Chemical Abundances in the Universe: Connecting First Stars to Planets
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s/r ratios in carbon-enhanced metal-poor stars

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Abstract. We present the results of [Ba/Eu] ratio determinations for a sample of Carbon-Enhanced Metal Poor (CEMP) stars, comparing them with other CEMP stars found in the literature for which abundances for both elements are available. The stellar spectra were observed at 4.2m William Herschel Telescope (WHT) on July/2003, using Utrecht Echelle Spectrograph (UES) with R $\sim$ 52000 and S/N $\sim$ 40. WHT covers a wavelength range of $\lambda\lambda$3700-5700.

Keywords. stars: abundances, stars: carbon, stars: chemically peculiar

1. Introduction

Most of CEMP stars have Ba abundance available, whereas only a few of them have Eu abundance published and, some of them, only an upper limit. The lack of accurate abundances for a more pure *r*-element such as Eu has made the abundance pattern of many stars unclear, since the ratio of the two elements are necessary to correctly classify them. As an example, some stars classified as CEMP-*s* through Ba abundance were only found to be CEMP-*r/s* after the determination of Eu abundance by Tsangarides (2005). CEMP stars with [Ba/Fe] $<$ 0 could be CEMP-*no* or CEMP-*r* and those with [Ba/Fe] $>$ 1 could be CEMP-*s* or CEMP-*r/s*, depending on the Eu abundance.

2. Atmospheric parameters and abundances

Since there are no available Hipparcos paralaxes for the stars of the sample, the first guess for the absolute magnitude (M_v) of each star was taken from Color Magnitude Diagram ((B-V) *vs.* M_v) given by Lejeune *et al.* (1998) and Green *et al.* (1987). This M_v was used to estimate the distance, that altogether with galactic coordinates was used to calculate the visual extinction A_v, following Hakkila *et al.* (1997). Then, the temperatures were calculated from photometric data available in the literature (or provided by Tim Beers in private communication), by using color-temperature calibrations by Alonso *et al.* (1998), and the average of several photometric temperatures was the first input for the iterative process to determine a consistent set of parameters.

Elemental abundances were derived through spectrum synthesis, using the code SYNTHE created by R. Kurucz. The synthesis of molecular lines of CH at $\lambda\lambda$4295-4315 provided the abundance of carbon, whereas for Eu and Ba, atomic lines were used to perform the abundances.

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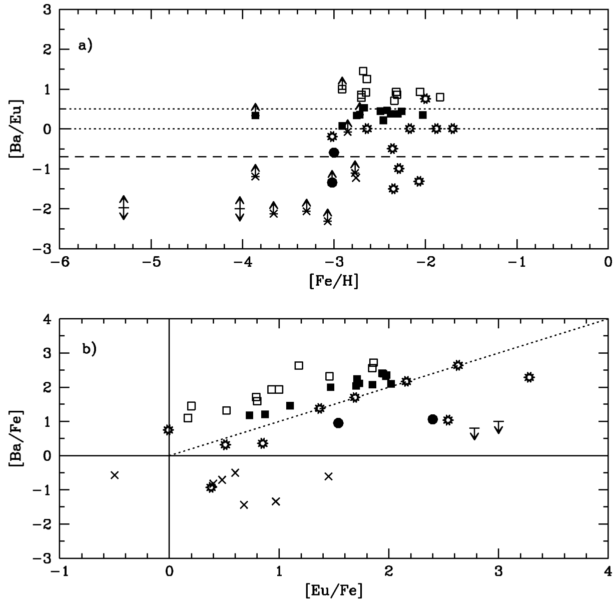

Figure 1. Abundance ratios for CEMP stars from the literature and 10 stars from this work. In panel a), dotted lines represent the region of CEMP-r/s and the dashed line is the limit for r-process only. The dotted line in panel b) represents [Ba/Fe] = [Eu/Fe]. Symbols: starred circles: this work; filled squares: 0 < [Ba/Eu] < 0.5 (CEMP-r/s); open squares: [Ba/Eu] > 0.5 (CEMP-s); crosses: [Ba/Fe] < 0 (CEMP-*no*); filled circles: [Ba/Eu] < 0 (r); dashes: upper limit for both, Ba and Eu.

3. Results

The panel a) of Fig. 1 shows that one star of our sample might be CEMP-s. Although its Ba abundance is not so high ([Ba/Fe] = 0.75), the low Eu abundance ([Eu/Fe] = -0.01) increases the ratio [Ba/Eu]. This star is close to the line [Eu/Fe] $\sim$ 0 in panel b). Four stars are in the lower limit of the range 0 < [Ba/Eu] < 0.5, the CEMP-r/s zone represented by the dotted lines in panel a). These stars are in the dotted line in panel b), since their [Ba/Fe] $\approx$ [Eu/Fe]. The other five stars have [Ba/Eu] < 0, the region of CEMP-*no* and CEMP-r, where three of them are below the dashed line in panel a), which represents the production of Ba only through the r-process, [Ba/Eu] $\sim$ -0.7. Two stars with [Ba/Eu] < -0.7 have [Eu/Fe] higher than the ones from the literature called CEMP-r (filled circles), whereas the third could be called CEMP-*no*, since its [Ba/Fe] < 0. Two stars with [Ba/Fe] $\sim$ 0.3 might be CEMP-r since [Ba/Eu] < 0 for them. The very high [Eu/Fe] of four stars deserves further investigation in order to confirm the classification inferred here.

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