Exotic Objects at High Redshifts

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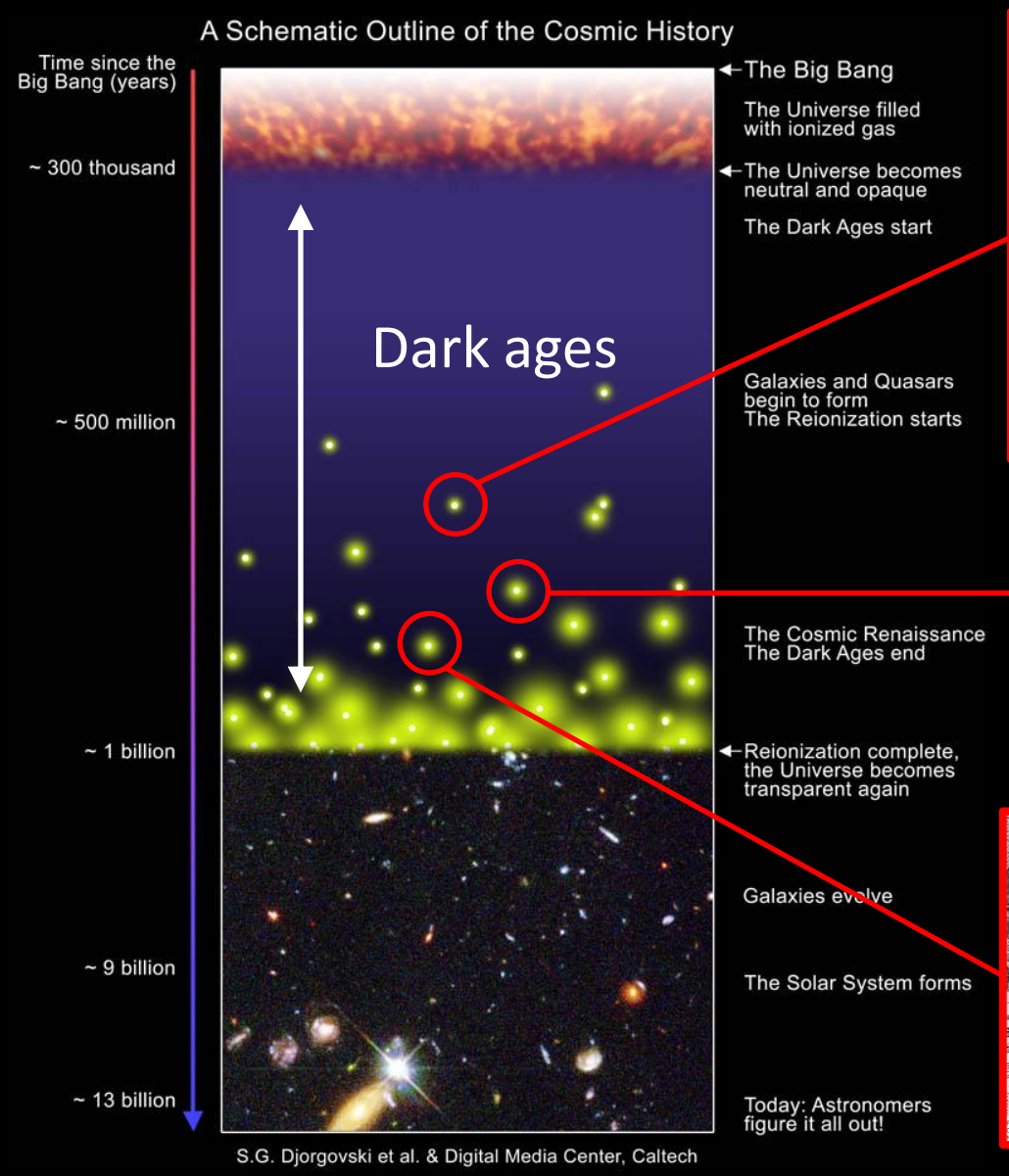
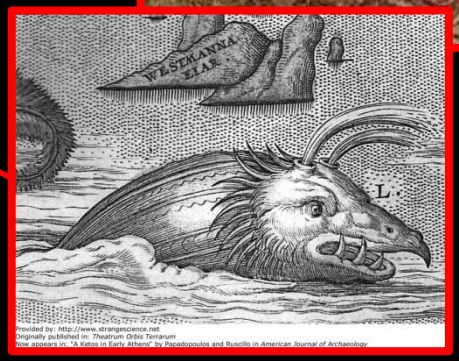
”Here be monsters!”

