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CHEMICAL EVOLUTION OF MILKY WAY TYPE GALAXIES IN THE MILLENNIUM SIMULATION

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RESUMEN

En este trabajo utilizamos la Simulación del Millennium, la cual constituye hasta el momento la mayor simulación de formación de la estructura, combinada con el modelo semi-analítico de De Lucia & Blaizot (2007), para seguir la evolución química de galaxias semejantes a la Vía Láctea con el objetivo de entender su nivel de enriquecimiento químico y la dispersión en la correlación masa-metalicidad. Nuestros resultados sugieren que los sistemas semejantes a la Vía Láctea tienden a evolucionar en forma pasiva con el tiempo sin sufrir acreción de masa significativa. El enriquecimiento químico de estos sistemas parece estar dado principalmente por el enfriamiento del gas, la eficiencia de formación estelar y para los progenitores más masivos por el *feedback* por AGNs.

ABSTRACT

In this work we make use of the Millennium Run, which is at the moment the largest high-resolution simulation of structure formation ever carried out, combined with the semi-analytical model of De Lucia & Blaizot (2007), to follow the chemical evolution of Milky Way type galaxies with the aim at understanding their level of enrichment and the dispersion in the mass-metallicity correlation. Our results suggest that Milky Way type systems tend to evolve passively with time without suffering significant mass accretion. The chemical enrichment of these systems seems to be driven mainly by gas cooling, star formation efficiency and for the most massive progenitors by AGN feedback.

Key Words: cosmology: theory — galaxies: abundances — galaxies: evolution — galaxies: formation

1. INTRODUCTION

In the local Universe, there is a well-defined correlation between the stellar masses of galaxies and their chemical properties, in such a way that more luminous and more massive galaxies are more enriched (Tremonti et al. 2004; Lee et al. 2006). Moreover, this correlation tends to evolve with time in such a way that, at a given stellar mass, systems at higher redshifts show lower abundances (Savaglio et al. 2005; Erb et al. 2006).

In recent years, with the development of more sophisticated numerical codes and semi-analytical models, it has been possible to follow the chemical enrichment of galaxies in a cosmological framework (e.g., Tissera et al. 2005). In particular, De Rossi et al. (2007) employed cosmological hydrodynamical simulations to follow the chemical enrichment of galaxies in a hierarchical scenario finding that the luminosity-metallicity and the mass-metallicity relations are naturally generated as a consequence of the hierarchical building up of structure.

In this work, we employ the Millennium Simulation of structure formation to follow the chemical evolution of Milky Way type galaxies in the mass-metallicity plane with the aim at understanding the implication of their formation history on their current level of enrichment and the origin of its dispersion.

2. THE GALAXY CATALOGUE

We employed the galaxy catalogue generated by the implementation of the semi-analytical model for galaxy formation of De Lucia & Blaizot (2007) on the Millennium Simulation (Springel et al. 2005), which is available on-line from the public database of the Millennium Run (Lemson & the Virgo Consortium 2006). The evolution of $N = 2160^3$ collisionless particles is followed in a periodic comoving box of 500 Mpc h^{-1} on a side with a resolution in mass of $8.6 \times 10^8\ M_\odot\ h^{-1}$. The cosmological model is consistent with a concordance ΛCDM universe.

The semi-analytical model includes treatment for star formation, gas cooling, Supernova feedback and

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active galactic nucleis (AGNs) among others. For details about the model the reader is refered to Croton et al. (2006) and De Lucia & Balizot (2007).

From the full galaxy catalogue of De Lucia & Blaizot (2007) we selected a sample of Milky Way type galaxies (MWS) as central galaxies of their dark matter halos, with circular velocities in the range 200–240 km s^{-1} and with total-to-bulge ratios between 1.5 to 2.6, which corresponds to a spiral morphology according to Simien & de Vaucouleurs (1986). For the sake of comparisson we also follow the evolution of a sample of dwarf irregular systems (DIS) and giant elliptical ones (GES). The GES is constituted by galaxies with stellar masses $M_* > 10^{11}\ M_\odot$ and total-to-bulge ratios lower than 0.4, while the DIS is made of systems with $10^9 < M_* < 10^{9.5}\ M_\odot$ and without a bulge component. We requested their dark matter halos to have at least 100 particles.

3. RESULTS AND DISCUSSION

We found that the full galaxy catalogue of De Lucia & Blaizot (2007) exhibit a clear correlation between stellar mass and chemical content. For small and intermediate masses, metallicity tends to grow with stellar mass which is consistent with the observational trend. However, at the massive end, simulated galaxies have lower abundances than those expected from observations. This is in part due to the strong AGN feedback adopted in this model which becomes more efficient stopping cooling processes for more massive systems.

Milky Way type galaxies with $M_* \sim 10^{11}\ M_\odot$ lie on the turn over of the relation with a dispersion of 0.1 dex at redshift $z = 0$. However, the MWS shows an important spread in the mass-metlallicity plane at $z > 0$. In particular, at $z = 3$ this sample have metallicities ranging from -1 to 0.7 dex and stellar masses covering the range from 10^8 to $10^{11}\ M_\odot\ h^{-1}$, but all these systems get to a tighter relation by $z = 0$. By analysing the merger histories of these galaxies we found that this fact is related to the different evolution of more massive progenitors with respect to smaller ones (De Rossi et al., in preparation). More massive systems at $z = 3$ evolve more smoothly from $z = 3$ to $z = 0$ because of their low star formation efficiency due to the fact that they already transformed most of their gas into stars. On the other hand, less massive ones exhibit higher gas fractions and higher star formation rates which lead to a more important chemical evolution at $z > 1$. We also found that gas-poor progenitors at $z = 3$ have completed most of their accretion history by this redshift, while gas-rich ones accreted a factor of two more stellar mass at $z > 0$ than the former ones.

By analysing the mean accretion history for all Milky Way type progenitors we found that by $z = 0$ the total accreted stellar mass in these systems corresponds to approximately 15% their present stellar mass, which means that more than 80% their stellar mass at $z = 0$ have been formed in the main progenitors. We also encountered that these systems suffer no significant interaccions along their formation paths. Hence, the simulated MW-type systems may be described by a main progenitor which evolves passively through minor accretions.

In the case of the GES, we encountered that simulated galaxies accreted around 50% their stellar mass at $z = 0$, while dwarf irregular galaxies have no significant merger histories (De Rossi et al., in preparation). These different formation scenarios have important implications on chemical evolution. Giant elliptical systems reach $z = 0$ with negligible gas fractions, which means that these systems have died and are only able to evolve in the mass-metallicity plane via mergers. On the other hand, dwarfs irregular galaxies have gas fractions ranging from 0.2 to 0.8 at $z = 0$, hence they may be consider star-forming galaxies which could suffer important changes in their chemical content. For MW-galaxies we obtained gas fractions of ~ 0.1 at $z = 0$, which are low for feeding futher significat starbursts.

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