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Abundance analysis of late B stars⋆

Evidence for diffusion and against weak stellar winds

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Abstract. Based on high S/N spectra obtained at La Silla, Chile, and the Special Astrophysical Observatory, Russia, the abundances of He, C, O, Ne, Mg, Si, Ca, Fe, Sr, and Ba in 27 optically bright B5-B9 main-sequence stars were determined. NLTE effects were taken into account. A variety of abundance patterns is present in late B stars. Accurate surface abundances of the diffusion indicators O, Mg, Ca, Sr and Ba suggest that element stratification due to diffusion is common in the program stars. Models of stellar atmospheres which include meridional mixing can explain the observed anomalies. Although the program stars represent only a volume-limited sample of the solar neighbourhood this result is important for the cosmochemical evolution of the Galaxy: the surface abundances of the stars investigated do not necessarily reflect the chemical composition of the interstellar cloud they originated from. Furthermore, five program stars show narrow absorption lines in Ca II K which can be attributed to circumstellar gas. Neon serves as a trace element for the occurrence of weak stellar winds. Neon overabundances of some stars derived under the assumption of LTE suggest that such winds have been detected. In sharp contrast, the more realistic treatment of NLTE leads to solar neon abundances and thus reveals that weak stellar winds are absent in the program stars.

Key words. stars: abundances – stars: atmospheres – stars: chemically peculiar – stars: winds, outflows

1. Introduction

In stars of the upper main-sequence the increasing effective temperatures cause the ionisation zones of hydrogen and helium to be shifted more and more towards the stellar surface. As a result the outer convection zones of these stars become thinner and less turbulent. But this absence of turbulent convection does not necessarily lead to ideal, static atmospheres. Some A and B stars show spectroscopic signatures of microscopic and macroscopic transport processes. The diagnostics of these processes yield valuable information about the behaviour of an element under the influence of gravitation and radiation. Even in nonmagnetic stars this leads to a variety of abundance patterns.

On the *cooler* end of the upper main-sequence the well known *Fm-Am stars* are not exceptional (Wolff 1983). Michaud (1970) invoked diffusion processes as an explanation for those abundance anomalies. Since then various studies on both theoretical and observational aspects of abundance anomalies have been carried out (see, e.g., Gonzalez et al. 1995; Alecian 1996). The basic idea is that the competition of *gravitative settling* and *radiative levitation* leads to element separation via diffusion that occurs directly below the convection zone. Depending on its absorption cross-section a certain element in this reservoir will either be enriched or depleted. With the atomic data from the Opacity Project (Seaton et al. 1992) former shortcomings of theoretical calculations could be improved (Gonzales et al. 1995). Abundance determinations of A stars classified as "normal" have shown a variety of abundance anomalies (Holweger et al. 1986; Gigas 1986, 1988; Lemke 1989, 1990). In normal A stars diffusion leads to deficiencies of Ca as well as overabundances of strontium and barium.

In the same temperature regime the *λ-Bootis-phenomenon* may occur in pre-main-sequence stars. The characteristic metal underabundance of these young stars is attributed to a different mechanism of element separation: the *accretion* of metal-deficient gas from the circumstellar environment after gas-dust-separation (Venn & Lambert 1990). As a result the volatile elements carbon, nitrogen, and oxygen have nearly solar abundances while heavier elements with higher condensation temperatures are locked up in the dust grains and therefore are deficient in the stellar atmospheres (Stürenburg 1993; Paunzen et al. 1999). The λ-Bootis-phenomenon is believed to occur in pre-main-sequence stars at the end of their accretion phase (Holweger & Rentzsch-Holm 1995). Depending on the accretion rate the interplay of accretion and diffusion can lead to

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over- or underabundances of certain elements. In fast rotators, meridional circulation can reduce these abundance anomalies (Turcotte & Charbonneau 1993). The comparatively short phase of pre-main-sequence evolution is consistent with the paucity of the λ-Bootis stars. Interestingly, the standard star Vega is believed to be a member of this group.

On the *hot* end of the main-sequence, radiative processes are dominant and lead to massive radiatively-driven *stellar winds* in O stars and early-type B stars (Kudritzki & Hummer 1990). These stellar winds may lead to spectroscopic signatures of substantial mass loss (Kilian 1992). Furthermore, in fast rotators products of nuclear fusion can emerge to the stellar surface. In spite of their rarity, these stars play an important role in the enrichment of the interstellar medium with elements like carbon, nitrogen, or oxygen.

The transition between the *diffusion-accretion dominated atmospheres* and the *wind-driven atmospheres* lies in the region of the *late B stars* which are subject of this study. Theoretical approaches suggest that with increasing effective temperatures from the regime of the A stars, selective stellar winds set in (Babel 1995) which blow away metals with large absorption cross sections due to radiation pressure. One can expect that such a "metallic" wind changes the composition of the stellar surface, and may even contribute to the metallicity of the interstellar medium. Furthermore, Landstreet et al. (1998) suggests certain elements, like neon, are tracers for the detection of *weak stellar winds*: overabundances of these elements provide valuable evidence for the presence of weak stellar winds in the order of 10^{-14} $M_{\odot}$/yr. Up to now, these weak stellar winds have not been detected spectroscopically. Their detection would be of great importance for diffusion theories as they often have to be invoked to explain mild discrepancies between observations and models (see, e.g., Alecian 1996).

To date the previously described transition region in the range of the late B stars has been investigated only very sparsely, and literature on the processes of element separation is scarce. The status of research is documented in the studies of Adelman & Philip (1996), Smith & Dworetsky (1993), and Smith (1993, 1996). Adelman & Philip (1996) state that *"The general pattern of subsolar abundances among B stars [...] is contrary to what is expected for stars which are much younger than the Sun"*. In some of the 10 investigated northern B stars, abundance anomalies are found, but a diagnosis is carried out only in view of the chemical evolution of the Galaxy. In addition, the data are based largely on older photographic analysis, including low-dispersion, photographic spectra. Smith and Dworetsky analyse IUE-spectra of 8 normal B 5-B 9.5 stars of luminosity classes V and IV. Their result, *"Approximately solar abundances of these elements are obtained for the normal stars"*, is obviously contradictory to the findings of Adelman & Philip (1996). This suggests that in the crowded UV line spectrum of these stars, only large abundance anomalies can be traced. In all the mentioned papers deviations from LTE are neglected. Some of the stars investigated in this study have been analysed by Wohler (1996) and van Thiel (1997) assuming LTE. Their findings suggest star-to-star variations of carbon, magnesium, calcium, and iron, but no definite indications for diffusion could be found. Depending on the ionisation stage and the line strength, deviations from LTE can become significant, and neglecting NLTE effects – as usual in the case of A and late B stars – can conceal abundance patterns and make correlations insignificant.

By investigating the abundances of key elements for element separation processes, the present study aims at a coherent picture of the chemical composition of 27 late B stars based on optical spectra. Deviations from LTE are taken into account, and the results are discussed in view of diffusion processes and weak stellar winds.

2. Observations

We have studied 27 B5–B9 stars (see Table 1) taken from the Bright Star Catalogue (Hoffleit & Warren 1991, BSC) and classified as "normal", i.e. they neither have peculiar spectra nor emission lines. The sample consists of 20 southern and 7 northern hemisphere stars. The spectra of 20 stars have been collected by A. Kaufer in February and March 1995 with the ESO-50-cm telescope equipped with the HEROS spectrograph. The spectra have a resolution of $R = 20\,000$. Data reduction and wavelength calibration was carried out by A. Kaufer using MIDAS.

