Merger Histories of DM Halos

and the Baryonic Assembly of Galaxies

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Introduction:

There is a concern about the survivability of disk galaxies in ΛCDM cosmology:

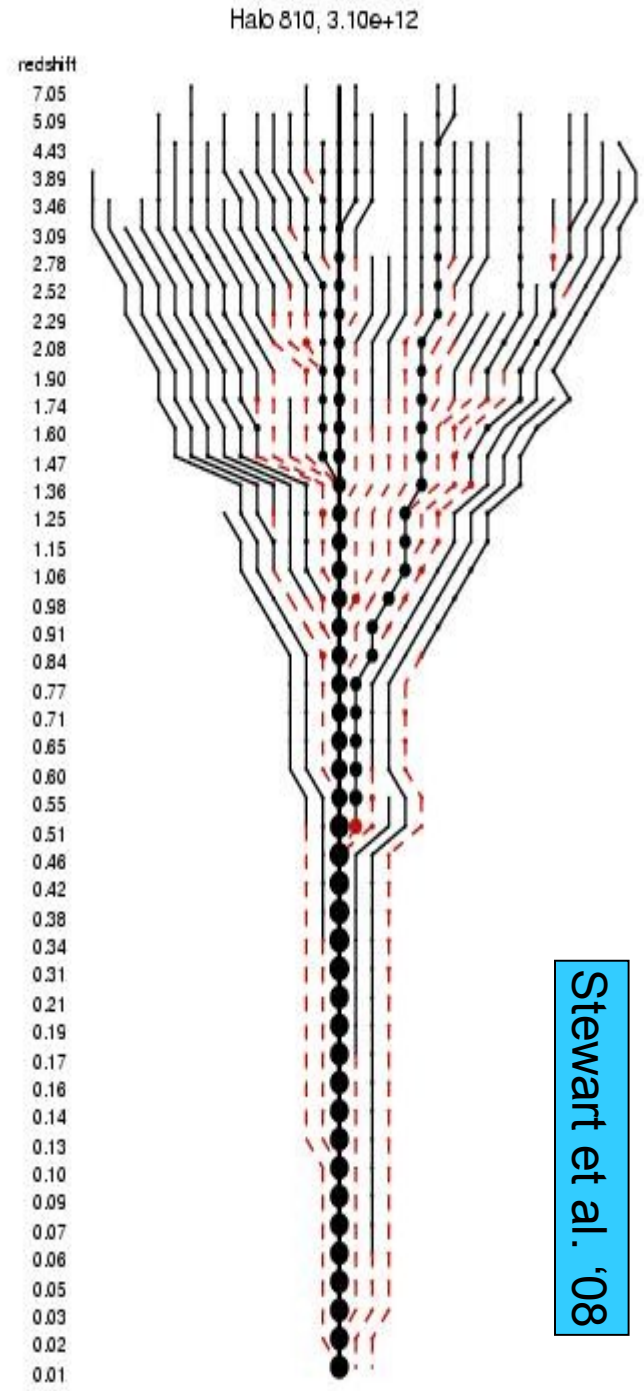
- Dark Matter Halos form by mergers.
- Major mergers turn disk-type galaxies into thick, flared, more bulgy systems. (eg. Kazantzidis et al. '07, '08; Purcell et al. '08b)
  - And Yet: Majority of Milky-Way sized DM halos contain thin disk-dominated galaxies (z=0). (eg. Weinmann et al. '06; Choi et al. '07; Park et al. '07; Ilbert et al. '06.)
- Fraction of galaxies with a major merger in a past dynamical time approximately doubles from z=0 to z=2. (Stewart et al. '08b)
  - And Yet: Large disk-like galaxies observed at z~2. (eg. Förster Shreiber '06; Genzel et al. '06; Shapiro et al. '08.)

How is all this compatible?

