Chemical Abundances in the Universe: Connecting First Stars to Planets
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Elemental abundances in the Galactic bulge from microlensed dwarf stars

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Abstract. We present elemental abundances of 13 microlensed dwarf and subgiant stars in the Galactic bulge, which constitute the largest sample to date. We show that these stars span the full range of metallicity from Fe/H = −0.8 to +0.4, and that they follow well-defined abundance trends, coincident with those of the Galactic thick disc.

Keywords. Galaxy: bulge, Galaxy: abundances, Galaxy: disk, Galaxy: evolution

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The formation and evolution of bulges are an integral and central aspect of galaxy formation and evolution. Much of what we know about the formation and evolution of the Milky Way bulge comes from giant stars. However, the underlying assumption that the giants accurately represent all the stars has not yet been rigorously tested (e.g., Santos *et al.* 2009). A true picture of the star formation history in the Galactic bulge requires the study of dwarf stars. Under normal circumstances, at the distance of the Galactic bulge, dwarf stars are too faint to acquire the high-resolution spectra that are crucial for abundance analysis. However, microlensing events offer, during a short time, the opportunity to obtain spectra of dwarf stars in the Bulge.

In 2009 we have obtained high-resolution spectra for several microlensed dwarf and subgiant stars using UVES on the VLT. Combined with previous events (Johnson *et al.* 2007, 2008; Cohen *et al.* 2008, 2009; Bensby *et al.* 2009a, 2009b) the total number of dwarf and sub-giant star in the Bulge that we have analysed is now 13.

These 13 microlensed dwarf and subgiant stars have an average metallicity of $\langle[\mathrm{Fe/H}]\rangle = -0.03 \pm 0.4$. A two-sided KS-test (see top panel in Fig. 1) does not allow us to reject the null-hypothesis that the MDF from the microlensed dwarfs and the MDF for the 500 Bulge giants from Zoccali *et al.* (2008) are identical, even adopting a loose significance level of 0.1. More microlensed events would help refining the comparison. It is, however, evident that the super-metal-rich MDF proposed by Cohen *et al.* (2009), is starting to shift toward lower metallicities.

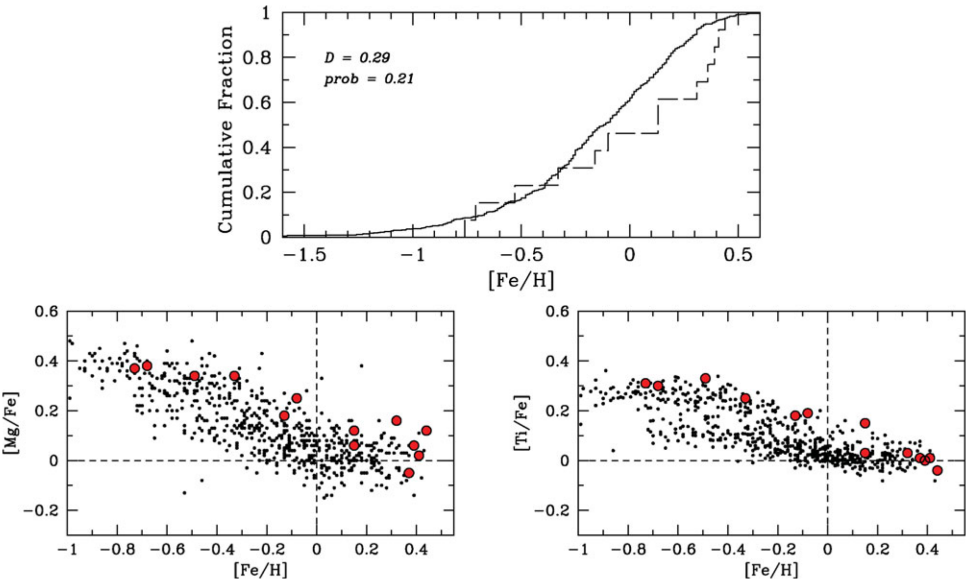

Figure 1. *Top panel* shows the two-sample KS-test between the Zoccali *et al.* (2008) giant stars (full line) and the 13 microlensed dwarf and subgiant stars (dashed line). *Bottom panels* show [X/Fe] versus [Fe/H]. Thin and thick disc stars from Bensby *et al.* (2003, 2005, and 2010 in prep) are marked by black dots, and the microlensed Bulge dwarfs by red (larger) circles.

Bottom panels of Fig. 1 show the abundance trends for the microlensed Bulge dwarf and sub-dwarf stars compared to nearby thin and thick disc dwarf stars. Two things can be taken from this figure: 1) The bulge stars do have a wide spread in metallicity; 2) The microlensed Bulge dwarfs fall together on the plot with dwarf stars that are known to belong to the Galactic thick disc, i.e., high alpha-element abundances relative to iron.

Regarding the Bulge membership for these microlensed dwarf stars, theoretical calculations for the distance to microlensed sources, assuming a constant disk density and an exponential bulge, show that the distance to the sources is strongly peaked in the Bulge, with the probability of having $D < 7$ kpc very small (Kane & Sahu 2006). Also, with regard to the sources being in the disk on the other side of the Bulge, the position of the stars in the OGLE/MOA color-magnitude diagram strongly argues against that. Basically, the stars are not faint enough, especially when considering the fact that there will be additional dust as we enter the disc on the other side.

The data set, the analysis, and results for other α-elements will be presented in Bensby *et al.* (in prep.), and results for r- and s-process elements in Johnson *et al.* (in prep.).

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