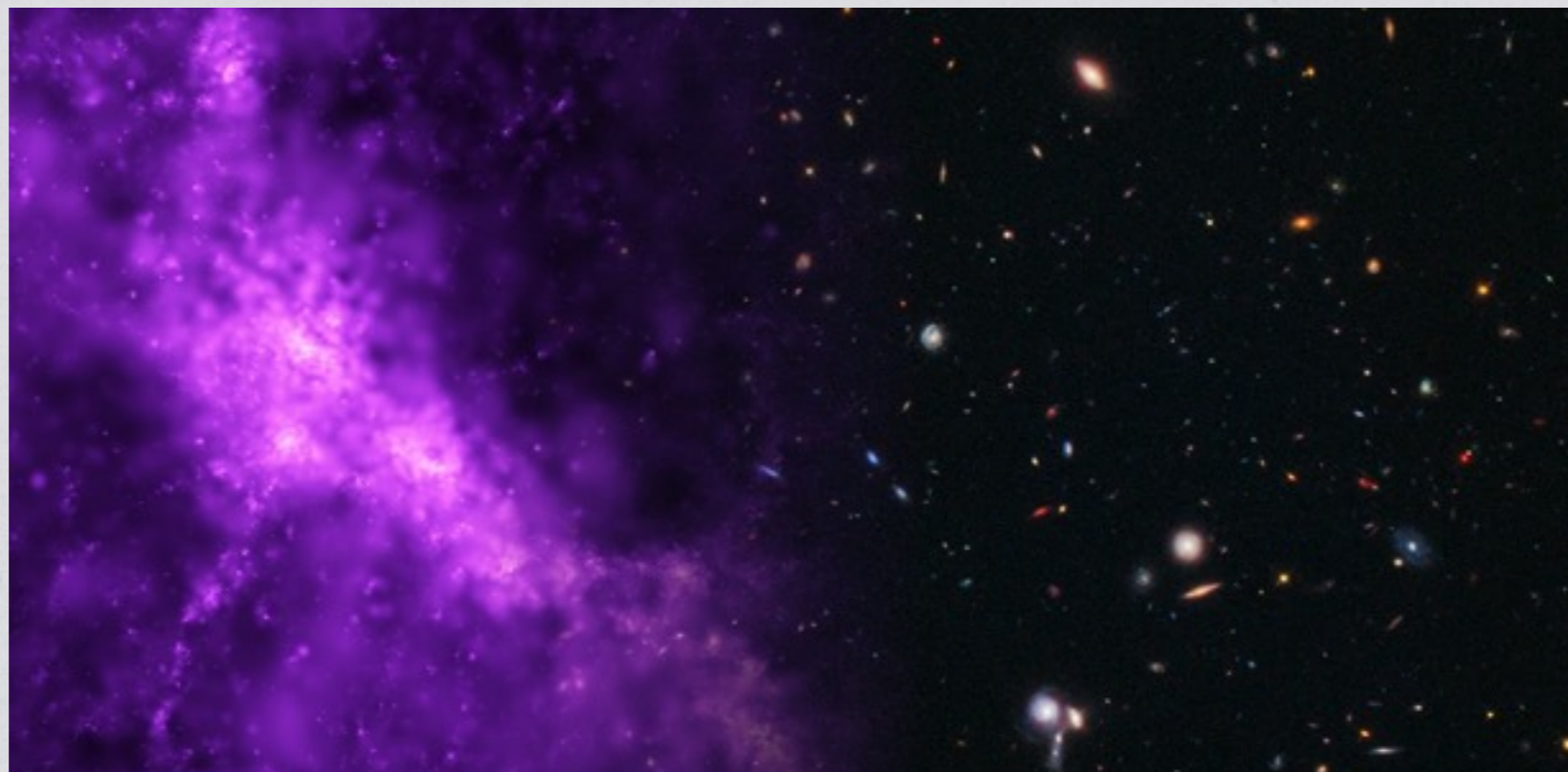


From First Stars to (First) Galaxies



Basic physics of star formation

★ Star forming regions experience struggle between:

★ Gravity

- acts to collapse the cloud

★ Pressure

★ Magnetic fields

★ "Bulk motions"



- sources of support preventing collapse

If gravity wins, on what timescale is the collapse happening?

The birth of the first stars

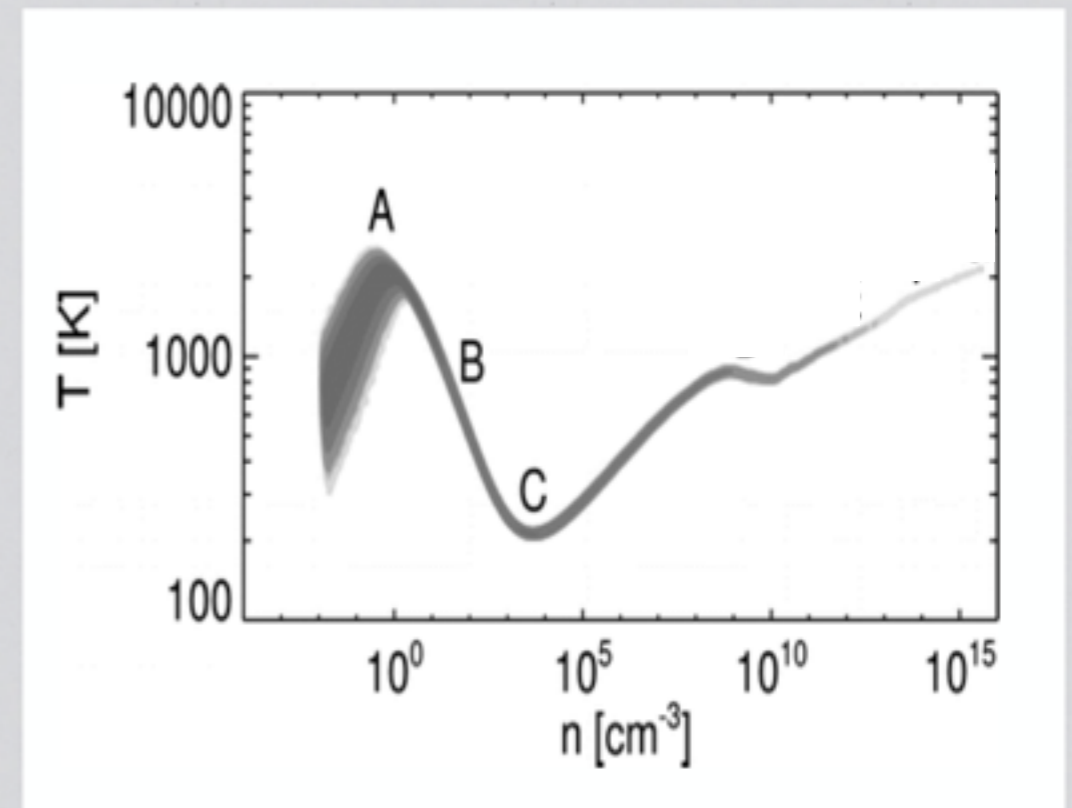
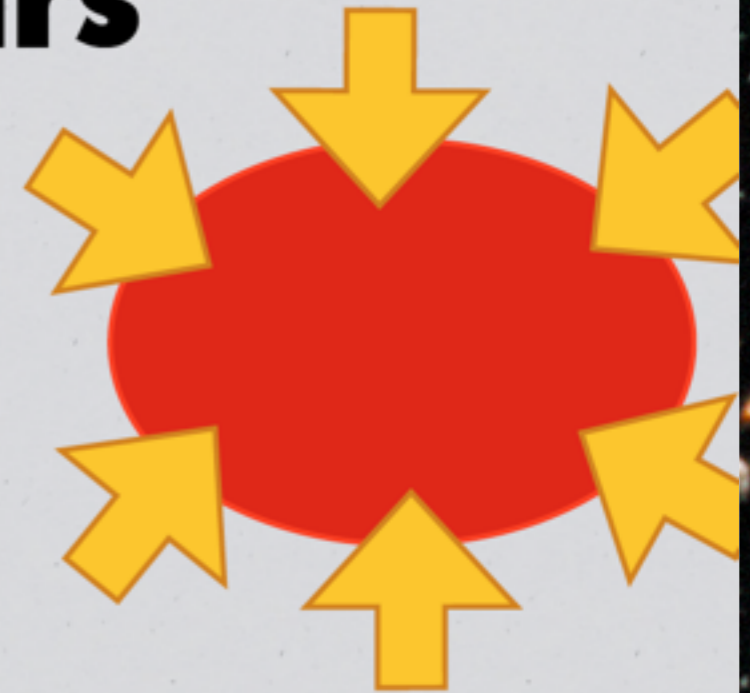
— The minihalo collapses and its gas (hydrogen+helium) reaches equilibrium between gravity and pressure support [A]

— Radiative cooling reduces temperature and rises density [B]

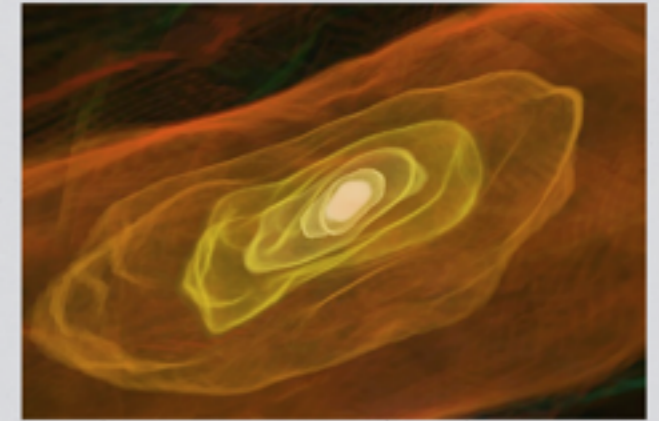
— Critical density for gravitational (Jeans) instability is reached [C]

