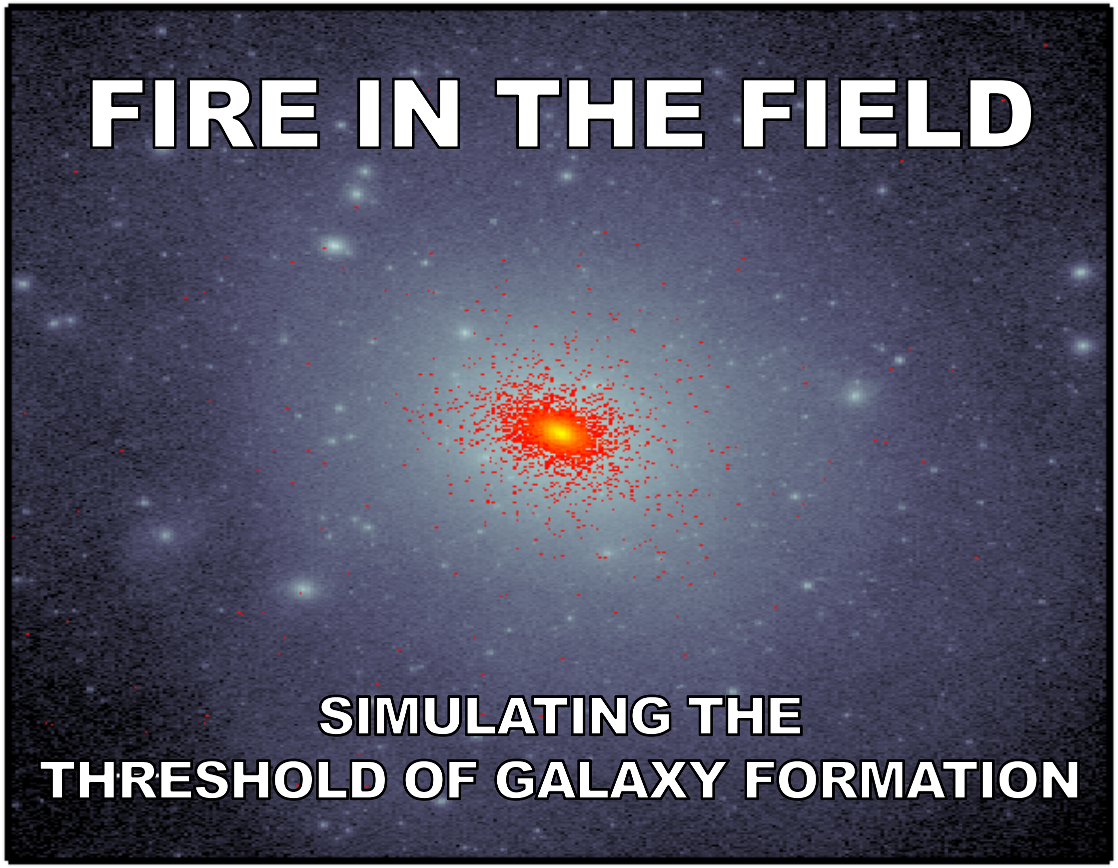


ALEX FITTS - UT AUSTIN

MIKE BOYLAN–KOLCHIN – UT AUSTIN

JAMES BULLOCK – UCI

OLIVER ELBERT – UCI

JOSE OÑORBE – MAX PLANCK

PHIL HOPKINS – CALTECH

AND THE FIRE TEAM

SANTA CRUX GALAXY WORKSHOP 2016

MOTIVATION

- **Dwarf galaxies challenge ΛCDM theory**

MOTIVATION

- Dwarf galaxies challenge ΛCDM theory
- Interesting scale at M_{vir}~10^{10} $M_{\odot}$, $M_{\star}$~10^{6} $M_{\odot}$

MOTIVATION

- **Dwarf galaxies challenge ΛCDM theory**
- **Interesting scale at M_{vir}~10^{10} $M_{\odot}$, $M_{\star}$~10^{6} $M_{\odot}$**
  - Core/cusp (Moore et al. 1994, Flores & Primack 1994)
  - Too Big to Fail (Boylan-Kolchin et al. 2011)

MOTIVATION

- **Dwarf galaxies challenge ΛCDM theory**
- **Interesting scale at M_{vir}~10^{10} $M_{\odot}$, $M_{\star}$~10^{6} $M_{\odot}$**
  - Core/cusp (Moore et al. 1994, Flores & Primack 1994)
  - Too Big to Fail (Boylan-Kolchin et al. 2011)
  - Scale of faintest observed isolated dwarfs

MOTIVATION

- **Dwarf galaxies challenge ΛCDM theory**
- **Interesting scale at M_{vir}~10^{10} $M_{\odot}$, $M_{\star}$~10^{6} $M_{\odot}$**
  - Core/cusp (Moore et al. 1994, Flores & Primack 1994)
  - Too Big to Fail (Boylan-Kolchin et al. 2011)
  - Scale of faintest observed isolated dwarfs
  - Sensitive to reionization

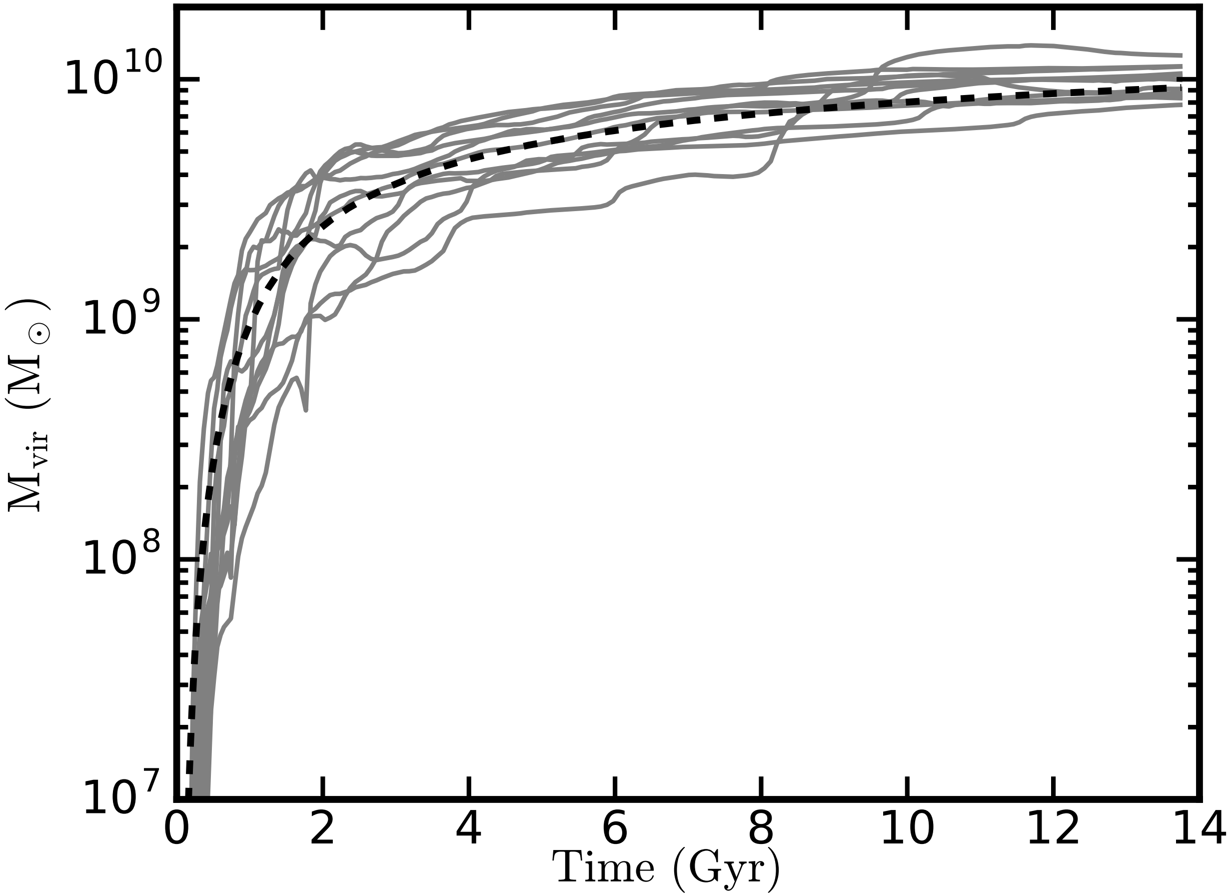
SIMULATION DETAILS

- **GIZMO code + MFM hydro** (Hopkins 2015)
- **FIRE feedback** (Hopkins et al. 2011, 2012, 2013)
- **12 isolated dwarfs at M_{vir}~10^{10} $M_{\odot}$ selected from 35^3 Mpc^3 boxes**

