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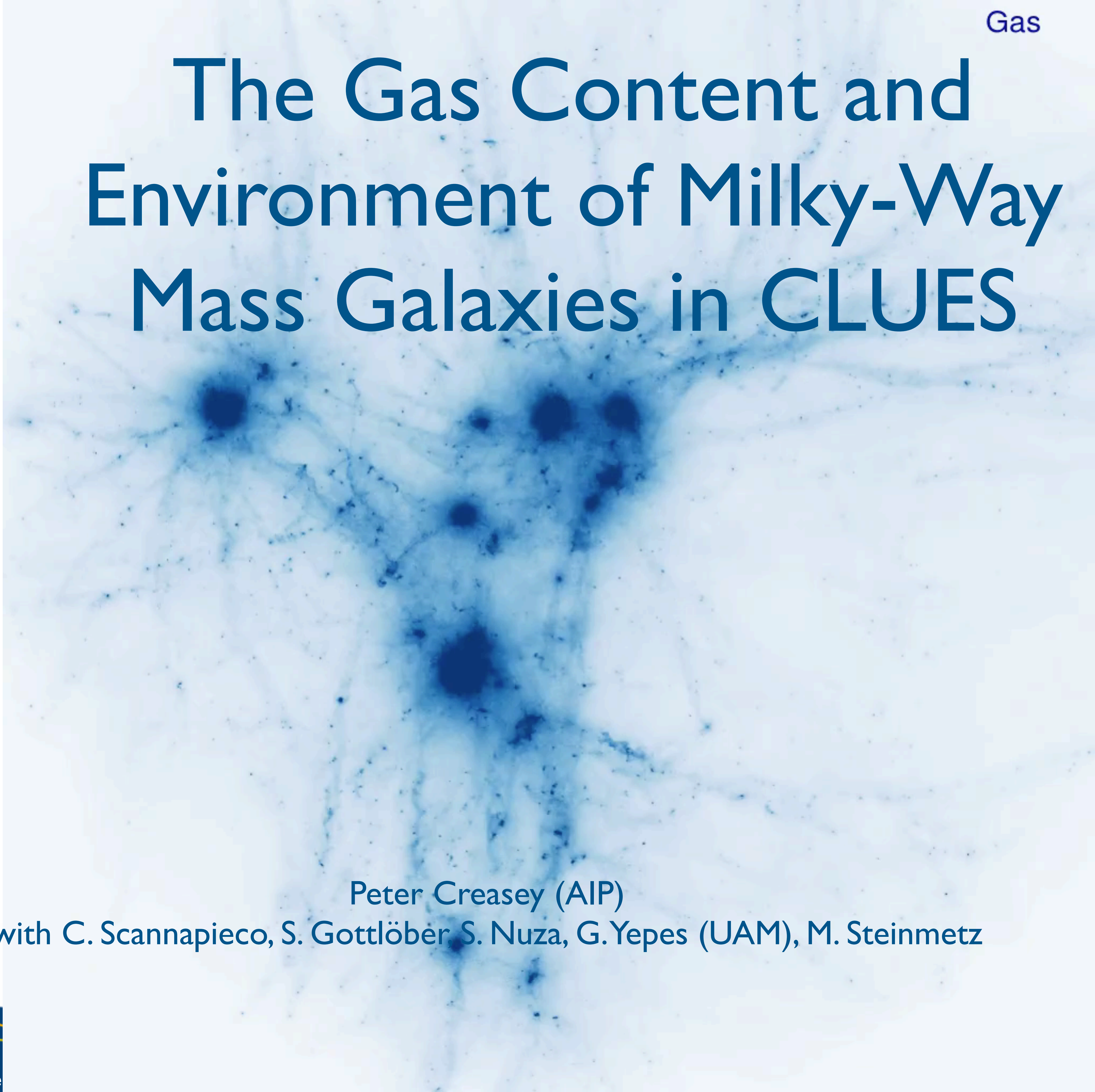

The Gas Content and Environment of Milky-Way Mass Galaxies in CLUES

Peter Creasey (AIP)
with C. Scannapieco, S. Gottlöber, S. Nuza, G. Yepes (UAM), M. Steinmetz

Outline

- Introduction - environment at the loose group range
- A simulated 10 Mpc (7 Mpc/h) sphere
- MW mass galaxies
- Trends of MW mass galaxies
- Conclusions

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Environment and galaxy formation

- Ellipticals more clustered than spirals (morphology-density, Dressler 1980 etc.)
- Environment is correlated with colour (clusters suppress star formation w.r.t. field, e.g. Blanton et al. 2003)
- In groups the effect is weaker, still see morphology-density, effect on gas in disks more controversial (McGee et al. 2008)
- MW and M31 at the extreme end, a pair or 'loose group'

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Effects of pairs in simulations

- Simulated MW mass field galaxies vs pairs exhibit little visible (morphological) difference (Few et al. 2012)
- No difference in concentrations or stellar masses within R_{200}, but an increased number of 'backsplash' galaxies (Garrison-Kimmel et al 2014)
- Filamentary structures more important? (Bahe et al 2013, Nuza 2014)

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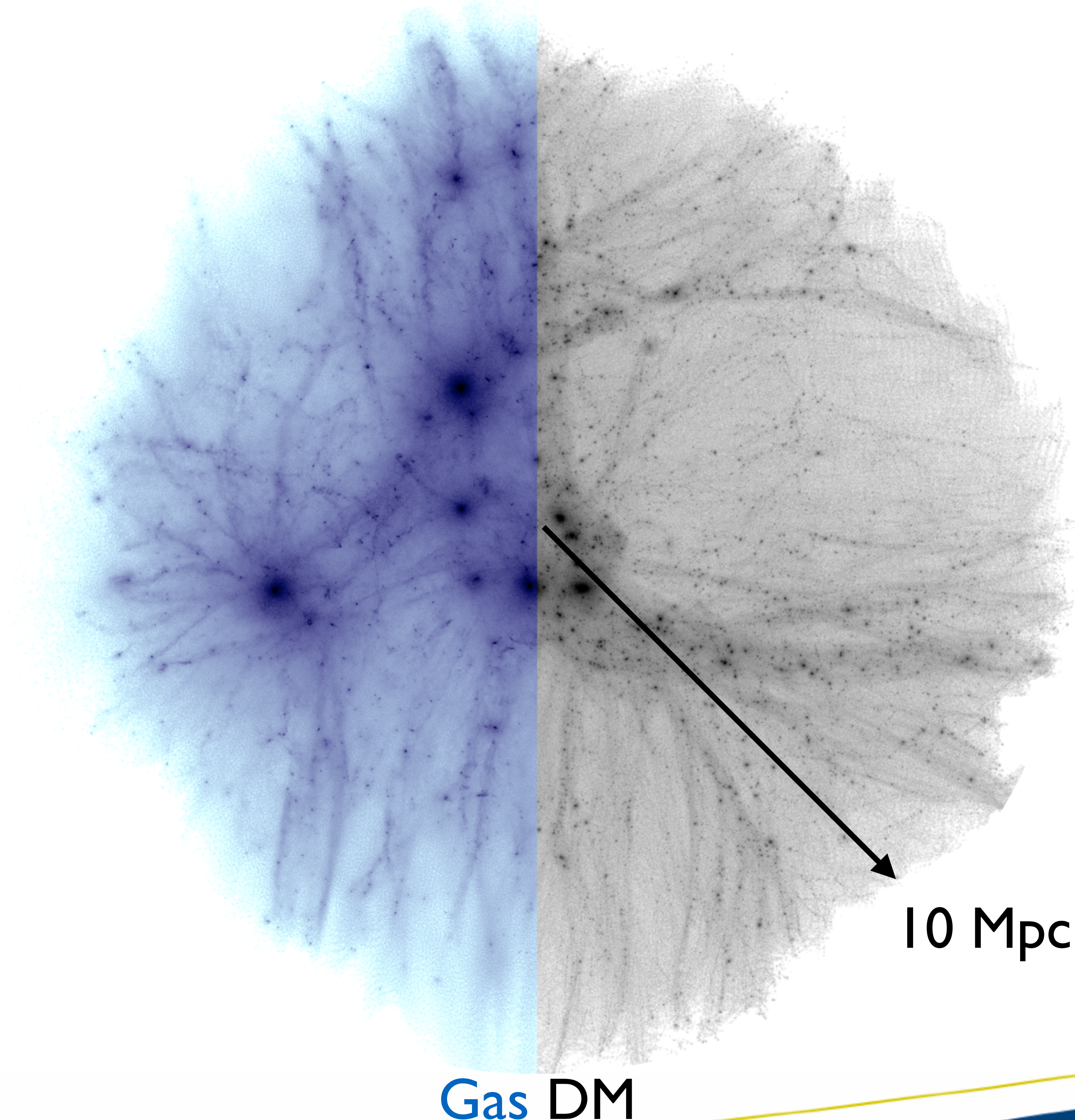
A 10 Mpc sphere of CLUES ICs

