EVOLUTIONARY CHANGES OF THE KINEMATICS OF THE GALACTIC THIN DISK STARS IN THE SOLAR NEIGHBORHOOD

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ABSTRACT. According to the data of Nordstrőm et al. (2004) catalog is carried out the comparative analysis of the velocity ellipsoid parameters of the galactic disk stars of different metallicity and the character of their change from the age is investigated. It is shown, that dispersions of all three components of spatial velocities increase with age, submitting to the power law $\sigma_i \sim t^{0.26}$, i. e., exponent proved to be beyond the ranges of errors less than previously usually obtained It is discovered a difference in the values of the semiaxes of velocity ellipsoids between stars with the metallicity more and less [Fe/H] ≈ -0.3, which can evidences about a difference in the dynamic state of the matter, from which they were formed. It is established that the form of the velocity ellipsoids of the stars of different metallicity in the course of time does not change – ellipsoid simply increases in the sizes and is turned. After exception of the stars of the moving groups the character of dependences on the age of the velocity ellipsoids parameters did not undergo the significant changes.

Key words: Galactic disk, velocity ellipsoid, moving groups.

Introduction

The observable morphological structure of the thin disk of our Galaxy, as well as any its other subsystem, is obliged to exclusively instantaneous shapes of orbits of the stars entering into it. Therefore the "external" form of the Galaxy can be recreated on the total three-dimensional velocities of the stars located even in the nearest vicinity of the Sun. It is simultaneously possible to attempt to trace the dynamic evolution of the thin disk subsystem on the stars of different age. A research of the dependences of the velocity ellipsoid parameters of nearest stars on the age is the classical method of the extraction of such information.

The properties of velocity ellipsoids can serve as a key for solving of both the problem of stationarity and the relaxation, and also they can shed light to the most important questions of star formation. If in the Galaxy effective relaxation mechanism acts, thus it should lead system to the steady state, in which the form of velocity ellipsoid depends only on rotation curve. But if the relaxation is insufficiently effective, then the relations of the semiaxes of ellipsoid can differ from steady-state values and should depend on the mechanism of relaxation.

Character of dependences between the age and the velocity dispersions in close field stars was investigated in many works on the basis of contemporary astrometric and spectroscopic measurements. In this case the exponent on the different samples of stars occurred within the limits from $\gamma \approx 0.33$ (Binney et al., 2000), to $\gamma \approx 0.5$ (Funch et al., 2001; Holmberg et al., 2007). Unfortunately, in all these works the dependence was built on all close field stars, among which is present a noticeable quantity of stars of the thick disk.

For obtaining the correct results it is necessary to remove stars of so-called Eggen moving groups from the sample of thin disk stars also. It is known, that in the Solar vicinity about third of stars it is possible to identify by members of various moving group. All these streams distort the velocity field of field stars of different age and hamper the extraction of the information, necessary for restoration of dynamic evolution of the Galaxy.

In order to verify, they do have an effect on the values of dispersions existence of the moving groups in the disk, we calculated the values of velocity ellipsoids both according to all field stars and after excluding the stars of the moving groups. In connection with much discussed recently existence of very old and simultaneously metal rich stars we traced also a change in the parameters of ellipsoids for the stars of the thin disk of different metallicity.

As the basic source the Geneva-Copenhagen catalog,

which contains ages, metallicity and kinematics for 14000 F–K- dwarfs (Norstrőm et al., 2004) was used. This catalog contains the stars not only of the thin disk subsystem, but also of the thick disk of the Galaxy. To select the stars of the thin disk it is necessary to use any criterion, however the unique and sufficient criterion there does not exist. The criterion used by us calculates the probabilities of a belonging of star to the thin disk subsystem against the alternative of belonging of it to the thick disk. Procedure of the calculation of the corresponding probabilities, which are based on the values of the dispersions of the components of the three-dimensional velocities $(\sigma_U, \sigma_V, \sigma_W)$ and the average rotational velocities of a subsystems (V_{asym}), is developed in Bensby, et al. (2003). As a result we receive the sample, for which probability of a belonging of stars to the thin disk above probability of their belonging to the thick disk subsystem. Then from the sample were removed the noted in the catalog binary stars, far evolutionized stars $(\delta M_V > 3^m)$ and star uncertainly obtained ages $(\epsilon t > \pm 3$ Gyr), as a result in the our sample remained 5116 single stars of the thin disk. For the account of influence of stars of moving groups on integrated kinematic parameters of stars of the thin disk we have counted sufficient to exclude from the sample of a star of the largest known streams. Such proved to be about 12 % of stars from the entire sample.