DM Merger Trees

- DM only, ΛCDM, N-Body simulation.
- 80 h^{-1}Mpc Box, σ_8=0.9, 512^3 particles
- m_p=3.16x10^8 $h^{-1}M_\odot$ (better resolution than Millennium.)
- **A**daptive **R**efinement **T**ree code. 512^3 cells, refined to max. of 8 levels. h_{peak} ~ 1.2h^{-1}kpc (Kravtsov et al. '97)
- Focus on host masses ranging from 10^{11}-10^{13} $h^{-1}M_\odot$ (~15,000 halos at z=0, ~9,000 halos at z=2.)
- Complete to 10^{10} $h^{-1}M_\odot$

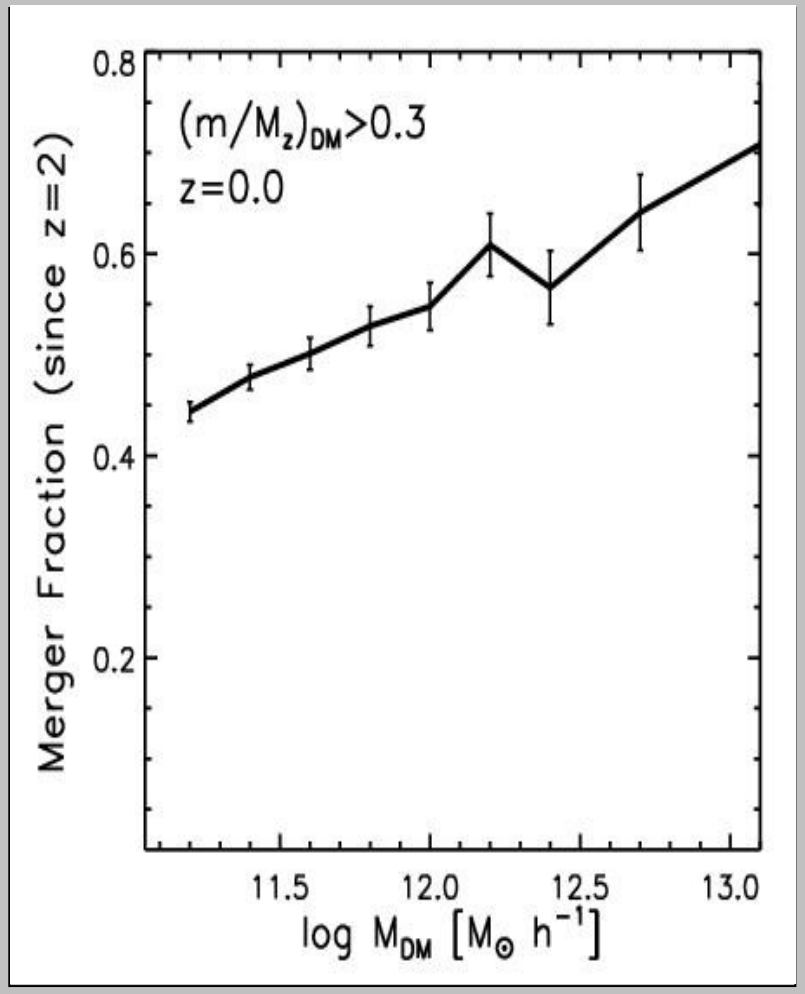
- Example merger tree shown is for a M_0 ~ 10^{12} h^{-1} $M_\odot$ halo (at z=0).



Stewart et al. '08

Fraction of halos with >1/3 mergers that hit the disk since z=2

Fraction of MW-halos that have ever had a big merger seems problematic…

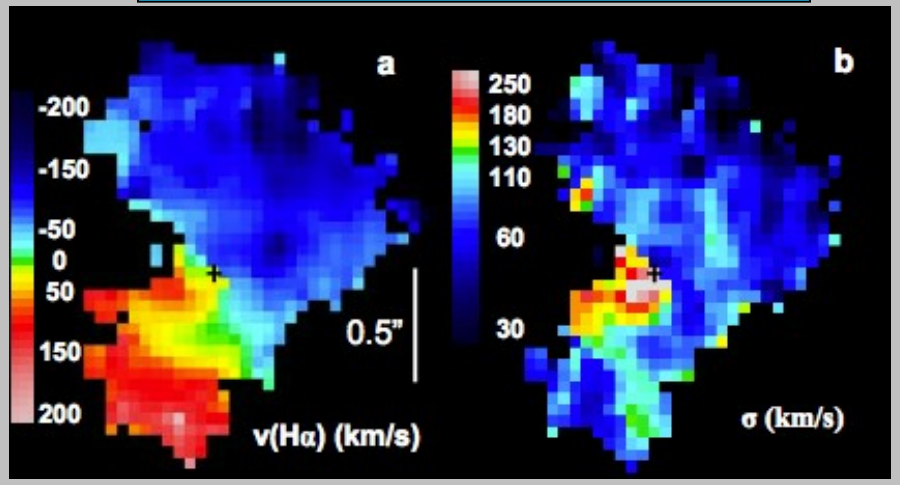


Gas Rich Mergers: the Solution?