A high-resolution region surrounding the simulated local group that at z=0 is approximately spherical, with 10 Mpc (7 Mpc/h) radius (provided by Gustavo).

Ω_M=0.279, Ω_Λ=0.721, Ω_{bar}=0.046, h=0.7, σ_8=0.8

$M_{gas}=5\times10^5\ M_{sun}$



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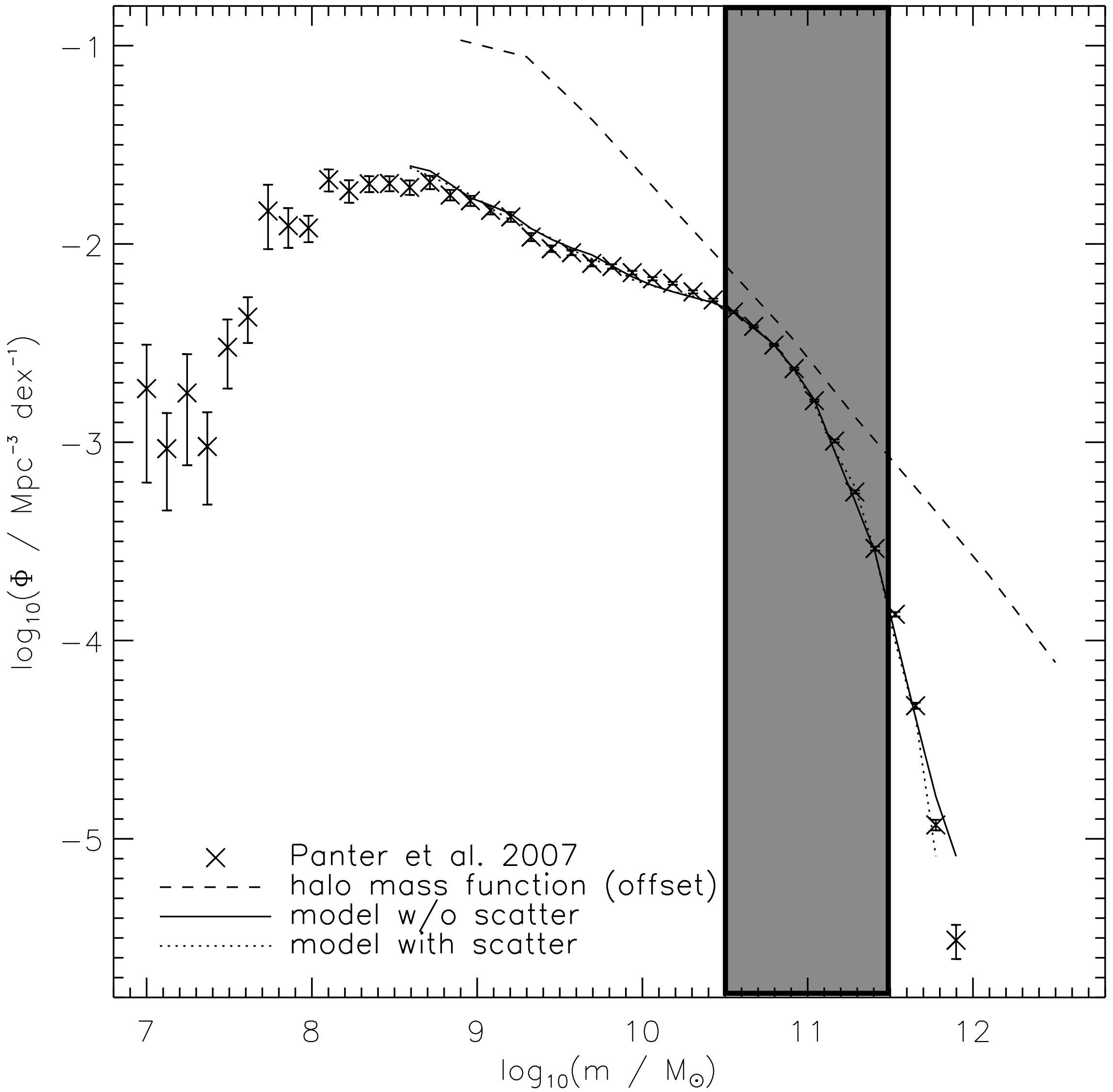
How common are MWs?

