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On the behavior of the C II 4267.261, 6578.052 and 6582.882 Å lines in chemically peculiar and standard stars ☆

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Abstract

With the aim of investigating the possible particular behavior of carbon in a sample of chemically peculiar stars of the main sequence without turning to modeling, we performed spectroscopic observations of three important and usually prominent single ionized carbon lines: 4267.261, 6578.052 and 6582.882 Å. In addition, we observed a large number of standard stars in order to define a kind of normality strip, useful for comparing the observed trend for the peculiar stars. We paid particular attention to the problem of the determination of fundamental atmospheric parameters, especially for the chemically peculiar stars for which the abundance anomalies change the flux distribution in such a way that the classical photometric methods to infer effective temperatures and gravities parameter cannot be applied. Regarding CP stars, we found a normal carbon abundance in Hg–Mn, Si (with some exceptions) and He strong stars. He weak stars are normal too, but with a large spread out of the data around the mean value. A more complicated behavior has been noted in the group of SrCrEu stars: four out of seven show a strong overabundance, being the others normal.

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1. Introduction

Chemically Peculiar (CP) stars are main sequence objects whose spectral types are between B and F and for which abundances are not consistent with their effective temperatures. Spectral, photometric and, in a subgroup, magnetic variability with a single period has been observed. In the oblique rotator model, proposed by Stibbs (1950), chemical elements are not homogeneously distributed over the stellar surface and the observed variations are due to the stellar rotation. It is commonly accepted that anomalous abundances are caused by diffusion processes (Michaud, 1970). Magnetic fields are suspected of influencing the diffusion suppressing mass-motions and chancing the path of ionized species (Michaud et al., 1981). Therefore, diffusion in CP

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stars results in a non homogeneous distribution of elements on the stellar surface.

Carbon, one of the major constituents of a normal stellar atmosphere and also one of the principal contributors to the metallicity of the stellar material, is also a probe to test the different theories on diffusion processes involved to explain the abundance anomalies observed in the various classes of CP stars. A standard or in some cases, a slight underabundance of carbon has been derived among the non magnetic Hg–Mn stars (Roby and Lambert, 1990). LTE analysis carried out by Adelman (1984) and Lopez-Garcia and Adelman (1994) confirms this underabundance also in cool Ap and He weak stars.

The approach to be used for the determination of the carbon abundance in normal and CP stars is sufficiently puzzling. Roby and Lambert (1990) reported about the abundances of CNO inferred by means of LTE analysis and found that abundances derived from C I differ from those coming from C II lines. They pointed their attention to some NLTE effects. The importance of using NLTE approach has been stressed by Eber and Butler (1988) and, later, by Garrison and Hamilton (1995) who reported a kind of erratic behavior of the C II λ4267.261 Å as observed in spectra of early B type stars. Gies and Lambert (1992) and, later on, Andrievsky et al. (1999) found that abundances inferred from LTE analysis are higher than the ones from NLTE calculations, being the discrepancy smaller than errors on those measurements. Gies and Lambert (1992) found also a dependence of carbon abundance on the effective temperature that could be a computational artifact.

Because of these difficulties, our purpose in this paper is to analyze the behavior of carbon in several groups of CP stars looking only at the equivalent widths (EW) of three important C II lines: namely C II λ6578.052, C II λ6582.882 Å and C II λ4267 Å that actually is a multiplet given by the fine structure transitions at 4267.001 and 4267.261 Å.

With this aim, we performed time resolved spectroscopy for 9 stars presenting He strong lines, 21 with He weak lines, 22 stars characterized by silicon overabundances, 8 Hg–Mn and 7 cool CP stars with overabundances of iron peak elements and rare earths. For these stars, listed in Tables A.2–A.4, the Renson et al. (1991) classification is reported. A sample of 45 B-type main sequence stars have also been observed in order to compare the behavior of carbon in CP stars with that observed in normal stars (Table A.1). In order to take into account the variability most of the selected CP stars have been observed several times.

2. Observations and data analysis

Equivalent widths for the normal B-type and peculiar stars listed in Tables A.1–A.4 have been measured with two different instruments

- the 1.4 m *Coudè Auxiliary Telescope* (CAT) equipped with the *Coudè Echelle Spectrometer* (CES) of the *European Southern Observatory* (ESO). The covered spectral range is about 50 Å centered on 6580 Å, the lines of the wavelength calibration lamp show that $R = 60\,000$;
- the 2.1 m telescope of the *Complejo Astronómico El Leoncito* (Casleo) coupled with a Boller and Chivens Cassegrain spectrograph with $R = 12\,000$ covering a spectral interval ranging from about 3500 Å to 7000 Å;

All the data have been reduced by means of IRAF packages. With both instruments the achieved S/N ratio was between 100 and 300.

When possible, equivalent widths were measured by a Gaussian fit of spectral lines after having removed the possible continuum slope, otherwise a measure of the area between the line profile and the continuum was obtained. Following Leone et al. (1995), we estimated the error in the measured equivalent width with the relation:

$$\Delta W(\text{Å}) = \frac{1}{2}\left(2\frac{v_e \sin i}{c}\,\lambda\right)\frac{1}{S/N} \quad (1)$$

where the quantity in brackets represents the total extension of the line as deduced from the rotational broadening. For the observed stars adopted $v_e \sin i$ values have been taken from Leone et al. (1997), for the stars not available in that paper we searched for rotational velocities in '*The Bright Star Catalogue*' by Hoffleit and Jascheck (1982) or otherwise we queried the SIMBAD database. For the He strong stars we adopted the rotational velocities measured by Zboril and North (1999).

3. Atmospheric parameters

The effective temperatures and gravities of the main sequence stars have been derived from Strömgren photometry according to the grid of Moon and Dworetsky (1985) as coded by Moon (1985). The photometric colors have been de-reddened with the Moon (1985) algorithm. The source of Strömgren photometric data was SIMBAD database. Because of the abundance anomalies which modify the flux distribution of chemically peculiar stars (Leckrone et al., 1974), classical methods cannot be used to estimate the effective temperatures and gravities of these stars.

With reference to He weak stars, Catalano and Leone (1996) have found that solar and zero helium abundance atmospheres are indistinguishable from each other when one looks just at the flux distribution. This result is consistent with the conclusion reached by Hauck and North (1993) that classical photometric methods can be used for the determination of the effective temperatures of helium weak stars. Hence, we have still used Moon and Dworetsky's algorithm for helium weak stars.