Monsters of the Early Universe



Dark stars

Pop III stars



Pop III galaxies

Our Hunting Crew

Main Collaboration:

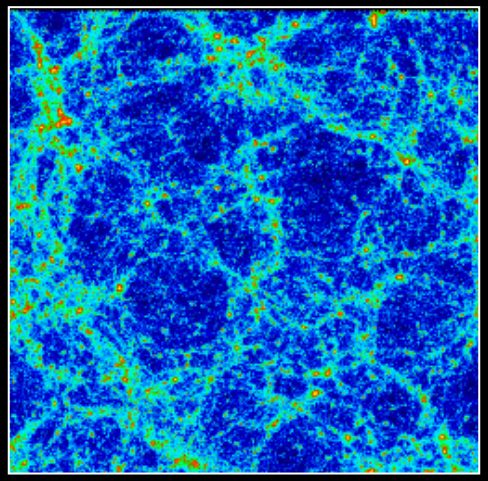
Oskar Klein Centre, Stockholm

Erik Zackrisson, Göran Östlin, Garrelt Mellema, Lucia Guaita, Fabio Iocco
Claes-Erik Rydberg, Florent Duval, Andreas Sandberg , Tina Ström, Manan Tuli

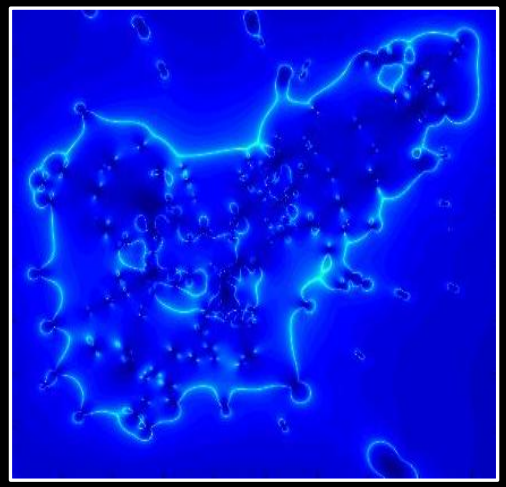
Elsewhere

Daniel Schaerer (Switzerland), Matthew Hayes (France), Akio Inoue (Japan), Adi Zitrin (Germany), Angela Adamo (Germany) Michele Trenti (US), Massimo Stiavelli (US), Pat Scott (Canada)

