From Lithium to Uranium: Elemental Tracers of Early Cosmic Evolution
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Spectroscopic analysis of chemically peculiar stars: abundance determination of lithium and some rare earth elements

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Abstract. We present the results of a study of some selected spectral regions, including those around the Li I lines at 6708 Å and 6104 Å in the magnetic chemically peculiar star HD 3980 and in a few other Ap stars with different effective temperatures and different strengths of the magnetic field. High resolution spectroscopic observations were carried out with the Coudé echelle spectrograph at the 74-inch telescope of the Mount Stromlo Observatory ($R = 88\,000$) and with the VLT UV-Visual Echelle Spectrograph UVES at UT2 at ESO ($R = 110\,000$). Using spectral synthesis we determined abundances of Li, Ce, Pr, Nd and some other rare earth elements and showed that the spectral feature at 6708 Å in the spectrum of HD 3980 is due to the Li I doublet with only a minor contribution of the Ce II line at 6708.099 Å.

Keywords. Stars: abundances, stars: chemically peculiar, stars: individual (HD 3980), stars: magnetic fields

1. Introduction

The lithium problem in chemically peculiar (CP) stars and particularly the identification of the Li I resonance doublet has been the matter of debate during several decades. This is because of the presence of several lines of rare-earth elements in the same spectral region. Furthermore, in many Ap and low-mass post-AGB stars the Li I doublet was found to be shifted redwards by about 0.2 Å compared to the expected position based on other photospheric lines rising the problem of the "shifted Li line".

The creation of the D.R.E.A.M. database (Database on Rare-Earths at Mons University, `http://w3.umh.ac.be/~astro.dream.shtml`) permitted Reyniers *et al.* (2002) to identify the absorption feature at 6708.1 Å in the spectra of post-AGB stars as the Ce II line at 6708.099 Å. This result brought new doubts regarding the presence of the Li I line in the spectra of Ap stars. Nesvacil, Hubrig & Mathys (2004) analyzed the spectra of five Ap stars with different magnetic field strengths and pointed out that the Ce II line might be responsible for the absorption feature at ∼6708 Å in Ap stars.

Using a large sample of high resolution spectra of Ap stars, we carried out a thorough analysis of the spectral regions around both lithium lines, the resonance Li I doublet

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at 6708 Å and the secondary Li I line at 6104 Å. Special attention was given to the identification of blending lines, especially of rare-earth elements.

Table 1. Abundances of lithium and rare-earth elements in HD 3980

Element	$\log \varepsilon(\mathrm{A})^*$	Element	$\log \varepsilon(\mathrm{A})$
Li	−7.9	Nd	−8.5
Ce	−8.5	Sm	< -8.6
Pr	−7.9	Yb	< -8.0

$^*\log \varepsilon(\mathrm{A}) = \log(N_\mathrm{A}/N_\mathrm{tot})$

2. Results and Conclusions

High resolution high signal-to-noise spectra were acquired with the Coudé echelle spectrograph at the 74-inch telescope of the Mount Stromlo Observatory ($R = 88\,000$) and with the VLT UV-Visual Echelle Spectrograph UVES at UT2, ESO, ($R = 110\,000$).

Using the databases VALD (Kupka *et al.* 1999) and D.R.E.A.M. and also data from the literature (weak Nd II and Sm II lines were added from Shavrina *et al.* 2003), we created the most complete as possible line lists in the Li I 6708 Å and 6104 Å regions. Synthetic spectra calculations were carried out using atmosphere models taken from Kurucz (1993). Stellar parameters for HD 3980 were determined by Drake *et al.* (2004). A number of unblended spectral lines of each element in different spectral regions have been selected for an abundance analysis. Derived abundances are quoted in Table 1. The relative contributions of Ce, Nd, and Sm (for this last one an upper limit of the abundance was adopted) to the absorption feature at 6708 Å in the spectrum of HD 3980 are shown in Figure 1. From this figure it is clear that Li is by far the main contributor to this spectral feature in HD 3980.

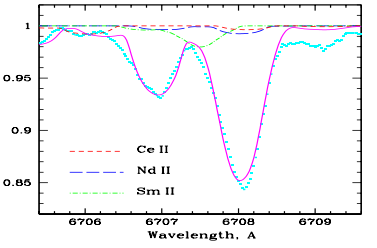

Figure 1. HD 3980. Contribution of cerium, neodymium and samarium to the Li I doublet at 6708 Å. Dots - observed UVES spectrum at the rotation phase $\phi = 0.514$, solid line - resulting synthetic spectrum. The spectra were calculated with the abundances given in Table 1 using the terrestial value of $^6\mathrm{Li}/^7\mathrm{Li} = 0.081$.

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