Population III Galaxy Candidates in CLASH

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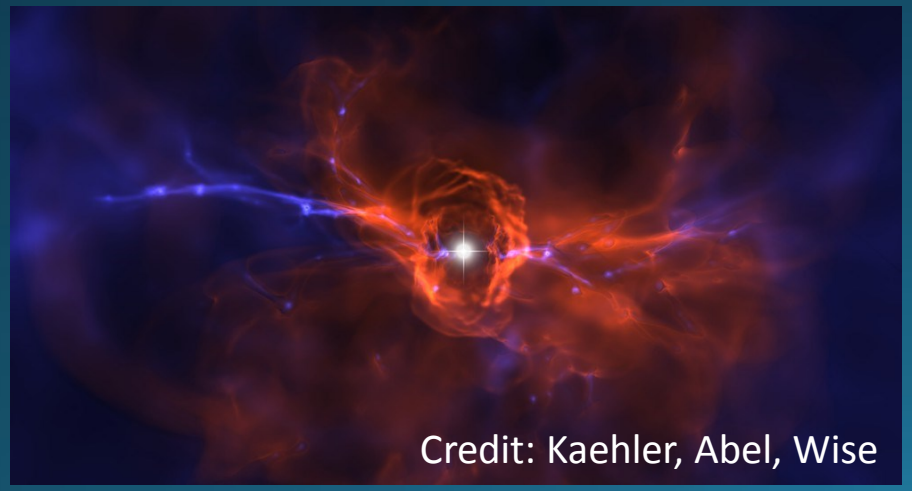
Population III stars

- First generation of stars
- Metallicity $Z \approx 0 \rightarrow$ Very hot ($T_{eff} \sim 10^5$ K)
- Start forming at $z \approx 30$, in 10^5-10^6 M_{solar} minihalos
- May continue to form until $z \approx 2$ (in 10^9 M_{solar} halos)
- Typical mass ~ 10 M_{solar} (top-heavy IMF)


Credit: Kaehler, Abel, Wise


Credit: Kaehler, Turk, Abel

Population III galaxies

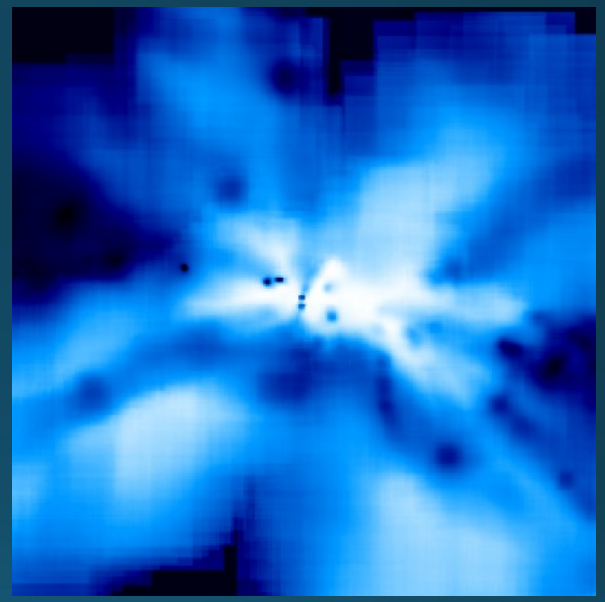
- **Definition typically adopted by observers:**
  ”A galaxy dominated by Pop III stars”

- **Spectral signatures:** Strong Lyα, strong HeII, extremely blue continuum slope β, Lyman bump, no metal lines
  (e.g. Schaerer 2002; Raiter et al. 2010; Inoue 2010, 2011; Zackrisson et al. 2011, 2012)

- **A few claimed detections:** Malhotra & Rhoads (2002), Fosbury et al. (2003), di Serego Alighieri et al. (2008), Inoue et al. (2011), Kashikawa et al. (2012), Cassata et al. (2013)

