Astron. Astrophys. 341, 233–240 (1999)

ASTRONOMY
AND
ASTROPHYSICS

The nature of the sharp-lined A1V star HD 72660*

O. Varenne

UMR 7550, Equipe évolution galactique, Observatoire Astronomique de Strasbourg, 11 rue de l'Université, F-67000 Strasbourg, France

Received 7 September 1998 / Accepted 9 October 1998

Abstract. In order to specify the nature of the sharp-lined A1V star HD 72660, its effective temperature and surface gravity have been determined using two different methods. First, the ultraviolet energy distribution of HD 72660 has been compared with that of the normal A0 star HD 10939 and with the predictions of two model atmospheres. Secondly, the parameters have been derived from Moon & Dworetsky's (1985) calibration of *uvby* colors. Both methods yield consistent values T_{eff} = 9750 $\pm$ 200 K, log*g* = 4.00 $\pm$ 0.20 dex.

In a second part, high resolution high signal to noise optical spectra centered on λ4500 Å, λ5080 Å and λ6160 Å have been synthesized using Gray's (1995) and Takeda's (1995) LTE codes. The abundances of 13 elements were derived. C and O are found to be underabundant with respect to the solar value (-0.60 and -0.52 dex respectively) whereas Ti, Cr, Fe, Ni are overabundant (between +0.37 and +0.72 dex). Ca appears to be moderately overabundant (+0.16 dex). These results suggest that HD 72660 is a hot Am star.

Key words: stars: abundances – stars: chemically peculiar – stars: fundamental parameters – stars: individual: HD 72660

1. Introduction

The A-type stars show a wide variety of spectral peculiarities and most of the abundance determinations have focused on the chemically peculiar A stars (Am and Ap) because of their narrow lines (low apparent rotational velocity *vsini*). Though "normal" A stars represent 80% of A stars (Preston 1974), their chemical composition is still poorly known.

Holweger et al. (1986) noticed significant abundance variations for C, Mg, the iron group elements and Ba among 7 "normal" slowly rotating A stars. Lambert et al. (1986) found no correlation between the C abundances of 22 early "normal" A stars and their *vsini* (up to 180 km/s). Lemke (1989,1990) studied 16 bright, sharp-lined normal main sequence A stars and pointed out iron abundances over a 0.6 dex range around the solar value with a strong deficiency (-1.3 dex) for 50 lib (HR 5959). For these stars, Sr and Ba often are overabundant (+1.0 dex) while Ca is found to be solar. Carbon abundances vary independently of the other elements with an amplitude of 1.0 dex around the solar value. Hill & Landstreet (1993) and Hill (1995) determined abundances of A-type stars with *vsini* between 6 and 109 km/s and found evidence for considerable star to star abundance variations. The abundance of Fe varies over a range of at least 0.7 dex and with the exception of Ca and C, the abundance of the elements seems to vary with that of iron.

More recently, Rentzch-Holm's work (1997) revealed overabundances of S (+0.1 up to 0.6 dex) in 15 sharp-lined "normal" main sequence A stars. Nitrogen abundances are on the other hand distributed over an interval of 0.5 dex around the solar value. In the same way that Holweger (1992) showed an anticorrelation of [C/Si] with [Si/H], she has noticed the same behaviour for [N/Si] and maybe for [S/Si].

Takeda & Sadakane (1997) have made a chemical analysis of several Hyades A-type stars both slow and fast rotators. Using the λOI 7771 Å triplet and the FeI λ7780 Å line they have confirmed the importance of the rotational velocity in the appearance of the Am phenomenon.

The aim of this paper is to clarify the nature of HD 72660 (see Table 1), an early A-type star classified as "normal" (A1V, Cowley et al. 1969) whose spectrum exhibits sharp lines. In order to derive its atmospheric parameters accurately, I have compared low resolution ultraviolet spectra obtained with the International Ultraviolet Explorer (IUE) with those of a normal A star and to model atmospheres of various metallicities and temperatures. Napiwotzki's revision of Moon & Dworetsky's (1985) calibration of *uvby* colors has also been used to derive the effective temperature and surface gravity. Then, a detailed abundance analysis has been carried out for C, O, Na, Mg, Si, Ca, Ti, Cr, Fe, Ni, Y, Ba and Nd using optical lines. Together with those of previous works (Lemke 1989,1990; Rentzch-Holm 1997), these new results are essential in addressing the chemical peculiarity or non-peculiarity of HD 72660.

2. Data and observations

Optical spectra have been obtained at the Haute Provence Observatory with the AURELIE spectrograph (double linear Thomson

---

Send offprint requests to: O. Varenne

[*] Based on observations collected at Observatoire de Haute Provence (France)

Table 1. Main data for HD 72660. References are (a): Cowley et al. 1969; (b): Eggen 1984; (c): Abt & Morrell 1995; (d): magnitude in Johnson V (Hipparcos data); (e): Johnson B-V color (Hipparcos data); (f): Hipparcos B - V standard error; (g): Hauck & Mermilliod 1980; (h): Hipparcos parallax (mas); (i): Hipparcos parallax standard error (mas)

Name	HD 72660 HR 3383 HIP 42028
Sp type	A1V (a) A0V (b) A1II (c)
V	5.80 (d)
B - V	0.007 (e)
σ_{B-V}	0.004 (f)
H_β	2.894 (g)
b-y	-0.010 (g)
m_1	0.163 (g)
c_1	1.058 (g)
π (mas)	10.00 (h)
σ_π (mas)	0.86 (i)

Table 2. Basic data for the ultraviolet spectra

Star	IUE spectra	Resolution	Aperture
HD 72660	SWP44438	Low	Large
	LWP22854	Low	Large
HD 10939	SWP56103	Low	Large
	LWP31606	Low	Large

array TH 7832 made of 2048 photodiodes) placed at the coudé focus of the 152 cm telescope.

