## Observations of Magnesium Isotopes

In order to determine the ratios $^{24}Mg/^{25}Mg/^{26}Mg$, it is necessary to have very high quality spectra. These can be obtained at the present time using the ESO 1.42 m telescope (CAT) with the Coudé Echelle Spectrometer (CES) and a reticon silicon photodiode array. With a temperature of the reticon maintained at about 150 K, a quantum efficiency around 40 % is achieved, at the wavelengths of 5140 Å, where a spectral resolution $\triangle\lambda = 0.08$ Å is obtained at a reciprocal dispersion of 2 Å $mm^{-1}$. The required signal-to-noise (above 500) and accuracy in the line profile are reached, as illustrated in Fig. 1.

Selection of lines: magnesium isotopic lines are better distinguished through the magnesium hydride. In the system $A^2\pi - X^2\sum$, the MgH (0,0) band forms a head at 5211 Å and the band degrades to the violet. The isotopic shifts vary from ~ 0.0 at the band head to 0.4 Å around 5000 Å. Besides having a convenient split of lines, it is important to have no blends and relatively strong lines, in order to still observe them in metal-deficient stars. A compromise between these three requirements is met with lines at λλ5134–5137 Å, where the isotopic shifts of 0.06 to 0.1 Å are seen as red asymmetries in each line.

Selection of stars: the MgH lines present a strong dependence on temperature, on gravity, and also on metallicity. In hot stars, most of the MgH molecules dissociate. Consequently, in order to reach metallicities down to $[Fe/H] \simeq -2.0$ (where $[X] = \log X_*/X_\odot$), we have selected cold unevolved halo stars from the catalogue by Carney (1980).

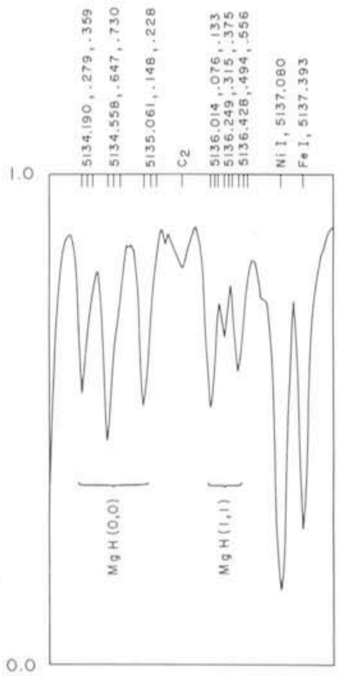


Fig. 1: *Spectrum of HD 175329 (ω Pav), star of visual magnitude V = 5.13, obtained in 2.5 hours exposure time in October 1982. The region contains unblended MgH lines: groups of 3 wavelengths indicate each the* $^{24,25}$ *and* $^{26}$*MgH isotopic components.*

## Method for the Determination of Isotopic Abundances

The spectrum synthesis technique is employed to estimate the magnesium isotope abundances. The MgH line profiles are computed, for each star, with the solar isotopic proportions: $^{24}Mg : ^{25}Mg : ^{26}Mg = 79 : 10 : 11$ and the extreme cases 100 : 0 : 0, 60 : 20 : 20. The input data required for the synthesis are: molecular data, model stellar atmosphere, elemental abundances and Doppler broadening velocity.

## Results

The results obtained so far show a best fit when solar isotopic ratios are assumed. The most metal-deficient star of the sample studied until now does, however, not show a deficiency greater than $[Fe/H] = -1.2$. If more metal-deficient stars show the same result, then we would have an indication for formation of magnesium by hydrostatic carbon burning. In other words, if the present results extend to all metal-deficient stars, then they are not consistent with production of magnesium isotopes through explosive carbon burning, but indicate rather their production under hydrostatic conditions. Such conditions are found in relatively massive stars, according to Arnett and Wefel (1978), and Truran and Iben (1977). The present results are otherwise in agreement with those by Spite and Spite (1980) regarding sodium and aluminium-to-magnesium ratios in halo stars.

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# The Ultraviolet Absorption Spectrum of NGC 4151

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NGC 4151 is one of the first Seyfert galaxies to have been discovered. Indeed it appears in the original list of 12 galaxies published by Seyfert (1) in 1943. It is certainly the most extensively observed of all Seyfert 1 galaxies. As a reminder, Seyfert 1 galaxies are characterized by the presence of an active, non-thermal nucleus, conspicuous both in X-ray and in the optical, and broad permitted emission lines. These nuclei are believed by many to be low luminosity quasars.

