Diagnostics of Lambda Bootis Stars Atmospheres Using NaD, H-alpha, and Paschen Lines

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Abstract

High signal-to-noise high-resolution spectroscopic observations of seven bright well-known Lambda Bootis stars: HD31295, HD91130, HD110411, HD125162, HD183324, HD192640, and HD221756 are presented. Sharp absorption details observed in the bottoms of NaD lines in HD192640 and HD221756 do not show any radial velocity changes with an accuracy up to 1 km/s. A conclusion of their interstellar origin is made. Manifestations of non-radial pulsation reported earlier in literature are observed both in NaD and H-alpha line profiles. Inglis-Teller formula was used to evaluate electron density in the upper atmospheric layers ($\tau \sim 0.1$). The values obtained for $\log N_e$ are typical for normal A stars with relevant effective temperatures and spectral classes.

1. Motivation

The small group named upon the prototype Lambda Bootis comprises of Population I late-B to early-F stars with metal deficient atmospheres. The underabundances of Fe-peak elements reach up to 2 dex, while the contents of light elements like C, N, O, and S are normal (solar). As a group Lambda Bootis type stars occupy almost the same place in the H-R diagram as Am-stars and cool Ap-stars (CP2), which, in opposite, exhibit metal-enriched spectra. Many other types of stars can be found in this crowded area of the diagram. Even the short list contains also: BHB, HAEBE, F-weak, field blue strugglers, intermediate Poplulation II, pre-MS, and Delta Scuti stars. A small piece of the puzzle is presented in the table.

	Rotation	Metals	Mag. Field	Variability
Normal A-stars	normal	normal	no	no
Cool Ap-stars	slow	excess	yes	sp, ph, puls
Am-stars	slow	excess	no	no
LamBoo stars	normal	deficient	no	puls

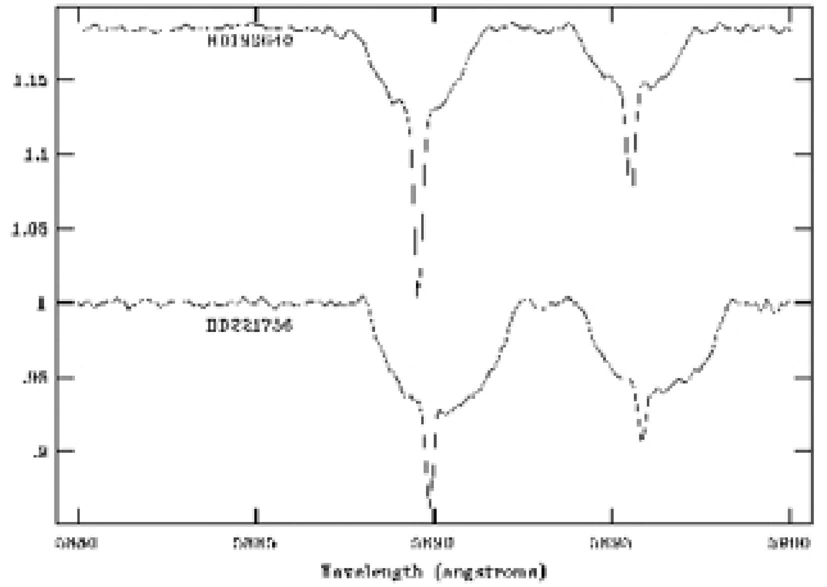
Our recent results (Iliev et al. 2002; Paunzen et al. 2002) show that Lambda Bootis phenomenon takes place in limited physical conditions that put strong constrains to any theoretical model.

Some of the leading concepts (Venn & Lambert 1990; Kamp & Paunzen 2002) postulate the crucial role of gas and dust around Lambda Bootis type stars. Interaction with the circumstellar medium is considered as main reason that controls the observed peculiarities. In connection with this we started a project targeted to NaD, H-alpha, and Paschen lines as markers of the atmospheric structure, and indicators of possible ongoing interaction with the matter that surrounds the star.