Among the 8 possible configurations for the AURELIE spectrometer, 3 different gratings are suitable for the regions of interest: the first one for the region 4475-4545 Å with 1800 lines/mm, the second one with 3000 lines/mm for the region 5050-5110 Å and the third one, working at its second order, with 1200 lines/mm for the 6120-6200 Å spectral range. For these 3 gratings, the resolving power (R=$\lambda/\Delta\lambda$) equals 25000, 65000 and 60000 respectively. In any case, a mean exposure time between 2 and 3 hours led to a signal over noise ratio (SNR) greater than 200. All the data have been reduced using the MIDAS software.

3. Fundamental atmospheric parameters

Napiwotzki et al.'s (1993) revision of Moon & Dworetsky's (1985) calibration of Strömgren photometry in term of effective temperature and surface gravity has been used to derive these parameters. Moon & Dworetsky (1985) published a grid for the determination of T_{eff} and log*g* in the range 6000 $\leq T_{eff} \leq$ 20000 K. This grid is based on synthetic *uvby* indices calculated by Relyea & Kurucz (1978), Philip & Relyea (1979) and Schmidt (1979) using LTE model atmospheres from Kurucz (1979).

Napiwotzki's (1992) revision of Moon's (1985) code consisted in improving the surface gravity determination for stars with $T_{eff} \geq$ 9000 K. Napiwotzki's (1992) code is the merged and modified version of the routines UVBYBETA and TEFFLOGG written by Moon (1985). The first part of the code, UVBYBETA, deredens the observed photometric indices $[(b-y)_1, m_1, c_1]$ obtained by Hauck & Mermilliod (1980). The corresponding dereddened indices are then transmitted to the second part, TEFFLOGG, which calculates the atmospheric parameters T_{eff} and log*g*. Using *b-y* = -0.010 and β = 2.894 for HD 72660 yields T_{eff} = 9750 ± 200 K and log*g* = 4.00 ± 0.20 dex. Errors on T_{eff} and log*g* were estimated using Moon & Dworetsky's (1985) grid (β, c_0). These values agree very well with Lemke's (1989) who used the same method.

3.1. *Comparison of the ultraviolet energy distribution of HD 72660 with that of the normal A star HD 10939*

As the ultraviolet flux for an A star is sensitive to temperature and metallicity, I have compared the low dispersion energy distribution of HD 72660 with that of the normal A0V star HD 10939 whose chemical composition I assumed to be solar and whose fundamental parameters have been deduced from the *uvby* color indices system (T_{eff} = 9355 K, log*g* = 4.00, $[M/H]$ = $[M/H]_\odot$). Ultraviolet spectra have been retrieved from the IUE final archive (Rodríguez Pascual et al. 1997) (see Table 2). These spectra have been merged using the IUERDAF (5^{th} version) procedure IUEMERGE where a cutoff wavelength equal to 1970 Å was chosen to obtain the ultraviolet flux from 1200 Å to 3300 Å. On Fig. 1 (top) the ultraviolet flux of HD 72660 (continuous line) is compared to that of HD 10939 (dotted line) after having normalized both to their fluxes at 5550 Å. The agreement between the two ultraviolet distributions is good. Assuming HD 72660 has a solar composition (which is wrong as the abundance analysis presented in Sect. 4 reveals), this would indicate its effective temperature is closer to 9400 K than 9700 K.

3.2. *Comparison of the ultraviolet energy distribution of HD 72660 with those of two model atmospheres*

As I suspected a non solar metallicity for HD 72660 (between +0.3 and +0.5 dex for the iron peak elements and heavier elements as is frequently found among Am stars), I have compared the predicted fluxes of two models of different metallicities and temperatures to the observed flux of HD 72660 and looked for the best fit. These models (calculated with Kurucz's ATLAS9 code (Kurucz 1992a,b)) have the following parameters: T_{eff} = 9600 K, log*g* = 4.00, $[M/H]$ = +0.3 (model 1) and T_{eff} = 9750 K, logg= 4.00, $[M/H]$ = +0.5 (model 2). Fig. 1 (middle and bottom for model 1 and 2 respectively represented by dotted lines) reveals that both models reproduce the overall shape of the ultraviolet energy distribution properly. The model with T_{eff} = 9750 K, logg= 4.00 and $[M/H]$ = +0.0 (depicted by a short dash) has

