The First Galaxies with JWST and Reionization

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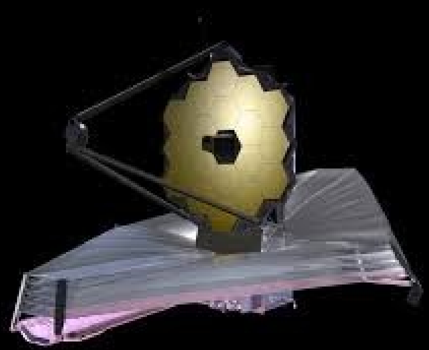

MANCHESTER 1824
The University of Manchester

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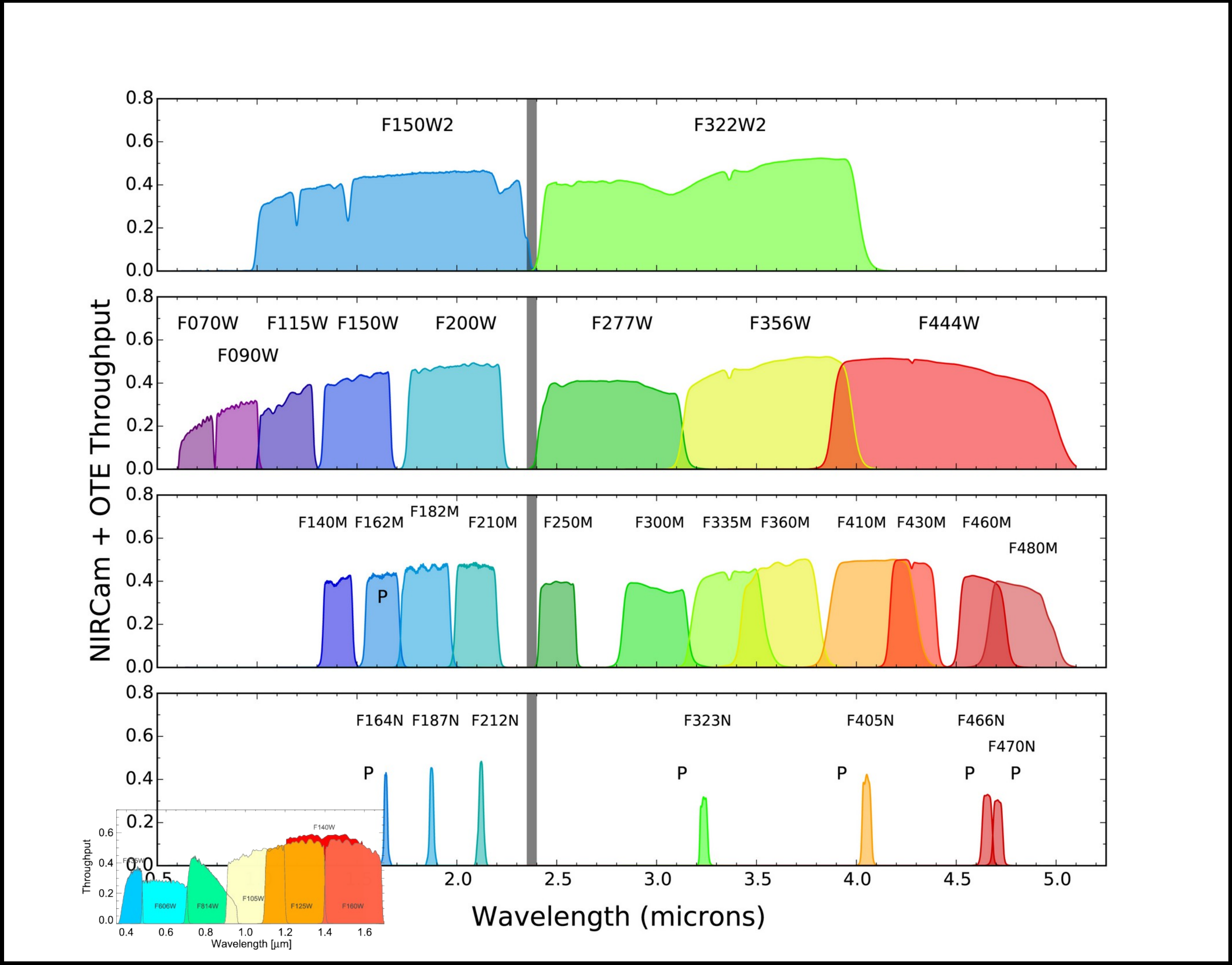
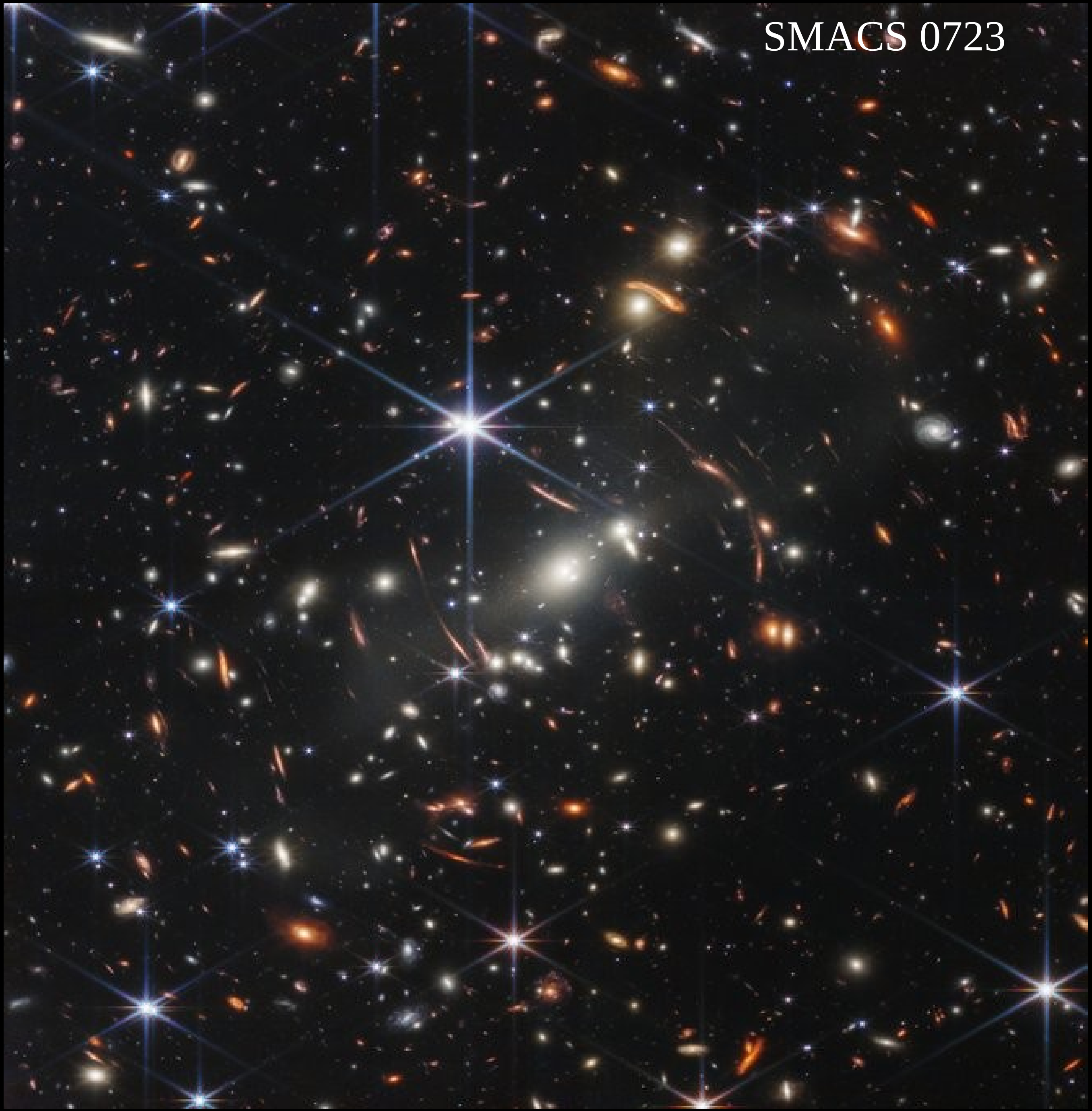
Why JWST?
Probes further into the red - NIRCam Filters




