Odessa Astronomical Publications, vol. 17 (2004)

THE MAGNESIUM ABUNDANCE IN THE THIN AND THICK DISK OF THE GALAXY

T.V. Nykytyuk[1] , T.V. Mishenina[2]

[1] Main Astronomical Observatory
Ak.Zabolotnoho St. 27, Kyiv 03680, Ukraine,*nikita@mao.kiev.ua*
[2] Department of Astronomy, Odessa State University
T.G.Shevchenko Park, Odessa 270014 Ukraine, *tamar@deneb.odessa.ua*

ABSTRACT. The chemical evolution of the thin and thick disk of our Galaxy was investigated in framework of the opened model with gas inflow. It was supposed that the thin and thick disks separate chemically and spatially and have different evolution timescales. The Galactic evolution of magnesium was investigated for the thin and thick disk. The obtained results allow us that the star formation history of the thin disk is more smooth and quiet than its for the thick disk of our Galaxy.A gas infall plays an important role in an appearance of chemical distinctions of relative abundances between the thin and thick disk - a inflow rate is more intensive for the thick disk.

Key words: Galaxy: evolution; Galaxy: abundances; Galaxy: thin disk; Galaxy: thick disk.

1. Introduction

Modern studies of a kinematics and ages of a stellar population of a disk of our Galaxy allow us to talk about a presence of two distinct populations in the disk named as the thick and the thin disk. The thin and thick disks has a different spatial and temporal characteristics (Gilmore & Raid 1983, Reyle & Robin 2001, Chen 1997, Fuhrmann 1998, Bensby et al. 2003, Robin et al. 1996). A metallicity distribution function of the thin and thick disk stars of our Galaxy has peak in a different values of metallicity (Wyse & Gilmore, 1995). It is found that the thick and thin disk trends are partly overlapped in the range $-0.8 < [Fe/H] < -0.4$ but they are separated in $[\alpha/Fe]$ where α are α-capture elements (Gratton et al. 1996, 2000; Fuhrmann 1998; Bensby et al. 2003, 2004) Furthermore, later investigations show that the two disk components are also separated in [Mn/Fe] and [Eu/Ba] (r- and s-process element ratio) (Nissen et al. 2000, Prochaska & McWilliam 2000).

Thus, our goal is to make clear a causes of distinction of a chemical characteristics of the Galactic disk subsystems.

2. The model

We consider the opened two-zone model of a chemical evolution of the disk (thick and thin) of our Galaxy. It is supposed that the thin and thick disks of our Galaxy are formed independently and the infall of intergalactic gas took place in the process of their formation. We will consider the Galactic evolution of the magnesium as an application of such model.

The idea of chemical evolution of a galaxy includes not only a temporal change of heavy element content in a galactic gas but also a temporal change of mass of gas and mass concluded into stars ans stellar remains.

A star formation process in a galaxy is considered as a sequence of bursts with a population of stars formed during each burst.

The contribution of elements, synthesized by a population of stars are described by Nykytyuk (2003) in detail. It will be noted that the Mg yield in the paper of Portinari et al. (1998) was determined from yields of Woolsey and Weaver (1995) which give the underestimated Mg value (see Thomas et al., 2000). Making use of Portinari's data in the calculation of a model of chemical evolution it was found that stars formed of a matter with the initial metallicity $Z < 0.15$ give a lower Mg yield in order to have possibility to reproduce the observed data. But stars with Z=0.15 give even more higher Mg yield; because we had to lower the predicted Mg yield from the stars with 9-15 $M_\odot$ above by a factor of 1.5 so that the model results be in good agreement with the observation data.

The star formation rate $\psi(t)$ in thick and thin disks is described in the following way (Pilyugin & Edmunds, 1996):

$$\psi(t) \sim \begin{cases} t \cdot e^{-t/T_{top}}, & \mathrm{t} \leq T_{top} \\ e^{-t/T_{sfr}}, & \mathrm{t} \geq T_{top} \end{cases}$$

where T_{top} amd T_{sfr} are free parameters of a star formation rate.