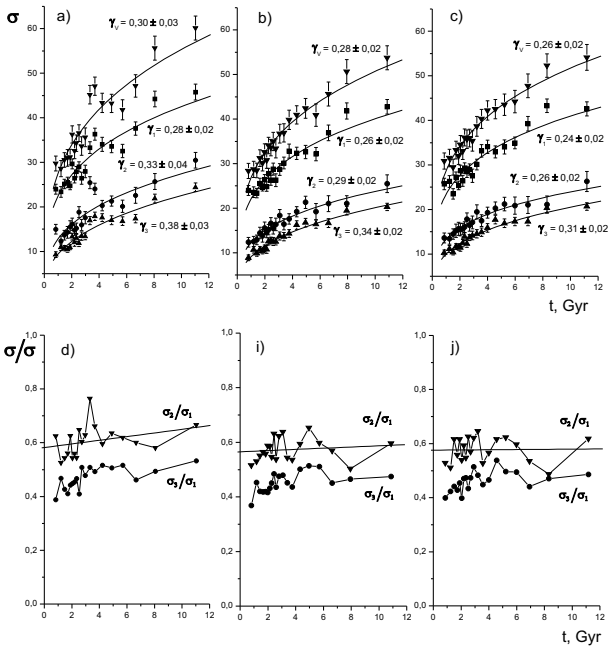

Figure 1: Relation semiaxes values of the stellar velocity ellipsoids (1a,1b,1c) and relationship of semiaxes values (1d,1i,1j) of age.

Results and discussions

Special interest was caused always the dependence of the velocity dispersion of starry populations on their age $\sigma_V(t)$, since by the character of this connection it is possible to judge whether there was a relaxation in the galactic disk and even to specify the mechanism, which increases in this case the peculiar velocities of stars. From the size of an exponent it is possible to judge the character of the heterogeneities of the gravitational potential of the Galaxy, which lead to a continuous increase in the velocity dispersion of the stars which have born simultaneously, that is to their "warming up".

On the panel (a) of Figure **??** are given the dependences of $\sigma_i \sim (t)$ for all close stars, while on the panel (b) – for the selected stars of the thin disk. All dependences by the method of least squares are approximated by the power law of the form of $\sigma_i \sim t^{\gamma}$. One can see well, that although the character of dependences was kept, but sizes of all exponents γ for the similar dispersions have noticeably decreased. And if for all close stars the values of exponents have turned out coincided with obtained usually by other authors and are equal on the average $\langle\gamma\rangle = 0.32 \pm 0.04$, then for the correctly selected stars of the thin disk all indices became somewhat less $\langle\gamma\rangle = 0.29 \pm 0.03$. An additional research showed that the application of a less strict criterion leads only to the small overstating in the oldest groups only of value of major semiaxis, whereas average and minor semiaxes remain in them constant. The exponents of all dependences within the limits of errors also did not change. In Fig. **??** c the age-semiaxes diagram for the thin disk stars without the moving groups are given. From the figure one can see that the exception of star streams has in turn led to the small (again within the ranges of errors) decrease of the values of all semiaxes of the star subgroups of each age – all dependences were simply displaced downward to themselves. As a result the exponents of all dependences still decreased up to the average value $\langle\gamma\rangle = 0.26 \pm 0.03$ and began to differ already beyond the ranges of errors from those receiving on all close stars.