SMACS 0723

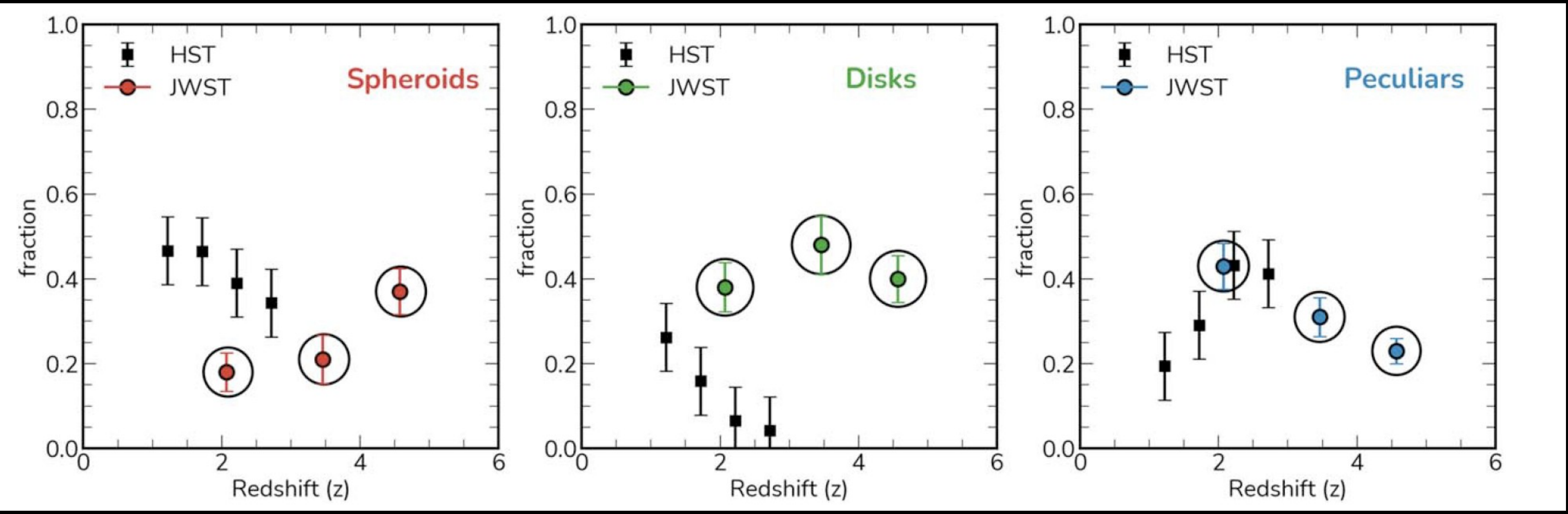
What type of object reionizes the universe?

JWST finds more disks at $z > 5$!

