The Millennium Simulation Compared to Observations of z~2 Galaxies

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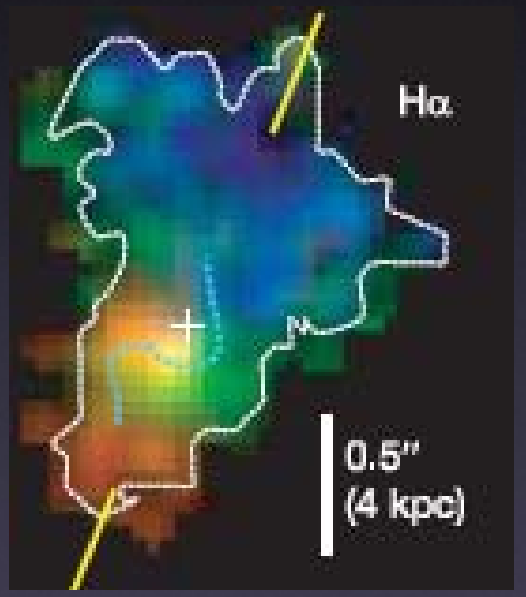
Genel et al. 2008, ApJ, 688, 789 & astro-ph/0808.0194

Outline

- Observational background and motivation
- The Millennium Simulation and the new merger trees
- Results and comparison to observations

Observational background – The SINS survey

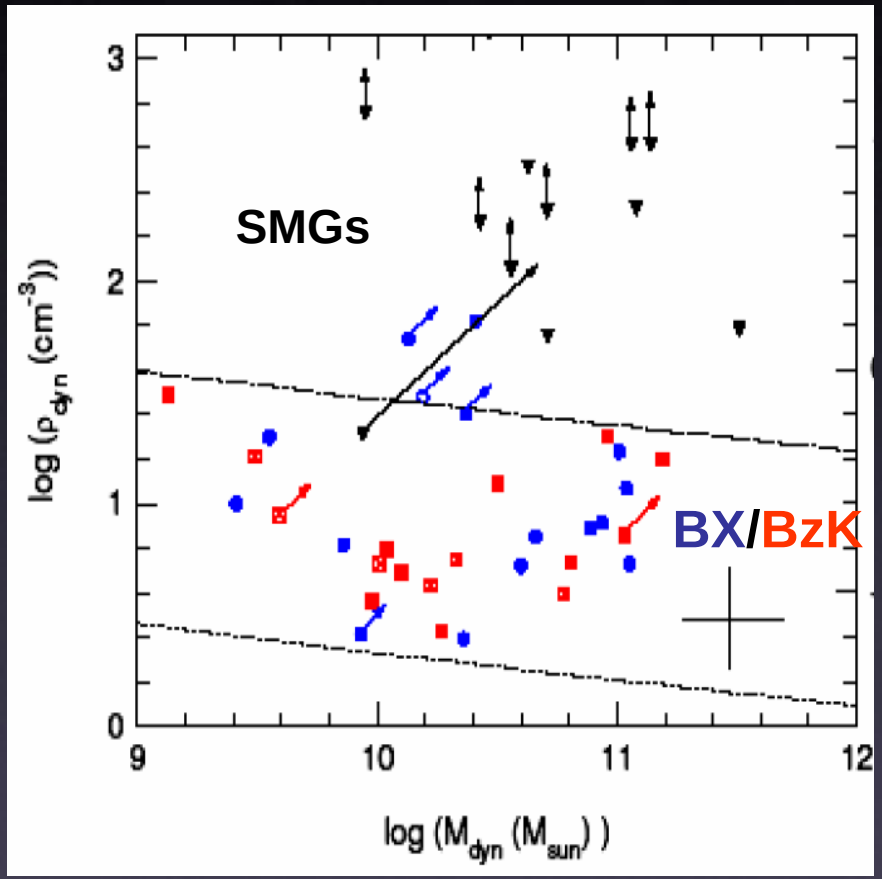
- High SFR (>~30$M_{sun}yr^{-1}$) UV-/optically selected systems at z~2
- They reside in halos of ~$10^{12}M_{sun}$ (Förster Schreiber et al. 2006).
- A fraction >~50% are gas rich thick turbulent disks (Shapiro et al. 2008), indicative of smooth accretion, rather than major mergers.



