Reconstructing the merger history of the Milky Way

Insights from cosmological simulations

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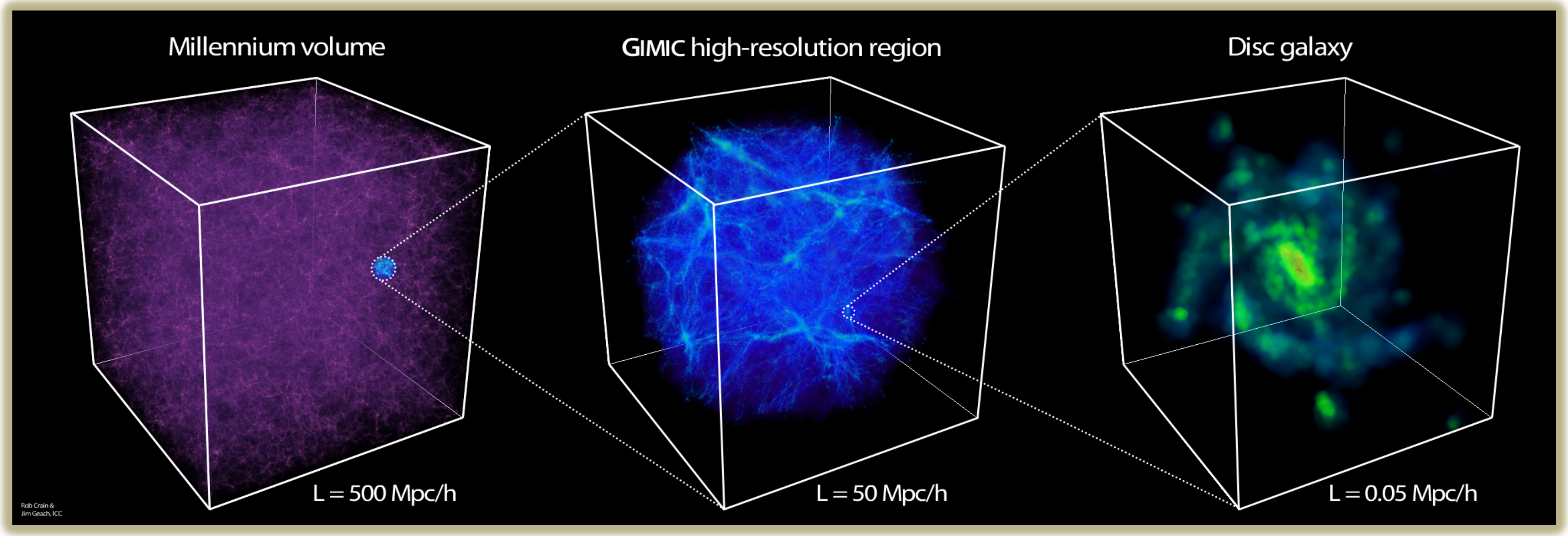
THE GIMIC SIMULATIONS
(Galaxies Intergalactic Medium Interaction Calculation)



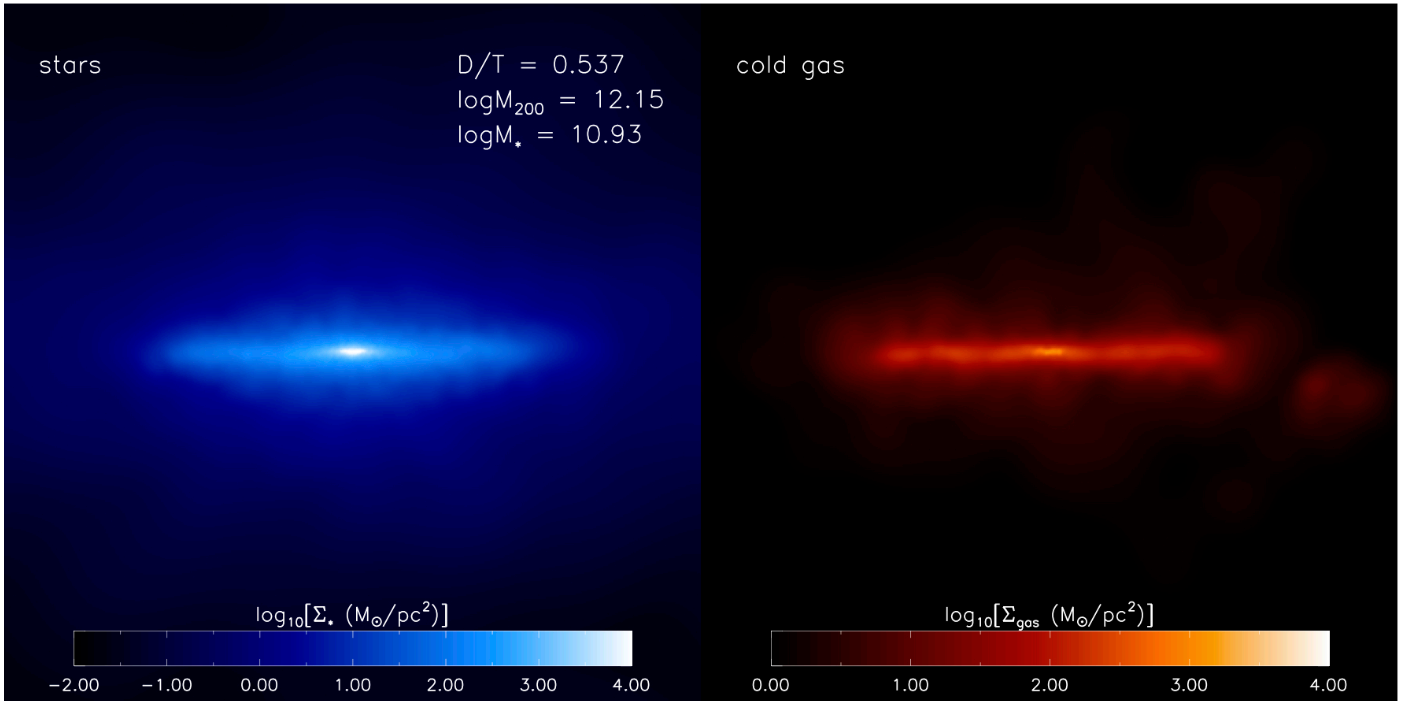
(Virgo Consortium for Computational Cosmology); Crain et al 2009.