More of this

Less of this

Morphological Evolution at z > 2

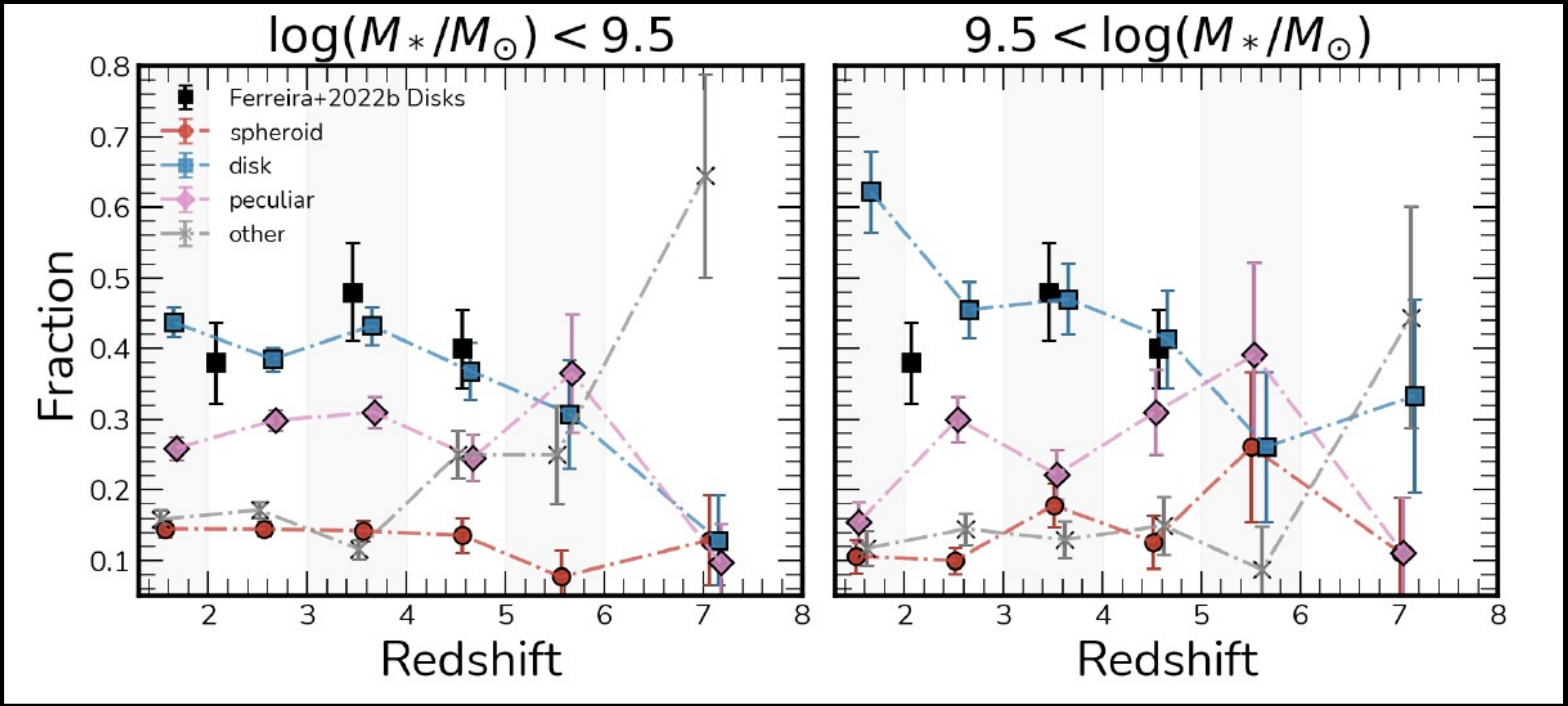


Evolution of galaxy types is very different than what HST found

Find many more disk galaxies than previously

Ferreira+22a

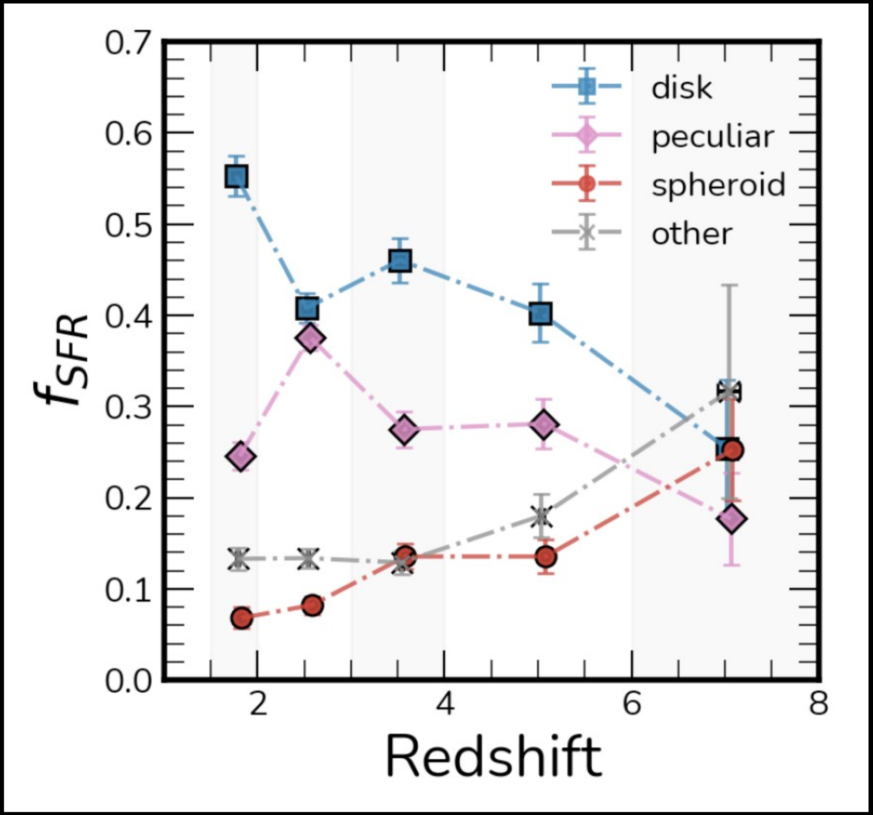