The spectra of the 7 other stars have been obtained by G.A. Galazutdinov and F. A. Musaev in March 1999 with the SAO 1-m-telescope using the echelle spectrograph. The wavelength range covers 3500 Å to 10 000 Å with a resolution of $R = 45\,000$. Data reduction, as well as wavelength calibration, was carried out by the observers using their echelle software package. The last column of Table 1 indicates the site of observation. The spectra of both datasets have a S/N of about 100.

3. Model-atmosphere analysis

The basic stellar parameters $T_{\rm eff}$ and $\log g$ (see Table 1) have been obtained via Strömgren photometry (Hauck & Mermillod 1990) using the calibration of Napiwotzki et al. (1993). The ATLAS9 code (Kurucz 1993) was used to calculate $T(\tau)$ relations assuming solar metallicity. The temperature structure serves as an input to our LTE/NLTE system. Pressures and particle concentrations were derived from the $T(\tau)$ relations using our ATMOS code. The spectrum synthesis was carried out with our line formation code LINFOR (Lemke 1991). Lemke (1989) found a microturbulence of $\xi \approx 2$ km s^{-1} in his analysis of A stars, and the work of Fitzpatrick & Massa (1999) on the physical properties of B stars reveals microturbulent velocities between 0 km s^{-1} and 1.9 km s^{-1} for six out of seven objects having similar $T_{\rm eff}$ and $\log g$ values to those of our program stars. In accordance with the findings of Krege (1995) we adopted a microturbulence of $\xi = 1$ km s^{-1}. We note that our NLTE abundance analysis of Si II and Fe II lines of different strengths revealed consistent abundances of weak and strong lines. This suggests that $\xi = 1$ km s^{-1} is a good estimate of this poorly defined parameter. The VALD database (Piskunov et al. 1995) was used to select lines for abundance analysis and to identify blend lines. The $\log gf$ values were also taken from the VALD compilation, except for carbon and oxygen for which we used the more recent data of Wiese et al. (1996).

Table 1. Parameters of the program stars. The data were taken from the Bright Star Catalogue (Hoffleit & Warren 1991). Distances have been calculated using HIPPARCOS parallaxes (ESA 1997). The last column indicates whether a star was observed from ESO (E) or SAO (S).

HR	Name	HD	m_v	Sp. Type	$T_{\rm eff}$ (K)	$\log g$ ($\rm cm\,s^{-2}$)	$v \sin i$ ($\rm km\,s^{-1}$)	d (pc)	RA h m s	DEC ° ′ ″	Obs.
806	ϵ Hyi	16 978	4.11	B9 V	10 910	4.29	100 ± 2	47.01	02 39 35	- 68 16 01	E
1070	17 Eri	21 790	4.73	B9 V	11 540	3.61	86 ± 2	116.69	03 30 37	- 05 04 31	E
1092		22 252	5.83	B8 V	11 860	3.27	260 ± 15	261.10	03 30 52	- 66 29 23	E
1214		24 626	5.11	B6 V	14 300	4.12	29 ± 2	108.81	03 53 39	- 34 43 56	E
1339	53 Tau	27 295	5.35	B9 IV	12 000	4.19	5 ± 2	81.96	04 19 26	+ 21 08 32	S
1582	62 Eri	31 512	5.51	B6 V	15 190	3.87	89 ± 4	226.76	04 56 24	- 05 10 17	E
1723		34 310	5.07	B9 V	11 180	4.12	158 ± 2	83.47	05 15 24	- 26 56 36	E
1728	17 Aur	34 364	6.14	B9.5 V	11 010	4.34	30 ± 4	121.95	05 18 19	+ 33 46 02	S
1973		38 170	5.29	B9.5 V	10 250	3.69	60 ± 4	111.24	05 42 15	- 34 40 04	E
2056	λ Col	39 764	4.87	B5 V	15 370	4.22	101 ± 3	104.71	05 53 07	- 33 48 05	E
2948		61 555	4.50	B6 V	15 460	4.20	50 ± 5	139.28	07 38 49	- 26 48 06	E
3158		66 552	6.15	B9 V	10 450	4.09	75 ± 4	91.57	08 04 45	+ 18 50 32	S
3439		74 067	5.20	B9 V	10 880	4.14	36 ± 3	85.98	08 40 19	- 40 51 15	E
3717		80 781	6.28	B5 V	14 980	3.22	30 ± 3	1052.63	09 19 33	- 55 11 12	E
4116	δ Sex	90 882	5.21	B9.5 V	10 360	3.84	140 ± 3	91.99	10 29 29	- 02 44 21	S
4119	β Sex	90 994	5.09	B6 V	14 570	4.21	85 ± 4	105.71	10 30 18	- 00 38 13	E
4943	14 CVn	113 797	5.25	B9 V	11 260	4.06	130 ± 3	86.58	13 05 45	+ 35 47 56	S
5501	108 Vir	129 956	5.69	B9.5 V	10 250	3.75	84 ± 4	188.32	14 45 30	+ 00 43 02	E
5685	β Lib	135 742	2.61	B8 V	12 040	3.26	320 ± 20	49.06	15 17 00	- 09 22 59	S
5994	ι^2 Nor	144 480	5.57	B9.5 V	10 580	4.29	87 ± 3	83.19	16 09 19	- 57 56 04	E
6628		161 840	4.83	B8 V	11 990	3.38	38 ± 2	186.22	17 49 11	- 31 42 12	E
6633		161 941	6.22	B9.5 V	9960	3.26	36 ± 3	757.58	17 48 20	+ 03 48 15	E
6647		162 374	5.90	B6 V	16 900	3.72	38 ± 2	254.45	17 52 14	- 34 47 57	E
6668		162 817	5.96	B9.5 V	9190	3.15	76 ± 4	258.40	17 54 27	- 34 27 59	E
6878		169 009	6.33	B9.5 V	10 440	3.95	47 ± 5	105.15	18 23 02	- 10 13 07	E
7337	β^1 Sgr	181 454	4.01	B9 V	11 960	3.83	77 ± 2	116.01	19 22 38	- 44 27 32	E
8781	α Peg	218 045	2.49	B9 V	9810	3.51	130 ± 2	42.80	23 04 46	+ 15 12 19	S

B stars are known to have very large rotational velocities, up to $v \sin i \approx 350\ \rm km\,s^{-1}$, which lead to extremely broadened line spectra. This causes difficulties for a reliable spectrum synthesis. Therefore we have selected the 20 southern hemisphere objects with $v \sin i < 100\ \rm km\,s^{-1}$. We have dropped this restriction for the 7 northern stars. The reason is the detection of narrow absorption features in the Ca II K line and will be discussed in Sect. 6. Nevertheless the rotational velocities (listed in Table 1) we derived via spectrum synthesis reveal large errors of the values given in the BSC.

Based on the assumptions that $\Delta T_{\rm eff} = 200\,K$, $\Delta \log g = 0.2$ dex, and $\Delta \xi = 1\ \rm km\,s^{-1}$ we carried out calculations in order to estimate the errors of our analysis. Both effective temperature and $\log g$ variations lead to maximum abundance uncertainties of ±0.1 dex, and variation of ξ yielded abundance changes below ±0.05 dex. Thus we found that the typical error of our abundances is between 0.2 and 0.3 dex.

