Feedback of Massive Stars in Dwarf Galaxy Formation

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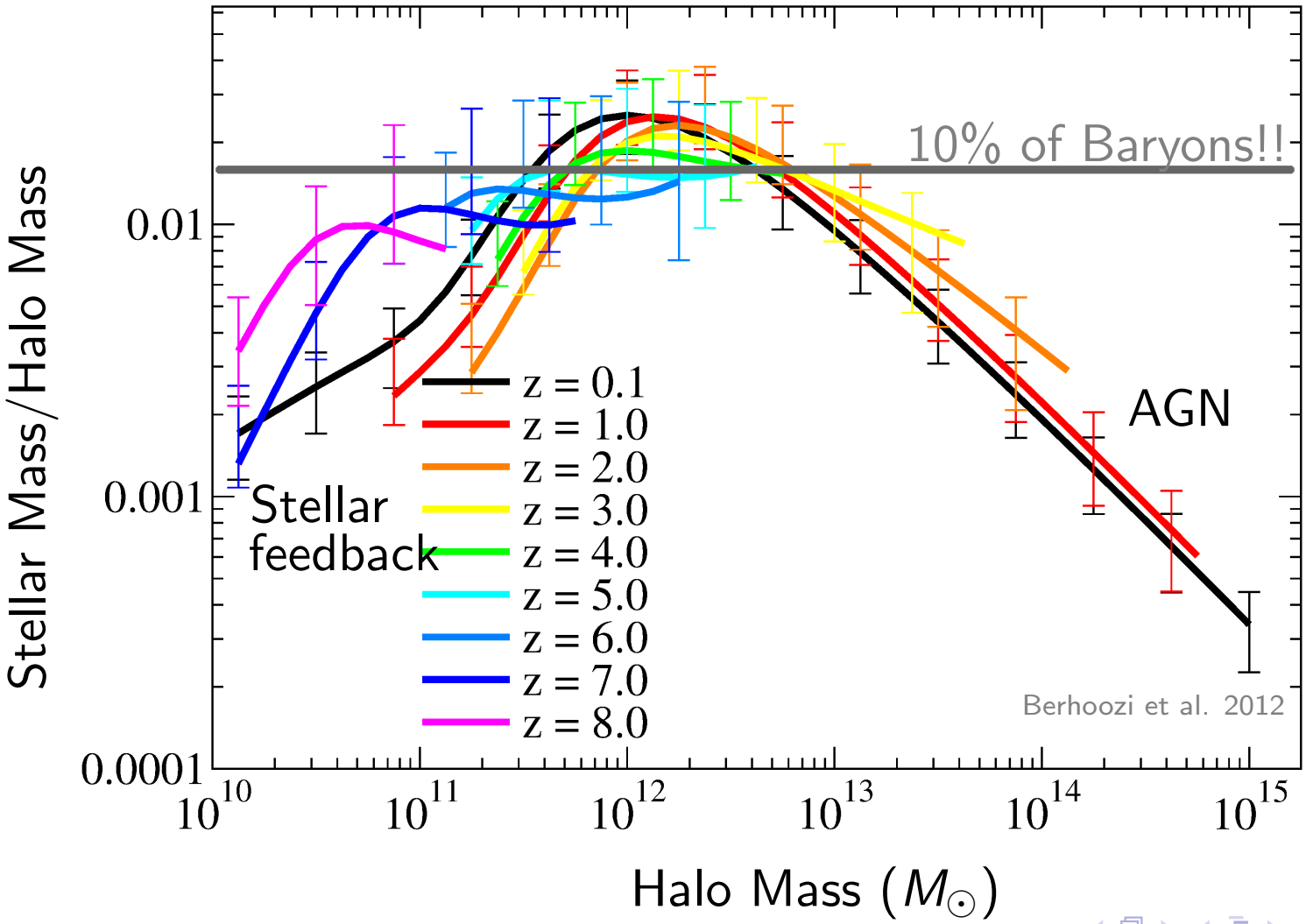
Feedback as the answer for inefficient star formation

$$\Sigma_* \sim 0.017\ \Sigma_g/\tau_{dyn}$$ Kennicutt 1998



Dealing with overcooling in cosmological hydrodynamical simulations

- Overcooling: $t_{cool} < t_{dyn} \Rightarrow$ high star formation efficiency
- Feedback: Subgrid models. Recent successful approaches but due to the limits of the model it is difficult to extrapolate:
  - Turning off cooling
  - Force wind by hand: kick out of galaxy