- Stellar mass $10^{10.5}$-$10^{11.5}M_{sun}$
- 1 per ~350 Mpc^3 at z=0



Moster et al., 2010

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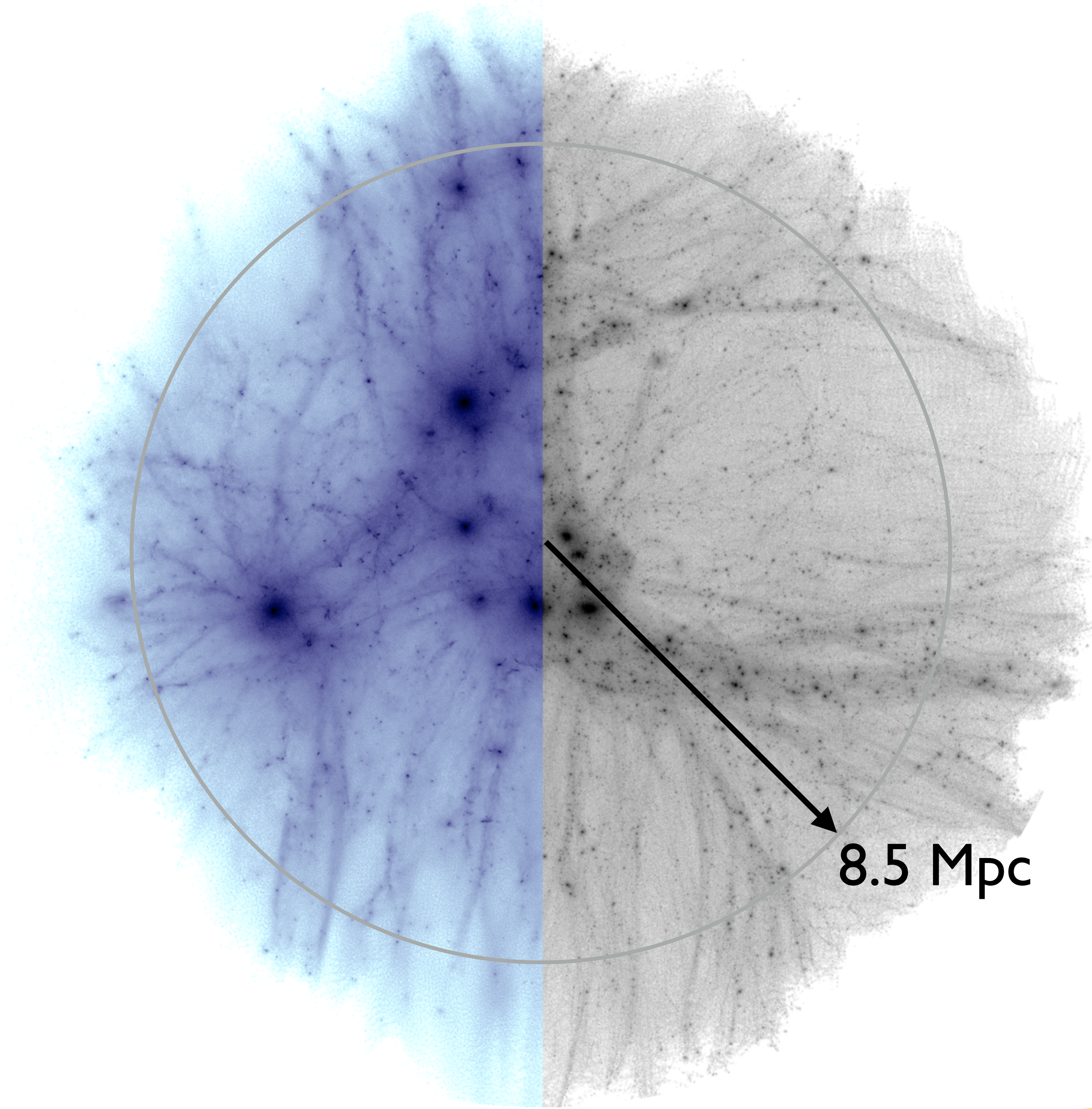
How common are MWs?

- 1 per ~350 Mpc^3
- R=8.5 Mpc central region (uncontaminated)
- Volume ~2500 Mpc^3
- About 7 MWs



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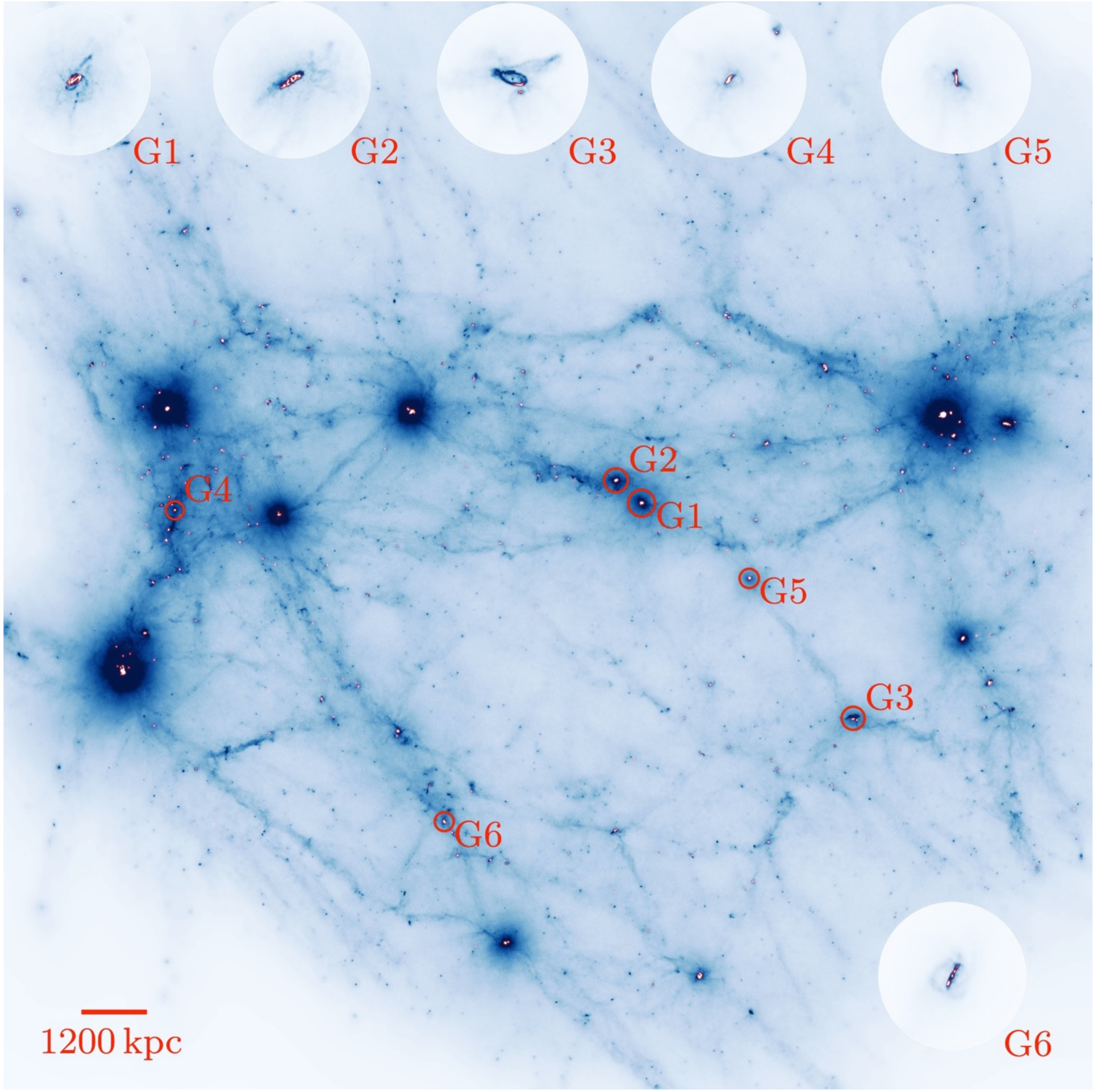
Our 6 Galaxies

- $10^{10.5\text{-}11.5}$ in stellar
- Gas column density
- R_{200} in red circles
- Star forming gas highlighted in orange