NGC 4151 is an Sab galaxy with a galactocentric radial velocity of 978 km/s, corresponding to a distance of about 20 Mpc.

A striking feature of the optical spectrum of NGC 4151 is the presence of non-stellar absorption features (Balmer lines, He I λ 3889) which are blue-shifted with respect to the emission lines and variable in time. The variations of the equivalent width of these emission lines have been interpreted either as real changes in the amount of absorbing matter, or as due to changes of the nuclear continuum brightness variously diluted by the constant stellar component arising in regions adjacent to the Seyfert nucleus (2).

A number of spectra have been obtained with the International Ultraviolet Explorer (3), a satellite launched on 26 January 1978. They cover the spectral range 1150–3250 Å. A number of absorption features of variable equivalent width have been identified (4). It has been claimed that the equivalent width of at least some of these ultraviolet absorption lines,

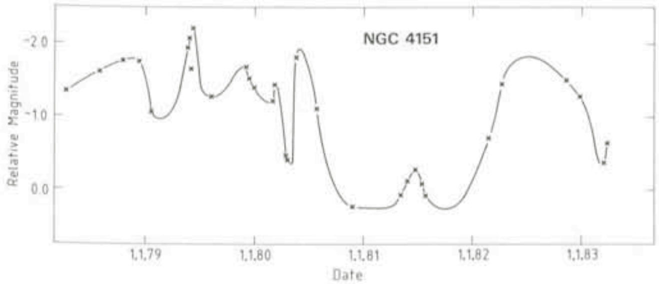


Fig. 1: *Light curve of the nucleus of NGC 4151. The plotted magnitudes are defined as ~ 2.5 × log F where F is the continuum flux measured in the spectral range λλ 1720–1850 in units of $10^{-13}$ erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$.*

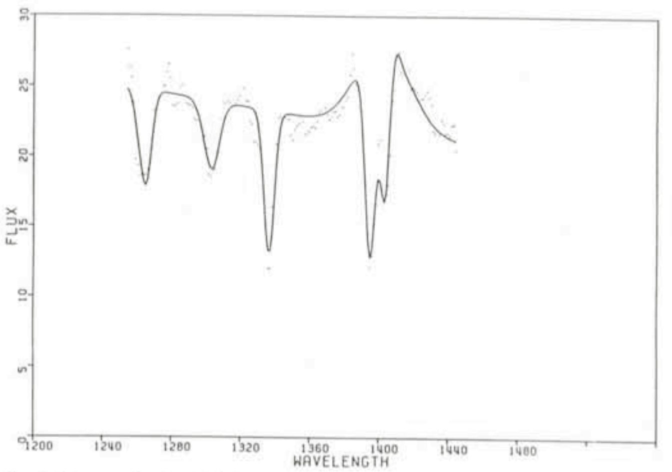


Fig. 3: *Example of a fit in the wavelength range λλ 1255–1445. Average of two spectra obtained on 23 May 1979, when the nucleus was very bright.*

such as for instance NV λ 1240, increases with the continuum flux with no time lag, suggesting that the absorption occurs in the outer parts of the very small broad line region (4) (5); the intensity of the broad emission lines is indeed strongly variable with the continuum flux, with a time lag of ~ 13 days, showing that this emitting region has a diameter of about 60 light days (6).

High dispersion IUE spectra of NGC 4151 show the CIV absorption doublet λλ 1548.20–1550.77, too deep to be explained solely as absorption of the continuum source. This is also true of the Hα absorption line. Some, if not all, of the broad line emission regions must be covered by absorbing Material (4) (7).

We have retrieved from the European Space Agency's Villafranca data base all available low dispersion (resolution ~ 8 Å), large aperture (10 × 20 arcsec), shortwave (1150–1950 Å) spectra, obtained between April 1978 and February 1982. There are 99 such spectra; nine of them could not be used, being affected by microphonic noise. All spectra taken within a few days have been compared and when no significant variation could be seen, averaged together. This resulted in 28 different epochs. The continuum flux has been measured in the spectral range λλ 1720–1850, which is free from any strong spectral features. The light curve is displayed in Fig. 1 (extending to March 1983).

Using this material, we have, independently, made again the analysis of the behaviour of the absorption lines.