As to He strong stars, Zboril et al. (1997) have investigated how an enhanced helium abundance influences the determination of fundamentals parameters. They studied a large number of He strong stars computing T_{eff} and log g both spectroscopically and photometrically taking into account the helium overabundance. Since their sample contains all our stars but HD 186205, we compared temperatures and gravities derived in that paper with those calculated by means of Moon and Dworetsky (1985) relation. All these values are listed in Table 1 and shown in Fig. 1. It is evident that Zboril et al. (1997) effective temperatures are lower than the ones calculated using the method defined by Moon and Dworetsky (1985). On the contrary, with the exception of HD 58260, gravities show a slope close to zero. The more likely explanation for that could be the helium peculiar abundance which modifies Balmer line profiles, as proved for the H_β line by Leone and Manfré (1997). In our study we adopted the fundamental parameters published in Zboril et al. (1997) for all the He strong stars but HD 186205 for which we used the values published in Zboril and North (2000). A least square fitting gives the following relations between Zboril et al. (1997) and Moon and Dworetsky (1985) calibrations:

Table 1
Effective temperatures and surface gravities taken from Zboril et al. (1997) (columns 2 and 3) for He strong stars compared with those calculated using Moon and Dworetsky (1985) relation (columns 4 and 5)

HD	T_{eff} (K)	log g	T_{eff} (K)	log g
36485	18 400	4.41±0.11	20 000±800	4.21±0.07
37017	19 200	4.45±0.10	19 810±800	3.80±0.07
37479	22 200	4.53±0.17	22 100±800	3.44±0.07
37776	21 800	4.52±0.07	22 360±800	3.84±0.07
58260	19 000	4.02±0.18	19 390±800	3.24±0.07
60344	21 700	4.48±0.18	21 390±800	3.53±0.07
64740	22 700	4.50±0.06	23 500±800	3.82±0.07
66522	18 800	4.39±0.10	19 760±800	3.41±0.07

$$T_{\mathrm{Zboril}} = 1.11 \cdot T_{\mathrm{MD}} - 2915 \quad (2)$$

$$\log g_{\mathrm{Zboril}} = -0.03 \cdot \log g_{\mathrm{MD}} + 4.59 \quad (3)$$

excluding HD 58260 in fitting the gravity relation.

For the other types of peculiar stars when the metal abundances are strong enough to modify the flux distribution we used the relation established by Napiwotzki et al. (1993).

4. The behavior of the carbon lines in main sequence stars

In order to study the behavior of the observed lines in CP stars, we firstly defined the 'normality region', that is the place in the EW versus T_{eff} graph drawn by the standard stars. For each line, equivalent widths have been measured from the spectra obtained with the two instruments described in Section 2 (see Table A.1). In addition, six stars have been observed with both instruments and used to check the consistency of the two data sets. Such a comparison (see Fig. 2) shows that no instrumental effect is present.

In Fig. 3 we plotted the measured EWs versus the T_{eff}. In order to reproduce the sequence of standard stars, we calculated for each spectral line a weighted polynomial fit (order 3). Errors on equivalent widths have been used as weight in the fitting procedure. The fitting relations giving EW (mÅ) versus T_{eff} (K) for each line are the following:

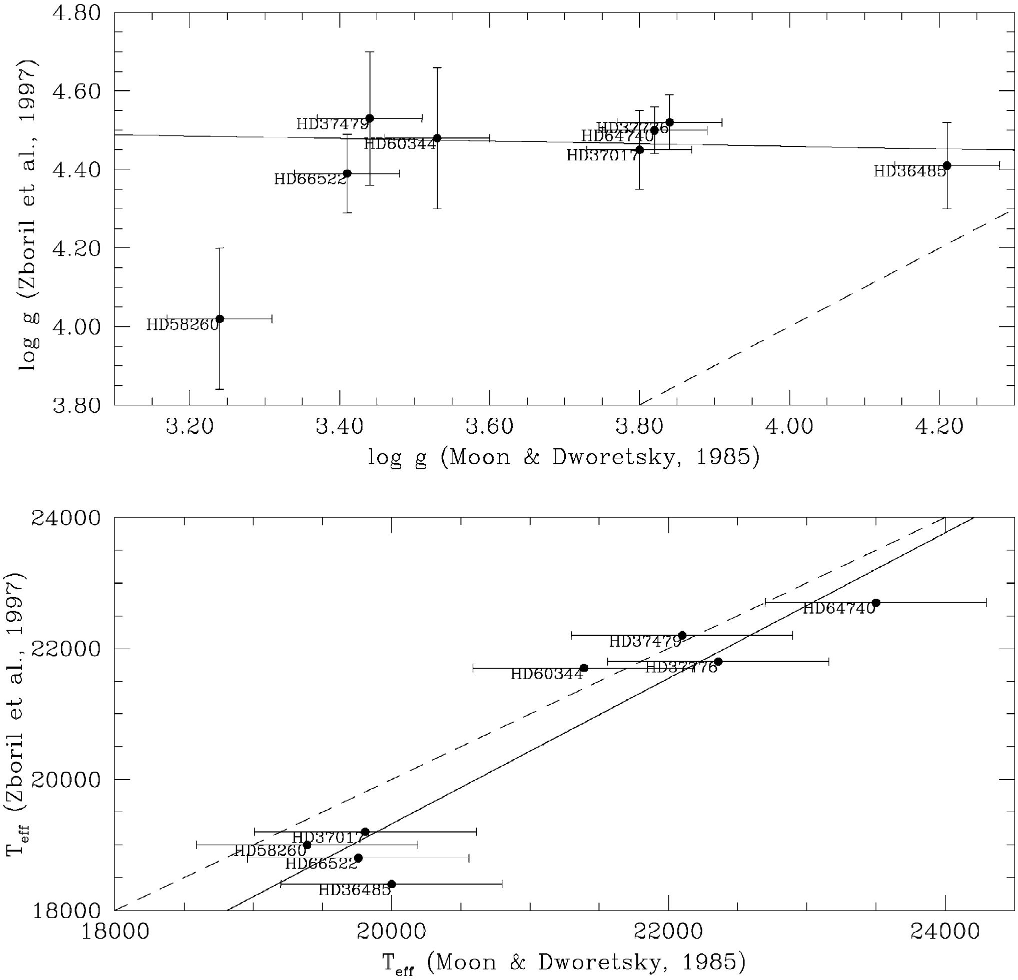

Fig. 1. Comparison between the effective temperatures and surface gravities calculated by Moon and Dworetsky (1985) relation and those from Zboril et al. (1997). Dashed lines represent the equality, while the solid lines are the linear regression. In the upper panel we fitted our data excluding HD 58260 for which its position in the graph is far from the behavior described by the others.

$$EW_{\lambda 4267} = -2.37\cdot 10^{-10}T_{eff}^3 + 9.45\cdot 10^{-6}T_{eff}^2 - 0.09T_{eff} + 250$$

$$EW_{\lambda 6578} = -4.21\cdot 10^{-10}T_{eff}^3 + 1.99\cdot 10^{-5}T_{eff}^2 - 0.29T_{eff} + 1300$$

$$EW_{\lambda 6582} = -3.67\cdot 10^{-10}T_{eff}^3 + 1.73\cdot 10^{-5}T_{eff}^2 - 0.25T_{eff} + 1140$$

The behavior of these curves is quite similar, but while for the red doublet the threshold temperature to observe these spectral lines is about 13 000 K, this value goes down to about 10 000 K when dealing with the 4267.261 Å line. It is worthy to note that points in Fig. 3 are spread out over a relatively wide range of equivalent widths. This effect has been already noted by Roby and Lambert (1990) and, regarding line 4267.261 Å, by Garrison and Hamilton (1995).

