Cosmological Simulations of Galaxy Formation:

Testing the “quiescent Milky Way” paradigm

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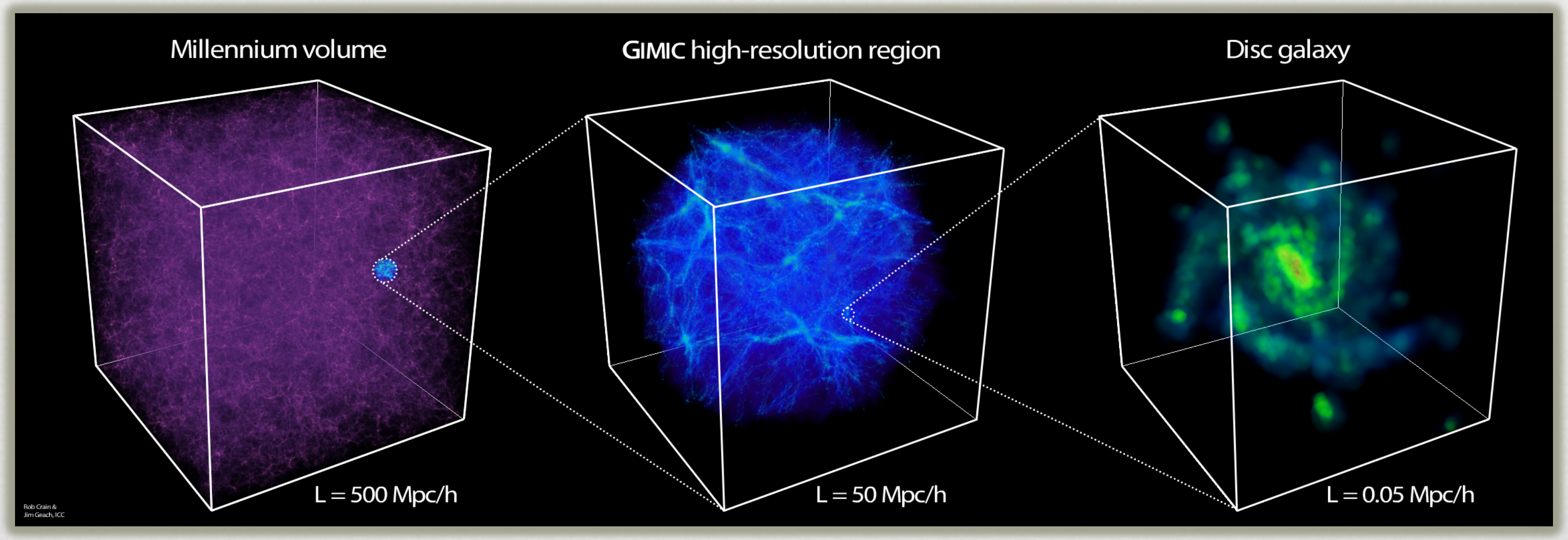
GIMIC: Galaxies Intergalactic Medium Interaction Calculation



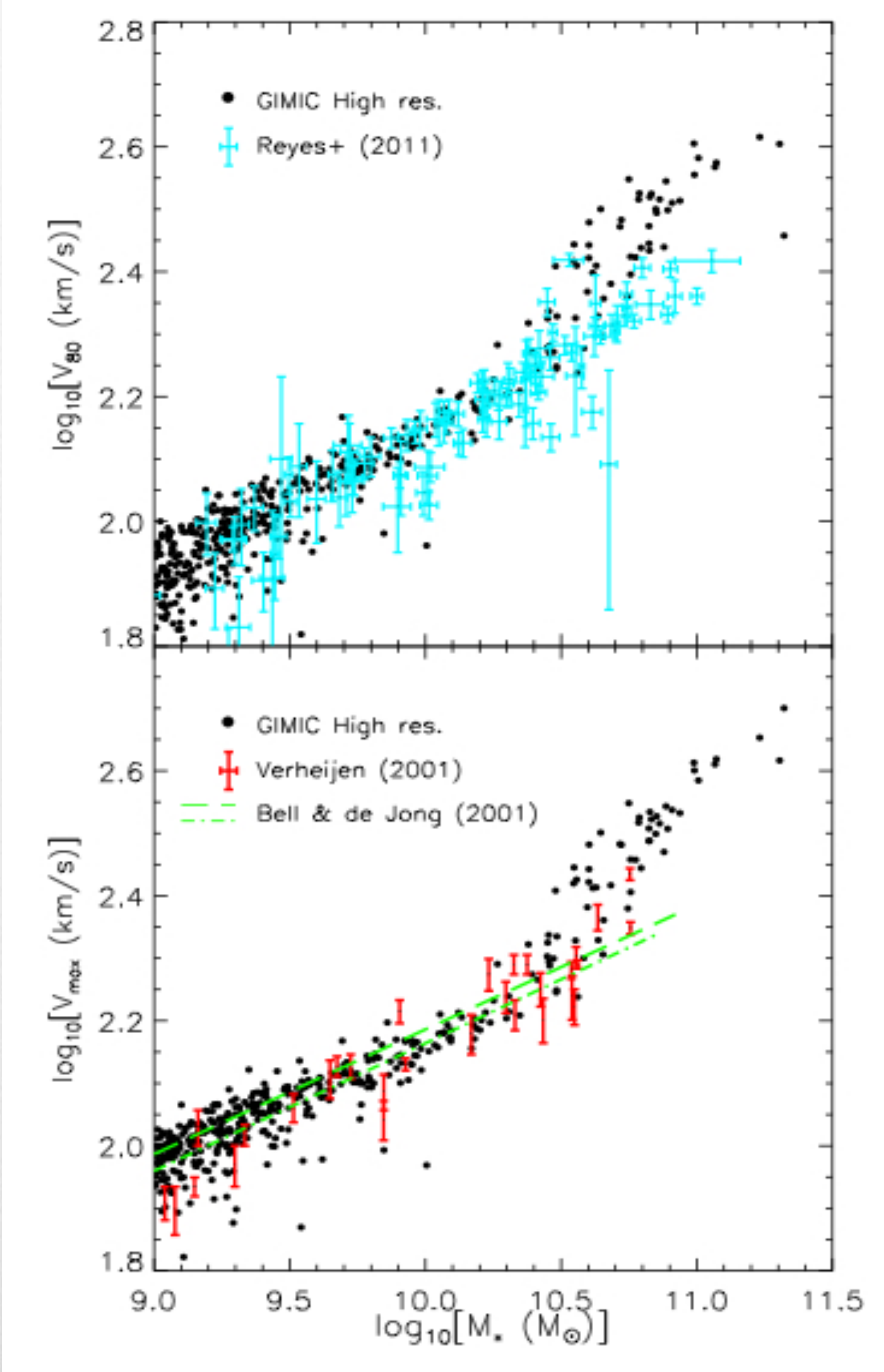
Hydrodynamical re-sims of 5 spheres (r ~ 20 Mpc) inside the Millennium Simulation $M_{bar} \sim 10^6\ M_{sun}$. Softening 0.5 h^{-1} kpc.