GIMIC "High res": cosmological hydro-dynamical re-simulations (run with Gadget-3)
2 spheres (~ 20 Mpc); spatial resolution ~ 0.5 h^{-1}kpc
M_{gas} ~ 1.46x10^6 h^-1 M_{solar}, M_{dm}=6.36x10^6 h^-1 M_{solar}

A sample of 87 Milky Way-mass (1 x 10^{12} – 3 x 10^{12} M_{sol}) galaxies;
69 of these are disc galaxies (D/T > 0.3)

Disc Galaxies with realistic properties

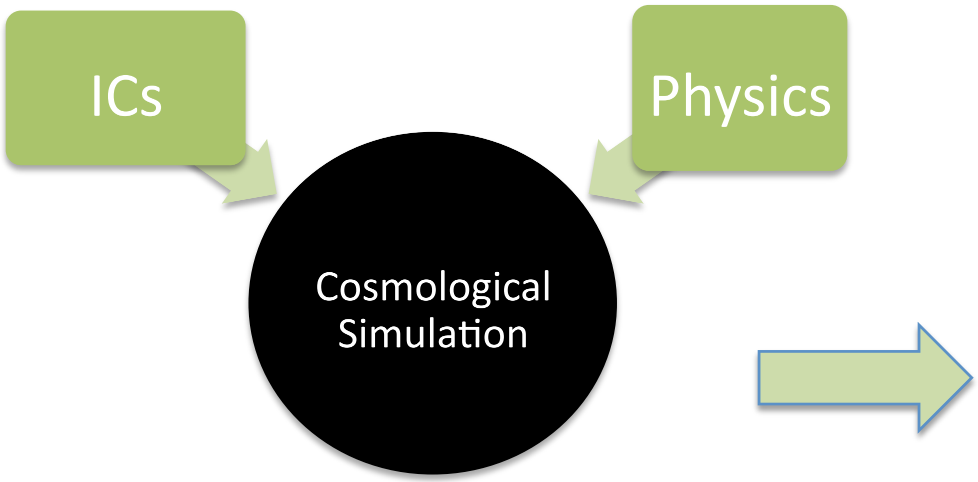
(Font et al 2011, McCarthy et al 2012)

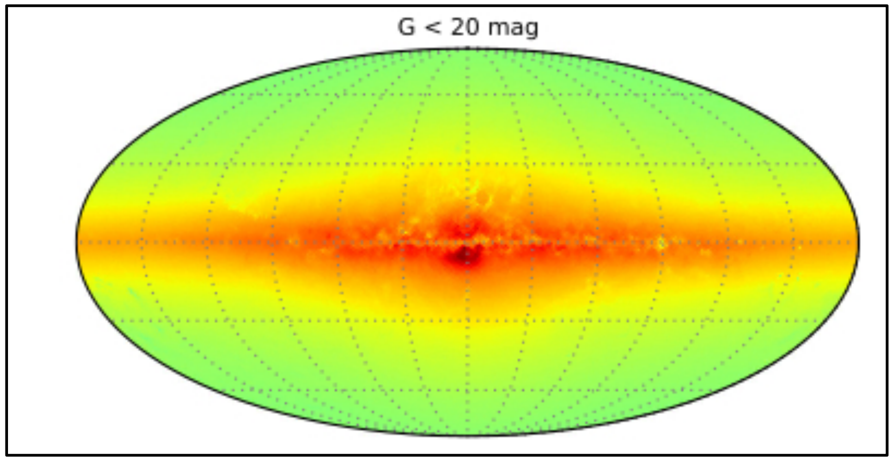


log M_{200} bin ($M_{\odot}$)	M_V (mag.)	$M_*(< r_{200})$ ($10^{10} M_{\odot}$)	$v_{\rm rot}(R_{\odot})$ (km/s)	$[{\rm Fe/H}]_{r<30{\rm kpc}}$	$[{\rm Fe/H}]_{r>30{\rm kpc}}$	$n_{\rm gal,bin}$
11.85 – 12.05	$-21.37^{-0.98}_{+1.46}$	$3.46^{+6.32}_{-2.15}$	184^{+76}_{-52}	$-0.49^{+0.27}_{-0.28}$	$-1.13^{+0.27}_{-0.19}$	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