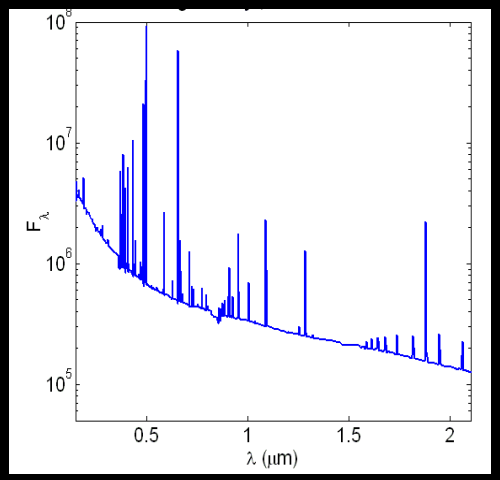
Hunting Gear



Simulations

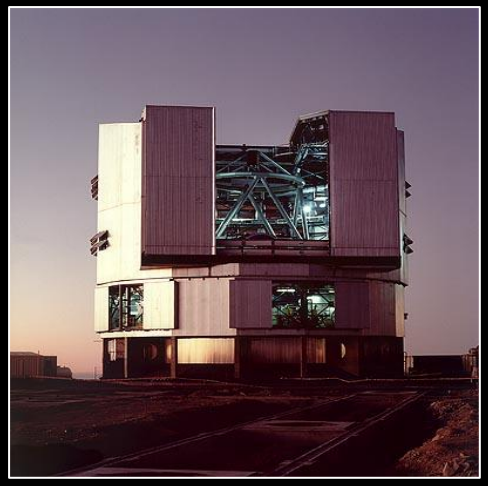


Lens models

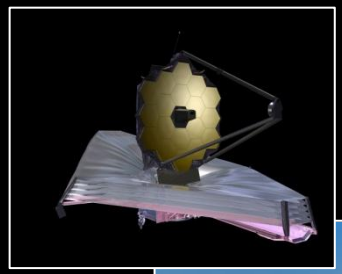


Spectral synthesis

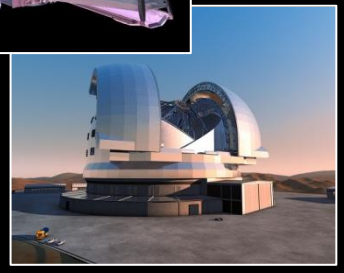
HST



VLT



JWST

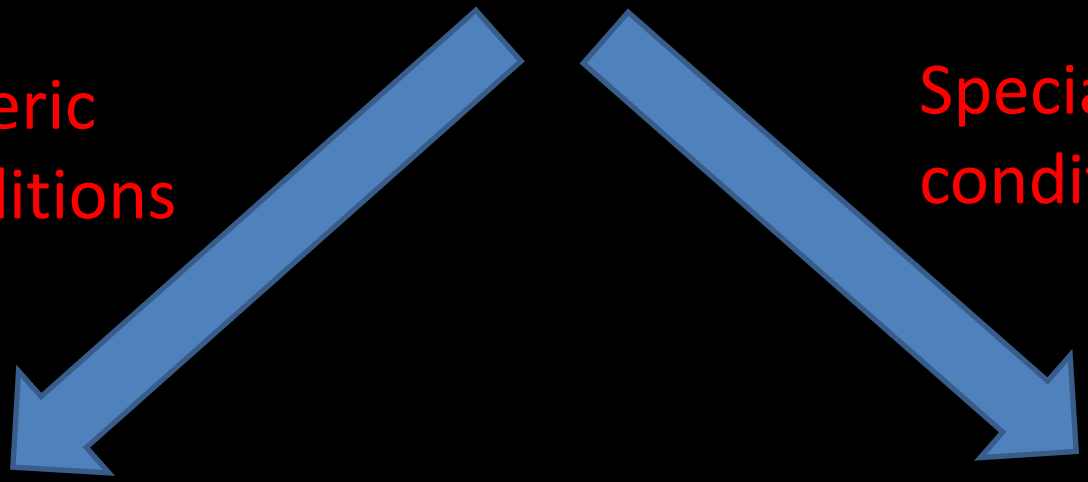


E-ELT

Future gear…

Two types of monsters

Predicted by theory & simulations



Generic conditions

Special conditions

”They have to exist!”

