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THE ABUNDANCES OF VEGA FROM THE ULTRAVIOLET SPECTRUM

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ABSTRACT We derived preliminary abundances from the ultraviolet spectrum of Vega by comparing high-resolution Copernicus spectra with spectra computed with the ATLAS9 code and with updated line lists. The T_{eff}=9400 K, log g=3.90 model, which fits the visual flux and the Balmer profiles is able to fit the ultraviolet flux either with [M/H]=−1 and microturbulent velocity ξ= 2 km s^{-1} or with [M/H]=−0.5 and ξ=0 km s^{-1}. The line spectrum is fitted by ξ=2 ± 0.5 km s^{-1} and by an iron abundance log (N(Fe)/N_{tot})=-5.2 ±0.1 dex. All the observed elements indicate underabundances ranging from about -0.35 dex (C) up to about -1 dex (Ni, Zn). The origin of the underabundances is an open question.

INTRODUCTION

Vega (α Lyrae = HR 7001 = HD 172167) is a Pop. I star of spectral type A0 V with a projected rotational velocity v*sini*=23 km s^{-1} (Gray,1980). Abundances derived from the visual range are lower than the solar ones from about 0 to -0.9 dex (Venn and Lambert,1990; Adelman and Gulliver, 1990). Vega is not unique, but is part of a group of metal-mild-underabundant slow-rotating A−type stars of luminosity class III−V for which abundance analyses based on high-resolution observations have been done only recently (see Cowley,1991). The observed underabundances could be due to physical mechanisms acting either inside the stars, as the differential diffusion (Michaud,1980), or acting outside the stars in the interstellar medium, as the separation of interstellar grains and gas (Venn and Lambert,1990), or acting both inside and outside the stars (Charbonneau, 1991). A quite attractive explanation could be the selective accretion by only the gas forming toghether with dust a circumstellar disk (Waters et al.,1992). Infrared observations have shown the existence of such a disk around Vega.

We have been studying the ultraviolet spectrum of Vega in order to add information to the abundance pattern of this star which nearly always is chosen as comparison standard in studies of A-type stars.

ANALYSIS AND RESULTS

Preliminary abundances were derived by comparing in the 130-135 nm and 200-318 nm regions LTE computed spectra with Copernicus U1 and V1 spectra with resolutions of 0.005 nm and 0.01 nm respectively. The U1 spectrum was observed by R.L. Kurucz in September 1974 and the V1 spectrum is published and exhaustively described by Rogerson (1989). Synthetic spectra were computed by using the SYNTHE code of Kurucz. The LTE model was computed by means of the ATLAS9 code with the new opacities (Kurucz,1991). The parameters T_{eff}=9400 K and log g=3.90 are obtained with the same methods and the same visual observed fluxes and observed Balmer profiles as decribed by Kurucz (1992). We derived the metallicity [M/H] and the microturbulent velocity ξ of the model from the comparison of the observed and computed ultraviolet fluxes. Observed fluxes are from IUE (Bohlin et al., 1990) and can be fitted either by a model with [M/H]=-1 and ξ=2 km s^{-1} or by a model with [M/H]=-0.5 and ξ=0 km s^{-1}.

TABLE I Preliminary abundances of Vega from the ultraviolet spectrum. $\log\epsilon = \log(N_{elem}/N_{tot})$

Elem	$\log\epsilon_{UV}$	$\log\epsilon_{Vis}$		$\log\epsilon_{Sun1}$	$\log\epsilon_{Sun2}$	$\log(\epsilon_{UV})$-$\log(\epsilon_{Sun1})$
		VL	AG	AG1	G	
C I	-3.88	-3.62	-3.81	-3.48	-3.44	-0.4
C II	-3.78			-3.48	-3.44	-0.3
N I	-4.49	-4.04		-3.99	-4.04	-0.5
O I	-3.71	-3.30		-3.11	-3.11	-0.6
Mg I	-4.96		-5.11	-4.46	-4.46	-0.5
Mg II	-4.96	-5.33	-5.15	-4.46	-4.46	-0.5
Si I	$\leq$-5.09			-4.49	-4.49	$\leq$-0.6
Si II	-5.09			-4.49	-4.49	-0.6
Si III	-4.49			-4.49	-4.49	0
S I	-4.83/-5.83	-4.83		-4.83	-4.77	0/-1
Ca II	-6.18	-6.20		-5.68	-5.70	-0.5
Ti II	-7.80	-7.49	-7.47	-7.05		-0.75
V II	-8.54			-8.04		-0.5
Cr II	-7.12		-6.80	-6.37		-0.5
Mn II	>-7.15		-7.24	-6.65		>-0.5
Fe I	-5.2	-5.06	-5.05	-4.37	-4.52	-0.83
Fe II	-5.2	-5.19	-5.16	-4.37	-4.52	-0.83
Co II	-8.12?			-7.12		-1 ?
Ni I	-6.79		-6.42	-5.79		-1
Ni II	-6.79		-6.33	-5.79		-1
Cu II	-8.83?			-7.83		-1 ?
Zn II	-8.44			-7.44		-1

VL=Venn and Lambert(1990); AG=Adelman and Gulliver(1990);
AG1=Anders and Grevesse(1989); G=Grevesse(1991).

The computed line spectra are, however, independent from ξ and [M/H] adopted for computing the model, because both models (1) T_{eff}=9400 K, log g=3.90, ξ=0 km s^{-1}, [M/H]=−0.5 and (2) T_{eff}=9400 K, log g=3.90, ξ=2 km s^{-1}, [M/H]=−1 yield the same synthetic spectrum, provided that the same ξ and the same abundances are used for computing the spectrum. The adopted line lists are basically those of Kurucz (1989).

The iron abundance log (N(Fe)/N_{tot})=−5.2±0.1 dex was obtained from saturated strong Fe II lines, which weakly depend on ξ. After having fixed the iron abundance we derived ξ=2±0.5 km s^{-1} from the other Fe II lines depending on ξ. Preliminary abundances results are summarized in Table I. They are compared with the abundances from the visual spectrum (Venn and Lambert,1990; Adelman and Gulliver,1990), and with the solar photospheric abundances (Anders and Grevesse,1989; Grevesse, 1991). All the elements are underabundant ranging from −0.35 dex for carbon up to −0.83 dex for iron and to −1 dex for Ni and Zn. With the new solar iron determination of −4.52 dex the iron underabundance is reduced to -0.68 dex. Abundances of V, Mn, Co, and Cu may be affected by systematic errors, owing to the lack of hyperfine splitting in the calculations. Some lines, as, for instance, the blended features consisting mainly of N I (12) at 131.8998, 131.9005 nm, Mg I (1) at 285.2127 nm, S I (8) at 132.35156, 132.3523 nm, Fe II (1) at 259.837 and 259.9939 nm, and the strongest lines of Ti II Vis. mult. 5 at 307 nm require solar or nearly solar abundances in order to be correctly reproduced.

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