SPH (Gadget-3). Prescriptions for star formation (Schaye & Dalla Vecchia 2008), SN feedback (Dalla Vecchia & Schaye 2003), metal-dependent radiative cooling with UV background (Wiersma et al. 2009), and chem.evolution (Type Ia, Type II, AGB stars; Wiersma et al. 2009).

A representative sample of realistic disk galaxies

Match of the Tully Fisher relation, rotation curves, stellar efficiencies for a *representative* sample of simulated galaxies

McCarthy, Schaye, AF et al 2012



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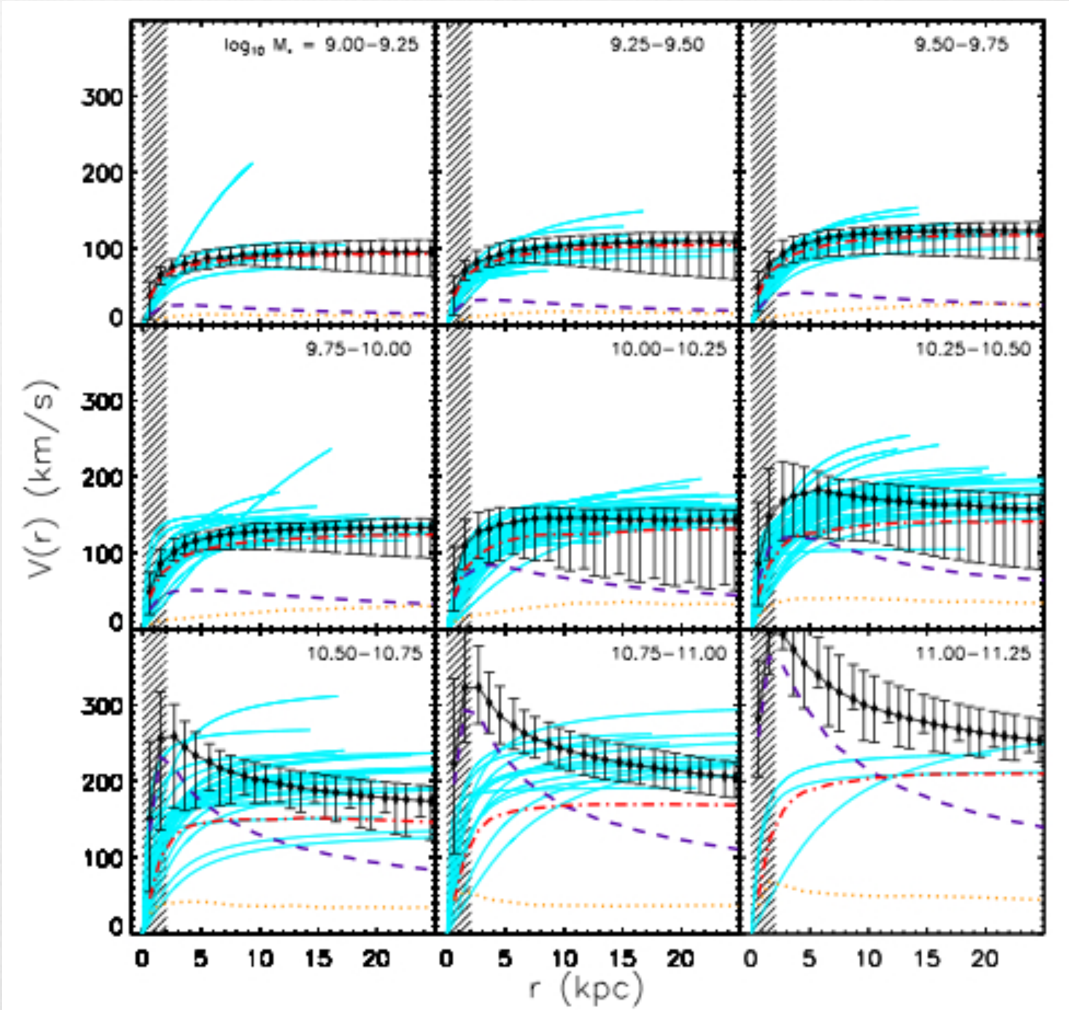
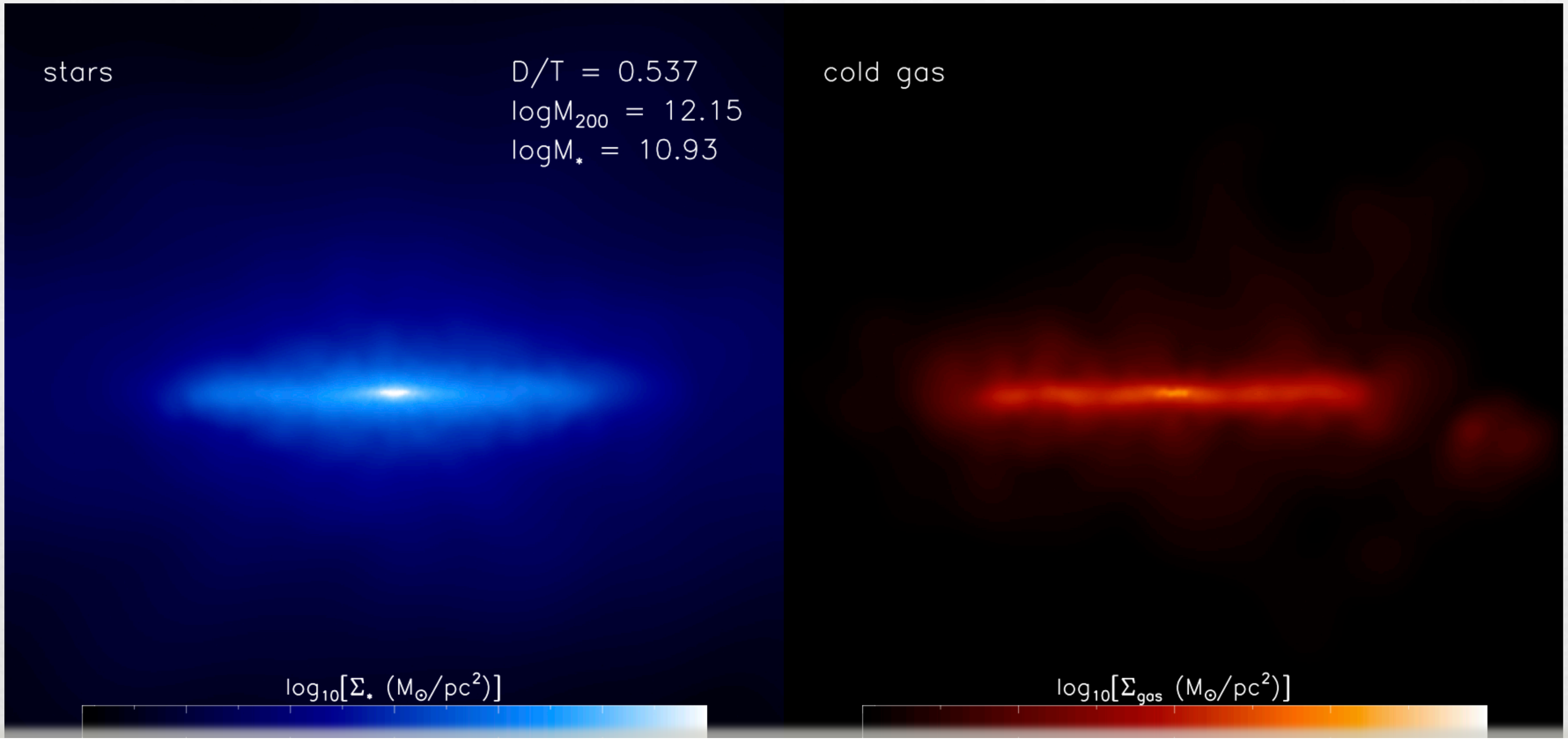
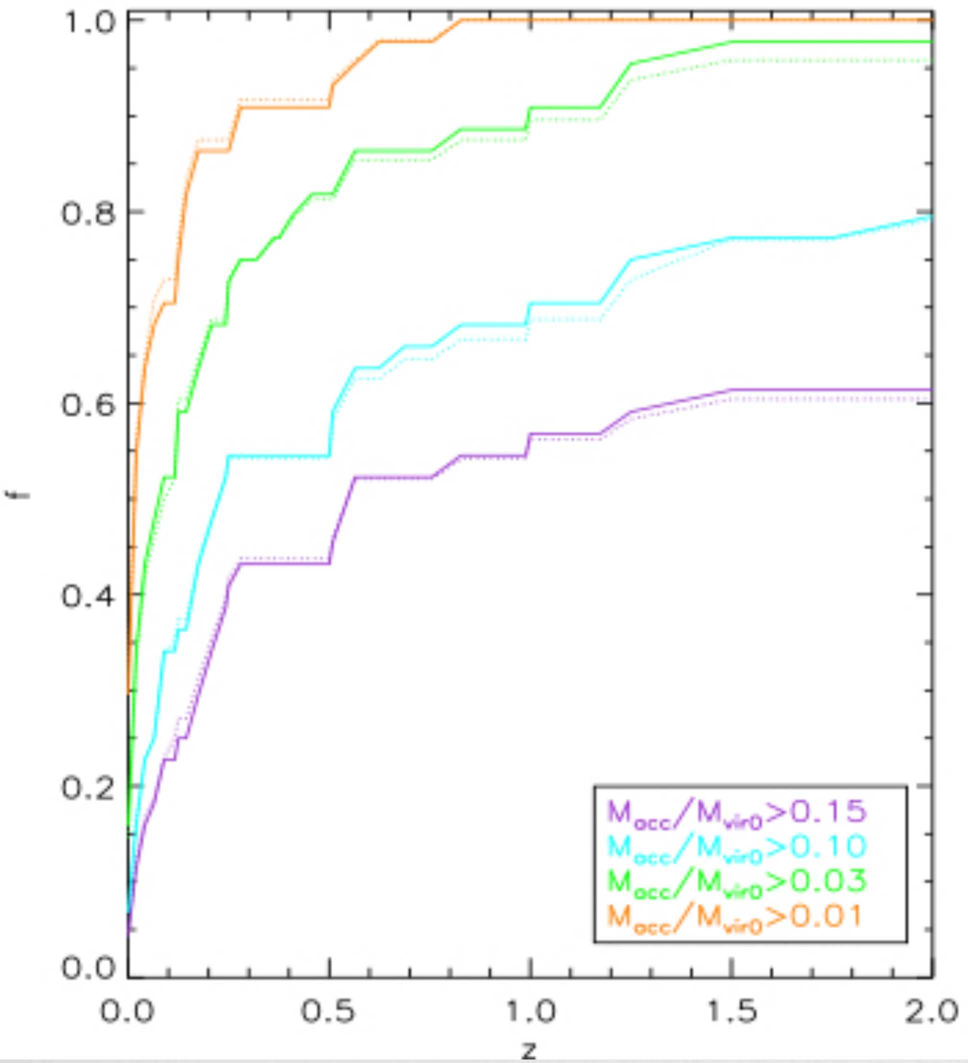