— Gravity dominates over pressure

— Collapse of $\sim 10^{3-4} M_{\text{sun}}$ of gas



First Star: life & death

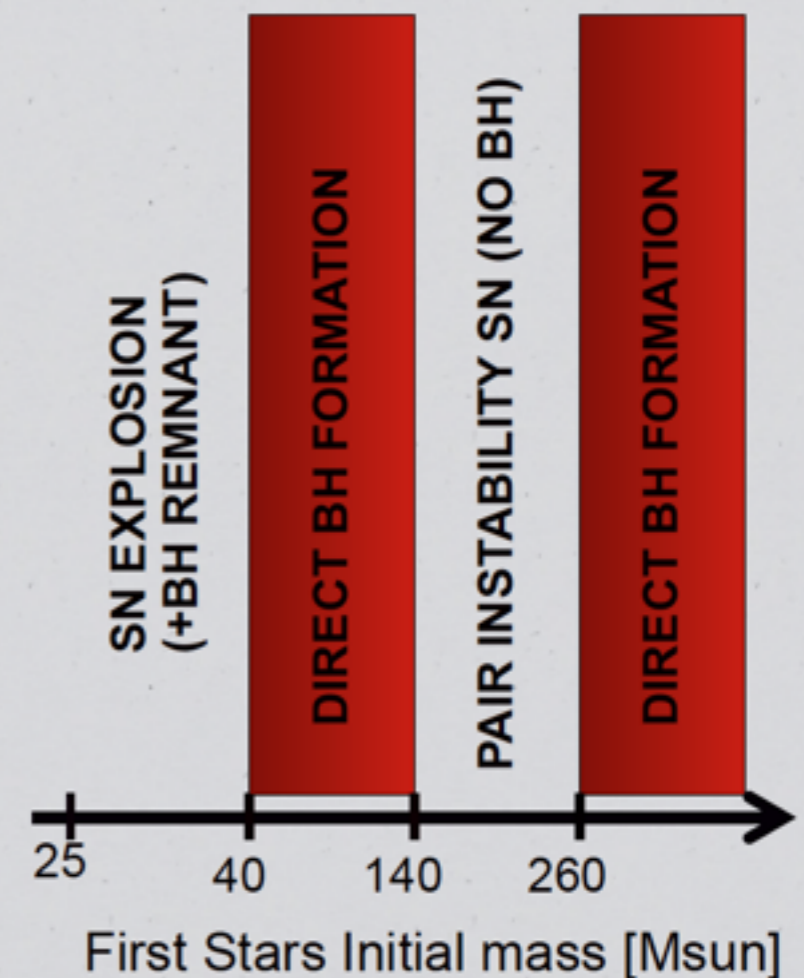


Simulations predict one (or two) stars per minihalo, with heavy masses [$\sim 10-100 M_{\text{sun}}$]

Heavy masses imply short lifetimes (a few Myr)

Supernova explosion can release heavy elements into the interstellar medium

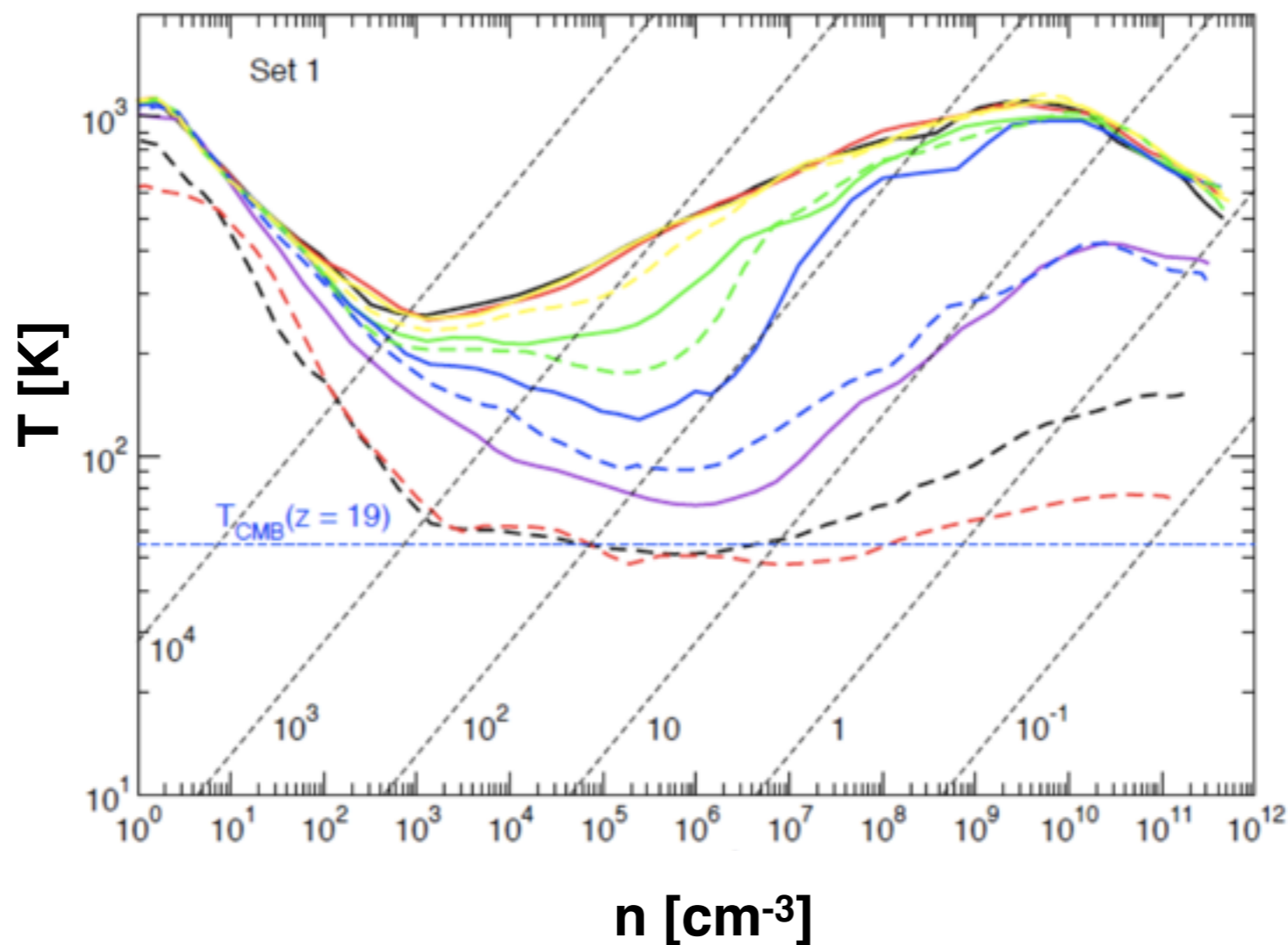
Or... direct black hole formation, possibly providing the first seeds that later grow into supermassive black holes



from Heger et al. (2003)

Metal cooling: transition to PopII

At $Z \sim 10^{-3.5} Z_{\text{sun}}$ Transition from PopIII to PopII



Smith et al. (2009)