The strongest absorption lines are shown in Fig. 2.

To determine the strength of each line, we have fitted the spectrum with Gaussian components (Fig. 3). We have assumed that all absorption lines were unresolved (σ = 3 Å) and have the same redshift. The relative strengths of the components of each multiplet were fixed.

For many of the absorption lines, there is a problem in determining accurately the strength. The unresolved CIV doublet (λλ 1548–1551) is superimposed onto the strong and variable CIV emission; the SiIV doublet (λλ 1394–1403) is blended with the variable SiIV λ 1397, OIV] λ 1402 emission blend; the NV λ 1240 and SiII λ1260 absorption lines are blended with the NV emission and with the red wing of Lyα. The absorption feature at λ 1300 is most probably a blend of SiIII and OI multiplets, so the total strength of this feature can be measured with a reasonable accuracy, but not the relative contribution of each component. The easiest absorption feature to measure is the CII triplet at 1335 Å which appears in a region free of emission lines. Fig. 4 shows a plot of the strength of this absorption feature versus the strength of the continuum. The correlation between these two parameters is strikingly good. The relation is linear, but the absorption line disappears when the continuum still has a finite value

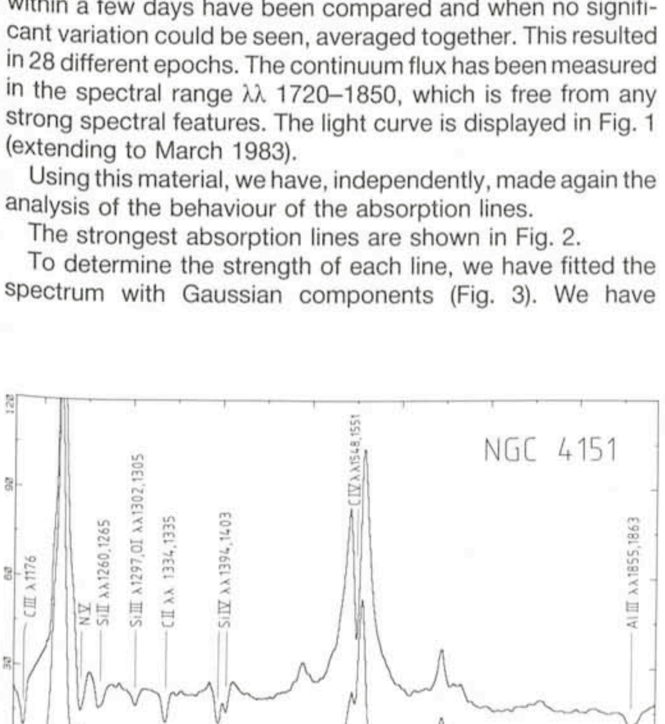


Fig. 2: *Spectra of NGC 4151 in the spectral range λλ 1150–1950. The upper curve is the average of all spectra obtained when the nucleus was in a bright state; the lower curve is the average of all spectra when the nucleus was faint. The strongest absorption lines are identified.*

