Eu III identification and Eu abundance in cool CP stars

T. Ryabchikova[1], **N. Piskunov**[2], **I. Savanov**[3] **and F. Kupka**[4]

[1] *Institute of Astronomy, RAS, Moscow, Russia*

[2] *Uppsala Astronomical Observatory, Uppsala, Sweden*

[3] *Crimean Astrophysical Observatory, Nauchny, Crimea, Ukraine*

[4] *Institute for Astronomy, University of Vienna, Vienna, Austria*

Abstract. We report the first identification of the Eu III λ 6666.317 line in optical spectra of CP stars. This line is clearly present in the spectra of HR 4816, 73 Dra, HR 7575, and β CrB, while it is marginally present or absent in spectra of the roAp stars α Cir, γ Equ, BI Mic, 33 Lib, and HD 24712.

Key words: Stars: atmospheres – Stars: line identification – Stars: abundances

1. Introduction

Magnetic Chemically Peculiar stars (CP2 stars) are known to have large overabundances of rare-earth elements (REE) in their atmospheres. Among all REE, europium shows the most prominent overabundances of up to +5.0 dex, in many CP2 stars violating the odd-even pattern observed in the solar atmosphere. In the atmospheres of many CP2 stars the dominant europium ion is Eu III. The strongest lines of Eu III are located in the UV region. A few relatively intense lines are observed in the optical spectral region (Sugar & Spector 1974). This fact justified a careful study of a few CP2 stars in the spectral region 6620-6680 Å, where unblended lines of both Eu II λ 6645.05 and the strongest optical Eu III λ 6666.35 are located.

2. Observations and line analysis

A list of the programme stars is given in Table 1. CCD spectra of five stars: HR 4816, 73 Dra, HR 7575, β CrB, and GZ Lib (33 Lib) were obtained at the Crimean Astrophysical Observatory. For all spectra the S/N ratio is at least 200 and the resolving power is 35000. For the remaining stars we used spectra from our previous abundance study of roAp stars. The spectrum of the star HD 24712 (DQ Eri) was obtained at the Nordic observatory and kindly provided to us by V. Malanushenko. In Table 1 a horizontal line separates a group of roAp stars (lower part) from the non-oscillating CP2 stars (upper part).

Contrib. Astron. Obs. Skalnaté Pleso **27**, (1998), 359– 361.

Table 1. The list of the programme stars. Effective temperatures, surface gravities, surface magnetic fields, and rotational velocities are given.

Star name	$T_{\rm eff}$	$B_{\rm s}$ (kG)	$v \cdot \sin i$ ($\rm km\,s^{-1}$)	log(N/H) Cr	Fe	Eu	log(gf) Eu III
HR 4816	9000	3.6	9	-3.56	-3.51	-8.36	1.15
73 Dra	8900	2.0	9	-3.56	-3.56	-8.53	1.25
HR 7575	8500	3.6	2	-4.21	-3.98	-7.66	1.00
β CrB	8000	5.7	3.5	-4.46	-3.96	-8.36	1.10
α Cir	7900	2.0	12.5	-5.31	-4.46	-9.66	0.95
γ Equ	7700	4.0	0	-5.31	-4.31	-9.86	1.07
BI Mic	7450	0	12.5	-5.51	-4.46	-9.96	1.25
GZ Lib	7350	4.5	$\leq$8	-4.86	-4.26	-8.81	1.07
DO Eri	7250	3.0	5.6	-5.76	-4.96	-9.36	...

The Vienna Atomic Line Database (VALD, Piskunov et al. 1995) was extensively used for line identifications, based on preliminary abundances extracted for the program stars from the literature. VALD does not contain any information on the second ions of the REE. A list of the Eu III lines classified by Sugar & Spector (1974) was used by us. The strongest optical line Eu III λ 6666.347 ($^6\mathrm{I}^0_{17/2} - ^6\mathrm{H}_{15/2}$) is very strong in non-roAp stars, and there are no other candidates for the identification of the observed feature. This line is noticeable in roAp stars, too, but it is very weak, and partially blended from both sides with unidentified lines. Figure 1 shows spectra of the programme stars where the positions of the Eu II (λ 6645.05) and Eu III lines have been marked.