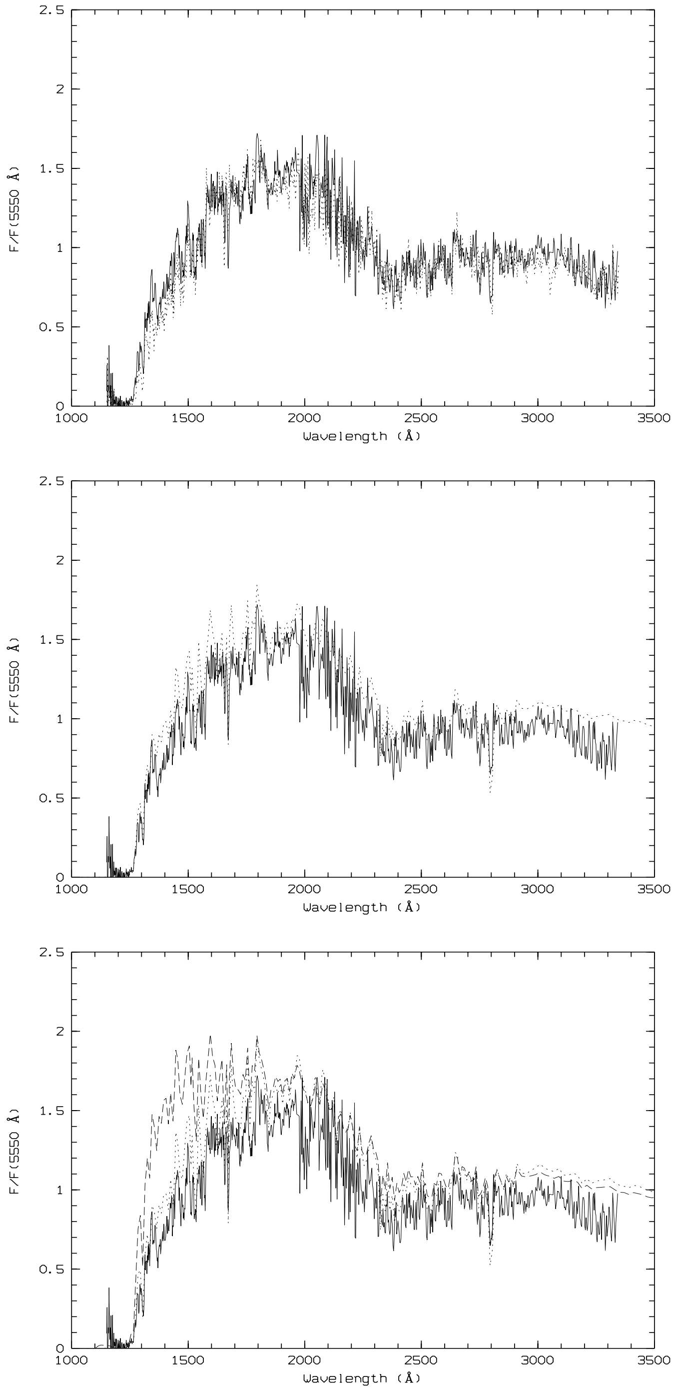

Fig. 1. HD 72660 ultraviolet flux (continuous line). Dotted line is for: HD 10939 (T_{eff} = 9355 K, log*g* = 4.00, $[M/H]$ = $[M/H]_{\odot}$) (*top*); model 1 (T_{eff} = 9600 K, log*g* = 4.00, $[M/H]$ = +0.3) (*middle*); model 2 (T_{eff} = 9750 K, log*g* = 4.00, $[M/H]$ = +0.5) (*bottom*). Short dash (*bottom*) is for: T_{eff} = 9750 K, log*g* = 4.00, $[M/H]$ = 0.0

been also included in the lowermost panel of Fig. 1. Therefore, I infer that the effective temperature of HD 72660 is in the range 9600 - 9750 K provided the metallicity is higher than solar in the range +0.3 to +0.5 dex. As this estimation of the effective temperature agrees very well with that derived from the Strömgren photometry, I have retained the following parameters: T_{eff} = 9750 K and $[M/H] \simeq$ +0.3/+0.5 dex.

4. Chemical abundances analysis

4.1. Method and input data

Abundances for 13 chemical elements have been derived by adjusting synthetic spectra to the observed spectra, after normalizing to the continua. Synthetic spectra were computed assuming LTE using Gray's SPECTRUM code (1995) and Takeda's (1995) code. Both need Kurucz's ATLAS9 model atmospheres. SPECTRUM uses the mass depth points, the temperatures and the pressures given by Kurucz's models for each layer to calculate electron number density and the number density of the main species (H, He, C, N, O). For the opacities, SPECTRUM includes the following transitions: H bound-free and free-free, He bound-free, HeI and HeII free-free, H^- bound-free and free-free, and Rayleigh scattering due to H, H2 and HeI. The broadening parameter includes natural, van der Waals and quadratic Stark broadening. Takeda's (1995) code consists of two distinct routines: the first one, a modified version of Kurucz's WIDTH9 code (Kurucz 1992a), computes the opacity data. Once calculated, opacities are transmited to the second routine that uses the least-squares method to minimize the dispersion

$$\sigma^2 = \sum_{i=0}^{N} (y_i - \eta_i - C)^2 / N$$

where, using Takeda's notations, *N* is the number of wavelength points, y_i and η_i are the logarithmic quantities of the observed (f_{λ_i}) and calculated (F_{λ_i}) spectra respectively, and *C* an offset constant (to be adjusted) reflecting the difference between f_{λ_i} and F_{λ_i}. The spectral parameters to be determined by this code can be the abundance of elements of interest, the microturbulence (ξ), the apparent rotational velocity and the wavelength shift relative to the laboratory frame. In any case, abundances given by the two codes were identical.