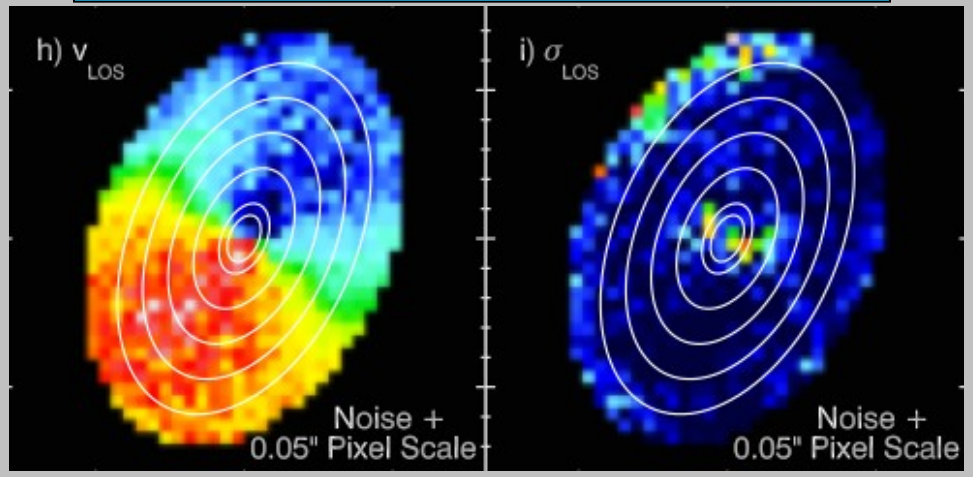
- Gas rich minor mergers help form rotationally supported gaseous disk galaxies.
- Given a sufficiently high gas fraction (f_{gas}> 50%), even major mergers (3:1) quickly reform into a disk.
  (Robertson et al. '06)

Example: Observed disk galaxy at z~2 resembles simulated gas-rich merger remnant:

Observation (Genzel et al. '06)



Simulation (Robertson & Bullock '08)



The baryonic assembly of galaxies via mergers

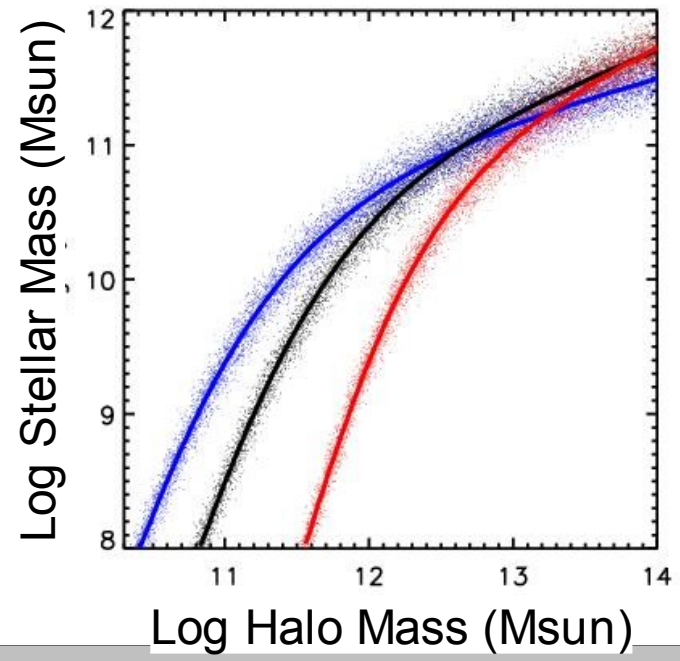
Stewart et al. 08c

1. DM halo merger trees
2. Empirical Stellar Mass -- Halo Mass relation (Conroy & Wechsler 2008)
3. Empirical Gas Mass -- Stellar Mass relation (McGaugh et al. 2005; Erb et al. 2006)

Step 2: Stellar Masses.

