Lyman Alpha Galaxies: Babies or Baby Boomers?

Steven Finkelstein
Mitchell Institute for Fundamental Physics and Astronomy
Texas A&M University

Collaborators: James Rhoads, Sangeeta Malhotra & Casey Papovich

What are Lyα galaxies?

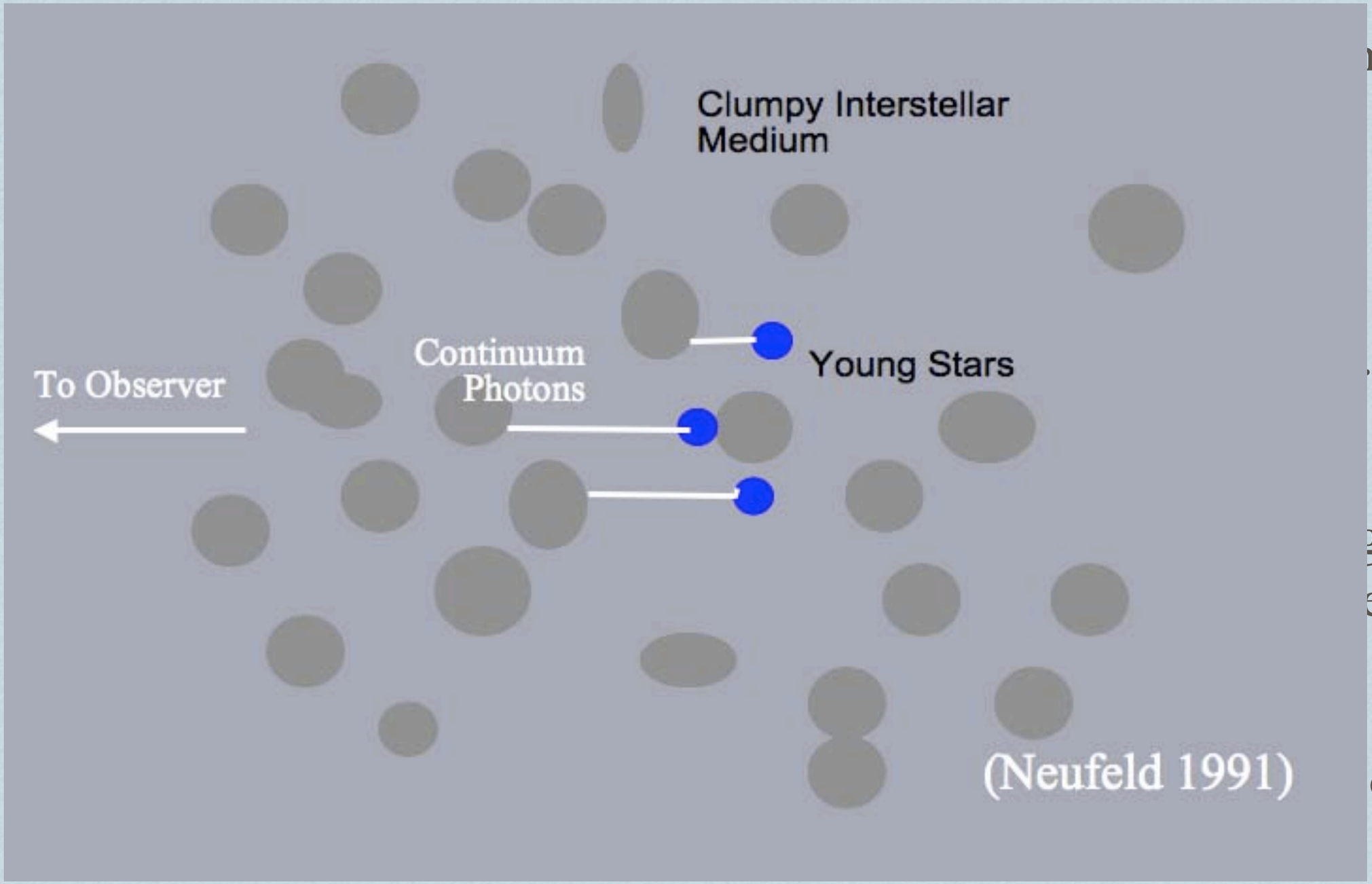
- Originally thought to be representative of primitive galaxies in formation.