  (Oppenheimer & Dave 2006, Stinson 2006, Piontek & Steinmetz 2009...)
- Resolution: $\epsilon \sim 1000 - 100$ pc; $m_{gas} \sim 1E4 - 1E3 M_{\odot}$

Can we do better?
New sub-grid model developed to resolve ISM

Goal: Resolve higher ρs to have a resolved multiphase ISM $\Rightarrow$ Still subgrid but trying to go one layer below $\Leftrightarrow$ stellar evolution models

- `GADGET-3`. new SPH implementation Hopkins et al. 2013

- Explicit momentum flux: SNe (II & Ia), Stellar winds and radiation pressure. Heating: SN, stellar winds, rad. young stars. Fine structure cooling ($< 100K$)

- Interesting results with non-cosmological models: self regulated star formation, different mechanisms dominating different regimes,... (Hopkins et al. 2011, 2012a, 2012b, 2013)

Dwarf galaxy halos cosmological runs

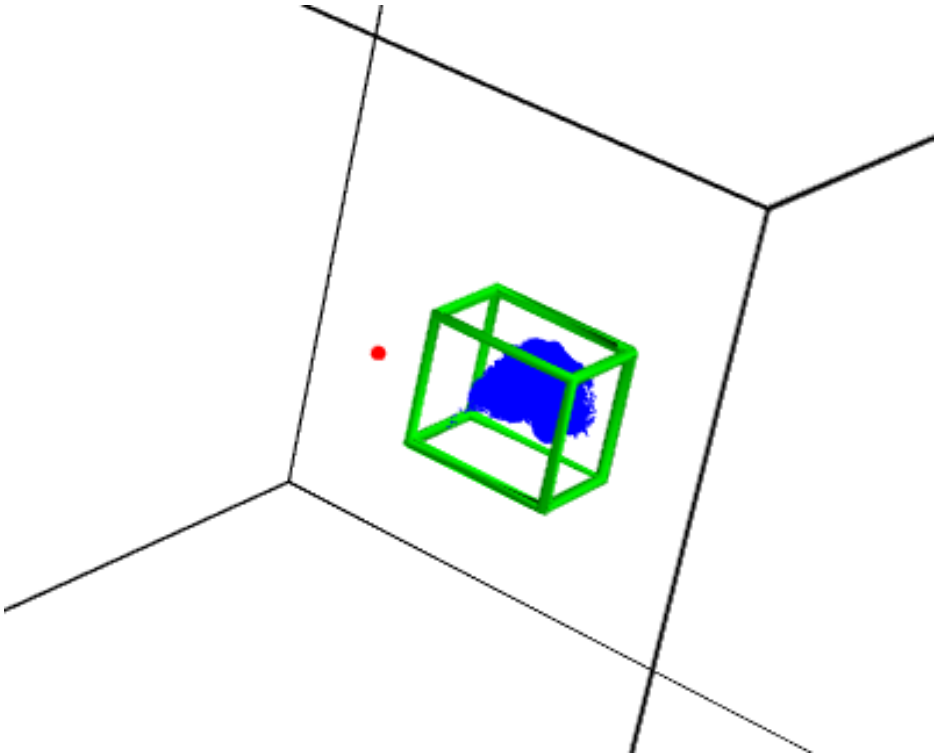
Why?

- Reach high resolution:
  $M_g = 2.5E2M_\odot$
  $M_{dm} = 1.2E3M_\odot$
- Significant increase of observational data in the last years (number & detail)
- Similar (or lower) baryon content and gas-to-star efficiency than bigger galaxies
- No predominant role of AGN feedback

How?