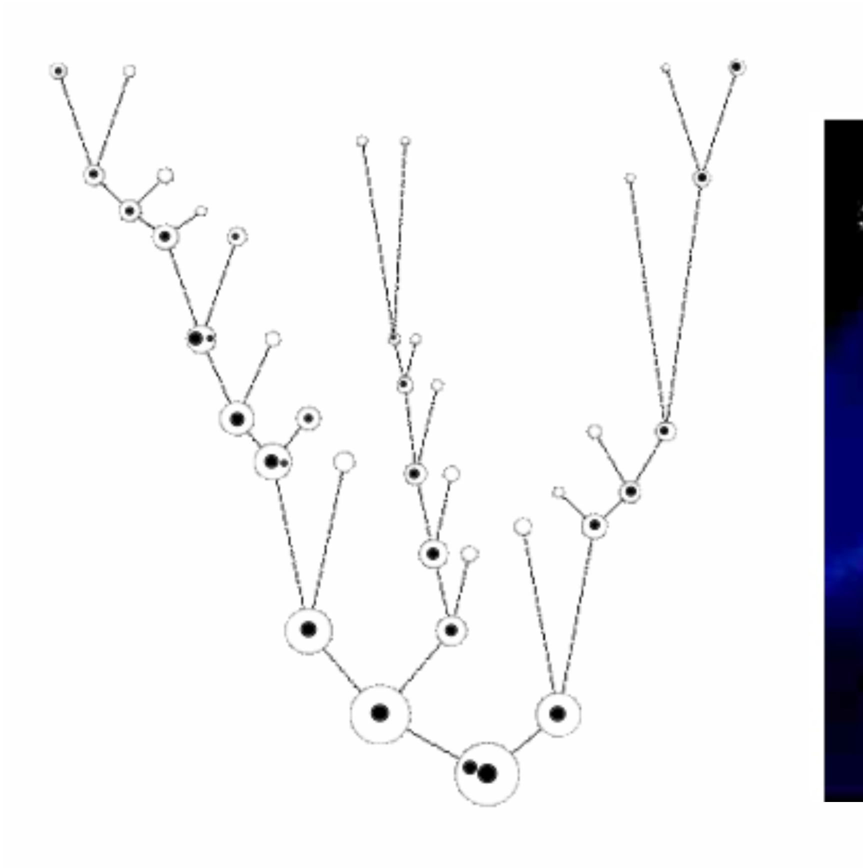
How do we get from here ...

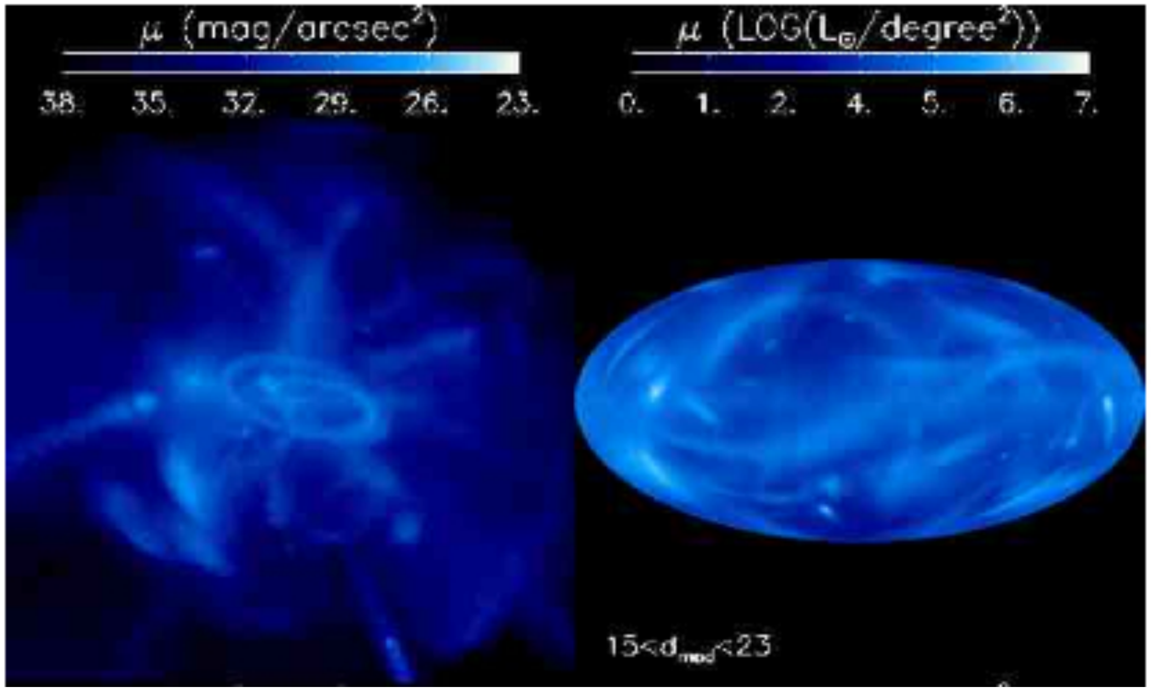
... to here?





