Oxygen Abundances Derived from UV OH and O I IR Lines in Very Metal-Poor Stars

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Abstract. Oxygen abundances have been derived in a sample of very metal-poor stars using the O I triplet at $\lambda\lambda$ 7771–5 Å and OH lines in the near UV. A detailed NLTE analysis of iron lines has been carried out for one of the observed stars, BD +23° 3130, providing consistent values of effective temperature and surface gravity that are in very good agreement with independent estimates from the infrared flux method and *Hipparcos* parallaxes, respectively. These parameters, especially the higher gravity obtained with respect to previous analyses, reduce the discrepancies claimed between the oxygen abundances determined from OH, O I triplet and [O I] λ 6300 Å lines, and give consistent abundances to within 0.16 dex for BD +23° 3130 ([Fe/H]$_{\mathrm{NLTE}}$ = -2.43). The oxygen abundances derived for this new sample confirm previous findings for a progressive linear increase in the oxygen-to-iron ratio with a slope -0.33 ± 0.02 (including NLTE corrections to the iron abundances for all the stars considered) from solar metallicity to [Fe/H]~ -3, and [O/Fe] values as high as ~ 1.1 for stars with [Fe/H]$\lesssim -2.5$. These results can be interpreted as evidence for oxygen overproduction in the very early epoch of the formation of the Galactic halo, possibly associated with supernova events with very massive progenitor stars.

1. Oxygen abundances

Oxygen is produced in the interiors of massive stars by hydrostatic burning and returned to the interstellar medium when the stars explode as Type II supernovae, while iron is produced in both Type II and the less massive Type I supernovae. Oxygen is then expected to be overabundant with respect to iron
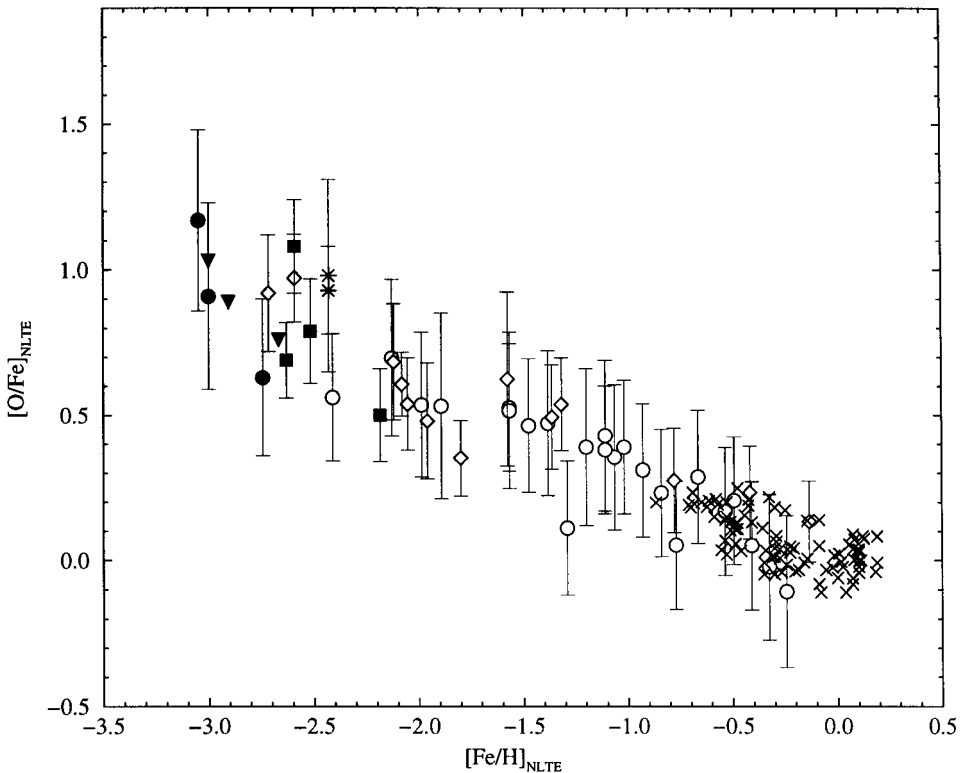
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Figure 1.   Oxygen overabundance with respect to iron, derived from the UV OH lines and the O I triplet (triangles) in metal-poor unevolved stars. The results for OH lines are denoted by filled circles, the triplet by filled squares, and upper limits from the triplet by filled downward-pointing triangles. The asterisks indicate the oxygen abundance derived from OH and the triplet for BD +23° 3130. Data taken from Israelian et al. (1998), Boesgaard et al. (1999) and Edvardsson et al. (1993) are marked by unfilled circles, unfilled diamonds and crosses, respectively.

