An abundance analysis for Vega: Is it a λ Boo star?

S. Ilijić[1], M. Rosandić[1], D. Dominis[1], M. Planinić[2] and K. Pavlovski[1]

[1] *University of Zagreb, Faculty of Geodesy, Ul. Andrije Kačića Miošića 26, 10000 Zagreb, Croatia*

[2] *University of Zagreb, Faculty of Sciences, Bijenička 32, 10000 Zagreb, Croatia*

Received: July 31, 1998

Abstract. Since Baschek & Slettebak (1988) drew attention to the similarity between the abundance pattern of λ Boo stars and that of Vega, there has been a long debate whether Vega should be listed among the chemically peculiar stars of λ Boo type. We performed an elemental abundance analysis using a high dispersion spectrum in the optical region, and confirmed its mild metal underabundance. In our discussion we reinforce the suggestion that Vega is a mild λ Boo star.

Key words: stars: chemically peculiar – λ Boo stars – Stars: individual: Vega

1. Introduction

Vega (α Lyr = HD 172167 = HR 7001) is a Population I star of spectral type A0 V, with a projected rotational velocity $v \sin i = 23$ km s^{-1}. It has been extensively studied both for its role of primary spectrophotometric standard in the visual and in the UV, respectively, and for its role of comparison star in abundance studies of A-type stars.

Vega has a distinctly non–solar composition. Since Baschek & Slettebak (1988) drew attention to the similarity between the abundance pattern of λ Boo stars and that of Vega, there has been a long debate whether Vega should be listed among the chemically peculiar stars of λ Boo type.

Moreover, Baschek & Slettebak suggested that the λ Boo stars may be regarded as *rotating Vegas*, or conversely Vega may be regarded as a *mild non–rotating λ Boo star*.

2. An abundance analysis

High dispersion spectrum (4 Å mm^{-1}) of Vega was obtained with the Coudé spectrograph of the Ondřejov Observatory 2–m telescope on 19 August 1992. The blue region was covered, $\lambda\lambda$ 4043 to 5057 Å.

Table 1. Abundances derived for Vega in the present work (the number of lines used is indicated in parentheses), and compared with the study by Adelman & Gulliver (1990, hereafter AG), and solar composition as derived by Anders & Grevesse (1989).

Element	AG	This work	Sun	Element	AG	This work	Sun
Cr I		-6.04 (3)	-6.33	Mg II	-5.11	-5.05 (3)	-4.42
Cr II	-6.76	-6.52 (2)	-6.33	Si II		-4.85 (2)	-4.49
Mn I	-7.16	-7.22 (2)	-6.61	Ca I	-6.21	-6.07 (2)	-5.64
Fe I	-5.05	-5.29 (4)	-4.33	Sc II	-9.62	-9.46 (3)	-8.90
Fe II	-5.12	-4.73 (4)	-4.33	Ti I		-7.51 (2)	-7.01
Ni I	-6.38	-6.60 (2)	-5.75	Ti II	-7.47	-7.19 (7)	-7.01
Sr II		-9.27 (2)	-9.14	V II		-7.44 (1)	-8.04
Zr II		-9.08 (2)	-9.54				

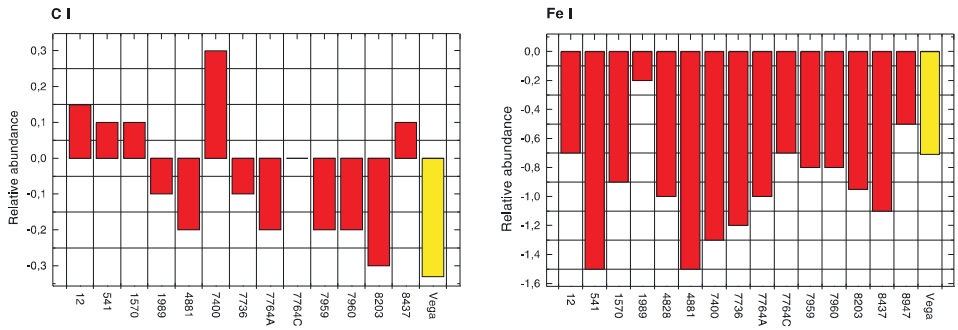

Figure 1. Abundance of carbon (left panel) and iron in Vega compared to abundance pattern of λ Boo stars as derived by Stürenburg (1993).

