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Barium Abundances of 20 Metal Deficient Stars[1]

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Abstract. We present high resolution, high signal–to–noise spectra for a sample of 20 metal deficient dwarfs and subgiants. Barium abundances are deduced from two Ba II lines λλ5853 Å and 6496 Å. The results show [Ba/Fe] values 0.25 dex higher than solar for [Fe/H] > −1.8. Then [Ba/Fe] goes down with the metallicity, decreasing to very low values for [Fe/H] < -1.8. We compare our results with some previous investigations. The general trends of [Ba/Fe] are the same.

1. Introduction

The determination of the heavy elements abundances in the metal-poor stars allows to investigate the chemical evolution of the early Galaxy. The predominance of r-process signatures in population II stars had been suggested by Truran (1981) and discussed recently by Mathews et al. (1992), but the situation remains largely unclear.

2. Observations and Reductions

The analysis is based on high resolution, high S/N spectra obtained with the Coudé Echelle Spectrometer (CES) fed by the 1.4 m Coudé Auxiliary Telescope (CAT) at the European Southern Observatory (La Silla, Chile). The short camera was used with a CCD detector (RCA SID 503, 1024 × 640 pixels of 15 × 15 μm each). The slit width was set to 2 arc seconds, corresponding to a resolving power of the order of 55000. The exposure times were chosen in order to reach a signal–to–noise ratio above 200 in all spectral regions. They were selected in order to obtain a good metallicity coverage below [Fe/H] ∼ -0.5. The spectra were collected during five observing runs, from August 1987 to July

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1992. They cover a range of 40 to 50 Å around the following central wavelengths: 4900, 5197, 5254, 5860 and 6485 Å.

The data reduction was carried out with the help of the MIDAS software running on a Sun SPARC 2 workstation at Beijing Astronomical Observatory, China. The procedures of data reduction are the same as described in a previous paper (Zhao & Magain 1991). However, a non-linearity present in the data was corrected by using an empirical formula (Gosset & Magain 1993).

3. Analysis and Results

The line analysis is based on Gustafsson et al. (1975)'s model atmosphere. We adopt the same method of analysis as in most recent investigations, the abundance being deduced from each line by forcing the computed EW to agree with the observed one. The theoretical EW is computed by integration of the line profile, the latter being determined by solving the transfer equation in a model atmosphere, under the assumption of local thermodynamic equilibrium (LTE).

The atmospheric parameters of these program stars have been determined in the following way. Effective temperatures were derived from $b - y$ and $V - K$ color indices by using the calibration of Magain (1987). Surface gravities were determined by forcing the Fe II lines to indicate the same abundance as the high excitation Fe I lines. Metallicities were derived from Strömgren m_1 indices.

The barium abundance is determined from two Ba II low excitation lines, $\lambda\lambda$5853.68 Å and 6496.91 Å, with oscillator strengths from Wiese and Martin (1980), and a damping enhancement factor $f_6 = 1.0$ (Magain & Zhao 1994). The effect of hyperfine structure (HFS) is negligible in the case of the λ5853 Å line (see Holweger & Müller 1974). We took the HFS of the λ6496 Å line into account according Biehl (1976). The Ba II resonance line at 4554.03 Å shows a strong HFS effect and is not used since we poorly know the barium isotopes contribution which have to be considered for this line.

The iron abundance [Fe/H] is determined on the basis of weak Fe I lines. Following the results presented by Magain and Zhao (1994). we use only lines with an excitation potential above 3.5 eV. The oscillator strengths are deduced from the solar lines, measured on the Liège atlas (Delbouille et al. 1973). The Holweger–Müller model (Holweger & Müller 1974) is used in the solar analysis. A damping enhancement factor $f_6 = 1.4$ is adopted.

The barium abundances relative to iron were obtained by comparing Ba II to Fe II lines. The Fe II oscillator strengths are deduced from the solar spectrum, using the same technique as for the Fe I lines, but with a damping enhancement factor $f_6 = 1.2$ (Magain & Zhao 1994). The mean value and scatter of [Ba/Fe] in the range $-0.5 > \mathrm{[Fe/H]} > -1.8$ amount to:

$$\mathrm{[Ba/Fe]} = 0.25 \pm 0.21 \text{ (15 stars)}$$

Note that the scatter mentioned is not the standard deviation of the mean but the star-to-star scatter.

Several investigations of the barium abundance in metal–poor stars have appeared in the literature. The present results are compared to those of Gratton & Sneden (1994), and of Gilroy et al. (1988). The general trends of [Ba/Fe] agree quite well. The mean value of [Ba/Fe] from Gratton and Sneden is lower than our results by 0.32 dex.

4. Concluding remarks

Our work has confirmed that barium abundances relative to iron in metal deficient stars have a constant value for $[Fe/H] > -1.8$, then go down with decreasing metallicity. One may notice that barium abundances deduced from two ionic lines, 5853 Å and 6496 Å, disagree obviously. This difference is about two times larger than for other heavy elements, such as Y and Zr, and far exceeds the estimated errors in our analysis. More work is required to solve this problem, including very high resolution spectra which would be needed to determine the isotopic mix of barium (Magain & Zhao 1993).

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