and increases with decreasing metallicity. However, despite the considerable observational effort performed over the last decade, the trend of the oxygen-to-iron ratio in the Galactic halo is still not completely clear (see, for example, Kraft, this conference; Israelian et al. 2001).

The halo dwarf stars can be considered as the best tracers of the early Galaxy's composition. Spectroscopic observations in a sample of unevolved very metal-poor stars have been carried out in different runs using the 4.2 m WHT and the 2.5 m NOT (Observatorio del Roque de los Muchachos, La Palma), the 10 m Keck I (Hawaii), and the 8.2 m VLT Kueyen (ESO, Paranal), aimed at deriving oxygen abundances and metallicities to better understand the production of oxygen in the early Galaxy. A detailed NLTE analysis of iron lines has been performed for one of the observed stars (BD +23° 3130) in order to obtain consistent stellar parameters used to compare the oxygen abundances derived

from three different indicators: UV OH lines (3080–3300 Å), the O I IR triplet (7771–5 Å), and the [O I] λ 6300 Å line.

Details on the stars observed, spectral parameters adopted, tools used to derive oxygen abundances, and the NLTE analysis carried out for BD +23° 3130 can be found in Israelian et al. (2001). Metallicities estimated in LTE for the other stars in the sample (as well as for stars taken from previous work in the literature) were corrected for NLTE effects following Thévenin & Idiart (1999).

The effective temperature and surface gravity found spectroscopically for BD +23° 3130 are in very good agreement with the estimates from the infrared flux method and *Hipparcos* parallaxes, respectively. Assuming these stellar parameters and $[Fe/H]_{NLTE} = -2.43$, our new triplet observations, the OH measurements by Israelian, García López, & Rebolo (1998), and the equivalent width measurement by Cayrel et al. (this conference) for the forbidden line, we find $[O/H] = -1.50 \pm 0.14$, -1.45 ± 0.33, and -1.61 ± 0.15, respectively. There is a clear agreement between these three indicators, given the error bars from each measurement, which provides a mean value of $[O/Fe] = 0.91$ representative of the oxygen overabundance measured in this star. Furthermore, Israelian et al. (2001) show a similar good agreement in oxygen abundances derived from OH and [O I] lines in a number of stars whose parameters have been estimated in this way, covering the metallicity range from -1 to -2.5.

As can be seen in Figure 1, our results support a linear increase of $[O/Fe]$ with decreasing metallicity with a slope -0.33 ± 0.02 (taking the error bars into account). In particular, the high value found for the most metal-poor star in our sample (G64-12, $[Fe/H]_{NLTE} = -3.05$) from the UV OH lines ($[O/Fe] = 1.17$) provides evidence for enhanced oxygen production in the first nucleosynthesis events in our Galaxy. This trend is in agreement with previous findings for unevolved stars and is at odds with other measurements made mainly on giant stars (see Kraft, this conference). Examination of several scenarios for nucleosynthesis in low-metallicity Type II supernovae and/or hypernovae provides a variety of possible explanations for the increase of oxygen overabundance with decreasing metallicity in the early Galaxy, as discussed by Israelian et al. (2001).

References

Boesgaard, A.M., King, J. R., Deliyannis, C. P., & Vogt, S. S. 1999, AJ, 117, 492

Edvardsson, B., Andersen, J., Gustafsson, B., Lambert, D. L., Nissen, P. E., & Tomkin, J. 1993, A&A, 275, 101

Israelian, G., García López, R. J. & Rebolo, R. 1998, ApJ, 507, 805

Israelian, G., Rebolo, R., García López, R. J., Bonifacio, P., Molaro, P., Basri, G., & Shchukina, N. 2001, ApJ, (submitted)

Thévenin, F. & Idiart, T. 1999, ApJ, 521, 753