THE BEHAVIOR OF α – ELEMENTS ABUNDANCES IN THE THIN AND THICK DISKS OF THE GALAXY

T.V. Mishenina[1] , T.I. Gorbaneva[1], C. Soubiran[2], O. Bienayme[3], V.V. Kovtyukh[1], S.A. Korotin[1]

[1] Department of Astronomy, Odessa State University
T.G.Shevchenko Park, Odessa 270014 Ukraine, *tamar@deneb.odessa.ua*

[2] Observatoire Aquitain des Sciences de l'Univers,
CNRS UMR 5804, BP 89, 33270 Floirac, France

[3] Observatoire Astronomique de l'Universite Louis Pasteur, Strasbourg, France

ABSTRACT. We have carried out the detailed analysis of 350 high-resolution spectra of FGK dwarfs and giants. Abundances of Fe, Si, Ca and Ni have been determined under LTE approximation, whereas abundances of Mg have been determined under NLTE approximation. Spatial velocities with an accuracy better than 1 $km\,s^{-1}$, as well as orbits, have been computed for dwarfs (or all) stars. They have been used to define 2 subsamples kinematically representative of the thin disk and the thick disk in order to highlight their respective properties. A transition occurs at [Fe/H] = −0.3. Stars more metal-rich than this value have a flat distribution with $Z_{max} < 1$ kpc and $\sigma_W < 20$ $km\,s^{-1}$, and a narrow distribution of [α/Fe] . There exist stars in this metallicity regime which cannot belong to the thin disk because of their excentric orbits, neither to the thick disk because of their low scale height. Several thin disk stars are identified down to [Fe/H] = −0.80. Their Mg enrichment is lower than thick disk stars with the same metallicity. Both the dwarfs and the giants show a decrease of [α/Fe] with [Fe/H] in the thick disk.

Key words: Stars: fundamental parameters; stars: abundances; stars: kinematics; stars: atmospheres; Galaxy: stellar content.

Introduction

In this paper we put particular attention to the transition between the thin disk and the thick disk and to the abundances of the α-elements Mg and Si and the iron-peak element Ni. According to the current nucleosynthetic theory, α-elements are being produced as a result of α-capture reaction, taking place in the core of massive stars during their explosion as SN II (Burbidge et al. 1957). Fe is produced by both massive SN II and less massive SN Ia. If the percentage of massive stars in the earlier Galaxy was higher than today, one can predict that the α/Fe ratio is going to change over time. A well established observational fact shows that in old metal-poor stars of the Galaxy, [α/Fe] , in particular [Mg/Fe] , is overabundant relative to Sun's value (Wallerstein 1961; Gratton & Sneden 1987; Magain 1989; Nissen et al. 1994; Fuhrmann et al. 1995, etc). If the α-element overabundance is a typical chemical pattern in halo stars in comparison with disk stars, there is a question whether there is a distinction in the Mg behaviour in other subsystems of the Galaxy, in particular in the thin and thick disks. Such a difference would have important consequences on the choice of the most probable scenario of formation of the thick disk (collapse, accretion etc.) and its timescale.

1. Observations, parameters and abundances

All the spectra used in this paper are extracted from the most recent version of the library of stellar spectra collected with the ELODIE echelle spectrograph at the Observatory de Haute-Provence by Soubiran et al. (1998) and Prugniel & Soubiran (2001). The performances of the instrument mounted on the 193cm telescope, are described in Baranne et al (1996). A resolving power of 42 000 in the wavelength range $\lambda\lambda$ 3850–6800 ÅÅ.

The continuum level drawing and equivalent width measurements were carried out by us using DECH20 code (Galazutdinov 1992).