Interest causes also the relation of semiaxes, mainly the ratio of average axis to the large one. In the second row of Figure **??** the dependences on the age of the values of the relations of semiaxes for all close field stars, for the stars of the thin disk and for the thin disk stars without the moving groups are consistently given. From the figure one can see that the values of the relations of semiaxes in the appropriate subgroups of different age practically did not change. Approximation by the direct regressions of variation on the age of these relations did not reveal the statistical significant trend. As a result it is possible to conclude that the form of the velocity ellipsoid of the stars of the thin disk does not depend on age.

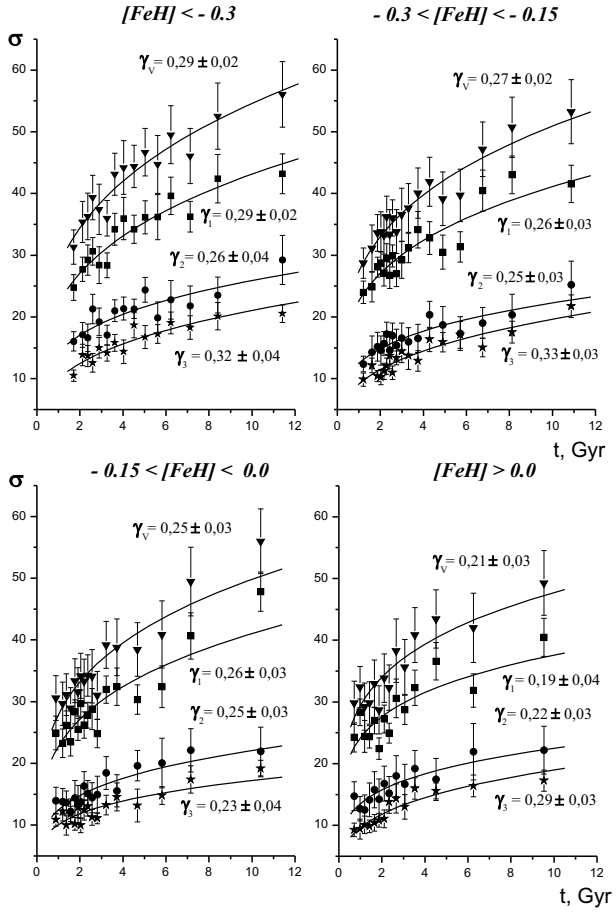

Figure 2: Relationship between the semiaxes values of the stellar velocity ellipsoids of different metallicity and age.

On (Fig. **??**) changes in the values of the semiaxes of the velocity ellipsoids of the stars of different metallicity from age are shown. It is evident from the figures that the behavior of all semiaxes is approximately identical. As well as generally, this change is described by power law with the same exponent $\langle\gamma\rangle = 0.26 \pm 0.06$.

We will note that most metal poor stars demonstrate the greatest sizes of semiaxes at any age. It seems that metal poor stars are formed from the matter of that falling into the galactic plane from the external parts of the Galaxy.

Conclusions

The properties of the velocity ellipsoid parameters of the thin disk stars in the dependence on the age and the metallicity are investigated. It is shown that a change in the course of time in the values of all ellipsoid semiaxes of star of different metallicity, are described by power law with the approximately identical exponent $\langle\gamma\rangle = 0.26 \pm 0.02$. This result contradicts the results, obtained in other works, where the index is located in the range $(0.33 - 0.50)$. It is discovered, that the semiaxes size of the thin disk stars with metallicity [Fe/H] ≤ -0.30 at any age have more than ones of more metal rich stars. Investigating chemical composition in the thin disk, we have found out that among so metal poor stars appears much with the anomalously high relative contents of magnesium (Marsakov, Borkova, 2006). Presence of the metal poor stars with different kinematics and the relative content of magnesium testifies in favor that these stars could be formed from the matter, which fell into the thin disk as a result of accretion from the regions with another history of chemical evolution. In this case the parameters of the velocity ellipsoids of the stars of different metallicity can reflect the state of interstellar medium at the moment of their generation. It is finally shown that the velocity ellipsoids of the thin disk stars are far from on state of equilibrium and depend neither from the age nor from the metallicity – ellipsoids simply vary in the sizes and are turned.

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