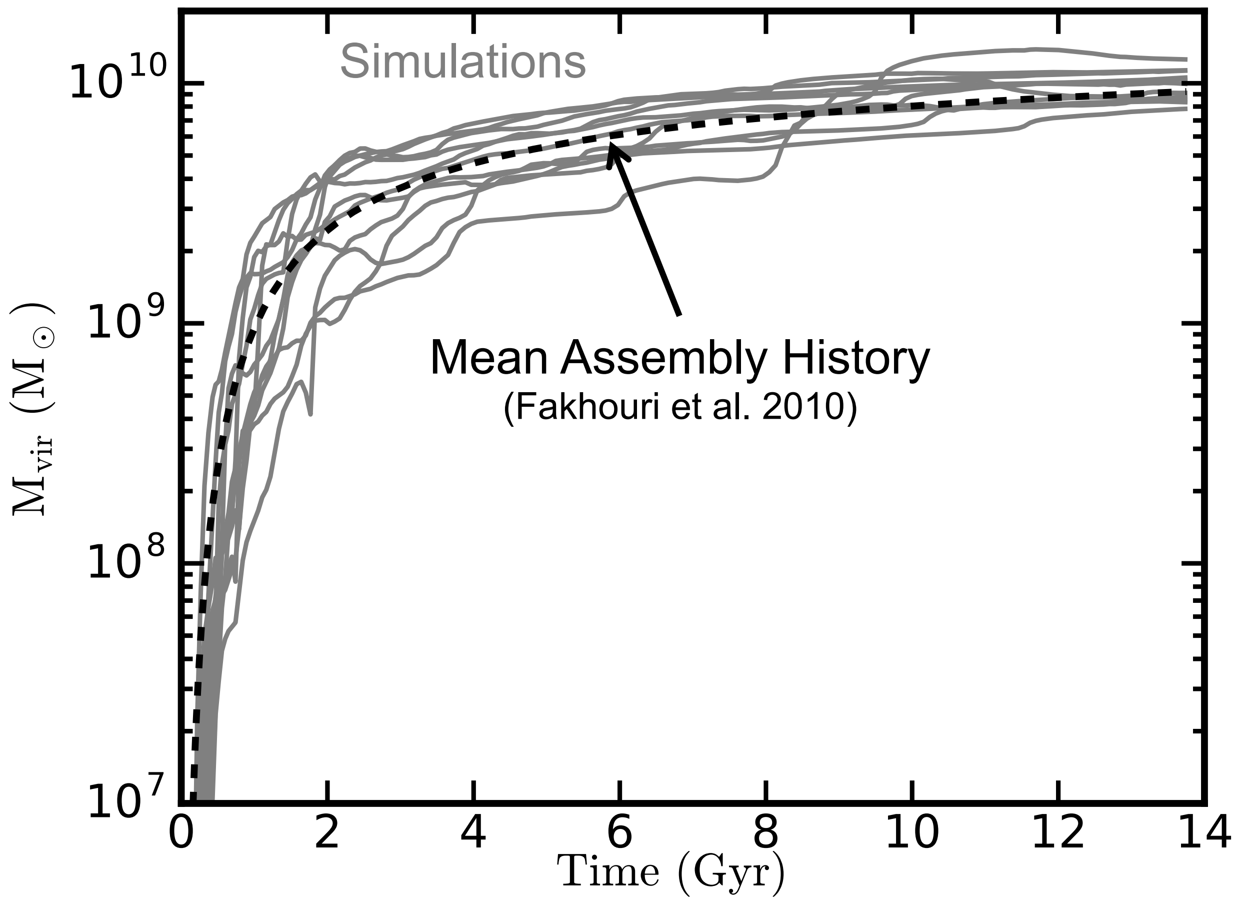
SIMULATION DETAILS

- **GIZMO code + MFM hydro** (Hopkins 2015)
- **FIRE feedback** (Hopkins et al. 2011, 2012, 2013)
- **12 isolated dwarfs at $M_{vir} \sim 10^{10}\ M_{\odot}$ selected from $35^3\ Mpc^3$ boxes**
- **$\varepsilon_{gas} \sim 1.4$ pc, $\varepsilon_{dm} \sim 25$ pc**
- **$M_{gas} \sim 500\ M_{\odot}$, $M_{dm} \sim 2500\ M_{\odot}$**