4. LTE-abundances

Apart from iron, solar abundances are from Anders and Grevesse (1989); for iron the revised value of 7.51 Holweger et al. (1995) was used. Lines of ten elements, namely helium, carbon, oxygen, neon, magnesium, silicon, calcium, iron, strontium, and barium, were selected for abundance analysis. The lines are compiled in Table 2. Additionally, we included all relevant blend lines.

A closer look at the LTE results in Tables 5–7 reveals that some stars show conspicuous deviations from solar values clearly above the error limit of 0.3 dex. Oxygen shows pronounced overabundances in most stars, and neon is overabundant in some objects by nearly 0.6 dex. Studies on oxygen (Baschek et al. 1977; Takeda 1992; Paunzen et al. 1999) and neon abundances (Dworetsky & Budaj 2000) reveal that these elements are expected to show large non-LTE effects. The values for magnesium scatter largely between −1.3 dex and 0.31 dex with most abundances being subsolar. Nevertheless, some stars have definitely non-solar magnesium abundances. Silicon and iron show scatter around the normal, solar abundances. Calcium has obvious underabundances in some objects. Lastly, the heavy elements strontium and barium are overabundant in most cases.

To sum this up one can state that clear compositional differences have been found in the program stars. The question arises whether these abundance patterns are real or due to the inadequate assumption of LTE. To investigate this the NLTE calculations outlined in the next section were carried out.

5. NLTE corrections

NLTE corrections were carried out using the Kiel NLTE-code (Steenbock & Holweger 1984) for C, O, Ne, Mg, Si, Ca, Fe, Sr, and Ba. In the following some details concerning the model atoms are provided.

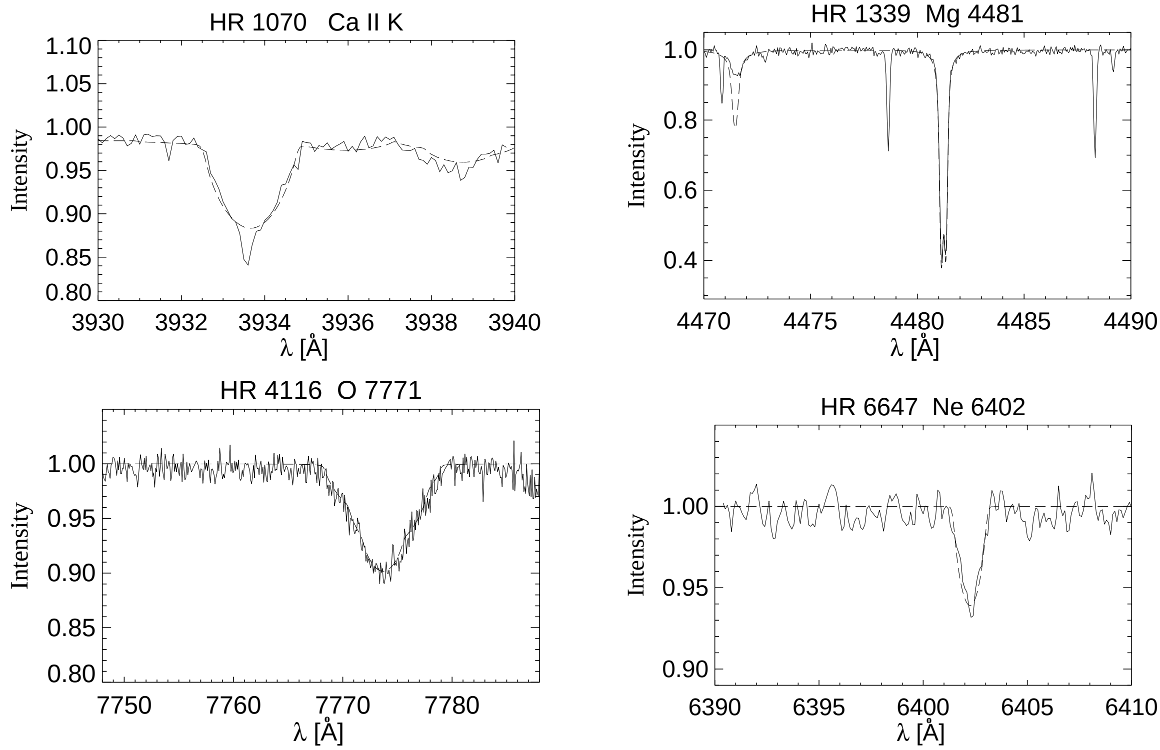

Fig. 1. Some typical observed (solid lines) and synthetic spectra (dashed lines). Note the narrow absorption feature in the core of the Ca II K line of HR 1070 (see Sect. 6 for details).

5.1. Carbon

The carbon model atom by I. Kamp (Rentzsch-Holm 1996) contains 83 C I levels, 15 levels of C II and 79 line transitions. It is an improved version of an older C I/II atom with a total of 88 levels and 66 transitions (Stürenburg & Holweger 1990). A detailed description of the atom can be found in Rentzsch-Holm (1996). Although the NLTE corrections are not negligible, they are not very pronounced for most of the program stars which is in accordance with the findings of Rentzsch-Holm (1996). In fact, only for four stars of the twelve objects where carbon lines have been analyzed are the corrections above 0.2 dex. No temperature dependency can be found for the sample stars. As outlined by Stürenburg & Holweger (1990) and Rentzsch-Holm (1996) NLTE corrections of strong carbon lines depend on the equivalent width. This effect is only important for lines with $W_\lambda > 100$ mÅ. Because the lines of the program stars are weaker this is not observed here. The NLTE abundances of most stars investigated here scatter around the solar value.

5.2. Oxygen

The O I 7771-5 triplet investigated in this study shows large non-LTE effects as outlined by Baschek et al. (1977) and Takeda (1992). Furthermore, from previous work on A stars (Paunzen et al. 1999) non-LTE corrections of up to −0.7 dex can be expected. An O I model atom containing 15 energy levels and 17 transitions has been developed by I. Kamp & M. Hempel for the analysis of λ Bootis stars (Paunzen et al. 1999). This model atom is not appropriate for the application to B stars having sufficiently higher temperatures. Therefore an improved version was developed which is based on the old one described in Paunzen et al. (1999). It contains 29 energy levels plus the continuum of O II and 71 line transitions. The energy levels have been obtained from the Atomic Spectra Database of NIST[1]. All energy levels up to 5f at 13.07 eV were implemented and are listed in Table 3. Higher levels will only have negligible effects. When available, energy resolved electron collisional cross-sections were adopted. The values for the $2p^3P - 2p^1D$ and $2p^3P - 2p^1S$ transitions were adopted from Tayal (1992), for $2p^3P - 3s^3So$, $2p^3P - 3s^3Do$, and $2p^3P - 3d^3Do$ the data from Wang & Mc Conkey (1992) were used. Tayal & Henry (1989) provide values for $2p^3P - 3s^5So$, $2p^3P - 3p^5P$, $2p^3P - 4s^3So$, and $2p^3P - 4p^3P$. Allowed electron collisional cross-sections missing were calculated according to Van Regemorter (1962). Concerning the electron cross-sections for optically forbidden transitions the formula given by Allen (1973)

$$\sigma_{\max} = \frac{\Omega}{g_l} \frac{E_H}{\Delta E} \pi a_0^2 \qquad (1)$$

was applied. In (1) Ω denotes the collision strength, assuming $\Omega = 1$, g_l is the statistical weight of the lower level, E_H is the energy difference between lower and upper level, and a_0^2 is the Bohr radius. Collisions with neutral hydrogen atoms were calculated following Steenbock & Holweger (1984). Because hydrogen is primarily ionised, electron collisions are dominant and collisions with neutral hydrogen are not relevant for

[1] `http://physics.nist.gov/PhysRefData/contents.html`

Table 2. This table comprises all lines used for the abundance analysis. In Cols. 3 and 4 we compiled the contributions of blend lines and additional comments, respectively.