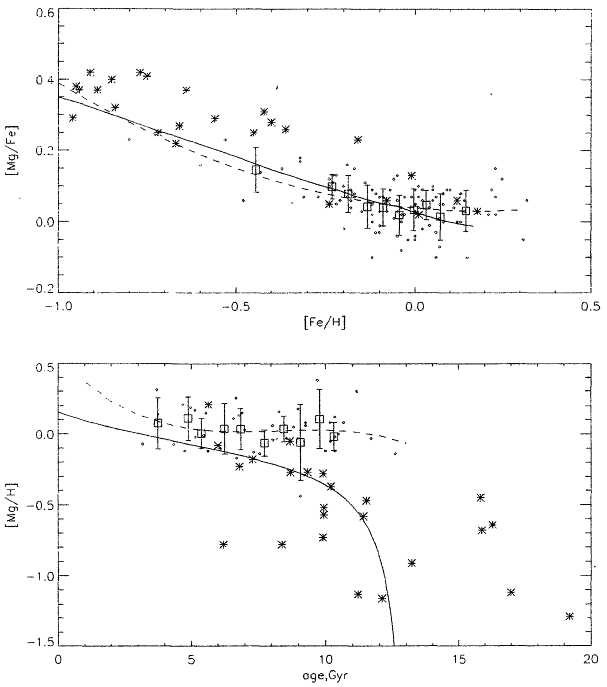

Figure 1: [Mg/Fe] vs [Fe/H] and [Mg/H] vs age diagrams for the thin disk of our Galaxy. The observed abundances of thin and thick disk stars of our Galaxy (Mishenina et al.(2004)) are marked by the small diamonds (the thin disk stars) and the asterisks (the thick disk stars). The squares are mean observed thin disk data in 10 bins with equal numbers of stars.Dashed line is curve drawn by the least-squares method in the observed data of the thin disk. The prediction for the thin disk is indicated by solid line

The star formation history is described by a set of star formation bursts whose amplitudes are derived from:

$$M_{b_i} = \int_{t_{i-1}}^{ti} \psi(t)\,dt, \qquad (1)$$

where time interval between t_i and t_{i-1} is a burst duration. It is supposed that a infall of intergalactic gas takes place on the disk during galaxy's life. According to Pilyugin & Edmunds (1996), the infall rate is described by a function

$$A(t) = a_0 e^{-t/T_{inf}},$$

where T_{inf} and a_0 are free model parameters.The accreted gas has primordial chemical composition.

The star formation histories of disk components were choosed in such a way as to order to a majority of thick disk stars has been formed 10-13 Gyr ago while thin disk stars would have ages less then 10 Gyr.

3. The results

The iron is predominantly synthesized by SNIa type (intermediate mass stars in binary systems), while α elements are synthesized by massive stars. Difference in the stellar lifes mean that α-element enrichment of interstellar medium takes place during several tens million yrs and the iron amount in the interstellar medium reaches to maximum in the first Gyr after beginning of star formation. This allows to use $[\alpha/Fe]$ ratio as an indicator of the star formation history (Matteucci, 1992). And as the $[\alpha/Fe]$ ratio of the thick and thin disk has a some distinctions we suppose that star formation histories of the disk components must be different. Therefore we will look for a such parameters of the star formation history and accretion rate whose use gives the possibility to reproduce the observed abundances of the thin and thick disk stellar population of our Galaxy.

3.1. The thin disk

Fig.1 represents the predictions of thin disk model. The ages in this paper were determined using the Bertelli (1994) isochrones. Model predictions demonstrated in Fig.1 were obtained at the following star formation parameters: $T_{top} = 1$ Gyrs and $T_{sfr} = 8$ Gyrs. The parameter T_{inf} determining the accretion rate equals 5 Gyrs. The amounts of parameters were choosed so that use of such parameters of the star formation and accretion rate would give the possibility to reproduce the observed data. It is assumed that the age of the disk of our Galaxy equals 13 Gyrs (Cowan et al., 1991).

As Fig.1 illustrates, the thin disk model with using of above-mentioned parameter values reproduces the [Mg/Fe] - [Fe/H] ratio quite well- the model track is agreed closely with the line drawn by the least- squares method through a cloud of points marked the positions of the thin disk stars on the [Mg/Fe]vs[Fe/H] diagrams. But the model don't reproduce the averaged observed data at the super-solar metallicities. The model prediction for element abundances as a function of time is noticeable worse – Fig.1 shows that the predicted abundances of the thin disk model are lower on average as compared with the Mishenina's observations.

Obtained values of parameters of the thin disk evolution are in a good agreement with parameters of the best fit model of Pilyugin and Edmunds (1996) having investigated the "age - [Fe/H]" and "age-[O/H]" ratios and the solar neighbourhood metallicity distribution function.

