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Stellar metallicity gradients in simulated disc galaxies

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Abstract. Stellar metallicity gradients provide information on the assembly of disc galaxies, on star formation processes and on chemical evolution. The evolution of the gradients over time also holds clues on dynamical processes, such as migration, which could mix stars a posteriori affecting the distribution of chemical elements in the stellar components. We aim to investigate the metallicity gradients of the whole stellar populations in the disc component of simulated galaxies in a cosmological context. For low-redshift galaxies, we explore the dependence of the stellar metallicity gradients on stellar ages, sizes, and mass of the stellar discs. We also focus on exploring their evolution since $z = 1$. We analyse simulated disc galaxies from a cosmological hydrodynamical simulation which includes chemical evolution and a physically motivated supernova feedback. We compare our simulated galaxies to results from the CALIFA survey. We find that the simulated stellar discs have metallicity profiles with slopes in global agreement with observations. As a function of redshift, we detect a mild evolution in the metallicity gradients, in the sense of slopes becoming flatter since $z = 1$.

Resumo. Gradientes de metalicidade estelar proporcionam informações sobre a formação de galáxias, sobre processos de formação estelar e sobre evolução química. A evolução temporal dos gradientes também traz pistas sobre processos dinâmicos, como migração, que pode misturar as estrelas a posteriori, afetando a distribuição de elementos químicos na componente estelar. Nosso objetivo é o estudo dos gradientes de metalicidade de todas as populações estelares dos discos de galáxias simuladas em um contexto cosmológico. Para galáxias em baixo redshift, exploramos a dependência dos gradientes com idades, massas e tamanhos do disco estelar. Também exploramos sua evolução desde $z = 1$. Analisamos galáxias simuladas provenientes de uma simulação cosmológica hidrodinâmica que inclui evolução química e um feedback de supernovas fisicamente motivado. Comparamos nossas galáxias simuladas com resultados do survey CALIFA. Encontramos que os discos estelares simulados apresentam gradientes globalmente em acordo com as observações. Em função do redshift, detectamos uma evolução suave dos gradientes, no sentido de se tornarem mais planos desde $z = 1$.

Keywords. Galaxies: abundances – Galaxies: evolution – Galaxies: stellar content – Methods: numerical

1. Introduction and Methods

The chemical abundances of stars hold relevant information to understand the history of galaxy assembly. Both observational and theoretical results indicate the presence of metallicity gradients, whose origins may be linked to the effects of gas inflows and outflows that regulate chemical abundances and star formation activity (e.g. Chiappini et al. 2001; Mollá & Díaz 2005; Gibson et al. 2013; Mott et al. 2013).

We analyse the stellar populations of galaxies whose gas has been studied by Tissera et al. (2016). The disc galaxies were selected from a cosmological simulation that was carried out with a version of the code GADGET-3, an update of GADGET-2 Springel (2005). This version includes treatments of chemical enrichment, a multiphase model for the ISM, metal-dependent radiative cooling, stochastic star formation, and the supernova feedback scheme of Scannapieco et al. (2005, 2006). Th initial conditions of the simulation are consistent with the concordance cosmology with $\Omega_\Lambda = 0.7$, $\Omega_m = 0.3$, $\Omega_b = 0.04$, the normalization of the power spectrum of $\sigma_8 = 0.9$ and Hubble constant of $H_0 = 100h\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$, with $h = 0.7$. The simulation volume is a box of 14 Mpc (comoving) side, resolved with 2×230^3 initial particles.

2. Results

An illustrative example of one massive galaxy from the simulation is given in Fig. 1. For the disc component, it shows the projected stellar mass density, the oxygen abundace of the stars and the ages of stars.

We find that the simulated stellar discs have metallicity profiles with slopes in global agreement with observations. Low-mass galaxies tend to have a larger variety of slopes. The stellar metallicity gradients correlate with the half-mass radius more strongly than with stellar mass. Fig. 2 shows the gradients obtained from the galaxies in our simulation compared to the observational results of the CALIFA survey (Sánchez-Blázquez et al. 2014). They were measured with the region $[0.5–1.0]r_{\rm eff}$. In the lower panel, the gradients are normalized by the effective radius of each galaxy.

As a function of redshift, we detect a mild evolution in the metallicity gradients, in the sense of slopes becoming flatter. Fig. 3 shows the evolution of the metallicity gradients since $z \sim 1.5$, comparing our simulation results with observational estimates of the Milky Way Maciel et al. (2003). We also resort to an archaeological estimation of metallicity gradients in the simulation. This is done by defining mono-age stellar populations within the $z \sim 0$ snapshot of the simulation. For further details, see Tissera et al. (2016, 2017).