Multimass Simulations

(Oñorbe et al. 2013)

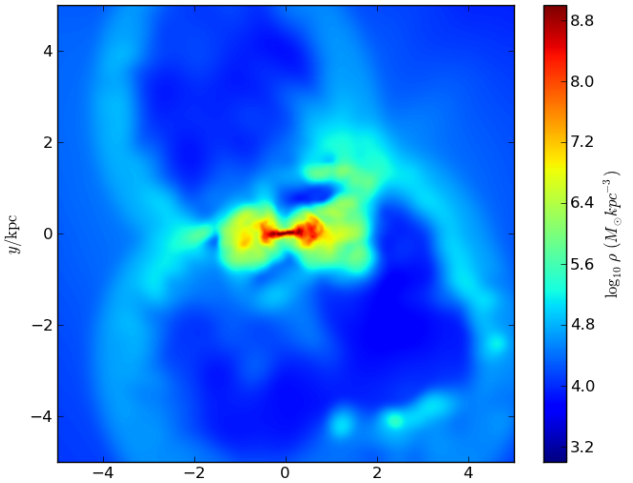


First set of simulations are finished

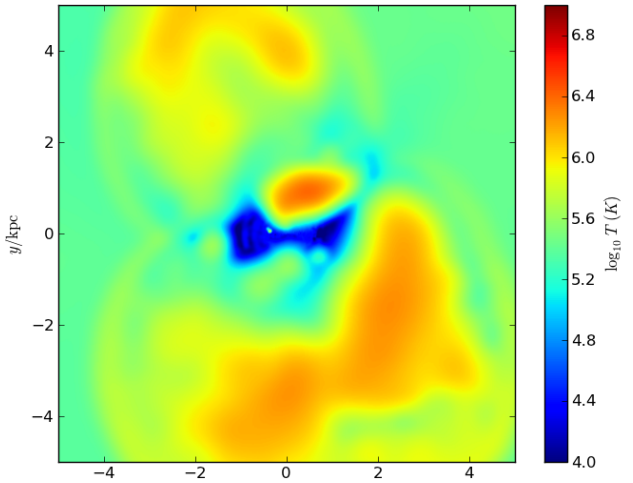
Supernova explosions @ $z = 3.5$