Element/Ion	Wavelengths	Blends	Comments
Helium	He I 5876	weak Fe II	blend of 5 He I lines
	He I 6678	weak Fe II/Si II $\gtrsim$ 15 000 K	He I 6 times stronger than blends
	He I 7065	none	useful $\gtrsim$ 12 000 K
Carbon	C II 3918/3920	H_ζ (3889 Å), Ca II K (3934 Å)	blends have well-known gf values, clearly traceable
		weak Fe II/Ti II/S II	blends become weaker with rising $T_{\rm eff}$
	C II 4267	weak Fe I/Fe II/S II	blend of 3 C II lines, C II becomes stronger with rising $T_{\rm eff}$
	C II 6578	weak Fe II	C II becomes stronger with with rising $T_{\rm eff}$
Oxygen	O I 7771	weak Fe II on red wing	O I triplet, suitable for the determination of $v \sin i$
Neon	Ne I 6402	none	tracer for weak stellar winds, useful $\gtrsim$ 11 500 K
	Ne I 6506	none	tracer for weak stellar winds, useful $\gtrsim$ 11 500 K
Magnesium	Mg II 4481	weak Fe II	Mg triplet, suitable for the determination of $v \sin i$
		weak He I (4471 Å)	of minor importance for fast rotators
Silicon	Si II 4128/4130	weak Mn II/Fe II	
	Si II 5041/5ß55	weak Fe I	
	Si II 6374	two weak Mg II lines	
	Si II 6371	one weak Fe I line	
Calcium	Ca II K 3934	31 weak blend lines	indicator for diffusion processes
			K line used for detection of CS gas
Iron	Fe II 4233	weak Fe I	
	Fe II 4584	weak Ti II/Cr II	blend of four Fe II lines
Strontium	Sr II 4077	weak Fe I/Si II	diffusion indicator, weaker Sr II line with rising $T_{\rm eff}$
	Sr II 4215	weak Cr II/Fe I	diffusion indicator, weaker Sr II line with rising $T_{\rm eff}$
	Sr II 4305	weak Fe II/Ti II	diffusion indicator, weaker Sr II line with rising $T_{\rm eff}$
Barium	Ba II 4554	weak Fe II/Cr II/S II	diffusion indicator, weaker Ba II line with rising $T_{\rm eff}$

our calculations. The completed O I model atom was compared with the old version and a study by Przybilla et al. (2000) who have carried out a study on NLTE effects of oxygen and applied their model atom to the three stars, Vega (A0 V), η Leo (A0 Ib), and HD 92207 (A0 Ie). The value for the oxygen abundance of the standard star Vega ($T_{\rm eff}$ = 9500 K, $\log g$ = 4.0, [M/H] = −0.5) obtained with the O I model atom used in this work for the O I 7774 line is 8.52 which is accordance with 8.59 calculated by Przybilla et al. (2000). The Vega spectrum used for the abundance analysis of oxygen was recorded by I.K. & M.H. in January 2000 with the 1.52-m telescope of OHP equipped with the AURÉLIE spectrograph (Kamp et al. 2002).

For most of the program stars the NLTE corrections are in the range of −0.3 dex to −0.7 dex. Somewhat exceptional is the large correction for HR 3717 with −1.18 dex. The reason for this is the low gravity of $\log g$ = 3.22 – the second lowest of the whole sample. A lower surface gravity leads to a weaker coupling between the levels because the collisional rates decrease due to lower electron and gas pressures. Therefore NLTE effects are more important.

5.3. Neon

The neon model atom was developed by J. Graf (2000[2]) and consists of 45 Ne I levels, 47 Ne II levels, and 120 transitions. The atomic data was obtained from the Opacity Project (Seaton et al. 1992) and the NIST compilation. The oscillator strengths are based on Seaton (1998) and Kurucz & Peytremann (1975). The NLTE corrections are negative for all sample stars. While neon shows conspicuous overabundances in LTE for some stars, the NLTE abundances are rather solar. This is of importance for the question of weak stellar winds and will be discussed later.

5.4. Magnesium

The MgI/II atom contains 99 levels and 71 line transitions and is an improved version by Gigas (1988) of the model developed by Lemke (1986). The model atom was adapted by Gigas for the use with ATLAS6 models having a frequency grid of 336 points. This grid defines the ODF averaged mean intensities and is used for the computation of the photoionization rates. For the calculations carried out in the course of this study the more recent ATLAS9 version was used and therefore the extended frequency grid containing 1212 points had to be implemented in the model atom. As outlined by Gigas (1988) the corrections for Mg 4481 are expected to be negative. This result is confirmed here. Nevertheless the deviations from LTE are small, usually well below −0.2 dex. Therefore LTE is a good approximation of Mg 4481 abundances for late B stars.

5.5. Silicon

The silicon atom used was developed by Wedemeyer (2001). It includes 115 energy levels of Si I/II and 84 lines. The NLTE calculations show negative corrections for the sample stars with the lowest temperatures whereas the deviations for

[2] http://www.astrophysik.uni-kiel.de/d-pubalpha_hol.html

Table 3. Energy levels of the O I model atom.

No.	E [eV]	Designation
1	0.01	$2p^4\ ^3P$
2	1.97	$2p^4\ ^1D$
3	4.19	$2p^4\ ^1S$
4	9.15	$3s\ ^5S^o$
5	9.52	$3s\ ^3S^o$
6	10.74	$3p\ ^5P$
7	10.99	$3p\ ^3P$
8	11.84	$4s\ ^5S^o$
9	11.93	$4s\ ^3S^o$
10	12.08	$3d\ ^5D^o$
11	12.09	$3d\ ^3D^o$
12	12.29	$4p\ ^5P$
13	12.36	$4p\ ^3P$
14	12.54	$3s\ ^3D^o$
15	12.66	$5s\ ^5S^o$
16	12.70	$5s\ ^3S^o$
17	12.73	$3s\ ^1D^o$
18	12.75	$4d\ ^5D^o$
19	12.76	$4d\ ^3D^o$
20	12.77	$4f\ ^5F$
21	12.77	$4f\ ^3F$
22	12.85	$5p\ ^5P$
23	12.88	$5p\ ^3P$
24	13.02	$6s^5S^o$
25	13.04	$6s^3S^o$
26	13.07	$5d\ ^5D^o$
27	13.07	$5d\ ^3D^o$
28	13.07	$5f\ ^5F$
29	13.07	$5f\ ^3F$
30	0.0	CONT

Table 4. Line transitions of the O I model atom: Lower level number (Low), upper level number (Up), wavelength and $\log gf$-value (Wiese et al. 1996).