4.1. LTE modeling

Although we are mainly interested in directly

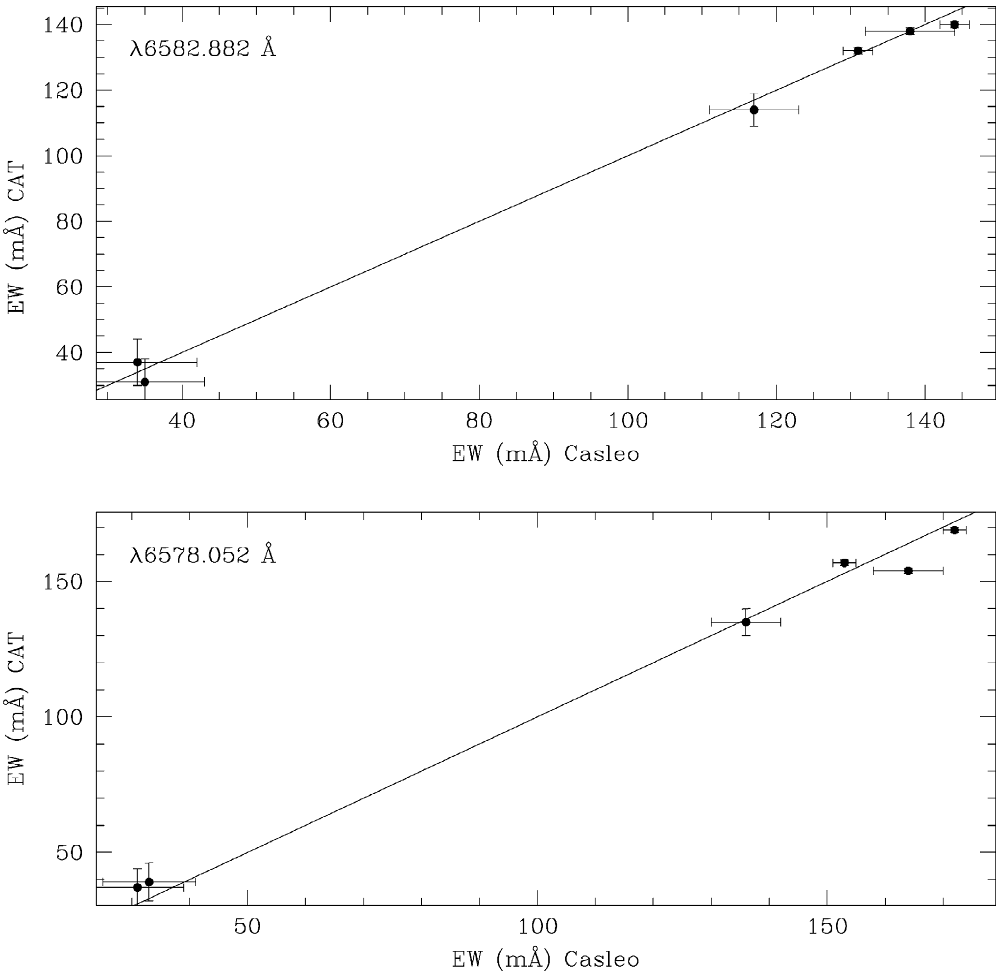

Fig. 2. Comparison of ESO-CAT equivalent widths with those measured using Casleo instrument. Solid line represents the equality. Because of the different spectral range covered with these telescopes, we could compare measurements from only the red carbon doublet.

comparing the EW of carbon lines of CP and main sequence stars to overcome the modeling difficulties pointed out, as first step of our study we tried to reproduce in LTE approximation the observed sequence of standard stars to check the capabilities of the most recent progress in spectral line modeling, especially for what concerns the atomic parameters and atmospheric models.

To pursue this objective we computed a grid of atmospheric models with effective temperatures matching the ones covered from our standard stars and log $g = 4$, ATLAS9 (Kurucz, 1993) has been used for this calculations. Afterwards, to compute the expected equivalent widths and to build the curves of growth we used WIDTH9 (Kurucz, 1993) for the red lines and XLINOP (Kurucz, 1993) to resolve the blend of the 4267.261 Å. Atomic data used for our calculations have been reported in Table 2. As for C II λ4267.261 Å, it is worthy to stress that we have calculated its expected EW taking into account all the spectral lines blended with it according to the Kurucz (1993) lines list and assuming the solar composition.Our results are displayed in Fig. 4. Only the linear part of the observed curve of growth can be reproduced theoretically. In any case, the sub solar carbon abundance reported in literature is confirmed. These conclusions led us to avoid performing calculations for our CP stars, but just

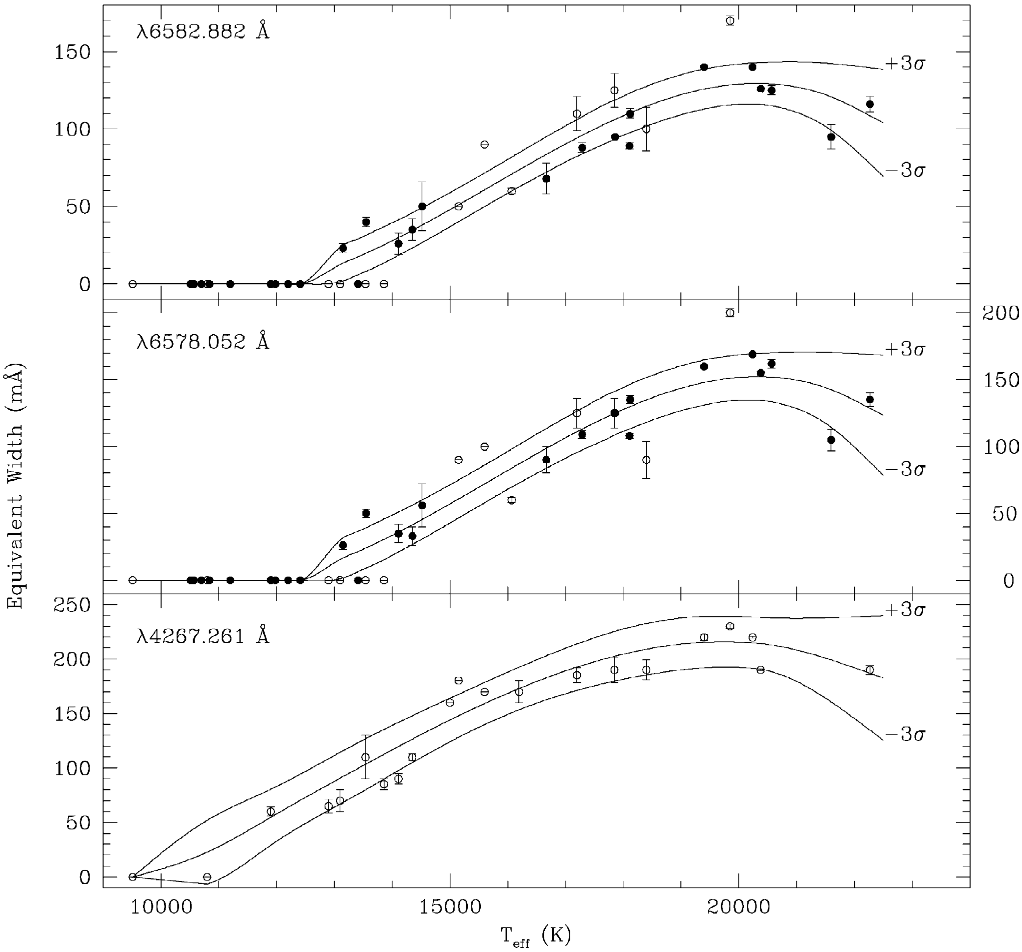

Fig. 3. Equivalent widths measured in our standard stars plotted as function of T_{eff}. Open circles represent EW measured at Casleo while those filled are relative to the ESO CAT measurements. The error bars have been estimated following Eq. (1). Curves represent the polynomial fit and the 3σ error zone.

compare their observed EW with the standard stars sequence as defined in the previous section.