3.2. The thick disk

Predictions of the thick disk model are presented in the Fig.2. The following parameters of thick disk evolution were found: the star formation history $T_{top} = 1$ Gyr, $T_{sfr} = 5$ Gyrs, and the gas accretion rate $T_{inf} = 7$ Gyr. As Fig.2 shows, solid line of the prediction of

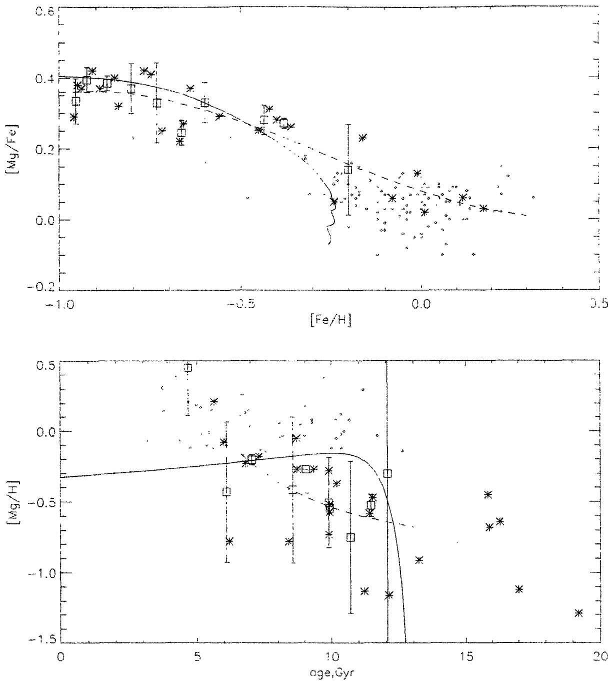

Figure 2: [Mg/Fe] vs [Fe/H] and [Mg/H] vs age diagrams for the thick disk of our Galaxy. The observed abundances of thin and thick disk stars of our Galaxy (Mishenina et al.(2004)) are marked by the small diamonds (the thin disk stars) and the asterisks (the thick disk stars). The squares are mean observed thick disk data in 10 bins with equal numbers of stars.Dashed line is curve drawn by the least-squares method in the observed data of the thick disk. The prediction for the thick disk is indicated by solid line

thick disk model is in agreement with dashed line obtained by the least-squares method from the results of observations of relative abundance of Mg of thick disk stars. Otherwise matter stands with an abundance determination as a function of time. Unfortunately, the number of stars belonging kinematically to the thin disk exceeds distinctly the number of stars belonging to the thick disk; among later there are not enough an objects for which one can surely determine the ages. Therefore, the trend in the "age - [Mg/H] " diagram for the thick disk stars is less obvious then its for the thin disk stars.

3.3. Star formation history

An index of star formation history in a model is a "gas fraction - time" relation since it indicates how fraction of a galactic gas was converted to a stars and during what time it will be.

The star formation history of the thick disk was rather quick as the majority of the thick disk stars was formed during 2 - 3 Gyrs and was almost stopped above 10 Gyrs ago (Fig.3). On the contrary, the thin

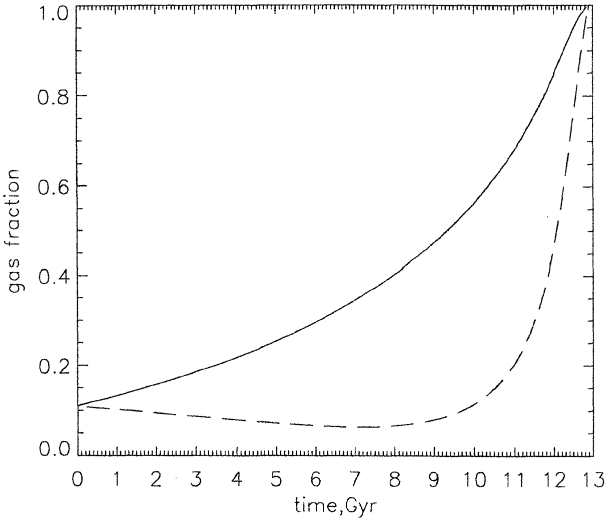

Figure 3: The gas fraction as a function of the time for thin (solid line) and thick(dashed line) disk