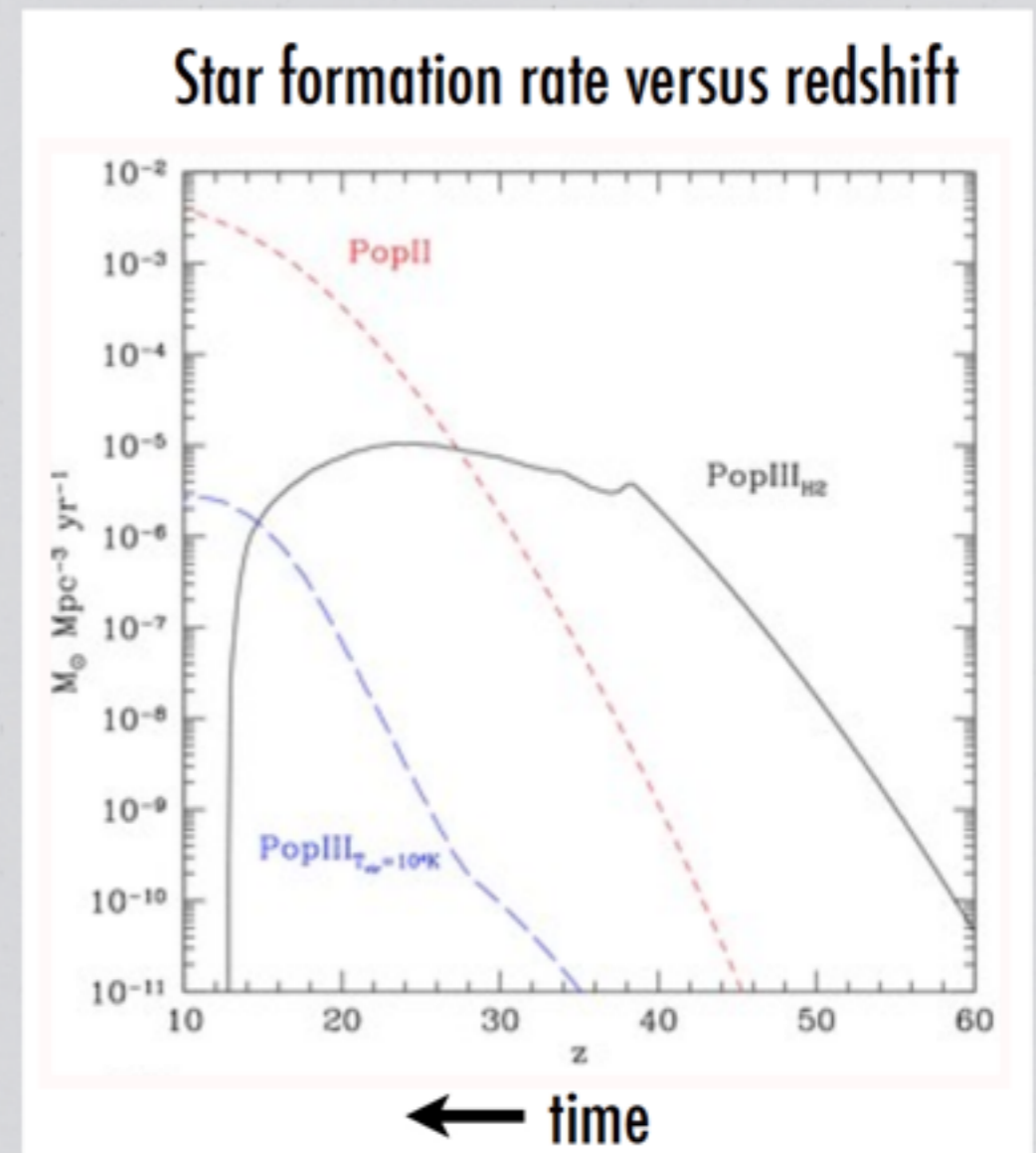
Early Star Formation history

Star formation history evolution:

PopIIIs begin forming very early on ($z > 60$, or $t < 40\text{Myr}$) in minihalos ($M_h < 10^{5-6} M_{\text{sun}}$)

Radiative feedback self-regulates their formation rate after $z \sim 35$ ($t \sim 80\text{Myr}$), suppressing cooling of gas in minihalos

PopII stars become dominant at $z < 25$ ($t > 150\text{Myr}$)



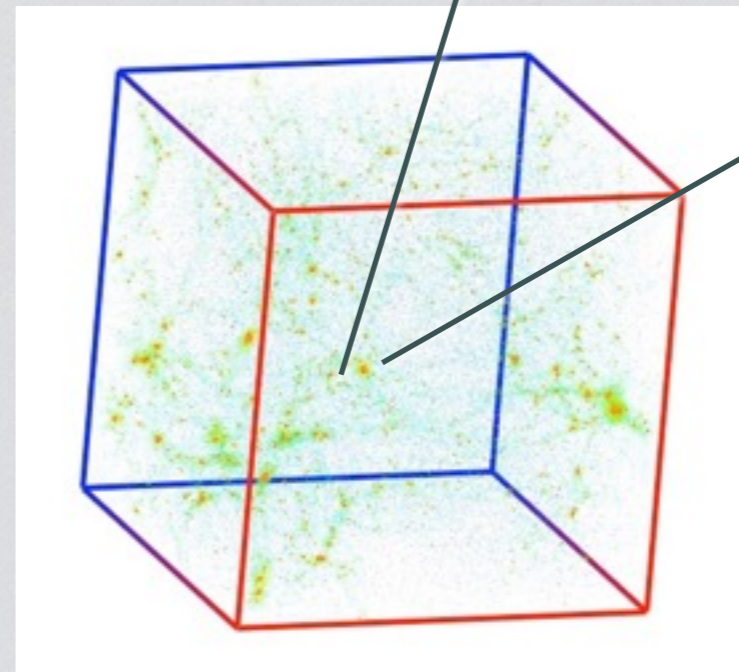
Trenti & Stiavelli (2009)

A model for galaxy formation

★ Goal: Simplest meaningful model to understand evolution of galaxy formation

★ Galaxies form within dark-matter halos

- Working hypothesis: Dark matter halo assembly main driver of star formation



Our model for LF evolution

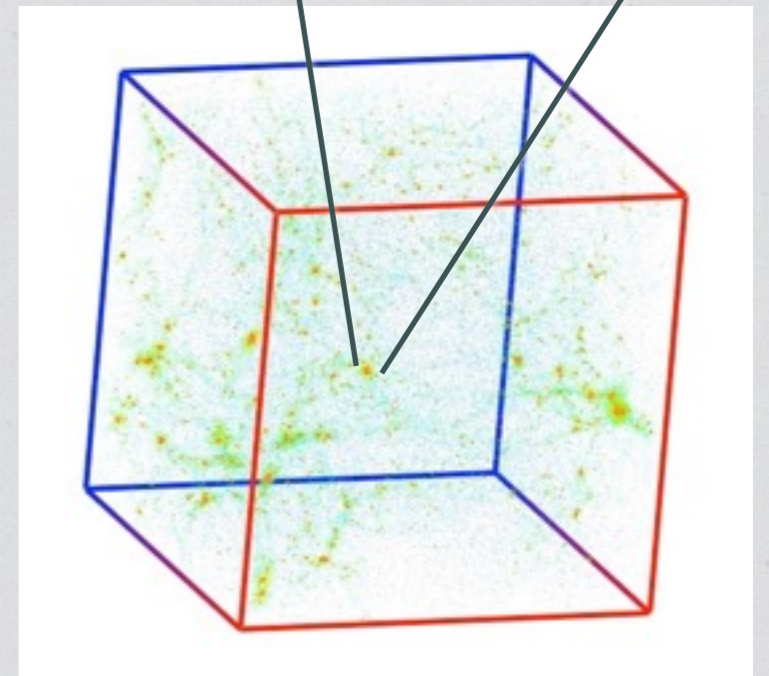
★ DM halos populated by galaxies with UV luminosity $L(M_h, z)$

★ $L(M_h, z)$ depends on:

1. Stellar populations [young stars brighter]: $\text{Age}(M_h, z)$
2. Stellar mass: $M_{\text{star}}(M_h, z)$

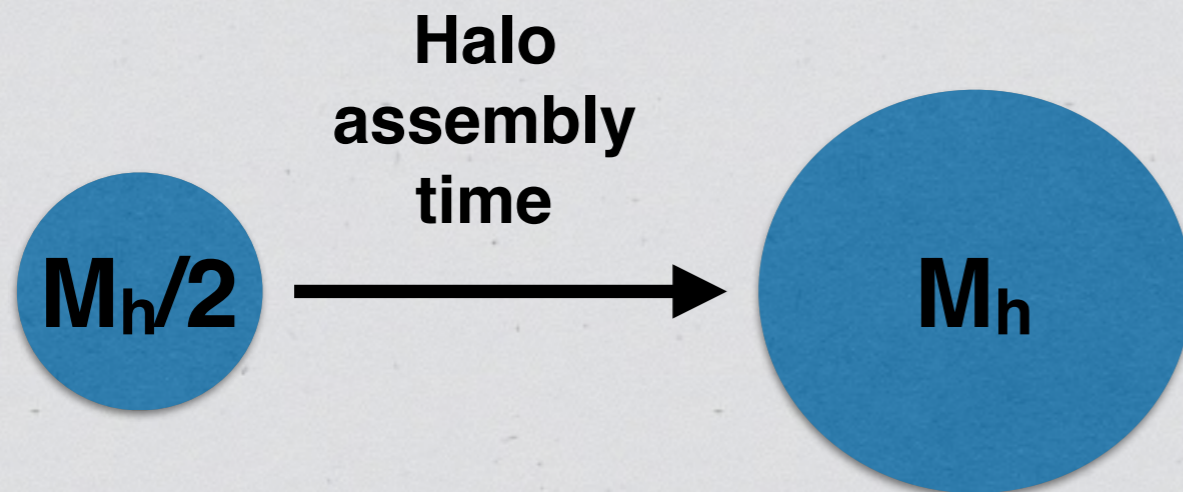
$$L(M_h, z) \sim M_{\text{star}} / \text{Age}$$

[with constant star-formation history]