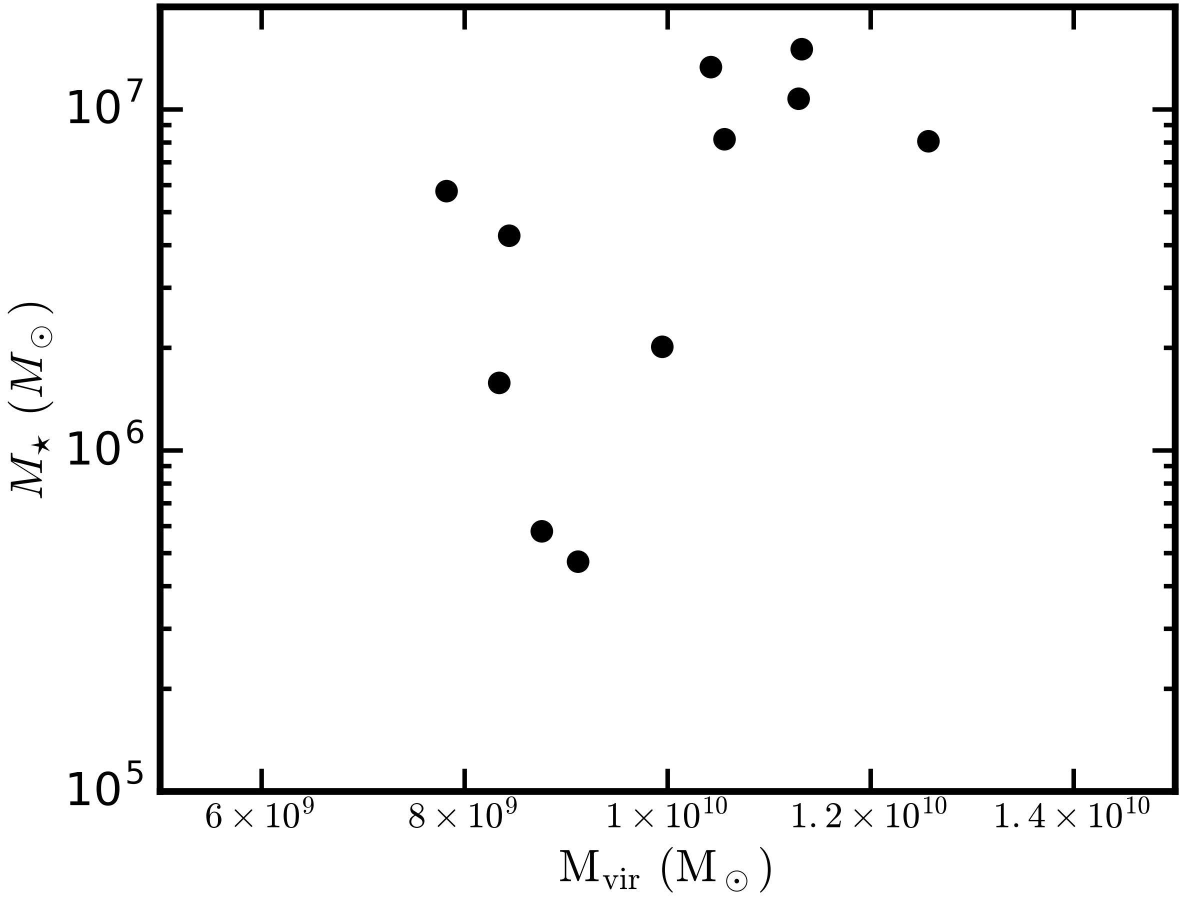
MASS ASSEMBLY HISTORIES



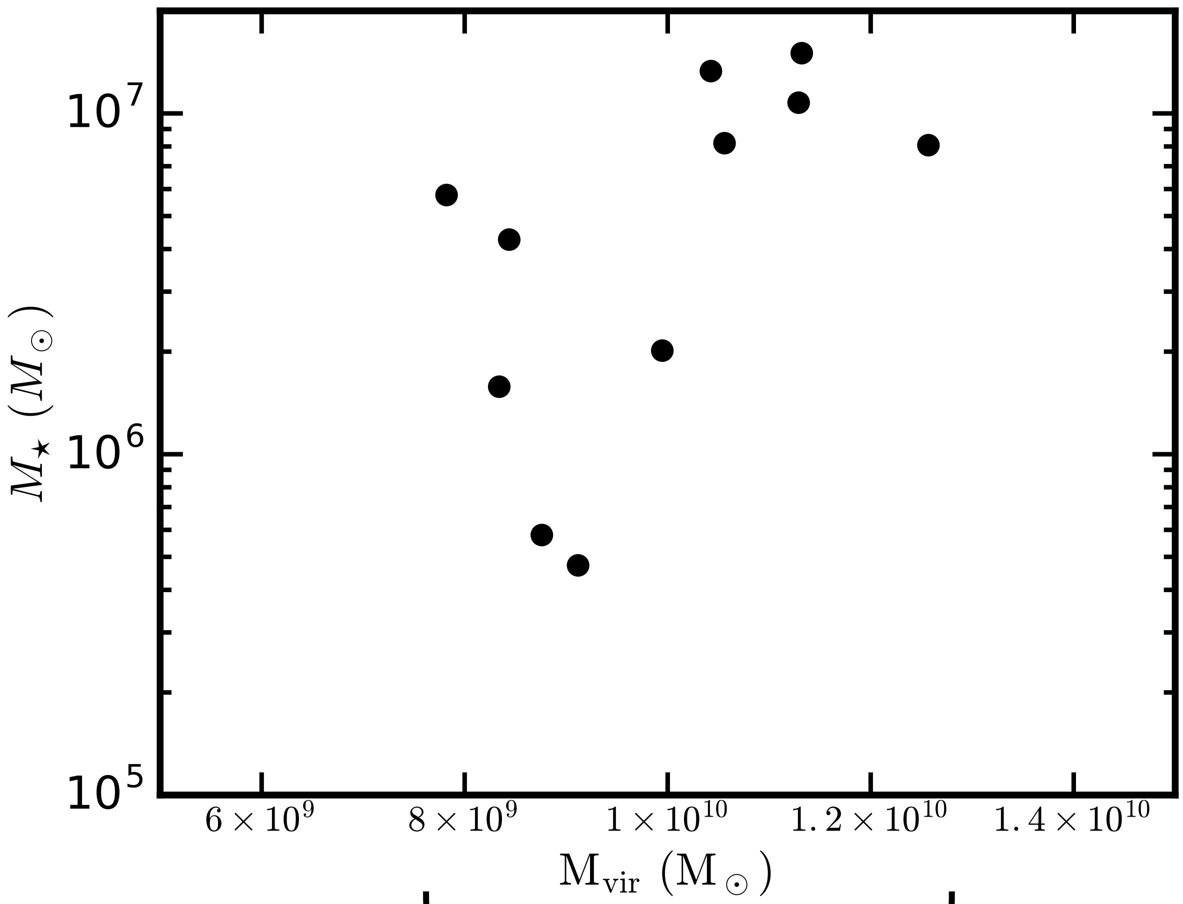
MASS ASSEMBLY HISTORIES



A GLANCE AT $M_\star$

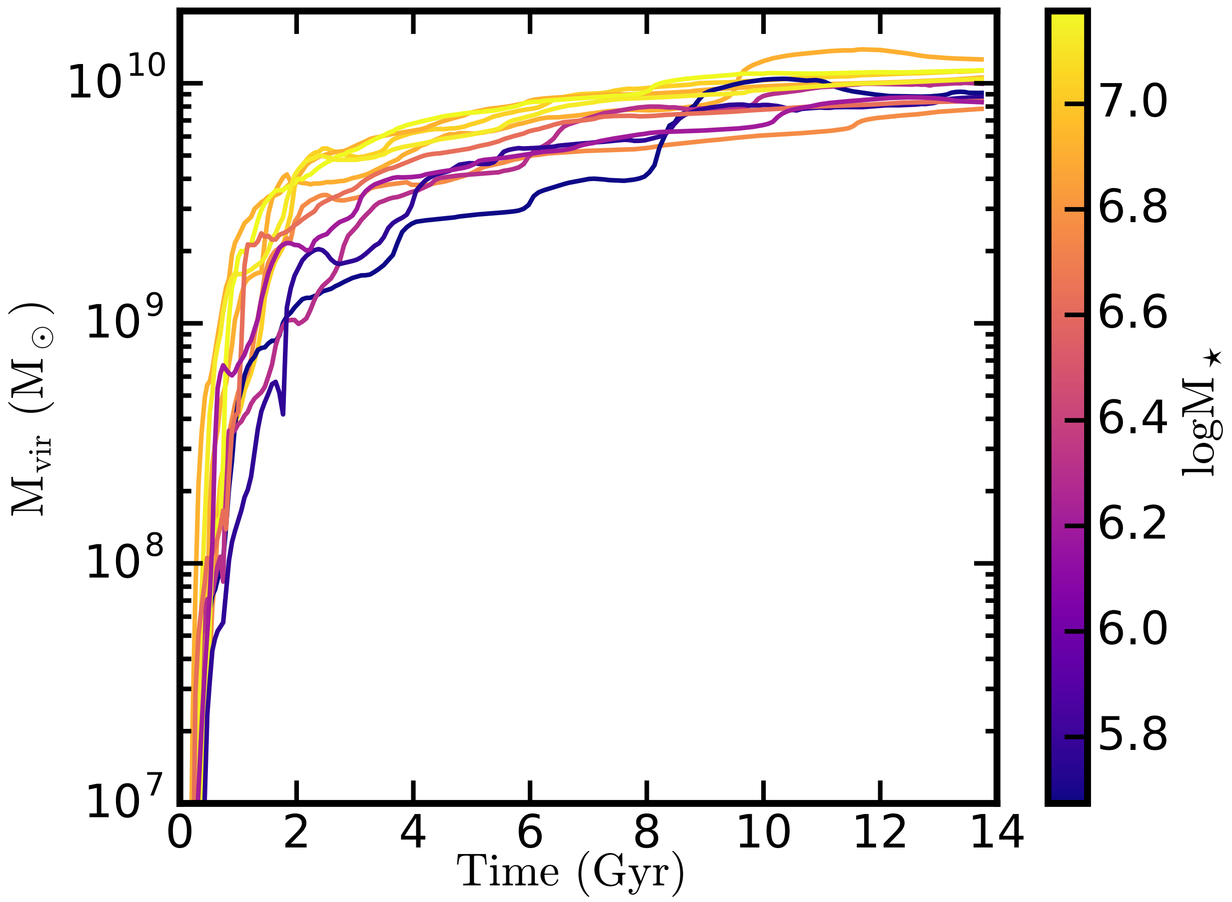


A GLANCE AT $M_\star$

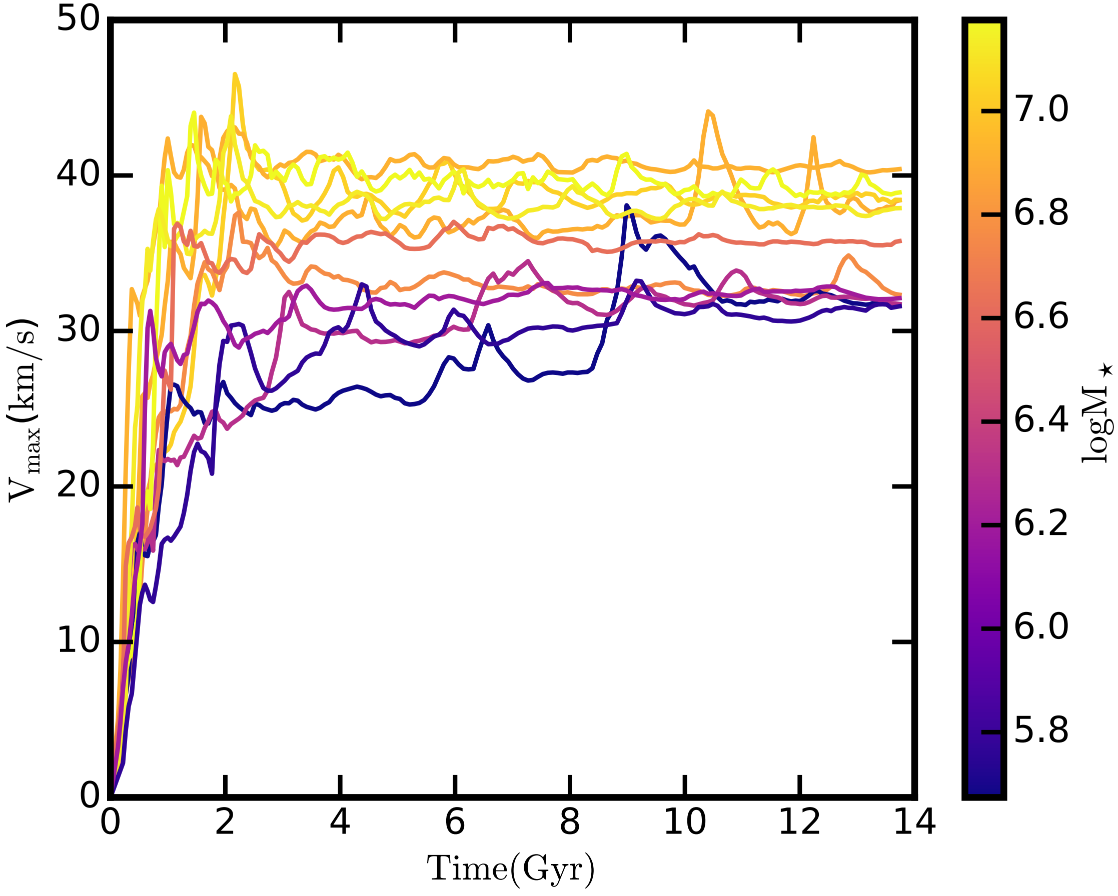