To synthesize Eu lines properly one needs to know the full hyperfine splitting for all isotopes. For the Eu II λ 6645.05 line hfs data were taken from Biehl (1976). For Eu III lines hyperfine splitting is unknown, therefore we neglect this effect in our study. Synthetic spectrum calculations which took into account the presence of a magnetic field, full Zeeman patterns for all synthesized lines and nine hyperfine components for the Eu II line were carried out with the help of the new code SYNTHMAG. Besides Eu II and Eu III lines we also synthesized lines of Cr I and Fe I to derive chromium and iron abundances. The adopted effective temperatures and magnetic field strengths are given in Table 1. The synthetic spectra which give the best fit to the observations are shown in Fig. 1 by thick lines. Observations are shown by thin lines.

3. Results

The results on the Cr, Fe and Eu abundances in the atmospheres of the programme stars are presented in Table 1. One immediately sees that non-roAp CP2 stars are more chemically peculiar then their roAp counterparts. It is the

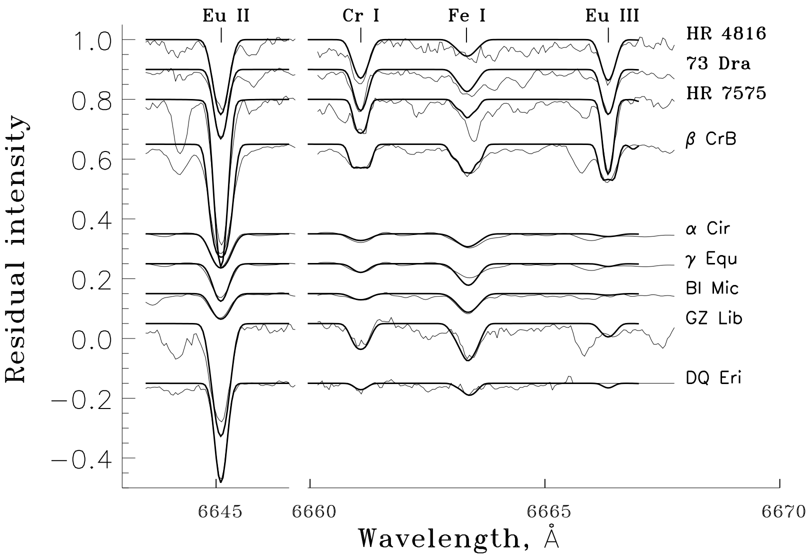

Figure 1. A comparison between the observations and synthesized lines of Eu II, Eu III, Cr I, and Fe I.

main conclusion of the present paper, which still needs confirmation based on the observations of a larger sample of stars of both groups.

Assuming an ionization balance in the stellar atmospheres we estimated the astrophysical oscillator strength of the Eu III λ 6666.347 line. The mean value obtained from individual estimations given in the last column of Table 1 results in log(gf)=1.10 $\pm$ 0.10. It gives us an upper limit for the oscillator strength because we did not take hfs for this line into account.

Acknowledgements. International cooperation was supported by the Fonds zur Förderung der Wissenschaftlichen Forschung (project S7303-AMS) and by the Russian Federal program "Astronomy" (grant 2.2.1.5).

References

Biehl, D.: 1976, Ph.D. thesis, Christian-Albrechts-Universität, Institut für Physik und Sternwarte, pp. 187

Piskunov, N.E., Kupka, F., Ryabchikova, T.A., Weiss, W.W., Jeffrey, C.S. 1995, *Astron. Astrophys., Suppl. Ser.*, **112**, 525

Sugar, J., Spector, N.: 1974, *JOSA*, **64**, 1484