5. The behavior of the carbon lines in chemically peculiar stars

CP stars are usually characterized by spectral lines with anomalous strength if compared with standard stars of the same spectral type. Thus, unblended lines in normal stars could be blended in peculiar objects and vice-versa. In order to evaluate spurious contribution coming from other spectral lines, we calculated atmosphere models for $T_{eff} = 10\,000$, 15 000, 20 000 and 25 000 K and log $g = 4.0$, whose metal abundances have been set to ten times the solar value. ATLAS9 has been used to compute the atmosphere models and SYNTHE (Kurucz and Avrett, 1981) to reproduce synthetic spectrum in two regions centered around λ4267 Å and λ6580 Å. To better estimate the residual equivalent width we set the carbon abundance to zero. We found a maximum residual EW of about 115 mÅ at $T_{eff} = 20\,000$ K in the blue region, while no residual has been found in the red region.

For the sake of clarity we reported our measure-

Table 2
Atomic data for the carbon lines studied and for the metal lines blended with the λ4267.261 Å. When no superscript is indicated data come from Kurucz (1993) lines list

Element	λ(Å)	log(gf)	Γ_R	Γ_S
Ar II	λ4266.527	-0.571[a]	8.09	-5.54
Fe III	λ4266.771	0.170	8.99	-5.83
C II	λ4267.001	0.563[a]	9.39	-4.76
C II	λ4267.183	0.716[a]	9.39	-4.76
C II	λ4267.261	-0.531[a]	9.39	-4.76
C II	λ4267.261	0.769	9.39	-4.76
S II	λ4267.762	0.294[a]	8.71	-5.25
Fe III	λ4267.970	-2.637	8.98	-6.68
C II	λ6578.052	-0.026[a]	9.16[b]	-6.15[b]
C II	λ6582.882	-0.327[a]	9.16[b]	-6.15[b]

[a] From NIST database.
[b] From Gies and Lambert (1992).

ments in three separate plots: one for Hg–Mn, silicon and SrCrEu stars (Fig. 5), one for the helium weak (Fig. 6) and the last for helium strong stars (Fig. 7).

5.1. Hg–Mn stars

Both Heacox (1979) and, later, Roby and Lambert (1990), noted the tendency for the carbon abundance in Hg–Mn to decline with temperature. Detailed discussion provided in the former paper suggests that carbon abundance in the Hg–Mn stars is very close to that observed in standard stars and the Sun. They found also an evidence for a slightly overabundance of carbon in the hottest stars of their sample ($T_{eff} >$ 12 000 K). This conclusion is shared in part by Smith and Dworetsky (1990). We observed 8 stars whose peculiarity class is defined as Hg–Mn in *The general catalogue of Ap and Am stars* by Renson et al. (1991) and with effective temperature varying in the interval from 9320 K to 14 400 K. Only HD 49606 and HD 78316, the hottest ones, show lines with EWs different from zero.

The behavior of the EWs of the Hg–Mn stars included in our sample is consistent with the one described by the standard stars displayed in Fig. 3. This leads us to conclude that there is no difference in the carbon abundance between Hg–Mn and standard stars of the same T_{eff}.

5.2. Si stars

Regarding stars with Si overabundance, Roby and Lambert (1990) did find that almost all the stars of their sample (7000 K $< T_{eff} <$ 13 000 K) have a carbon abundance smaller than the solar value.

The general trend of equivalent widths measured in our 22 silicon stars is in agreement with the standard strip sequence, but some exceptions are present. Two stars show overabundances: HD 25267 and HD 29009, while a moderate underabundance is evident for 4 of them: HD 24155, HD 37808, HD 73340 and HD 79416. No conclusion can be reached for HD 35502 because of the high error in the EW due to the fast rotation and for HD 74560, that shows a strong variability.

5.3. SrCrEu stars

Things appear to be more complicated for SrCrEu stars, since for four of them we observed a strong overabundance of carbon. To remove the possibility of a trivial error in the temperature determination, we compared our T_{eff} calculations with the literature values, but the discrepancies we found cannot justify the observed overabundance (see Table 3 for details).

Considering the peculiarity type of these stars, a possible solution could be the presence of other lines blended with carbon. Anyway, being HD 168733 a member of a double system, HD 170397 and HD 183806 suspected roAp star and HD 220825 oscillating (Aliev and Ismailov, 2000), the presence of relatively strong C II lines should be a matter of further detailed investigation. Unfortunately, all these four stars have been observed only in the spectral region centered around λ6580 Å, thus we could not check possible stratification of carbon in these stars.

5.4. He weak stars

Several analysis have been carried out on single He weak stars: HD 37043B ($= \iota$ Ori B) by Conti and Loonen (1970), HD 5737 ($= \alpha$ Scl) by Schmitt (1973) and Vilhu (1972), HD 23408 ($=$20 Tau) by Mon et al. (1981) and HD 115735 ($=$21 CVn) by Zverko et al. (1994), just to quote some. All these papers are in good agreement with a carbon abundance close to normal.