GIMIC: Realistic "Milky Ways"



log M_{200} bin ($M_\odot$)	M_V (mag.)	$M_*(< r_{200})$ ($10^{10} M_\odot$)	$v_{rot}(R_\odot)$ (km/s)	$[Fe/H]_{r<30kpc}$	$[Fe/H]_{r>30kpc}$	$n_{gal,bin}$
11.85 – 12.05	$-21.37^{-0.98}_{+1.46}$	$3.46^{+6.32}_{-2.15}$	184^{+76}_{-52}	$-0.49^{+0.27}_{-0.28}$	$-1.13^{+0.27}_{-0.19}$	127
12.05 – 12.25	$-22.17^{-0.47}_{+1.53}$	$8.18^{+5.66}_{-6.32}$	243^{+58}_{-93}	$-0.35^{+0.18}_{-0.37}$	$-1.12^{+0.16}_{-0.17}$	154
12.25 – 12.50	$-22.45^{-0.50}_{+0.69}$	$12.82^{+8.83}_{-8.85}$	280^{+85}_{-89}	$-0.30^{+0.13}_{-0.25}$	$-1.15^{+0.23}_{-0.18}$	128

A 'quiescent' MW is extremely rare in a ΛCDM model



~100% of ~ (1-3) x 10^{12} M_{sol} haloes have a M_{sat} >$10^{10}M_{sol}$ merger since z=2 (~10 Gyrs ago)

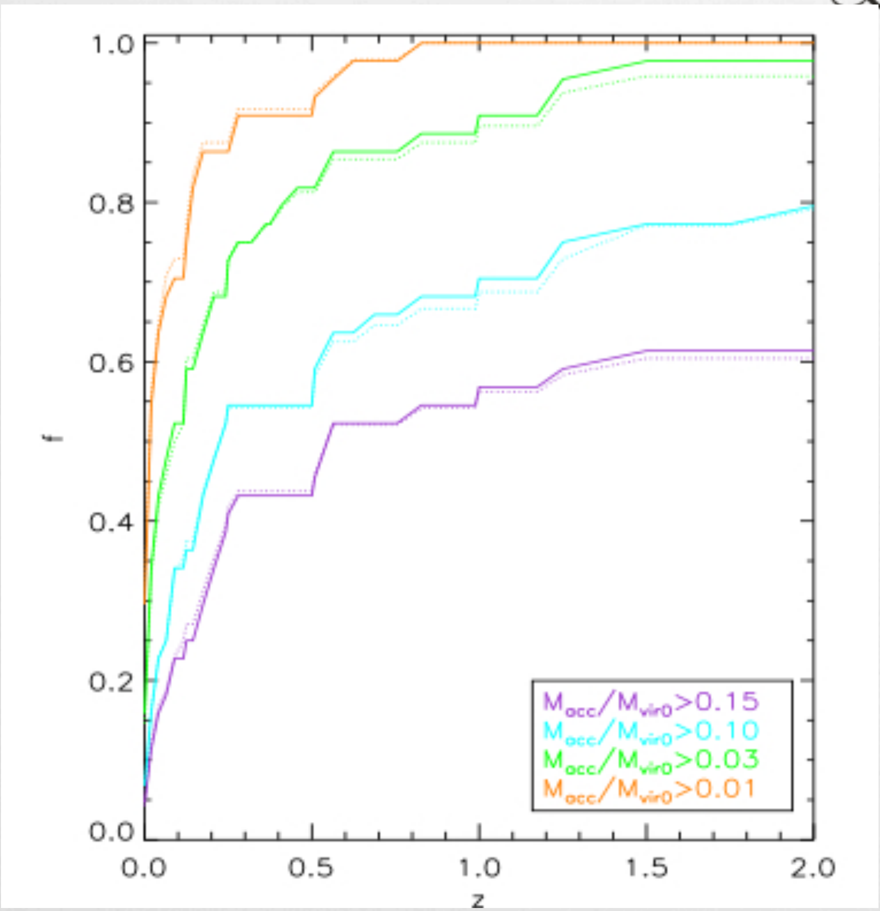
>80% of (1-3) x 10^{12} M_{sol} haloes have a M_{sat} > 10^{11} M_{sol} merger (2 times the mass of the disc!)