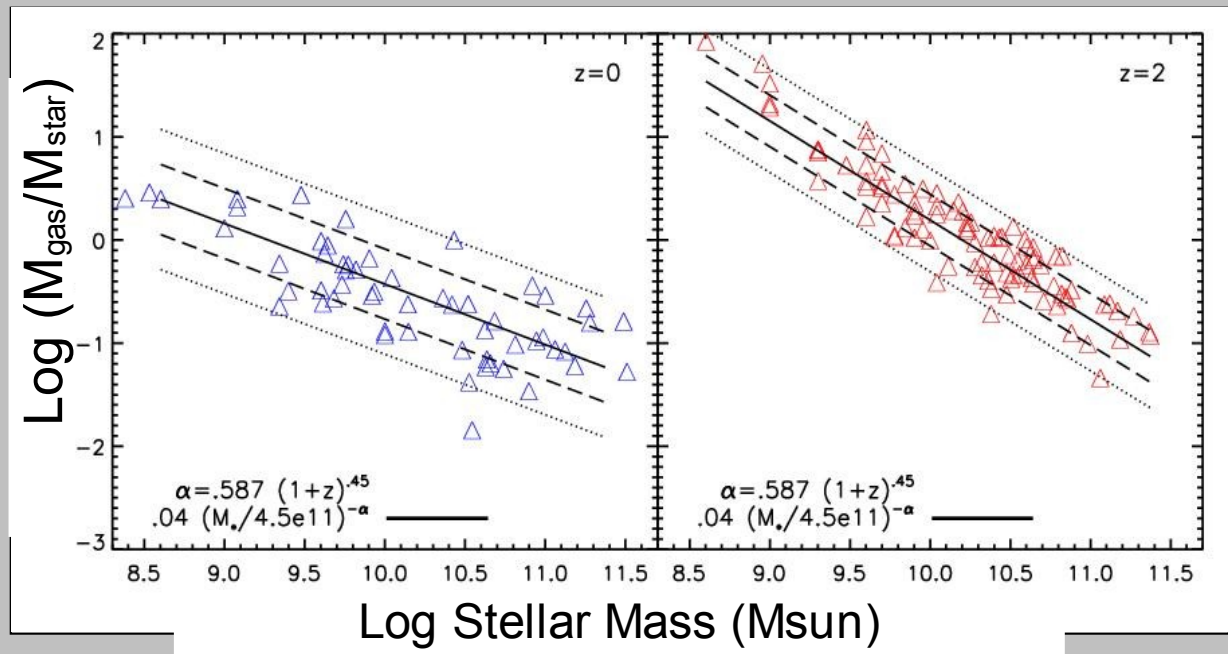
- Use number density matching to statistically assign an average stellar mass, given DM mass (and redshift). (data from Conroy & Wechsler 2008.)

- Conroy & Wechsler 2008



Step 3: Gas Masses.

- Use observations of galaxies at z=0 (McGaugh 2005) and z~2 (Erb et al. 2006) to estimate M_{gas}, given M_{star} and z (out to z=2).