- Over the past dozen years, thousands of LAEs have been discovered, many with large Lyα equivalent widths (e.g., Kudritski et al. 2000; Malhotra & Rhoads 2002; Dawson et al. 2007; Finkelstein et al 2007).

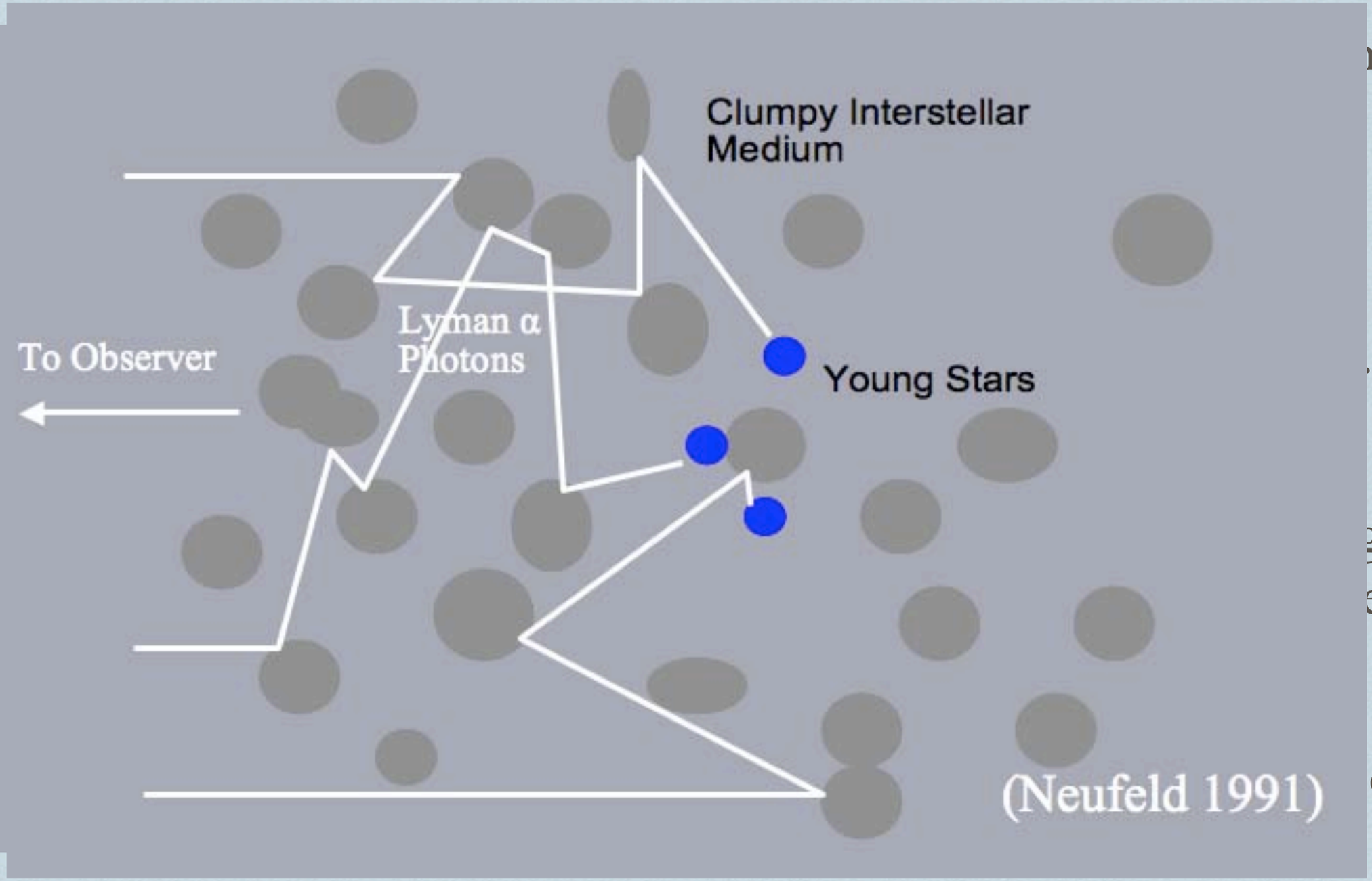
- These high EWs require some special mechanism to occur: e.g., very low metallicity, top-heavy IMF, or preferential Lyα escape.

