THE LOCAL DWARF GALAXIES:BUILDING BLOCKS OF MASSIVE ONES? I.THE FORNAX DWARF GALAXY

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ABSTRACT. A chemical evolution of the Local Group dwarf galaxy Fornax is considered in the framework of the merger scenario. We suppose a galactic stellar halo to be formed as separate fragments which then merge; thus, we can calculate the set of such the fragments to reproduce the observed metallicity distribution function of a galaxy. Accordingly, if dwarf galaxies were such the systems, which, once merged, have formed massive galaxies, we need to obtain only one fragment to reproduce the observed metallicity distribution function of a dwarf galaxy. To test this assumption, the stellar metallicity distribution functions of Fornax was calculated in the framework of the merger scenario. The more than one fragment was obtained for galaxy under consideration; thus, it is unlikely the systems similar to Fornax to be building blocks of massive galaxies.

Key words: galaxies: merger; galaxies: Local dwarfs; Fornax: metallicity distribution function.

1. Introduction

The theory of hierarchical clustering of galaxies considers the formation of massive galaxies by merger of smaller ones. As it shown in our previes works (Nykytyuk, 2004; 2008), massive spiral galaxies in Local Group could be formed by merger of individual fragments; two of them (M31 and M33) were formed by merger of 2 fragments only. It is natural to suppose the systems like Local dwarf galaxies to be building blocks of massive ones.

The Fornax dwarf galaxy is one of the most massive and luminous of the dwarf galaxy satellites of our Galaxy. The Fornax stellar population is quite metal-rich as for a dwarf galaxy; Pont et al. (2004) found a metallicity distribution of Fornax centered at [Fe/H] = - 0.9 with metal-rich population reaching [Fe/H]=-0.4. Thus, the system like Fornax galaxy could be building blocks for M31 and M33 galaxy formation.

Our goal is to analyze a possibility for Fornax dSph to be a fragment for formation of more massive galaxies and to study the chemical evolution of this galaxy.

2. The merger scenario

We suppose that the halo stellar population is composed of a mixture of stars that were formed in fragments originally evolving independently from the main protogalactic cloud and/or from each other. Hence, there should be a set of fragments whose total stellar populations reproduce the observed stellar halo metallicity distribution.

The mass of fragments from which the halo is formed, to equal the sum of the masses of their stellar population and the gas fallen onto the disk up to the present epoch. The star formation process in different fragments can begin at different times. A fragment can evolve up to a given astration level s before falling onto a protogalaxy.The stars formed up to this moment replenish the halo stellar population, and the gas falls onto the galactic disk. Fragments can be captured by a protogalaxy before a stellar population is formed, i.e. fragments composed completely by gas can be captured.

Let a_j - number of stars finding in a range of metallicities Z_j, $Z_j + \Delta Z_j$ in a fragment with mass m. Then an observable amount of halo stars finding in a range of metallicities Z_j, $Z_j + \Delta Z$ will be represent an total amount of stars $N_{Z_j} = a_j \sum_{i=1}^{n} m_i$ of a given metallicity Z_j from all fragments whose the maximum metallicity exceeds Z_j. For given set of metallicities we have

$$\begin{aligned} a_1 \cdot m_1 + a_1 \cdot m_2 + a_1 \cdot m_3 + \ldots + a_1 \cdot m_n &= and N_{Z_1} \\ a_2 \cdot m_2 + a_2 \cdot m_3 + \ldots + a_2 \cdot m_n &= and N_{Z_2} \\ \vdots \quad & \quad \vdots \\ a_n \cdot m_n &= and N_{Z_n} \end{aligned} \tag{1}$$

Thus, the fragment with the high astration level s determines a number of stars a_n with the greatest value of a metallicity Z_n. Having solved a set of equations (1), it is possible to obtaine masses of fragments with maximum metallicities of stars from Z_1 up to Z_n (i.e. number of fragments falling on given Z_j and responsible for halo stars with such metallicity). Thus, using observed metallicity distribution of halo stars and

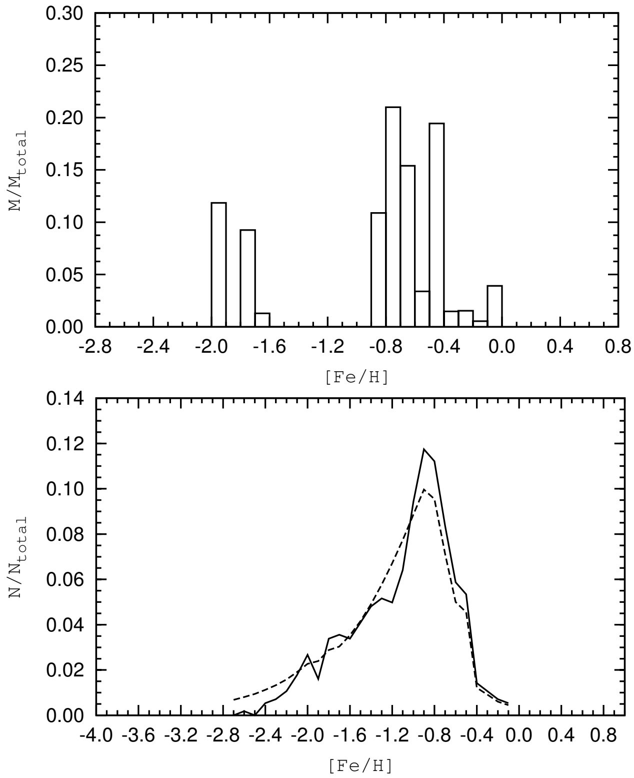

Figure 1: The masses and metallicities of merging fragments(top panel); the comparison of observed (solid line, Battaglia et al. 2006) and modelled (dashed line) halo metallicity distribution functions of Fornax (bottom panel).

model of evolution of a single fragment we shall obtaine a value of an total mass of all fragments evolved up to each given value of astration level s. The chemical evolution of a fragment is described in details in the paper of Nykytyuk (2008).

