# Helium in Chemically peculiar stars

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**Abstract.** For the purpose of deriving the helium abundances in chemically peculiar stars, the importance of assuming a correct helium abundance has been investigated for determining the effective temperature and gravity of main sequence B-type stars, making full use of the present capability of reproducing their helium lines.

Even if the flux distribution of main sequence B-type stars appears to depend only on the effective temperature for any helium abundance, the effective temperature, gravity and helium abundance have to be determined simultaneously by matching the Balmer line profiles. New MULTI NLTE calculations, performed adopting ATLAS9 model atmospheres and updated helium atomic parameters, reproduce most of the observed equivalent widths of neutral helium lines for main sequence B-type stars and they make us confident of the possibility to correctly derive the helium abundance in chemically peculiar stars.

An application of previous methods to the helium rich star HD 37017 shows that helium could be stratified in the magnetic pole regions, as expected in the framework of the diffusion theory in the presence of mass loss.

## 1. Introduction

Chemically peculiar (CP) stars can present helium lines whose strength is different than in main sequence stars with equal Balmer lines and/or flux distribution. Usually, helium lines are weaker in the coolest CP stars and stronger in the hottest ones. As for other chemical elements, helium is supposed to be under- or overabundant in the photosphere because of diffusion processes. Computations by Vauclair et al. (1991) show that helium should also be stratified in the outer stellar layers.

All methods already known and used to determine stellar effective temperatures and gravities, which are necessary to derive helium abundances, are calibrated assuming a solar chemical composition. Thus, to correctly derive the peculiar helium abundance in CP stars, we have to understand

– the importance of helium abundance in determining the effective temperature and gravity.

A further fundamental step to derive the helium abundance of CP stars is the comprehension of

– the present capability of reproducing the helium lines of main sequence stars.

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## 2. Importance of helium abundance in the determination of $T_{\rm eff}$ and $\log g$

Because of the peculiar metal abundances, the flux distribution of CP stars is different from the flux distribution of main sequence stars with the same Balmer jump (Leckrone et al. 1974) and *ad hoc* methods are necessary to determine the effective temperature of CP stars (Napiwotzki et al. 1993).

As to helium peculiar stars, Hauck & North (1993) concluded that *classical* photometric methods can be reliable to infer their effective temperature. To investigate the possibility that an inhomogeneous helium distribution on the stellar surface could contribute to the observed photometric variability of helium-weak stars, Catalano & Leone (1996) computed the emergent flux for ATLAS9 model atmospheres (Kurucz 1993) with solar helium abundance and without helium. The negligible magnitude difference they found confirms the result of Hauck & North.

To investigate the importance of a correct helium abundance assumption in determining the effective temperature and gravity by matching Balmer lines, Leone & Manfrè (1997) have compared the $H_\beta$ line profile of some helium-weak stars with SYNTHE spectra (Kurucz & Avrett 1981) computed adopting ATLAS9 model atmospheres with different helium abundances. These authors found that several models could match a single observed line profile and concluded that the effective temperature and gravity of helium-weak stars have to be determined simultaneously with the helium abundances. The determination of gravity appears to be very sensitive to the helium abundance, probably because of its contribution to the electron pressure, hence to the Stark effect. As to the case of the helium weak star HD 175362, Leone & Manfrè found that matching the $H_\beta$ line profile assuming a solar-composition atmosphere, the resulting effective temperature is underestimated by 1000 K and the gravity by 0.25 dex.

## 3. Present capability of reproducing helium lines of main sequence B-type stars

Leone & Lanzafame (1998) found that the NLTE calculations which are available in the literature are not reliable in deriving the helium abundance since they are not able to match the observed equivalent width of neutral helium lines of main sequence stars with $10000 < T_{\rm eff} < 30000$ K. These authors performed new MULTI (Carllson 1986) NLTE calculations combining line blanketing ATLAS9 model atmospheres and the latest helium atomic data from the NIST database. The agreement between theory and observations found for most of the neutral helium lines of main sequence stars reinforces our confidence in the possibility to correctly derive the helium abundance in chemically peculiar stars.

## 4. Evidence of possible helium stratification in the photospheres of CP stars: the case of HD 37017

Calculations by Vauclair et al. (1991) show that helium should appear as normal or slightly underabundant at the magnetic equator of the hottest magnetic stars, according to the strength of the horizontal magnetic field. In the presence of mass-loss, helium accumulates at the magnetic poles. Moreover, according to these calculations, helium is stratified in the atmospheres of magnetic CP stars: helium abundance increases with optical depth, reaches a maximum and then decreases. The position of the helium abundance maximum depends on the effective temperature, mass loss and diffusion strength.

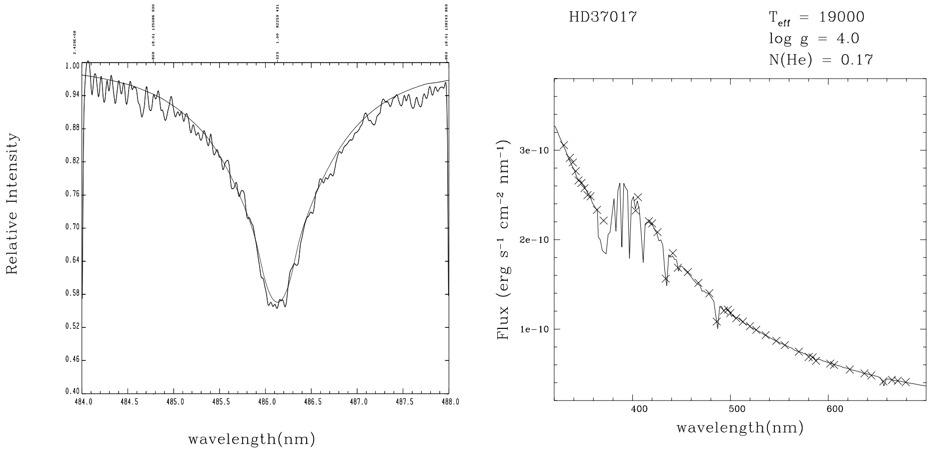


**Figure 1.** The $H_\beta$ line profile and visible flux distribution of HD 37017 are matched assuming $T_{\rm eff} = 19000$ K, $\log g = 4.0$ and $n(He)/n(H) = 0.17$, using an ATLAS9 model atmosphere.