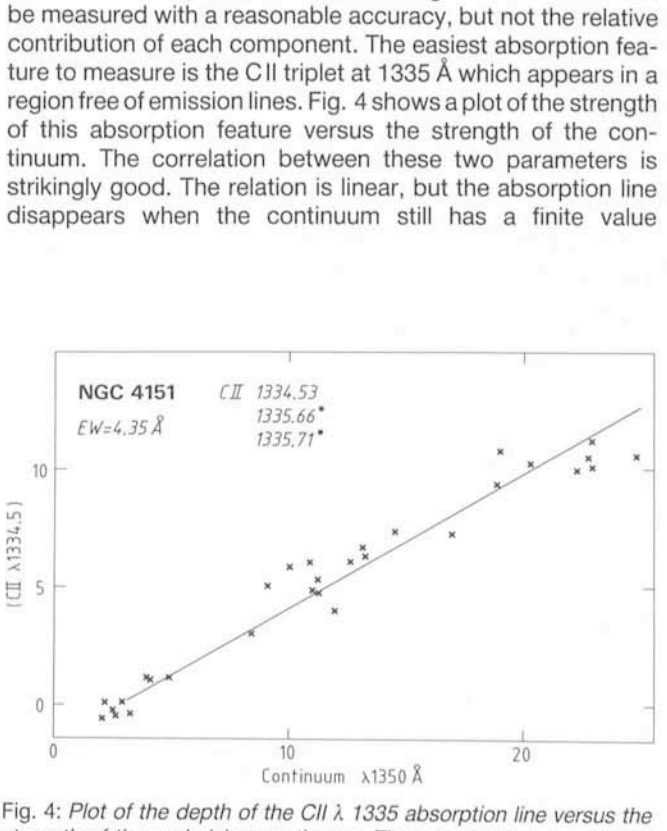


Fig. 4: *Plot of the depth of the CII λ 1335 absorption line versus the strength of the underlying continuum. There is clearly a good linear correlation between these two parameters, but the absorption line vanishes when the continuum has still a finite value which probably shows that the absorbing cloud covers only a fraction of the continuum source.*

(~ $3.0 \times 10^{-14}$ erg $cm^{-2}$ $s^{-1}$ $Å^{-1}$). This suggests that the continuum flux comes from two spatially distinct components: the first ("A") is variable and covered by the absorbing cloud; the second ("B") is constant and not covered by the absorbing cloud. The equivalent width of the C II feature *with respect to component A alone* is constant and equal to 4.3 Å. It has indeed been previously shown (4) that the ultraviolet continuum is made up of two components with different spectra, one dominating at the long, the other at the short wavelengths.

The X-ray spectrum of NGC 4151 shows a low energy absorption turnover corresponding to a very high hydrogen column density (~ $4 \times 10^{22}$ hydrogen atoms $cm^{-2}$) (8); however, the spectral data cannot be reconciled with absorption from a uniform column of cold gas, as the observed spectrum shows a pronounced excess at energies below 2 keV; one suggested possibility is that the low-energy excess is produced farther out from the central source than is the bulk of the X-ray emission (9). It seems possible to identify these two hypothetical X-ray components with the two UV components A and B. In this picture, component B could be a "jet", somewhat similar to the X-ray, optical jet observed in the elliptical galaxy M 87 (10) and may be related to the radio jet (11).

As noted earlier (12), several absorption lines in the spectrum of NGC 4151 arise from metastable states. These include the Balmer lines and He I λ 3899 seen in the optical (13), C III λ 1176 and Si III λ 1297. The C III multiplet is the easiest to measure, being unblended, although it is in a very noisy part of the spectrum. Its equivalent width, with respect to continuum component A, is constant and equal to 2.95 Å. The main populating mechanism for the metastable levels must be collisional, and this probably implies a high density ($N_e \gtrsim 10^{8.5}$) in the absorbing cloud responsible for the C III λ 1176 multiplet (12).

In the optical spectrum of NGC 4151, the CA II K λ 3933 line appears relatively strong, the measured equivalent width being 360 ± 30 mÅ (13) of 130 mÅ (14). The radial velocity is −41 km $s^{-1}$; this absorption line has been attributed to material lying within our galaxy.

A 21-cm spectrum has been obtained by W. Huchtmeier and O. Richter, on January 4, 1984, with the Effelsberg radio telescope, at the position of NGC 4151 (Fig. 5): the total observed galactic column density in this direction is N(HI) ~ $2 \times 10^{20}$ $cm^{-2}$. The galactic HI column density in the direction of the quasar 3C 273 is almost the same: N(HI) = $1.8 \times 10^{20}$ $cm^{-2}$; the equivalent width of the K line is 220 Å and the IUE spectra show a number of galactic absorption lines including OI λ 1302, with an EW in the range 0.5 to 1.1 Å (15). If the OI absorption line observed in the spectrum of NGC 4151 is produced in the dense absorbing cloud associated with the