Thin slice z-axis

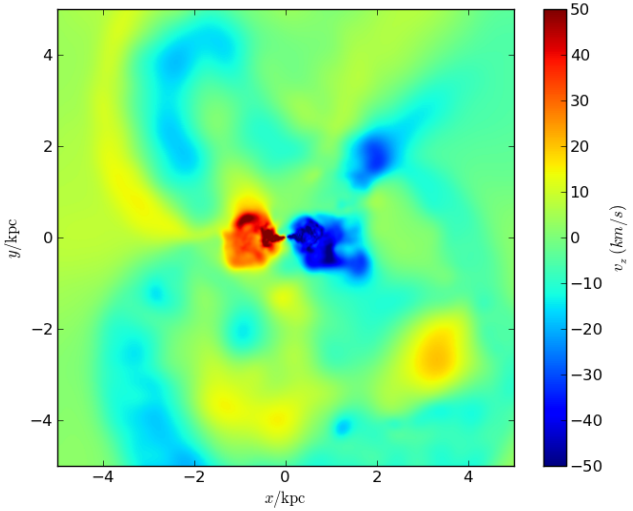
Density



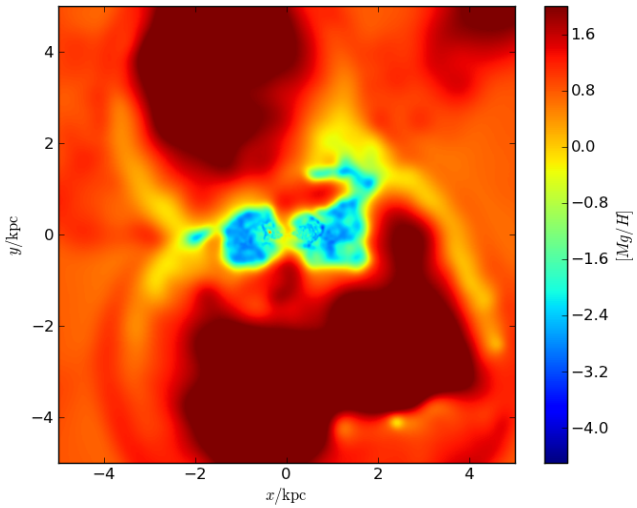
Temperature



Velocity

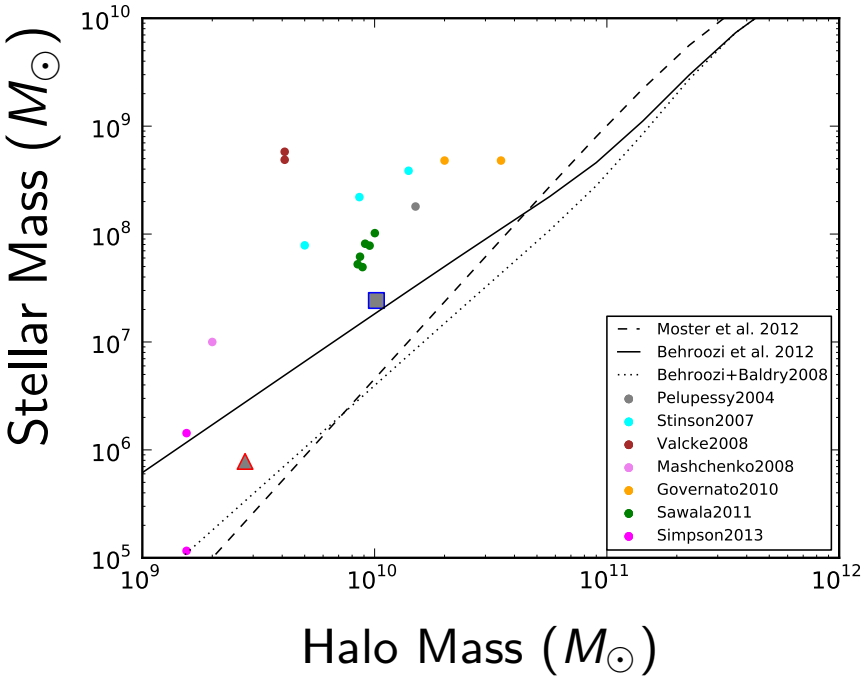


Metallicity [Mg/H]