- If the ISM in a galaxy is inhomogeneous, with the dust and neutral H together in clumps, the Lyα photons can be screened from ever encountering dust.

What are Lyα galaxies?

- 

What are Lyα galaxies?



What are Lyα galaxies?

- This enhancement of the EW can allow older galaxies to be detected with large EWs in narrowband-selected surveys.

- We examined 14 Lyα galaxies at $4.4 \leq z \leq 4.5$ in the GOODS CDF-S (Finkelstein et al. 2008, 2009a).

  - We fit their SEDs to stellar population models to learn about their age, mass, dust extinction, and the possibility of (varying amounts of) ISM clumpiness affecting the EW.

- We found that 12/14 LAEs had ages ≤ 15 Myr, and $M \leq 6 \times 10^9\ M_\odot$ → "babies"

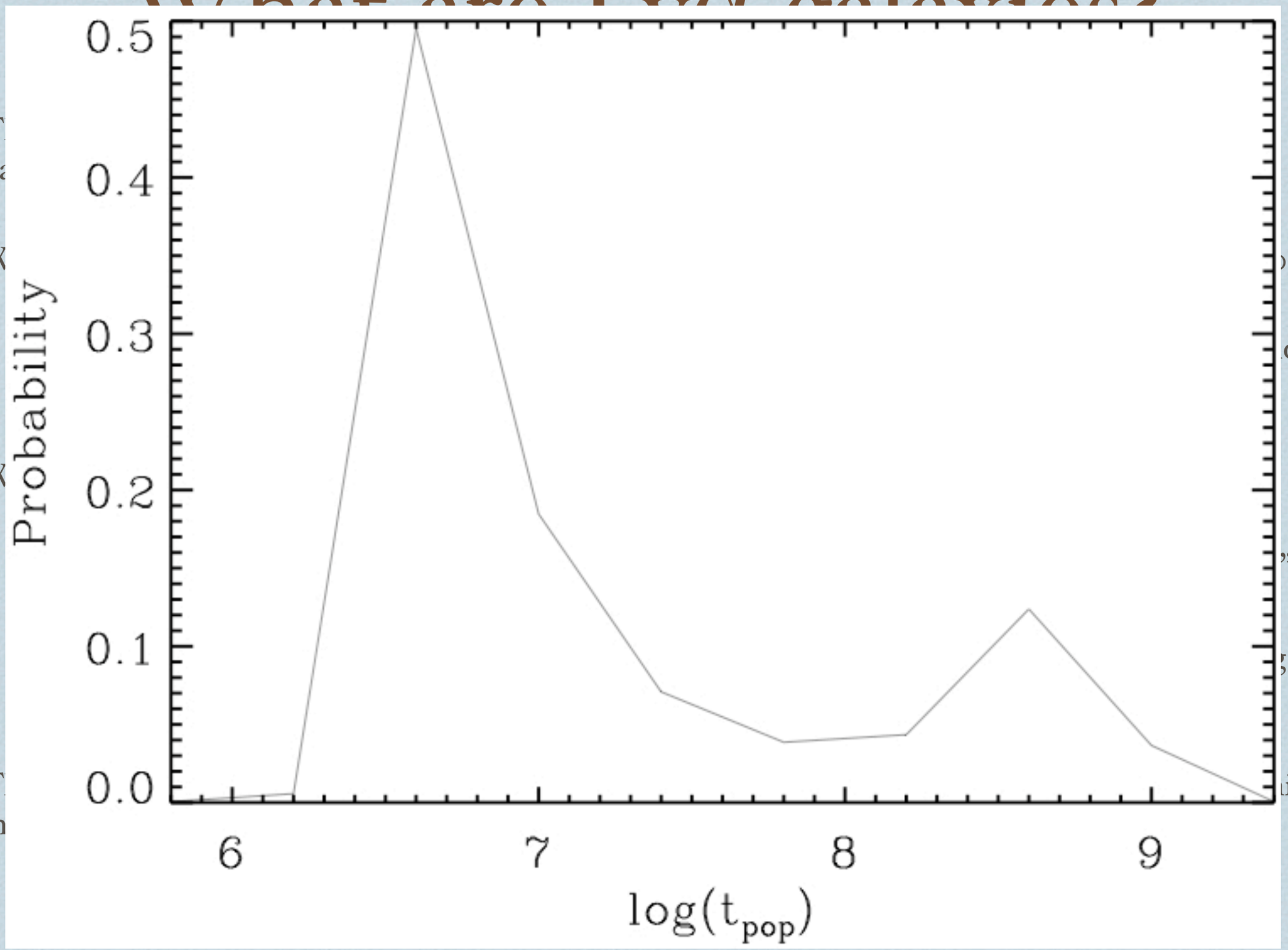
  - The other two had ages of 450 - 500 Myr, and $M = 4 \times 10^9 - 5 \times 10^{10}\ M_\odot$ → "baby boomers"