Genzel et al. 2006

Observational background – Submillimeter Galaxies (SMGs)

- Submillimeter selected high luminosity (~$10^{13}L_{sun}$) high SFR (~$10^{3}M_{sun}yr^{-1}$) systems at z~2
- Dense, compact, low j
- Dissipative gas rich major mergers (Tacconi et al. 2006, 2008).
- Much lower number density: ~$10^{-5}Mpc^{-3}$



Bouché et al. 2007

Motivation

- Can the high SFR in the SINS galaxies be achieved without major mergers?
- Is the theoretically predicted merger rate consistent with the SINS galaxies being smooth accretors, and the SMGs being major mergers?
- (Where do the SINS galaxies end up at z=0?)

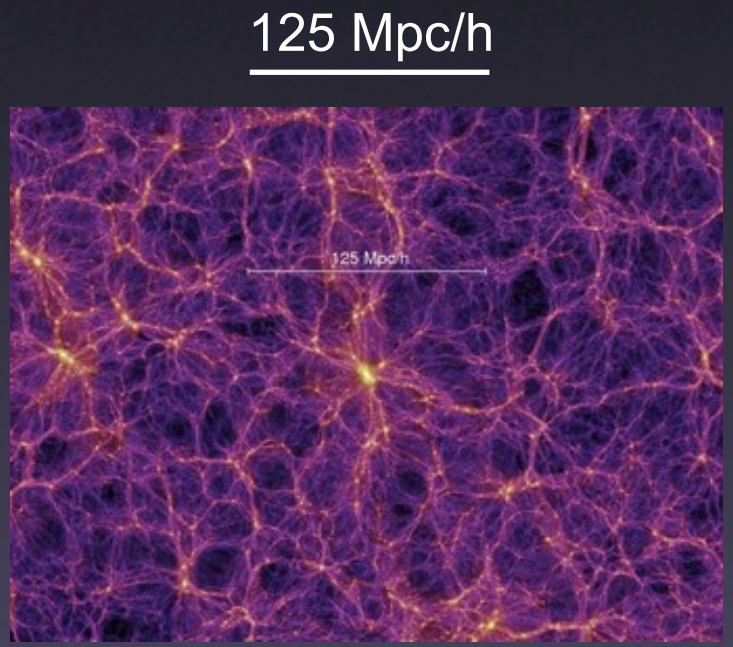
Main results

- There is a significant population of halos at z~2 that have high “smooth” DM accretion rates. This allows for the observed SINS SFRs, provided a high SF efficiency.
- The merger fraction is consistent with the SMGs being hosted in major merging ~$10^{12.5}$ M_{sun} halos.
- Many of them do not experience any major mergers until z=0 – Probably a significant role for minor mergers and/or secular evolution.

