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

DOI: 00.0000/X000000000000000X

Fe-peak element abundances in disk and halo stars

Maria Bergemann[1] **and Thomas Gehren**[2]

[1]Max-Planck Institute for Astrophysics, Karl-Schwarzschildt str. 1
87541, Garching, Germany
email: mbergema@mpa-garching.mpg.de

[2]University Observatory Munich, Scheiner str. 1
81679, Munich, Germany
email: thomas.gehren@gmx.de

Abstract. At present none of galactic chemical evolution (GCE) models provides a self-consistent description of observed trends for all iron-peak elements with metallicity simultaneously. The question is whether the discrepancy is due to deficiencies of GCE models, such as stellar yields, or due to erroneous spectroscopically-determined abundances of these elements in metal-poor stars. The present work aims at a critical reevaluation of the abundance trends for several odd and even-Z Fe-peak elements, which are important for understanding explosive nucleosynthesis in supernovae.

Keywords. Line: formation, Line: profiles, Stars: abundances, Nucleosynthesis

As a rule, abundances of Fe-peak elements in the atmospheres of the Sun and metal-poor stars are calculated using a local thermodynamic equilibrium (LTE) assumption for the element line formation. However, recent studies indicate that LTE breaks down for majority of metals in stellar atmospheres, in particular, for neutral atoms with low ionization potential. Our earlier investigations of Mn and Co in cool stars (Bergemann & Gehren 2007, 2008, Bergemann et al. 2009) confirm large departures from LTE in the excitation-ionization balance of these elements, which are mainly stipulated by overionization of neutral atoms. As a result, the LTE-based abundances of Mn and Co in metal-poor stars are severely underestimated. Under NLTE, the trend of [Mn/Fe] with [Fe/H] is only slightly subsolar, whereas [Co/Fe] ratios steadily increase with decreasing Fe abundances in the disk and halo stars.

In this work, we have expanded our sample of disk and halo stars from Bergemann et al. (2009) with 9 members of the thin and thick disks. Contrary to the prevalent belief that NLTE effects on differential abundances are minor for less metal-poor stars, we find that NLTE abundance corrections for Co are significant even at [Fe/H] ~ -0.8, $\log \varepsilon^{\rm NLTE} - \log \varepsilon^{\rm LTE} \sim +0.25$ dex. Our new data reveal a well-defined increase of [Co/Fe] ratios at [Fe/H] ~ -0.5 (Fig. 1). An ostensive dichotomy of [Co/Fe] values seen for the stars with $-1 <$ [Fe/H] < -0.5 is not significant. Apparently, there is a large continuous spread of Co abundances in stars with mildly sub-solar metallicities, which can be explained by GCE models with radial migration (Schönrich & Binney 2009).

We find similar NLTE effects on abundances of Cr in metal-poor stars. The details of statistical equilibrium calculations will be published elsewhere. We only note that quantum-mechanical photoionization cross-sections for Cr I are now available (Nahar 2009). This allowed us to put constraints on poorely-known cross-sections for inelastic collisions with H I, which are computed according to Drawin (1969) and scaled down by few orders of magnitude. Under NLTE, ionization equilibrium in Cr I/Cr II is shifted to lower number densities of Cr I, thus requiring larger Cr abundances to fit the observed spectral lines of Cr I. The main stellar parameter that determines the sign and magnitude of NLTE abundance corrections is metallicity: the effect of overionization on the line opacity monotonously increases with decreasing [Fe/H]. In addition to the metallicity effect, high temperatures control overionization at higher [Fe/H], whereas at low [Fe/H] the effect of low gravity is more important. Hence, NLTE line formation and abundance corrections for giants and dwarfs at a given [Fe/H] are different for transitions involving different levels of Cr I.

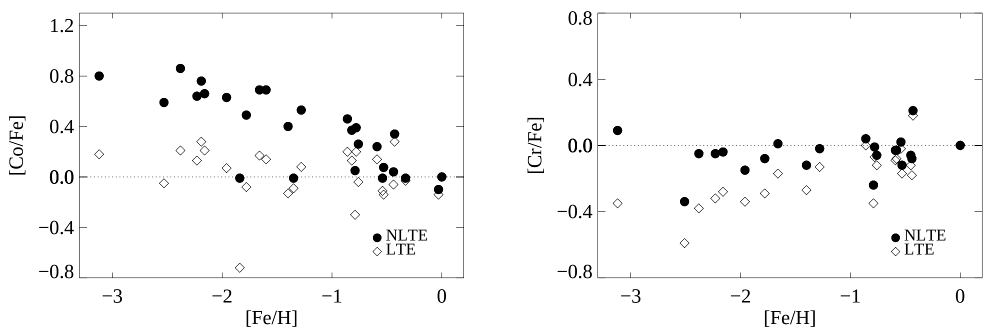

Figure 1. [Co/Fe] and [Cr/Fe] ratios in metal-poor stars as a function of metallicity. The abundances of Co and Cr are determined from the lines of neutral atoms.

NLTE abundances of Cr were calculated for a sample of dwarfs and subgiants (Fig. 1) with atmospheric parameters taken from Bergemann et al. (2009). In short, the effective temperatures and surface gravities are determined from Balmer line profiles and *hipparcos* parallaxes, respectively. The iron abundances and microturbulent velocities were obtained from Fe II line profile fitting under LTE requiring that the derived Fe abundances are independent of the line strength. Ionization equilibrium of Cr in metal-poor stars is satisfied when we apply a very small scaling factor to cross-sections for inelastic collisions with H I, $S_H \leqslant 0.05$. With this choice of S_H, our study yields [Cr/Fe] ~ 0 throughout the range of metallicities analyzed here, $-3 \leqslant$ [Fe/H] $\leqslant 0$. The metallicity-independent [Cr/Fe] ratios in metal-poor stars are well reproduced by most of the GCE models (e.g. Samland 1998, Kobayashi et al. 2006). On the other side, these same models tend to underestimate the NLTE [Mn/Fe] and [Co/Fe] ratios in metal-poor stars. It is tempting to relate the discrepancy to stellar yields used in the GCE models. According to Kobayashi et al. (2006), it is possible to find a combination of SN II explosion parameters, like mass cut and amount of mixing, to reproduce [Cr/Fe], [Mn/Fe], and [Co/Fe] simultaneously. This problem will be investigated further.

References

Bergemann, M., & Gehren, T. 2007, *A&A* 473, 291
Bergemann, M., & Gehren, T. 2008, *A&A* 492, 823
Bergemann, M., Pickering, J. C., & Gehren, T. 2009, *MNRAS* (accepted), eprint arXiv:0909.2178
Schönrich, R., & Binney, J. 2009, *MNRAS* 396, 203
Nahar, S. 2009, JQSRT 110, 2148
Samland, M. 1998, *ApJ* 496, 155
Kobayashi, C., Umeda, H., Nomoto, K., Tominaga, N., & Ohkubo, T. 2006, *ApJ* 653, 1145