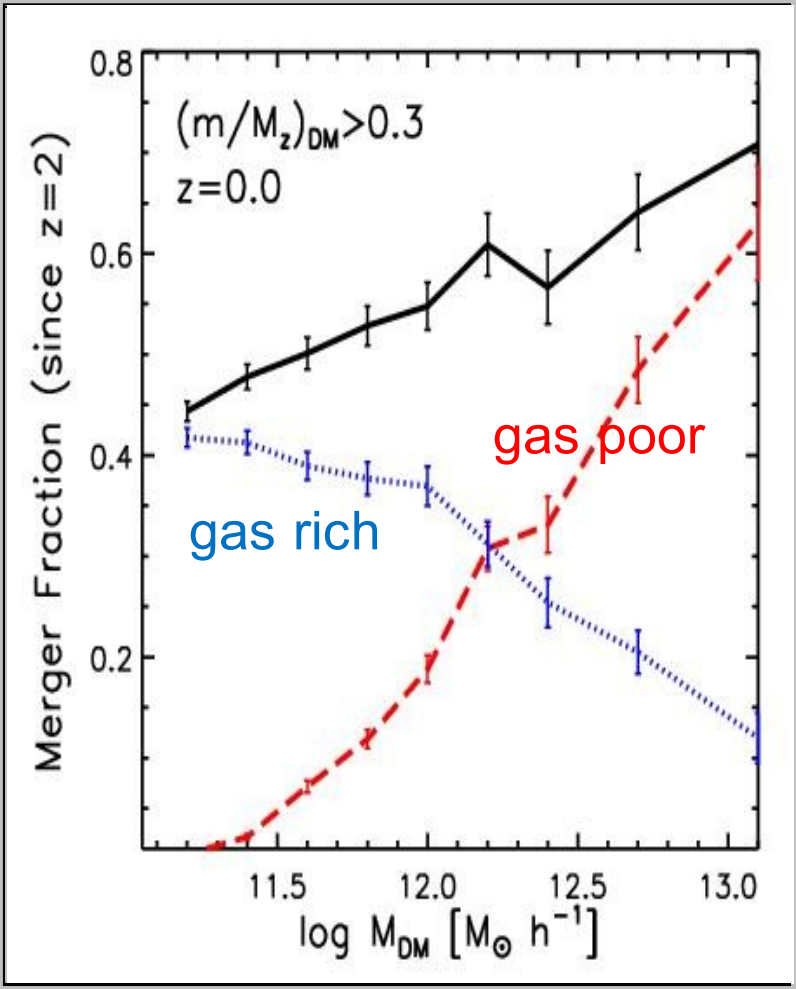
> 1/3 mergers that hit the disk

- Seems problematic…

But what if we only look at gas rich* vs. gas poor* mergers?

Small halos → gas rich mergers

Large halos → gas poor mergers



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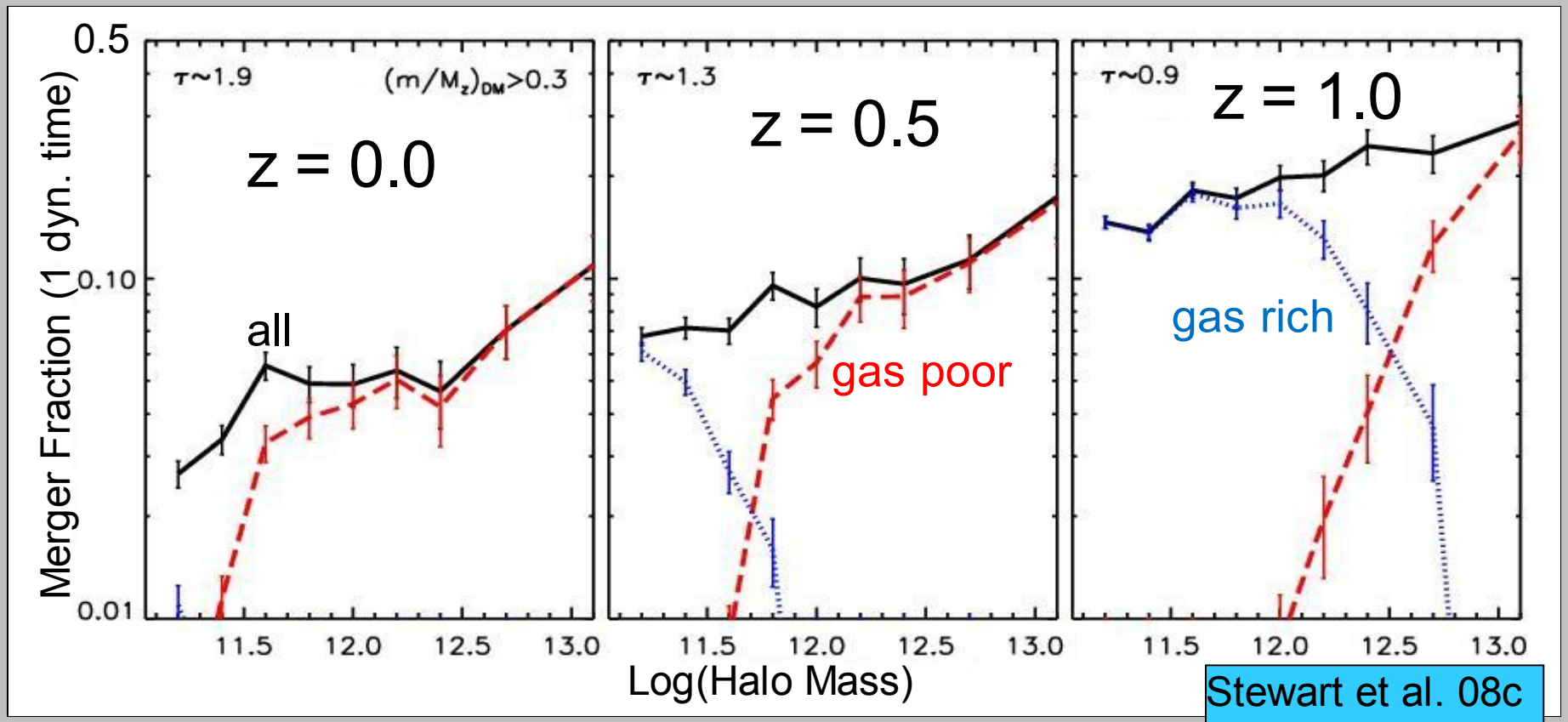
* Definitions:

- "Gas Poor" : both galaxies with gas fraction < 50%
- "Gas Rich" : both galaxies with gas fraction > 50%

Gas Rich/Poor Merger Fractions vs. z

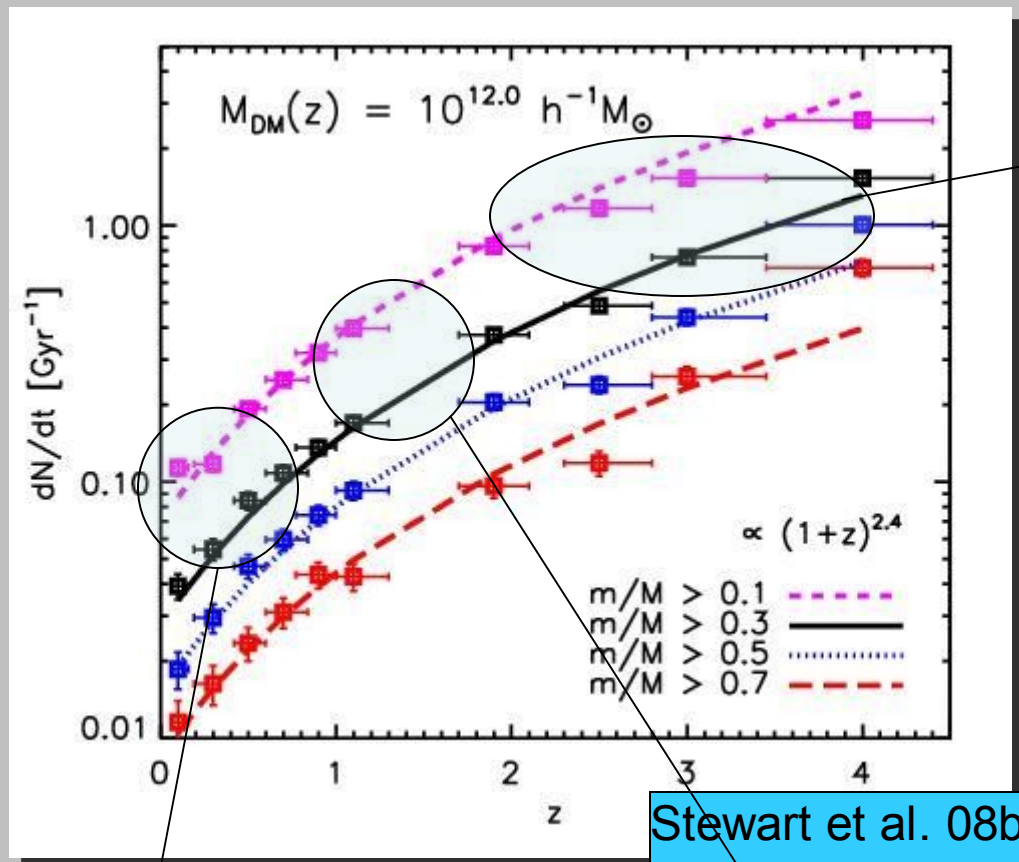


Stewart et al. 08c

- Note transition mass above/below which gas rich/poor mergers dominate. ($<10^{11.2}$, z=0 ; $\sim10^{11.6}$, z=0.5 ; $\sim10^{12.7}$, z=1)

Summary:

- Consider the DM merger rate for a 10^{12} $M_\odot$ halo:



Stewart et al. 08b

Merger rate high, but nearly ALL of them are **very** gas rich.

Disk survivability?

Not a problem!

Merger rate low.