Genel et al. 2008, ApJ, 688, 789 & astro-ph/0808.0194

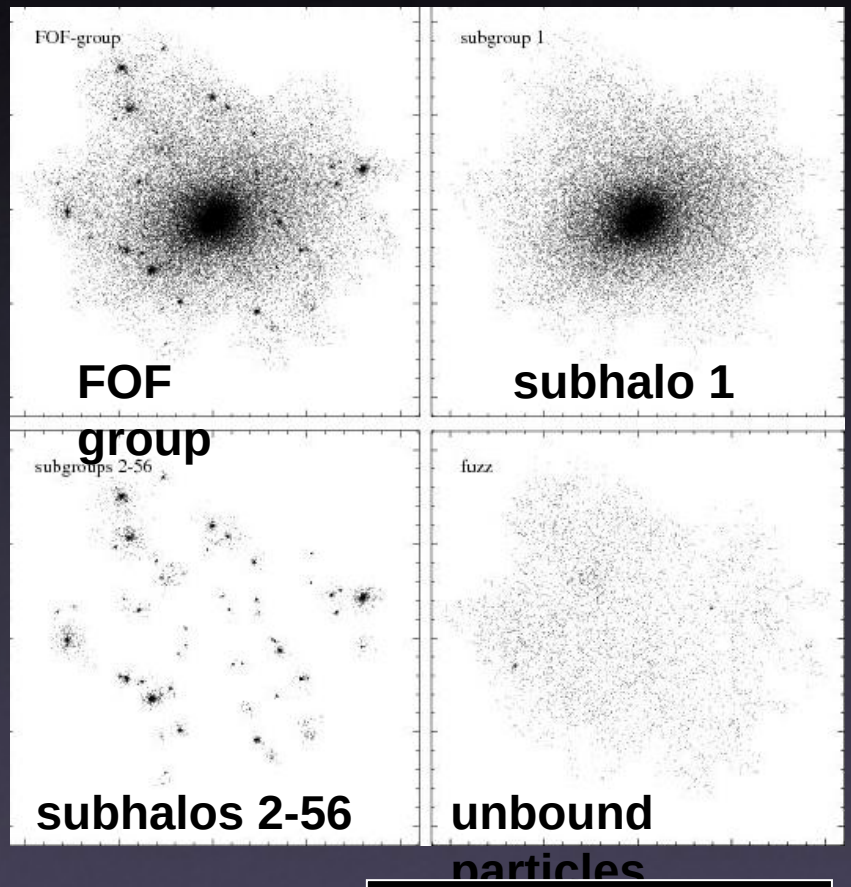
Approach

- Perform a robust dark-matter-based plausibility study
- Use the Millennium Simulation (Springel et al. 2005)
  - $M \sim 10^{12} M_{sun}$ halos are resolved with $\sim 10^3$ particles.
  - There are ~300,000 halos with $M > 10^{12} M_{sun}$ at z~2.



Structure in the Millennium Simulation

- Friends-of-friends (FOF) groups are built by iterative linking of close particles, and represent halos.
- SUBFIND finds subhalos within FOF groups: bound particle groups around maxima in the density field.



Springel et al. 1999

Identifying mergers – what are the start points?

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- Solution: Splitting the pre-maturely merged FOF groups “by hand”