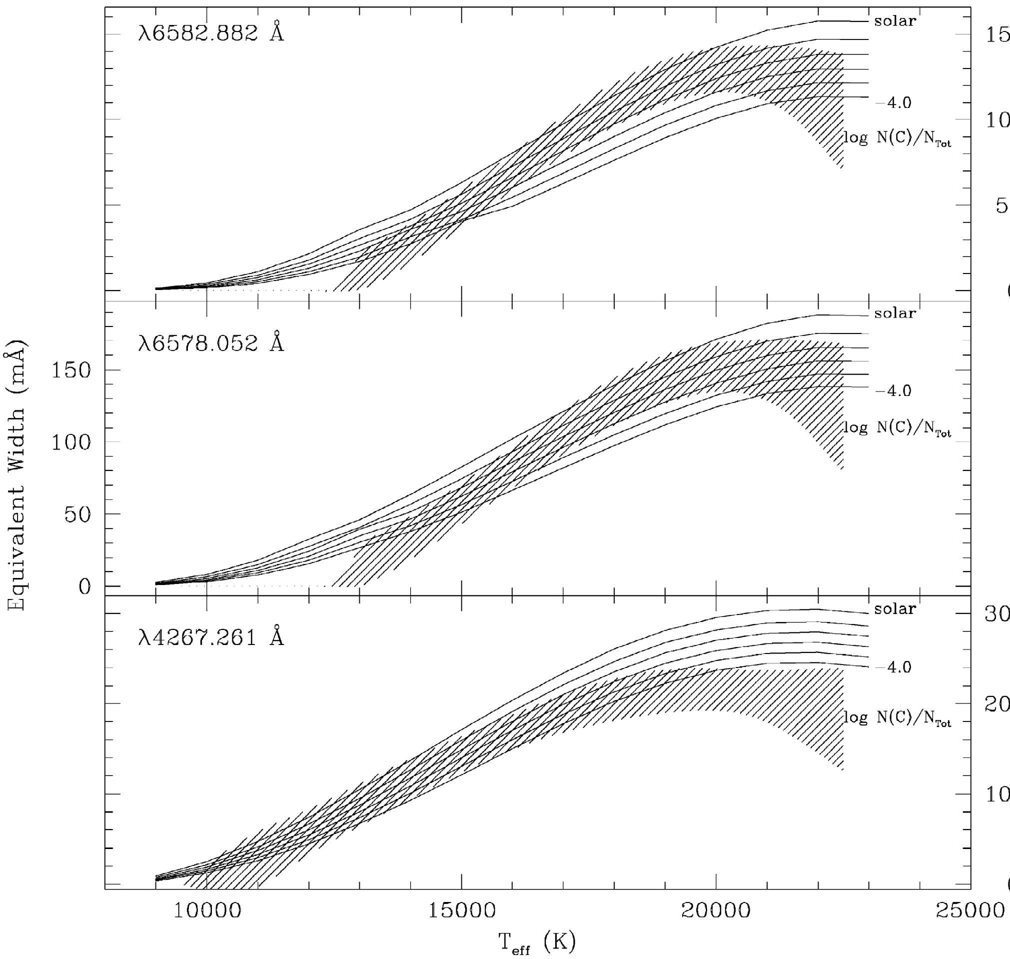

Fig. 4. Theoretical curves of growth plotted against the observed standard sequence for each line (shaded surfaces). Models have been calculated for 6 carbon abundances starting from the solar value (− 3.48) up to log $N_C/N_{Tot} = -4.0$, used step was 0.1 dex. Only the linear part of each observed curve can be reproduced theoretically, namely the range in T_{eff} from 15 000 to 20 000 K for the red lines and toward lower temperatures (10 000–17 000 K) for the blue line.

An extensive analysis of He weak stars has been performed by Topilskaya (1993). The author carried out spectroscopy for 47 He weak stars calculating chemical abundances in LTE approximation for helium and other light elements. Regarding carbon he found $[N_C/N_{Tot}] = -0.18 \pm 0.35$, a result in good agreement with the sub solar content of carbon in normal B-type stars reported in Section 4.1. The error is indicative of a large scatter of each single point around the average.

All the He weak stars analyzed in this paper (excluding some exceptions) show an almost standard behavior, since the average value matches the standard stars sequence. Nevertheless, some differences appear evident looking at the Fig. 6. CII λ4267.261 Å shows an almost normal EW, with the exception of three stars. Two of them show an underabundance which is strong for HD 74196 and slight for HD 28843, while the EW of HD 35456 is greater than the normal value. The same trend has

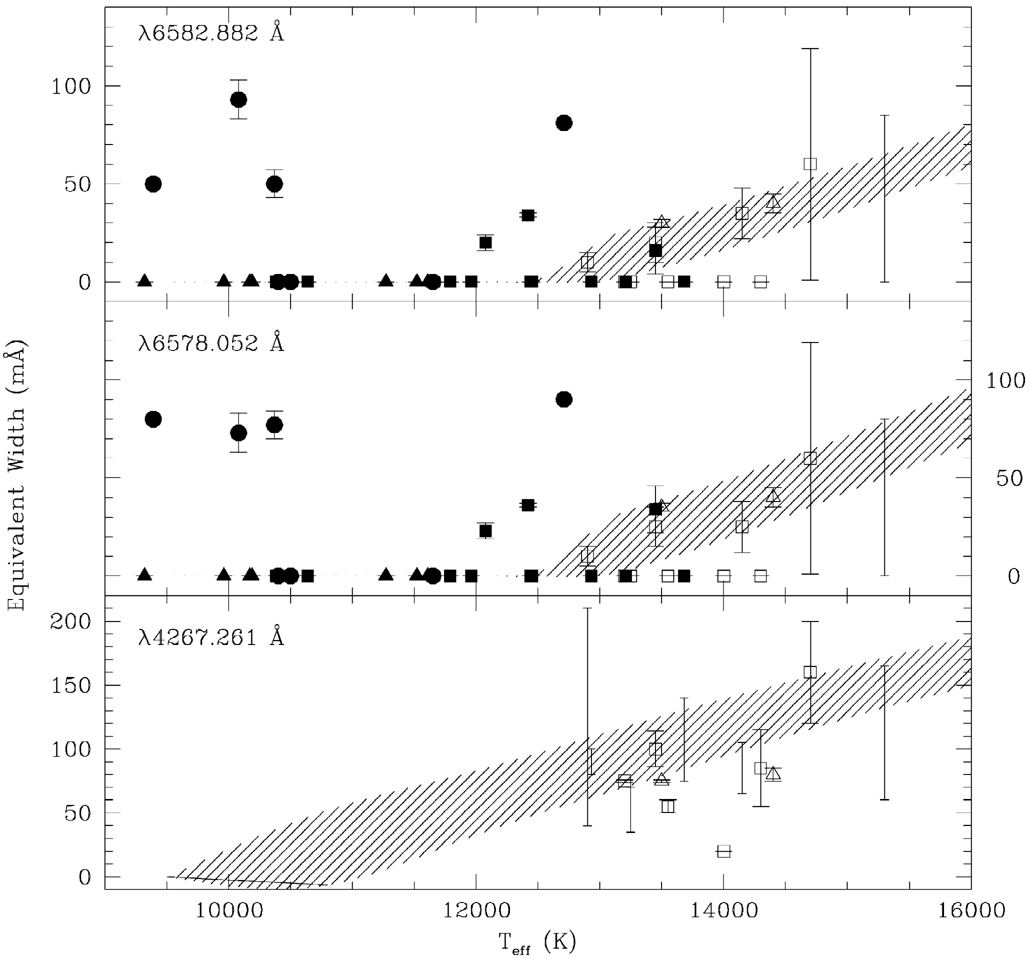

Fig. 5. Behavior of EWs versus T_{eff} for our sample of Hg–Mn, Si and SrCrEu stars. Measurements have been represented as open and filled symbols. In general open symbols refer to Casleo data while those filled refer to ESO-CAT data. The meanings are: triangles represent Hg–Mn stars, squares are silicon stars and circles are SrCrEu stars, error bars extend by 1σ up and down the measured EW. All the stars showing variability belong to the Si group and have been observed with Casleo equipment. These objects are represented as bars extending from minimum to maximum EW observed. The shaded surface represents the strip of the normal stars as described in the text.

been observed for the red doublet, but in this case the spread out of the points around the standard strip is larger than that for the blue line.