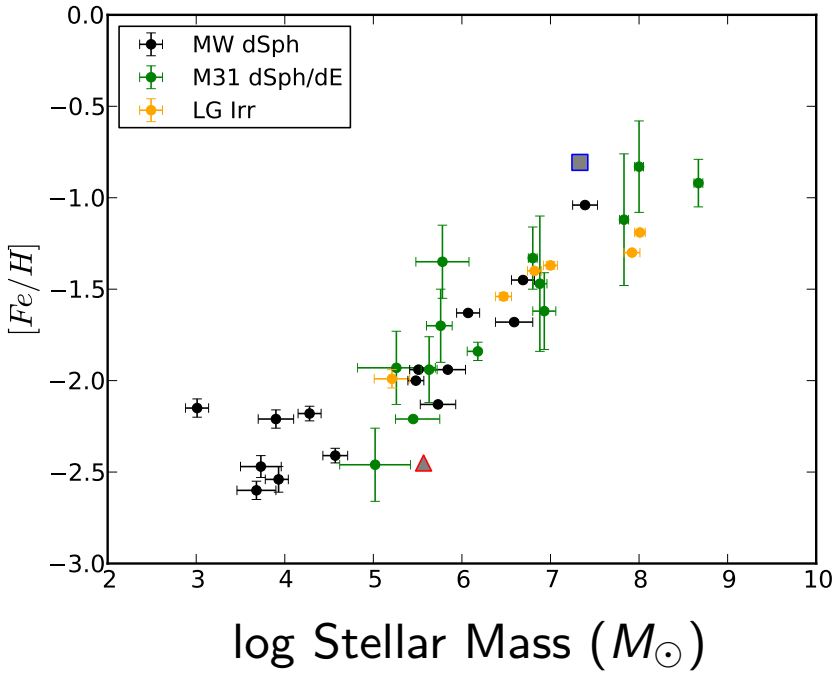


Overall good agreement with observational properties at $z = 0$

Halo-Stellar Mass



Metallicity



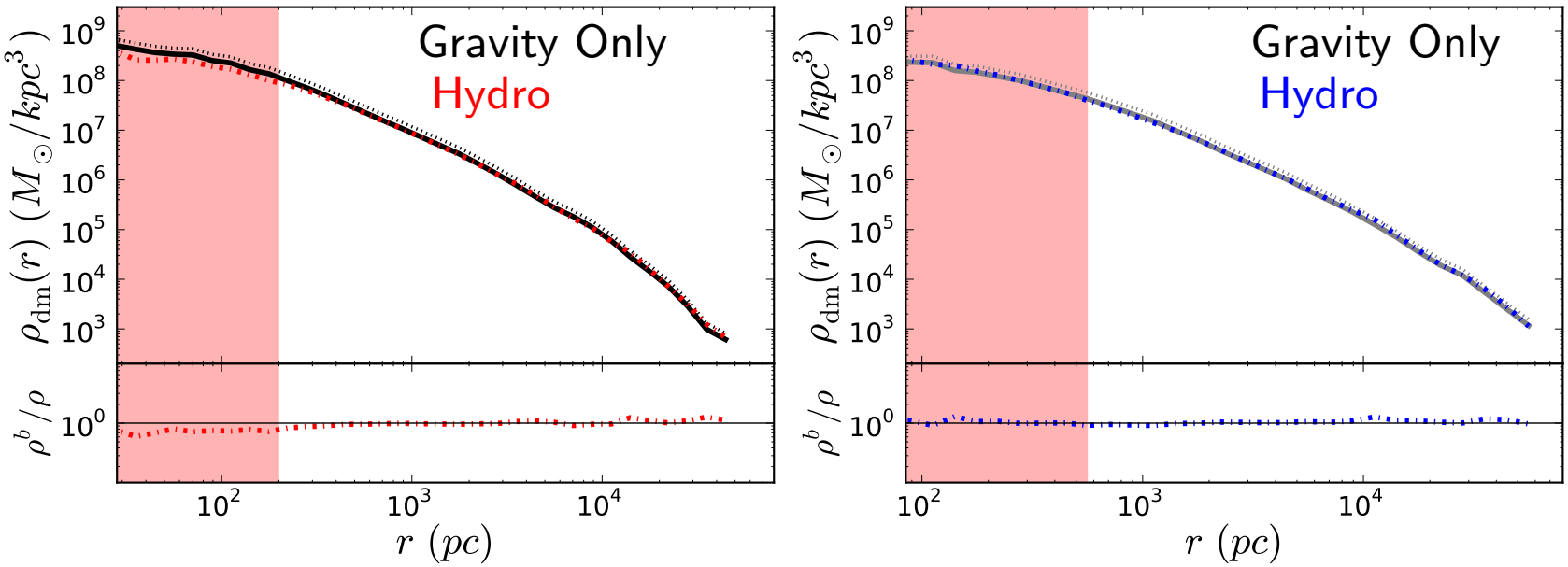
[Fe/H]

Obs. data E. Kirby priv. com.

Feedback & the dark matter distribution

Observed densities in dwarf galaxy halos smaller than expected from ΛCDM n-body cosmological simulations. (Boylan-Kolchin et al. 2012)