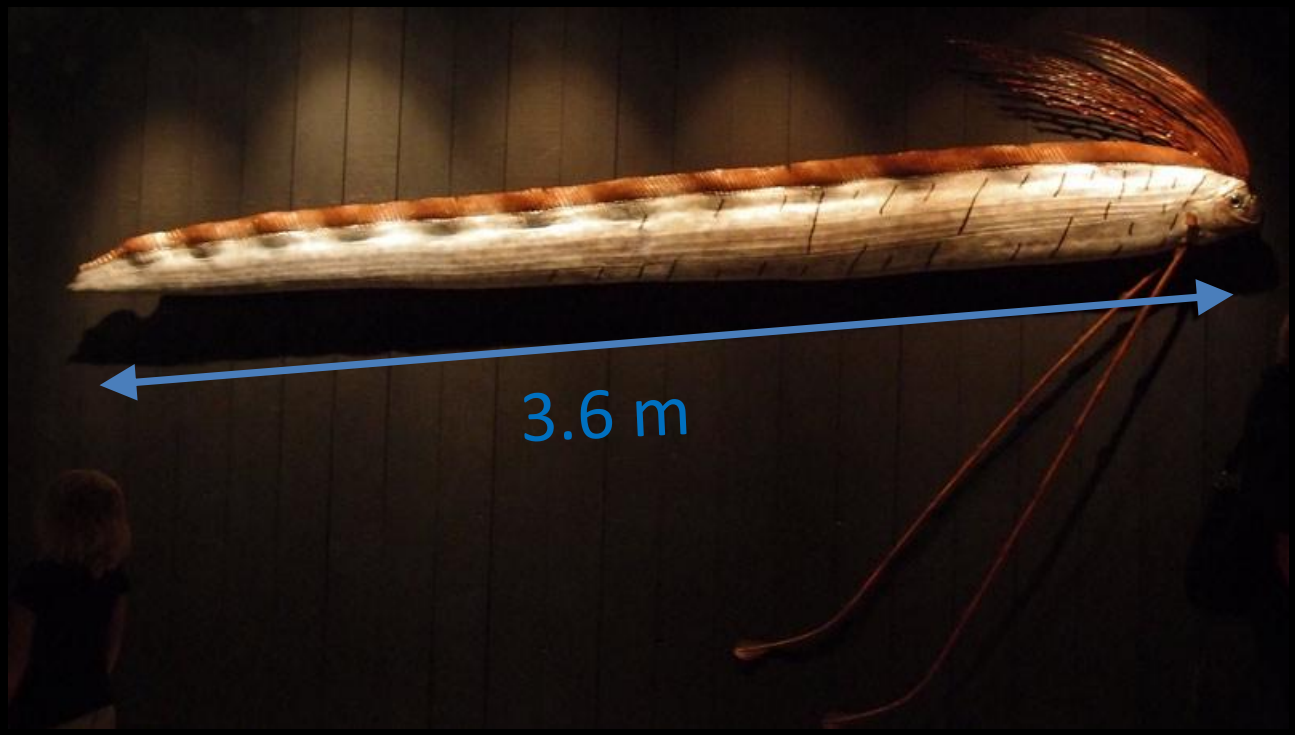
Population III stars/galaxies

”They may exist, and it would solve all kinds of problems if they did!”

Dark stars

Why believe in monsters?

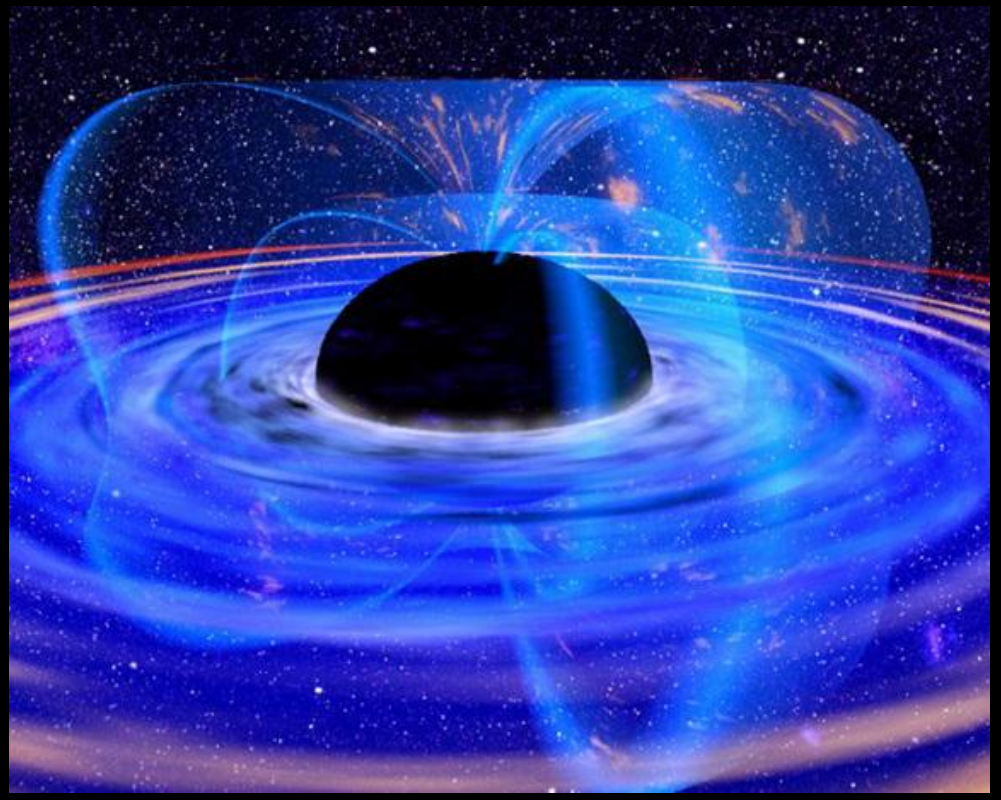
One reason: Dead specimens have washed up on local shores!