Creasey, Scannapieco et al., 2015 ApJ

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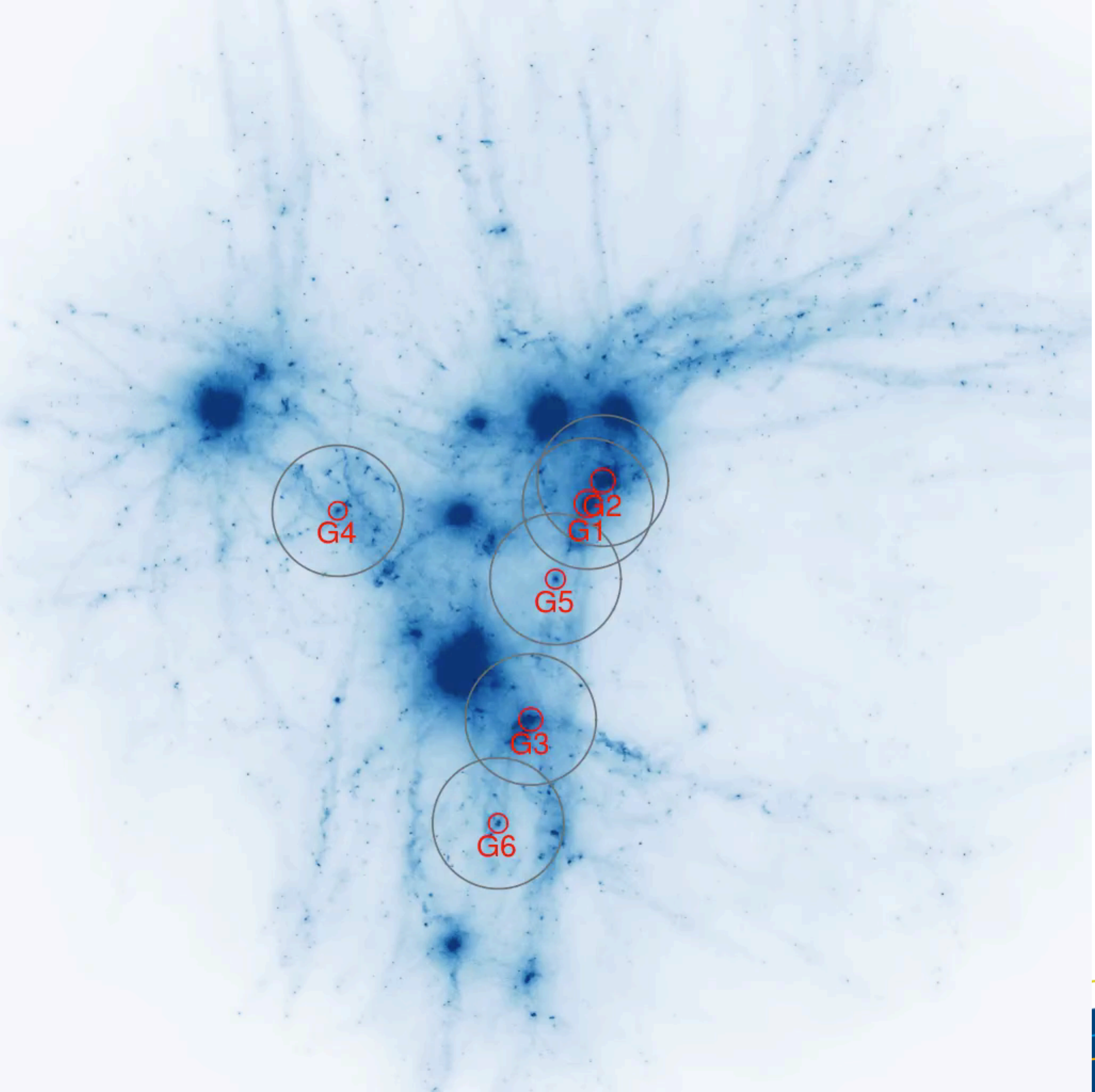
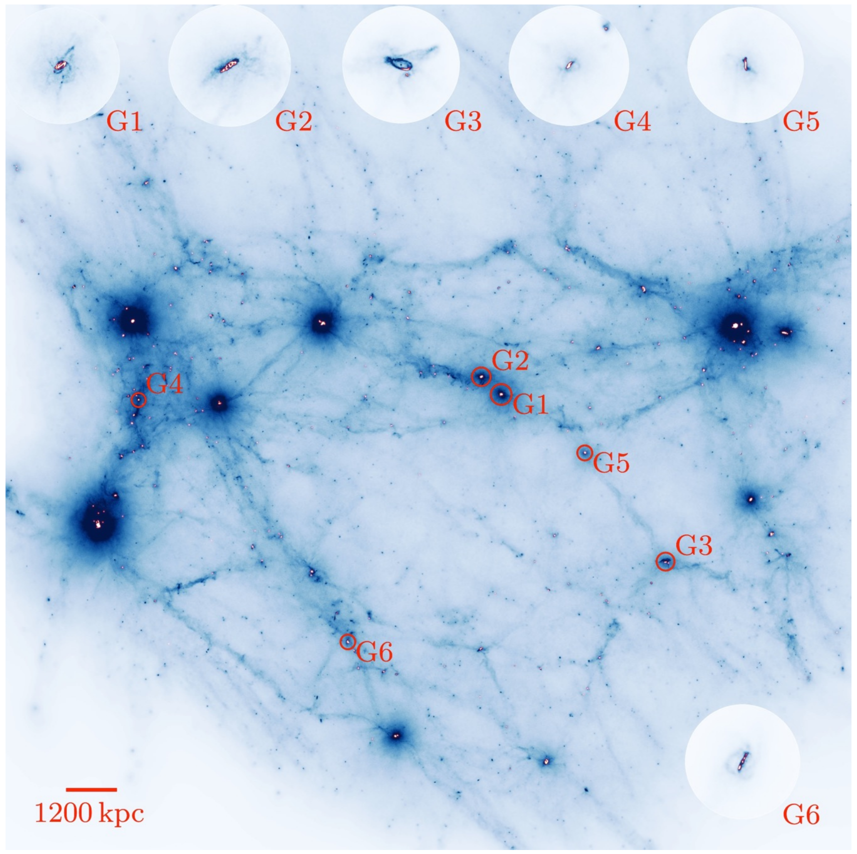
The 1200 ckpc environment