Note narrow range of halo masses

MASS ASSEMBLY HISTORIES

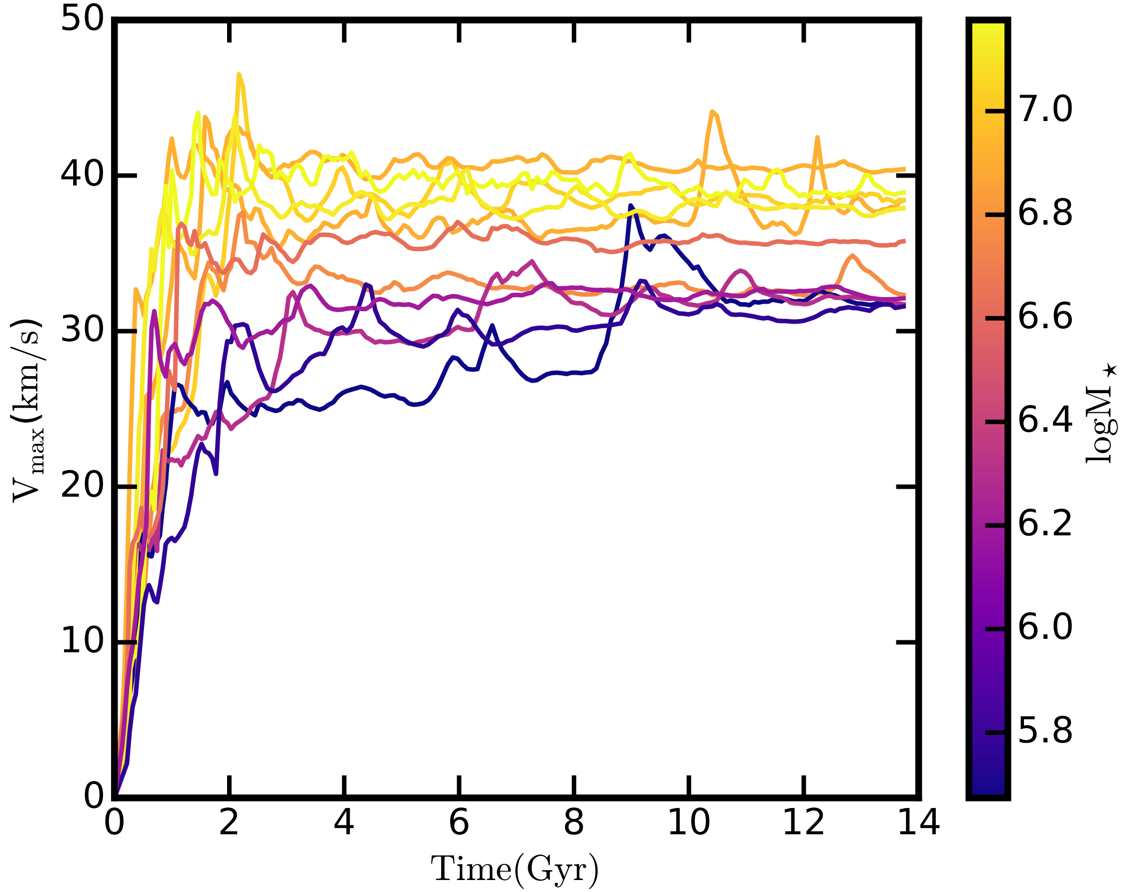


V_{MAX} THROUGH TIME

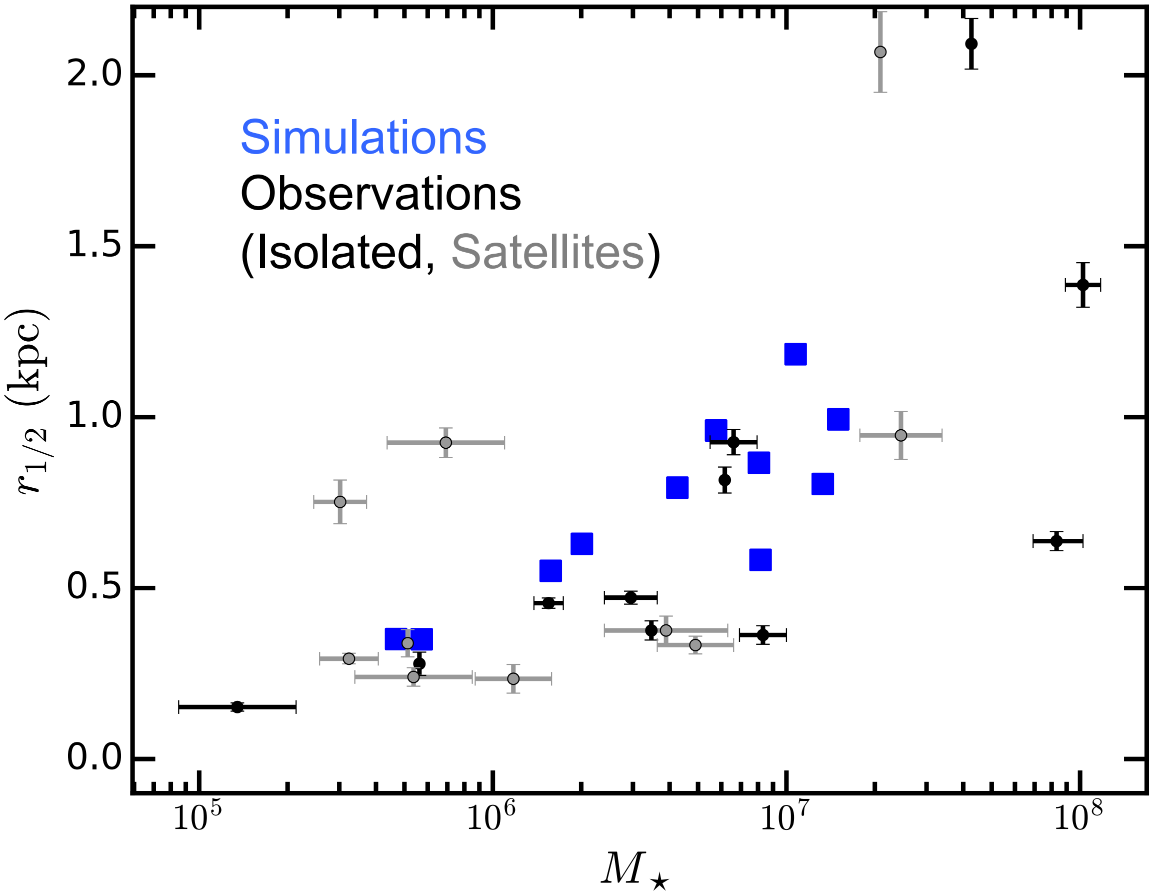


V_{MAX} THROUGH TIME

Increasing Stellar Mass

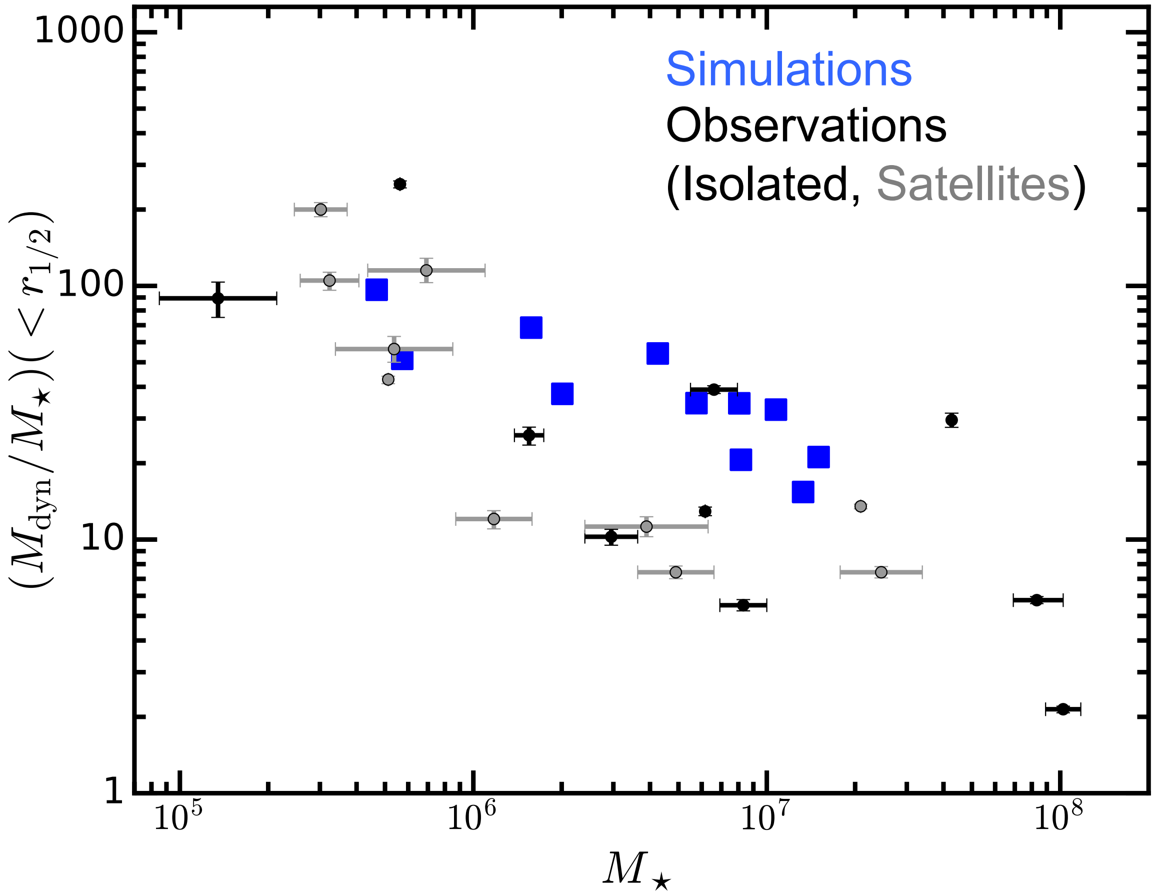


COMPARISON TO OBSERVATIONS