Giant Oarfish or King of herrings (”Sillkungen”)

Supermassive black holes

- Mass ~10^9 Msolar
- Detected in local Universe and up to z ≈ 7 (800 Myr after Big Bang)
- Formed by some process in the early Universe
- The descendants of monsters?



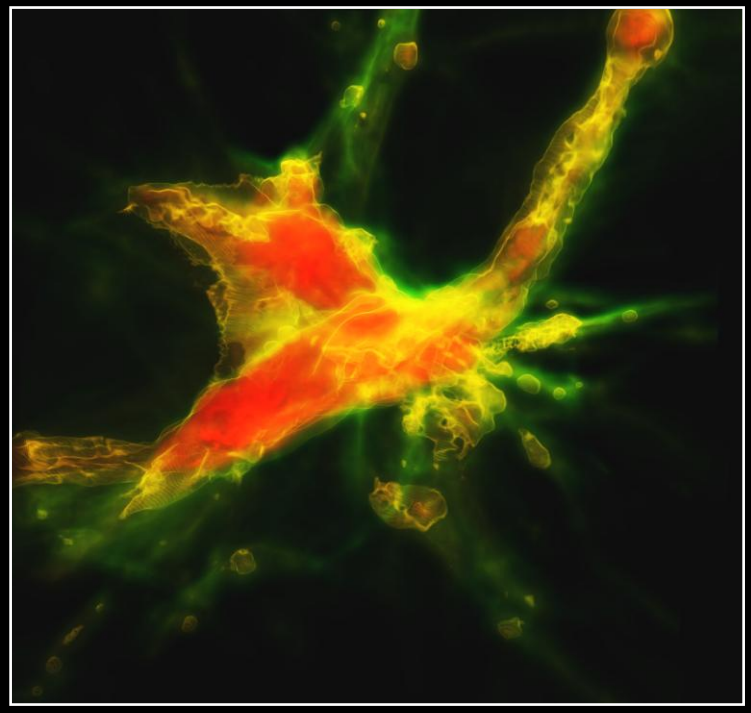
Population III stars

- Metal-free stars
- Mass ~10-100 Msolar
- Very hot (Teff ~ 10^5 K at the highest masses)
- Start forming at z ≈ 30 (100 Myr after Big Bang)
- May leave black hole remnant behind