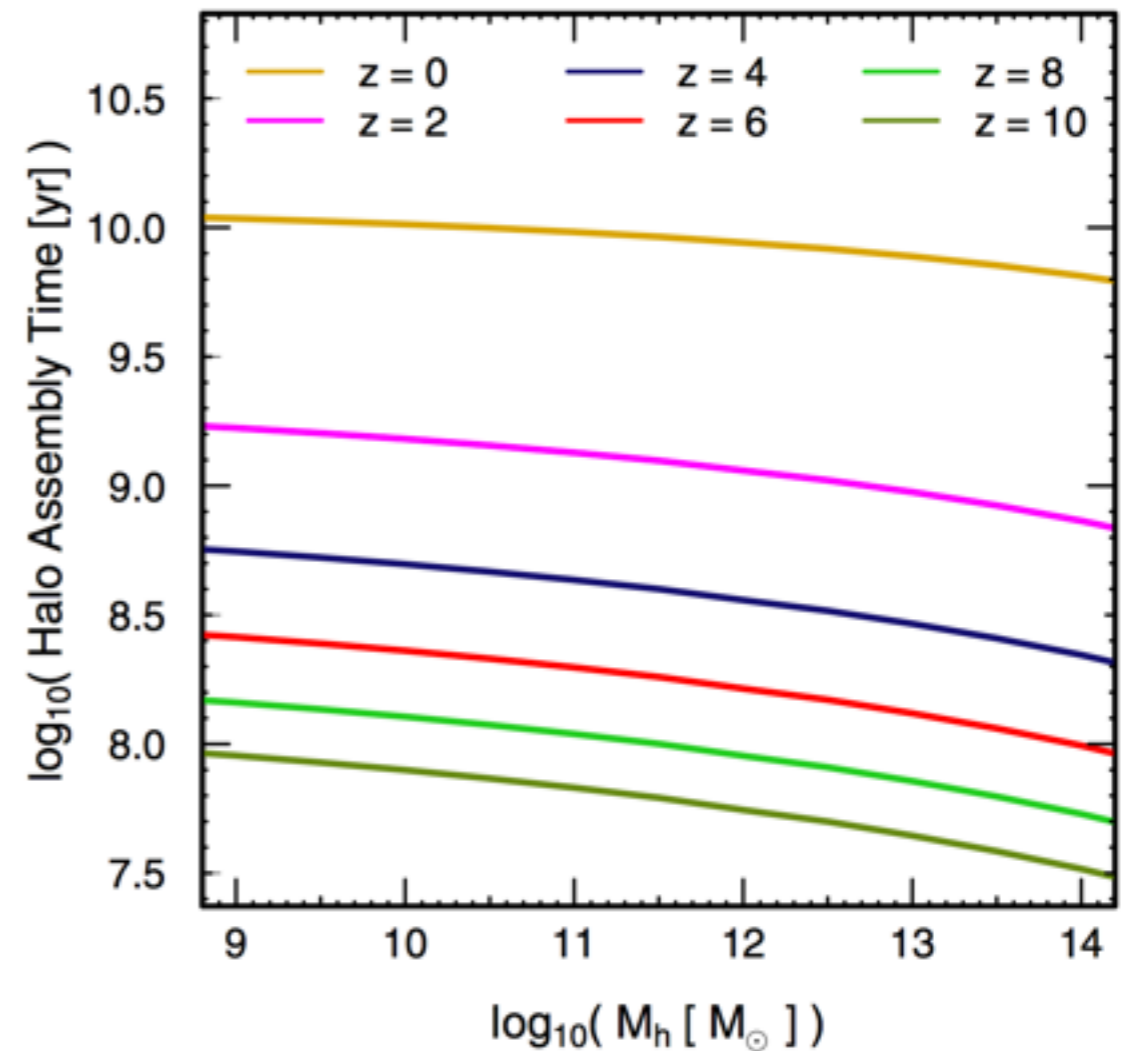
Galaxy ages

★ Adopted galaxy "age": **DM halo assembly time**



★ Rapid high- z assembly

★ No free parameters

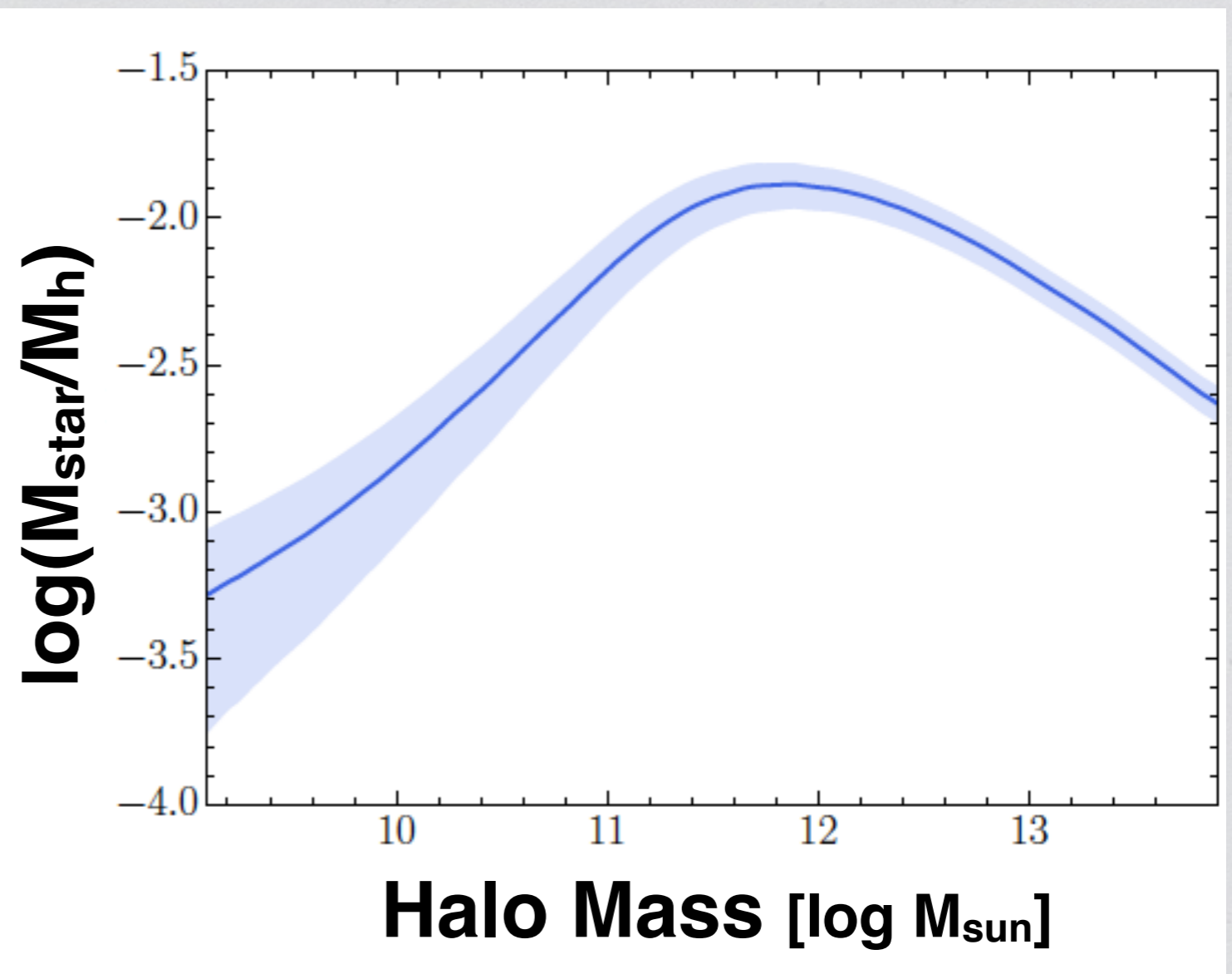


Tacchella, Trenti & Carollo (2013) [MSc project]

From halo to stellar mass

★ Minimal assumption: Stellar mass does not depend on redshift: $M_{\text{star}}(M_h, z)$