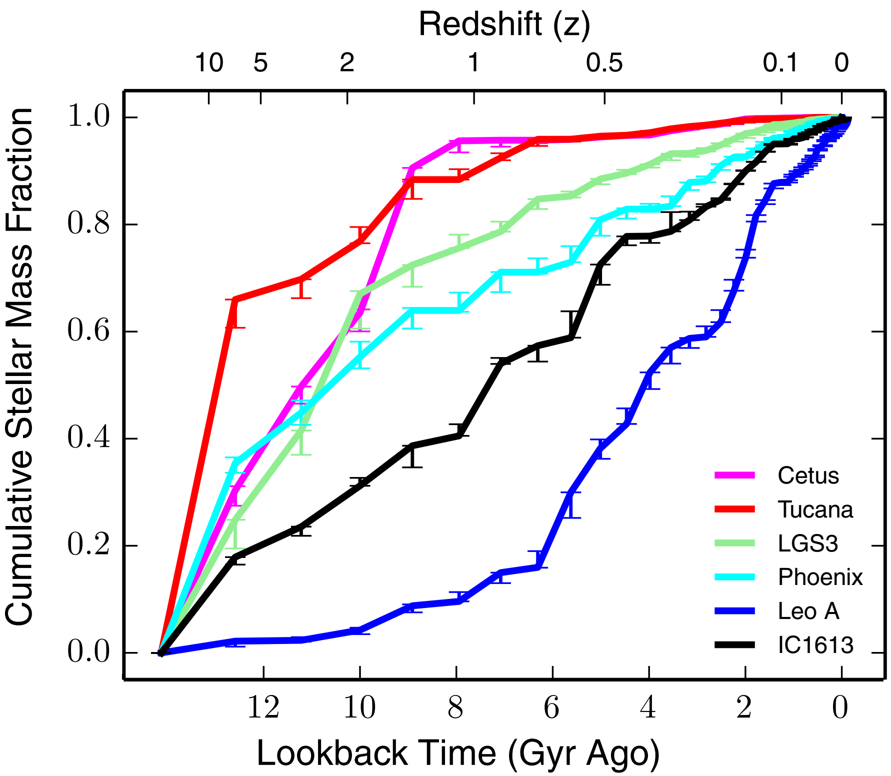
Kirby et al. 2013, 2014

COMPARISON TO OBSERVATIONS



Kirby et al. 2013, 2014

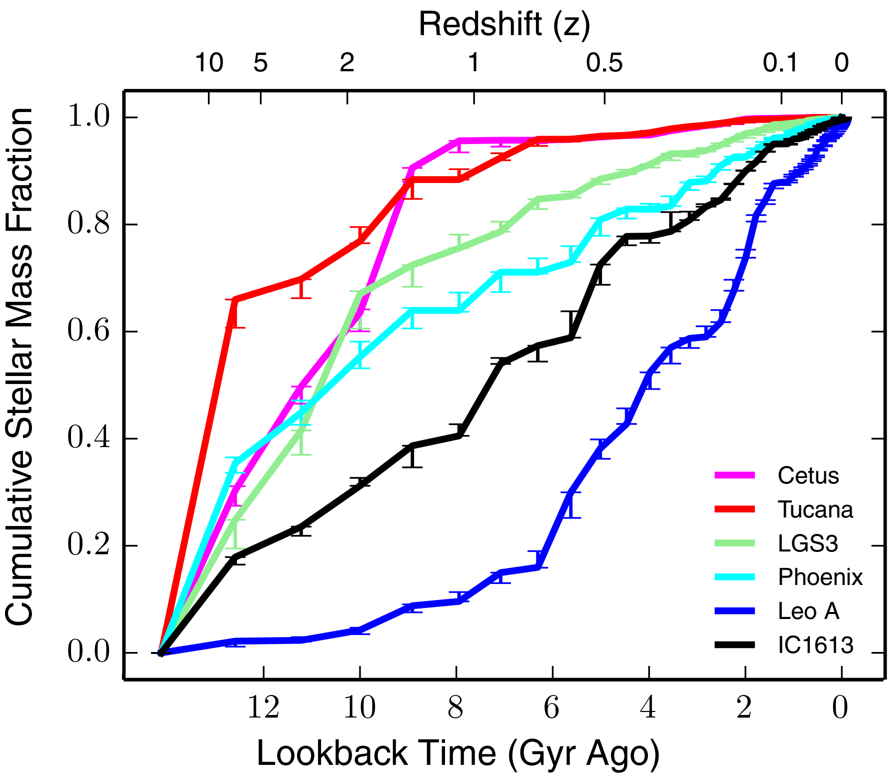
COMPARISON TO OBSERVATIONS



Skillman et al. 2014

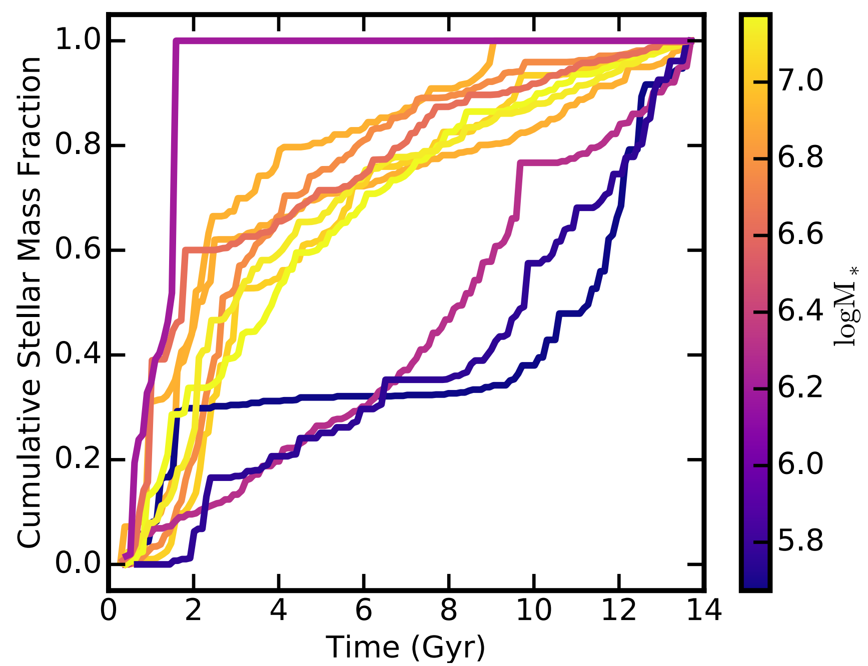