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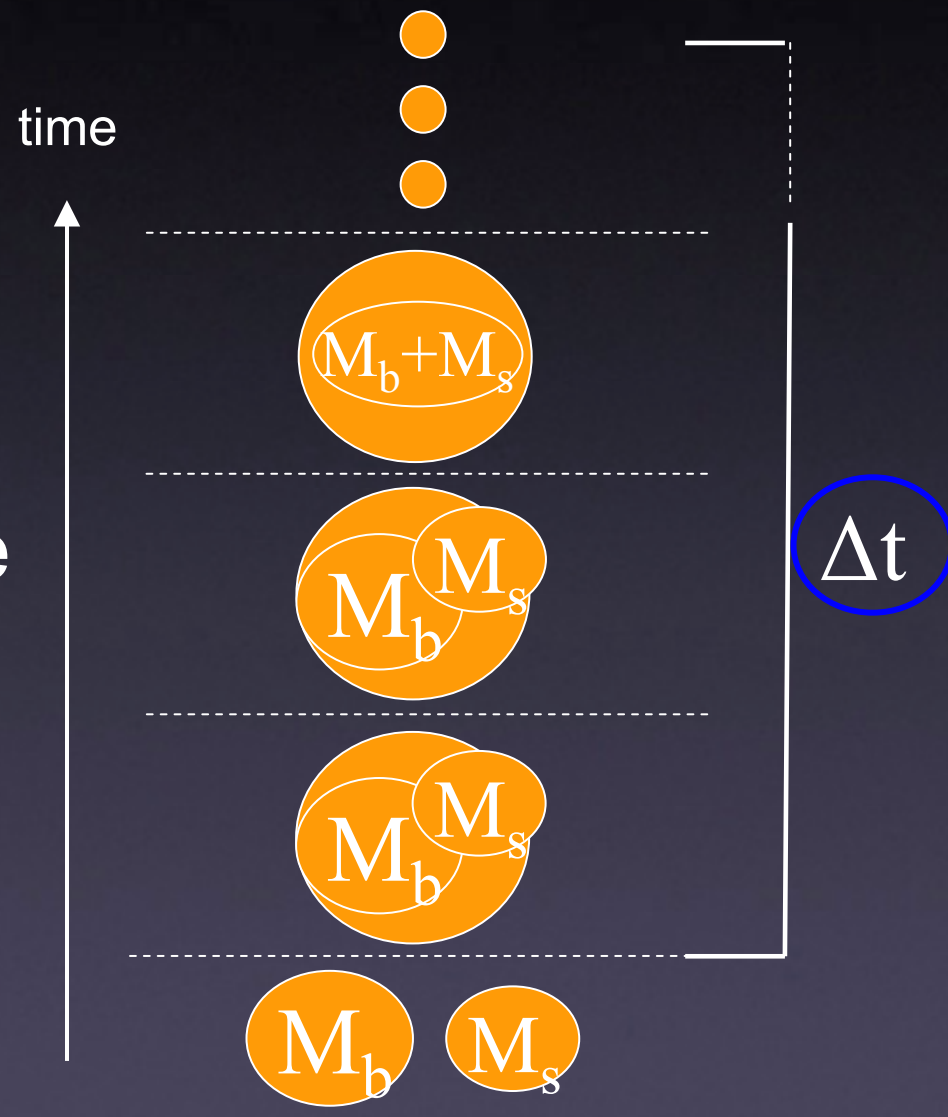
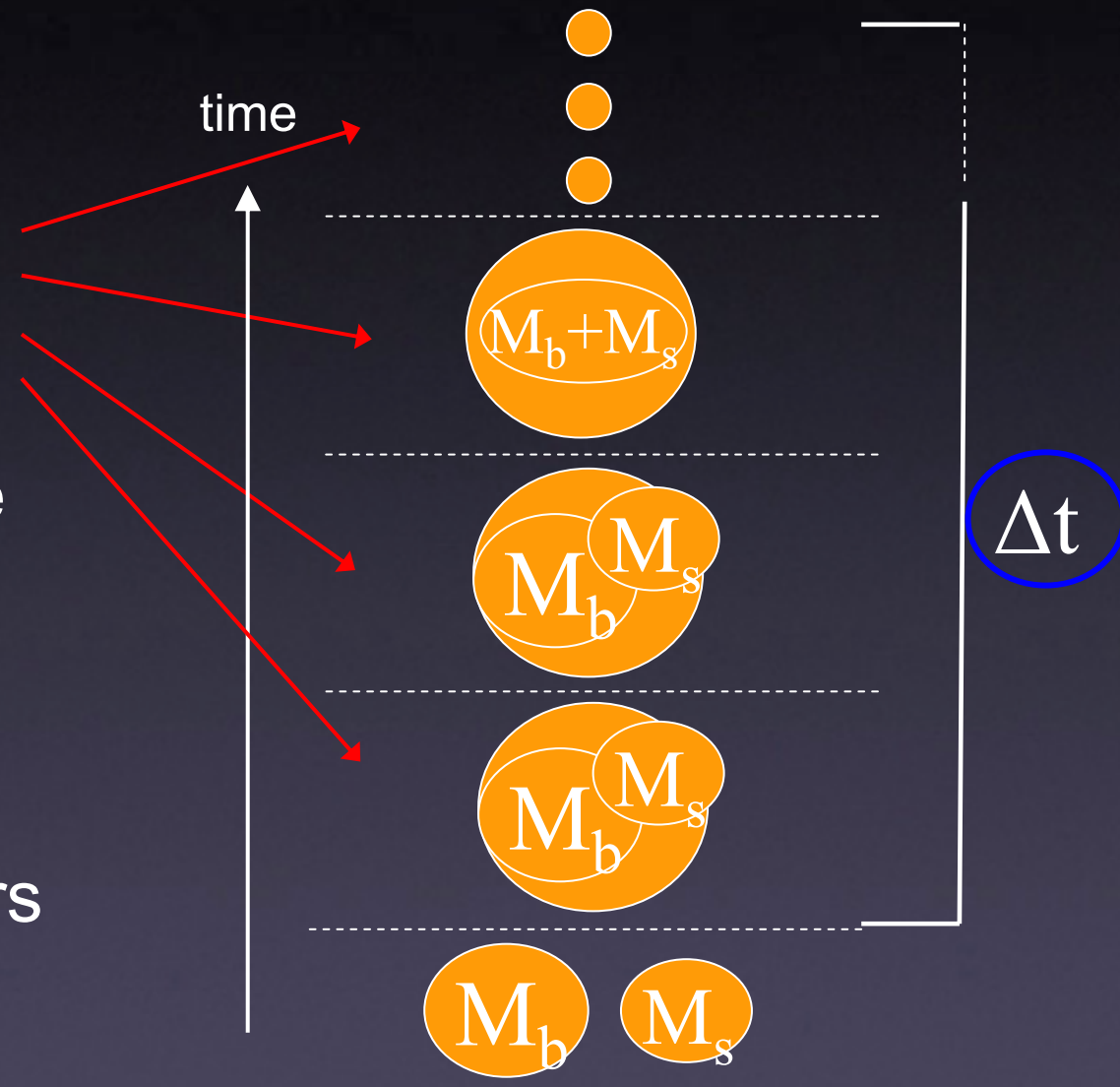
- Problem: Subhalos disintegrate due to resolution, not physical, effects.
- Solution: Estimating time Δt until final merger, using calibrations from detailed merger simulations (Boylan-Kolchin et al. 2008)



