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Y, Ba, and La abundance in the stars of open clusters and Galactic field

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Abstract. The lanthanum abundances were determined by the synthetic spectrum method using the VLT spectra of 30 stars of eight open clusters, namely Ruprecht 4, Ruprecht 7, Berkeley 25, Berkeley 73, Berkeley 75 and NGC 6192, NGC 6404, NGC 6583. The analyses of the behaviour of the yttrium, barium, and lanthanum abundances with ages in the stars of the open clusters and galactic field were carried out. We found that the scatter of the barium abundances is larger than those of the yttrium and lanthanum. The resulting scatter can be caused by both real causes and methods of abundance determinations (using the equivalent widths of the lines, LTE approach, etc.). The traced trends of Y, Ba, La abundances with the age can indicate the growth of contribution in the n-capture enrichments from low-mass AGB stars. Comparison of the barium and lanthanum abundances with ages for a thin disc stars (Mishenina et al. 2013a) and those obtained by us for the open cluster stars, shows that the lanthanum as well as barium demonstrates large values for several clusters, but its value is only reaches 0.3 dex. The barium overabundance in the cluster Ruprecht 7 may be indicative of other ways (not AGB stars) barium enrichment.

Key words. Stars: abundances – Stars: late-type – Galaxy: disc – Galaxy: evolution

1. Introduction

The abundances of n-capture elements (at near solar metallicity) define the role of the AGB stars, which are the main sources of these elements according to the modern concepts (e.g. Travaglio et al. 1999) in the enrichment processes of the interstellar medium. However, the behavior of barium abundance differs from that of other elements produced in the n-capture process. The stars of several open clusters and field show the barium overabundance of 0.6 dex. It is important to clarify:

1) reliable determination of barium (based on the NLTE approximation, etc);
2) existence of the dependence of Y, Ba, and La abundances from the age in the galactic disk;
3) comparison of La and Ba abundances, since these elements produced in similar (the same) processes in AGB stars;
4) the origin of the open clusters.

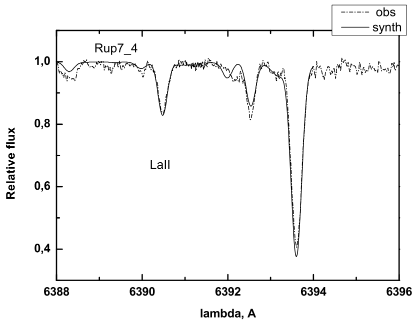

Fig. 1. The fitting of synthetic and observed spectra in the region of the La line 6320.4 Å.

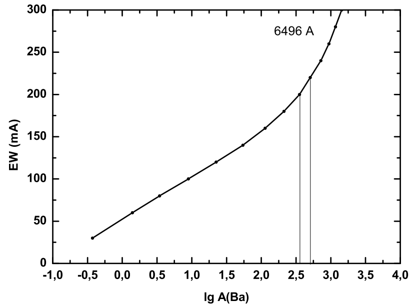

Fig. 2. The curve of growth for 6496 Å barium line.

2. Observations and estimation of precision of the Ba abundance determination

The spectra for eight open clusters: Rup4, Rup7, Be25, Be73, Be75, NGC 6192, NGC 6404, NGC 6583 were obtained with the high-resolution echelle spectrograph UVES mounted on the VLT with resolving power R = 40 000 for the wavelengths range 4750–6800 Å. We used the atmospheric parameters from Carraro et al. (2007) and Magrini et al. (2010). To estimate abundances we used the models by Castelli & Kurucz (2004), computed for the atmospheric parameters of each star. The yttrium and lanthanum abundance were determined with the LTE STARSP software package (Tsymbal 1996). The VALD atomic data were used for the lines Y II 4854.8, 4883.7 Å, and 5087.4 Å and La II 5303.5, 6320.4, and

