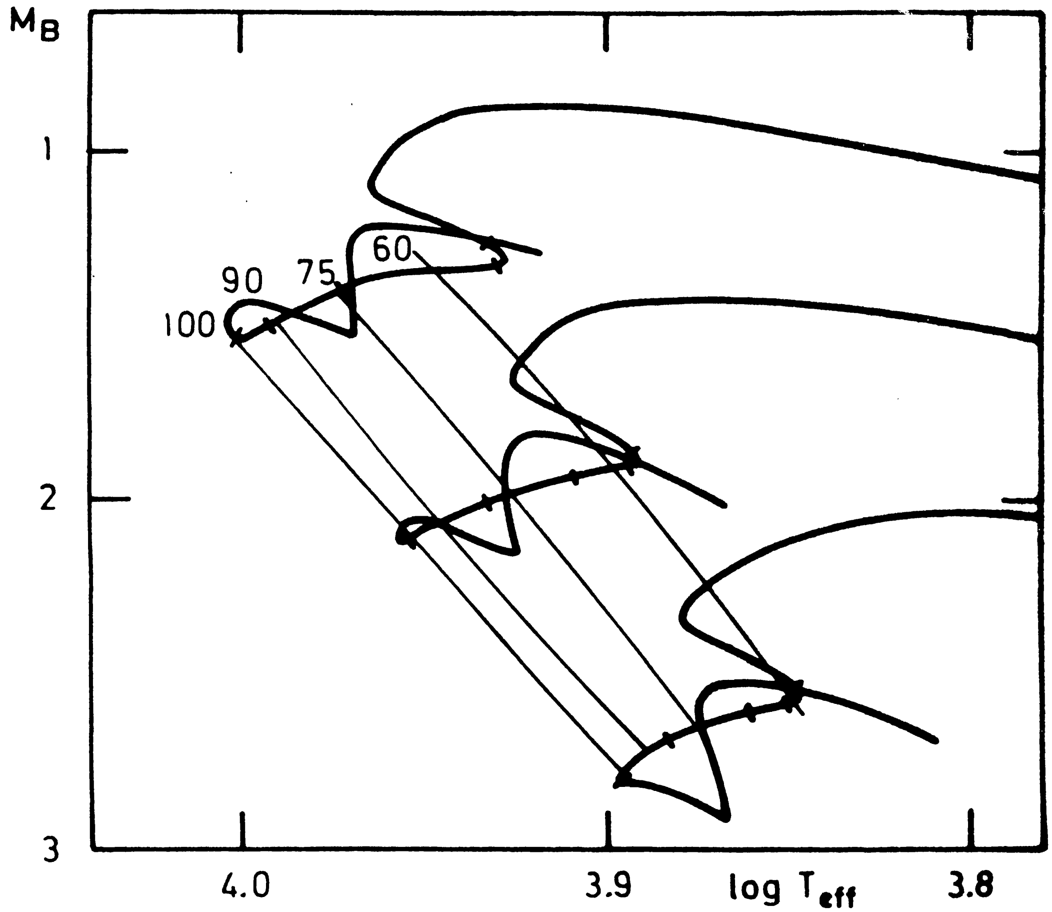

FIG. 1 : Evolutionary tracks for 1.5, 1.75 and 2 $M_\odot$ (heavy lines). Dashes indicate the location of the models studied. Thin lines give curves of constant $\Delta\nu$. The values of $\Delta\nu$ are given in μHz.

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