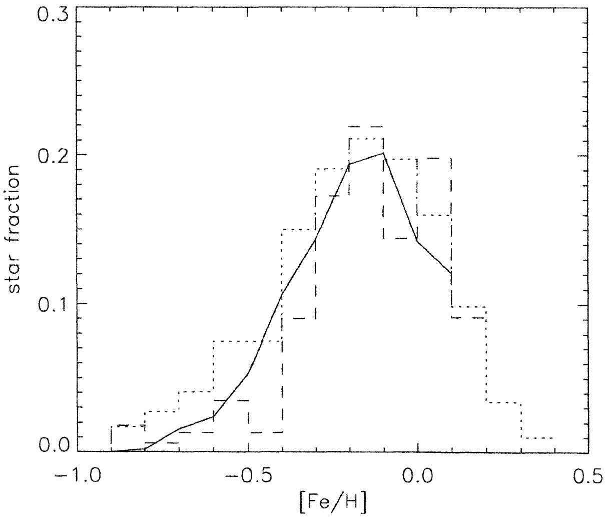

Figure 4: The metallicity distribution function. The dotted line is the observed distribution obtained by Hou et al.(1998), dashed line is the observed distribution obtained by Jorgensen (2000), solid line is the prediction of thin disk model

disk stars only begun to form 9-10 Gyrs ago, and a star formation in the thin disk gone smoothly , gradually coming to naught at our time.

It is necessary to note that the accretion of intergalactic gas have played a noticeable role in the evolution of the disk subsystems of our Galaxy. Model line of the relative abundances of the thin disk stars will change a location and approach to the thick disk star region if mass of gas infalling on the disk at the each accretion episode increases. In other words, the more massive accretion in a unit of time is characteric feature for thick disk evolution then for thin disk.

3.4. Metallicity distribution function

The prediction of model was compared with the observations of metallicity distribution function of the solar neighbourhood in Fig.4. It is known that 94 % of solar neighbourhood stars belong to the thin disk whereas remaining 6 % belong to thick disk population (Robin et al., 1996). Therefore the metallicity distribution function in Fig.4 was obtained in framework of the thin disk model. Under above-mentioned parameters of the star formation and gas accretion in the thin disk, solid line reproduces quite well the observed metallicity distribution function in the Fig.4.

4. Main results

1. It was found that the thin and thick disks has a different star formation rates. The thin disk star formation history is more smooth and quiet than its for the thick disk of our Galaxy.

2. A gas infall plays an important role in an appearance of chemical distinctions of Mg relative abundance between the thin and thick disk - a inflow rate is more intensive for the thick disk.

References

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

Bensby T., Feltzing S., Lundstrom I.: 2004, A&A **415**, 155.

Bertelli G., Bressan A., Chiosi C., Fagotto F., Nasi E.: 1994, A&A Supl.Ser. **106**, 275.

Chen B.: 1997 ApJ **491**, 181.

Cowan J.J., Thielemann F.-K., Truran J.W.: 1991, ARA/A **29**, 447.

Gratton R., Caretta E., Matteucci F., Sneden C.: 1996, In Formation of the Galactic Halo...inside and out, 1996, ed. H.Morrison, A.Sarajedini (San Francisco: ASP) **92**, P. 307.

Gratton R., Caretta E., Matteucci F., Sneden C.: 2000, A&A **358**, 671.

Fuhrmann K.: 1998, A&A **338**, 161.

Gilmore G. & Raid N.: 1983, MNRAS, **202**, 1025.

Hou J., Chang R., Fu C.: 1998, Pacific Rim Conference on Stellar Astrophysics, ASP Conf. Ser. **138**, P. 143.

Jorgensen B.R.: 1997, A&A **363**, 947.

Matteucci F.: 1992, MetSAIt **63**, 301.

Mishenina T.V., Soubiran C., Kovtyukh V.V., Korotin S.A.: 2004, A&A **418**, 551.

Nissen P.E., Chen Y.Q., Schuster W.J., Zhao G.: 2000, A&A **353**, 722.

Nykytyuk T.: 2003, KFNT, **19**, 259.

Portinari L., Chiosi C., Bressan A.: 1998, A&A **334**, 505.

Pilyugin L.S., Edmunds M.G.: 1996, A&A **313**, 783.

Prochaska J.X., McWilliam A.: 2000, ApJ **537**, L57.

Reyle C., Robin A.C.: 2001, A&A **373**, 886.

Robin A.C., Haywood M., Creze M., Ojha D.K., Bienaumé O.: 1996 A&A **305**, 125.

Thomas D., Greggio L., Bender R.: 2000, The Evolution of the Milky Way: stars vs clusters, ed. by Matteucci F. & Giovanelly F., p.541.

Woosley S.E., Weaver T.A.: 1995, ApJS **101**, 181.

Wyse R.F.G., Gilmore G.: 1995, AJ **110**, 2771.