2. The Observations

The spectroscopic observations were carried out with the 2-m RCC telescope of the Bulgarian National Astronomical Observatory Rozhen. They cover two spectral regions centered at NaD, H-alpha, and two more regions near the Paschen jump including interval between Pa_{13} and Pa_{21} lines. Resolving power R is about 30000. The typical S/N ratio exceeds 300. Standard IRAF procedures were used.

3. Results

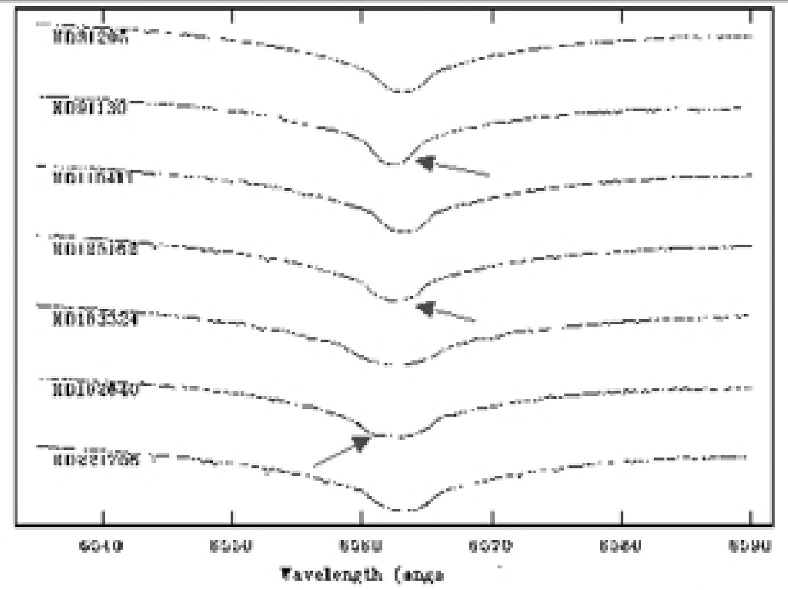


3.1. Sharp NaD details

Such details are inherent to two stars of our sample: HD192640 and HD221756. They have been observed in the line bottoms and have constant R.V.: -19.8 ± 1.2 km/s in HD192640 (7 measurements, time span of about two months), and –3.7 ± 1.5 km/s in HD221756 (3 measurements, the same time span). Note that the case of HD221756 is asymmetrical.