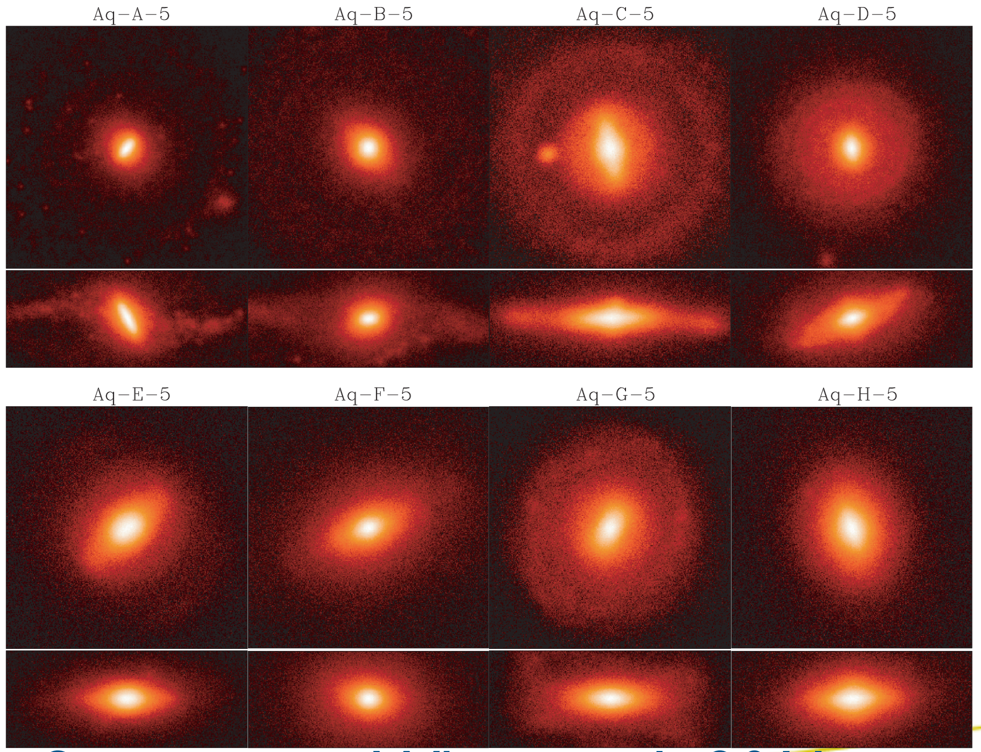
- 100 km s^{-1} for 12 Gyr, (ignoring cosmological expansion), giving some measure of the domain from which baryons fall to the halo, i.e. how far does a baryon move.
- Some baryons can move faster (>1000 km s^{-1}!) but typically driven by SNe or AGN but not for anything like a Hubble time in MW mass objects.
- At this distance the MW and M31 share an environment
- (‘Local volume’ for Garrison-Kimmel et al 2014)


G4
G2
G1
G5
G3
G6

Properties within R_{200}

	R_{200} [kpc]	M_{200} [10^{10} M$_\odot$]	$\mathrm{M_{star}}$ [10^{10} M$_\odot$]	$\mathrm{M_{gas}}$ [10^{10} M$_\odot$]	$\mathrm{M_{SF}}$ [10^{10} M$_\odot$]
G1	245	168	8.1	6.6	0.479
G2	219	120	6.4	5.2	0.369
G3	211	108	6.8	3.6	0.078
G4	166	52	3.3	1.8	0.146
G5	177	63	4.4	1.8	0.151
G6	174	60	3.7	1.5	0.090





Scannapieco, White et al., 2011

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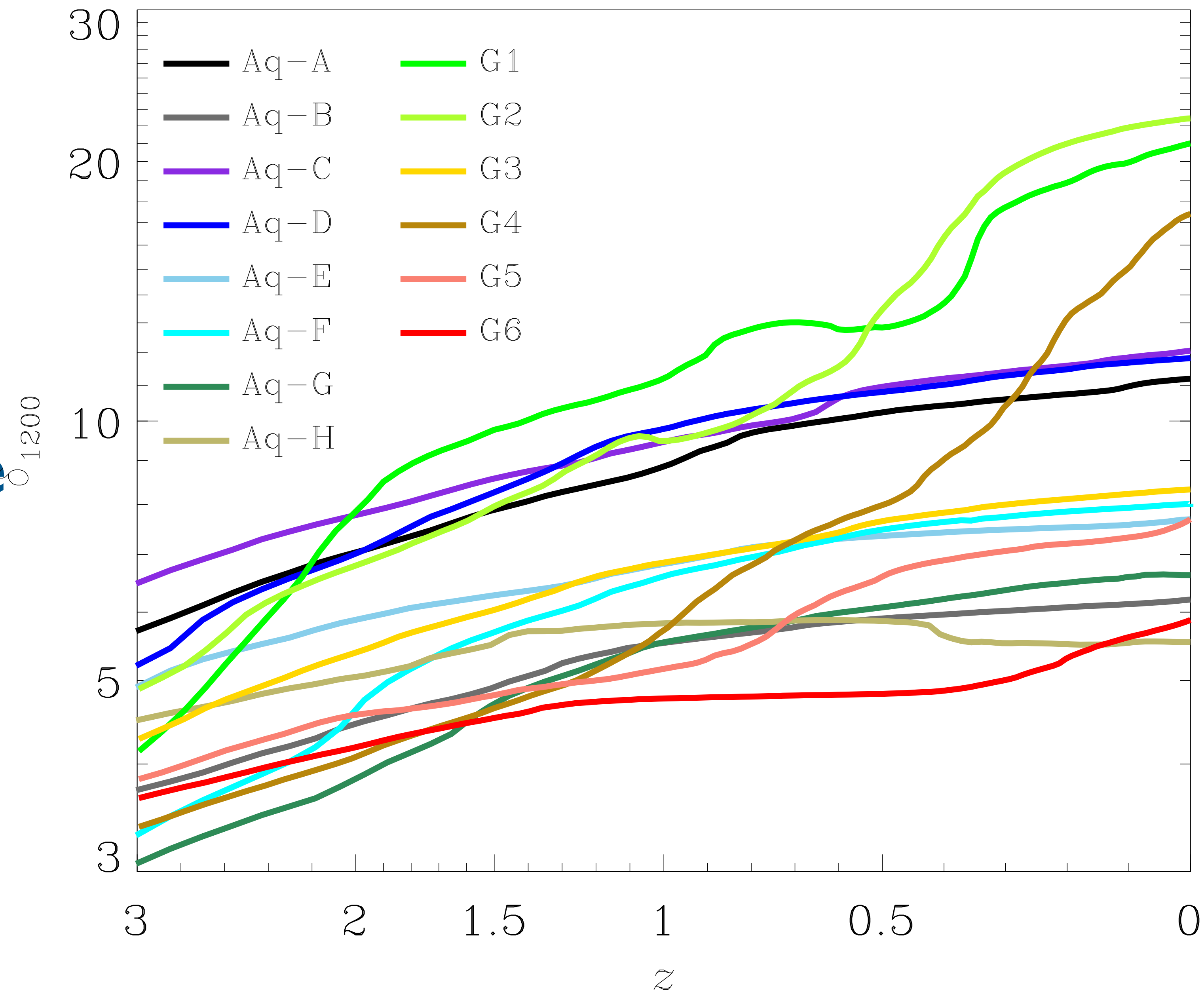
Matter density in 1200 ckpc

$$\delta_{1200} \equiv \left\langle \frac{\rho_{\rm M}}{\Omega_{\rm M}(z)\rho_{\rm c}} \right\rangle_{r<1200\,{\rm ckpc}}$$

- Overdensity of ~3-4 just from having a MW mass halo in the sphere
- Around z=0.5 the environments of G1 and G2 start to overlap