Population III galaxies

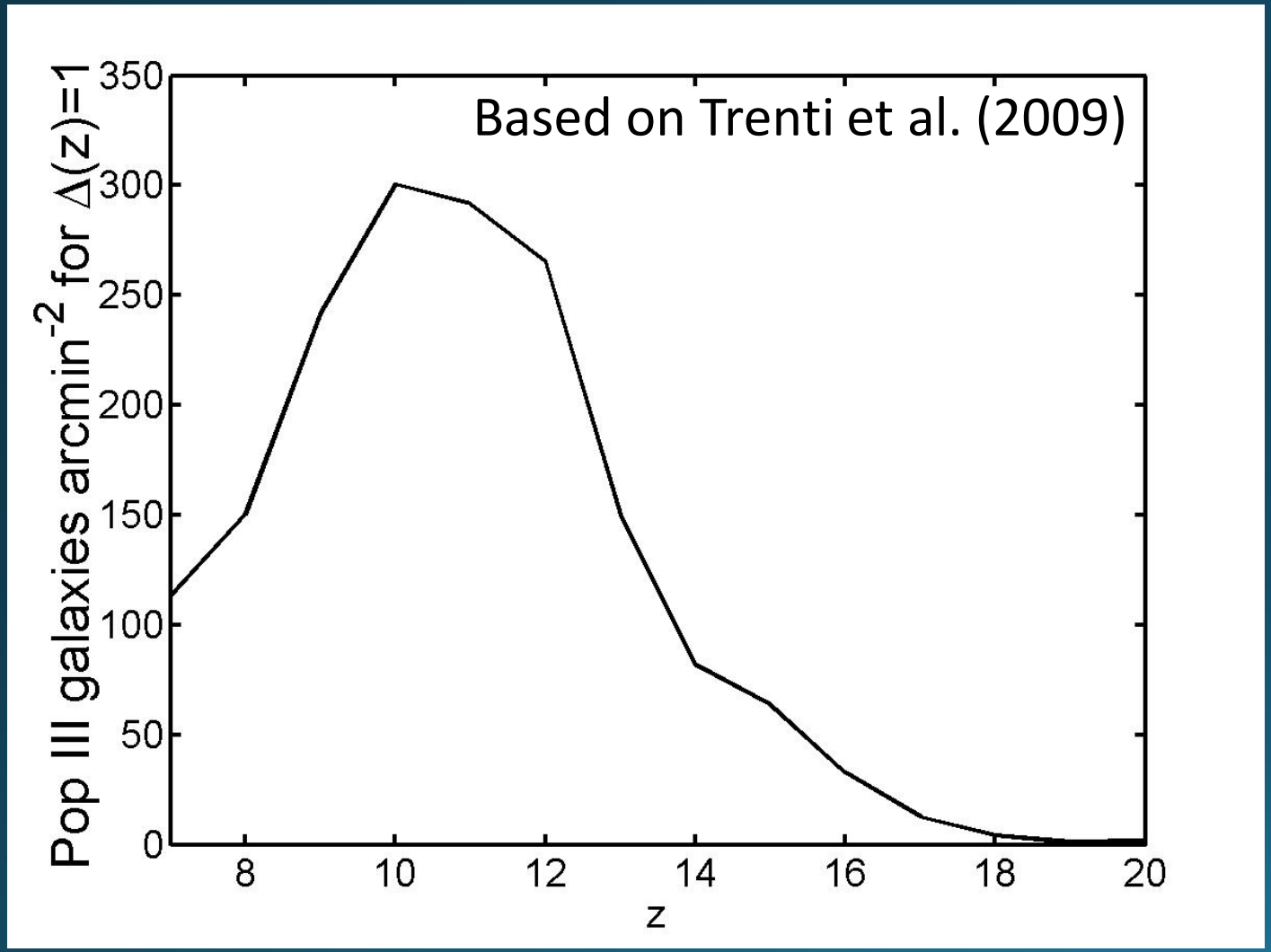
Problem: These claimed Pop III galaxies are way too massive to correspond to the Pop III galaxies seen in simulations!



Johnson+09

Simulations predict pure Pop III galaxies to have very low mass, and hybrid Pop III+II+I objects to have very low Pop III content (e.g. Johnson+09, Johnson 10, Salvaterra+11, Safranek-Shrader+12, Muratov+13, Johnson+14)