Morphological Evolution at z > 2

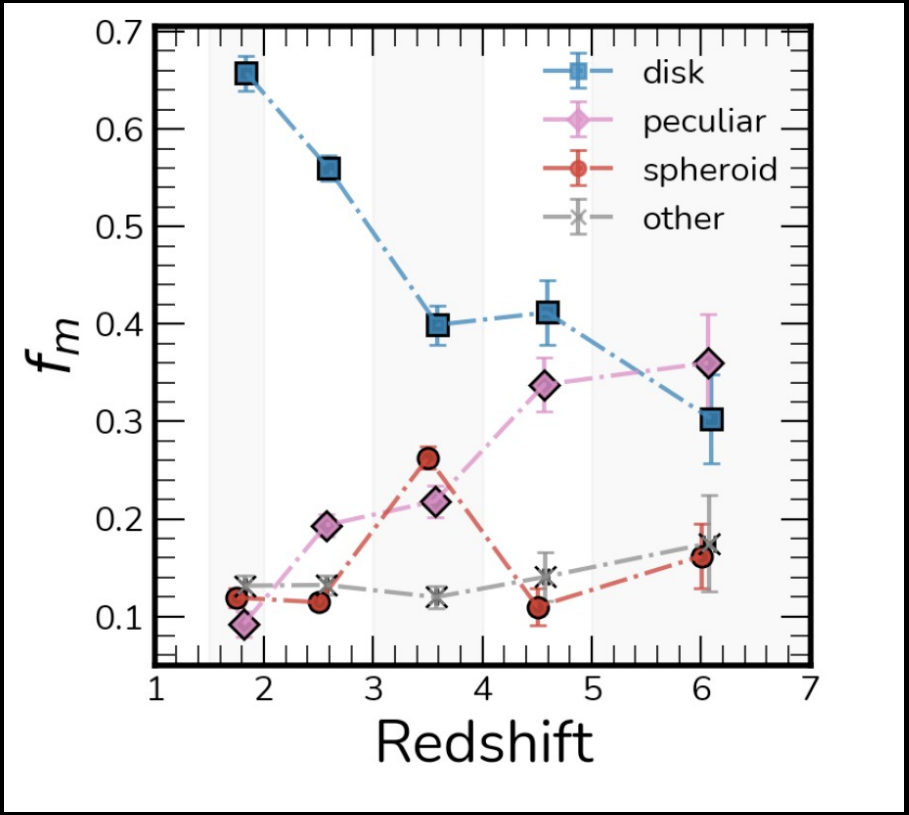


Disk galaxies dominate at the end of the EoR

Ferreira+2022b

Morphological Evolution at z > 2

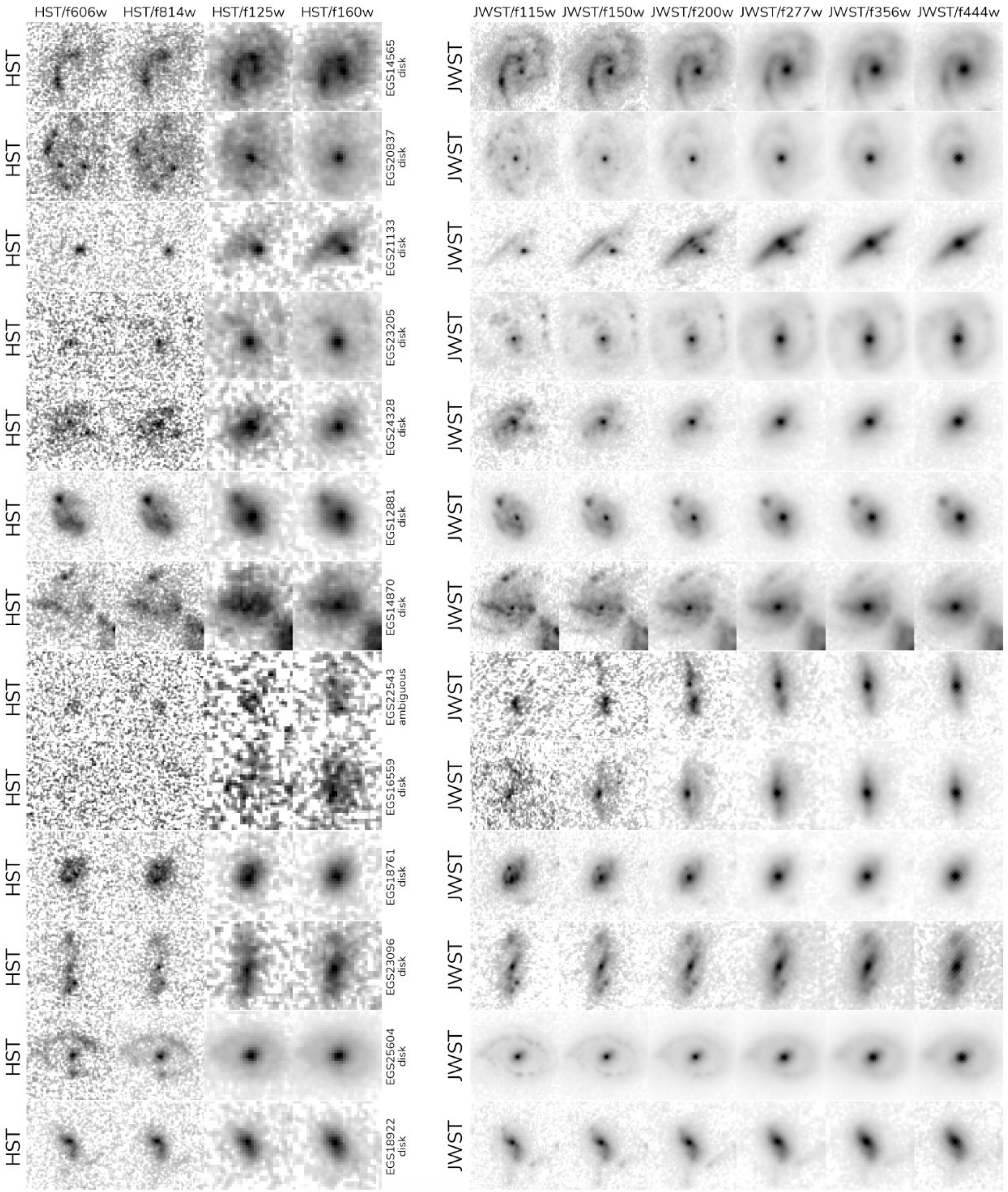




Disks also dominate in SFR and stellar mass