Mergers gas poor (destroys disks)

Merger rate increasing.

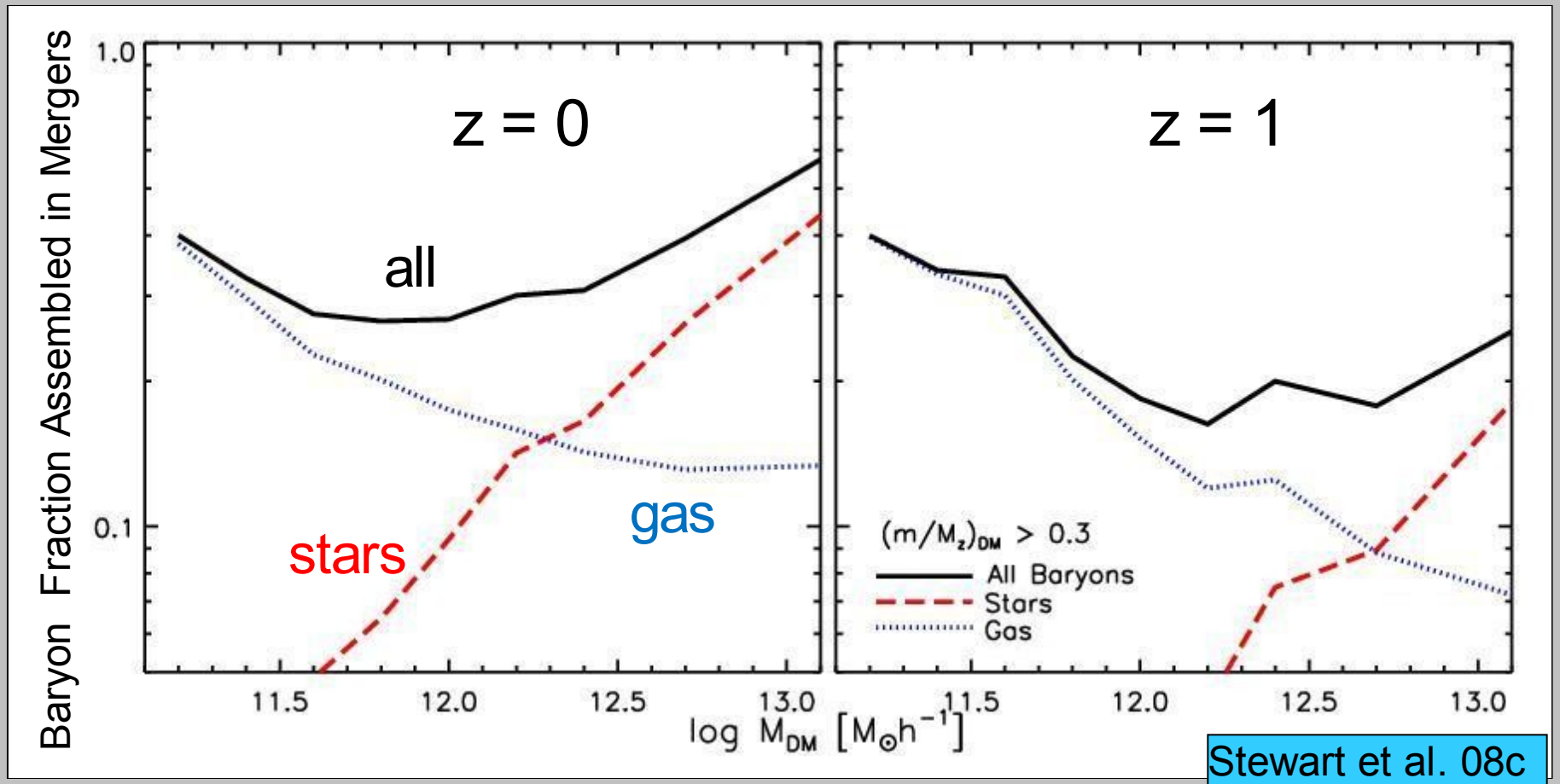
So is the gas rich merger fraction.

Extra Slides (if time allows)

Baryonic Mass Assembly

How do galaxies get their mass (in mergers)?