    - All 14 were constrained to have some level of dust extinction, with this dust enhancing the EW in the majority (10/14) of objects, including the two "baby boomers."

- The overall age distribution shows that (for our small sample), up to 15% of LAEs at this redshift may in fact be evolved galaxies.

What are Lyα galaxies?

- T
  na
- W
  - 009a).
  - on,
- W
  - ”
- T
  - ; the
  - ift
  m



What are Lyα galaxies?

- This enhancement of the EW can allow older galaxies to be detected with large EWs in narrowband-selected surveys.

- We examined 14 Lyα galaxies at $4.4 \leq z \leq 4.5$ in the GOODS CDF-S (Finkelstein et al. 2008, 2009a).

  - We fit their SEDs to stellar population models to learn about their age, mass, dust extinction, and the possibility of (varying amounts of) ISM clumpiness affecting the EW.

- We found that 12/14 LAEs had ages ≤ 15 Myr, and $M \leq 6 \times 10^9\ M_\odot$ → "babies"

  - The other two had ages of 450 - 500 Myr, and $M = 4 \times 10^9 - 5 \times 10^{10}\ M_\odot$ → "baby boomers"

    - All 14 were constrained to have some level of dust extinction, with this dust enhancing the EW in the majority (10/14) of objects, including the two "baby boomers."

- The overall age distribution shows that (for our small sample), up to 15% of LAEs at this redshift may in fact be evolved galaxies.

- Other studies have shown a few cases of evolved galaxies (Lai et al. 2008; Pentericci et al. 2009), while others find that most LAEs appear to be very young (e.g., Gawiser et al. 2006; Pirzkal et al. 2007).

Do Lyα galaxies evolve?