★ $M_{\text{star}}(M_h)$
derived from
single redshift
calibration



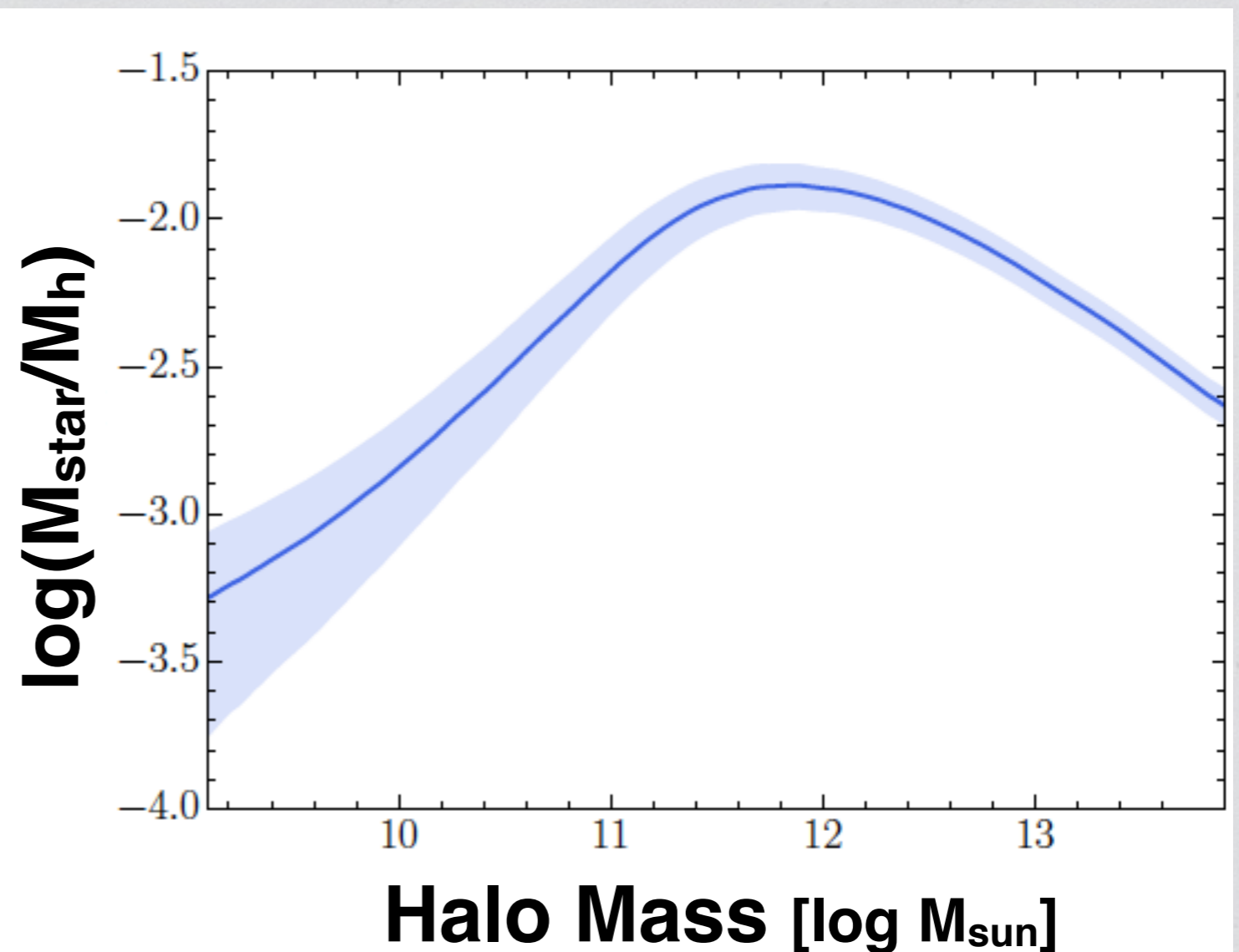
From halo to stellar mass

★ Minimal assumption: Stellar mass does not depend on redshift: $M_{\text{star}}(M_h, z)$

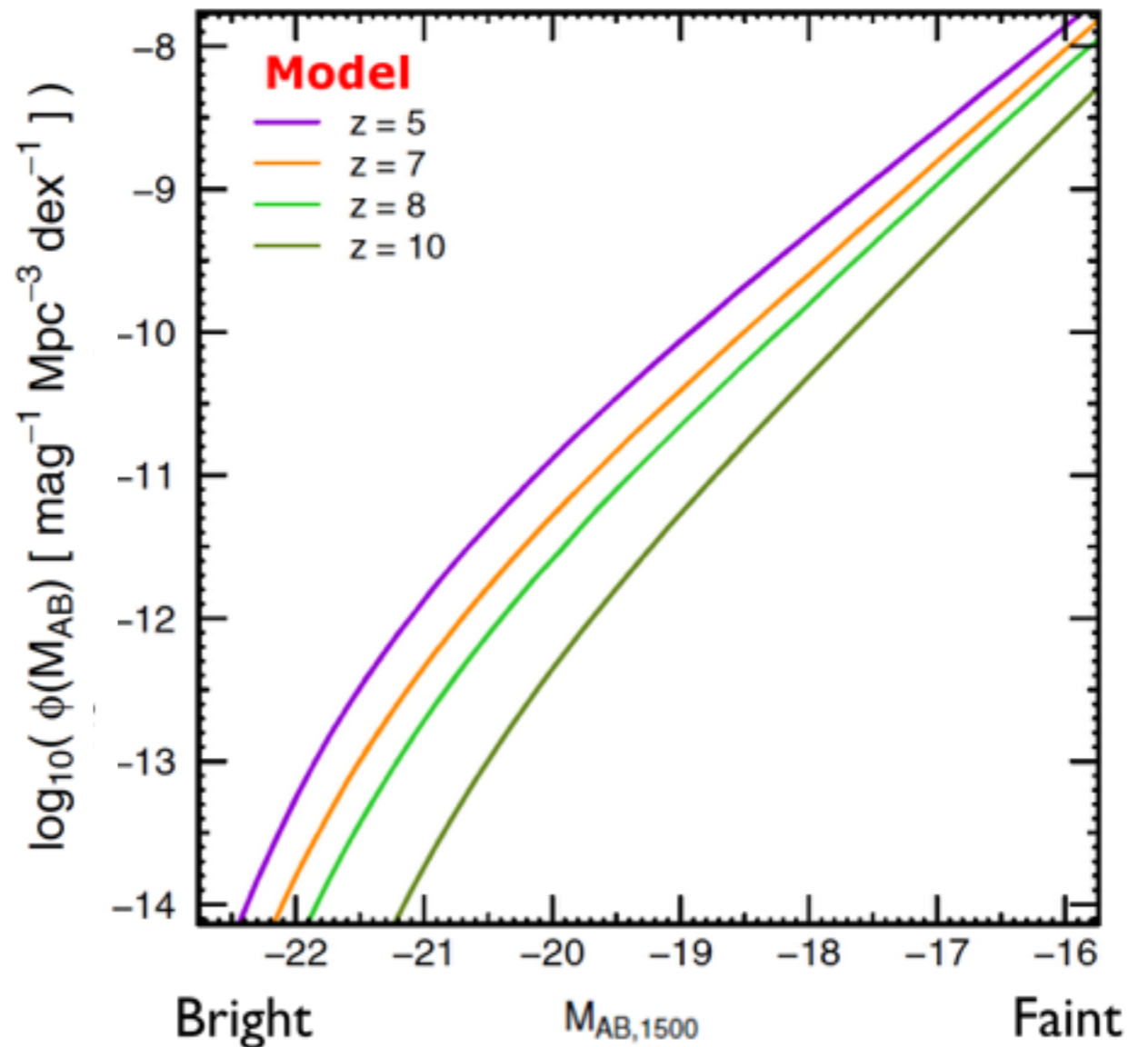
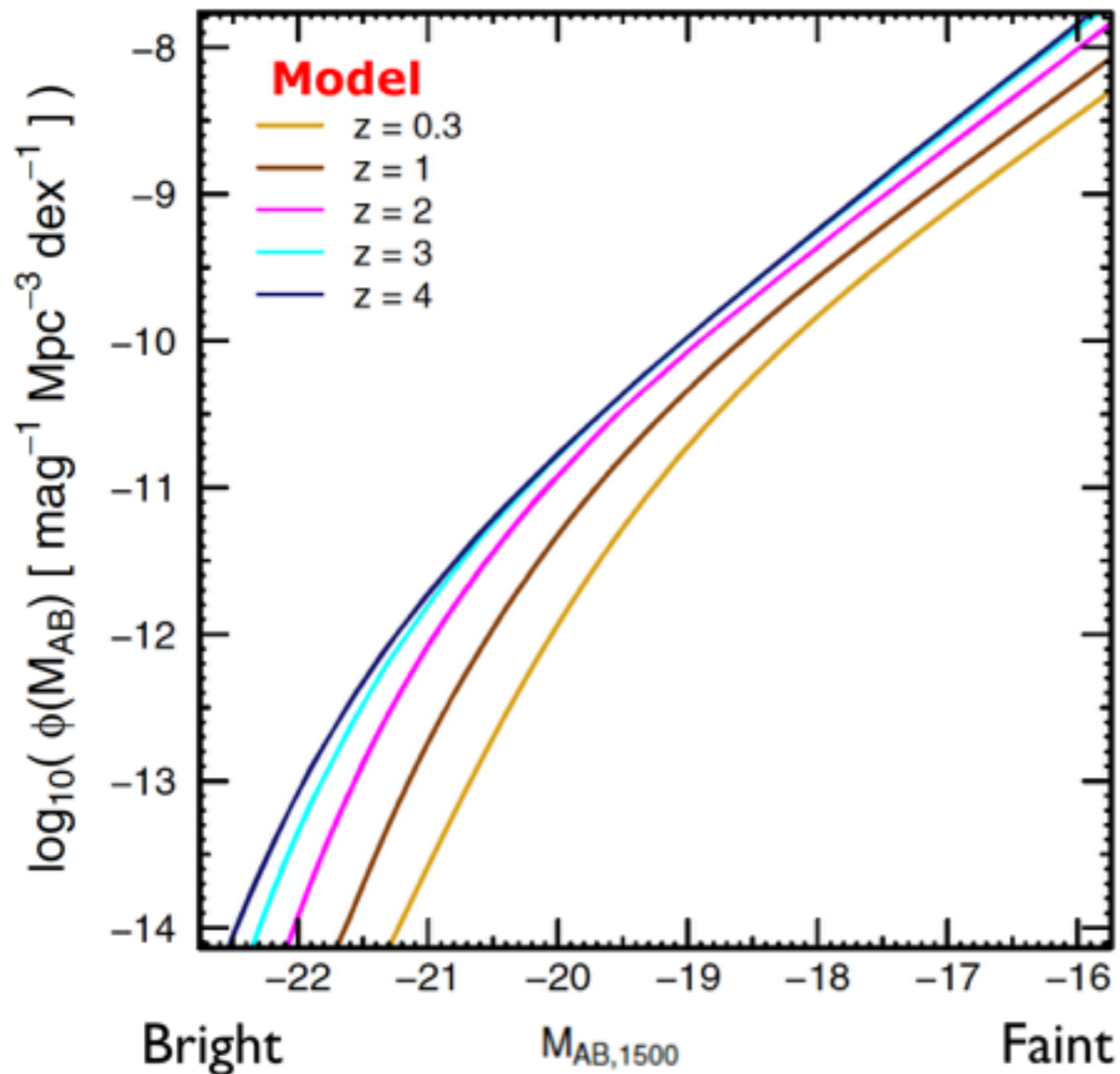
★ $M_{\text{star}}(M_h)$
derived from
single redshift
calibration