The abundances of individual elements are derived by the curve-of-growth method. Altogether, 245 lines of 16 elements have been identified and their equivalent widths were measured. The mean microturbulent velocity was $v_t = 1.75\ \mathrm{km\,s^{-1}}$.

The results of the abundance analysis are given in Table 1 along with the results of a previous study by Adelman & Gulliver (1990). For reference we also give the solar composition from Anders & Grevesse (1989). Abundances are expressed as $\log\epsilon = \log(N_{\mathrm{el}}/N_{\mathrm{tot}})$.

3. Is Vega a λ Boo star?

The λ Boo stars are a class of metal-poor Population I A-type stars. Since the prototype was recognized by W.W. Morgan in 1943, somewhat different criteria of classification of λ Boo stars were used (c.f. review by Paunzen in the present

volume for more details). The most detailed abundance study of λ Boo stars was performed by Stürenburg (1993) who analyzed 13 stars. The abundance pattern known from previous studies was confirmed: (i) the light elements (C, N, O and S) have a solar abundance, and (ii) the heavier elements (Mg, Al, Ca, Fe,...) are underabundant by up to a factor of 100.

Vega is not included in the recent 'Consolidated catalogue of λ Bootis stars' by Paunzen et al. (1997) since at classification resolution it does not share the properties of λ Boo stars (c.f. Gray, 1996, for details). However, its abundance pattern clearly resembles those of λ Boo stars as inferred from comparison with Stürenburg's results for his sample of λ Boo stars (Fig. 1). It certainly is slightly metal-weak, and either 1) may possibly represent what a λ Boo star would look like some tens of millions of years after the λ *Boo mechanism* turns off, or 2) may derive its properties from a similar mechanism to the λ Boo mechanism – which, presumably, is the accretion of metal-depleted gas – under slightly different conditions, which would lead to a result similar to, but not identical with what we see in the λ Boo stars (Gray 1997, priv. commun.). Holweger & Rentsch–Holm (1995) have found that if Vega was observed at a more typical inclination, it would follow the correlation between Ca deficiency and rotation shown by other stars of the λ Boo class. In that sense, Vega is exceptional among so-called Vega-type dusty A stars. Evidence for rapid rotation of Vega came from luminosity excess (Gray 1988) and detailed line profile calculations (Gulliver et al. 1994). The idea that Vega is a rapid rotator seen pole-on may have an important role in interpreting the observed properties of Vega.

Acknowledgements. The authors are thankful to Dr. Richard Gray for stimulating correspondence. KP thanks the staff of the Stellar Dept. of the Astronomical Institute of the Academy of Sciences of the Czech Republic for their help and hospitality during an observing run in August 1992. This work has been supported by a MZT Project 007002 of Croatian Ministery of Science and Technology.

References

Adelman, S.J., Gulliver, A.F.: 1990, *Astrophys. J.* **348**, 712
Anders, E., Grevesse, N.: 1989, *Geochim. Cosmochim. Acta* **53**, 197
Baschek, B., Slettebak, A.: 1988, *Astron. Astrophys.* **207**, 102
Gray, R.O.: 1988, *J. Roy. Astro. Soc. Canada* **82**, 336
Gray, R.O.: 1996, *The Standard Star Newsletter No.* **21**, 9
Gulliver, A.F., Hill, G., Adelman, S.J.: 1994, *Astrophys. J.* **429**, L81
Holweger, H., Rentzsch–Holm, I.: 1995, *Astron. Astrophys.* **303**, 819
Paunzen, E., Weiss, W.W., Heiter, U., North, P.: 1997, *Astron. Astrophys., Suppl. Ser.* **123**, 93
Stürenburg, S.: 1993, *Astron. Astrophys.* **277**, 139