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Abundances in the Galactic Bulge: evidence for fast chemical enrichment

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Abstract. We spectroscopically characterize the Galactic Bulge to infer its star formation timescale, compared to the other Galactic components, through the chemical signature on its individual stars. O, Na, Mg, Al were obtained for 50 K giants in four fields towards the Galactic bulge from UVES spectra (R=45,000), while Fe was measured in more than 400 stars with a slightly low resolution (R=20,000) and the GIRAFFE spectrograph at VLT. Oxygen and Magnesium show a well defined trend with [Fe/H], with abundances larger than those measured in both thin and thick disk stars, supporting a scenario in which the bulge formed before and more rapidly than the disk. On the other hand the iron distribution peaks at solar metallicity and it is slightly narrower than that measured in previous works. Part of the present results have been published by Zoccali *et al.* (2006) and Lecureur *et al.* (2006), and part will be discussed in forthcoming papers.

Keywords. Galaxy: bulge – Stars: Abundances, Atmospheres

1. Introduction

The detailed chemical composition of stars carries the signature of the enrichment processes undergone by the interstellar medium up to the moment of their formation. Thus, elemental ratios are sensitive to the previous history of star formation and can be used to infer whether there is a genetic link between different stellar groups. In particular, the relative abundances of iron and α-elements play a key rôle because α-elements are predominantly produced by Type II supernovae (SNII) while supernovae of Type Ia (SNIa) dominate instead the production of iron. As a consequence, the $[\alpha/\mathrm{Fe}]$ ratio depends on the relative contribution of SNIIs and SNIas, and therefore it depends on the timescale of star-formation and metal production (Matteucci & Greggio, 1986).

† Observations collected both at the European Southern Observatory, Paranal, Chile (ESO programmes 71.B-0617 and 73.B-0074) and La Silla, Chile.

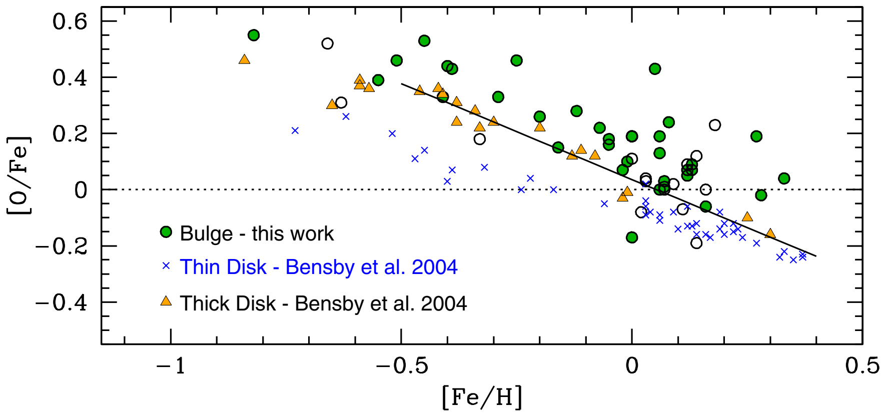

Figure 1. Oxygen/iron trend in our bulge stars vs. that for thick and thin disk stars. The solid line shows a linear fit to the thick disk data points with [Fe/H]> -0.5 and is meant to emphasize that all bulge stars with $-0.4 <$[Fe/H]$< +0.1$ are more oxygen-enhanced than thick disk stars. This plot enlightens the systematic, genetic difference between bulge and disk stars, thus excluding that bulge stars were once disk stars that then migrated inward to build up the bulge.

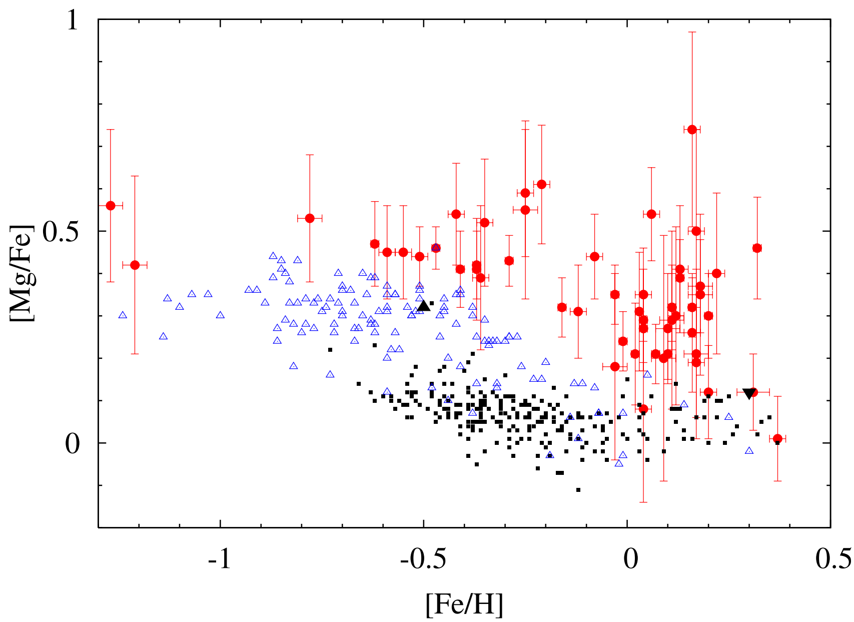

Figure 2. Same as Fig. 1 for Magnesium.