The predicted formation history of pop III galaxies



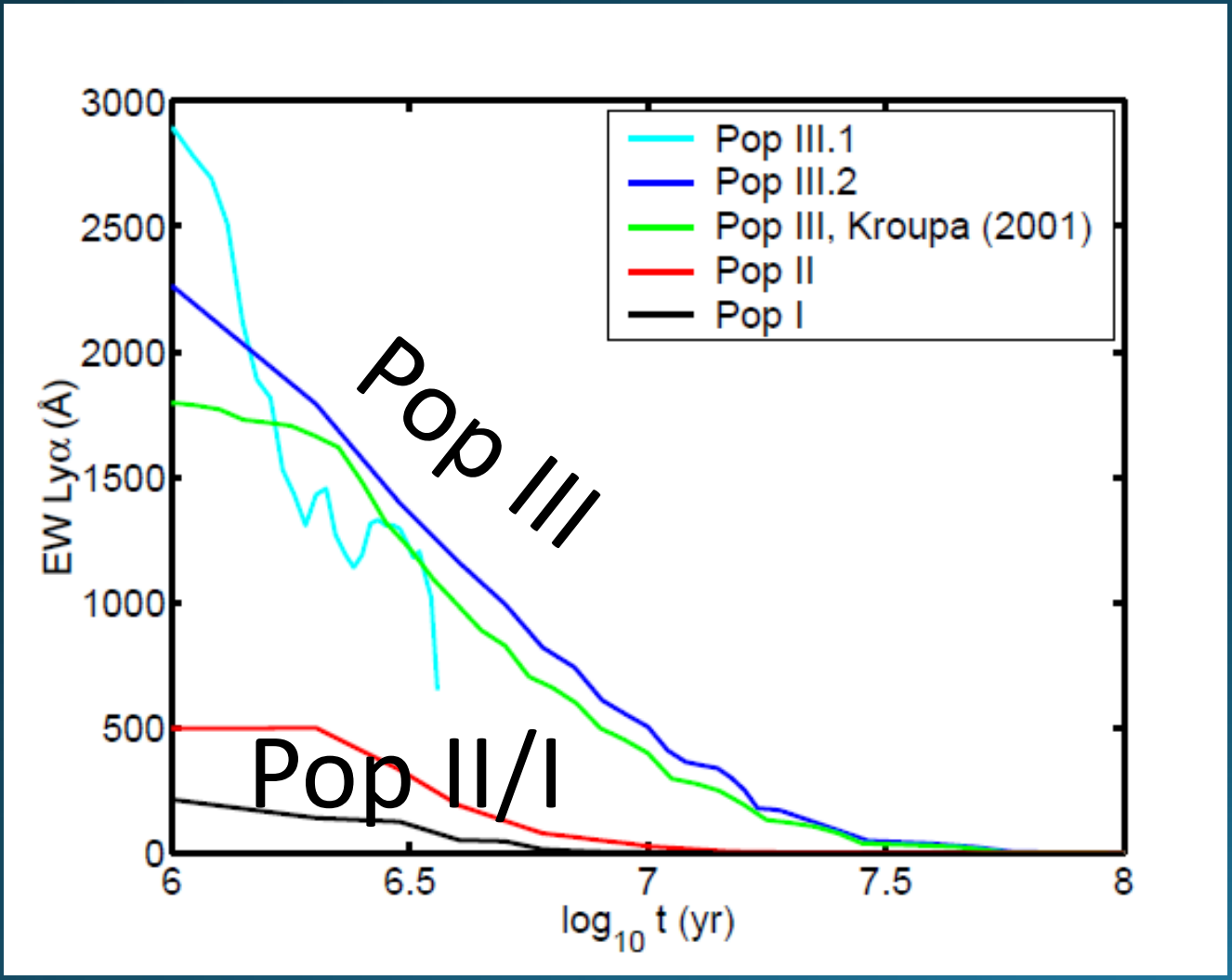
Zackrisson et al. 2012, MNRAS, 427, 2212

Huge number densities in the sky, but probably extremely faint!

Stellar mass per object perhaps no more than ~10^3-10^4 Msolar

”Pop III star clusters” – but sitting inside their own dark matter halos (~10^7-10^8 M_{solar} at these redshifts)

How do you hunt them down in the pre-JWST era?