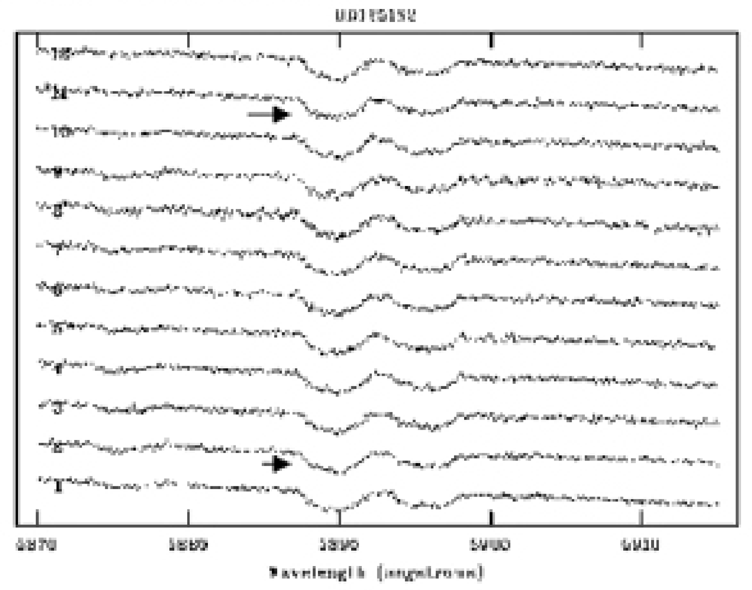
3.2. H-alpha

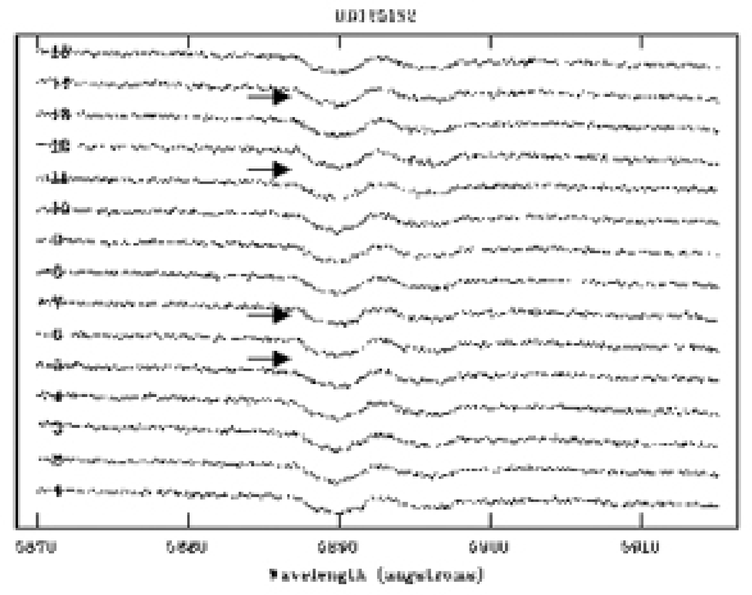
The cores of H-alpha lines are smooth and free of even weak emissions. Some deviations from the regular (rotational broadened) shape can be seen.

