Chemical Abundances in the Universe:
Connecting First Stars to Planets
Proceedings IAU Symposium No. 265, 2009
K. Cunha, M. Spite & B. Barbuy, eds.

doi:10.1017/S174392131000102X

Evolution of [O/Mg], [Na/Mg], [Al/Mg], and [K/Mg] in the Galaxy, from a NLTE analysis

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Keywords. abundances, line:profiles, Pop II, halo

1. Introduction

In the framework of he ESO Large Program "First Stars", high resolution (R=45000) high S/N ratio spectra have been obtained for a sample of Extremely Metal Poor Stars (EMP stars), 35 giants and 18 turnoff stars. Among them 37 have a very low metallicity: [Fe/H] < -2.9.

The trends in abundance ratios have been presented in Cayrel *et al.* (2004) and Bonifacio *et al.* (2009) from LTE computations of the abundances of the different elements.

However the abundance of light "metals" such as Na, Al and K had been determined from resonance lines, particularly sensitive to NLTE effects. Moreover Bonifacio *et al.* (2009) found for some other elements such as magnesium, chromium etc. a significant disagreement between the mean value of [X/Fe] in the giants and the turnoff stars, and it has been even shown that the abundances deduced from Cr I and Cr II were different. These anomalies suggest the importance of NLTE effects in EMP stars.

2. Non LTE abundance of Na, Mg, Al and K

We thus decided to determine, where possible, the abundance of the elements taking into account the NLTE effects. The atmospheric parameters (Teff, log g, vt) were taken from Cayrel *et al.* (2004) and Bonifacio *et al.* (2007,2009) and the NLTE computations of the line profiles were obtained using a modified version of the Carlson's MULTI code (Korotin *et al.* 1999). The NLTE abundances of Na and Al are given in Andrievsky *et al.* (2007, 2008). There is a much better agreement between the behaviour of [Mg/Fe] in dwarfs and in giants as soon as the NLTE effects are taken into account. (Potassium could be measured only in giant stars).

3. Evolution of [O/Mg], [Na/Mg], [Al/Mg], and [K/Mg] in the Galaxy

Mg is a priori a better "reference element" than Fe to trace the Galactic chemical evolution:
- [Mg/H] should be a better index of time than [Fe/H] since Mg is only formed in massive SN II with a short lifetime (unlike iron formed in SN II and SN I of different life times).
- The predictions of [X/Mg] in the ejecta of supernovae (for comparison) should be more precise since the nucleosynthesis channels of Mg are better known: Mg is mainly formed during hydrostatic burning in massive stars and, unlike Fe, is only slightly affected by explosive burning and "fallback".

We can thus plot [O/Mg], [Na/Mg], [Al/Mg], and [K/Mg] versus [Mg/H] (Fig.1). The abundance of oxygen has been computed under the LTE assumption. But, in this case, since we have used the forbidden lines of oxygen, the LTE hypothesis is valid.

In the Fig. 1 we have added the NLTE measurements obtained by the group of T. Gehren (Gehren *et al.* 2004, 2006, Mashonkina *et al.* 2008, Zhang *et al.*2006), to extend our sample toward higher metallicity.

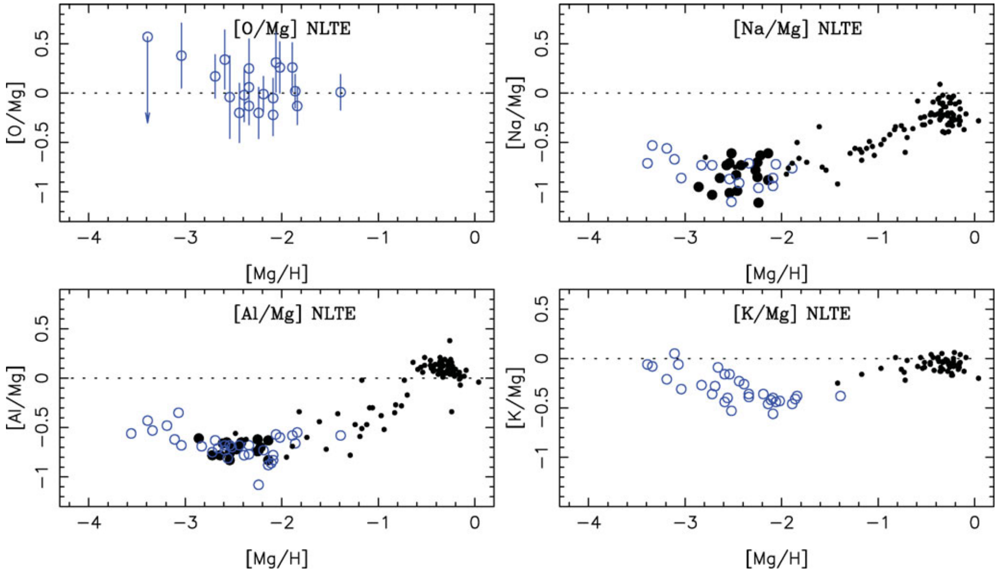

Figure 1. Variation of [O/Mg], [Na/Mg], [Al/Mg] and [K/Mg] in the Galaxy. The open circles represent our sample of giants,the black filled circles our sample of turnoff stars. The thin dots are the measurements of Gehren *et al.* (2004, 2006) Mashonkina *et al.* (2008) and Zhang *et al.* (2006). For Na only the unmixed stars have been plotted.

It can be seen (Fig. 1) that:

- O/Mg at low metallicity is close to the solar value ([O/Mg] ≈ 0.0)
- the ratios [Na/Mg], [Al/Mg], and [K/Mg] have a negative slope in the interval $-3.5 <$ [Mg/H] < -2.5. The error on [O/Mg] at low metallicity is too large to firmly establish any trend in this region.
- Between [Mg/H] $= -2.5$ and -1.5, [Na/Mg], [Al/Mg], and [K/Mg] are stable and then increase toward the solar value.

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