Low	Up	λ [Å]	$\log gf$	Low	Up	λ [Å]	$\log gf$
1	2	6333.79	−9.652	7	16	7256.4	−0.799
1	3	2972.29	−10.478	7	19	7004.1	−0.410
1	4	1355.60	−5.238	7	25	6048.1	−1.286
1	5	1303.5	−0.330	7	27	5960.2	−1.140
1	9	1040.1	−1.084	8	12	27637.0	0.868
1	11	1026.6	−0.743	8	22	12267.0	−1.100
1	14	989.46	−0.303	9	12	34850.8	−4.248
1	16	977.19	−1.527	9	13	28927.0	0.666
1	17	974.07	−4.108	9	23	13077.0	−1.180
1	19	972.47	−0.906	10	20	18021.0	1.401
1	25	951.59	−1.849	10	22	16110.0	−1.628
1	27	949.39	−1.246	10	28	12511.0	0.606
2	3	5577.34	−8.930	11	13	45596.0	0.442
2	5	1641.305	−5.654	11	21	18244.0	1.188
2	14	1172.504	−4.512	11	23	15666.0	−1.218
2	17	1152.15	−0.280	11	29	12570.0	0.380
3	5	2325.452	−7.950	12	15	33075.0	0.655
4	6	7773.4	0.700	12	18	26507.0	1.231
4	7	6728.16	−4.398	12	19	26207.0	−3.215
4	12	3947.4	−1.766	12	24	16872.0	−0.371
5	6	10167.3	−4.553	12	26	15891.0	0.261
5	7	8446.5	0.492	13	16	36607.0	0.463
5	13	4368.2	−1.709	13	18	31393.6	−3.142
5	23	3693.4	−2.767	13	19	30977.0	1.037
6	8	11299.0	0.407	13	25	18229.0	−0.594
6	10	9263.9	1.156	13	27	17453.0	−0.092
6	11	9207.46	−3.831	14	21	54557.28	−2.260
6	15	6455.0	−0.589	14	23	36666.0	−1.328
6	18	6157.3	0.034	14	29	23259.0	−1.131
6	19	6142.28	−4.420	18	20	973302.0	−2.467
6	24	5437.7	−1.067	18	22	131395.0	−0.136
6	26	5331.5	−0.540	18	28	38808.0	1.326
7	9	13165.0	0.222	19	23	103975.7	−0.229
7	10	11374.0	−3.861	19	29	39463.0	1.126
7	11	11299.0	0.407	20	26	33135.0	−0.288
7	14	7992.0	−2.094				

the hotter ones turn to positive values. About 50% of the program stars show solar values within the error limits.

5.6. Calcium

The Ca I/II model was developed by W. Steenbock and is based on the work of Watanabe & Steenbock (1985) on the Sun and Procyon. The improved version used for this study contains 125 levels with 100 transitions. The corrections for the Ca II K line are generally small and positive in most cases. Only for three stars do we find $|\Delta \log \epsilon| \geq 0.2$ dex. Most of the stars which have non-solar Ca abundances within the error limits show conspicuous NLTE underabundances up to −0.85 dex. This will be discussed further in Sect. 7.

5.7. Iron

An iron model containing 99 energy levels of Fe I and Fe II with 75 lines was developed by W. Steenbock & T. Gehren. An extensive study using this model in a temperature range between 7000 K and 12 000 K was carried out by Rentzsch-Holm (1996). Iron shows only slightly negative abundance corrections below −0.1 dex in NLTE. Therefore LTE is a good approximation for the program stars. This is in accordance with the results of Rentzsch-Holm (1996).

5.8. Strontium

The strontium model atom (Belyakova et al. 1997) incorporates 41 levels of Sr II including the ground state of Sr III. The level energies were taken from Moore (1952) and Lindgard & Nielsen (1977), and the f values were adopted from Wiese & Martin (1980), Lindgard & Nielsen (1977), and Kurucz (1994). Further details concerning the model atom can be found in Belyakova et al. (1997). Non-LTE calculations for strontium were kindly performed by Elena Belyakova using the Kazan non-LTE code (Belyakova et al. 1999). With one exception (HR 2948) strontium lines of sufficient strength were only found in sample stars below 12 000 K. Strontium is overabundant in LTE in most of those objects. The NLTE corrections are positive in all cases and quite conspicuous. This deserves some comments in Sect. 7.

5.9. Barium

The Ba II model by D. Gigas (1988) includes 42 levels and 36 transitions. Only in one star was a barium line of sufficient strength found. A new ATLAS9 frequency grid had to be

Table 5. LTE and NLTE abundances. The NLTE corrections and abundances of C, O and Ne are given with respect to the solar values.

HR	[He/H]	[C/H] LTE	$\Delta \log \epsilon$	[C/H] NLTE	[O/H] LTE	$\Delta \log \epsilon$	[O/H] NLTE	[Ne/H] LTE	$\Delta \log \epsilon$	[Ne/H] NLTE
806	0.44	-	-	-	0.8	−0.46	0.34	-	-	-
1070	0.08	−0.15	0.15	0.00	0.9	−0.55	0.35	-	-	-
1092	1.05	0.36	0.09	0.45	1.3	−0.74	0.56	-	-	-
1214	0.19	−0.17	0.22	0.05	0.8	−0.58	0.22	0.15	−0.15	0.00
1339	-	−0.08	0.09	0.01	0.9	−0.55	0.35	-	-	-
1582	0.38	−0.05	0.24	0.19	1.3	−0.86	0.44	0.3	−0.28	0.02
1723	0.30	-	-	-	0.9	−0.35	0.55	-	-	-
1728	-	-	-	-	0.0	−0.33	−0.33	-	-	-
1973	0.01	-	-	-	−1.5	−0.43	−1.93	-	-	-
2056	0.17	−0.17	0.2	0.03	1.0	−0.64	0.36	0.1	−0.17	−0.07
2948	−0.25	0.45	−0.05	0.40	0.0	−0.35	−0.35	0.45	−0.17	0.28
3158	-	-	-	-	0.5	−0.31	0.19	-	-	-
3439	0.42	-	-	-	−1.5	−0.33	−1.83	-	-	-
3717	0.60	−0.16	−0.03	−0.19	1.5	−1.18	0.32	0.58	−0.47	0.11
4116	-	-	-	-	0.8	−0.38	0.42	-	-	-
4119	0.29	−0.23	0.15	−0.08	1.0	−0.62	0.38	0.45	−0.19	0.26
4943	-	-	-	-	1.0	−0.38	0.62	-	-	-
5501	-	-	-	-	0.8	−0.42	0.38	-	-	-
5685	-	-	-	-	1.6	−0.7	0.9	-	-	-
5994	-	-	-	-	0.8	−0.44	0.36	-	-	-
6628	0.12	−0.2	0.24	0.04	1.3	−0.7	0.6	0.15	−0.15	0.00
6633	-	-	-	-	1.16	−0.53	0.63	-	-	-
6647	−0.71	−0.42	0.14	−0.28	0.5	−0.61	−0.11	0.55	−0.41	0.14
6668	-	-	-	-	1.1	−0.47	0.63	-	-	-
6878	-	-	-	-	−0.5	−0.35	−0.85	-	-	-
7337	0.41	−0.14	0.15	0.01	1.0	−0.51	0.49	0.0	−0.08	−0.08
8781	-	-	-	-	1.2	−0.4	0.8	-	-	-

provided for the model atom. The NLTE correction of 0.4 dex is in accordance with the findings of Gigas (1988).