Honing in on the Milky Way “ICs”:
Method I: Reconstruct the merger history from tidal debris in the halo





Requires large volume coverage,
inner halo is phase-mixed,
In situ halo?

Method II (Indirect): using disc heating arguments

Toth & Ostriker (1992):
"… we find that no more than 4% of its [Galaxy] mass inside solar radius can have been accreted within the last 5 billion years or else its scale height and Q would exceed the observational constraints."

-> M_{sat} ~ a few 10^9 M_{sol}

+

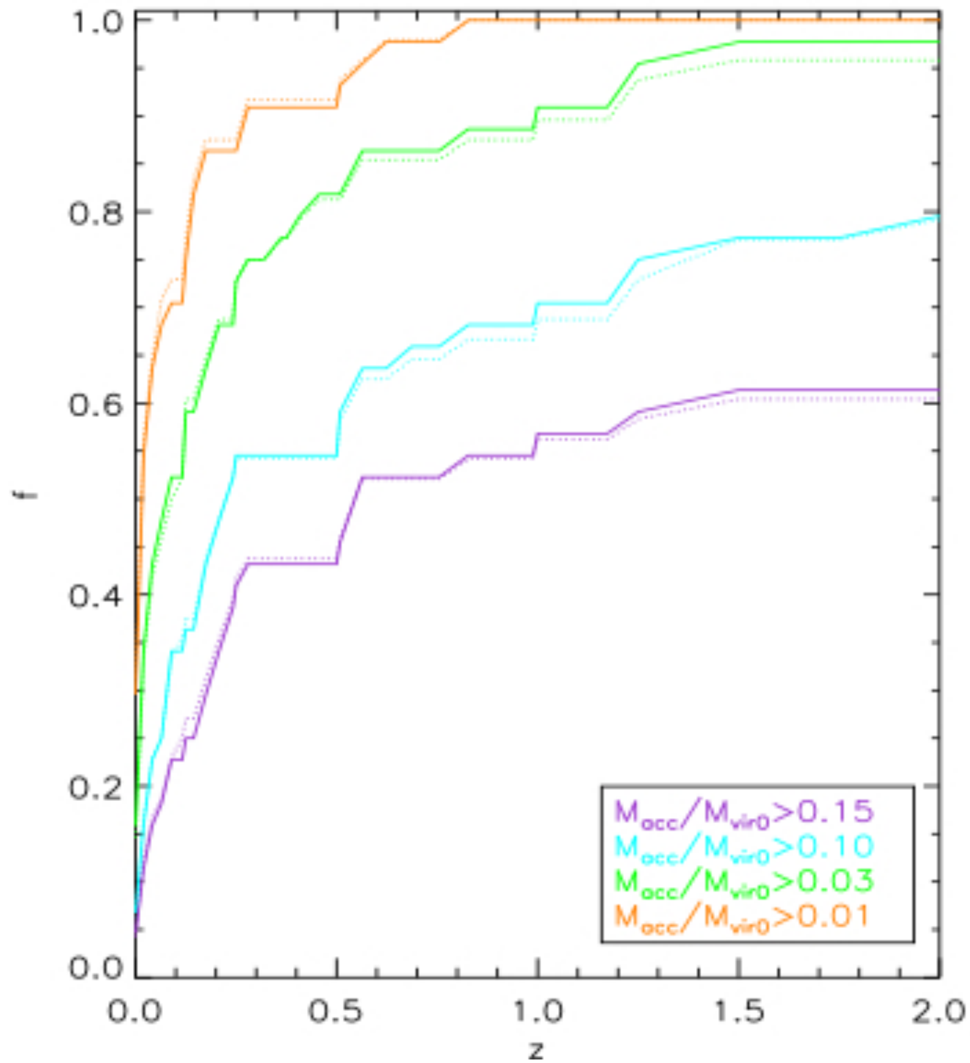
Thin disc has some very old stars + …

↓

Current paradigm:

MW had a quiescent merger history for the past ~10Gyr

But this makes MW (and other disc galaxies) hard to make in LCDM!