- Stellar population modeling results imply similar populations from $3 \leq z \leq 6$.
- The Lyα luminosity function does not appear to vary from $3 \leq z \leq 6$ (e.g., Gronwall et al. 2007; Dawson et al. 2007).
  - Implies that LAEs at $z = 3$ are physically similar objects to LAEs at $z = 6$.
- GALEX results at $z \sim 0.3$ show that LAEs are much rarer and fainter than at high-z (Deharveng et al 2008).
  - We've also shown that these $z \sim 0.3$ LAEs are much older, more massive, and more metal enriched that LAEs at $z \sim 4.5$ (Finkelstein et al. 2009c).
- Thus, at some point between $z \sim 0.3 - 3$, LAEs have begun to evolve.
  - HETDEX will provide large samples of LAEs from $2 \leq z \leq 3$, which we can use to probe this critical regime.
    - Important for HETDEX to cover as many multi-wavelength fields as possible.

Detecting the first stars with HETDEX

- Although we've shown that LAEs *can* be evolved, the majority still appear to be very young, as low as 1 Myr.

- If a stellar population is observed in its first ~ 3 Myr, it is possible that Population III stars could be detected via He II 1640 Å emission (Schaerer 2002).

  - High-mass Pop III stars could emit > 10% of their ionizing photons in the He II continuum, producing strong fluxes in He II recombination lines, with the 1640 Å line being the strongest (Tumlinson & Shull 2000).

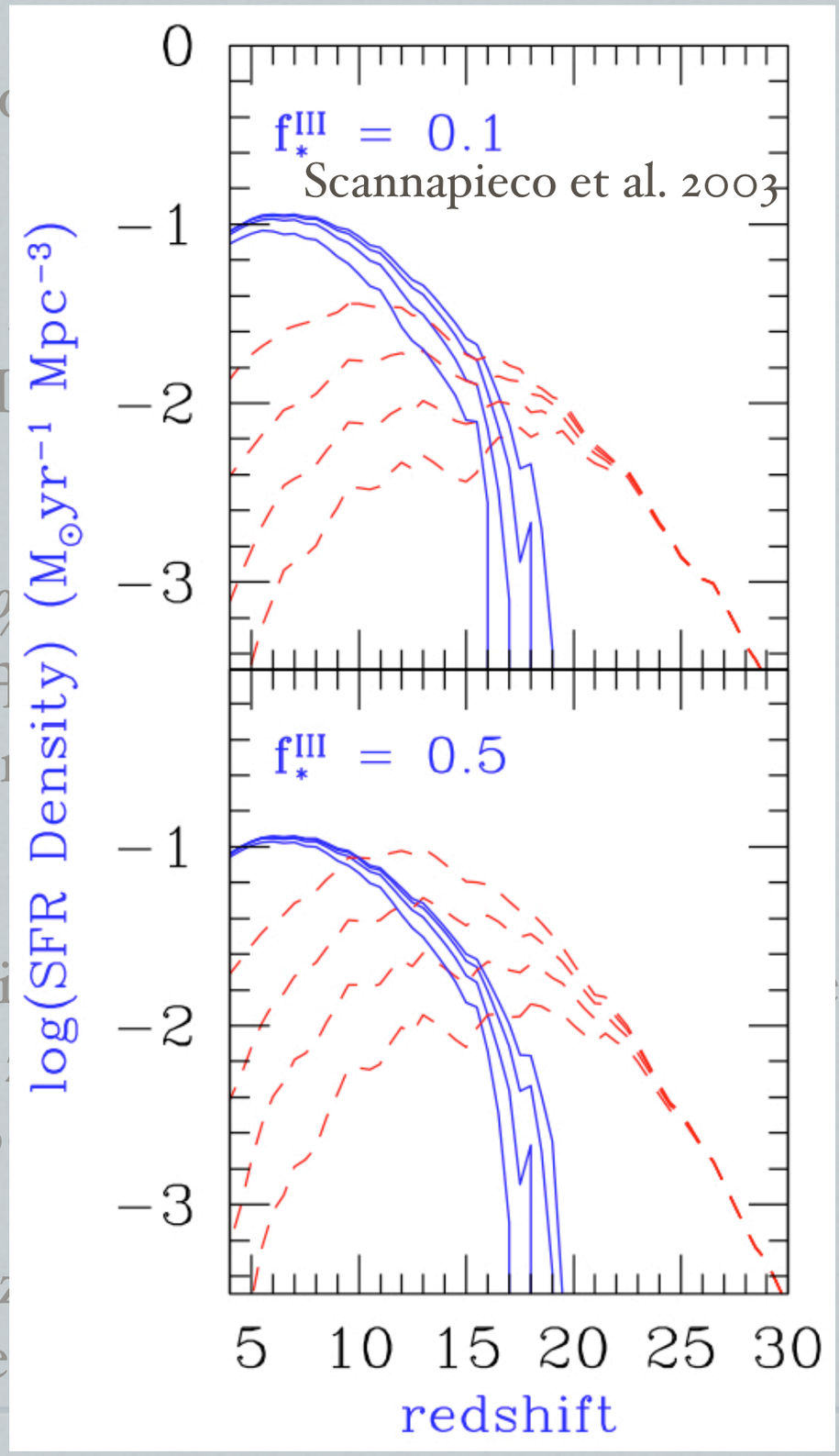
- From theoretical models, the mean metallicity of the Universe can cross the critical value ($Z \sim 10^{-4}\ Z_\odot$) for Pop III SF by $z \sim 15$, *but* the peak of Pop III SF can occur at $z < 10$ (Scannapieco et al. 2003).