The model atmosphere has been calculated with Kurucz's ATLAS9 code, assuming a plane parallel geometry, a gas in hydrostatic and radiative equilibrium and the LTE hypothesis. Calculations were carried out with a depth independent microturbulence of 2.5 km/s and a solar metallicity. The atmosphere has been split up into 64 layers equally spaced in $log\tau_{Ross}$ ($\Delta log\tau_{Ross} = 0.125$). The line opacity calculation uses the 58 million line list compiled by Kurucz (Kurucz 1992a, 1992b).

The line list and atomic parameters were taken from the Vienna Atomic Line Database (VALD) (Piskunov et al. 1995). An important effort has been made to find the most accurate oscillator strengths. If the bibliographical research did not give satisfaction (uncertainty greater than 50% for the atomic transition probability *ie* for *gf* where *g* is the statistical weight of the lower level of the transition and *f* the oscillator strength of the line), *gf* values were obtained by fitting Delbouille et al's (1973) solar spectrum using Kurucz's solar model (T_{eff} = 5777K, log*g*=4.44) with Grevesse and Noels (1993) solar chemical abundances. In most cases, this method led to very similar

Table 3. Atomic lines used in the spectral synthesis. References for the oscillator strengths are: b91: Bard et al. 1991, e93: Edvardsson et al. 1993, f88: Fuhr et al. 1988, g88: Gilroy et al. 1988, g81: Gurtovenko & Kostik 1981, h82: Hannaford et al. 1982, i: this paper, k93: Kurucz 1993, k94: Kurucz 1994, m83: Moity 1983, ob91: O'Brian et al. 1991, p93: Pinnington et al. 1993, r94: Ryabchikova et al. 1994, ro73: Roberts et al. 1973, t89: Thévenin 1989, t90: Thévenin 1990, w66: Wiese et al. 1966, w69: Wiese et al. 1969

Element	λ (Å)	log *gf*	Accuracy	Reference
CI	5052.167	−1.648		k93
OI	6155.961	−1.399	B	w66
	6155.971	−1.047	B	w66
	6155.989	−1.158	B	w66
	6156.737	−1.524	B	w66
	6156.755	−0.934	B	w66
	6156.778	−0.731	B	w66
	6158.149	−1.877	B	w66
	6158.172	−1.031	B	w66
	6158.187	−0.445	B	w66
NaI	6154.226	−1.660		t90
	6160.747	−1.310		e93
MgII	4481.126	+0.740		k93
	4481.325	+0.590		k93
SiI	6125.021	−1.630		t90
	6155.134	−0.840		t90
SiII	5055.984	+0.593		k93
	5056.317	−0.359		k93
CaI	6122.217	−0.409	C	w69
	6156.023	−2.600		i
	6162.173	−0.218		w69
TiII	4518.327	−2.640	B	r94
	4533.969	−0.710	C	ro73
	5069.090	−1.540	B	r94
	5072.281	−0.990	B	r94
CrII	4539.595	−2.290		p93
	5097.311	−2.900		i
FeI	4482.253	−1.482		ob91
	4484.220	−0.720	D	f88
	4494.563	−1.136	B+	f88
	4528.614	−0.822	B+	f88
	5065.014	−0.134		k94
	5068.766	−1.110	A	g81
	5072.076	−0.740	A	g81
	5074.748	−0.000	A	g81
	5078.972	−0.240	A	g81
	5090.774	−0.400	C+	f88
	5096.998	−0.277		k94
	6136.615	−1.400	B+	f88
	6137.692	−1.403	B+	f88
	6141.732	−1.610	C	f88
	6147.835	−1.700	C	f88
	6163.544	−3.619	B+	b91
	6170.507	−0.400		i
	6191.558	−1.600	D-	f88
FeII	4491.405	−2.710	C	m83
	4507.102	−1.920		k94
	4508.288	−2.330	C	m83
	4515.339	−2.490	C	m83
	4520.224	−2.550	C	m83
	4522.634	−2.190	C	m83
	4541.524	−2.990	C	m83
	5061.718	+0.217		k94
	5065.097	−0.446		k94
	5067.893	−0.198		k94
	5070.899	+0.242		k94
	5074.053	−1.973		k94
	5075.764	+0.277		k94
	5082.230	−0.099		k94
	5089.214	−0.035		k94
	5093.465	−2.140		k94
	5093.576	+0.112		k94
	5093.780	−0.568		k94
	5097.271	+0.308		k94
	5098.685	−0.380		k94
	5100.607	+0.171		k94
	5100.727	+0.703		k94
	5100.852	−1.778		k94
	5106.109	−0.276		k94
	6147.741	−2.721		k94
	6149.258	−2.800		i
NiI	5080.528	+0.220		t89
	5081.107	+0.250		t89
	5084.089	+0.030	D-	f88
	5096.854	−0.957		k94
	5099.927	−0.190		k94
	6163.418	−0.740		i
	6170.567	−1.808		k94
	6175.360	−0.580		i
	6176.807	−0.370		e93
NiII	5087.355	+0.726		k94
YII	5087.416	−0.170		h82
BaII	6141.713	−0.080		g88
NdII	5107.575	−0.332		k93

results to Thévenin's (1989,1990). Table 3 gathers optical lines used for the chemical abundance study. When available, *gf* accuracy is indicated by a letter in column 4: A, B, C, D means an uncertainty within 5%, 10%, 25% and 50% respectively (Fuhr et al. 1988). Column 5 displays the references of the *gf* values.