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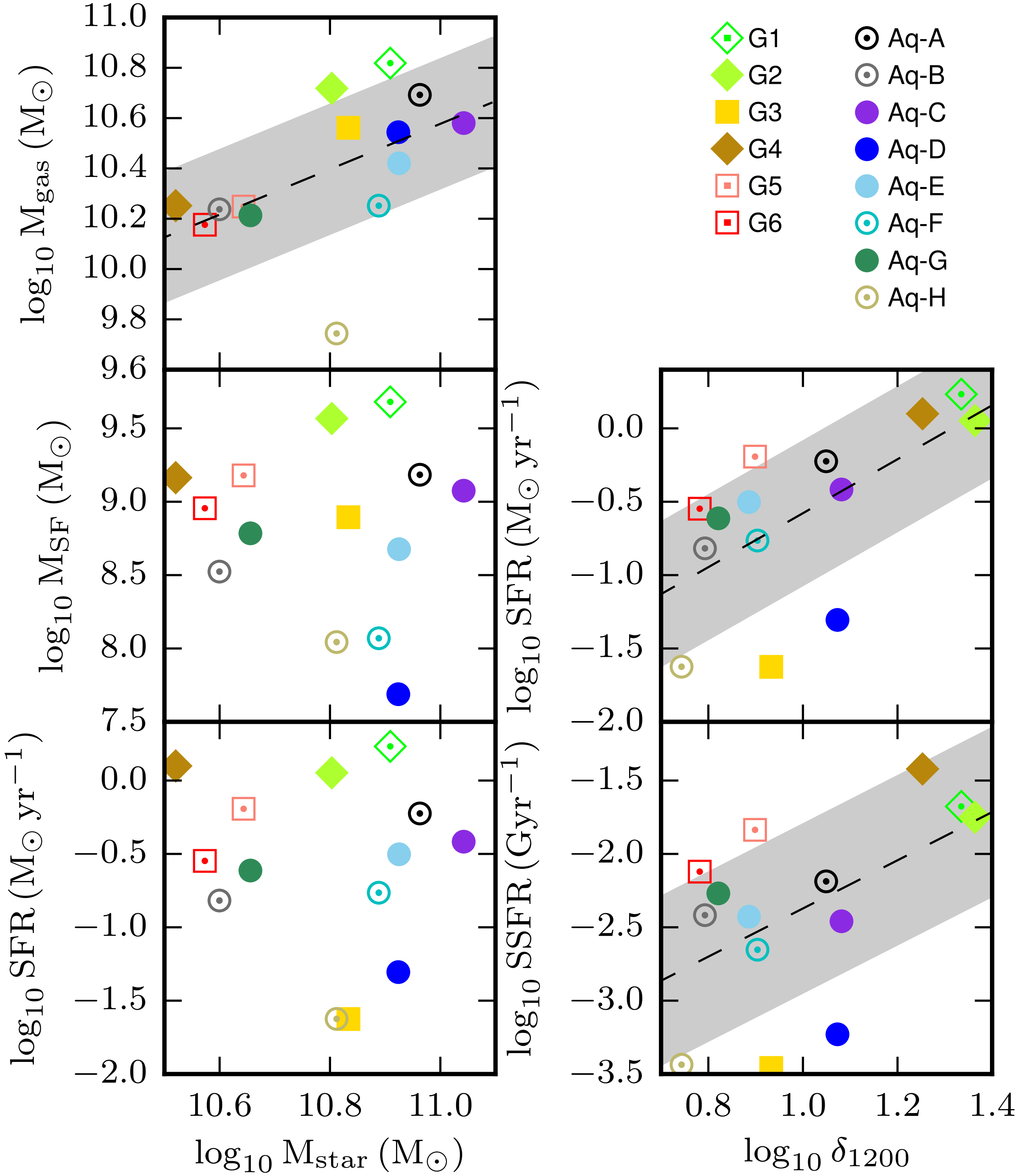
Some statistics

- All in the restricted stellar mass range
- Filled symbols have stellar disks (by circularity, see also Sebas' talk)
- No (significant) correlation between stellar mass and SFR or star forming gas, or presence of a disk
- 4.4σ correlation between gas and stellar mass (not so surprising)
- 3.8σ correlation between δ_{1200} and SFR (a bit surprising)



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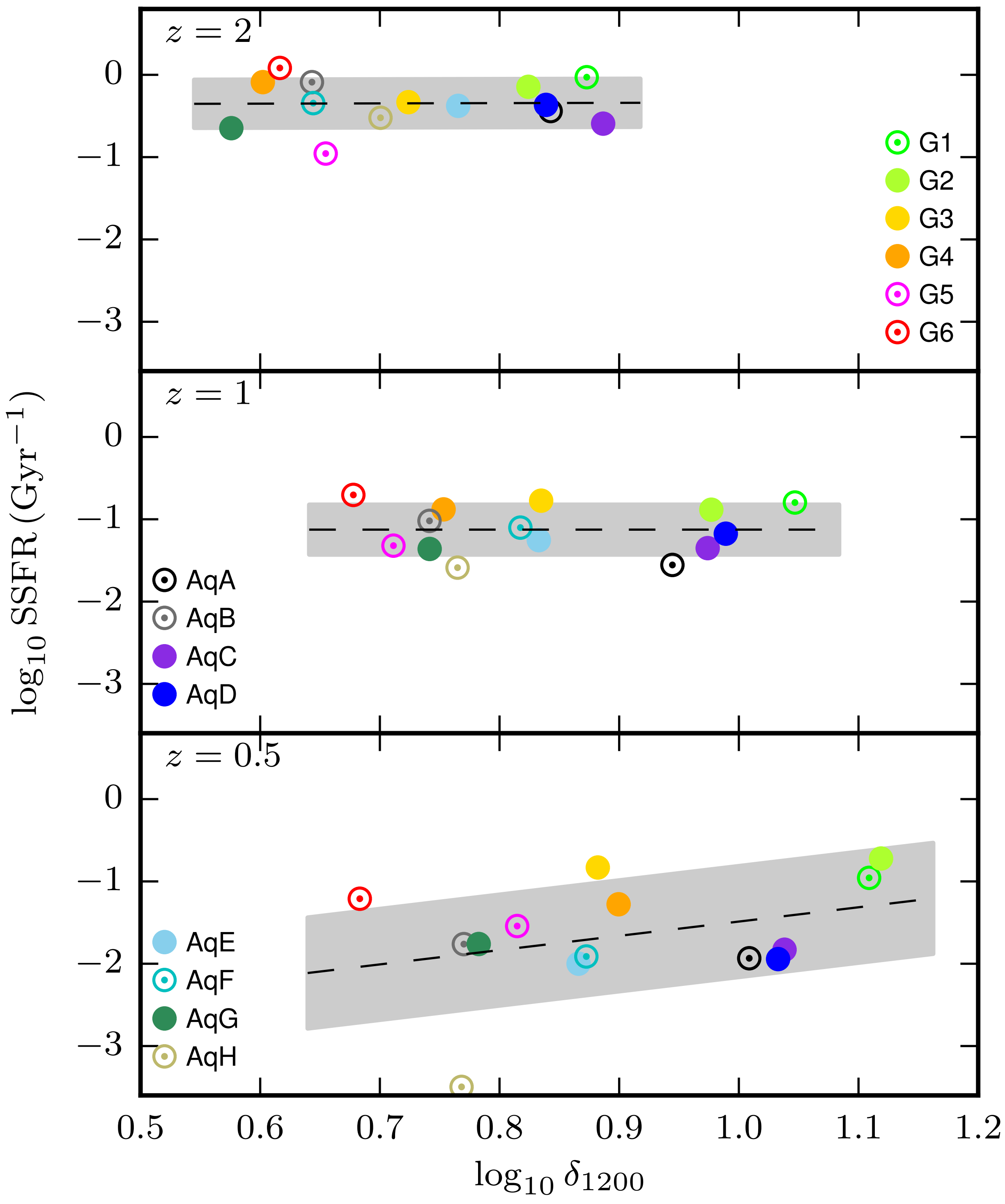
Evolution with redshift?