>95% of ~ (1-3) x 10^{12} M_{sol} haloes have a M_{sat} >$10^{10}$$M_{sol}$ merger since z=2 (~10 Gyrs ago)

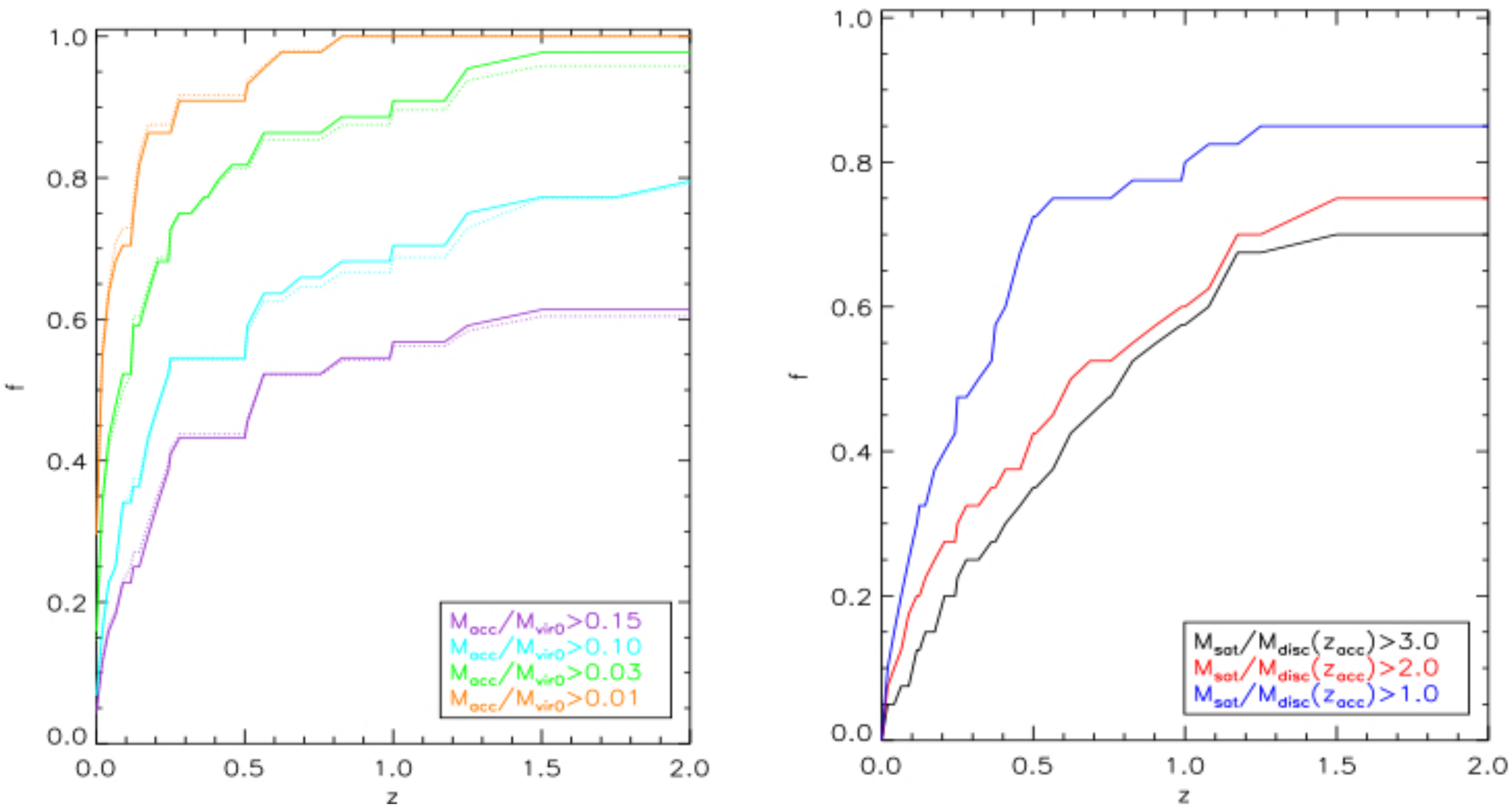
>80% of (1-3) x 10^{12} M_{sol} haloes have a M_{sat} > 10^{11} M_{sol} merger (3 times the mass of the disc!)

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

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

Stewart et al 2008; Boylan-Kolchin et al 2009; Le Brun, AF et al 2012.