If you are a star at z < 6 – most likely you are formed in a disk

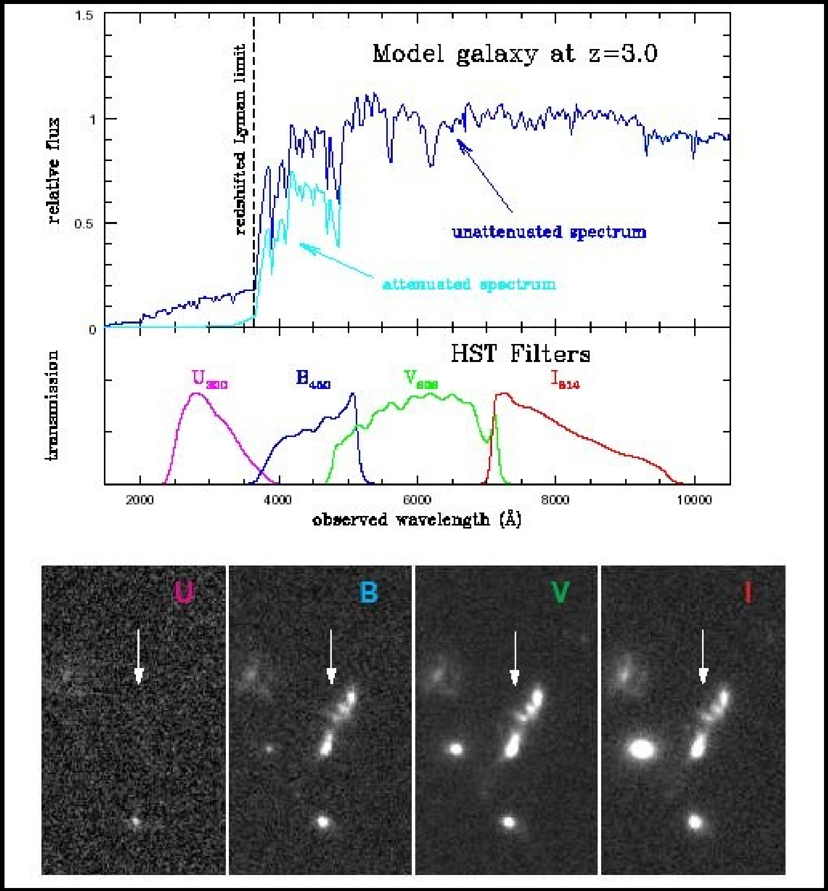
Ferreira+22b



HST vs. JWST for the Same galaxies

Ferreira et al. 2022b

The most (first?) distant galaxies
Finding and studying them with JWST