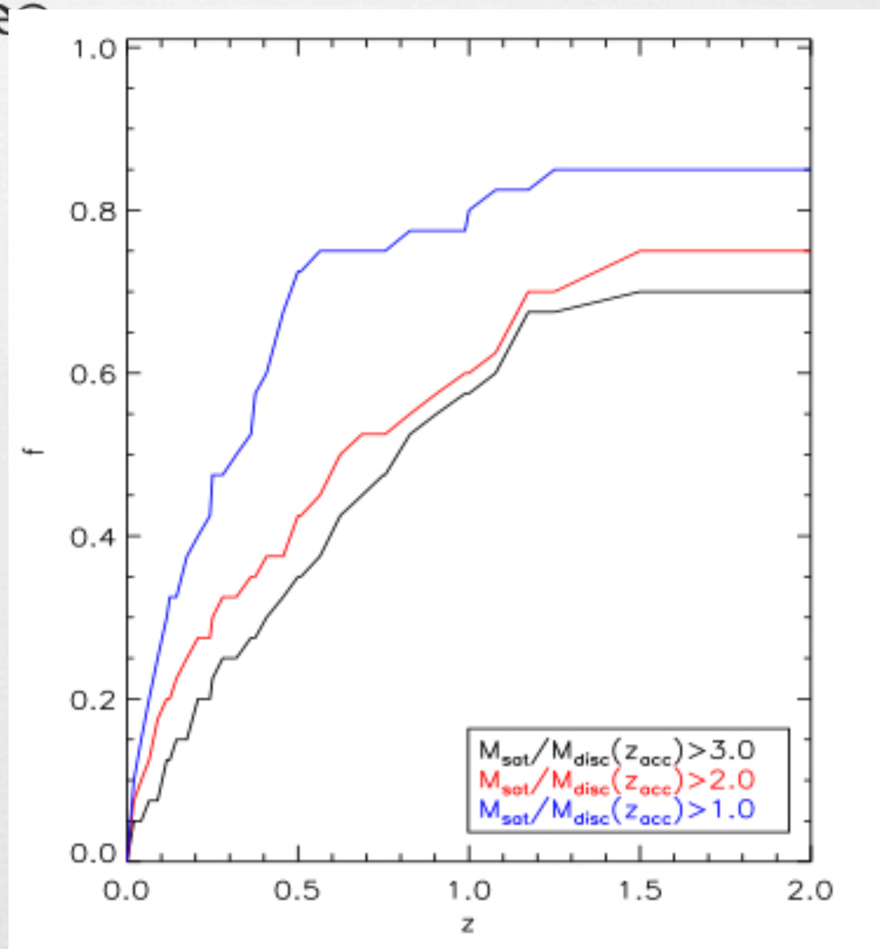
According to TO92 argument, these haloes should not host discs!

Yet ~70% of L* galaxies in nearby Universe are disc galaxies (SDSS data)

Boylan-Kolchin et al 2010; Le Brun, AF, McCarthy 2012.

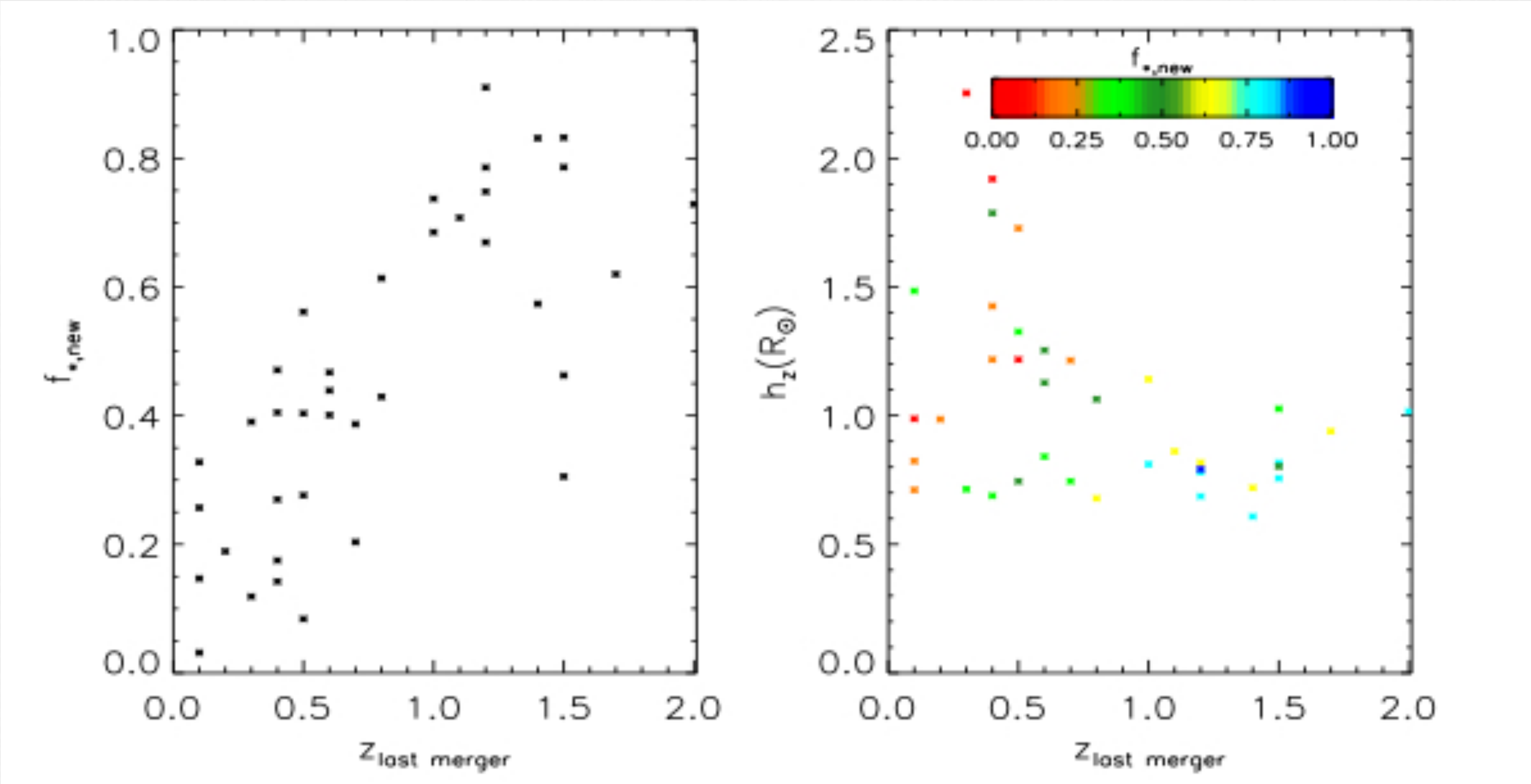
>80% of (1-3) 10^{12} M_{sol} galaxies in GIMIC are disc galaxies