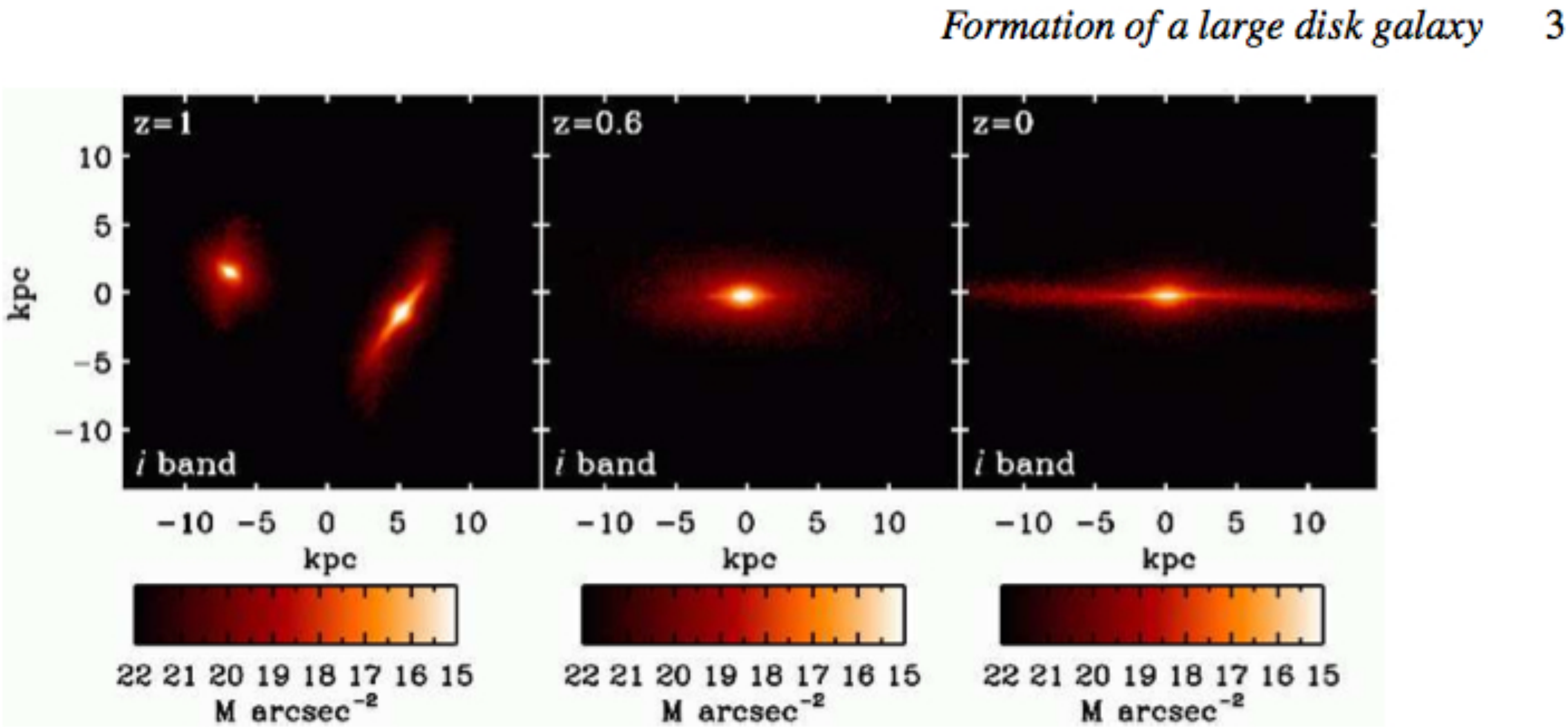
>80% of (1-3) 10^{12} M_{sol} galaxies in GIMIC are disc galaxies



Le Brun, AF et al 2012

Gas physics: key ingredient in disc survival

(this was not included in TO92)



(Barnes 2002; Springel & Hernquist 2005; Roberston et al 2006; Governato et al 2007,2009; Scanappieco et al 2009; Moster et al 2010; Le Brun, AF et al 2012)

The AVR

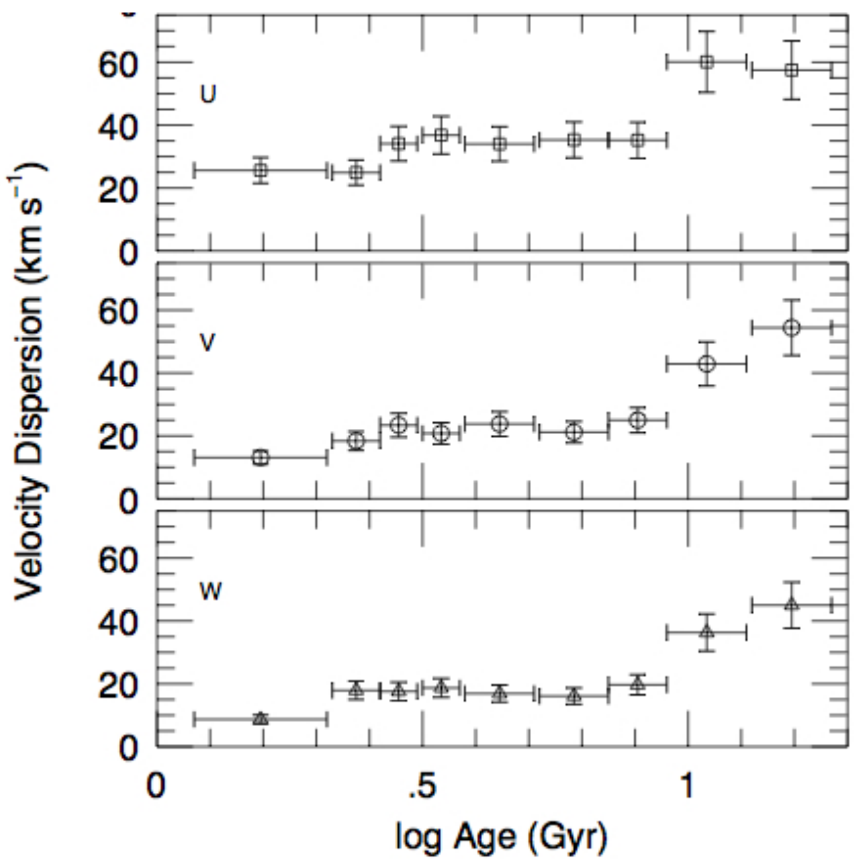
Toth & Ostriker (1992):

"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."