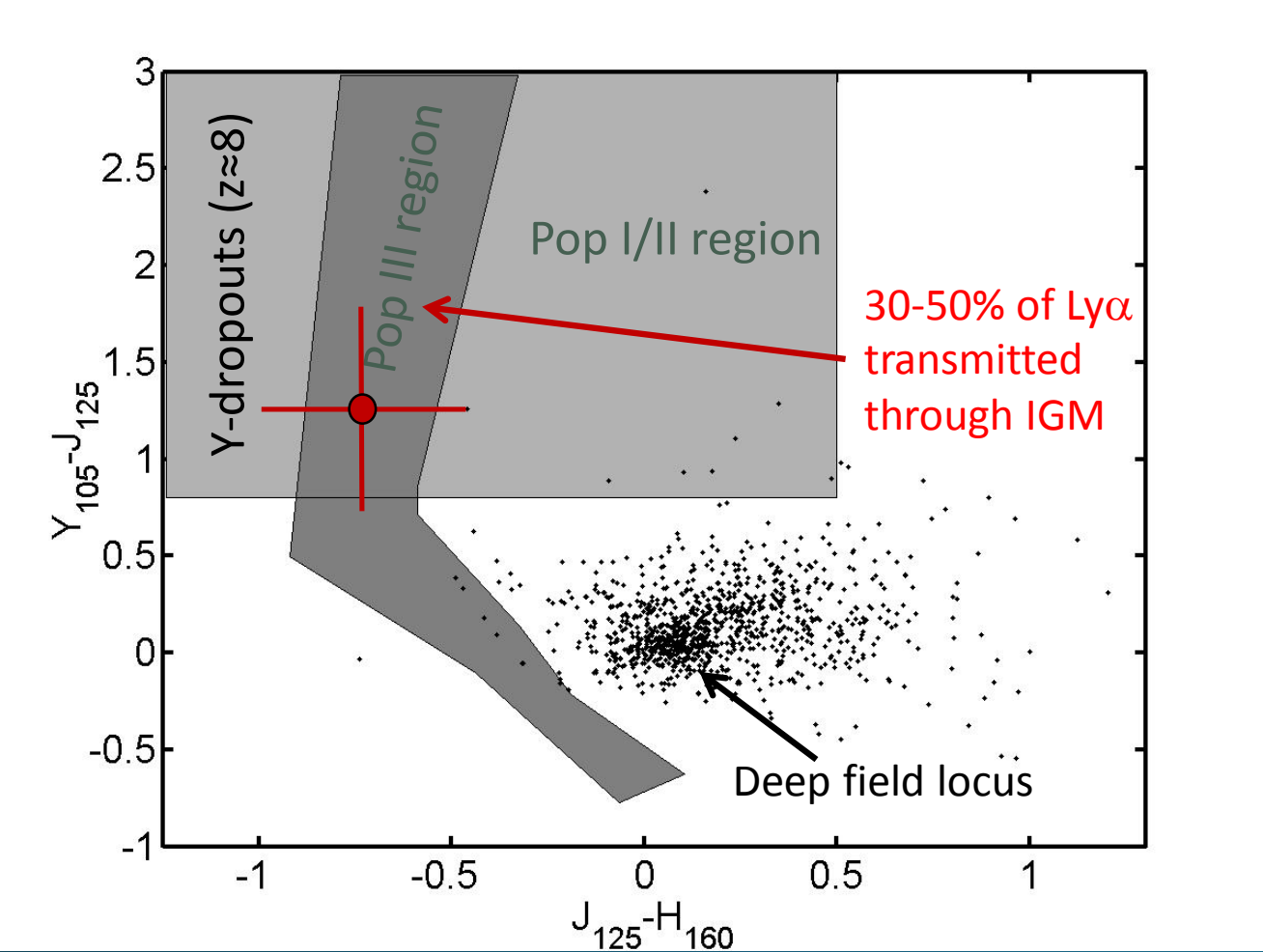


Lyα!

Lyα easily absorbed by neutral IGM at z > 6-7, but you could get lucky…

Outflows and patchy reionization → strong Lyα for a fraction of objects (Dijkstra+11, Dayal+11, Jeeson-Daniel+12)

The HST colour signatures of strong Lyα emission



Zackrisson et al. 2011, MNRAS 418, L104

Zackrisson+11: There are photometric Pop III candidates like these at z≈8 in unlensed fields

Kashikawa+12: Spectroscopic detection of extremely strong Lyα from a z ≈ 6.5 galaxy in an unlensed field

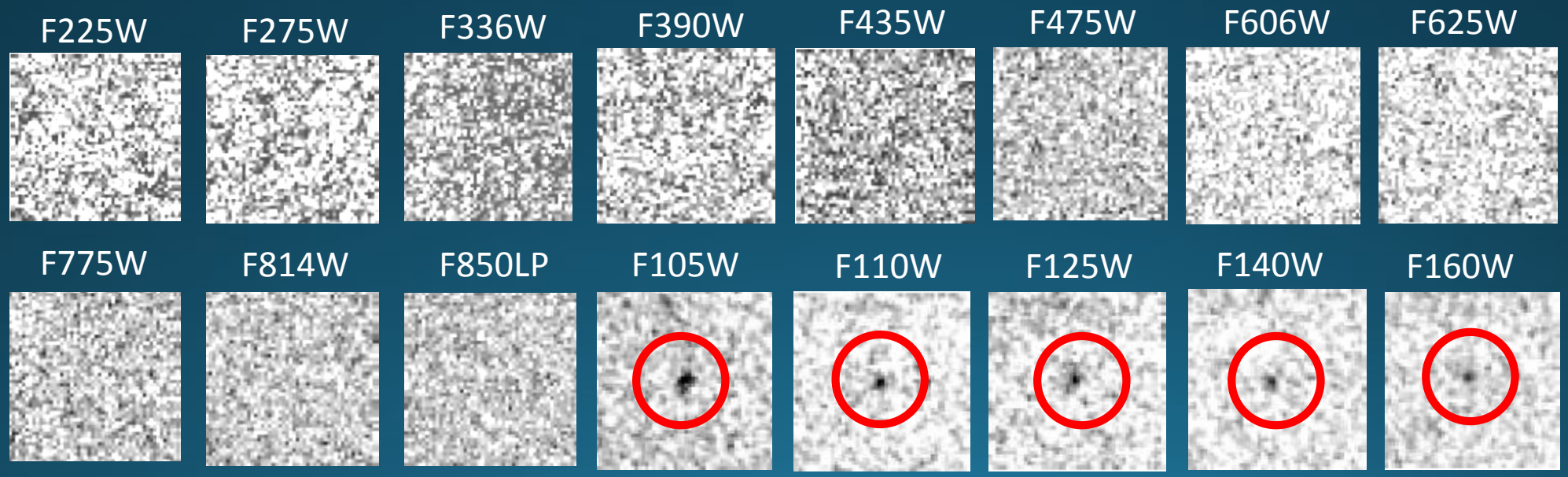
But these are still too massive! Strong Lya rather due to cooling radiation or anisotropic leakage?

Go for lensed fields instead!