Using the Fast Fourier Transform algorithm, Ramella et al. (1989) have proposed a value of 12.1 ± 2 km/s for the apparent rotational velocity. Brown et al. (1997) suggest this parameter is equal to 7±2 km/s whereas Lemke (1989) and Bohm-Vitense et al. (1997) take 4.5 and 2.9 km/s respectively.

A first convolution test of the synthetic spectrum by the appropriate instrumental profile and a rotational profile with *vsini*

= 12.1 km/s led to line wings too wide compared to the observed ones. As the best fit was realized, using Takeda's code, for *vsini* = 6 km/s and ξ = 2.5 km/s, I have retained these values with an uncertainty of ± 2 km/s for the apparent rotational velocity and ± 1 km/s for the microturbulence.

4.2. Abundance determination and estimated uncertainties

Abundances have been determined from each line for each element by adjusting the synthetic spectrum to the observed one. For each element, the mean abundance $< [\frac{N}{N_H}] >$ (column 3 of Table 4) has been calculated as follows:

$$< [\frac{N}{N_H}] >= \frac{\sum_i([\frac{N}{N_H}]_i/\sigma^2_{tot_i})}{\sum_i(1/\sigma^2_{tot_i})}$$

and the standard deviation, σ_{sd} (column 4 of Table 4), using:

$$\frac{1}{\sigma^2_{sd}} = \sum_i(1/\sigma^2_{tot_i})$$

where *i* is the number of lines per element. The total uncertainty estimated for each line, σ_{tot}, includes the uncertainty on the transition probability (σ_{loggf}), on the surface gravity (σ_{logg}), on the effective temperature (σ_{Teff}), on the microturbulence velocity (σ_ξ) and on the apparent rotational velocity (σ_{vsini}). Since these four uncertainties are supposed to be independent:

$$\sigma^2_{tot} = \sigma^2_{loggf} + \sigma^2_{logg} + \sigma^2_{Teff} + \sigma^2_\xi + \sigma^2_{vsini}$$

In spite of the effort made to obtain the most reliable *gf* values, this atomic parameter is still the major source of uncertainty on the final result. In the best case, the transition probability inaccuracy is around 5% but is often closer than 50%. For each line, I have determined the abundance variation (σ_{loggf}) according to the class assigned by Fuhr et al. (1988) when available. If not available, an uncertainty within 50% has been considered (letter D). On average, σ_{loggf} = ± 0.03, ± 0.07, ± 0.10 and ± 0.21 dex corresponding to Fuhr et al.'s symbols A, B, C, D respectively. The second source of uncertainty comes from the inaccuracy on T_{eff} (σ_{Teff}) and log *g* (σ_{logg}). For neutral elements, σ_{Teff} has been estimated at ± 0.11 and ± 0.06 for single ionized elements. For gravity, σ_{logg} = ± 0.04 and ± 0.07 dex for neutral and single ionized elements respectively. For the microturbulence, σ_ξ = ± 0.12, ± 0.07 and ± 0.06 for silicon, iron and barium respectively and is negligible for the other elements. At last, the uncertainty on *vsini* induces an abundance variation σ_{vsini} = ± 0.06 dex. Solar abundances (column 2 of Table 4) are from Grevesse & Noels (1993).

Examples of synthetic spectra are given in Fig. 2 for the regions centered on λ5080 Å and λ6160 Å. We notice the good agreement between the observed spectra (thick line) and the synthetic spectra (thin line) in the strongest lines.

4.3. Comparison with previous studies

Lemke (1989) calculated iron and titanium abundances for HD 72660 with almost identical atmospheric parameters as those derived here. His LTE calculations established that Fe is overabundant by +0.26 dex for FeI and +0.48 dex for FeII. I find a similar overabundance for both FeI (+0.37 dex ± 0.03) and FeII (+0.36 dex ± 0.04). Non-LTE corrections should be small for FeII and below +0.3 dex for FeI according to Lemke (1989). My results do not agree with the recent LTE value found by Rentzch-Holm (1997) who has estimated an FeI overabundance equal to +0.62 dex. But as she points out, we have to consider cautiously her result since it is based on one FeI line. In both quoted papers, T_{eff}, log *g* and the microturbulence are the same.

For carbon, Lemke (1990) found an underabundance of -0.5 dex assuming that Non-LTE correction is small for weak lines. This result agrees well with my value. So do the abundances of titanium and barium:+0.39 ± 0.06 dex (+0.38, Lemke 1989) and +1.08 dex (+1.15 LTE / +1.27 Non-LTE, Lemke 1990) respectively.

Table 4. Chemical abundances deduced from the 84 lines

Element	$log[\frac{N}{N_H}]_\odot$	$< [\frac{N}{N_H}] >$	σ_{sd}
CI	−3.45	−0.60	–
OI	−3.13	−0.52	±0.04
NaI	−5.67	+0.53	±0.17
MgII	−4.42	+0.23	±0.16
SiI	−4.45	+0.20	±0.19
SiII	−4.45	+0.21	±0.18
CaI	−5.64	+0.16	±0.11
TiII	−6.98	+0.39	±0.06
CrII	−6.33	+0.72	±0.16
FeI	−4.50	+0.38	±0.04
FeII	−4.50	+0.37	±0.04
NiI	−5.75	+0.67	±0.08
NiII	−5.75	+0.67	–
YII	−9.76	+0.84	–
BaII	−9.87	+1.08	–
NdII	−10.50	+2.11	–