Observed Star Formation Histories

COMPARISON TO OBSERVATIONS



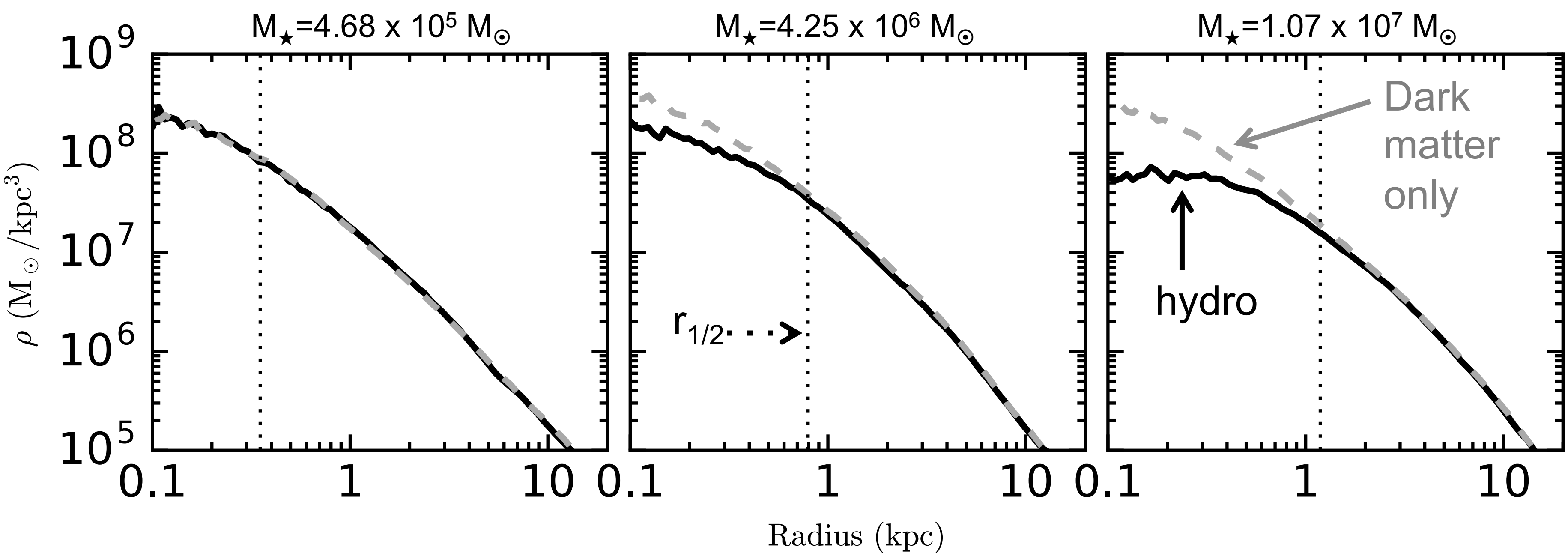
Skillman et al. 2014

Observed Star Formation Histories

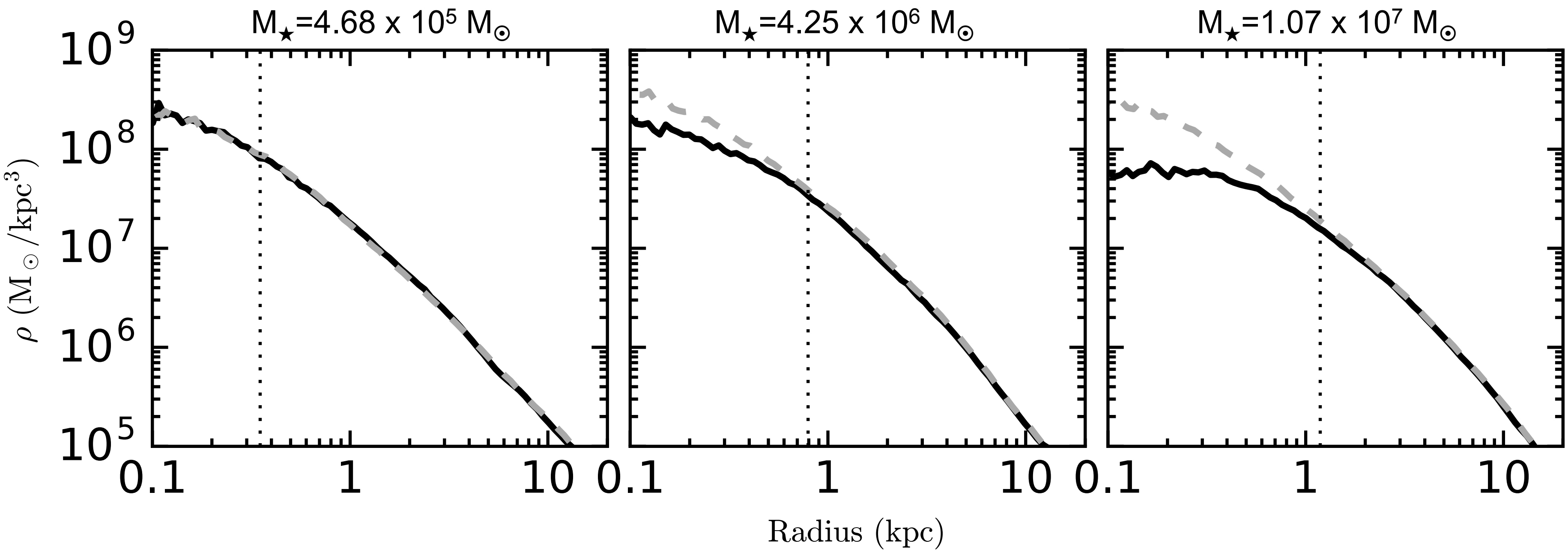


Simulated Star Formation Histories

RADIAL DENSITY PROFILES