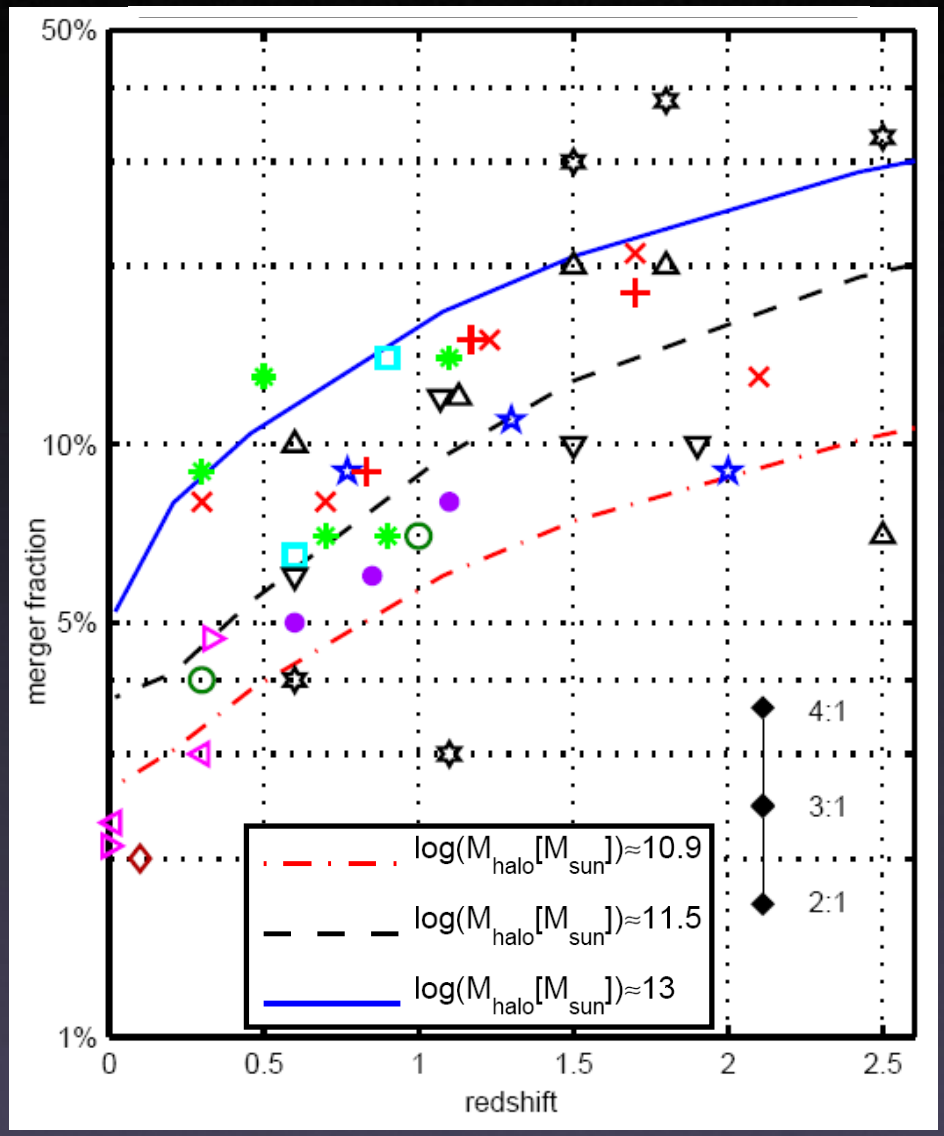
The Millennium Simulation - Identifying mergers

- Identify merging halos between the start point and the end point.
- Allows extraction of the merger fraction.
- Merger durations give dark matter accretion rates, due to all mergers plus smooth accretion.



Results - Major merger fractions

- The major merger fractions agree well with observed galaxy merger fraction (cf. Kyle Stewart's talk yesterday).
- The mean dark matter accretion rate agrees well with EPS predictions (Neistein et al. 2006).