5.10. Helium

For helium no NLTE calculations were carried out in the course of this study. Leone & Lanzafame (1998) investigated the behaviour of several He I lines – including two lines at 5876 Å and 6678 Å which were as well examined in this work – in a wide temperature range. Their comparison between their NLTE calculations and LTE models of various authors reveal that for spectral types between A0 and B3 equivalent widths and thus LTE and NLTE abundances of these two lines are in concordance. Therefore in the case of the scrutinized He I lines LTE is a good approximation for the program stars.

6. Narrow absorptions in Ca II K

In some cases we found narrow absorption features in the Ca II K line and – after removing telluric lines – in Na D of two stars as well (see Table 8). They are similar to those detected in our former work on A stars (Holweger et al. 1999). The most prominent star with narrow Ca II K absorptions is β Pictoris. Its Ca II K profiles show redshifted narrow absorption features with a time dependency of the order of weeks and months which is attributed to the infall of cometary-like objects which evaporate as they approach the stellar surface (see e.g. Lagrange-Henri et al. 1992). In addition about 30% of the 28 normal A stars and 18 λ Bootis stars studied by Holweger et al. (1999) show detectable Ca II K features. The question arises as to whether these absorptions are of *inter*stellar or rather of *circum*stellar origin. As outlined in Holweger et al. (1999) such features have only been found in stars with $v \sin i > 80$ km s^{-1}. This is true for the B stars discussed in this work as well. Therefore a stellar property is correlated with the occurrence of Ca II K feature which supports a *circum*stellar origin. Holweger & Rentzsch-Holm (1995) give the following tentative interpretation: for stars with circumstellar gas concentrated in a disk-like structure the column density of absorbing gas along the line of sight will be at its maximum if the disk is viewed edge-on. Therefore circumstellar absorption lines should be detected preferably in objects with

Table 6. LTE and NLTE abundances. The NLTE corrections and abundances of Mg, Si and Ca are given with respect to the solar values.

HR	[Mg/H] LTE	Δ log ε	[Mg/H] NLTE	[Si/H] LTE	Δ log ε	[Si/H] NLTE	[Ca/H] LTE	Δ log ε	[Ca/H] NLTE
806	−0.09	−0.04	−0.13	0.02	−0.11	−0.09	−0.04	0.14	0.10
1070	−0.46	−0.1	−0.56	−0.26	−0.14	−0.40	−0.52	0.2	−0.32
1092	−0.08	−0.09	−0.17	0.2	−0.18	0.02	0.14	0.18	0.32
1214	−0.26	−0.11	−0.37	−0.18	0.27	0.09	−0.45	0.03	−0.42
1339	−0.4	−0.06	−0.46	0.04	−0.18	−0.14	0.16	0.15	0.31
1582	0.09	−0.07	0.02	−0.04	0.45	0.41	−0.57	−0.05	−0.62
1723	0.18	−0.04	0.14	0.02	−0.15	−0.13	−0.14	0.17	0.03
1728	−1.2	−0.03	−1.23	−0.37	−0.09	−0.46	−0.98	0.13	−0.85
1973	−0.52	−0.1	−0.62	−0.25	−0.10	−0.35	−0.69	0.17	−0.52
2056	0.31	−0.06	0.25	−0.03	0.36	0.33	0.01	−0.02	−0.01
2948	−0.72	−0.04	−0.76	−0.33	0.33	0.00	−0.08	−0.06	−0.14
3158	−0.8	−0.05	−0.85	−0.25	−0.12	−0.37	−0.68	0.13	−0.55
3439	−0.09	−0.05	−0.14	−0.21	−0.15	−0.36	−0.82	0.18	−0.64
3717	−0.19	0.07	−0.12	−0.48	0.41	−0.07	0.98	0.11	1.09
4116	−0.5	−0.05	−0.55	0.06	−0.18	−0.12	−0.32	0.17	−0.15
4119	0.00	−0.06	−0.06	0.02	0.29	0.31	0.52	0.09	0.61
4943	−0.5	−0.04	−0.54	−0.02	−0.12	−0.14	−0.4	0.17	−0.23
5501	−0.37	−0.07	−0.44	−0.09	−0.14	−0.23	−0.24	0.15	−0.09
5685	−1.3	−0.02	−1.32	1.0	−0.20	0.80	0.0	0.21	0.21
5994	−0.44	−0.05	−0.49	−0.07	−0.12	−0.19	−0.24	0.09	−0.15
6628	−0.02	−0.05	−0.07	−0.02	−0.24	−0.26	0.09	0.21	0.30
6633	0.07	−0.07	0.00	0.12	−0.24	−0.12	−0.17	0.17	0.00
6647	−0.36	−0.17	−0.53	−0.11	0.54	0.43	−0.19	−0.19	−0.38
6668	0.06	−0.07	−0.01	0.12	−0.25	−0.13	−0.53	0.17	−0.36
6878	−0.69	−0.08	−0.77	−0.26	−0.16	−0.42	−0.46	0.12	−0.34
7337	−0.24	−0.06	−0.30	−0.04	−0.21	−0.25	−0.62	0.17	−0.45
8781	−0.1	−0.07	−0.17	−0.13	−0.29	−0.42	−0.1	0.16	0.06

$\sin i \approx 1$. Hence the chance to find a star with narrow absorption lines *and* low $v \sin i$ is small.

7. Discussion

The results presented in Tables 5–7 reveal that the abundances of the program stars are widely distributed. A closer inspection of the data shows some interesting correlations.

7.1. Diffusion

In some stars cool enough to show detectable strontium and barium lines, we detect NLTE overabundances of these elements. Most obviously, the diffusion indicators barium and strontium are clearly overabundant in HR 1728, HR 1973, HR 2948, HR 3439, HR 5501, HR 5994, HR 6633, HR 6668, and HR 6878. Furthermore, some of these stars (HR 1973 and HR 3439 as well as HR 6633 and HR 6668) show similar abundance patterns which suggests that they can be ascribed to the same physical process. In the widely accepted diffusion scenario (Michaud 1970; Michaud & Charland 1986) this indicates element separation by diffusion in their outer layers. In addition to that the three other scrutinized diffusion indicators (oxygen, magnesium, and calcium) are deficient in the strontium and barium overabundant stars HR 1728, HR 1973, HR 3439, and HR 6878. This strengthens the diffusion hypothesis. Some program stars show abundance anomalies of the diffusion indicators to a lesser extent while other stars, namely HR 1723, HR 2056 and HR 4119, have abundances which are close to the solar values. For stars with deviations from solar composition similar abundance patterns were as well found for HR 3158, HR 4116, HR 4943 and HR 8781 and for HR 806, HR 1070, HR 1092 and HR 1723. We illustrate these correlations in Fig. 2. All stars where both strontium and calcium were analysed are overabundant in strontium and solar or underabundant in calcium. In fact, only one of these stars, namely HR 6633, has a solar value of calcium. The values obtained for strontium reveal as well a correlation with the oxygen abundances: while strontium is radiatively driven outwards oxygen sinks down. For strontium and magnesium the situation is similar: all stars where magnesium is deficient show overabundances of the diffusion indicator strontium. In contrast, neon – which is not an indicator of diffusion – shows a very small scatter and illustrates the quality of the NLTE-analysis.