Our group has improved the line-depth ratio technique to determine T_{eff} (Kovtyukh et al. 2003). This method, relying on ratios of the measured central depths of lines having very different functional dependences on T_{eff} , is independent of interstellar reddening and takes into account the individual characteristics of the star's atmosphere. For the most metal-poor stars, T_{eff} was determined earlier (Mishenina & Kovthyukh

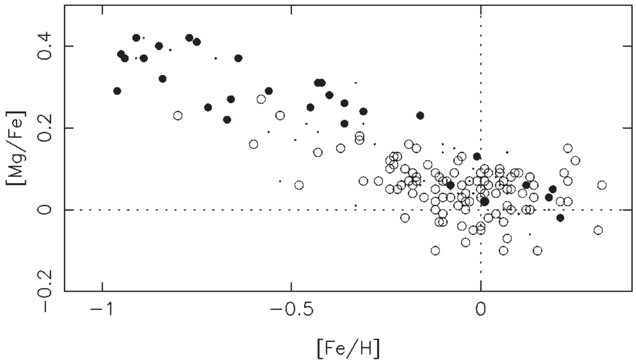

Figure 1: [Mg/Fe] vs [Fe/H] for the whole sample. Black dots indicate thick disk stars, open dots thin disk stars, small dots represent the unclassified stars.

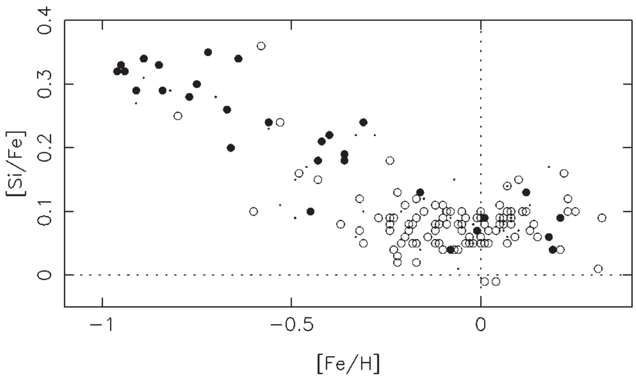

Figure 2: Same as Fig. ?? for Si.

2001). The H_α line-wing fitting was used for stars studied in this work.

The surface gravity log g was determined using two different methods, the method based on the ionisation balance for iron and a second method by fitting the wings of a Ca I line profole.

Microturbulent velocities V_t were determined by forcing the abundances determined from individual FeI lines to be independent of equivalent width.

Fe, Si, Ni abundances for dwarfs and Fe, Si, Ca, Ni, for giants were determined from an LTE analysis of equivalent widths using the WIDTH9 code and the atmosphere models by Kurucz (1993).

The determination of Mg abundance was carried out through detailed NLTE calculations using equivalent widths of 4 lines ($\lambda\lambda$ 4730, 5711, 6318, 6319 ÅÅ) and profiles of 5 lines ($\lambda\lambda$ 4571, 4703, 5172, 5183, 5528 ÅÅ).

NLTE abundances of Mg were determined with the help of a modified version of the MULTI code of Carlsson (1986) described in Korotin et al. (1999a,b).

2. Stellar kinematics, metallicity, elemental abundances

We have selected our sample to span the metallicity range -1.0 <[Fe/H] $< +0.3$ in order to define 2 subsamples representative of these two populations. A discrimination of thin disk and thick disk stars is possible using the fact that the two disks are known to be distinct by their spatial distribution and local density, and by their velocity, metallicity and age distributions.

We have computed the probability of each star, with a measured velocity (U,V,W), to belong to the thin disk (Pr_1) and to the thick disk (Pr_2).

