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CHEMICAL ABUNDANCES IN THE GALACTIC BULGE: EVIDENCE FOR A FAST ENRICHMENT

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RESUMEN

Hemos derivado abundancias de oxígeno para 42 gigantes K en cuatro campos hacia el bulbo galáctico. Aquí presentamos los resultados para oxígeno, de acuerdo a las líneas prohibidas en 6300 Å. El oxígeno muestra una bien definida tendencia con [Fe/H]. Siendo [O/Fe] más alto en las estrellas del bulbo que en las del disco grueso, estas últimas ya se encuentran más enriquecidas por el oxígeno que las estrellas del disco delgado (Bensby, Feltzing, & Lundström 2004). Este resultado apoya el escenario en el cual el bulbo se formó de manera más rápida, y probablemente antes que el disco grueso.

ABSTRACT

We derived oxygen abundances for 42 K giants in four fields towards the Galactic bulge. We present here the results for Oxygen, as measured from the forbidden line at 6300 Å. Oxygen shows a well defined trend with [Fe/H]. with [O/Fe] being higher in bulge stars than in thick disk ones, the latter already more oxygen enhanced than thin disk stars (Bensby, Feltzing, & Lundström 2004). This result supports the scenario that the bulge formed faster and probably earlier than the thick disk.

Key Words: **GALAXY: BULGE — STARS: ABUNDANCES — STARS: ATMOSPHERES**

1. INTRODUCTION

The central regions of spiral galaxies, known as bulges, are made of stars in randomly oriented orbits for which two distinct formation processes have been proposed. In the so-called “classical bulges”, most stars originate in a short phase of star formation when the universe was only a few Gyr old. Instead, in the so-called “pseudobulges” stars form in the disk, over a more extended period of time, and the bulge results from the secular evolution of the disk driven by the development of a bar (Kormendy & Kennicutt 2004) . It is currently believed that the pseudobulge mode dominates among late-type spirals (Sc and later) and the old-starburst mode (similar to the formation of elliptical galaxies) dominates among early-type spirals (Sb and earlier). The Sbc Milky Way galaxy sits on the borderline, and to establish the origin of its bulge (either old starburst or disk secular evolution) extensive spectroscopic observations have been undertaken to obtain precise element abundance ratios, such as [Fe/H] and [O/Fe].

Spectra for a sample of ∼ 800 K giants in four bulge fields have been collected at the VLT-UT2 with the FLAMES fibre spectrograph. All the stars have been observed with the GIRAFFE arm of the instrument, with resolution R∼20,000, while 48 of them have *also* been observed with the UVES arm, at higher resolution R∼45,000, in the range 4800-6800 Å. Here we focus on the high resolution UVES spectra. Observed targets include 11 stars in a low reddening window at $(l, b) = (0, -6)$, 26 stars in Baade’s Window, 5 stars in the Blanco field at $(l, b) = (0, -12)$ and 13 stars in a field centered on the Globular Cluster NGC 6553. In the color-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 are instead red clump stars.

The equivalent widths for selected lines of Fe, Na, Mg, Al, Si, Ca, Sc, Ti and Ni were measured using the new automatic code DAOSPEC (Stetson and Pancino in preparation). Atomic parameters for iron lines will be listed in Zoccali et al. (2006, in preparation). LTE abundance analysis were performed using well tested procedures (Spite 1967) and photospheric 1-D models (Gustafsson et al. 1975). Spectrum synthesis was performed including the ef-

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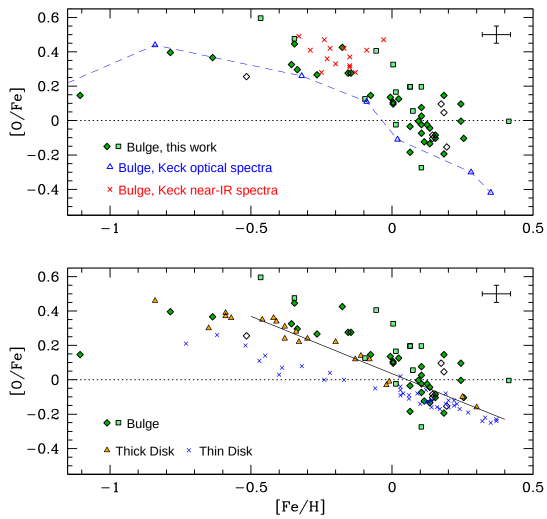

Fig. 1. Upper panel: The oxygen over iron ratio vs. the iron abundance for our bulge stars (diamonds for red giants and squares for red clump stars) along with with previous determinations in other bulge stars from optical (McWilliam & Rich 2003; open triangles) and near-IR spectra (Rich & Origlia 2005; crosses). Open symbols in our measurements refer to low S/N spectra, for which we expect a larger uncertainty. Lower panel: oxygen/iron trend in our bulge stars vs. that for thick and thin disk stars (Bensby et al. 2004).

fects of molecular lines (Barbuy et al. 2003) on the derived atomic abundances, which is of special importance in the case of oxygen, due to the formation of CO and TiO molecules respectively locking part of the oxygen and changing the continuum shape. Excitation equilibrium were imposed on FeI lines in order to refine the photometric $T_{\rm eff}$, while photometric gravity was imposed, due to the weakness of all FeII lines. The $T_{\rm eff}$, log g, [Fe/H] and microturbulence velocity were then used as input for the construction of a synthetic spectrum for each star. α-element abundances were then iteratively changed until the equivalent widths measured for each line in the observed spectrum would match, on the mean, the ones in the synthetic spectrum. Standard solar abundances (Grevesse & Sauval 1998) were adopted as reference zero point for the abundances of bulge stars, except for the value of solar oxygen, where $\epsilon(\mathrm{O})_\odot = 8.77$ was assumed (Allende Prieto, Lambert & Asplund 2001).

The main goal of the present paper is a consistent comparison of the [O/Fe] trend of bulge stars with that of the other galactic components, in order to derive the *relative* star formation timescales in a way that is independent of chemical evolution models. To this end, the atomic parameters for the [OI] and NiI lines around 6300 Å were assumed identical to those employed in previous measurements for disk stars. Consistency in [Fe/H] values has also been insured by checking that both linelists give [Fe/H]=0.0 for the Sun.

The resulting [O/Fe] vs. [Fe/H] plot is shown in Fig. 1. The upper panel shows the comparison between our measurements (diamonds and squares), and recent oxygen abundance determinations for bulge stars (McWilliam & Rich 2003; Rich & Origlia 2005). This panel shows that our measurements are not in conflict with previous results, but the larger size and metallicity coverage of the present sample allows us to draw much more robust conclusions that would have been possible based only on the old data.

The lower panel of Fig. 1 shows the *main result* of the present investigation: the [O/Fe] vs. [Fe/H] ratios in the bulge as compared with those for the thick and the thin disk. This plot shows that the thin disk, thick disk and bulge evolved through different chemical trajectories: the [Fe/H] value for which the oxygen/iron ratio has dropped to solar is [Fe/H]$\sim$ +0.1 for the bulge, [Fe/H]$\sim$ 0 for the thick disk, and [Fe/H]~ -0.25 for the thin disk. The straightforward interpretation is that the bulge stars did not originate in the disk and then migrated 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).*

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