In order to compare the calculated and observed metallicity distribution functions, we have used the Kolmogorov - Smirnov criterion of convergence of two distributions. The significance level σ denotes the coincidence level of two distribution: a small values of σ indicates that the data samples have different probability distributions.

3. The results: merger vs. monolitic evolution

We suppose that the halo stellar population is the sum of stellar populations of separate fragments. If using the observed metallicity function for Fornax under solving the set of equations (1) we would obtain one fragment only, this means that the systems like Fornax could be building blocks of Local Group massive spirals.

But our results show that the Fornax metallicity distribution function can be reproduced by merger of

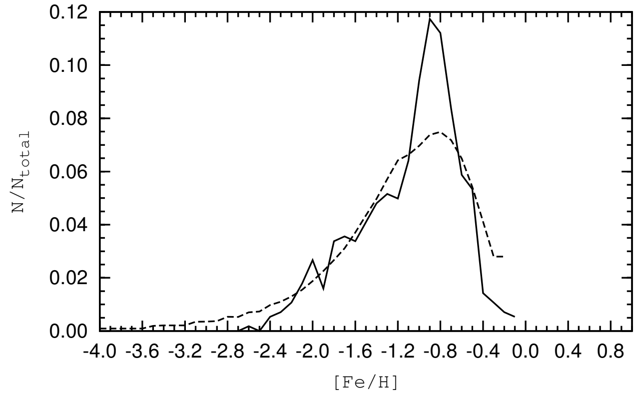

Figure 2: Monolitic evolution: the comparison of observed (solid line, Battaglia et al. 2006) and modelled (dashed line) halo metallicity distribution functions of Fornax.

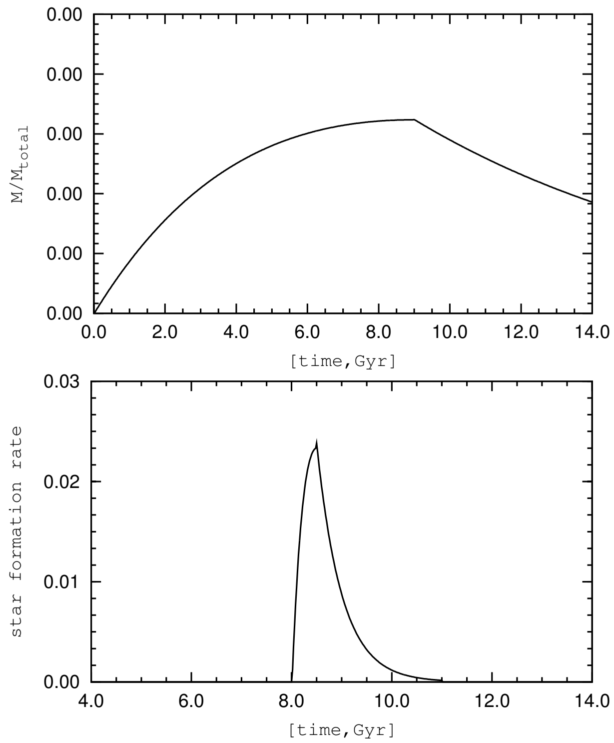

Figure 3: The star formation rates: the case of merger (top panel) and monolithic evolution (bottom panel).

twelve fragments, Fig.1; metallicity dispersion of the obtained set of fragments rather high. The shape of the metallicity distribution function of a halo stellar population depends on the characteristics of the fragments which have formed the halo of Fornax. The evolution of fragments before merger is considered in the framework of closed model of chemical evolution with SNIa yields. The star formation history in a single fragment before merger is shown in Fig.3. In the case of merger scenario the criterion of convergence ~ 0.93.

For comparison, we have investigated monolithic evolution of the Fornax dwarf galaxy, Fig.2. The metallicity distribution function have been obtained in the framework of closed chemical evolution model without SNIa yields. In this case we have no need to use the SNIa yields in our model because the star formation passes during 3 Gyr only; thus, SNIa has no enough time to contribute the main mass of iron into interstellar medium of Fornax. The star formation history in the case of monolitic evolution is shown in Fig.3. In this case the criterion of convergence ~ 0.74.

Thus, one can see that the merger scenario better reproduces the observed metallicity distribution function of Fornax than the monolitic scenario; the using of the latter don't allow to reproduce the central part of the observed metallicity distribution function quite well, Fig.2. Battaglia et al. (2006) found a different kinematic behavior of metal-rich and metal-poor stars. They interpreted this fact as recent capture of external material by Fornax. Authors argue that part of the object accreted by Fornax must have been dominated by stars more metal poor than [Fe/H] < -1.3.

4. Main results

The Fornax metallicity distribution function can be reproduced by merger of more than one fragment; I.e. the systems like Fornax could not be building blocks of massive galaxies. Probably, the merger did play role in the formation of the Fornax dwarf galaxy; the merger scenario represents the observed metallicity distribution function better than the monolitic scenario. To reproduce the observed metallicity function of the Fornax, it need the twelve fragments evolved as closed systems. To reproduce the metallicity distribution function in the framework of monolitic scenario, it's enough to use the closed box model as in the merger scenario.

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