Figs. 1, 2 show the trend, of the abundances of Mg and Si as a function of [Fe/H] for dwarfs. It can be seen that :

- there are a few thin disk stars with [Fe/H] < -0.30
- metal poor stars ([Fe/H] < -0.60) are all enriched in Mg and Si ([Mg/Fe] $> +0.20$, [Si/Fe] $> +0.15$)
- on the contrary at solar metallicity, the enrichment of Mg and Si does not exceed +0.20
- at a given metallicity thick disk stars have higher [Mg/Fe] on average than thin disk stars
- the dispersion of [Si/Fe] is remarkably small for [Fe/H] > -0.30 but quite high at lower metallicity
- [Mg/Fe] and [Si/Fe] decline with metallicity from about +0.40,+0.35 to 0.0, +0.08 respectively
- there are stars with thick disk kinematics at solar metallicities, their abundance trends follow the thin disk

Mg and Si are α elements which are supposed to be mainly produced in SNII. It can be seen in this plot that a transition occurs at [Mg/Fe] $\simeq +0.2$. Stars with [Mg/Fe] $< +0.2$ have a mean abundance of [Si/Fe] =+0.08 with a very low dispersion of ± 0.03, lower than our error estimates. [Mg/Fe] is more dispersed (± 0.06) around the mean of [Mg/Fe] =+0.05. For stars with [Mg/Fe] $> +0.2$ the distribution is consistent with a linear correlation: [Si/Fe] =0.7 ; [Mg/Fe] +0.06 (rms=0.06).

2.1. The thin disk

Several thin disk stars are found at low metallicity, down to [Fe/H] = -0.80. Reddy et al (2002) have found in their samples a significant number of stars with [Fe/H] < -0.40 that they identify as belonging to the thin disk. Our observations suggest that the distribution of [α/Fe] in the thin disk is very narrow, specially for Si, at [Fe/H] > -0.30. On this point we are in perfect agreement with Reddy et al (2002) and Bensby et al. (2003). For the metal-rich part, we obtain as mean values and dispersions : [Mg/Fe] =+0.05, $\sigma_{[Mg/Fe]}$=0.07, [Si/Fe] =+0.07, $\sigma_{[Si/Fe]}$=0.03. Such a narrow chemical distribution implies that the stars formed from an homogeneous gas.

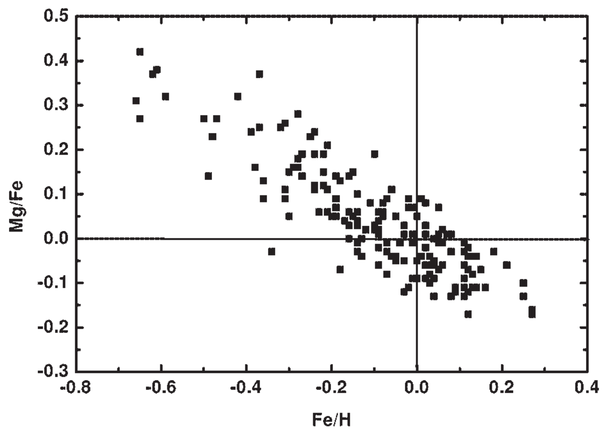

Figure 3: [Mg/Fe] vs [Fe/H] for giants.

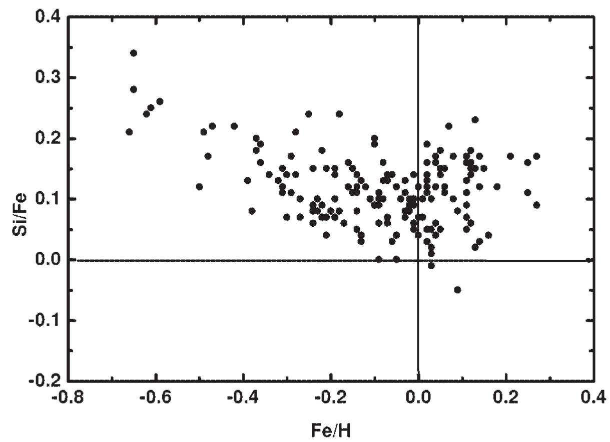

Figure 4: Same as Fig. 3 but for Si.