5.5. He strong stars

He strong stars are characterized by helium overabundance. To try to explain these anomalies Vauclair (1975) suggested a model with several ingredients: magnetic field, radiative diffusion, abundance anomaly and mass loss. Michaud et al. (1987), modeling the abundance anomalies with selective mass loss, suggested CNO abundance should be normal in their atmospheres. Even in this group a spread of carbon abundances around the average value (Osmer and Peterson, 1974; Zboril and North, 1999) is present.

Our sample of He strong stars is composed by 9

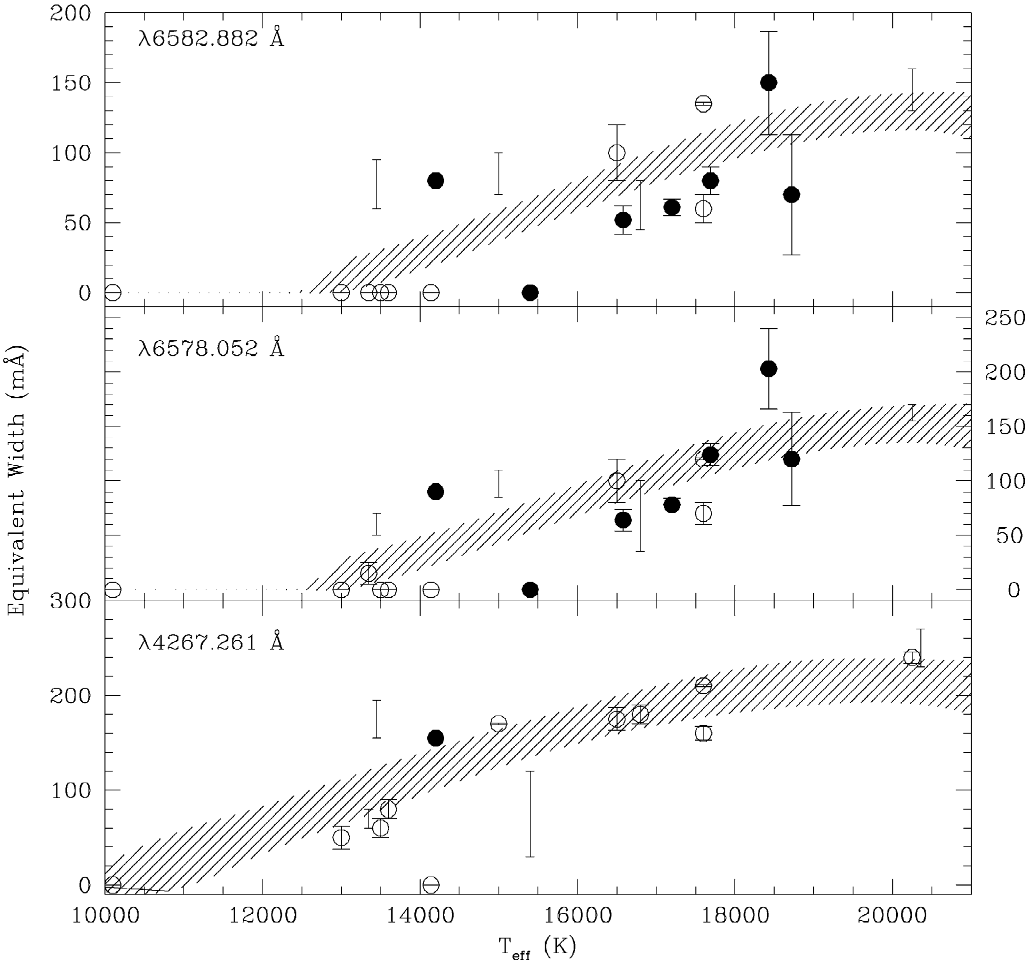

Fig. 6. Behavior of equivalent widths versus effective temperature for our sample of helium weak stars. Filled circles refer to ESO-CAT data and the open ones to Casleo measurements. All stars for which we detected variability have been observed at Casleo. Shaded surface is, as usual, the standard stars sequence.

objects with effective temperature ranging in the interval from 17 000 to 23 000 K. The normal values of EW measured by us for the λ4267.261 Å (Fig. 7, bottom panel) are in contrast with the results reported by Zboril and North (1999), who found for these stars an underabundance of about 10 times the solar value. For the red doublet, points are arranged slightly over the 3σ zone or close to its limit with the exception of three stars: HD 37017, HD 37479 and HD 64740. For these objects the red doublet is absent while the λ4267.261 Å appears normal.

We observed all these stars for 6 nights: HD 37479 shows an emission region that warpes the red wing of H_α and consequently could help hiding the C II lines. Moreover, it is a fast rotator so the rotational Doppler effect contributes remarkably to blend the red doublet. On the contrary, in the spectra of HD 37017 and HD 64740 the red carbon lines were never detected and they do not show any strange pattern, so we should search for some mechanism useful to explain its absence. As stated in previous works (Shore and Brown (1990) and refer-