  - Thus, the fraction of Pop III objects vs. z is heavily dependent on the distribution of metals rather than the mean metallicity.

Detecting the first stars with HETDEX

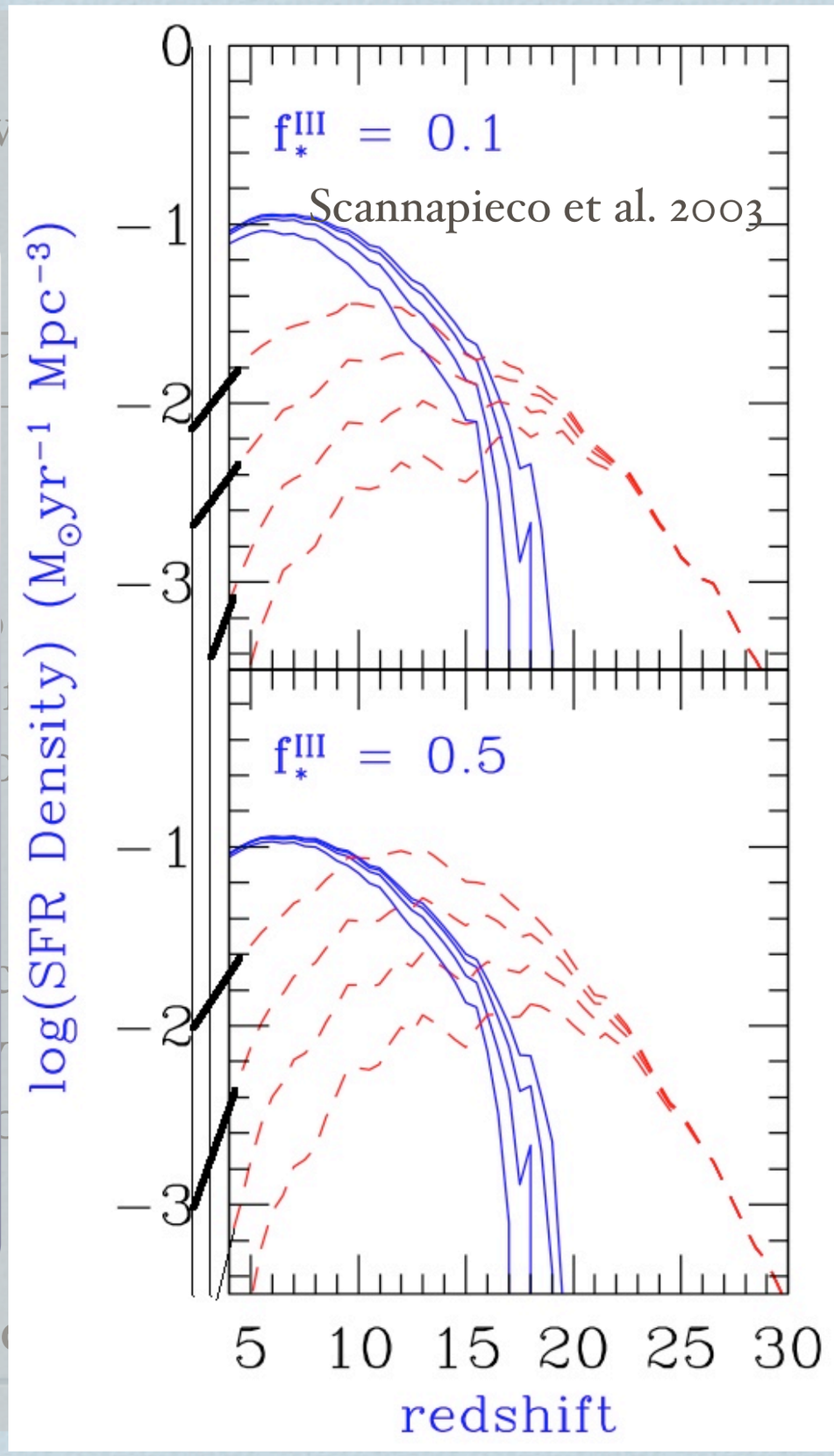
- Although we've shown that LAEs *can* be evo
  to be very young, as low as 1 Myr
- st
  H
- o%
  f
  ro
- ici
  y
  20
- Thus, the fraction of Pop III objects vs. z
  distribution of metals rather than the me