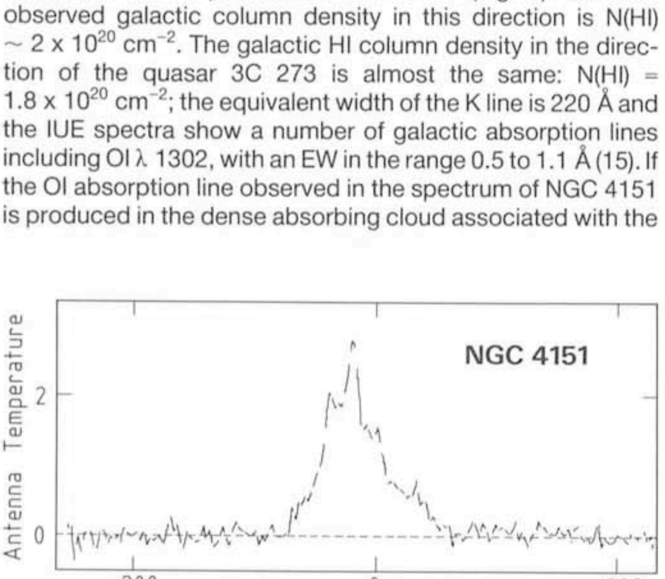


Fig. 5: *21 cm emission profile due to neutral hydrogen in our galaxy in the direction of NGC 4151. The total HI column density is ~ $2 \times 10^{20}$ $cm^{-2}$. The spectrum was obtained by W. Huchtmeier and O. Richter, on 4 January 1984, with the Effelsberg radio telescope.*

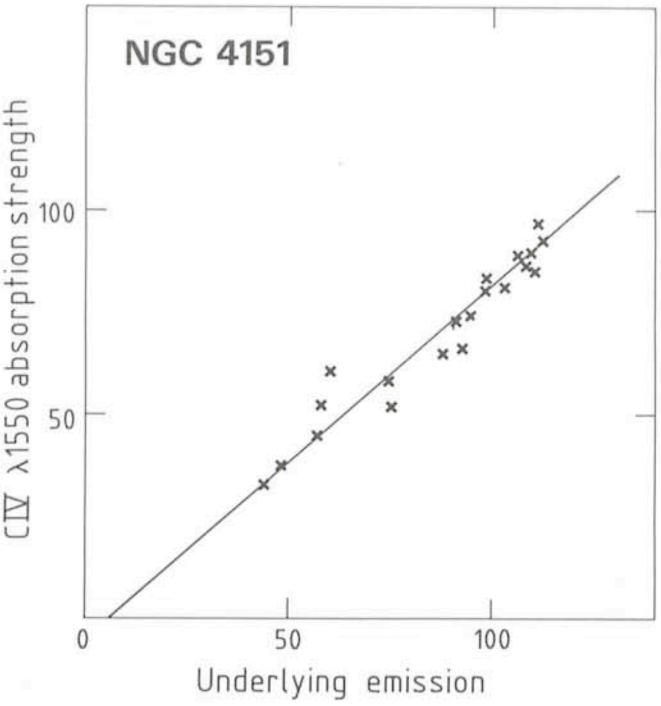


Fig. 6: *Plot of the depth of the CIV λ 1550 absorption doublet versus the strength of the underlying emission. Again there is a good linear correlation, but in this case, it is not possible to say if the line vanishes before this underlying emission.*

nucleus of NGC 4151, the excited fine structure line OI λ 1304.87 is expected to appear with a strength equal to 60 % of that of the OI λ 1302.17; our fits show that this line is certainly much weaker than this; it is most probably at least three times fainter, suggesting that the observed OI line arises in a low density cloud which could be galactic. Its equivalent width is ~ 0.9 Å, close to the value observed in 3C 273; the measurement errors are rather large, due to the blend with the Si III λ 1299 absorption line. The measurements are compatible with a constant EW with respect to the whole continuum intensity, including both components A and B. The observed wavelength of the line is here of no help because the best estimate of the velocity of the absorption lines is −820 ± 100 km $s^{-1}$ relative to the emission lines (12), and the emission line radial velocity of the nucleus is 978 km $s^{-1}$; therefore the radial velocity of the absorption lines is ~ 160 km $s^{-1}$ and the wavelength difference between the two absorption line systems is only 0.5 Å which is too small to be measured with the present resolution which is about 8 Å. Nevertheless, there is some evidence that the OI λ 1302 absorption line is mainly of galactic origin.