Le Brun, AF, McCarthy 2012

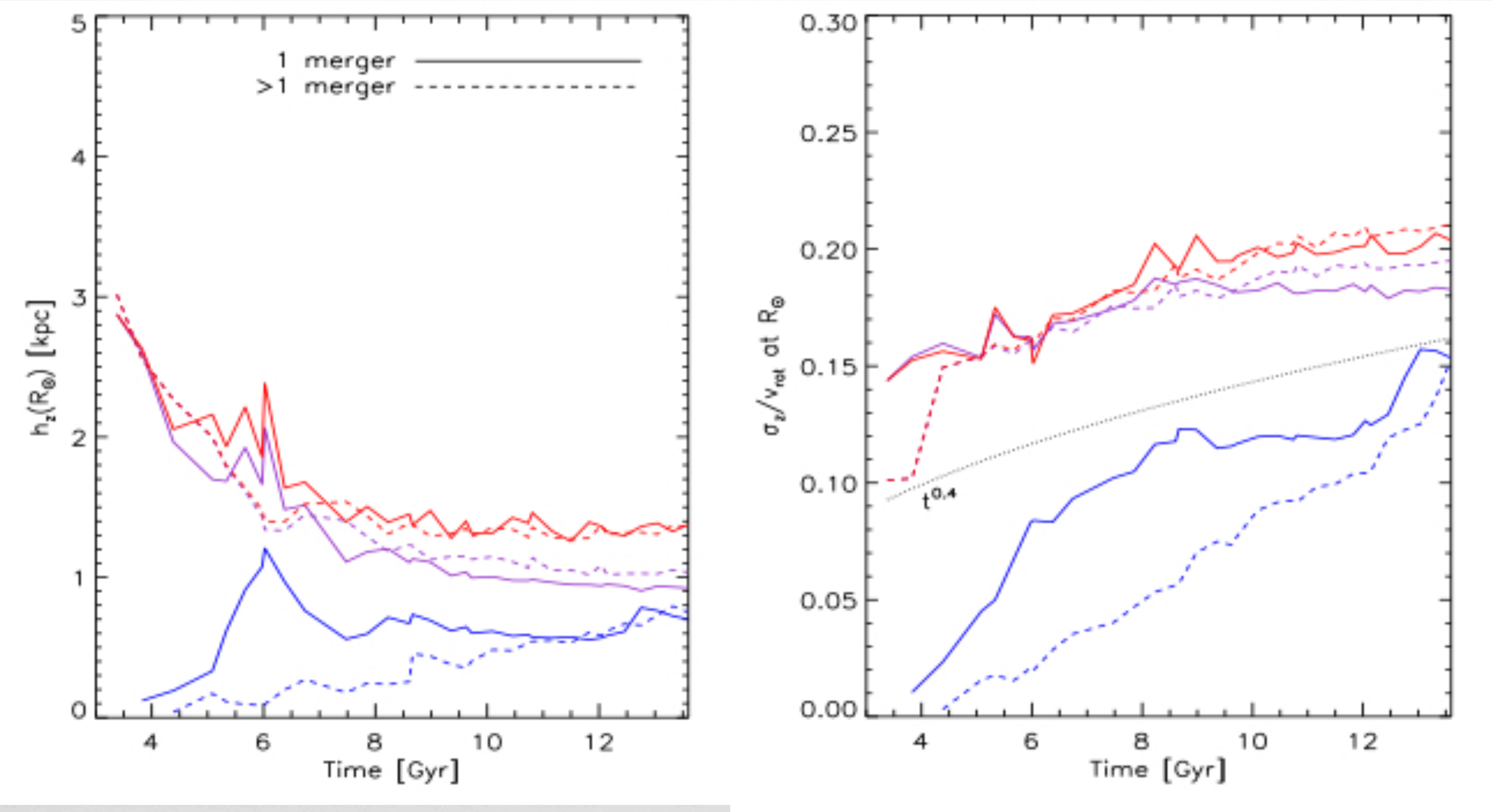
Major mergers do not destroy disks in gas dynamical simulations
(gas physics not included in TO92)



- Disks have similar scale heights before and after mergers
- For mergers that occur early ($z>1$) : significant fraction of new stars in the disk

-Star formation rates in disks do not correlate strongly with merger histories.