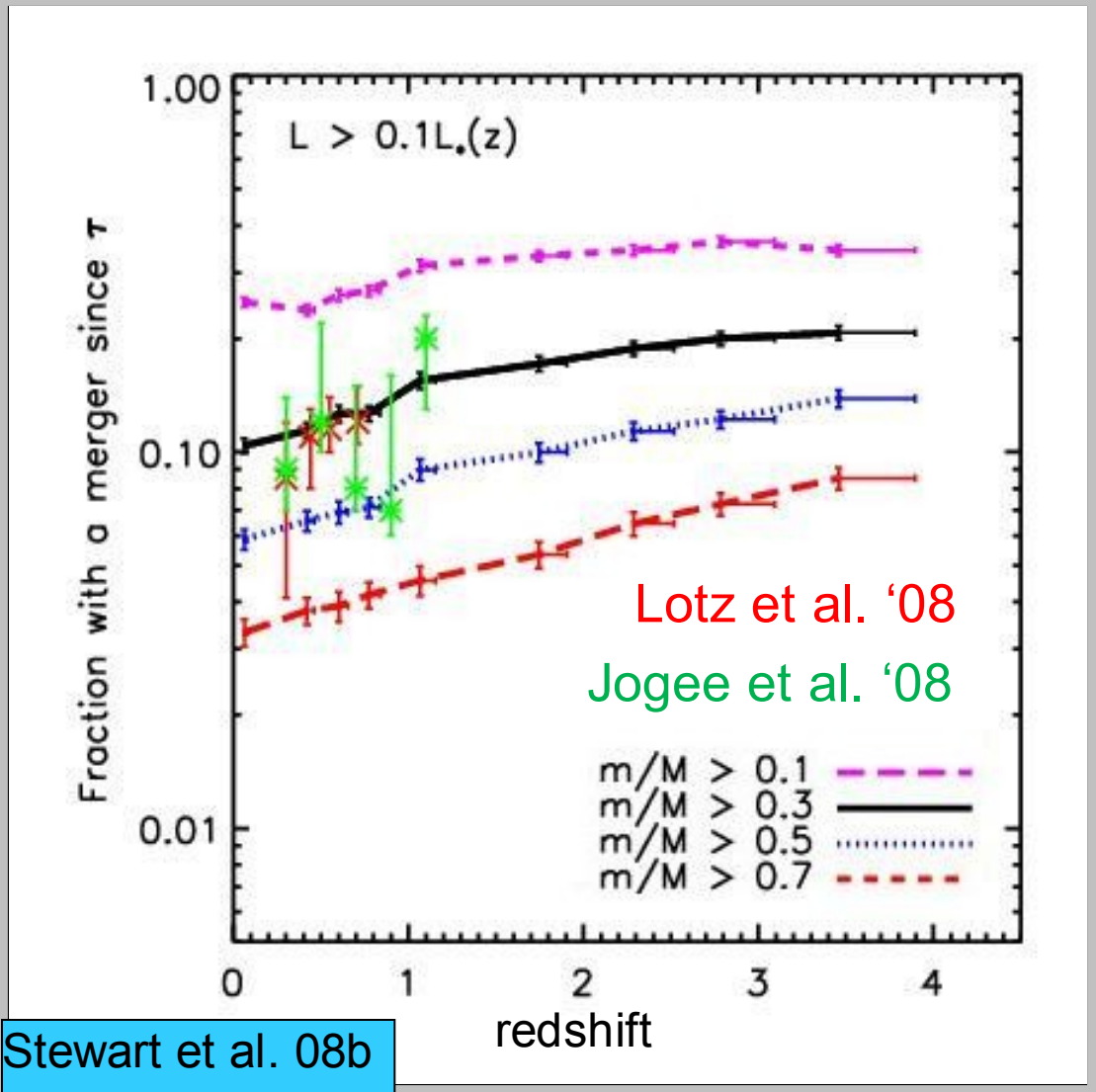
- **~30% of MW-mass baryons accreted directly in >1:3 gas-rich mergers (since z~2)**



Stewart et al. 08c

Merger Fraction in past dynamical time*.

*Use halo dynamical time as a proxy for morphological dyn. time.



Stewart et al. 08b

Use number density matching to associate halos with ~0.1L* galaxies from observed luminosity function (e.g. Faber et al. 07)

(Agrees reasonably well with observations.)

Fakhouri & Ma DM Merger Rate

- There appears to be a fairly universal merger rate (FM08).
- To first order, we find the same result, with slight variations.