Genel et al. 2008(b), ApJ, submitted

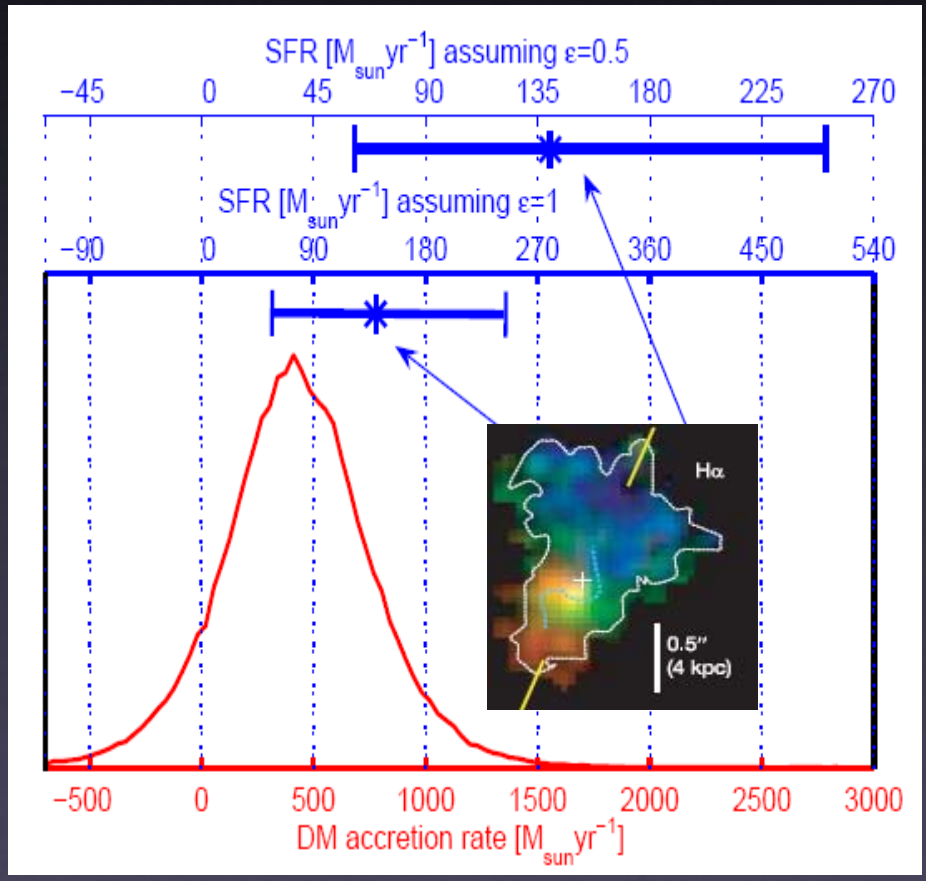
Results – SFR of SINS disks are expected for smooth accretors

Assuming

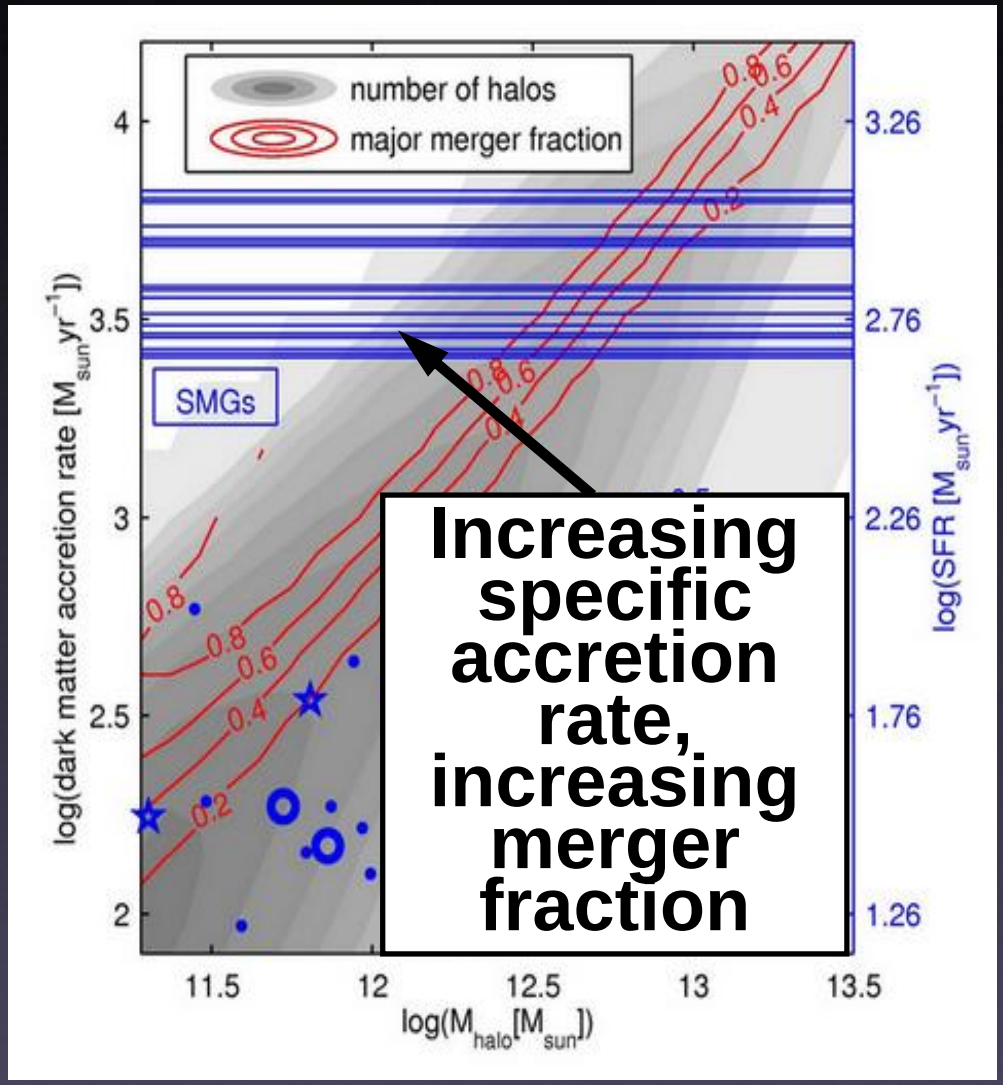
- $$\frac{dM_*}{dt} = \eta_B \times \epsilon \times \frac{dM_{DM}}{dt}$$

