The incidence of nonradial pulsation in the λ Bootis stars

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Abstract. We have completed a high-resolution, high-signal-to-noise, spectroscopic survey of the northern members of the peculiar λ Boo stars in order to investigate the frequency of the incidence of nonradial pulsation (NRP) in these metal-deficient stars. Of 18 objects observed, 9 show conclusive evidence of NRP, which suggests that pulsation instability is a common phenomenon in the λ Boo class.

Key words: Stars: chemically peculiar – Stars: λ Boo – Stars: oscillations

1. The λ Boo Stars

The peculiar HgMn, Am, and magnetic Ap stars are now thought to be reasonably well understood, but the same can not be said about the λ Boo stars. These objects have Ca II K and metallic-line types near A0, weak Mg II λ4481 lines, and H lines with cores typical of early to late A-type stars, but often with shallow wings. Relative to the Balmer line cores the K and metal line types are too early - the stars are metal weak (Gray 1988). Quantitative measurements suggest that CNO abundances are approximately normal while Fe, Mg, Ca and other elements are underabundant by up to 2 dex (Venn & Lambert 1990; Stürenburg 1993).

2. What is the Origin of the λ Boo Stars?

Several ideas have been put forward in the last few years to explain the λ Boo phenomenon. Venn & Lambert's (1990) observation that the abundances of elements in 3 members of the class are similar to that of interstellar gas depleted by the formation of grains has led to a promising model developed by

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Table 1. Program Star Data.

HD	NRP	Δt (min)	$\|m\|$	P (d)	Phot. Var.?	P_{phot} (min)
319	No	–	–	–	$<$ 4.2 mmag	–
4158	?				?	
30422	Yes	32	19	0.4	Yes	30
31295	Yes	9	30	0.2	$<$ 7.4 mmag	–
38545	No	–	–	–	$<$ 4.2 mmag	–
110411	No	–	–	–	Yes	multimode?
111604	Yes	50	20	0.7	Yes?	
111786	Yes	39	17	0.5	Yes	96,43,71,46
125162	Yes	22	18	0.3	$<$ 6.6 mmag	–
142703	No	–	–	–	Yes	46?,87?
142994	?				Yes	228,140,195,174
183324	Yes	23	15	0.3	Yes	30
192640	Yes	42	14	0.4	Yes	39,49
193256	?				$<$ 2.6 mmag	
193281	?				$<$ 3.4 mmag	
204041	No	–	–	–	$<$ 1.8 mmag	
210111	Yes	62	12	0.5	Yes	51,85
221756	Yes	49	17	0.6	Yes	63

Charbonneau (1991) and Turcotte & Charbonneau (1993) in which the λ Boo stars are accreting mass at a rate on the order of $10^{-13} M_{\odot}$ yr^{-1}.

If the λ Boo stars have accreted their atmospheres, this theory predicts that members of the class should be accreting in the present epoch and therefore many of them may be near the ZAMS. Since asteroseismology has the potential to provide direct measurements of the evolutionary state of pulsating stars, our recent discovery of nonradial pulsation (NRP) in the λ Boo star HD 111604 encouraged us to complete a spectroscopic search for NRP in all members of the class observable from the Canada-France-Hawaii Telescope. Our program objects are listed in Table 1, and as an examination of the table reveals, positive detection of NRP has been obtained in 50% of the 18 observed λ Boo stars.

3. NRP in the λ Boo Stars

One of the more prominent λ Boo nonradial pulsators is shown in Fig. 1. Where the length of the time series for a particular star warrants, we have attempted to estimate feature crossing times, Δt, principal modes, $|m|$, assuming sectorial modes, and the time it takes for one wave to travel around the star, P. These values are tabulated in Table 1. Also of interest is the fact that most of the non-radial pulsators are also photometric variables. (See the column labeled "Phot. Var.?" in the Table 1 for upper limits in photometric variability for stars in which no photometric varations have been observed.) Photometric periods are given in the last column of the table where known.

HD 30422, HD 111604, HD 192640, and HD 210111 have the highest amplitude NRP among our program stars. Of these, HD 192640 (29 Cyg) has V=4.92 which makes it very attractive as a target for future multisite photometric and spectroscopic campaigns. HD 31295, HD 111604, HD 183324, and HD 221756 also warrant consideration as bright ($V < 6$) pulsators. We also would like to encourage additional photometric observations of λ Boo itself.

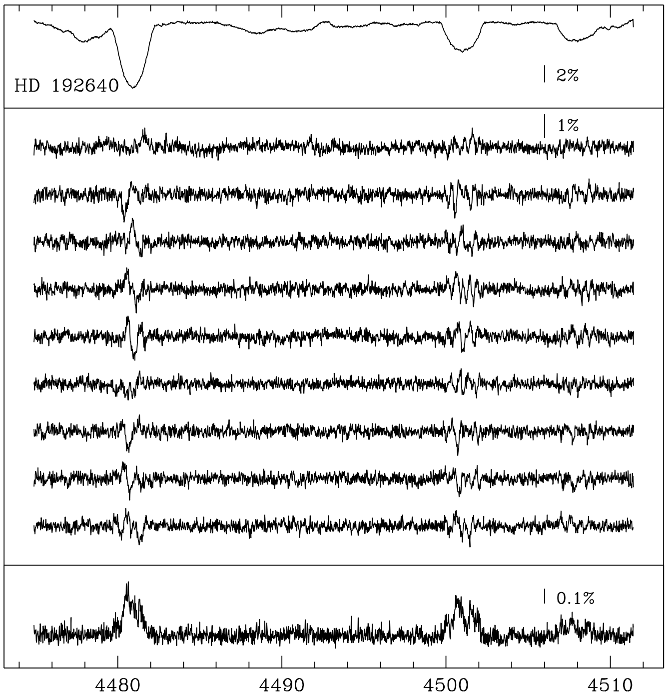

Figure 1. Observed spectra for HD 192640 in the Mg II line region. The top panel shows the average of a sequence of spectra, the middle panel shows the residuals of each spectrum from the mean (time increases downwards) and the bottom shows the mean-absolute-deviation of the spectra from the mean. The relative intensity scale is indicated in each panel. Individual exposures were approximately 10 min long.

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