5. Discussion

As mentioned in Sect. 1, HD 72660 is classified as a "normal" A-type star (Cowley et al. 1969). However its unusually low apparent velocity (71% of the "normal" A stars have *vsini* $\geq$ 100 km/s, Abt & Moyd 1973), its weak ScII λ4246 Å/SrII λ4215 Å ratio reported by Ramella et al. (1989) combined with its strong helium deficiency (Lemke 1989) led us to suspect that it might be a hot Am star. To know whether or not HD 72660 could be an Am star, let us recall the 3 groups of Am stars introduced by Conti (1970): "(a) stars with weak Ca (Sc) *and* strong metallic lines; (b) stars with *only* weak Ca (Sc) lines; and (c) stars with only strong metallic lines (but no strong Ca (Sc))". In this framework, HD 72660 shows some typical patterns of group (c) *ie* overabundances for Cr and the iron peak elements Fe and Ni whereas Ca is found to be solar or even slightly overabundant (+0.16 ± 0.11 dex). The 4 other even -Z light elements Mg, Si, S and Ti seem to be also enhanced since their overabun-

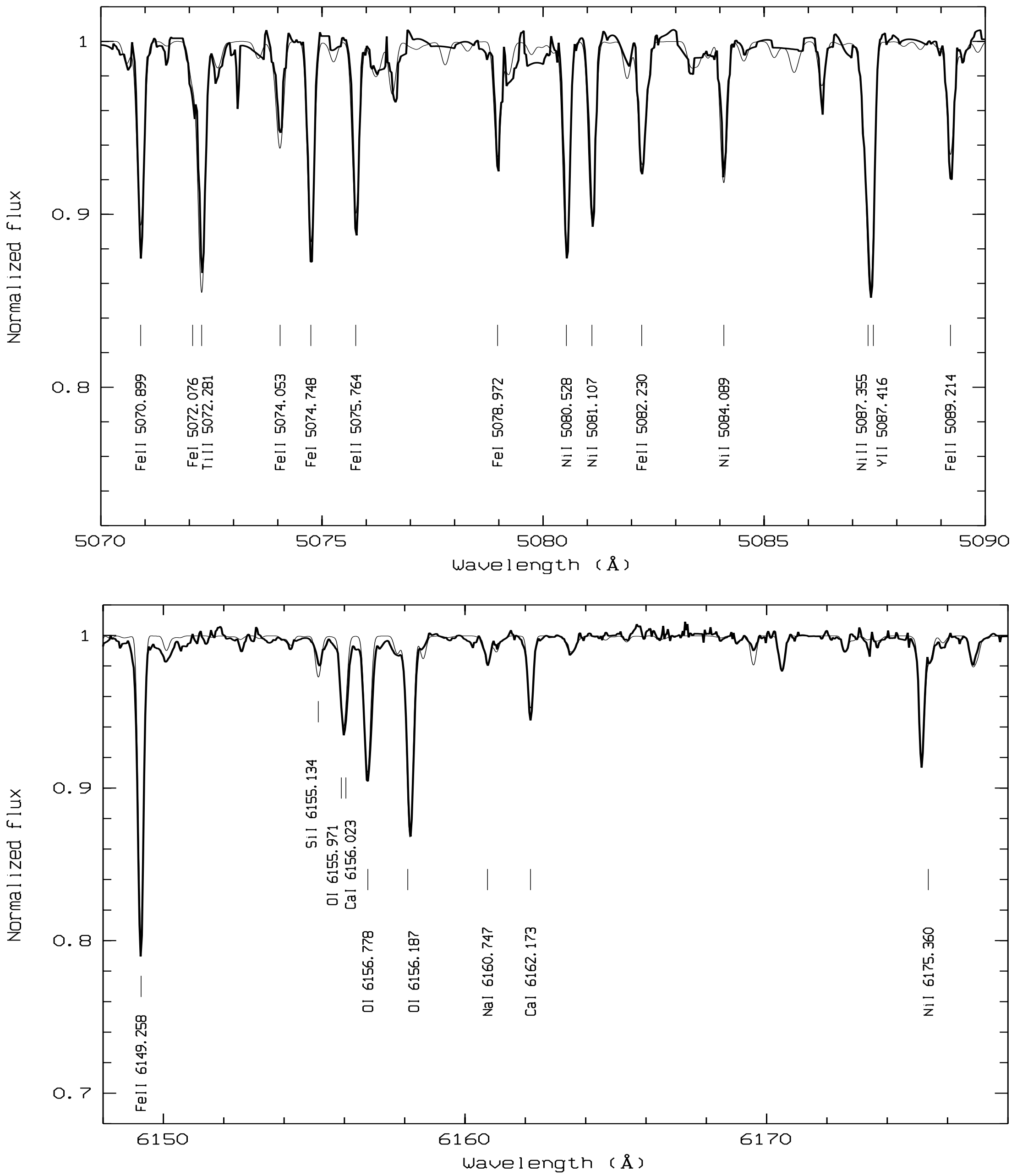

Fig. 2. HD 72660 synthetic (thin line) and observed spectra (thick line) in the 5080 Å and 6160 Å regions

dances range from +0.20 ±0.17 dex for SiI to +0.43 dex for SI (Rentzsch-Holm 1997). So is the odd -Z element Na (+0.53 ±0.17 dex). Underabundances are found for the light elements C, O (-0.60 and -0.52 ±0.04 dex) and N (-0.67 dex, Rentzsch-Holm 1997). The oxygen underabundance has been obtained using several lines that have reliable *gf* values (accuracy B). LTE hypothesis has been used since Kiselman (1993) showed that Non-LTE corrections are weak for the 6158.17 Å OI line in solar type stars. Takeda (1992) evaluated a Non-LTE correction smaller than 0.1 dex for this line in an A0V star. Finally this star shows pronounced overabundances for the *s*-process elements Y, Ba and Nd.