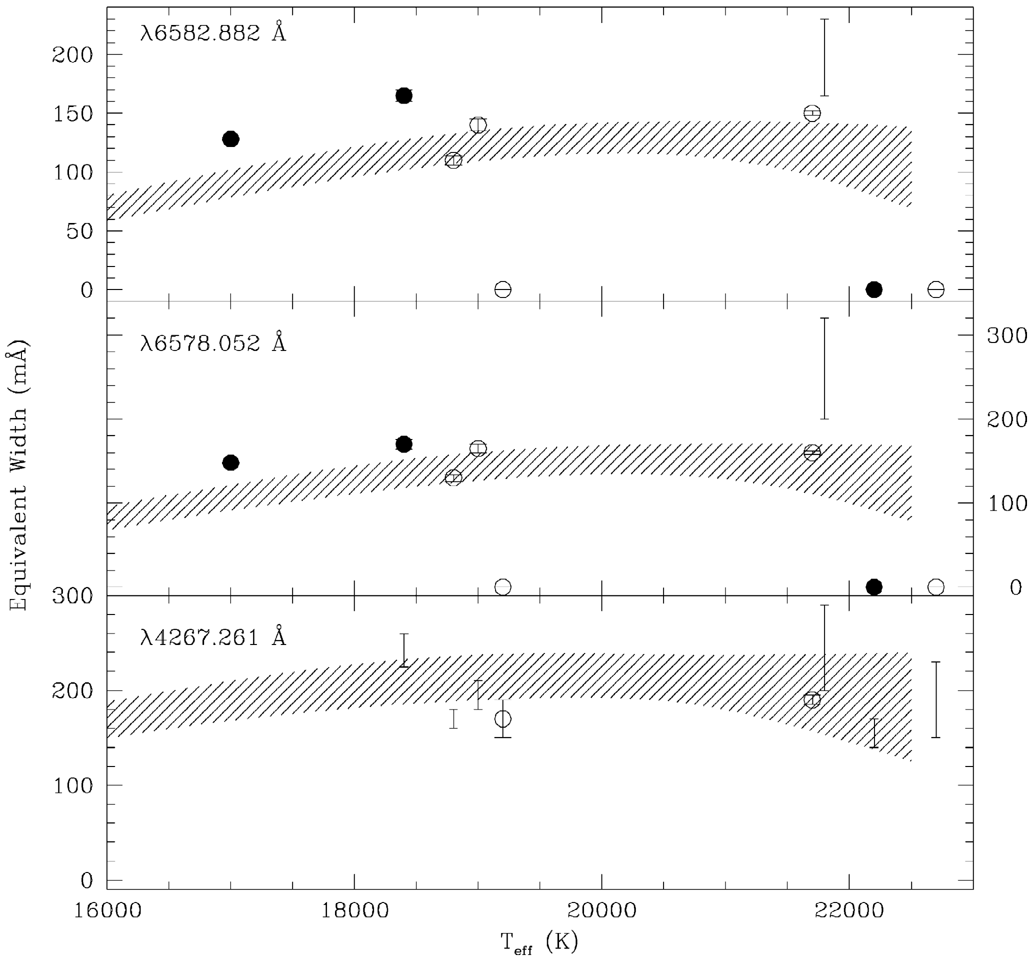

Fig. 7. Behavior of equivalent widths versus effective temperature for our sample of helium strong stars. Filled circles refer to ESO-CAT data and the open ones to Casleo measurements. All the observed variations have been detected from Casleo data. As in previous figure standard stars sequence is represented by shaded surface.

Table 3
Effective temperature calculated in this paper compared with values from literature data

HD	T_{eff} (K) this paper	T_{eff} (K) literature	References
168733	12 710	13 580	Glagolevski (1994)
170397	10 080	9400	Glagolevski (1994)
183806	9390	9460	North (1998)
220825	10 370	9070	Glagolevski (1994)

ences therein), these objects are characterized by a hot circumstellar plasma trapped in the stellar magnetosphere near the magnetic equator or alternatively channeled to form jet-like outflows from the magnetic polar regions. Recently, Smith and Groote (2001) have examined the processes responsible for resonance line emissions and anomalous absorption observed at a certain rotational phase in the UV spectrum of He strong stars. They found that variations in the UV and probably in the optical lines are related to absorptions that take place in the cloud of plasma corotating with the star as in the scenario described by Shore and Brown (1990). This result could explain the absence of the carbon doublet since there could be some emission process occurring in the cloud that fills the photosperic lines.

6. Conclusions

High resolution spectroscopic observations have been performed at the ESO-CAT telescope and at Casleo observatory for a sample of CP stars of different subclasses. In addition several standard stars covering the same interval of effective temperature have been observed in order to define a sequence of EW versus T_{eff} to which compare our measurements for the CP stars. We represented this sequence calculating a polynomial fit of the 3rd order plus or minus a quantity equal to 3σ.

By means of an LTE analysis we confirm the general agreement that carbon content in main sequence B-type stars is sub solar. Further, it is evident that LTE models are inadequate to reproduce the observed EW as a function of T_{eff} particularly for the hottest stars. This conclusion led us not to try to perform theoretical calculation for our sample of CP stars but to just compare their observed EWs with the standard stars sequence.

Our results are summarized below:

- **Hg Mn**: As concerns our data these stars show equivalent widths in agreement with the strip defined for standard stars. There is no hint of carbon anomalies as the slight underabundance noted by both Roby and Lambert (1990) and Smith and Dworetsky (1990).
- **Silicon**: Even with some exceptions solar like abundance is shown also by silicon stars observed in our sample. An underabundance has been observed for $T_{eff} > 13\,000$ K.
- **SrCrEu**: SrCrEu stars show on the contrary a more complicated behavior. In fact, four of them show a strong overabundance of carbon, being the remaining part in agreement with the standard stars.
- **He weak**: With the exception of HD 28843 and HD 74196 for which carbon appears to be underabundant, He weak stars seem to be normal when looking at the carbon abundance. According to their effective temperature these objects arranged themselves around the strip of standard showing an enhanced dispersion from star to star.
- **He strong**: Non-solar behavior has not been noted in this subclass of CP stars. As discussed in the text, for three stars red doublet lines are not measurable.

In conclusion, the general trend of the carbon abundance inferred by the equivalent widths of the three C II spectral lines here studied seems to be close to the solar values. However, a very large scatter is observed that could be due to significant abundance differences from the solar value without any systematic difference as previously stated. In the text we have discussed in particular some objects for which the discrepancy from the standard values was considerable.

Acknowledgements

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Appendix A

Table A.1
Measured equivalent widths of the carbon lines for the observed main sequence B-type stars. Spectral types (ST) and rotational velocities are taken from *The Bright Star Catalogue* (Hoffleit and Jascheck, 1982) or SIMBAD database. Effective temperatures and gravities have been determined following Moon (1985). Errors on equivalent widths have been computed by means of Eq. (1). Blank space means our spectrum does not cover the region with that line, dash means that spectral line is not present. Stars marked with an asterisk have been observed with the ESO-CAT telescope

Star HD	ST	T_{eff} K	log g	$v_e \sin i$ km s^{-1}	EW_{4268} mÅ	EW_{6578} mÅ	EW_{6582} mÅ
886*	B2IV	20 240	3.60	3	220±1	169±1	140±1
4622*	B9V	10 700	3.89	53		–	–
10982*	B9.5V	10 510	4.40	22		–	–
15371*	B5IV	13 550	3.45	24		50±3	40±3
16046*	B9.5V	10 570	3.96	72		–	–
16582*	B2IV	20 380	3.48	13	190±1	155±1	126±1
17543*	B6V	14 520	3.77	79		56±16	50±16
18883*	B7V	13 410	4.20	80		–	–
22203*	B8V	12 410	4.00	48		–	–
22252*	B8V	11 900	3.29	0		–	–
23793*	B3V	16 670	4.02	52		90±10	68±10
24587*	B6V	14 110	4.21	48	90±5	35±7	26±7
24626*	B6V	14 350	4.06	35	110±3	33±7	35±7
26171*	B9.5V	10 530	4.12	27		–	–
33331[a]	B7	13 100	4.10	55	70±10	–	–
34179	B8V	13 860	3.43	55	85±5	–	–
34798	B5V	16 070	4.09	16		60±2	60±2
35039	B2V	19 850	3.40	14	230±2	200±3	170±3
35299*	B1.5V	22 270	3.87	36	190±4	135±5	116±5
36351*	B1.5V	21 600	3.92	38		105±8	95±8
36589	B7	12 900	3.97	90	65±8	–	–
36960*	B0.5V	26 770	3.92	38		75±4	49±4
38602	B8III	11 900	3.61	25	60±4	–	–
42690*	B2V	19 400	3.58	25	220±3	160±1	140±1
43107	B8V	10 800	3.91	121	–	–	–
43157*	B5V	17 860	3.95	26		125±3	95±3
45572*	B9V	10 840	3.65	0		–	–
45813	B4V	16 200	3.99	135	170±10		
56779	B2V	17 850	3.76	132	190±12	125±11	125±11
62542	B3V	15 150	3.80	15	180±2	90±2	50±2
65575[a]	B3	17 200	3.54	65	185±7	125±10	110±10
72350	B4IV	15 000	3.50	130	160±12		
72798	B3III	15 600	3.50	1	170±1	100±1	90±1
74280	B3V	18 400	3.76	128	190±9	90±14	100±14
134687*	B3IV	18 110	4.17	16		108±2	89±2
157056*	B2IV	20 570	3.60	35		162±3	125±3
169467*	B3IV	17 290	3.98	35		109±3	88±3
170465*	B6IV	13 150	3.59	33		26±3	23±3
181454*	B9V	11 980	3.94	84		–	–
181869*	B8V	12 200	4.10	89		–	–
184707*	B9V	11 200	4.12	68		–	–
193924*	B2IV	18 120	3.79	39		135±3	110±3
209952	B7IV	13 540	3.79	236	110±20	–	–
215766*	A0V	11 200	4.29	71		–	–
216956	A3V	9510	4.37	100	–	–	–

[a] The real nature of these two stars has been established by Leone and Catanzaro (1998).