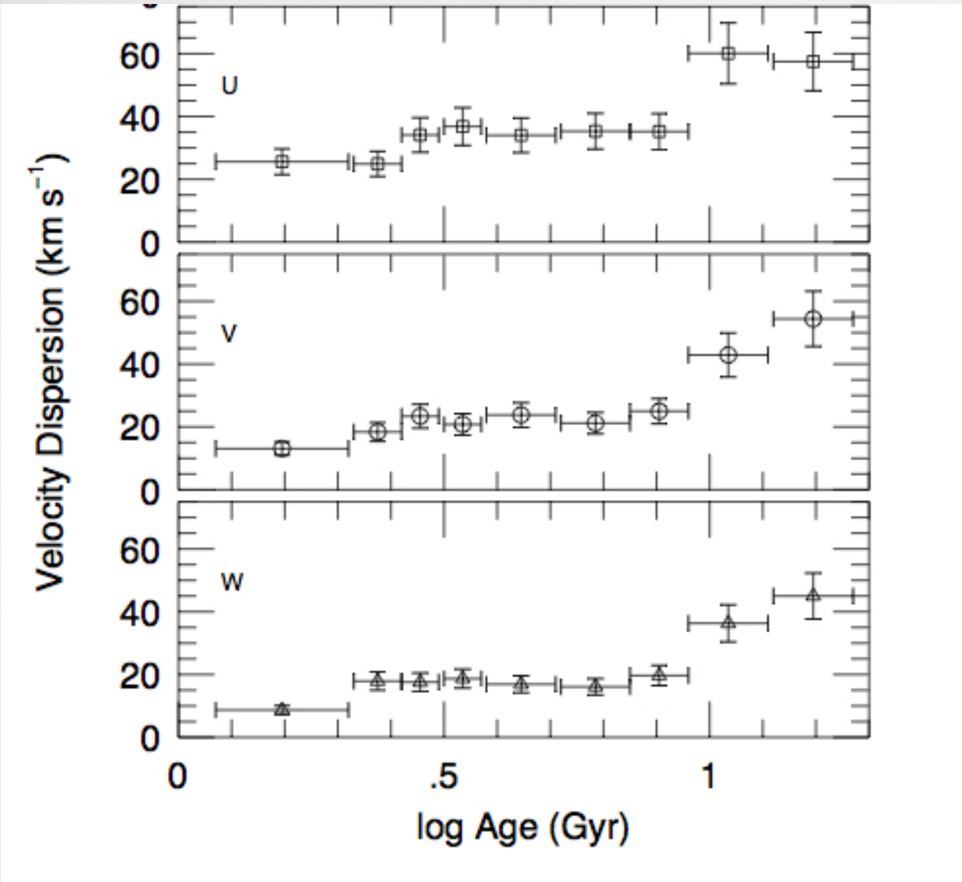
-Thick disk forms early, in situ, but are not associated with gas rich mergers.



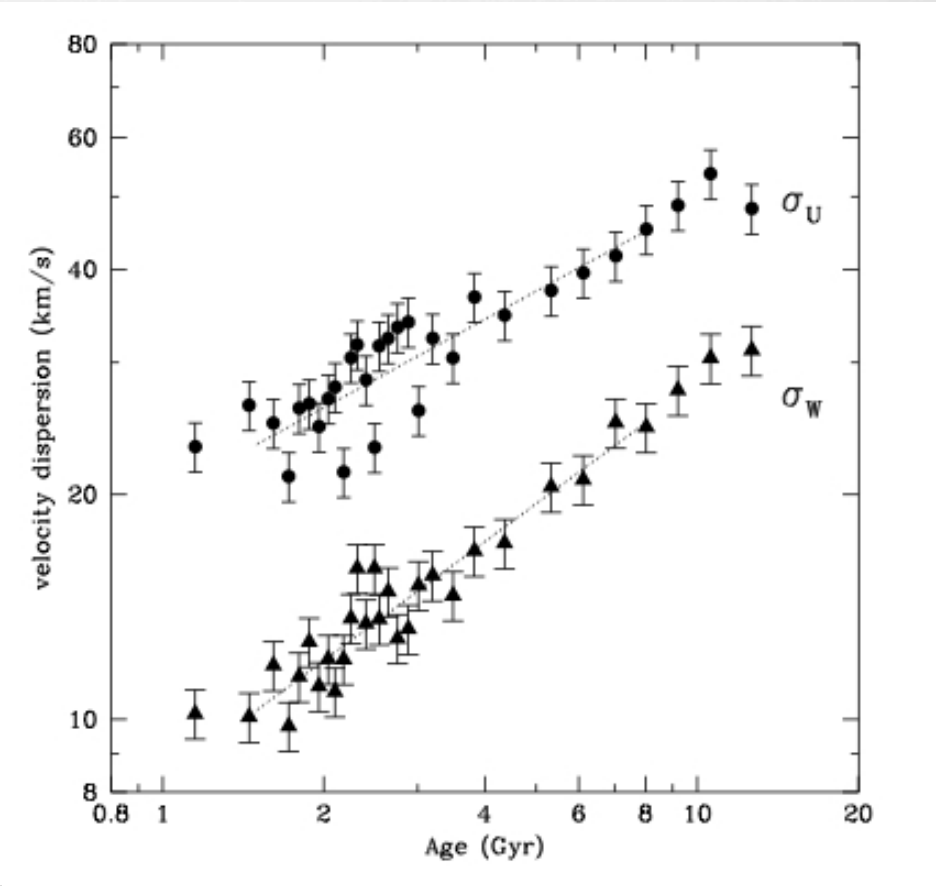
Toth & Ostriker (1992):