Population III galaxy candidates in CLASH

Zackrisson et al. 2012, MNRAS, 427, 2212: Magnification maps + Pop III galaxy simulations → A few bona fide Pop III galaxies may turn up in the CLASH survey

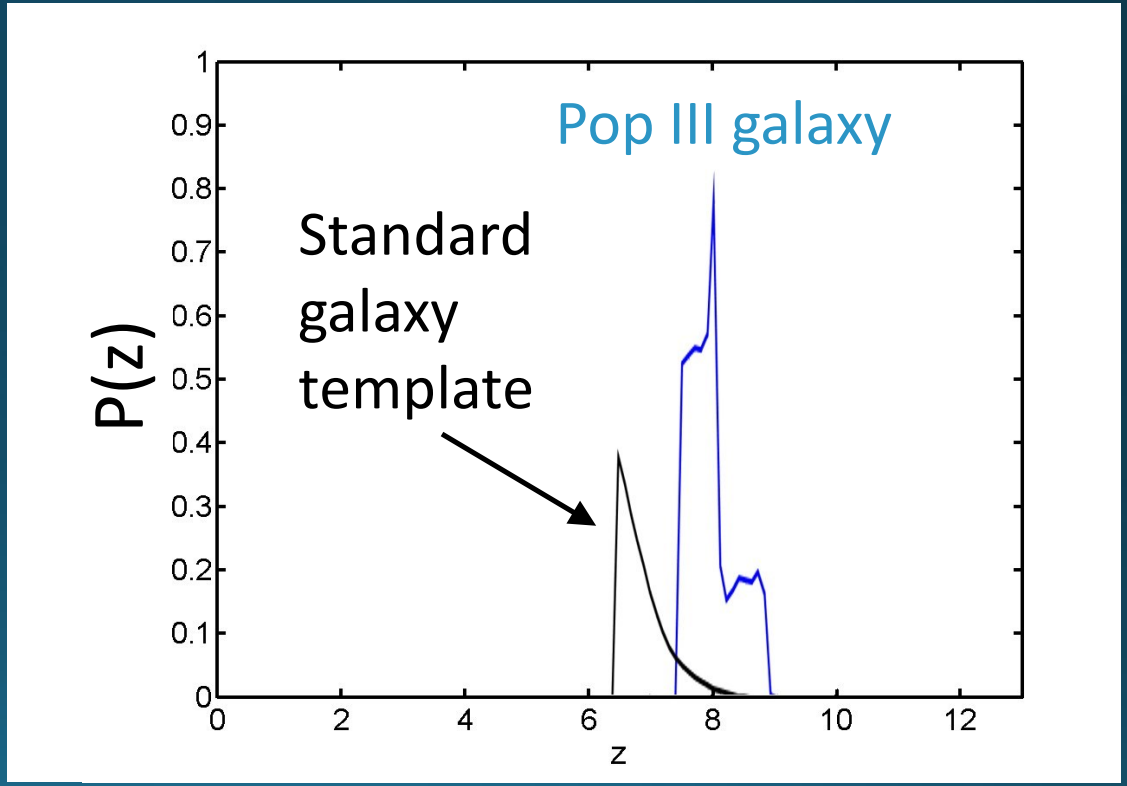
Rydberg et al. 2014ab, in prep: Six Pop III galaxy candidates detected in CLASH



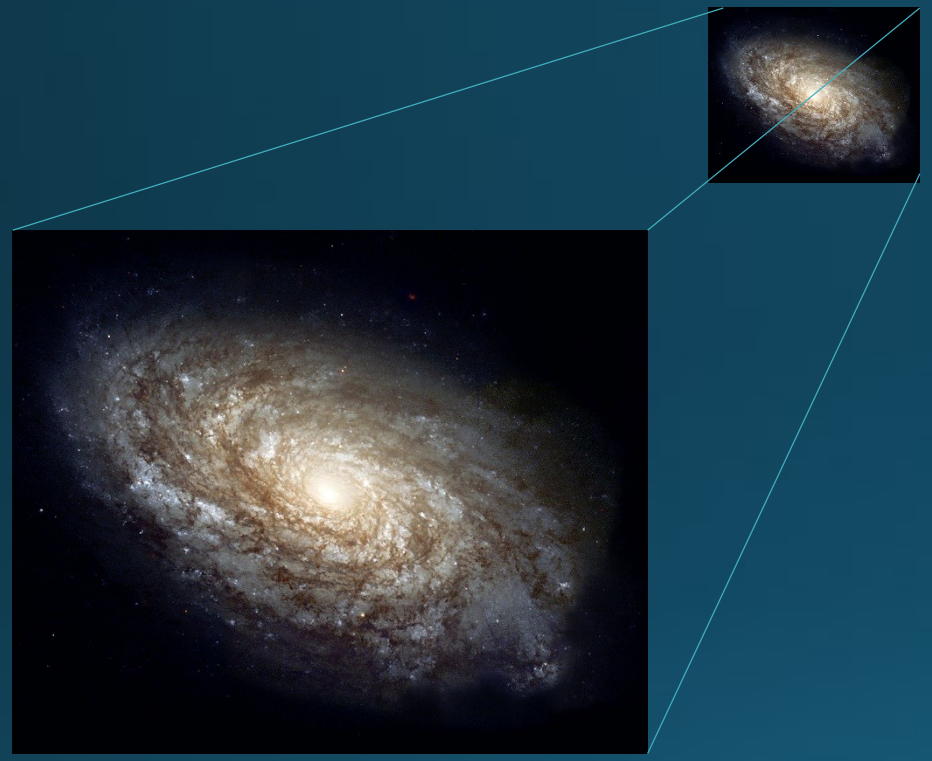
One of our z ≈ 8 candidates, detected at S/N>5 in five filters