- Red = Pop III SFRD
- Blue = Pop I/II SFRD
- f_*^{III} = Pop III star formation efficiency
- Different curves represent changing values of ε = energy per unit gas mass.
  - Specifies how efficiently metals are transported back into the ISM (e.g., winds and SNe).
- Pop III stars could account for as much as 2% of the total SFRD at z ~ 4.



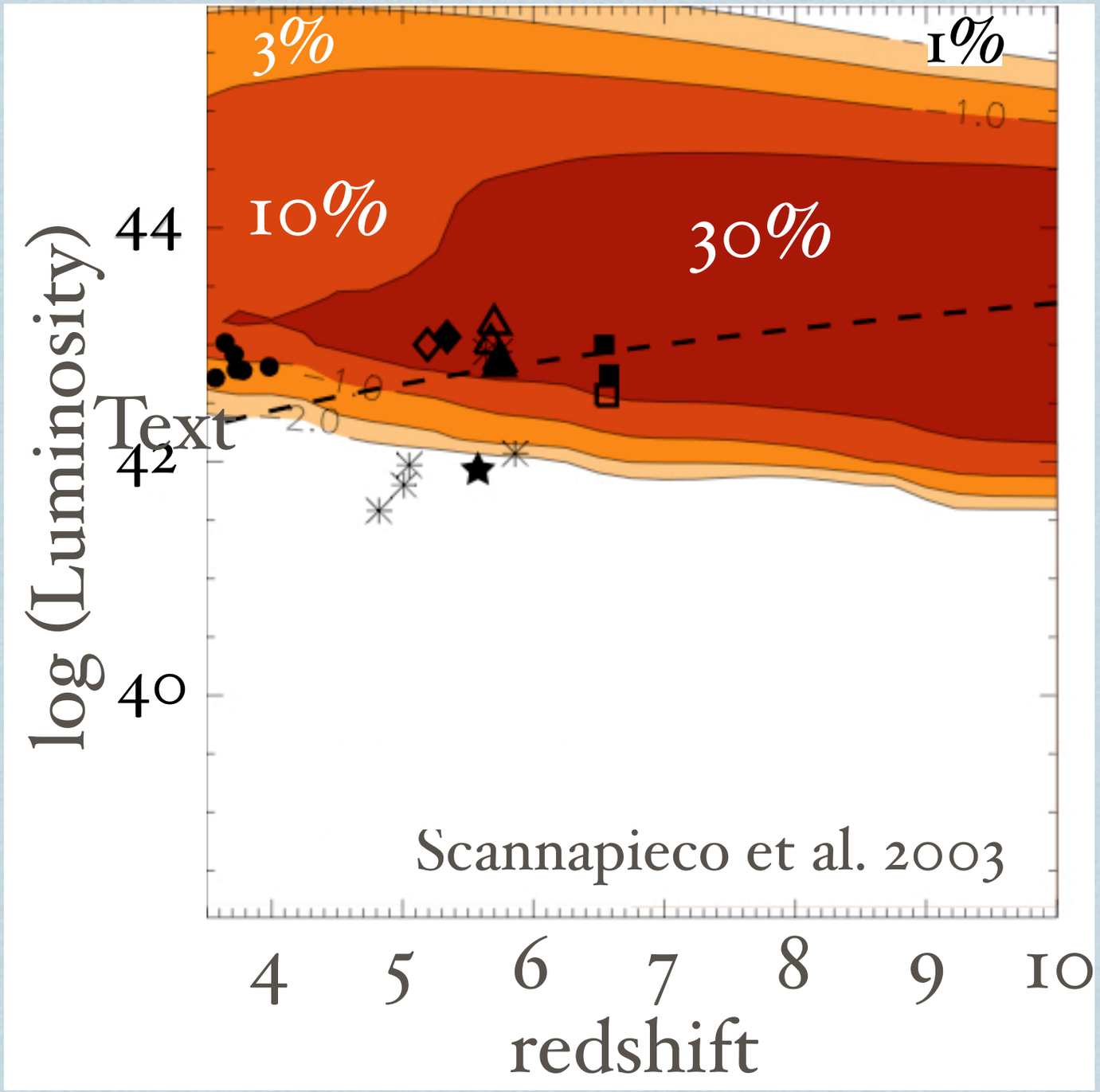
Detecting the first stars with HETDEX

- Although we've shown that LAEs *can* be ev
to be very young, as low as 1 Myr
-
  - If we want to guess, we can extrapolate these curves down to z ~ 2.
  - Thus, the Population III star formation could contribute as much as 1 % to the global SFRD at z ~ 2.
- Thus, the fraction of Pop III objects vs.
distribution of metals rather than the m



Detecting the first stars with HETDEX

- Figure: Fraction of Pop III objects as a function of Lyα luminosity and redshift
  - Assumes all Pop III stars are massive
- Extrapolating a little, Among the brighter LAEs at z ~ 3, we might expect ~ 3% to be hosting Population III stars.
- A few studies have looked (Dawson et al. 2004; Nagao et al. 2008), but have yet to find any PopIII objects.



Summary

- While originally thought to be primitive galaxies in formation, Lyα galaxies have been shown to be increasingly complex objects.
  - Their evolution with redshift at $z < 4$ is unclear.
  - HETDEX can gives us large samples to test galaxy evolution.
- However, the majority of studied Lyα galaxies do appear to be extremely young, thus they may be good labs for looking for the first stars.
  - We may expect Population III star formation to account for as much as 2% of the total star formation rate density at $z \sim 3$.
    - Pop III stars could exist inside ~ 3% of > L* galaxies at $z \sim 3$.
- The large number of Lyα galaxies which we will discover with HETDEX will give an unprecedented sample for exploring Population III star formation at $2 \leq z \leq 4$.