- Continues back to z=0.5, disappears at z=1 and above.



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ideas?

- G1 and G2 might be accreting each others extra-virial material (presumably as small objects)
- In a filamentary structure gas accretion may be faster (see also Nuza 2014, Bahé 2013), corresponding to G4
- Morphology might be more stochastic due to mergers
- Do the MW and M31 show enhanced SFR? (Mutch, Croton & Poole 2011)

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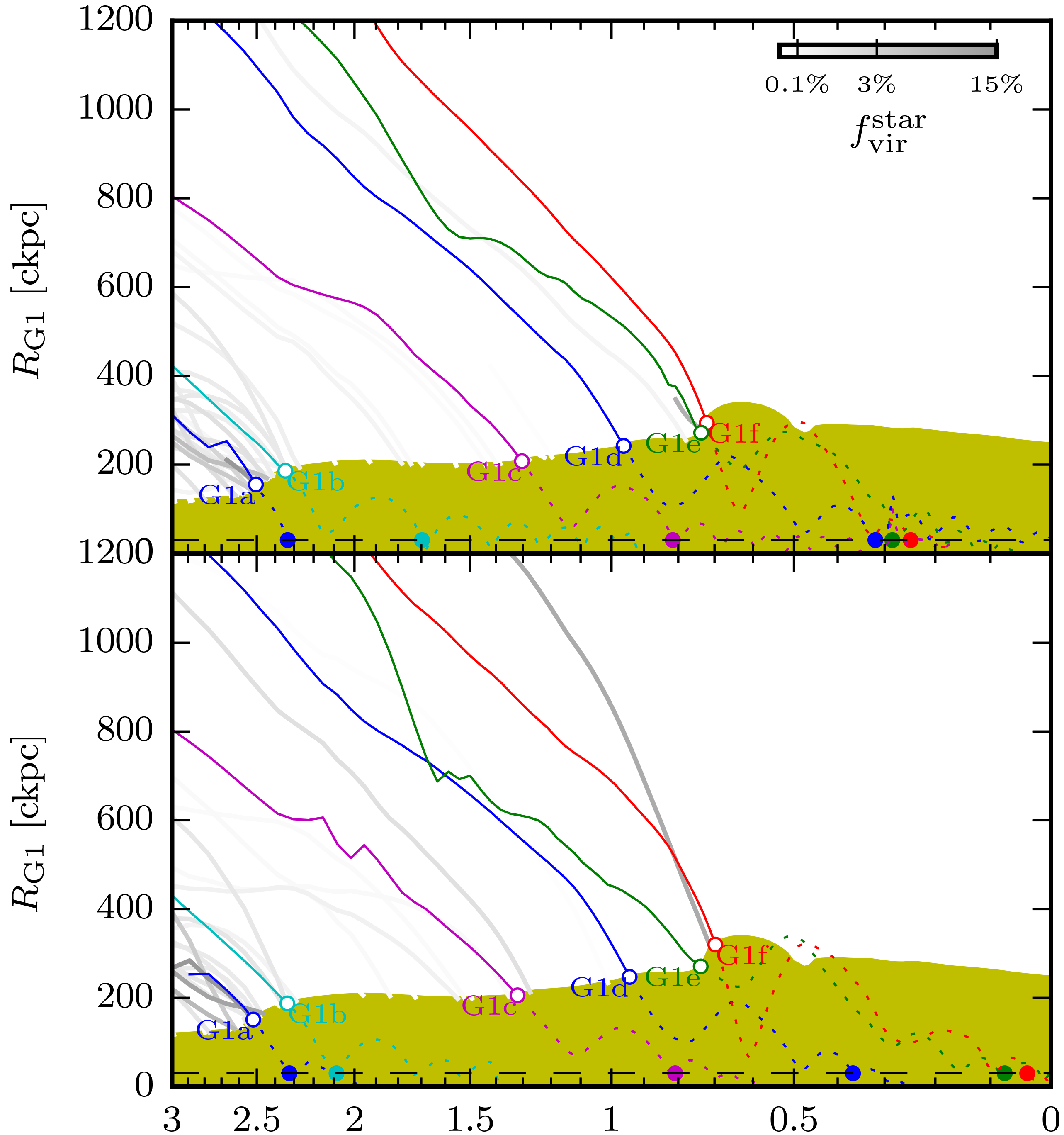
Merger history of G1 and G2