Population III galaxy candidates in CLASH

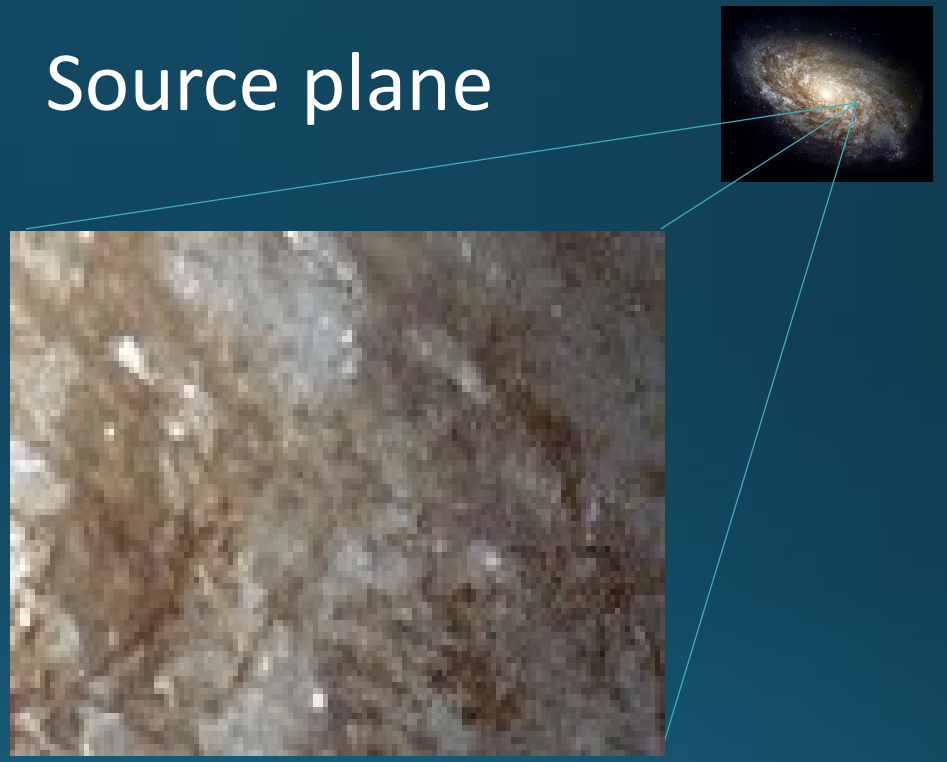
- Strong Lyα line $\rightarrow$ Standard dropout criterion for $z \approx 8$ not obeyed
- Two candidates have high magnifications ($\mu \geq 10$), and one is multiply imaged
- Follow-up spectroscopy from the ground should be able to confirm strong Lyα



Extreme magnifications ($\mu > 100$)