"We note that, since satellite infall events are discrete, the relation between age and velocity dispersion should reflect this, showing jumps at look-back times corresponding to accretion events."

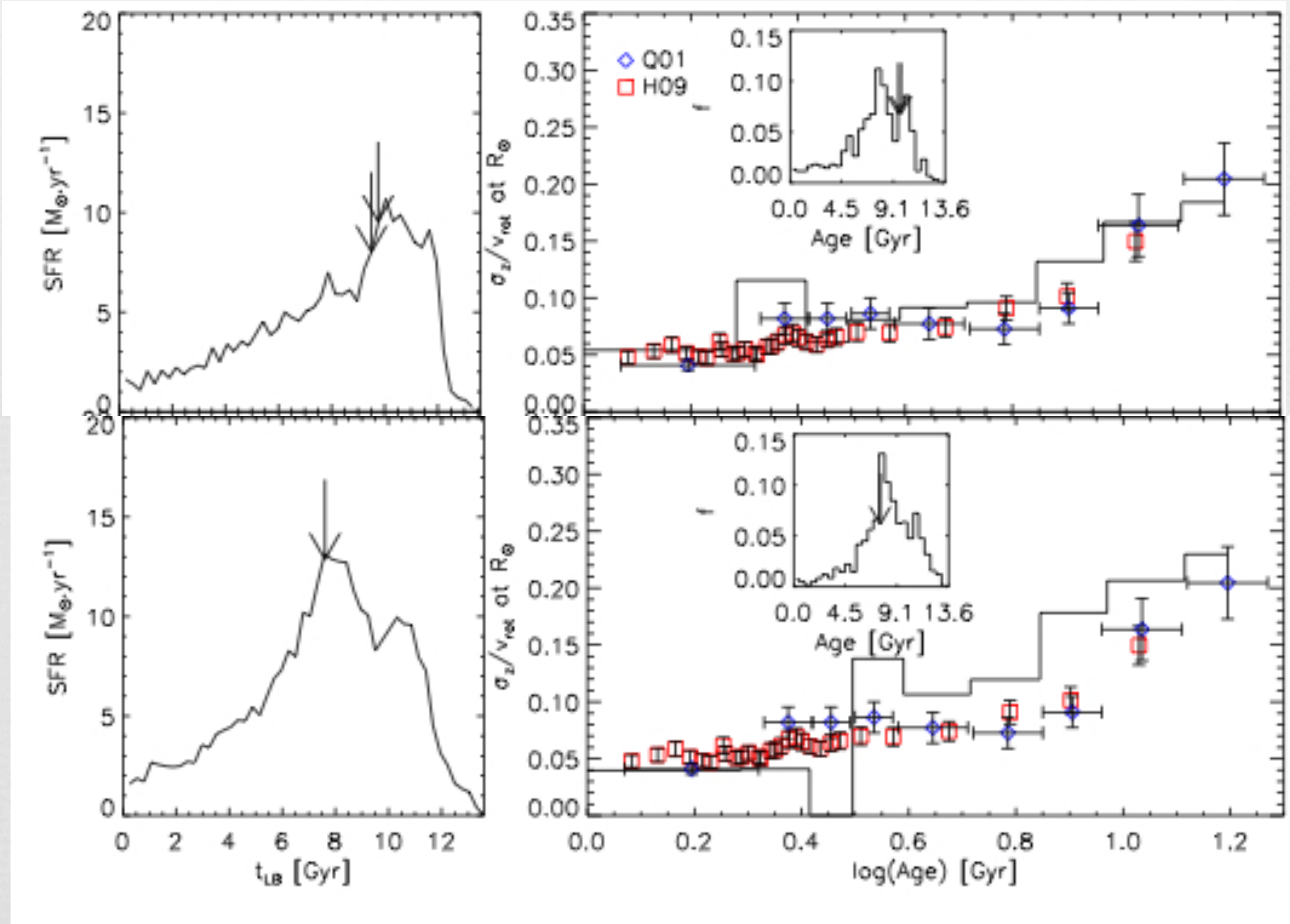
Quillen& Garnett (2000)



Holmberg et al 2009 (GCS 3)



AVR may not be a good predictor of the star formation/merger history:



Le Brun, AF, McCarthy 2012

Conclusions:

- Disk galaxies survive major mergers
- Star formation rates in disks do not correlate strongly with merger histories.
- Disks have similar scale heights before and after mergers.
- Thick disk forms early, in situ, but are not associated with gas rich mergers.
- AVR does not show jumps with mergers and is not a good indicator of the merger history,
- Milky Way history may be a ‘typical’ disk galaxy (i.e. not quiescent).
- Chemical abundances will be useful to constrain the merger history.