But very difficult to detect, even with the JWST or E-ELT

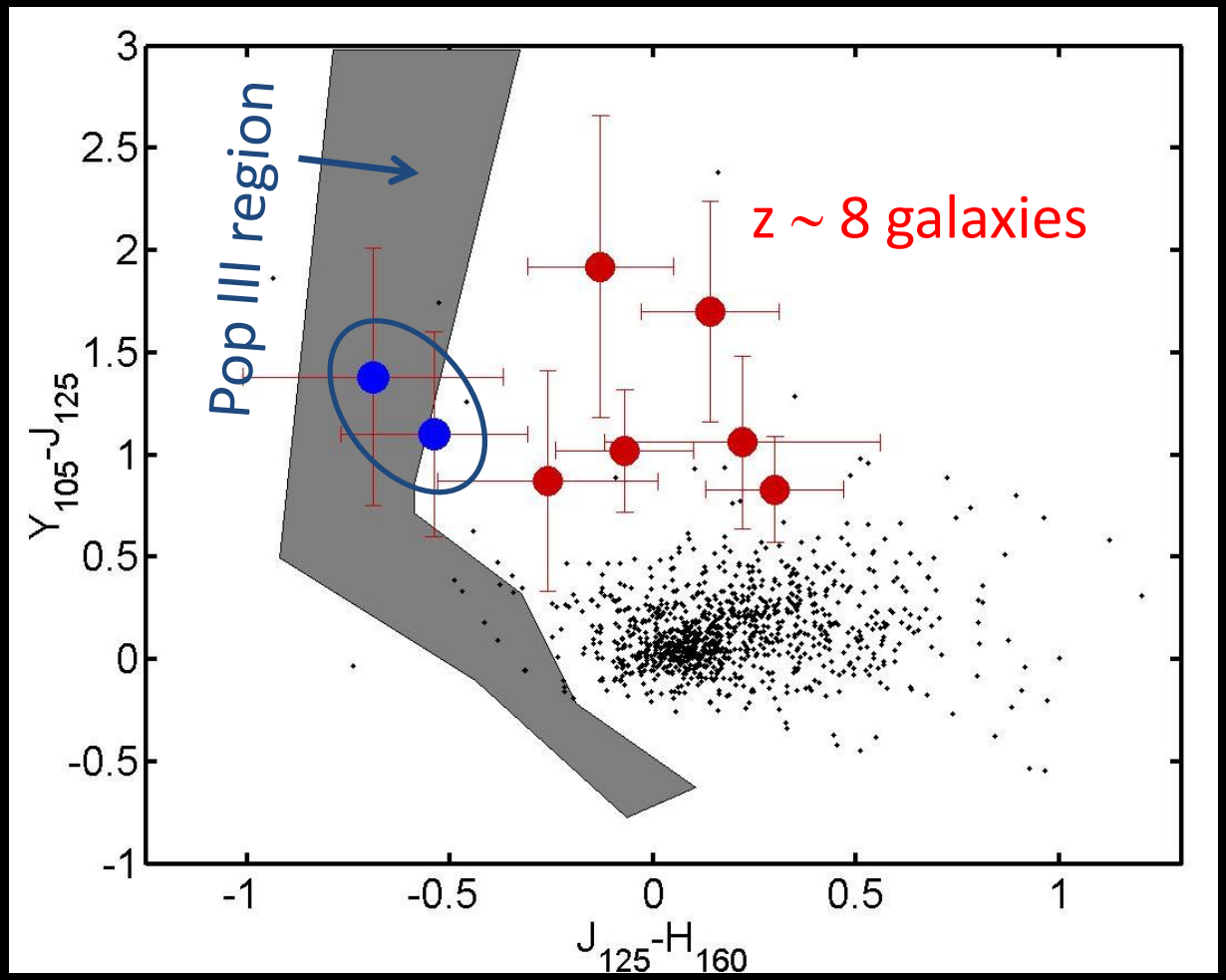
Population III galaxies

- Many pop III stars in the same object → bright!
- Very rare objects, but potentially detectable with existing telescopes
- Start forming at z≈15 and at least down to z≈7



