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Chemo-dynamical signatures in simulated Milky Way-like galaxies

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Abstract. We have investigated the chemo-dynamical evolution of a Milky Way-like disk galaxy, AqC4, produced by a cosmological simulation integrating a sub-resolution ISM model. We evidence a global inside-out *and* upside-down disk evolution, that is consistent with a scenario where the "thin disk" stars are formed from the accreted gas close to the galactic plane, while the older "thick disk" stars are originated *in situ* at higher heights. Also, the bar appears the most effective heating mechanism in the inner disk. Finally, no significant metallicity-rotation correlation has been observed, in spite of the presence of a negative [Fe/H] radial gradient.

Keywords. Galaxy: abundance, evolution, structure, kinematics and dynamics

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In order to study the chemo-dynamical signatures related to the galactic formation processes, we have analyzed a new ΛCDM cosmological simulation, AqC4, carried out with the GADGET-3 TreePM+SPH code, where star formation, chemical evolution and stellar feedback are described using a sub-grid Multi Phase Particle Integrator (MUPPI) model. The main parameters of this simulation are listed in Table 1, while further details on the model are described by Murante *et al.* (2015).

The morphology of AqC4 at redshift $z = 0$ is well represented by the three main stellar components of a Milky Way-like galaxy (i.e. bulge/spheroid, thin and thick disk). An extensive analysis of the spatial, kinematic, and chemical properties of AqC4 is presented by Giammaria (2017), who confirmed that the 6D $(\mathbf{x}, \mathbf{v})$ stellar distribution is similar to that observed in the Milky Way. The main difference is the presence of a more massive bulge (B/T=0.34), which also causes a faster rotation velocity ($V_\phi \sim 270$ km/s at $R \simeq 5 - 10$ kpc). Morever, the metallicity distribution of the stellar halo results a few dex higher than that of the Galactic halo.

However, the overall evolution of AqC4 appears quite consistent with similar studies based on independent simulations (e.g. Minchev *et al.* 2012, Bird *et al.* 2013, Martig *et al.* 2014, Ma *et al.* 2017).

Table 1. AqC4 parameters. $M_{\rm DM}$: mass of DM particles; $M_{\rm gas}$ initial mass of gas particle; ϵ = smoothing parameter; $M_{\rm vir}$ and $R_{\rm vir}$: DM mass and virial radius at redshift z=0; $N_{\rm DM}, N_{\rm gas}, N_{\rm star}$: number of DM particles, gas particles and stellar particles within $R_{\rm vir}$ at $z = 0$; Ω_i: density parameters; H_0: Hubble constant.

$M_{\rm DM}$ [M$_\odot$]	$M_{\rm gas}$ [M$_\odot$]	ϵ [kpc]	$M_{\rm vir}$ [M$_\odot$]	$R_{\rm vir}$ [kpc]	$N_{\rm DM}$	$N_{\rm gas}$	$N_{\rm star}$	$\Omega_{\rm m}$	Ω_Λ	$\Omega_{\rm b}$	H$_0$
$2.7 \cdot 10^5$	$5.1 \cdot 10^4$	0.163	$1.49 \cdot 10^{12}$	237	5 518 587	1 348 120	6 919 646	0.25	0.75	0.04	71

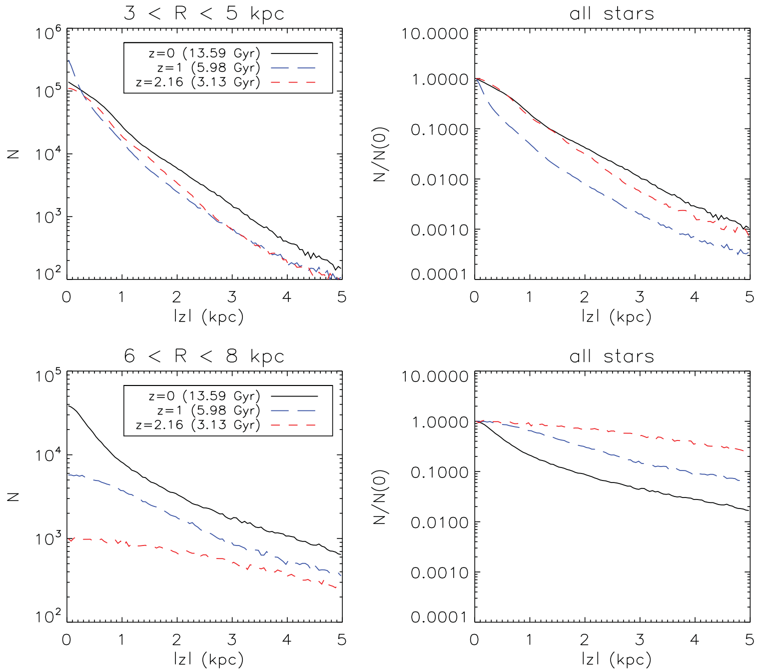

Figure 1. Disk $|z|$ distributions with R between 3-5 kpc and 6-8 kpc.

Figure 1 compares the evolution of the vertical distributions at redshift 0, 1, and 2.16, that clearly evidence an *upside-down* disk evolution in the "solar" annulus, 6 kpc $< R <$ 8 kpc. Such result supports a formation scenario that firstly generates the ancient "thick disk" stars *in situ*, from an initially turbulent ISM characterized by shorter scale-lenghts and higher scale-heights with respect to the younger "thin disk" stars (Haywood *et al.* 2013, Bird *et al.* 2013). Conversely, after about 6 Gyr ($z = 1$), a strong disk thickening is observed in the inner disk, 3 kpc $< R <$ 5 kpc, possibly due to the heating induced by the central bar (cfr. Grand *et al.* 2016).

Finally, although a typical negative [Fe/H] radial gradient is present in the disk of AqC4, no significant rotation-metallicity relation is present, as observed in our Milky Way (Spagna *et al.* 2010, Lee *et al.* 2011; see also Shönrich & McMillan 2017). This result deserves further investigation as it may be an effect of the specific formation history of this simulation.

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