  supported by the "cold streams" hypothesis (e.g., Birnboim & Dekel 2003, Kereš et al. 2008, Dekel et al. 2008)
- and a SF efficiency of $\epsilon \approx 1$
- => the SFR of SINS disks is typical for non-major-merging halos

Distribution of accretion rates among non-major-merging halos of ~$10^{12} M_{sun}$ at z~2.4

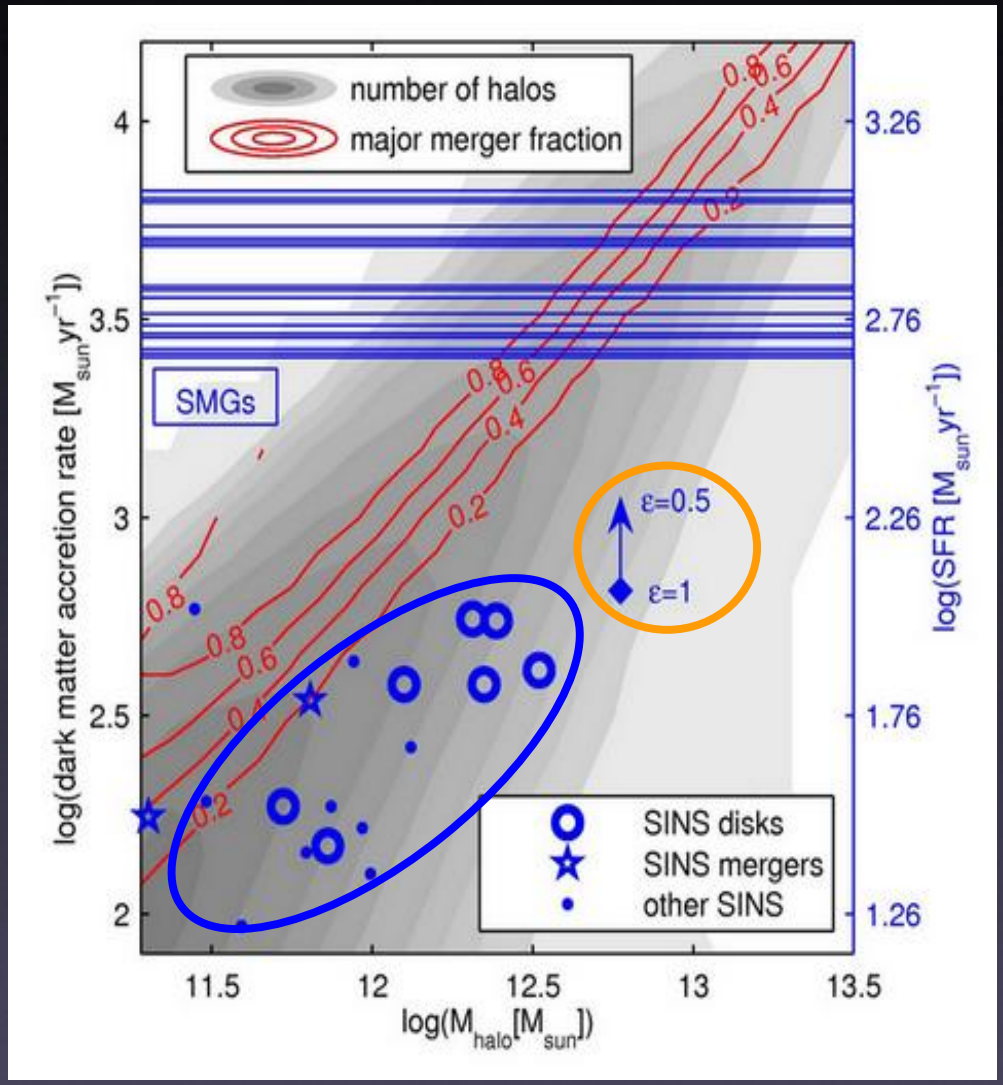


Results - Matching halos and galaxies



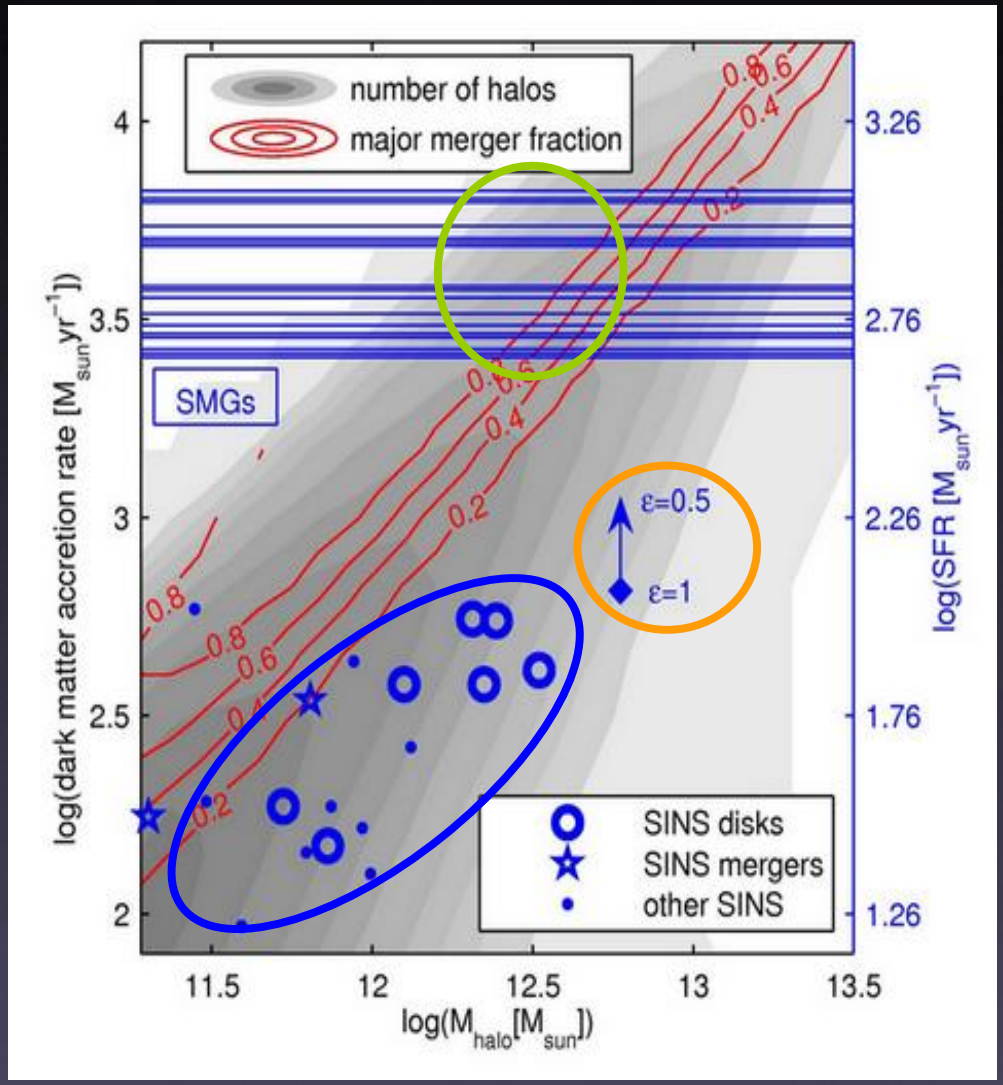
Results - Matching halos and galaxies

- SINS galaxies match halos with typical accretion rates and a low major merger fraction. There are enough of them (and even more).



Results - Matching halos and galaxies

- SINS galaxies match halos with typical accretion rates and a low major merger fraction. There are enough of them (and even more).
- SMGs match ~$10^{12.5} M_{sun}$ halos undergoing a major merger.



Conclusions and Open questions

- There is a significant population of halos at z~2 that have high “quiescent” DM accretion rates – what drives the extremely high efficiency of star formation?
- What is the source of high turbulent motions of the star-forming gas?
- Many of them do not experience any major mergers until z=0 – what do they turn into? Is there a significant role for minor mergers or is secular evolution dominant?

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