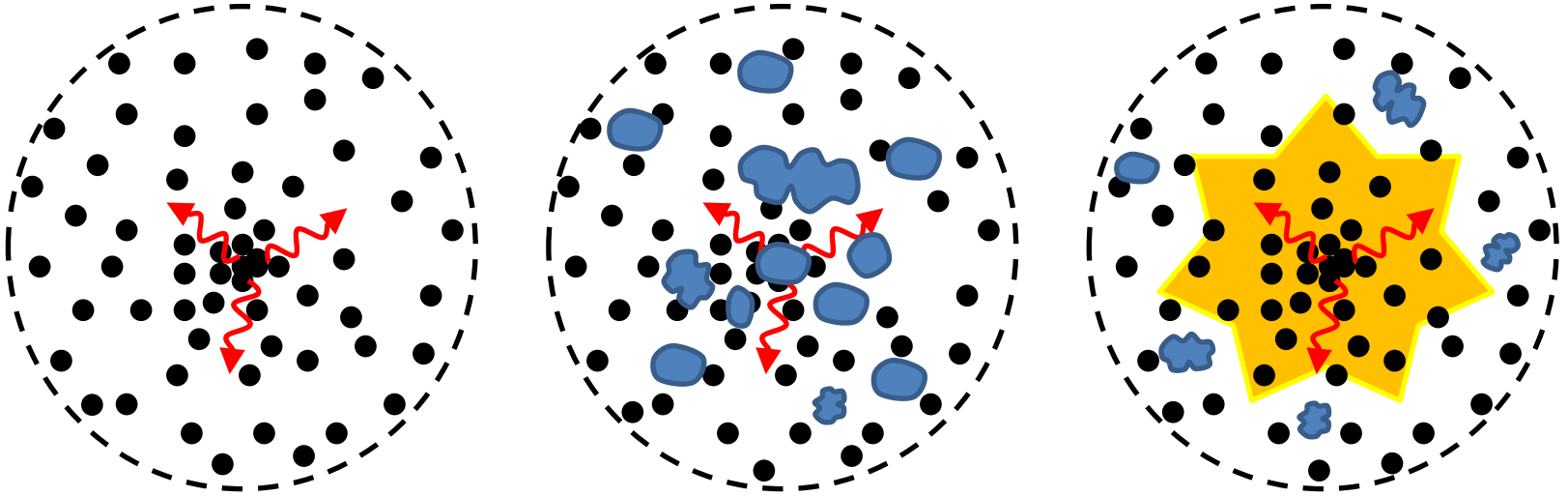
Greif et al. 08

Pop III galaxy candidates at z≈8 in ultradeep HST data



Zackrisson et al. 2011, MNRAS Letters, in press (arXiv1109.1556)