★ Luminosity
defined at all z :

$$L(M_h, z) \sim \frac{M_{\text{star}}(M_h)}{\text{Age}(M_h, z)}$$

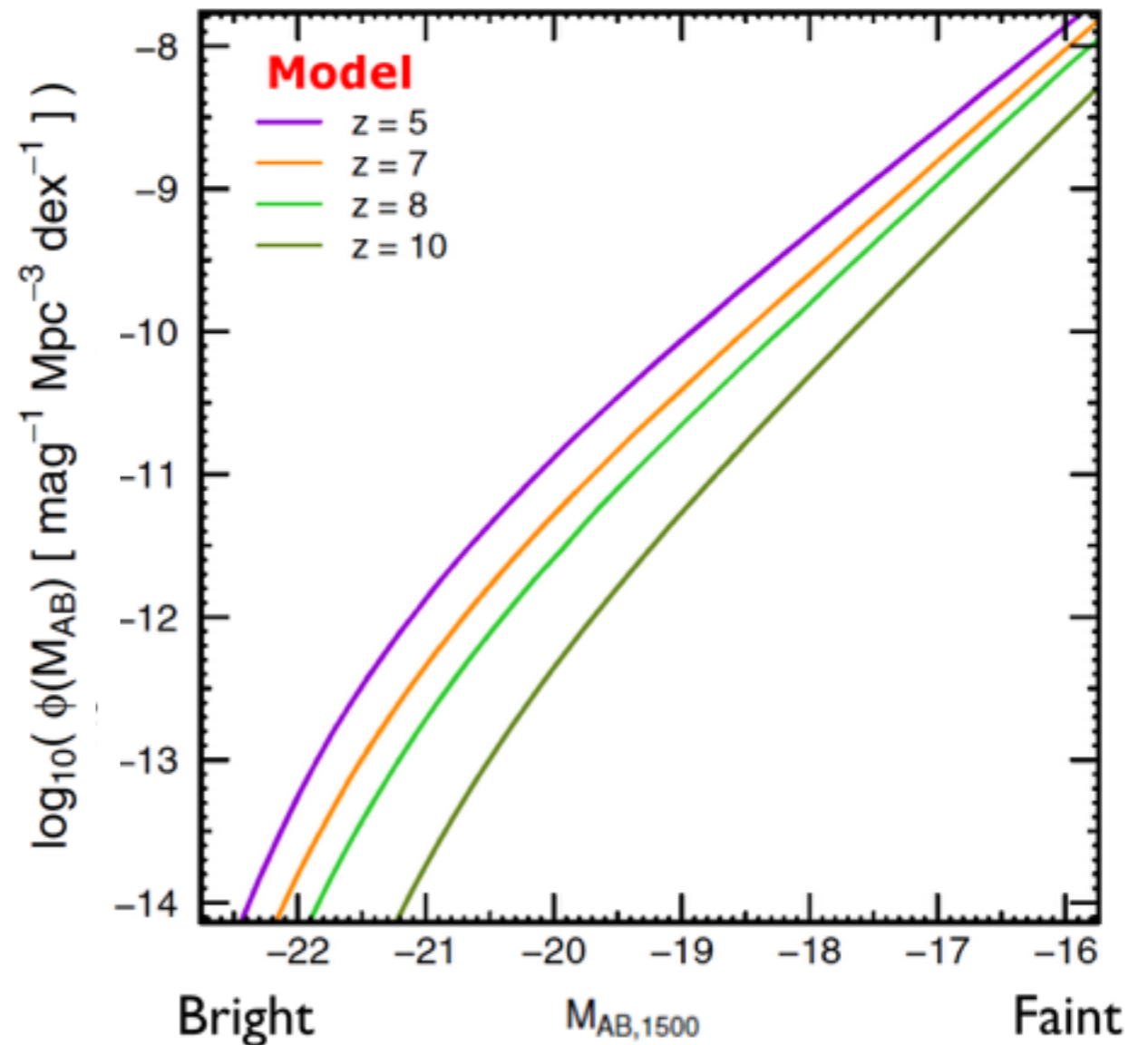
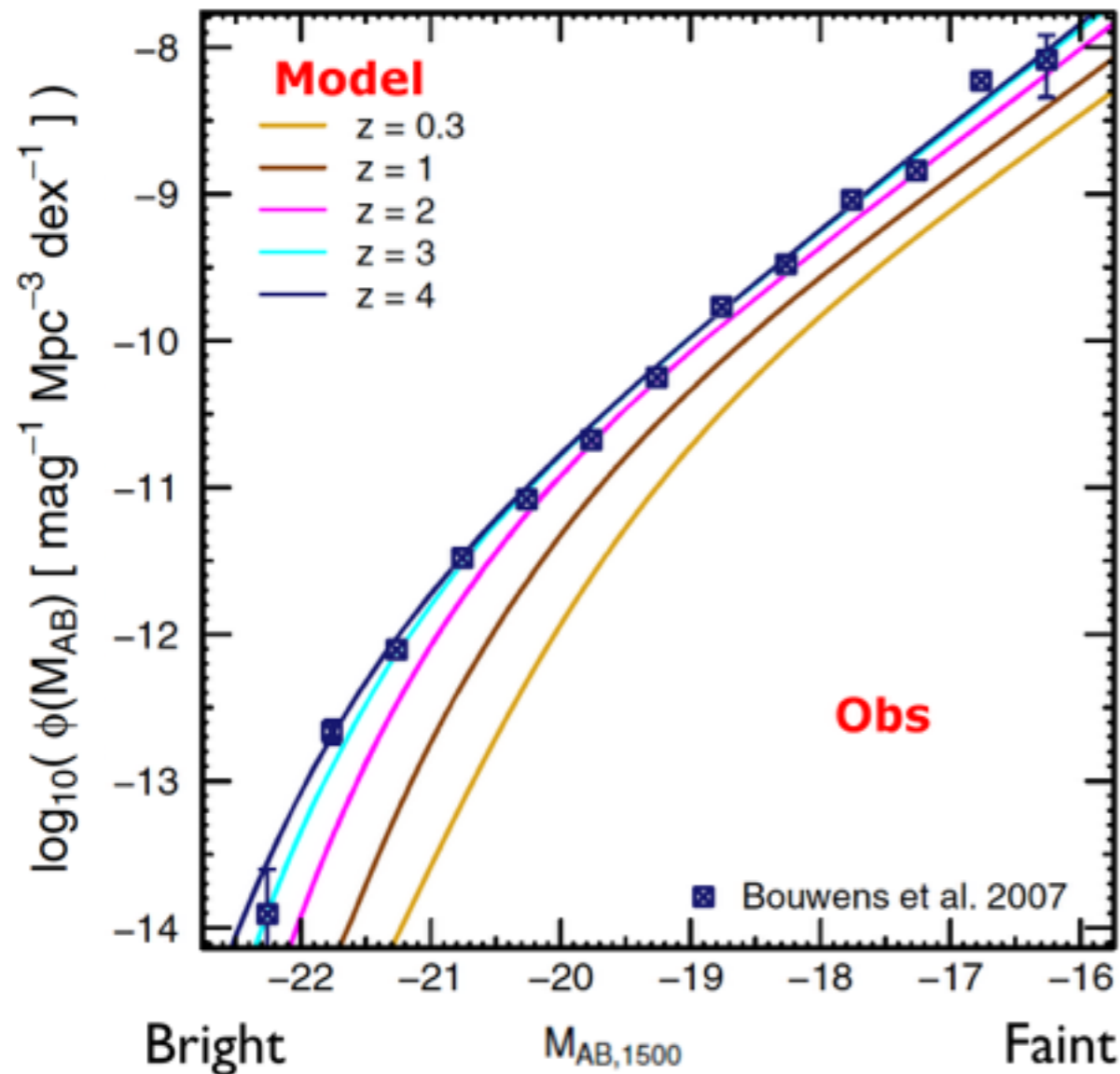


Luminosity function evolution



Tacchella, Trenti & Carollo (2013) [MSc project]