2.2. The thick disk

Having eliminated from the thick disk the 8 stars having high metallicity and a flat distribution, we see from Fig. 2 that [Mg/Fe] decreases from the halo value (+0.40) at [Fe/H] =–1.00 to +0.20 at [Fe/H] =–0.30. Si has the same behavior, decreasing from +0.35 to +0.17, with one deviating star HD 110897 having a lower enrichment in Si. These findings are nicely consistent with the trends found by Bensby et al. (2003) that they interpreted as the signature of the chemical enrichment by SNIa.

Fig. 3, 4 show the trend of the abundances of Mg and Si as a function of [Fe/H] for giants. A trend of [alpha/Fe] and Ni abundance with [Fe/H] for giants is a similar to one of dwarfs.

Main results

1. 2 subsamples kinematically representative of the thin disk and the thick disk are defined. A transition occurs at [Fe/H]=–0.3.

2. Stars more metal-rich than this value have a flat distribution with Zmax<1 kpc and W<20 km/s, and a narrow distribution of [al/Fe].

3. There exist stars which cannot belong to the thin disk because of their excentric orbits, neither to the thick disk because of their low scale height.

4. Several thin disk stars are identified down to [Fe/H]=–0.80. Their Mg enrichment is lower than thick disk stars with the same metallicity.

5. The star formation in the thick disk stopped at [Fe/H]=–0.30, [Mg/Fe]=+0.20, [Si/Fe]=+0.17.

6. A vertical gradient in [alpha/Fe] may exist in the thick disk.

7. Both dwarfs and giants show a similar trend of [alpha/Fe] and Ni abundance with [Fe/H].

References

Baranne A., Queloz D., Mayor M., et al.: 1996, *A&AS*, **119**, 373.

Bensby T., Feltzing S., Lundstrom I.: 2003, *A&A*, **410**, 527.

Burbidge E.M., Burbidge G.R., Fower W.A., Hoyle F.: 1957, *Rev. Mod. Phys.*, **29**, 547.

Carlsson M.: 1986, *Uppsala Obs. Rep.*, **33**.

Fuhrmann K., Axer M., Gehren T.: 1995, *A&A* **301**, 492.

Galazutdinov G.A.: 1992, *Prepr. SAO RAS*, **92**, 27.

Gratton R.G., Sneden C.: 1987, *A&A*, **178**, 179.

Idiart T.P., Thévenin F.: 2000, *ApJ*, **541**, 207.

Korotin S.A., Andrievsky S.M., Luck R.E.: 1999a, *A&A*, **351**, 168.

Korotin S.A., Andrievsky S.M., Kostynchuk L.Yu.: 1999b, *Ap&SS*, **260**, 531.

Kovtyukh V.V., Soubiran C., Belik S.I., Gorlova N.I.: 2003, *A&A*, **411**, 559.

Kurucz R.L.: 1993, CD ROM n13.

Kurucz R.L.: 1992, *The Stellar Populations of Galaxies, Eds. B. Barbuy, A. Renzini, IAU Symp.*, **149**, 225.

Magain P.: 1989, *A&A*, **209**, 211.

Mishenina T.V., Kovtyukh V.V.: 2001, *A&A*, **370**, 951.

Nissen P.E., Gustafsson B., Edvardsson B., Gilmore G.: 1994, *A&A*, **285**, 440.

Prugniel P., Soubiran C.: 2001, *A&A*, **369**, 1048.

Reddy B.E., Tomkin J., Lambert D.L., Prieto C.A.: 2002, *MNRAS*, **340**, 304.

Shimanskaya N.N., Mashonkina L.I., Sakhibullin N.A.: 2000, *ARep*, **44**, 530.

Soubiran C., Katz D., Cayrel R.: 1998, *A&AS* **133**, 221.

Soubiran C., Bienaymé O., Siebert A.: 2003, *A&A*, **398**, 141.

Wallerstein G.: 1961, *ApJS*, **6**, 407.

Zhao G., Gehren T.: 2000, *A&A*, **362**, 1077.