In Fig. 3 the abundances of HD 72600 (black square) are compared to those of 6 "normal" A stars (all slow rotators) studied by Hill & Landstreet (1993) and Hill (1995). The abundance pattern of *o* Peg (Hill 1995) are also displayed for comparison (dotted line) since this object is sometimes considered as a hot Am star prototype (Adelman 1988; Lemke 1990). This comparison indicates that under/overabundances of HD 72660 are more pronounced than those found in most "normal" A stars and reveals a similarity with *o* Peg. Moreover, the plot shows a gradient of abundances among "normal" A stars and no clear separation is found between their metallicities and those of *o* Peg and HD 72660. To explain the Am phenomenon, Michaud et al. (1983) have suggested that the diffusion process could compete

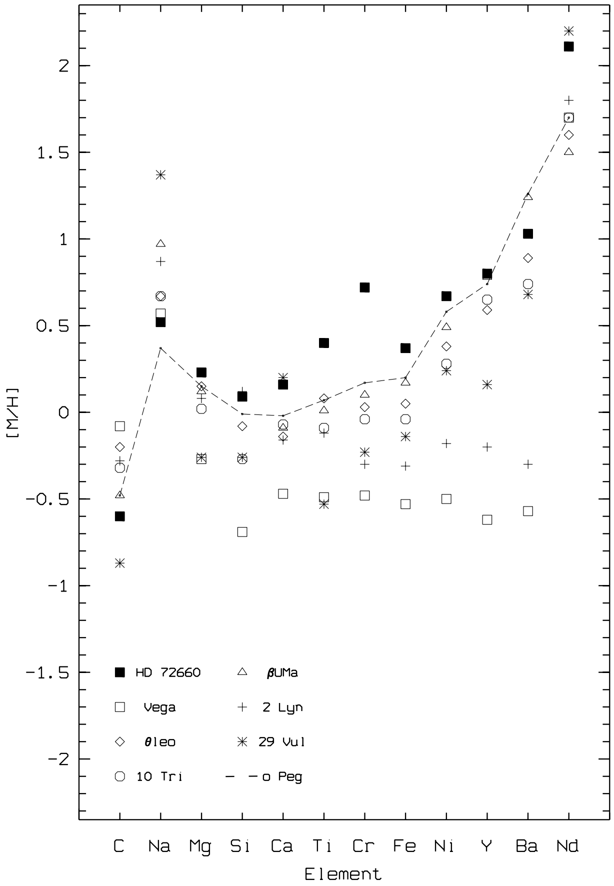

Fig. 3. HD 72660 abundances (black square) compared to those of 6 "normal" A-type stars (Hill & Landstreet 1993; Hill 1995) with *vsini* $\leq$ 50 km/s. The dotted line is for the hot Am star *o* Peg

with a weak stellar wind ($\dot{M} \sim 10^{-15} M_{\odot} yr^{-1}$). Landstreet et al. (1998) have proposed that for dwarf stars in the temperature range 8500 - 11000 K, a mass loss between 10^{-14} and $10^{-12} M_{\odot} yr^{-1}$ caused by a quasi non-turbulent wind (to allow microscopic diffusion to occur in the atmosphere) could lead to oxygen overabundance. Unfortunately, no oxygen enhancement has been found until now (van't Veer-Menneret et al. 1989) and this work reveals an underabundance of oxygen. This could mean mass loss is weaker than $10^{-14} M_{\odot} yr^{-1}$ or else the wind is turbulent enough (above the convection zone) to avoid element separation.

Alecian's (1996) simulations of the time evolution of the abundance of calcium have shown that depending on the mass loss rate and the depth of the convection zone a short phase of calcium overabundance might exist after the arrival of the star on the main sequence. Only after, would the calcium deficiency occur. Recent observations from Künzli & North (1998) tend to confirm Alecian's theoretical predictions.

6. Conclusion

Three high resolution optical spectra have been obtained for the sharp-lined A star HD 72660 usually classified as "normal". Its effective temperature and surface gravity have been estimated by two different methods which yield consistent values: T_{eff} = 9750 ± 200 K, log$g$ = 4.00 ± 0.20 dex. This gravity value is compatible with the one of a main sequence star but not with the one of a giant star as suggested by Abt & Morrell (1995).

Abundances have been derived for 13 chemical elements: Mg, Si, Ca, Ti, Cr, Fe, Ni, Y, Ba and Nd are more abundant than in the other normal A stars analysed so far whereas C and Na are less abundant. This finding together with a similarity with the abundance pattern of *o* Peg suggest that HD 72660 is a hot Am star.

However, it seems fundamental to extend this study to a larger sample of "normal" A stars (slow and fast rotators) and compare them to Am stars in order to establish whether or not normal and peculiar A stars exhibit different patterns.

Acknowledgements. I am grateful to R. Monier, my thesis advisor, for his help and his fruitful suggestions on this paper. Many thanks to R.O. Gray, R. Napiwotzki and Y. Takeda who have kindly provided me with their codes and to M. Lemke for his advice on the installation of his UNIX version of ATLAS9. I am also indebted to H. Holweger and Y. Takeda for their comments on the manuscript and to the OHP staff for the observational part of this work.