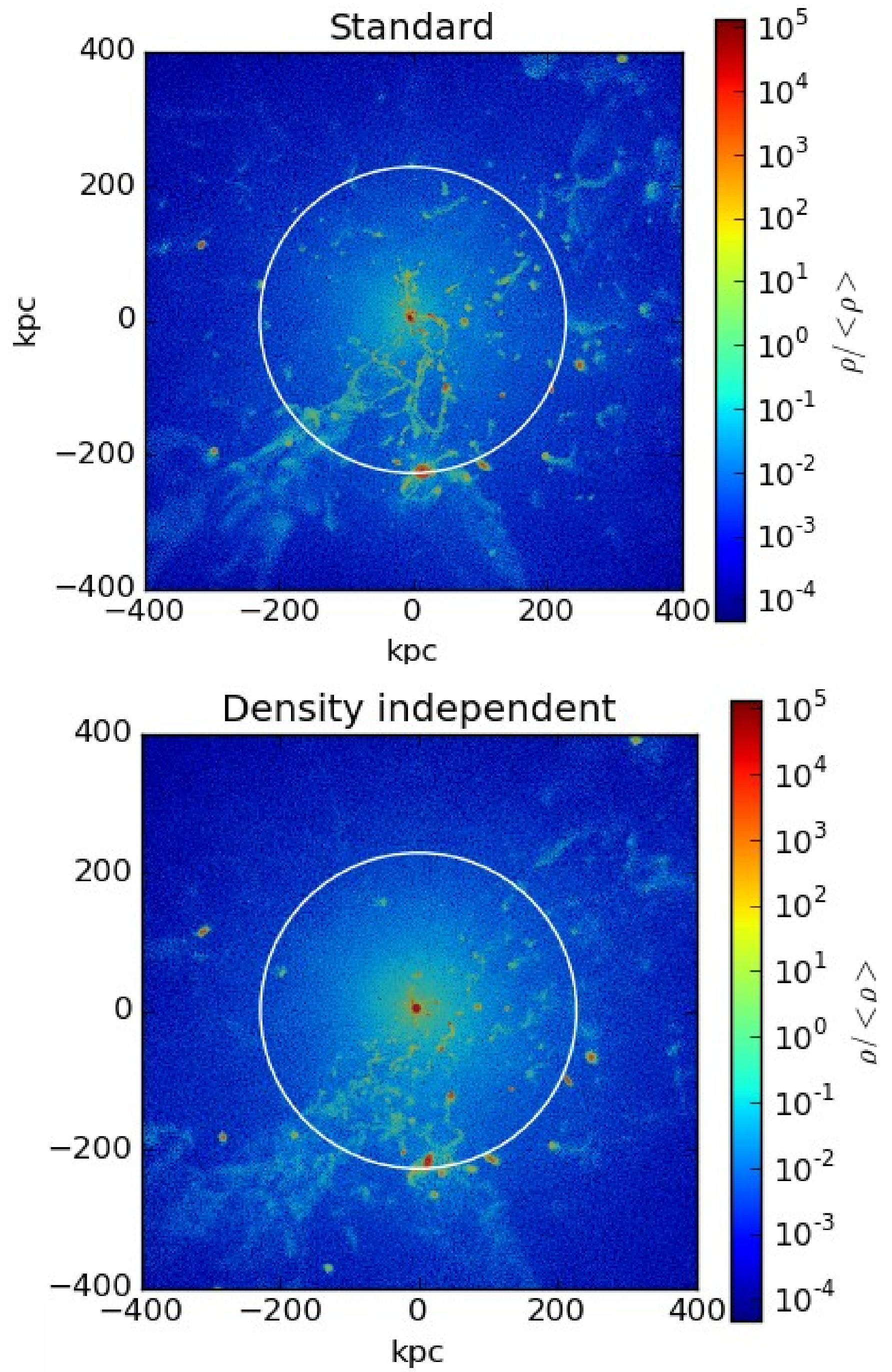
CS model

MA model

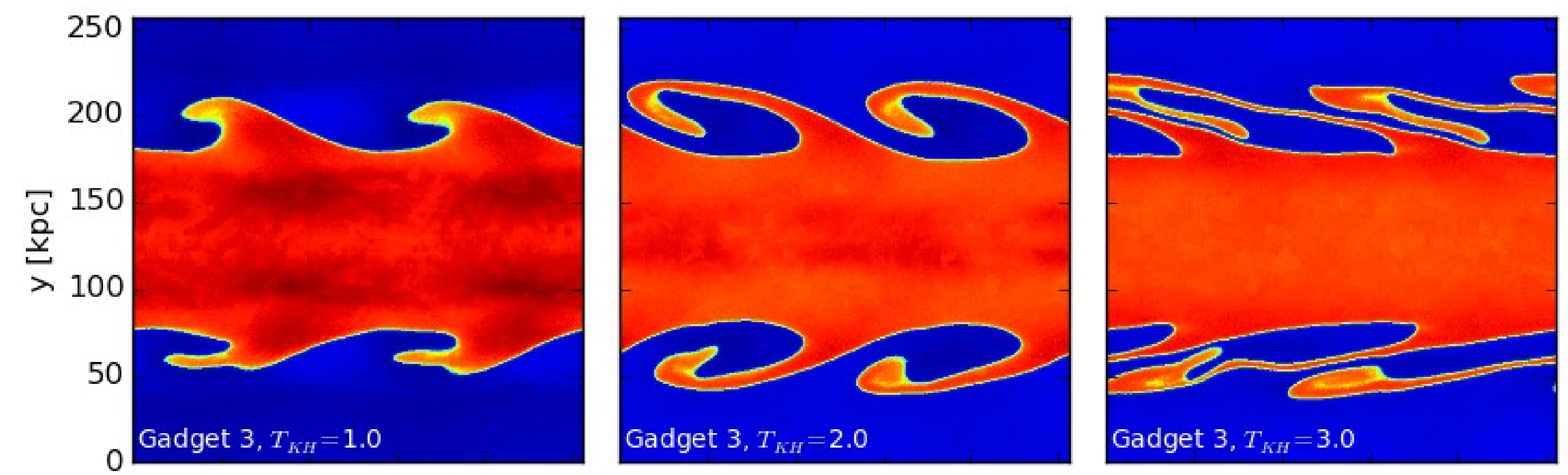
Scannapieco, Creasey, Nuza et al., 2015 A&A

Peter Creasey

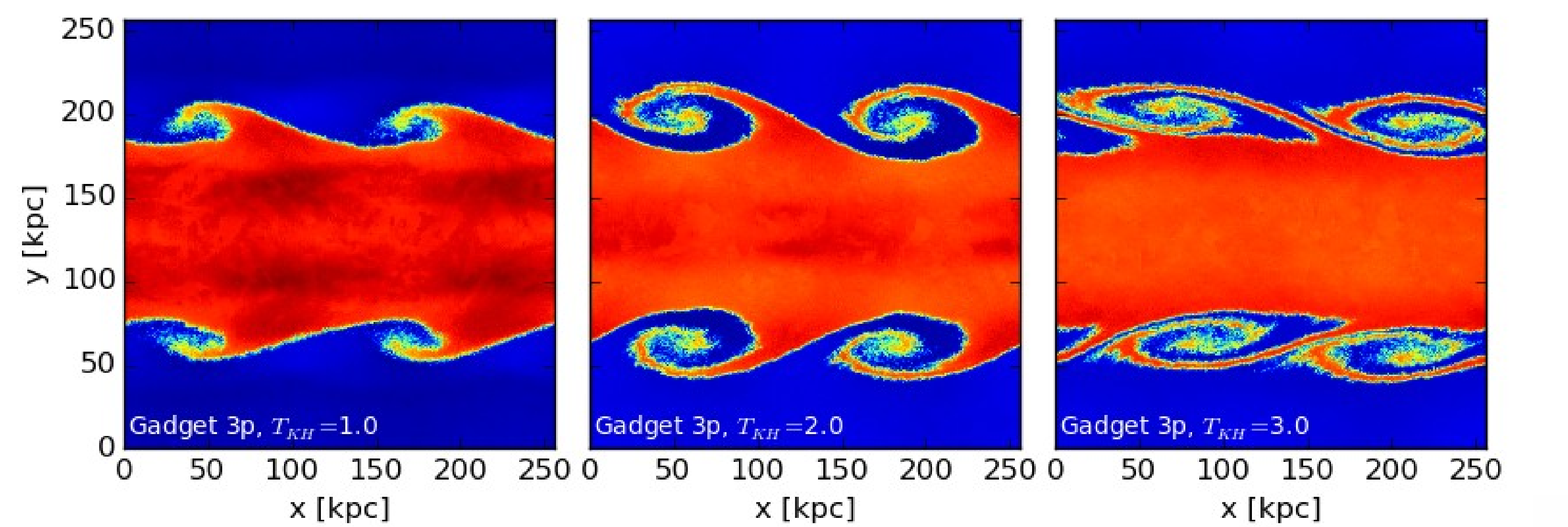
Mixing in SPH - Ondrej Jaura (AIP)



Density-Entropy (standard)



Pressure-Entropy (a la Hopkins 2013)



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Summary

- The MW and M31 are at the sparse end of the environment scale, the importance of which is an open question
- At the 1200 ckpc scale we see these environments merge around z=0.5, i.e. G1 and G2 live in a rich environment, the only other galaxy in a comparable density lies in a filament (G4), even when comparing with the Aquarius halos with the same code.
- Trends not seen with disk fraction (as with other studies), suggesting for loose groups merger history is a more important driving factor for morphology
- The galaxies in the highest density environments have the highest redshift zero SFRs, setting up a correlation between environment and SFR. This fades at higher redshift (z>0.5)
- In the richer environment gas accretion may replenish the star-forming gas (e.g. for G4 the filamentary structures of Nuza 2014, Bahé 2013),