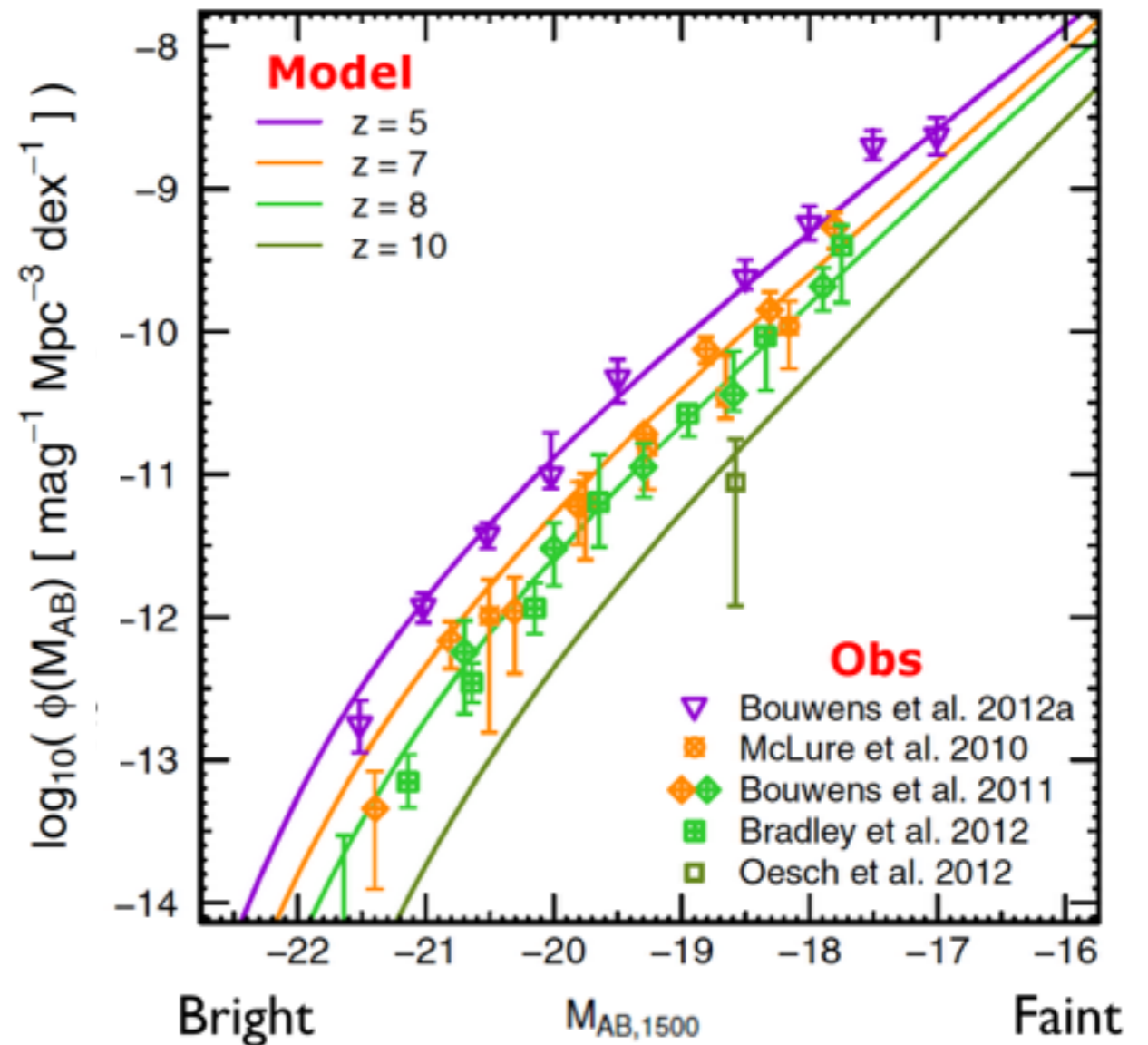
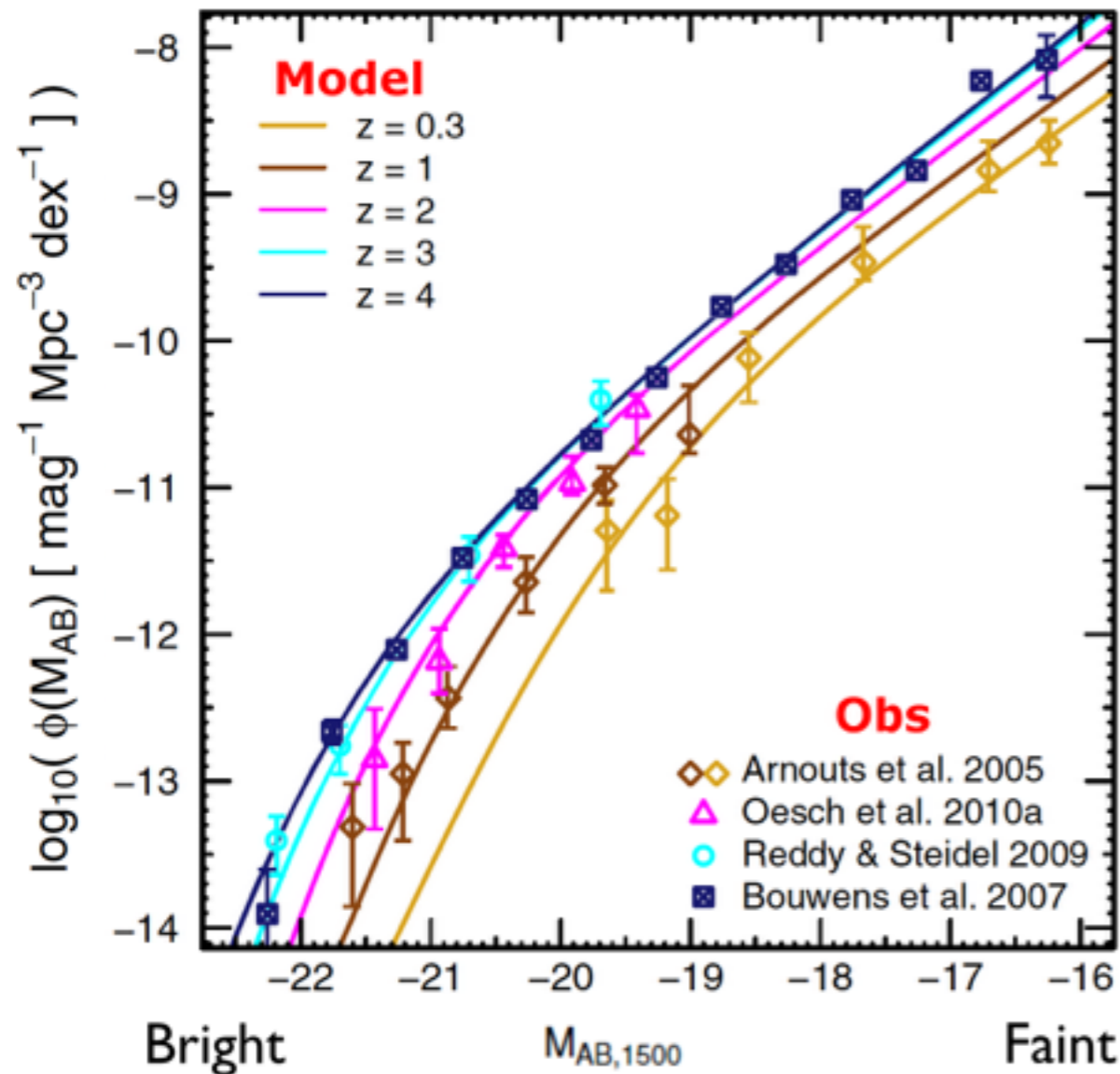
Luminosity function evolution



Tacchella, Trenti & Carollo (2013) [MSc project]

Luminosity function evolution

★ Model successful from $z=0$ to $z=10$!



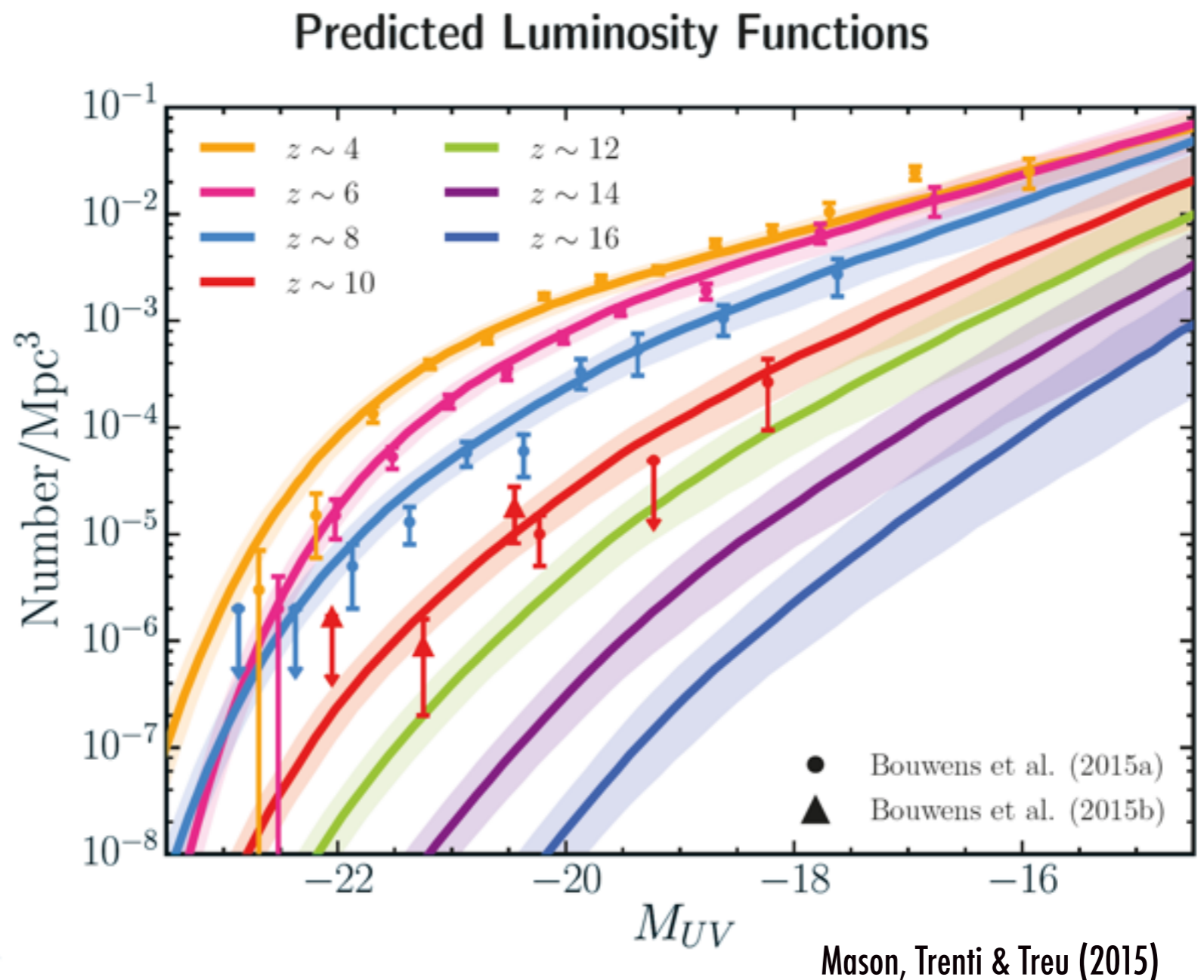
★ Assumptions validated!