$M_{vir} = 3E9 M_\odot$ at $z = 0$ $M_{vir} = 1E10 M_\odot$ at $z = 0$

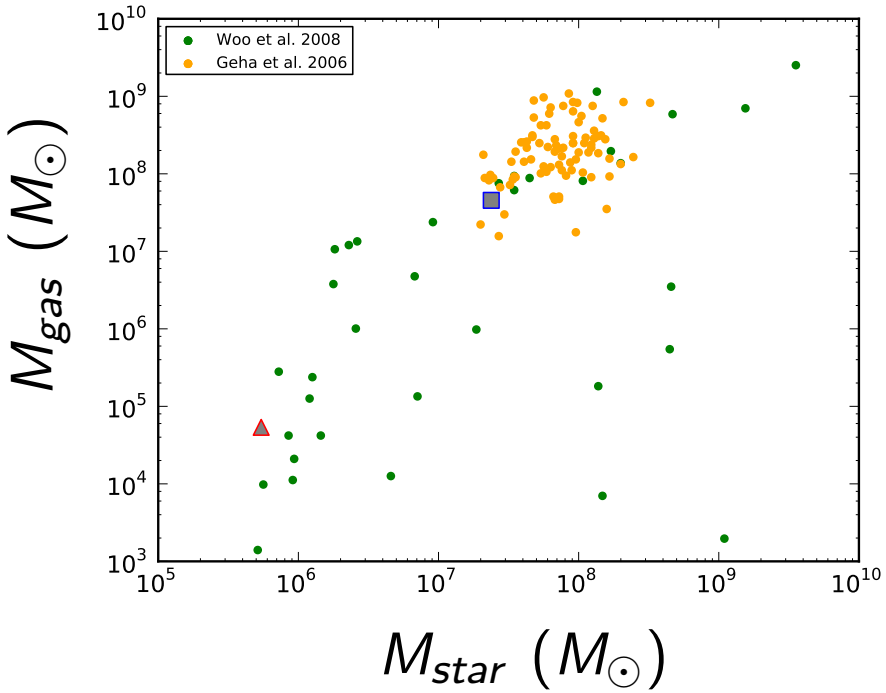


Feedback? (Oh et al. 2011) $< 5E9 M_\odot$ No

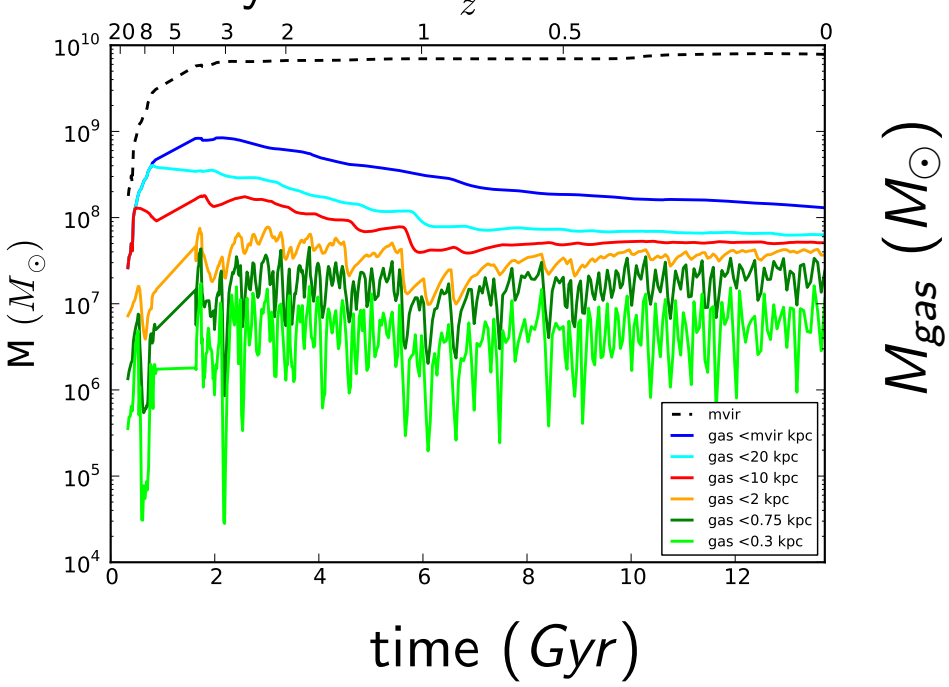
$> 5E9 M_\odot$ No for moderate resolution but higher resolution sims just finished!