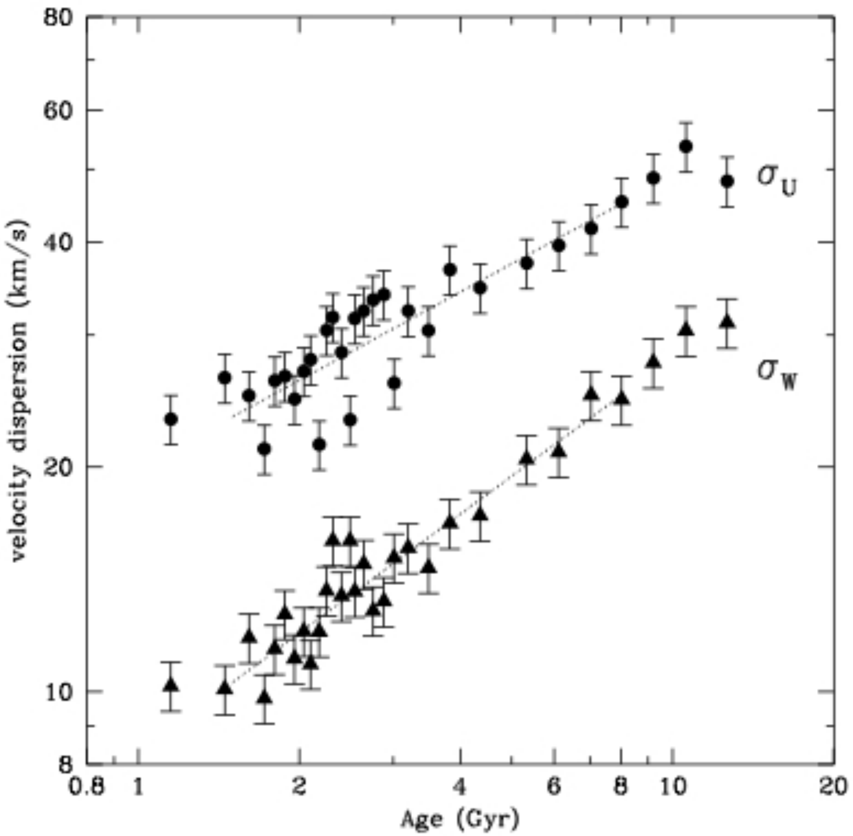
… but gas physics should also smooth out these discontinuities!

The latest observed age – velocity dispersion (σ_W) relation shows a monotonic increase (no jumps) up to ~10 Gyr

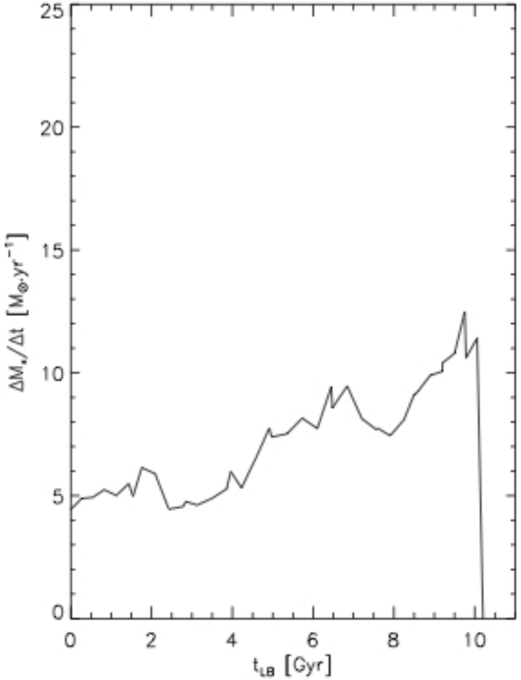
Quillen& Garnett (2000)