References

Abt H.A., Moyd K.I., 1973, ApJ 182, 809
Abt H.A., Morrell N.I., 1995, ApJS 99, 135
Adelman S.J., 1988, MNRAS 230, 671
Alecian G., 1996, A&A 310, 872
Bard A., Kock A., Kock M., 1991, A&A 248, 315
Blackwell D.E., Shallis M.J., 1977, MNRAS 180, 177
Bohm-Vitense E., Evans N.R., Carpenter K., et al., 1997, AJ 114, 1176
Brown A.G.A., Verschueren W., 1997, A&A 319, 811
Conti P.S., 1970, PASP 82, 781
Cowley A., Cowley C., Jaschek M., Jaschek C., 1969, AJ 74, 375
Delbouille L., Roland G., Neven L., 1973, Atlas photométrique du Spectre Solaire de λ 3000 à λ 10000. Institut d'Astrophysique, Liége
Edvardsson B., Andersen J., Gustafsson B., et al., 1993, A&A 275, 101
Eggen O.J., 1984, ApJS 55, 597
Fuhr J.R., Martin G.A., Wiese W.L., 1988, J. Phys. Chem. Ref. Data, V 17, Suppl.4
Gilroy K.K., Sneden C., Pilachowski C.A., Cowan J.J., 1988, ApJ 327, 298
Gray R.O., 1995, private communication
Grevesse N., Noels A., 1993, Physica Scripta T 47, 133
Gurtovenko E.A., Kostik R.I., 1981, A&AS 46, 239
Hannaford P., Lowe R.M., Grevesse N., Biémont E., Whaling W., 1982, ApJ 261, 736
Hauck B., Mermilliod M., 1980, A&AS 40, 1
Hill G.M., 1995, A&A 294, 536
Hill G.M., Landstreet J.D., 1993, A&A 276, 142
Holweger H., Gigas D., Steffen M., 1986, A&A 155, 58
Holweger H., 1992, In: Heber U., Jeffery C.S. (eds.) The Atmospheres of Early-Type Stars. Lecture Notes in Physics Vol.401, p 48
Kiselman D., 1993, A&A 275, 269
Künzli M., North P., 1998, A&A 330, 651
Kurucz R.L., 1979, ApJS 40, 1
Kurucz R.L., 1992a, Rev. Mex. Astron. Astrof. 23, 45
Kurucz R.L., 1992b, Rev. Mex. Astron. Astrof. 23, 181

Kurucz R.L., 1993, SAO KURUCZ CD-ROM NO 18
Kurucz R.L., 1994, SAO KURUCZ CD-ROM NO 20 to 22
Lambert D.L., McKinley L.K., Roby S.W., 1986, PASP 98, 927
Landstreet J.D., Dolez N., Vauclair S., 1998, A&A 333, 977
Lemke M., 1989, A&A 225, 125
Lemke M., 1990, A&A 240, 331
Michaud G., Tarasick D., Charland Y., Pelletier C., 1983, ApJ 269, 239
Moity J., 1983, A&AS 52, 37
Moon T.T., 1985, Comm. Univ. London Obs. 78
Moon T.T., Dworetsky M.M., 1985, MNRAS 217, 305
Napiwotzki R., 1992, private communication
Napiwotzki R., Schönberner D., Wenske V., 1993, A&A 268, 653
O'Brian T.R., Wicklife M.E., Lawler J.E., Whaling W., Brault J.W., 1991, J. Opt. Soc. Am. B8, 1185
Philip A.G.D., Relyea L.J., 1979, AJ 84, 1743
Pinnington E.H., Ji Q., Guo B., Berends R.W., van Hunen J., 1993, Can. J. Phys. 71, 470
Piskunov N.E., Kupka F., Ryabchikova T.A., Weiss W.W., Jeffery C.S., 1995, A&AS 112, 525
Preston G.W., 1974, ARA&A 12, 257
Ramella M., Gerbaldi M., Faragiana R., Böhm C., 1989, A&A 209, 233
Rentzsch-Holm I., 1997, A&A 317, 178
Relyea L.J., Kurucz R.L., 1978, ApJS 37, 45
Roberts J.R., Andersen T., Sorensen G., 1973, ApJ 181, 567
Rodríguez Pascual P.M., Schartel N., Wamsteker W., Pérez A., Proceedings of the Conference "Ultraviolet Astrophysics Beyond The IUE Final Archive", Sevilla, Spain 11-14 November 1997, ESA SP-413, 731
Ryabchikova T.A., Hill G.M., Landstreet J.D., Piskunov N., Sigut T.A.A., 1994, MNRAS 267, 697
Schmidt E.G., 1979, AJ 84, 1739
Takeda Y., 1992, PASJ 44, 309
Takeda Y., 1995, PASJ 47, 287
Takeda Y., Sadakane K., 1997, PASJ 49, 367
Thévenin F., 1989, A&AS 77, 137
Thévenin F., 1990, A&AS 82, 179
van't Veer-Menneret C., Faraggiana R., Gerbaldi M., et al., 1989, A&A 224, 171
Wiese W.L., Smith M.W., Glennon B.M., 1966, NSRDS-NBS 4
Wiese W.L., Smith M.W., Miles B.M., 1969, NSRDS-NBS 22, Vol. II