Spectra for a sample of $\sim$ 1000 K giants in four bulge fields have been collected at the VLT-UT2 with the FLAMES fibre spectrograph. All the stars were observed with the GIRAFFE arm of the instrument, with resolution R$\sim$ 20,000, while 58 of them have *also* been observed with the UVES arm, at higher resolution R$\sim$ 45,000, in the range 5800-6800 Å. In the colour-magnitude diagram, these stars are located on the red giant branch, about 1 magnitude above the red clump, with the exception of 13 stars in Baade's Window that instead are on the red clump itself. The LTE abundance analysis

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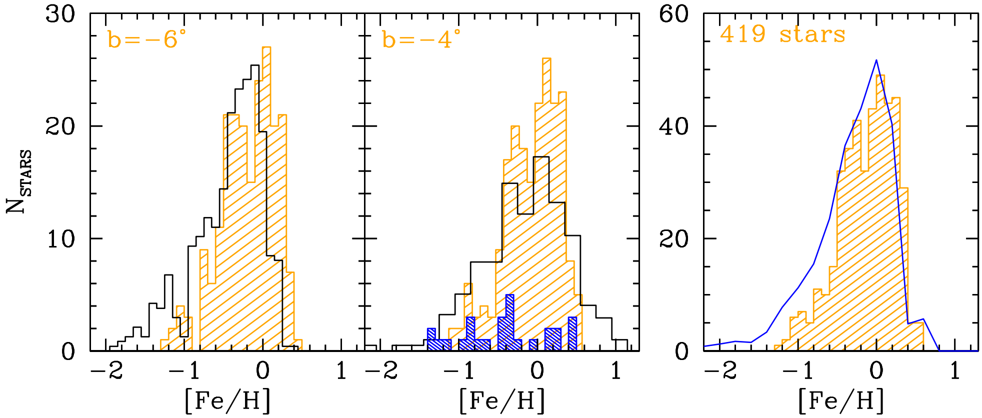

Figure 3. *Left panel*: Bulge MDF measured in the field at b=−6° compared with the photometric MDF of the same field, by Zoccali *et al.* (2003). *Middle panel*: Bulge MDF for Baade's Window, at b=−4°, compared with the MDF by Fulbright, McWilliam & Rich (2006). The latter is a re-calibration of the low-res. spectroscopic MDF by Sadler, Rich & Terndrup (1996), using a sample of high resolution spectra here shown as a grey histogram. *Right panel* Cumulative MDF from the two fields above, compared with the galactic chemical enrichment model by Ballero *et al.* (2006).

was performed using well tested procedures (Spite, 1967) and the new MARCS models (Gustafsson *et al.* 2002). Spectrum synthesis was performed with *turbospec* (Alvarez & Plez 1998) and counterchecked with Barbuy *et al.* (2003), including the effects of molecular lines on the derived atomic abundances.

The resulting [O/Fe] vs. [Fe/H] plot is shown in Fig. 1 The [O/Fe] vs. [Fe/H] ratios in the bulge compared with those for the thick and the thin disks (Bensby, Feltzing & Ludström 2004). These measurements are as consistent as possible, in the sense that they come from the same line, and we have intentionally adopted the same atomic parameters both for oxygen and for nickel. The solar oxygen abundance to which the disk stars were referred was lower by 0.06 dex, so an identical downward shift was then applied to their measurements. This plot shows that the thin disk, thick disk, and bulge evolved through different chemical trajectories. In other words, bulge stars did not originate in the disk and then migrate inward to build up the bulge, but rather formed independently of the disk (Minniti 1995; Ortolani *et al.* 1995). Moreover, *the chemical enrichment of the bulge, hence its formation timescale, has been faster than that of the thick disk, which in turn was faster than that of the thin disk (Matteucci, Romano & Molaro 1999).*

At the moment, iron has been measured in the GIRAFFE spectra of two of the four fields, for a total of 419 stars. The resulting metallicity distribution function (MDF) is the first one obtained entirely from high resolution spectra. The MDF measured in each individual field is shown in the left part of Fig. 3, compared with the photometric MDF by Zoccali *et al.* (2003) – for the field at b=−6° where the latter was derived – and with the Fulbright, McWilliam & Rich (2006) results – for Baade's Window –. It is important to note that Fulbright, McWilliam & Rich (2006) have measured on high resolution spectra only 27 stars, marked as a blue histogram in the figure, and used those to recalibrate the Sadler, Rich & Terndrup (1996) MDF, obtained from low resolution spectra of 322 stars. Indeed, the discrepancy between the two MDF at high metallicity is likely due to some systematics in the low resolution data, given that the Fulbright *et al.* recalibration does not extend above [Fe/H]=+0.40. It is also interesting to note that our spectroscopic

MDF, although preliminary, is narrower than previous ones. We find this result quite encouraging given that we are reducing statistical and systematic errors with respect to previous measurements; it would be unlikely that we are introducing new systematics conspiring to make the MDF narrower. The right panel of Fig. 3 shows the comparison of the cumulative MDF for the two fields with the galactic chemical enrichment model by Ballero *et al.* (2006). Here we see that the theoretical MDF is still slightly broader than the observed one, which is compatible with the fact that we are only measuring two lines of sight (showing indeed a shift in the mean metallicity between the two) while the model refers to the bulge as a whole. Adding the other two fields, at larger galactic latitude, we would expect to broaden the observed distribution and hence improve the agreement with this particular model.

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Scott Trager (right) talking to Mike Beasley.

Daniel Thomas (left), Brad Gibson and Bengt Gustafsson.

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