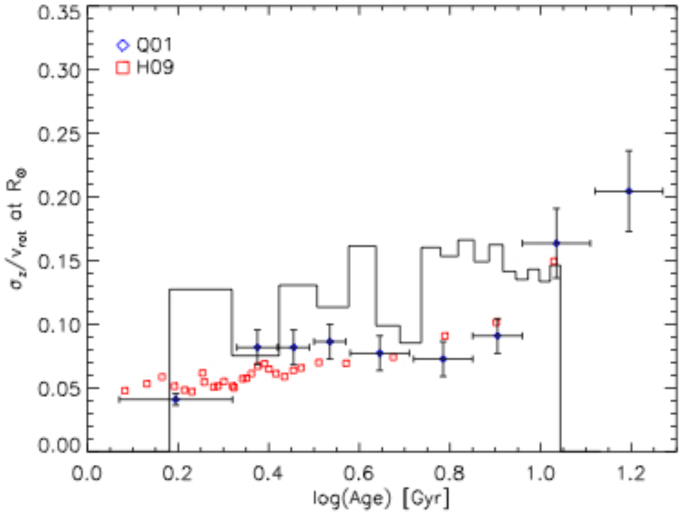


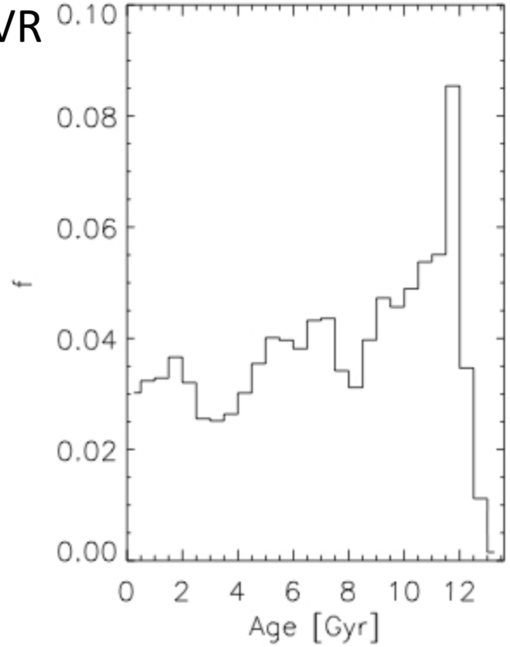
Holmberg et al 2009 (GCS)

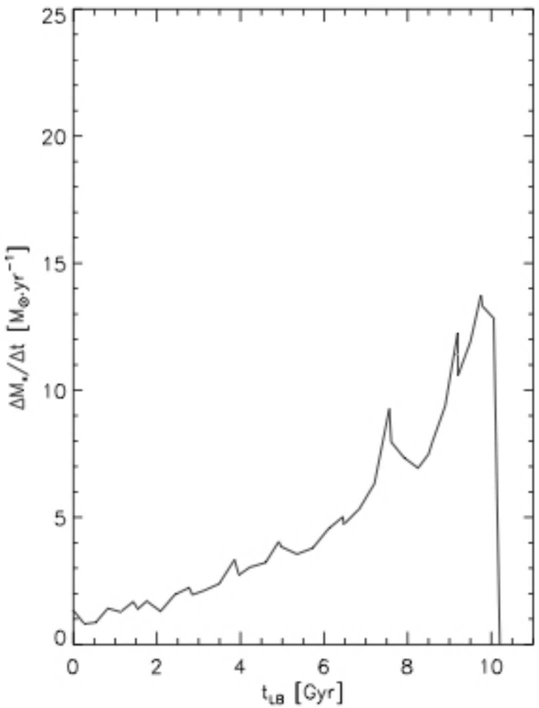


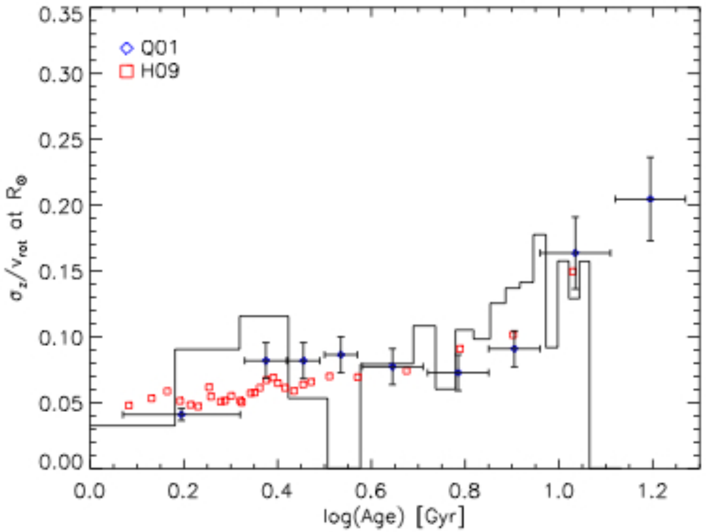
Two simulated galaxies that match the AVR but have different SF histories:

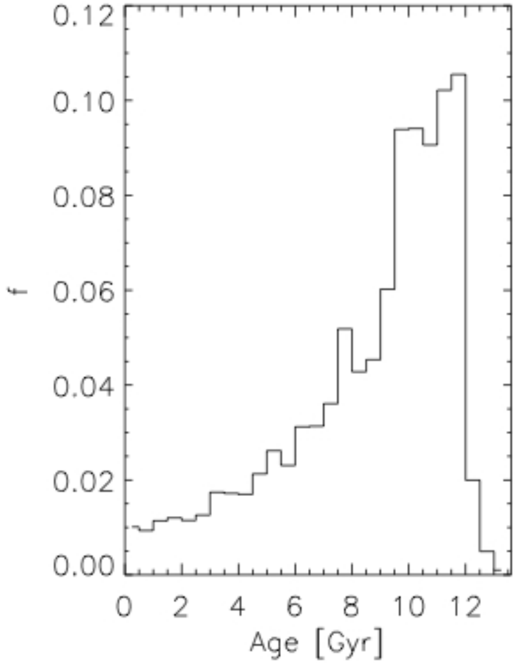












- Reconstructing the ~~merger~~ history of the Milky Way?
  star formation

<u>What do we need from Gaia:</u>

Disc diagnostics that improve significantly on the GCS data:

->the age - velocity dispersion relation

->the age – metallicity relation