Table A.2
Measured equivalent widths of the carbon lines for the observed chemically peculiar stars. Spectral types (ST) and peculiarity class are taken from *The General Catalogue of Ap and Am stars* (Renson et al., 1991). Effective temperatures and gravities have been determined following Napiwotzki et al. (1993). When available, rotational velocities are from Leone et al. (1997), otherwise they are taken from Hoffleit and Jascheck (1982). In each columns labelled EW we reported the observed variation if any, otherwise the average EW and its error, as in Table A.1 blank space means no observation and dash stand for null EW. Objects marked with an asterisk have been observed with the ESO-CAT

Star HD	ST+PC	T_{eff} K	log g	v_e sin i km s^{-1}	EW_{4268} mÅ	EW_{6578} mÅ	EW_{6582} mÅ
1909*	B9 Hg	11 520	4.04	25		–	–
3580	B8 Si	13 250	3.82	85	35–70	–	–
10783	A2 Si Cr Sr	10 387	4.10	25		–	–
12767*	A0 Si	12 930	3.87	87	80–100	–	–
20629	A0 Si Sr Cr	12 900	4.40	35	40–210	10±5	10±5
22470	B9 Si	13 450	4.15	98	100±14	25±10	20±10
22920	B8 Si	14 150	3.72	121	65–105	25±13	35±13
24155*	B9 Si	13 680	4.01	52	75–140	–	–
25267*	A0 Si	12 080	3.85	25		23±4	20±4
26571	B8 Si	13 200	3.16	1	75±1	–	–
27376*	B9 Hg Mn	9320	3.45	31		–	–
29009*	B9 Si	12 420	3.54	20		36± 2	34±2
35502	B6 Si Sr Cr	14 700	4.42	290	160±40	60±60	60±60
37808	B9 Si	13 550	4.07	45	55±5	–	–
49606	B8 Hg Mn	14 400	3.89	35	80±5	40±5	40±5
73340	B9 Si	14 000	4.02	1	20±1	–	–
74560	B3 Si	15 300	3.92	22	60–165	0–80	0–85
78316	B8 Hg Mn	13 500	3.78	9	75±1	35±2	30±2
79416	B8 Si	14 300	4.10	384	85±30	–	–
133652*	B9 Si	13 208	4.27	69		–	–
133880*	B9 Si	12 440	4.46			–	–
136347*	B9 Si	11 790	4.35			–	–
141556*	B9 Hg Y	9960	3.92	0		–	–
143939*	B9 Si Cr Sr	10 638	4.32			–	–
168733*	B8 Sr Ti	12 710	3.53	4		90±1	81±1
170397*	A0 Sr Cr Eu	10 080	3.94	46		73±10	93±10
183806*	A0 Sr Cr Eu	9390	3.63	5		80±1	50±1
187473*	B9 Sr Cr Eu	11 650	4.05	30		–	–
187474*	A0 Sr Cr Eu	10 400	4.10	6		–	–
191110*	A0 Hg	11 270	4.11	10		–	–
193452*	B9 Hg	10 190	4.08	97		–	–
199728*	B9 Si	11 960	3.80	60		–	–
203006*	A2 Sr Cr Eu	10 500	4.26	48		–	–
220825*	A1 Sr Cr Eu	10 370	4.36	41		77±7	50±7
221006*	A0 Si	13 450	4.06	69		34±12	16±12
221507*	B9 Hg Mn	11 610	4.15	37		–	–
223640*	B9 Si Sr Cr	12 450	4.18	40		–	–

Table A.3
As in Table A.2 for the He-weak stars observed

Star HD	ST	T_{eff} K	log g	v_e sin i km s^{-1}	EW_{4268} mÅ	EW_{6578} mÅ	W_{6582} mÅ
5737*	B6	14 200	3.11	7	155±1	90±1	80±1
19400	B8	13 350	3.76	44	60–80	15±10	–
28843*	B9	15 400	4.14	70	30–120	–	–
34797	B8	13 000	4.25	80	50±12	–	–
35456	B7	13 450	3.79	25	155–195	50–70	60–95
35575	B3	16 500	4.07	120	175±12	100±20	100±20
35730	B4	17 600	4.15	58	160±7	70±10	60±10
36629	B3	17 600	3.62	5	210±1	120±1	135±1
36916	B8	13 500	3.77	75	60±10	–	–
37058	B3	20 250	4.00	5	240±6	155–170	130–160
44953	B8	15 000	4.18	30	170	85–110	70–100
49333	B7	16 800	4.08	65	180±10	35–100	45–80
60325[a]	B3	20 360	3.02	70	230–270	?	?
74196	B7	14 140	3.82	235	–	–	–
79469	A0	10 100	4.19	100	–	–	–
142301*	B8	17 690	4.22	58		124±10	80±10
142990*	B8	18 720	4.22	200		120±43	70±43
144334*	B8	16 580	4.29	44		64±10	52±10
162374*	B7	17 200	3.64	40		78±6	61±6
175362*	B6	18 430	4.24	170		203±37	150±37
224926	B8	13 600	3.72	80	80±10	–	–

[a] Due to the high rotational velocity the red doublet is blended in this star.

Table A.4
As in Table A.2 for the He-strong stars observed (from Zboril et al. (1997))

Star HD	ST	T_{eff} K	log g	v_e sin i km s^{-1}	EW_{4268} mÅ	EW_{6578} mÅ	W_{6582} mÅ
36485*	B2	18 400	4.41	32	225–260	165–190	155–170
37017	B2	19 200	4.45	150	170±20	–	–
37479*	B2	22 200	4.53	150	140–170	–	–
37776*	B3	21 820	4.52	145	200–290	200–320	165–230
58260	B8	19 000	4.02	18	180–210	165±5	140±5
60344	B3	21 700	4.48	15	190±5	160±2	150±2
64740	B2	22 700	4.50	140	150–230	–	–
66522	B2	18 800	4.39	30	160–180	130±4	110±4
186205*[a]	B5	17 000	4.00	5	–	148±1	128±1

[a] Fundamental parameters from Zboril and North (2000).

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