The anomalies detected in the program stars do not occur to the same extent in all stars but show star-to-star variations. This suggests that a counterpart to diffusion may blur the abundance anomalies. B-type stars are fast rotators. The rotation of a star causes accelerations which lead to the mixing of the stellar envelope. The ability of stellar rotation to inhibit effective diffusion processes was already mentioned in the fundamental paper by Michaud (1970). This so-called *meridional mixing* is well-known to occur in A stars. The effectivity of the mixing of the stellar atmosphere increases with increasing rotational velocity.

Table 7. LTE and NLTE abundances. The NLTE corrections and abundances of Fe, Sr and Ba are given with respect to the solar values.

HR	[Fe/H] LTE	$\Delta \log \epsilon$	[Fe/H] NLTE	[Sr/H] LTE	$\Delta \log \epsilon$	[Sr/H] NLTE	[Ba/H] LTE	$\Delta \log \epsilon$	[Ba/H] NLTE
806	−0.01	−0.02	−0.03	-	-	-	-	-	-
1070	−0.41	−0.02	−0.43	-	-	-	-	-	-
1092	0.29	−0.08	0.21	-	-	-	-	-	-
1214	0.07	−0.05	0.02	-	-	-	-	-	-
1339	−0.42	−0.01	−0.43	-	-	-	-	-	-
1582	0.04	−0.05	−0.01	-	-	-	-	-	-
1723	0.09	−0.03	0.06	-	-	-	-	-	-
1728	−0.44	0.00	−0.44	0.02	0.49	0.51	-	-	-
1973	0.54	−0.03	0.51	0.65	0.60	1.25	0.9	0.4	1.3
2056	−0.06	−0.04	−0.10	-	-	-	-	-	-
2948	0.14	−0.04	0.10	2.26	0.26	2.52	-	-	-
3158	−0.51	−0.01	−0.52	-	-	-	-	-	-
3439	1.39	−0.01	1.38	2.38	0.40	2.78	-	-	-
3717	−0.21	−0.06	−0.27	-	-	-	-	-	-
4116	−0.51	−0.01	−0.52	-	-	-	-	-	-
4119	0.19	−0.05	0.14	-	-	-	-	-	-
4943	−0.21	−0.02	−0.23	-	-	-	-	-	-
5501	−0.26	−0.02	−0.28	−0.30	0.65	0.35	-	-	-
5685	-	-	-	-	-	-	-	-	-
5994	0.24	−0.02	0.22	0.60	0.55	1.15	-	-	-
6628	−0.26	−0.06	−0.32	-	-	-	-	-	-
6633	0.34	−0.04	0.30	0.18	0.77	0.59	-	-	-
6647	0.14	−0.05	0.09	-	-	-	-	-	-
6668	0.29	−0.03	0.26	−0.07	0.77	0.70	-	-	-
6878	0.14	−0.03	0.11	0.40	0.60	1.00	-	-	-
7337	−0.31	−0.04	−0.35	-	-	-	-	-	-
8781	−0.06	−0.04	−0.10	-	-	-	-	-	-

Table 8. Equivalent widths of the detected narrow absorption features.

HR	Equivalent width [mÅ]	
	Ca II K	Na $D_{1,2}$
1070	9	-/-
1092	121	300 / 241
1582	40	30 / 16
2056	13	-/-
4943	32	-/-

Therefore in a certain sample of stars with abundance anomalies, we expect to find more pronounced deviations from the normal values in slow rotators than in fast rotating stars. This is nicely illustrated for the case of λ Bootis stars in Holweger & Rentzsch-Holm (1995). Their Fig. 13 shows the calcium abundances of their λ Bootis stars investigated as a function of rotational velocity. While stars with low rotation show conspicuous underabundances, the fast rotators approach solar values.

Figure 3 shows the abundances of calcium as a function of $v \sin i$. Abundances of stars with rotational velocities below 100 km s^{-1} show a large scatter while the scatter for fast rotators ($v \sin i > 100$ km s^{-1}) is less pronounced. The abundances of the two fastest rotators (HR 1092 and HR 5685) are afflicted with larger errors of 0.4 dex. Therefore the result obtained from Fig. 3 is in accordance with simulations carried out by Turcotte & Charbonneau (1993) which have shown that rotational velocities above 125 km s^{-1} lead to an effective mixing of the stellar envelope.

Given our presented results we suggest that the variety of diffusion-driven abundance patterns known from A stars continues to the temperature regime of late B stars and conclude that the abundance anomalies discovered in some of the program stars can be attributed to *diffusion combined with meridional mixing*.

7.2. Weak stellar winds

In OB stars radiatively driven stellar winds are common (Abbott 1980, 1982; Friend & Abbott 1986). It is well-known that these winds not only lead to substantial mass loss with rates up to $\sim 10^{-4}$ $M_\odot$/year (Maeder 1983) but also affect the chemical composition of stars above 20 $M_\odot$ (Kilian 1992).

The masses of early-type B stars are far above the masses of the program stars but the objects investigated in this study are situated in a transition region between the diffusion dominated stellar surfaces and the wind driven atmospheres of hot B stars. In this temperature range the occurrence of *weak stellar winds* with a mass-loss rate of 10^{-14}–10^{-12} $M_\odot$/year is theoretically predicted (Babel 1995). These winds may compete with diffusion processes and are expected to affect the chemical composition of the stellar surface. Furthermore, these winds play an important role in the widely accepted diffusion scenario: the abundance patterns of several stars where diffusion