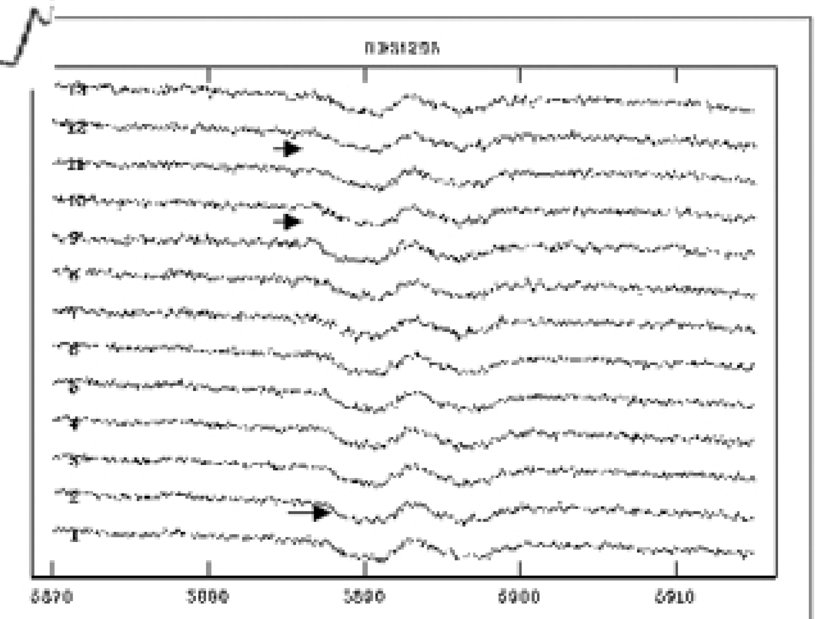


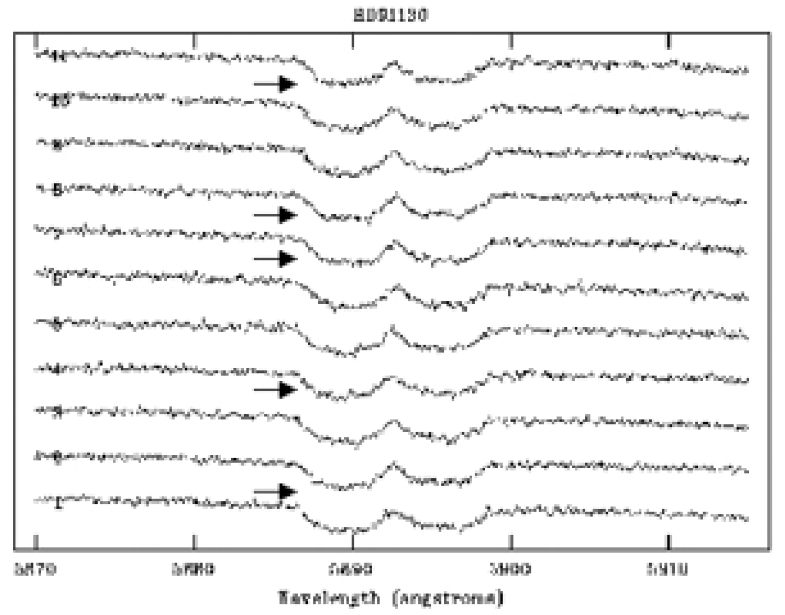
3.3. Non-radial Pulsations

Time dependant distortions from the regular shape observed previously by Bohlender et al. (1999) are seen in the NaD line profiles. Short time scale evolution of these profiles is shown in the figures below: HD31925 – two sequences 1-6, 7-13, 65 minutes each; HD91130 – two sequences 1-5, 6-11, 60 minutes each; HD125162 – two sequences – 1-15 and 1-12, 75 minutes each. The most prominent "complex" or "flat" cases are marked additionally with arrows.









3.4. Electron Density N_e

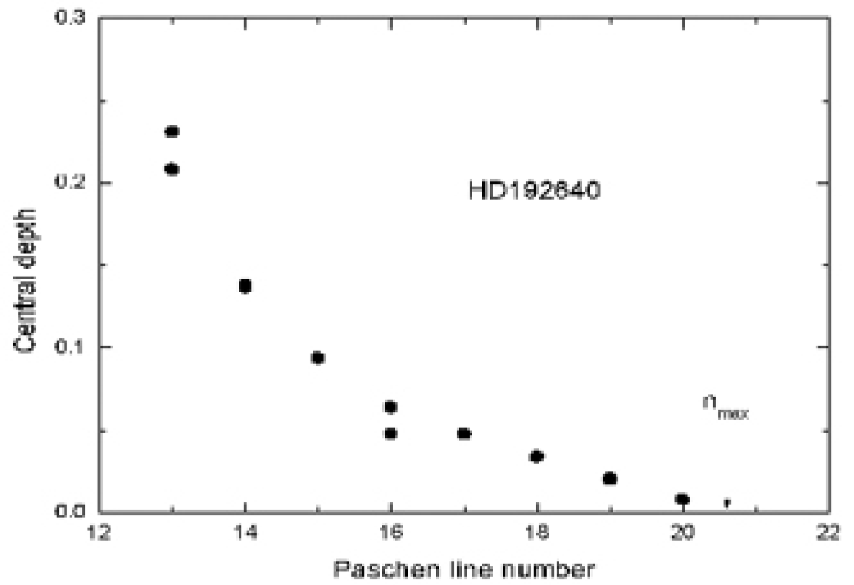
Inglis-Teller formula connects the electron density N_e with the number of last resolved hydrogen line (Balmer in visible and Paschen in near infrared):

$\log N_e = 22.7 - 7.5 \log n_{max}$

Thus we can obtain an estimation how dense are the uppermost atmospheric layers where the optical depth is close to 0.1. Typical values of n_{max} are shown in the small table in the right.

Determining n_{max} simply means to find where the Paschen lines vanish (its central depth R_c or equivalent width approaches zero). Corrections should be made to the bare numbers to take into account the overlapping of the line wings mainly due to rotation. Typical error in n_{max} determination is about 0.2 – 0.25. As a sample the relation between Paschen line number and its central depth measured for the star HD192640 is exhibited in the figure in the right.

The big table contains our final results. The range of N_e values is typical for main sequence stars. As it can be seen however, at least three stars: HD31295, HD192640, and HD221756 show n_{max} number a bit larger that can be expected from their position inside the main sequence strip. The most plausible explanation points to the extended or "giant-like" atmospheres.



A0-F0	ZAMS	mid-MS	TAMS	sub-giant
nmax	17	18.5	20	21-22

HD	Teff	log g	vsini	n_{max}	lgNe
31295	8920	4.20	123	20.0	12.94
91130	8135	3.78	152	19.9	12.95
110411	8970	4.36	154	19.8	12.98
125162	8720	4.07	115	17.8	13.33
183324	8950	4.13	100	17.5	13.38
192640	7940	3.95	80	21.1	12.78
221756	8510	3.90	105	20.5	12.87

References

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