Dark stars



WIMP annihilation in centre of CDM minihalo

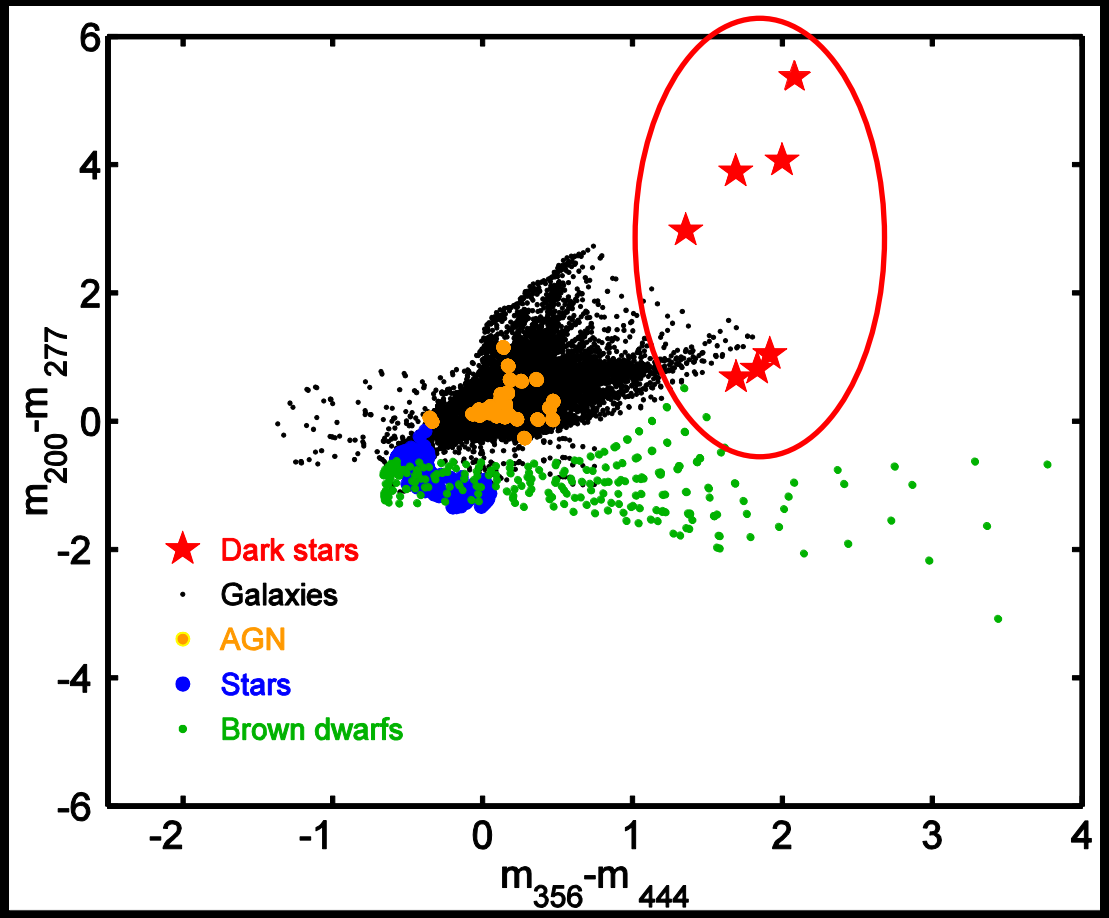
Gas cools and falls into the centre

Star fueled by WIMP annihilation rather than hydrogen fusion

Find dark star $\rightarrow$ Identification of dark matter!

May leave very massive black hole remnant behind!

Finding dark stars with the JWST

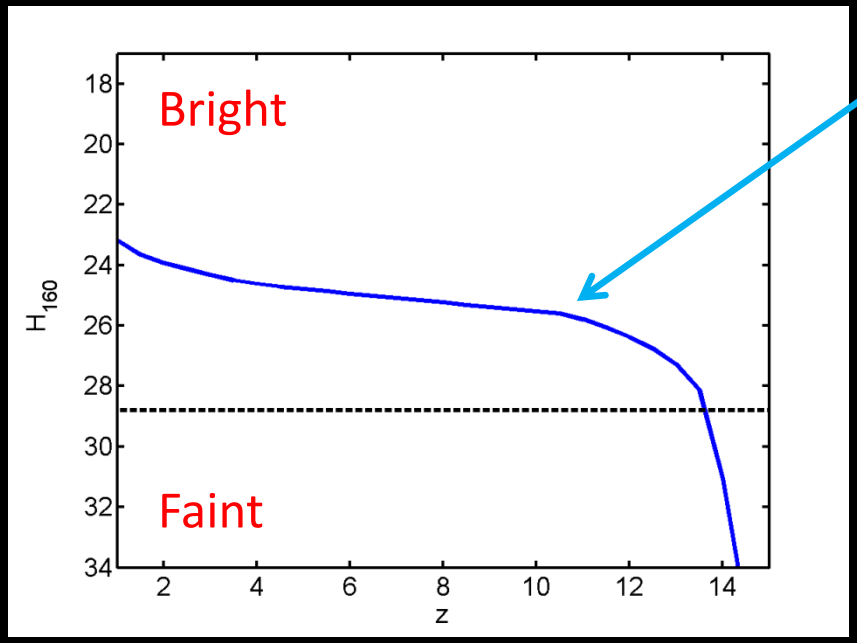


Zackrisson et al. 2010, ApJ 717, 257

Some dark stars will be bright enough for JWST and should stand out in photometric surveys because of their very red spectra

Supermassive dark stars?

- Freese et al. (2010) argue that dark stars may attain masses of up to 10^7 Msolar
- Our view: Not likely… 10^7 Msolar dark stars are already strongly constrained by HST/VLT data



10^7 Msolar dark stars *Should have been detected already!*

HST WFC3 detection limit

Zackrisson et al. 2010, MNRAS 407, L74

Summary

- Pop III galaxy candidates sighted at z ≈ 8 with HST
- Supermassive dark stars constrained by HST/VLT data
- Great future prospects to hunt for pop III galaxies and dark stars with JWST and E-ELT