Source plane



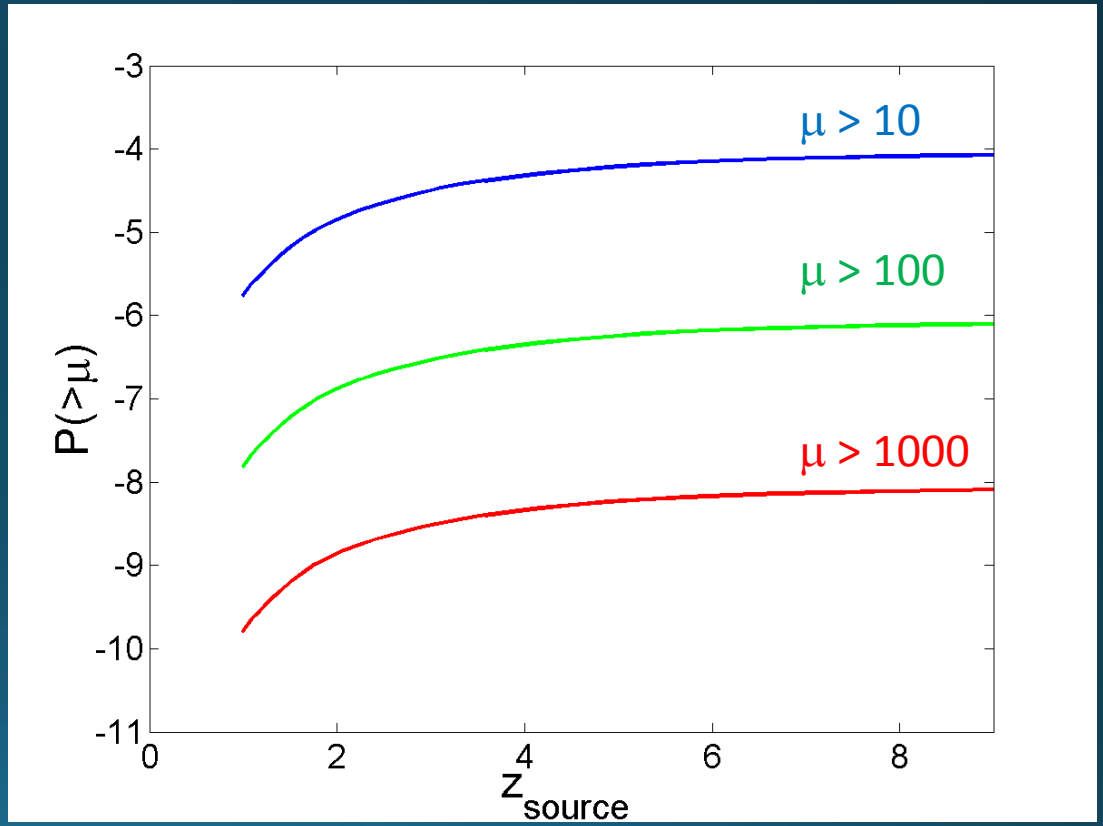
$\mu \approx 10$

$\mu \approx 1000$

Magnification $\mu > 100$ not realistic for normal (kpc scale) galaxies,
but high-z Pop III galaxies are basically just star clusters (< 10 pc across)!

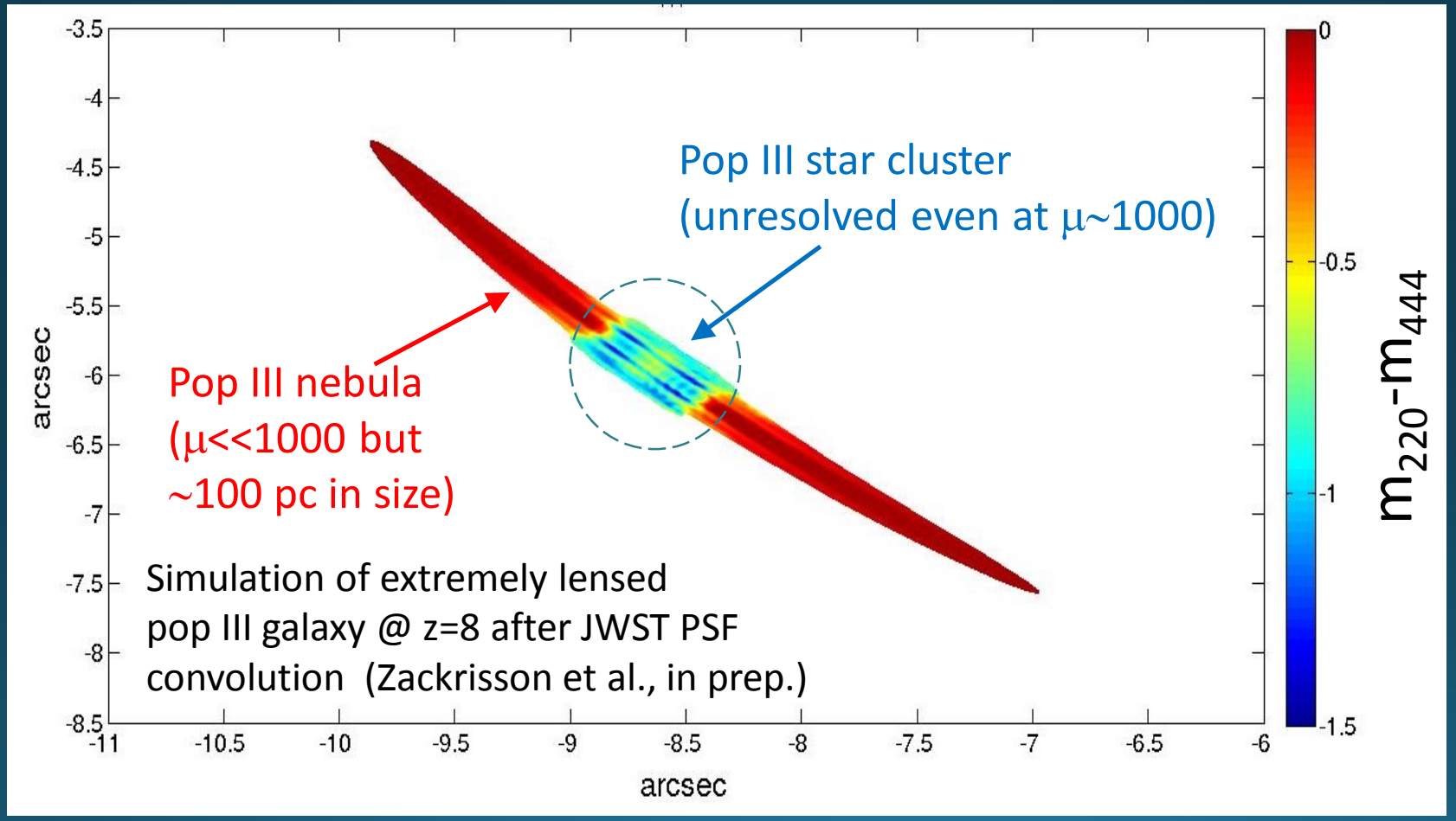
Extreme magnifications ($\mu > 100$)