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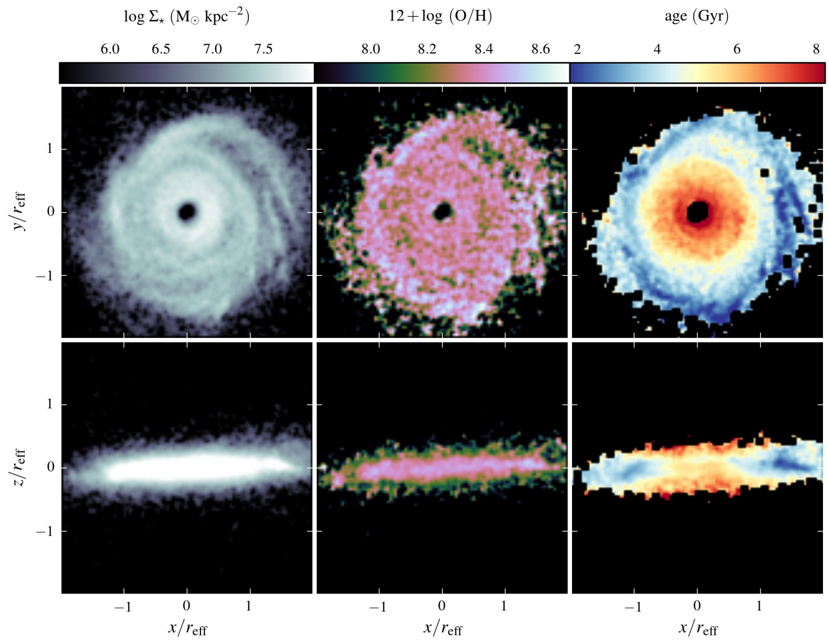

Figure 1. Example of a galaxy from our cosmological simulation, showing only the stellar disc component. The panels display the projected surface density, the oxygen abundance, and the ages of stars, each viewed both face-on and edge-on.

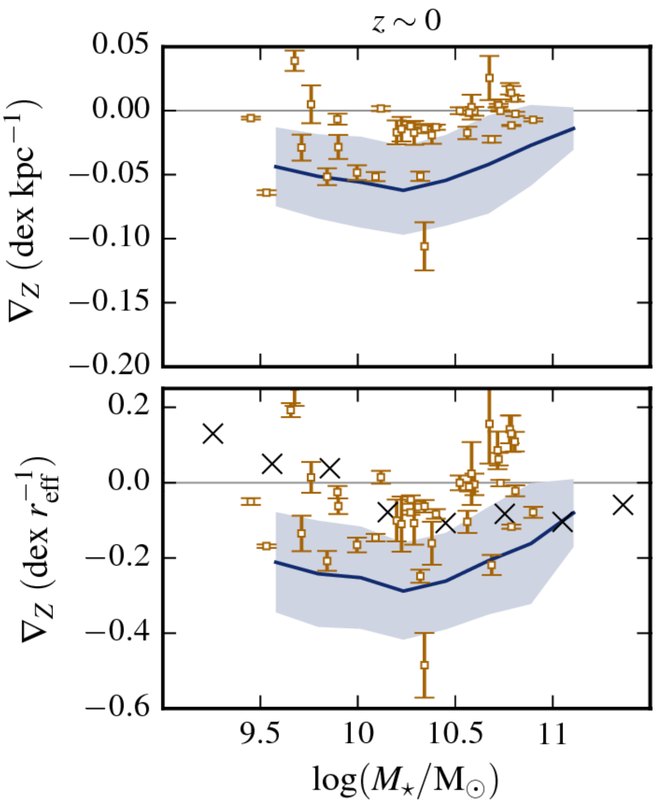

Figure 2. Metallicity gradients as a function os stellar mass, at redshift $z \sim 0$. The simulation means and dispersions are given by the solid lines with shaded areas. The yellow points are the observational results from the CALIFA survey Sánchez-Blázquez et al. (2014). The crosses in the lower panel are from González Delgado et al. (2015). In the lower panel, the gradients are normalized by the effective radius of each galaxy.

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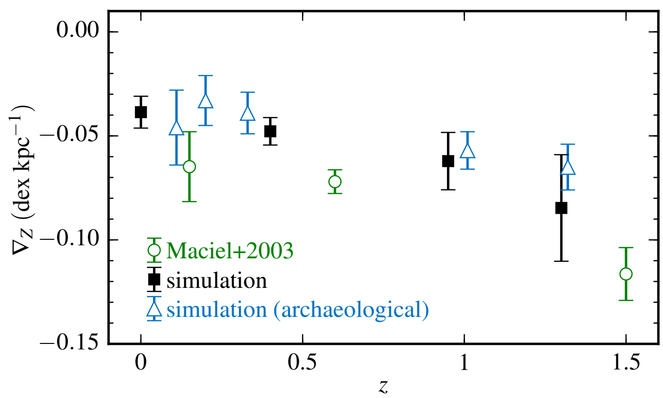

Figure 3. Evolution of the metallicity gradients. The green circles are estimates of the Milky Way from Maciel et al. (2003). The black squares are the gradients as a function of redshift from our simulations. The blue triangles are the archaeological gradients from the simulation.

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