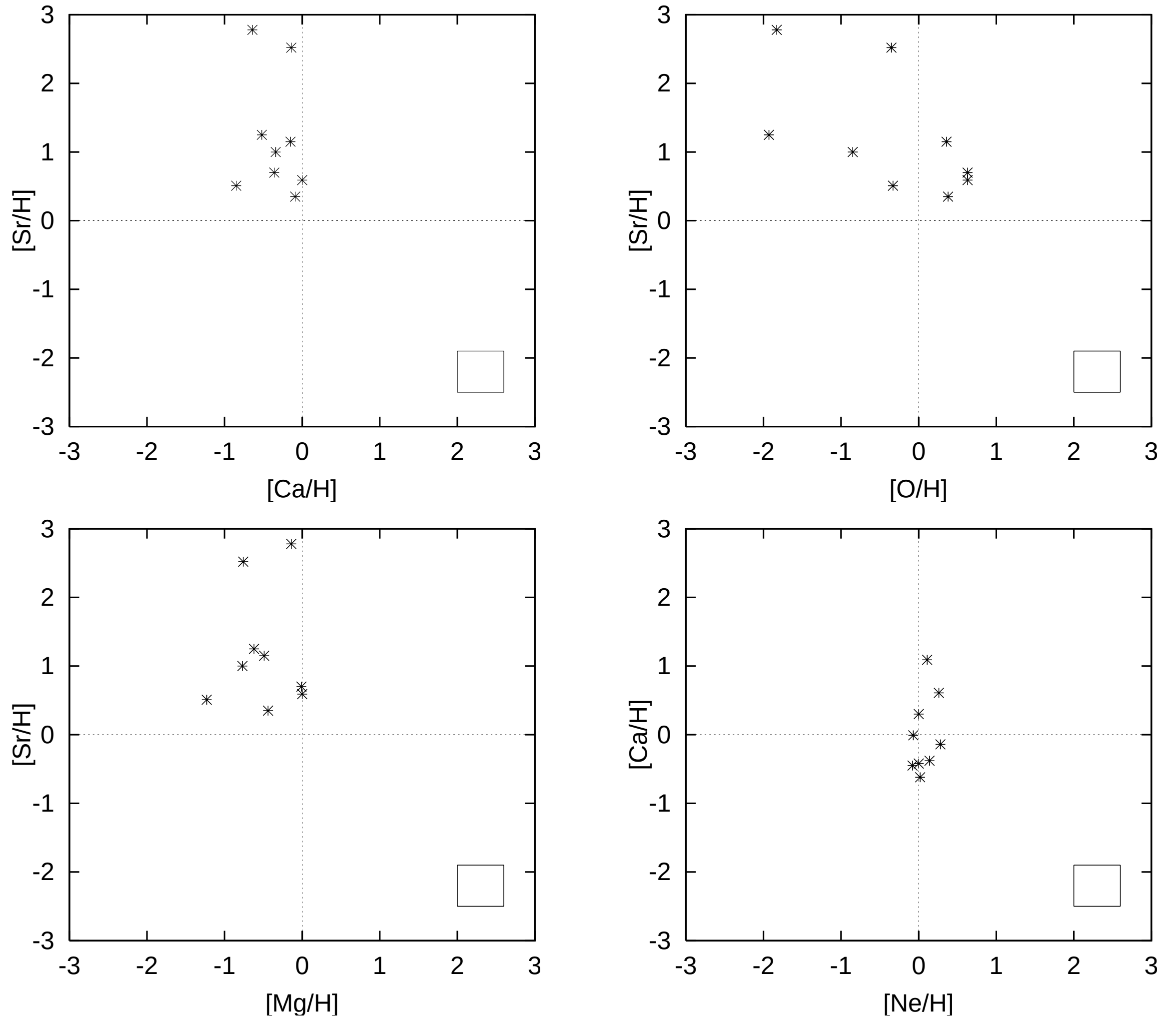

Fig. 2. Correlations between NLTE abundances of various elements. In the lower right corner of the plots there is an error box representing the typical error of ±0.3 dex of our abundance analysis. Note the small scatter of neon abundances which is in sharp contrast to the scatter of the diffusion indicator calcium.

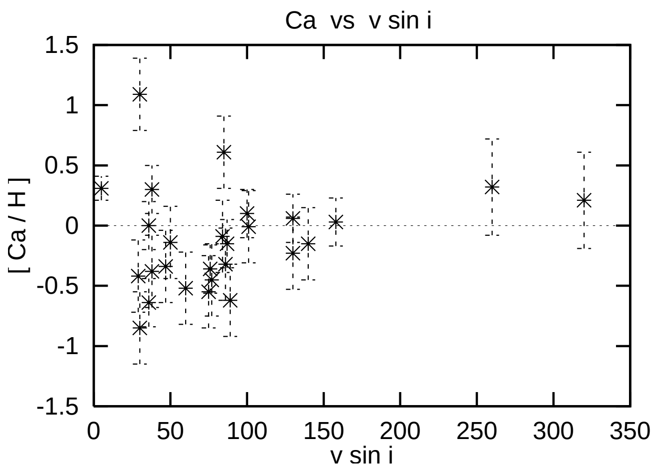

Fig. 3. The NLTE abundances of calcium as a function of $v \sin i$.

is efficient adopt in most cases the existence of a weak stellar wind to explain mild inconsistencies between theory and observation (Alecian 1996; Hui-Bon Hoa & Alecian 1998). A stellar wind of the order of 10^{-14}–10^{-12} $M_{\odot}$/year would be mild enough not to inhibit diffusion. Unfortunately, in contrast to the massive stellar winds of OB stars *there is no spectroscopic evidence for the existence of weak stellar winds to date*. A theoretical attempt to detect weak stellar winds in the temperature range of late B stars was proposed by Landstreet et al. (1998). The basic idea is that abundant elements like carbon, oxygen, and neon which are not expected to be affected by radiative acceleration may accumulate in the outer layers of a mass-losing star and thus serve as trace elements for the detection of weak stellar winds. The temperature range examined by Landstreet et al. (1998) is $8\,000 \leq T_{\rm eff} \leq 15\,000$ K. In view of these weak stellar winds investigations of two Ne I lines at 6402 Å and 6506 Å were carried out in the course of this study. Unfortunately neon is only observable for stars with $T_{\rm eff} > 11\,500$ K. Nevertheless, the LTE results (Table 5) reveal overabundances of Ne I of up to 0.58 dex in at least five program stars. This would have been the first spectroscopic detection of weak stellar winds. Since Ne I is known to be affected by large NLTE effects, this result is suspect. In order to examine this in more detail NLTE effects had to be taken into account.

The neon model atom developed by Graf (2000) reveals that the abundance corrections for neon are negative for all investigated stars. This leads to essentially solar neon abundances of all stars within the error limits (Table 5). Therefore weak stellar winds were not detected in the course of this study which suggests that if suchlike winds are present their intensity is below 10^{-14} $M_{\odot}$/year.

This is in accordance with the results obtained for oxygen which is a tracer of these winds in cooler stars (Landstreet et al. 1998). Moreover, this confirms the findings of Dworetsky & Budaj (2000) who analysed neon in a sample of normal B stars and HgMn stars. Their results reveal essentially solar neon abundances for normal B stars. For the only star in common with Dworetsky & Budaj (2000) – HR 1339 – we considered the neon lines in the spectra as too weak to allow a reliable abundance determination. In a recent study (Budaj & Dworetsky 2002) on radiative accelerations of late B stars they find the radiative accelerations well below the gravitational accelerations which leads them to predict underabundances for neon. As can be seen from Fig. 2 and Table 5 we do not find significant underabundances of neon for our stellar sample. This may be due to some competetive process, e.g. meridional mixing (see Sect. 7.1 and Fig. 3).

Nevertheless, the result achieved for the neon abundances demonstrates the importance of NLTE calculations in the investigated temperature range since an LTE analysis pretends the presence of weak stellar winds.

8. Galactic abundance gradients

Because of their brightness and as B stars are in general young objects they are often used for Galactic abundance studies (see e.g. Kaufer et al. 1994). The study of the chemical composition of stars and the variation of stellar abundances within the Galaxy is of fundamental importance for the understanding of Galactic evolution. The stars studied in this work cannot be used for that kind of investigations since they represent only a volume-limited sample within the solar neighbourhood. In order to obtain high S/N spectra the program stars were taken from the Bright Star Catalogue (Hoffleit & Warren 1991), therefore the stars lie in the solar vicinity (see Table 1). A different point is important here: the results of this work reveal that diffusion processes can occur in the outer layers of late B stars. As a consequence, the composition of such a star does not reflect the primordial abundances of the interstellar cloud it originated from and may therefore not be a reliable tracer for Galactic abundance studies if the effects of diffusion are neglected. This result is strengthened by the study of Luck et al. (2000) and reveals the importance of the investigation of late B stars.

9. Conclusions

The main results of this work can be summarized as follows: (1) A large fraction of late B stars show anomalous rather than solar abundances. (2) Combined with meridional mixing diffusion can explain the observed abundance patterns. (3) The result of the search for the occurrence of weak stellar winds of $\sim 10^{-14}$ $M_{\odot}$/year by using NLTE abundances as a diagnostic tool was negative. Thus mass loss rates must be below this limit. (4) Element separation processes seem to be common in late B stars. This constitutes a serious problem for using such stars for galactic abundance studies. (5) In five stars narrow absorptions in Ca II K have been found. They are rather of circumstellar than of interstellar origin.

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