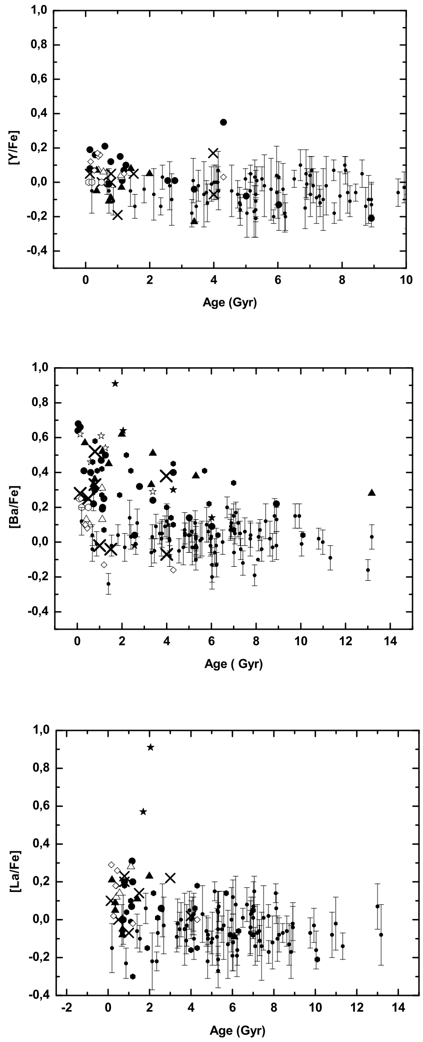

Fig. 3. The dependence of [Y/Fe], [Ba/Fe] and [La/Fe] on Age. Y abundances by Maiorca et al. (2011) and Ba abundances by D' Orazi et al. (2009) – marked as black circles; by Pancino et al. (2010) and Carrera & Pancino (2011) – marked as black triangles; by D' Orazi et al. (2012) – marked as open diamonds; by Reddy, Giridhar & Lambert (2012) – marked as open triangles; Ba abundances by Bragaglia et al. (2008) – as open asterisks and by Yong et al. (2005) as asterisks; by Mishenina et al. (2013a) – the thin disc (marked as black dots with error bars); by **?** Reddy et al. (2013) open rhombuses; by Jacobson, Friel (2013) Jacobson & Friel (2013) – black diamonds; the present study – marked as crosses circles.

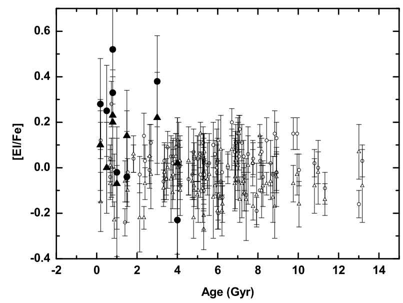

Fig. 4. The dependences of [La/Fe] (open triangles) and [Ba/Fe] (open circles) vs. Age for the thick disc stars (Mishenina et al. 2013a) and for our open cluster stars determinations (full symbols).

6390.5 Å. The fitting of synthetic and observed spectra in the region of the La II line 6320.4 Å is show at Fig.1. The barium abundance was calculated in the NLTE approximation with a version of MULTI (Carlsson 1986), modified by Korotin et al. (2011) for the lines of Ba II 5853, 6141 and 6496 Å. NLTE correction is around 0.1 dex. The problem of the reliable Ba determination associated with the saturation of the barium lines, since their equivalent widths are rather large. Fig.2 shows the curve of growth for 6496 Å barium line. As we can see from this Figure and from the fitting of the observed profile of the barium line (Mishenina et al. 2013b), the estimation of the accuracy of the Ba abundance determination is ±0.1 dex.

3. Results

To clarify the dependence of Y, Ba, and La abundances from the age in the galactic disc we compared the values of the yttrium [Y/Fe] and barium [Ba/Fe] abundances obtained earlier (Mishenina et al. 2013b) and the lanthanum [La/Fe] with estimates from other authors, for a number of open clusters (D' Orazi et al. 2009; Pancino et al. 2010; Carrera & Pancino 2011; Maiorca et al. 2011; D' Orazi et al. 2012; Reddy, Giridhar & Lambert 2012; Bragaglia et al. 2008; Yong et al. 2005) and the data for the thin disc stars were taken from the study by Mishenina et al. (2013a). We can see the trend for these elements with ages, but there is a large spread of barium abundances at the ages of 0–4 Gyr. The low AGB stars with M<1.5 Msol (e.g. Busso et al. 1999) can produce the increasing of Y, Ba, La abundance for young stars (up to 0.2 dex), but it is not enough for the barium overabundance of 0.5–0.6 dex!

As Ba and La have the same origin, we plot (see Fig.4) the dependences of [La/Fe] (open triangles) and [Ba/Fe] (open circles) vs. Age for the thick disc stars (Mishenina et al. 2013a) and our open cluster stars determinations (full circles). We have also found that the Ba abundance is higher than the La abundance and this Ba excess is not due to production in low AGB stars.

We note that Rup 7, besides showing a net overabundance, also possesses an abnormal orbit according to the calculations by Vande Putte et al. (2010), Gozha, Borkova & Marsakov (2012). Unfortunately, the accuracy in the orbit determination (large proper motion errors for distant clusters, and the adopted fixed Galactic potential) does not allow us to further explore the possible consequences of this result.

4. Conclusions

– We have determined yttrium, barium and lanthanum abundances for 30 stars in the eight open clusters, namely Ruprecht 4, Ruprecht 7, Berkeley 25, Berkeley 73, Berkeley 75, and NGC 6192, NGC 6404, NGC 6583 using the UVES, VLT spectra.
– We found that the scatter of the barium abundances is larger than those for the yttrium and lanthanum. The resulting scatter can be caused by both real causes and methods of abundance determination (the equivalent widths of the lines, LTE approach, etc.).
– The traced trends of Y, Ba, La abundances with the age can indicate the growth of contribution in the n-capture enrichments from the low mass AGB stars (Busso et al. 1999).
– Comparison of the barium and lanthanum abundances with ages for the thin disc stars (Mishenina et al. 2013a) and those obtained by us for the open cluster stars shows that the lanthanum demonstrates large values for

several clusters, but its value is only reaches 0.3 dex (the values of Ba are up to 0.6 dex!).
- The barium overabundance in the cluster Rup 7 can indicate the other ways of barium enrichment (not AGB stars).

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