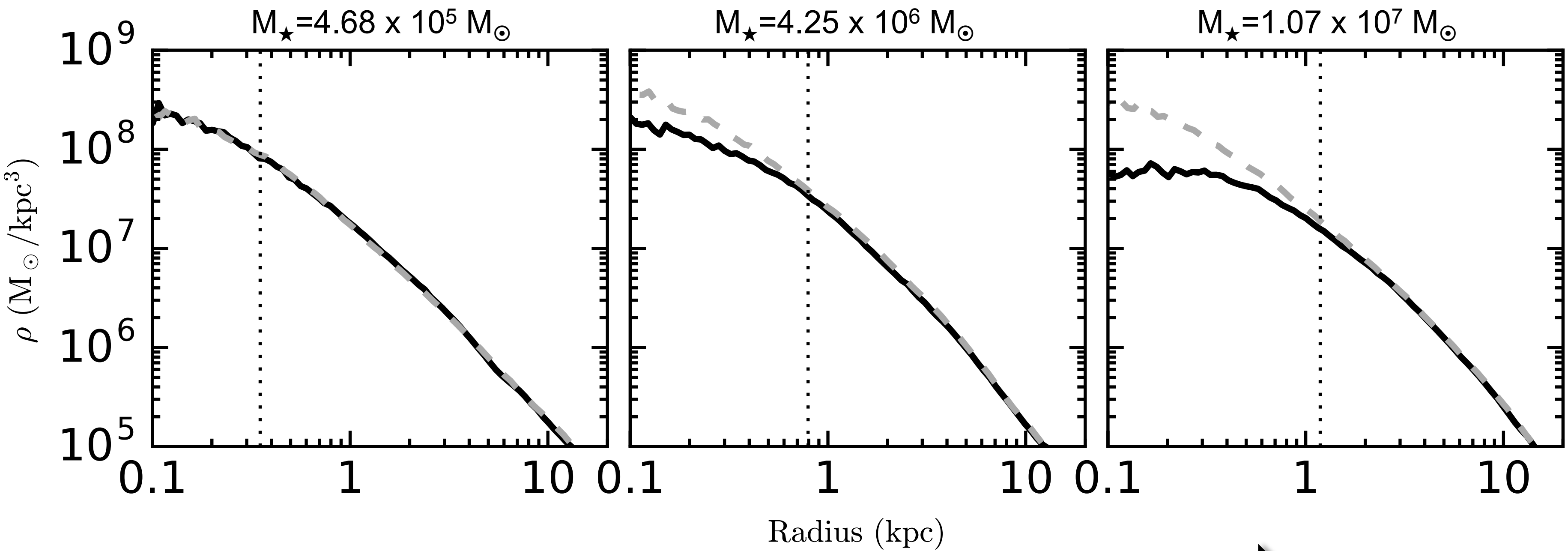


RADIAL DENSITY PROFILES



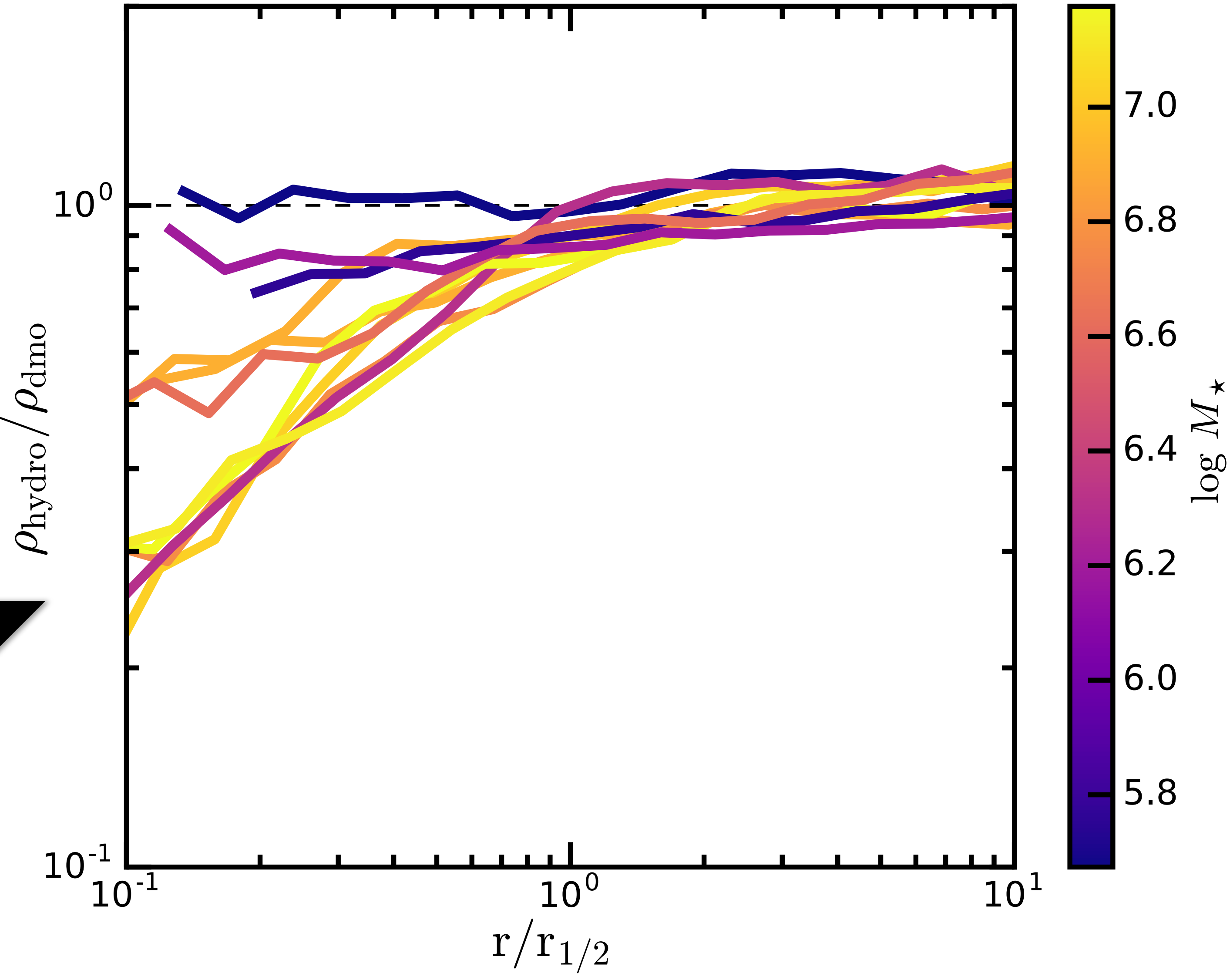
- All galaxies have **same** halo mass of ~10^{10} $M_\odot$
- No cores for halos with $M_\star$< ~10^6 $M_\odot$ (Governato et al. 2012, Di Cintio et al. 2014, Dutton et al. 2016)