Tacchella, Trenti & Carollo (2013) [MSc project]

Luminosity function evolution

★ Validation from latest $z \sim 8-10$ data

★ And
predictions
for $z > 10$
[first 500 Myr]

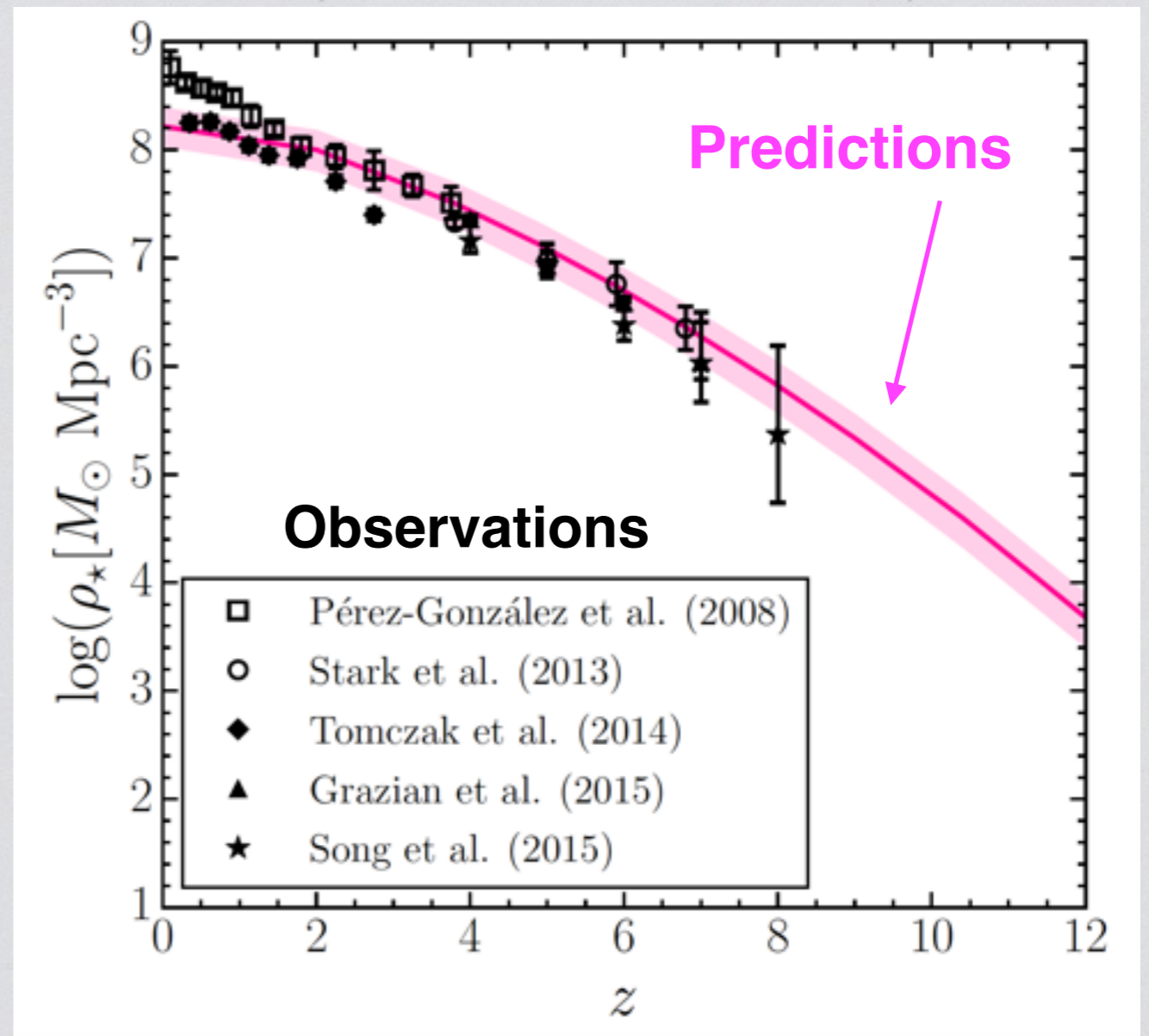


Stellar mass density evolution

★ Modeling based on galaxy light only

★ Yet... Evolution of stellar mass density described extremely well

★ Further confirmation that basic model captures essence of galaxy evolution

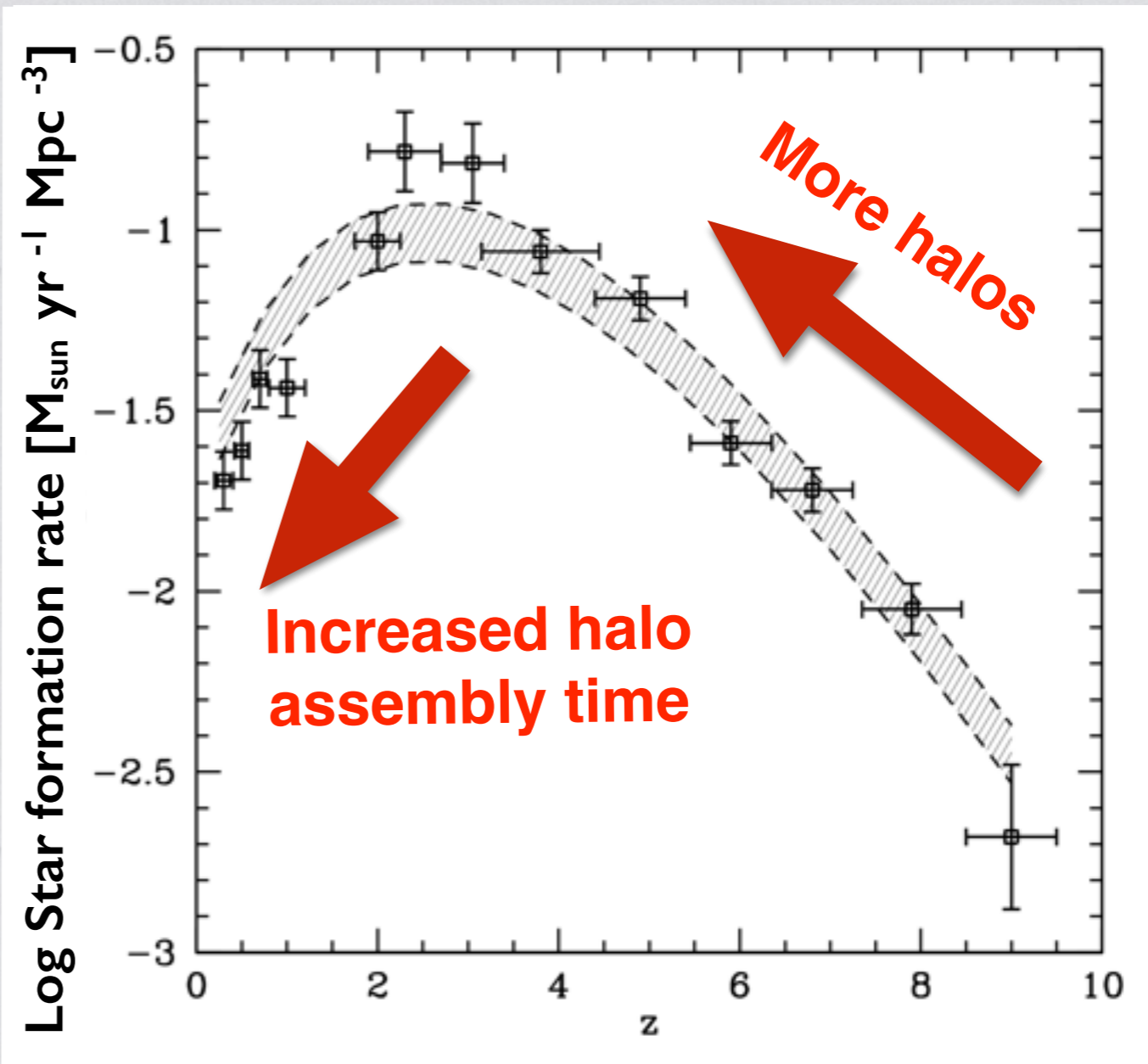


Mason, Trenti & Treu (2015)

Star formation history

★ Drivers of star formation:

- ★ Halo mass function evolution (galaxy abundance)
- ★ Halo assembly time (galaxy age)



Trenti et al. (2013)

Summary

- ★ Dark Matter halo assembly key driver of star formation
- ★ Basic model reproduces the evolution of the star formation history
- ★ Halos at fixed mass at different redshift have similar stellar mass, but different luminosities because galaxy ages change