Gas content and baryon fraction evolution

Galaxy scale
Gas-Stellar Masses



Baryon mass at fixed radii



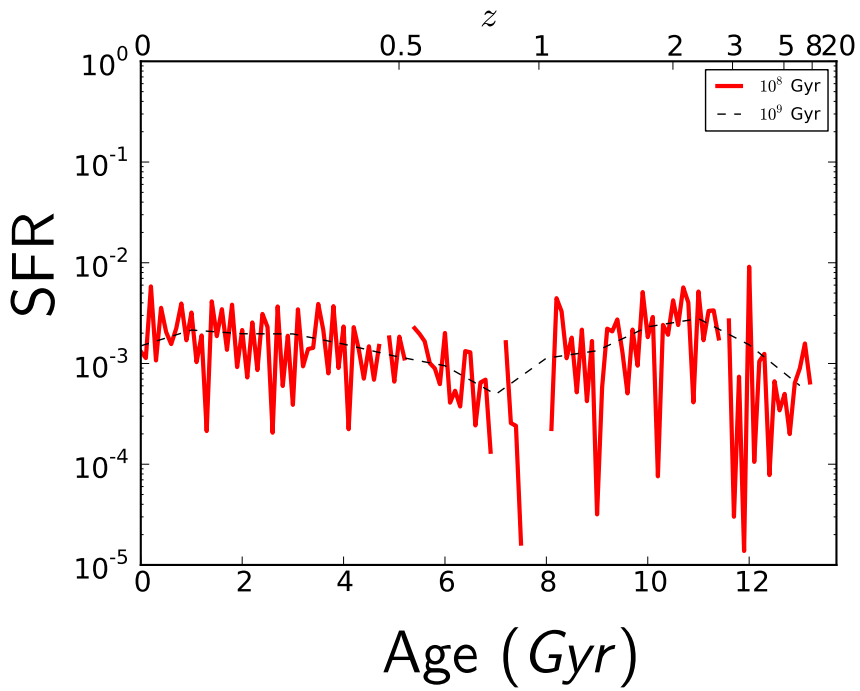
Two different mechanisms to expel gas depending on the scale:

Galaxy scale $\Rightarrow$ strong feedback episodes

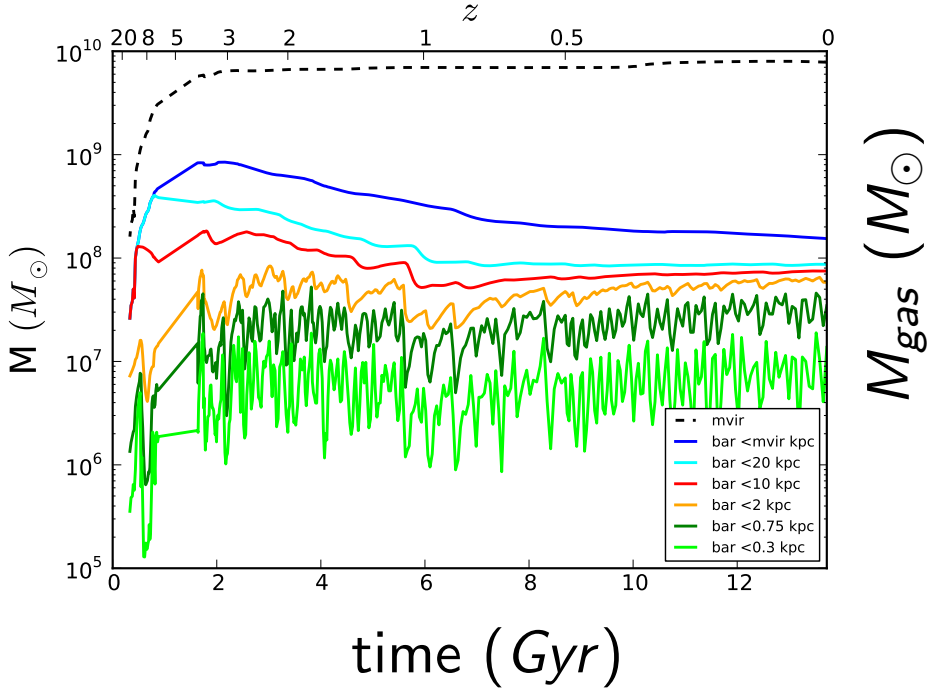
Halo scale $\Rightarrow$ Smoother process

Gas content and baryon fraction evolution

SFR



Baryon mass at fixed radii



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Conclusions

High-res cosmological simulations with new stellar feedback model

- More easy to extrapolate results and connect stellar physics with galaxy formation models

Preliminary results on dwarf galaxies

- Good agreement with observations: SF quenched, metallicity, gas content, stellar structural parameters

- Feedback & cores? No for $M < 5E9 M_{\odot}$. $M > 5E9 M_{\odot}$ very soon

- Gas expelled from the galaxy due to violent feedback episodes. Smoother process at the halo scale.