- The probability for $\mu \sim 1000$ is tiny ($\sim 10^{-8}$)
- HST and JWST cannot cover the survey areas required to find such objects…
- But the planned WISH telescope can do a 100 deg^2 survey at $m_{AB} \approx 28 \rightarrow$ A few $\mu \sim 1000$ Pop III galaxies could turn up!
- Once WISH has found an object like this, JWST and the ELTs can dissect it further

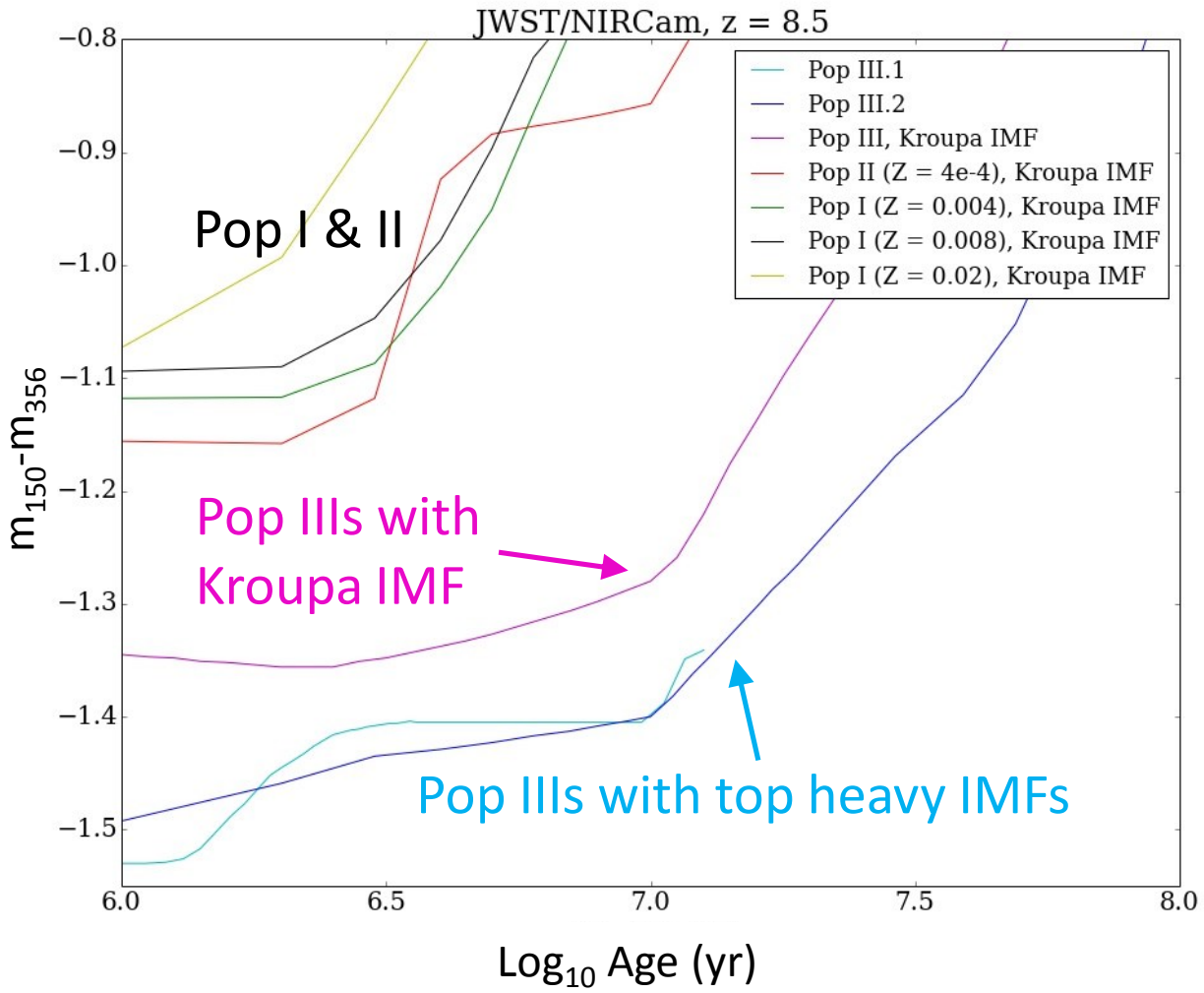


Zackrisson et al., in prep.

Pop III galaxies under the lens



Probing the Pop III IMF



JWST colour measurement towards Pop III star cluster → Possible to confirm top-heavy IMF

10 Myr burst of constant SFR

Summary

- A few Pop III galaxy candidates detected in CLASH
- Follow-up spectroscopy should be able to confirm Lyα @ $z \approx 8$
- The detection of a Pop III galaxy at extreme magnification ($\mu \sim 1000$) could provide a handle on the Pop III IMF