To verify the validity of the results by Vauclair et al. (1991), spectroscopic observations have been carried out of the helium lines (in the range 410 - 710 nm) of the helium-rich star HD 37017 during the phases of minimum and maximum helium line strengths. According to Bohlender et al. (1987), at these phases the line of sight lies in the magnetic equatorial plane and it is close to the negative magnetic pole respectively.

To look for evidence of helium stratification in the atmosphere of HD 37017, the helium lines which are mainly formed in different photospheric layers and which are reliably reproduced for main sequence stars by calculations of Leone & Lanzafame have been selected.

By using the iterative procedure described by Leone & Manfrè (1997), with the difference that helium abundances are derived here by performing NLTE calculations according to Leone & Lanzafame (1998), the effective temperature and gravity of HD 37017 have been determined simultaneously with the helium abundance by matching the $H_\beta$ line profile at the phase of helium line strength minimum (Fig. 1). As expected, the emergent flux of the corresponding ATLAS9 model atmosphere well represents also the flux distribution observed by Adelman & Pyper (1985) (Fig. 1)

When we are looking at the magnetic equator, all helium abundance values almost coincide, while they are derived from lines which are mainly formed in different photospheric layers, as expected for a non-stratified atmosphere. When we are looking at the negative magnetic pole, we obtain abundance values which decrease with optical depth (Fig. 2). This decrement cannot be removed by changing the microturbulence velocity, the effective temperature and/or gravity.

Thus, the results of Vauclair and co-workers appear to be confirmed: helium is more abundant at the magnetic poles than at the magnetic equator, and it is stratified in the outer photospheric layers of the hottest CP stars.

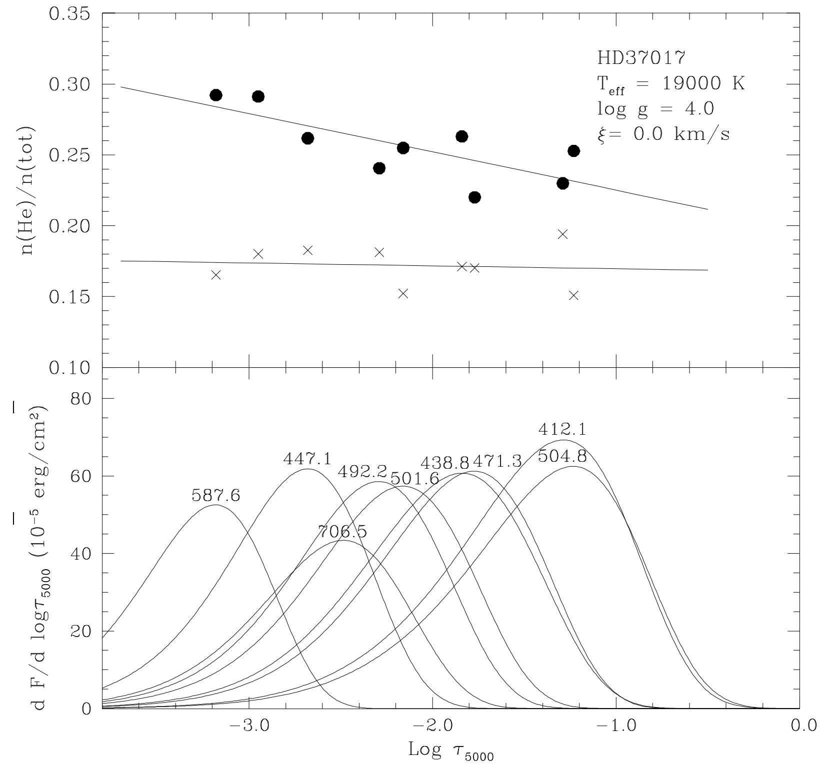


**Figure 2.** In the top panel, abundances are reported as a function of the optical depth for the helium rich star HD 37017. Crosses represents the abundances derived at the phase of minimum strength of helium lines. Dots correspond to the maximum strength. In the bottom panel are shown the source functions for the line cores.

## 5. Conclusion

Since the stellar flux distribution of B-type stars depends only slightly on gravity and helium abundance, it can be used to determine the effective temperature of chemically peculiar stars. Anyway, since the Balmer lines are necessary to infer the gravity and are influenced by helium abundance, the effective temperature, gravity and helium abundance have to be determined simultaneously by matching their profiles.

The NLTE calculations which are available in the literature do not reproduce the observed equivalent width of the neutral helium lines for main sequence B-type stars. Before deriving the helium abundance, the reliability of the method used should be at least tested on main sequence B-type stars before it is applied to chemically peculiar stars.

Using the method described by Leone & Manfrè (1997) to determine the stellar parameters from the Balmer line profiles, and using the NLTE calculations by Leone & Lanzafame (1998) of neutral helium lines, the helium abundance has been derived for the helium-rich star HD 37017 from a sample of lines which are mainly formed in different atmospheric layers. It appears that helium abundance decreases with optical depth in the magnetic pole regions while it remains constant with optical depth in the magnetic equatorial region. This result is consistent with the calculations by Vauclair et al. (1991), which foresee overabundant and stratified helium in the atmospheric regions close to the magnetic poles.

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