The CIV doublet (λλ 1548, 1551) appears in absorption, unresolved, on top of the broad, variable CIV emission line. To measure the strength of this absorption line, we have to model the emission line. As a guide, we first modelled the CIV emission in another variable Seyfert nucleus, NGC 5548, which has the advantage of not showing any absorption feature, making the fit much easier. We found that we could fit the CIV emission at all epochs with a three Gaussian profile model. The first Gaussian component is unresolved ($\sigma$ = 2.8 Å) and has a constant intensity; this is identified with the extended, narrow line region. Component 2 is resolved ($\sigma$ = 11.3 Å) and strongly variable. A third very broad component ($\sigma$ = 25.4 Å) is also needed; the intensity of this component varies much less than that of component 2. The central wavelengths of these three components are different. We were able to satisfactorily fit the CIV emission profile at all epochs by varying only two parameters, namely the intensity of the two broad Gaussian components. We found it reasonable to try a similar model in the case of NGC 4151. In this case, the widths of the two resolved components are $\sigma = 7$ and 15 Å respectively. With this model, we have a good fit for all epochs. Indeed the fit included an unresolved Gaussian component in absorption for which we were able to get the depth at each epoch. We have plotted the depth of the absorption component versus the strength of the underlying component; these two quantities are more or less proportional, but with a rather large scatter; we obtained a much better correlation when plotting the depth of the absorption line versus the total intensity of the emission (continuum plus the two broad emission components) at the wavelength of the absorption line (Fig. 6). The CIV equivalent width is found to be constant and equal to 7.5 Å.

It has been claimed (12) that the equivalent width of NV $\lambda$ 1240 strongly correlates with the continuum flux at 2500 Å. However, this line appears on the blue wing of the NV emission line and on the red wing of the very strong Ly$\alpha$ emission line. Therefore, the measurement of its strength strongly depends on the modelling of the Ly$\alpha$ emission and we have found it impossible to get measurements with a useful accuracy. Therefore we are not able to confirm the result quoted above and we strongly suspect it.

All the available data are compatible with the following conclusions.

- All observed absorption lines in the UV spectrum of NGC 4151 are produced in one or several (as suggested by the splitting of the He I $\lambda$ 3889 absorption line into three components, Anderson 1974); with the probable exception of OI $\lambda$ 1302 which may be mainly of galactic origin;
- these clouds have a high density ($N_e > 10^{8.5}$ cm$^{-3}$) as shown by the presence of several absorption lines from metastable levels (C III, Si III, He I);
- the continuum source is double with one constant component and one variable;
- the absorbing clouds cover the variable continuum source and the broad emission line region;
- taking into account the fact that the non-variable continuum source is not covered by the absorbing cloud, the equivalent width of all the absorption lines is constant.

## Acknowledgements

It is a pleasure to thank W. Huchtmeier and O. Richter for obtaining the 21 cm spectrum in the direction of NGC 4151. We are grateful to E. Zuiderwijk for putting at our disposal his line-fitting computer programme.

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# The Nature of Subdwarf B Stars

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## Introduction

Subdwarf B stars from the blue end of the horizontal branch. They occur both in the field and in globular clusters. A large fraction of the field sdB's (as well as sdO stars) has been found accidentally, during a search for faint blue objects (quasars) at high galactic latitudes, whereas the cluster sdB's are the result of a systematic search. The total number of subdwarf B stars presently known is estimated to roughly 70. It is anticipated that the true number is much larger.

Subdwarf B stars have colours and hence temperatures which are typical for B stars, but which, in some cases, even reach up to 40,000 K and beyond. The latter are more precisely defined as sdOB stars. At the temperatures in question, the neutral helium line $\lambda$ 4471 should be prominent in the spectrum of subdwarf B stars. However, in most sdB's this line is barely seen at moderate resolution, or even absent (Fig. 1). The main features are the strong and Stark broadened Balmer absorption lines, besides which hardly any other line can be traced. Most sdOB stars (e.g. Feige 110, Fig. 1) show He II, $\lambda$ 4686 Å, but the weakness of helium lines distinguishes subdwarf B and OB stars from the hot subdwarf O stars (Fig. 1). The latter are known to be helium rich (Hunger and Kudritzki, 1981). Do we then have to conclude that subdwarf B (and OB) stars are deficient in helium—a conclusion that obviously would be in conflict with the idea of horizontal branch stars as being evolved stars? Or is the definition of subdwarf B stars as horizontal branch stars to be questioned? For the discussion of the evolutionary status, a necessary prerequisite is the precise knowledge of the fundamental stellar (atmospheric) parameters like effective temperature, gravity and hydrogen-to-helium content.

## Spectral Analysis

Spectral analysis yields the wanted parameters. The best way to determine the effective temperature of a given star is by studying profiles and equivalent widths of an element that is observed in 2 stages of ionization. Only if one has the properly chosen model atmosphere which is defined by $T_{eff}$, besides g