RADIAL DENSITY PROFILES

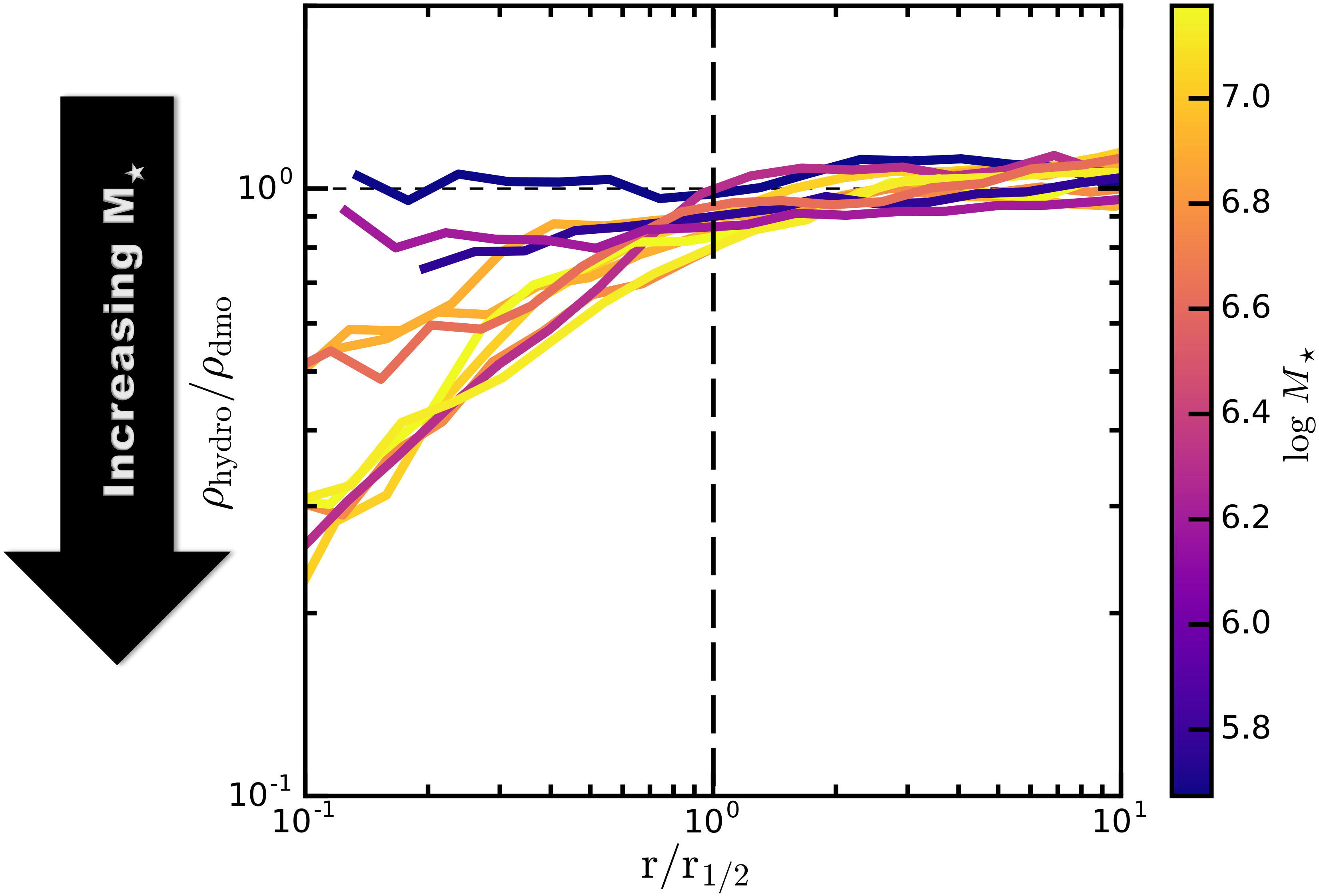


Increasing $M_\star$
Decreasing Central Density

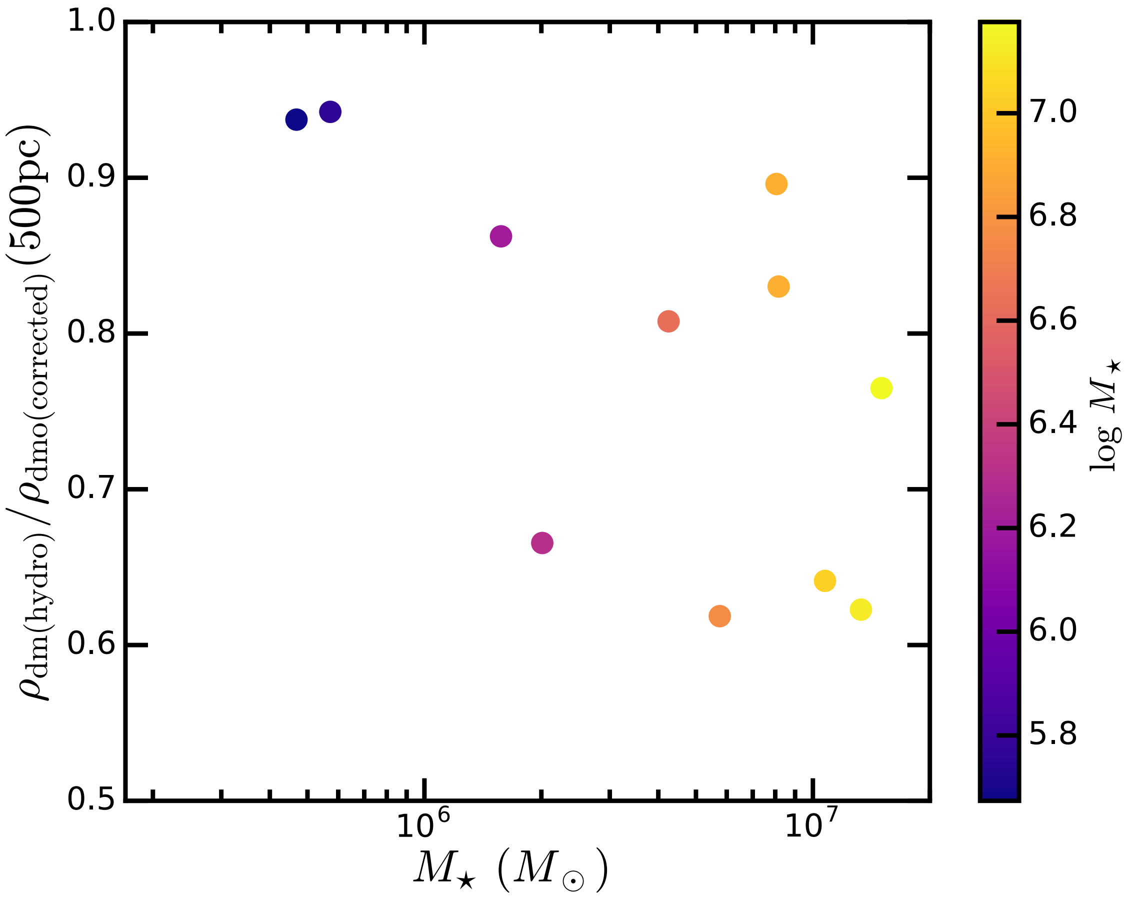
RADIAL DENSITY PROFILES



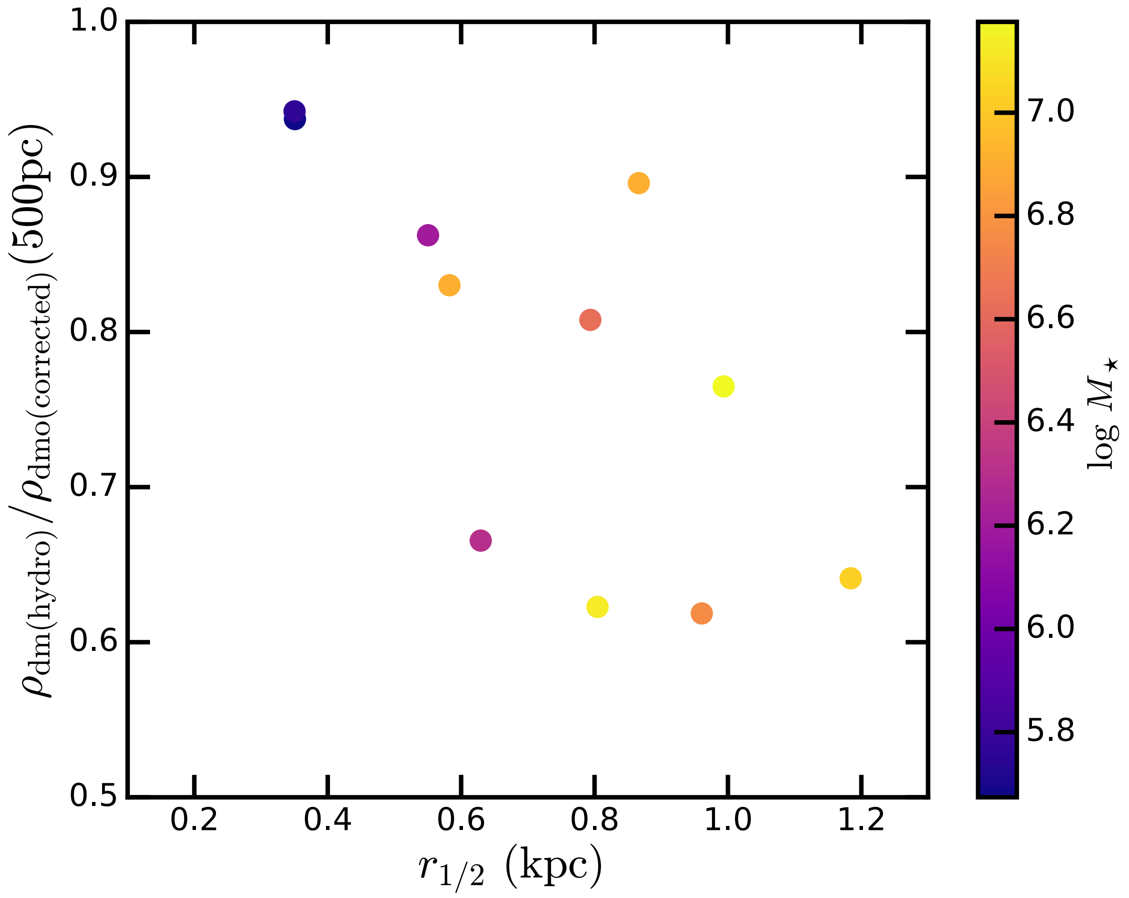
RADIAL DENSITY PROFILES



CENTRAL DENSITY VS STELLAR MASS



CENTRAL DENSITY VS HALF LIGHT RADIUS



CONCLUSIONS

- **12 high-resolution gizmo + FIRE simulations of isolated dwarf galaxies, all with $M_{vir}(z=0) \sim 10^{10}\ M_{\odot}$**
- **Good agreement between simulations and observed isolated dwarfs for $M_{\star}(z=0)$, SFH, $R_{1/2}$, $M_{dyn}/M_{\star}$**
- **Strong correlation between early dark matter mass assembly and present-day stellar mass**
    - higher concentration, higher V_{max} halos build up more stellar mass earlier
- **$M_{\star}(z=0)$ correlates well with density reduction**
    - No modification from dark-matter-only simulations below $M_{\star} \sim 10^6\ M_{\odot}$, increasingly large density reduction and dark matter cores at higher stellar masses
- **Future work: dwarfs in WDM, SIDM (including hydrodynamics; see talk by V. Robles)**

THANK YOU!

EXTRAS