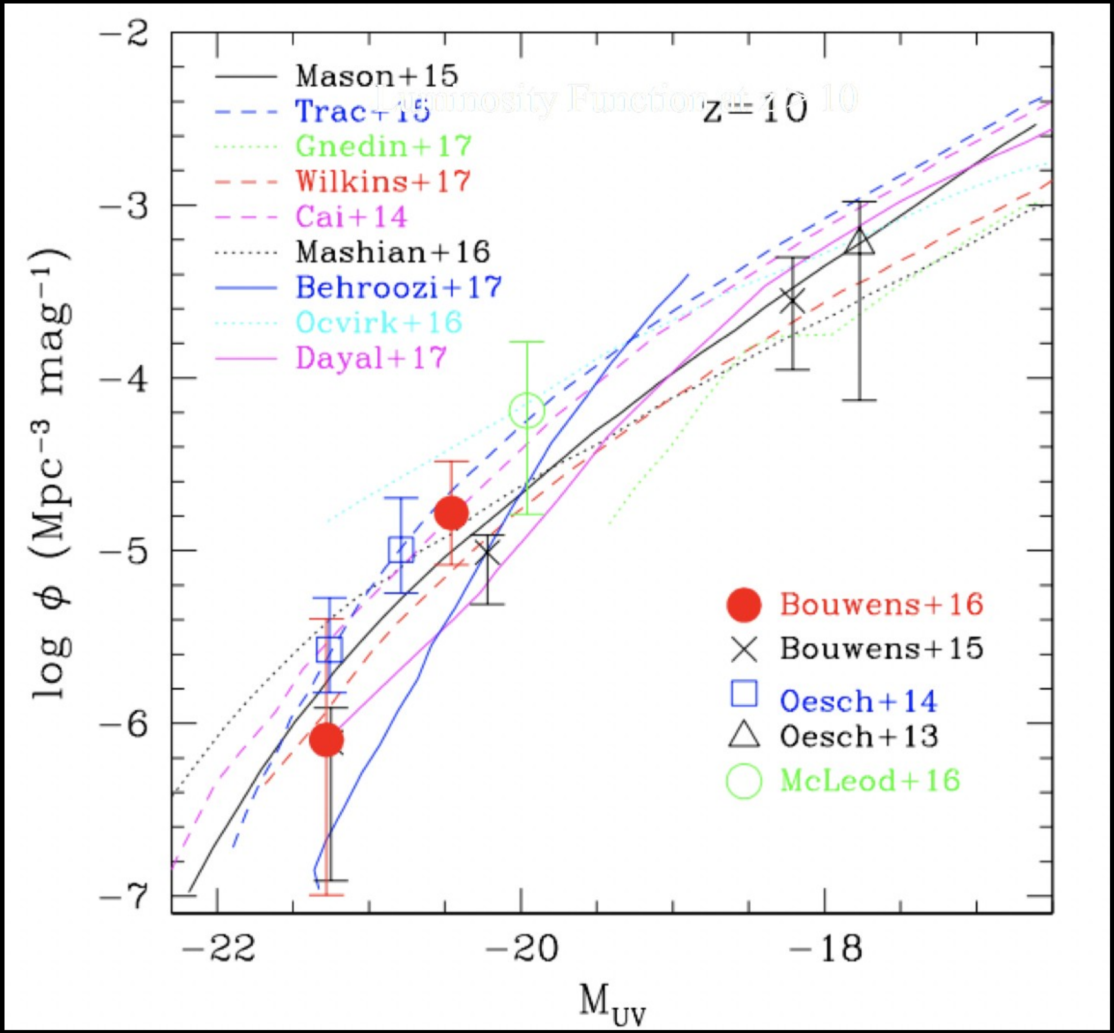


Cannot do with Hubble due to the Lyman-break becoming redder than the reddest filter at 1.6 µm

With JWST

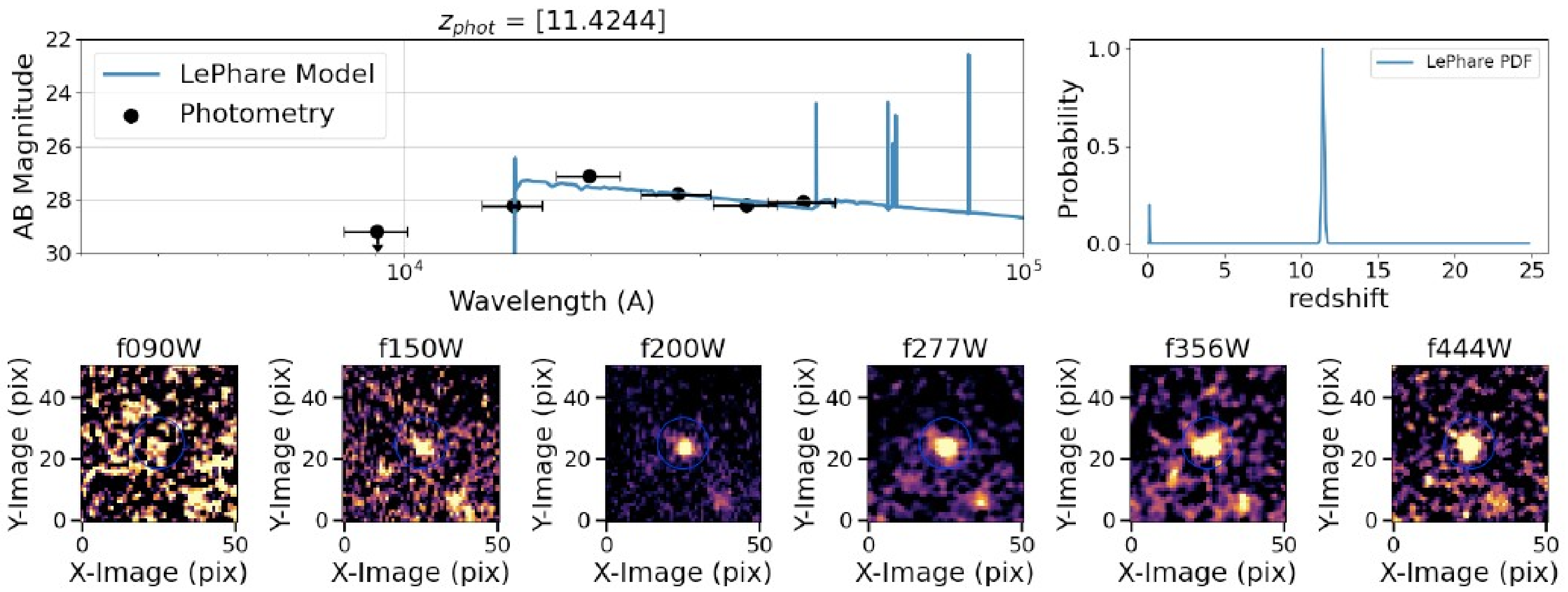
1. Find the first galaxies
2. Measure luminosity and mass functions
3. Examine star formation, structure, dust, first stars, pop III galaxies, etc.
4. Determine reionization sources

Pre-JWST Luminosity Functions at z > 10



Models are degenerate at z < 7, but at higher-z become distinct

Spectral Energy Distribution of z > 11 galaxies



(d) ID 10234

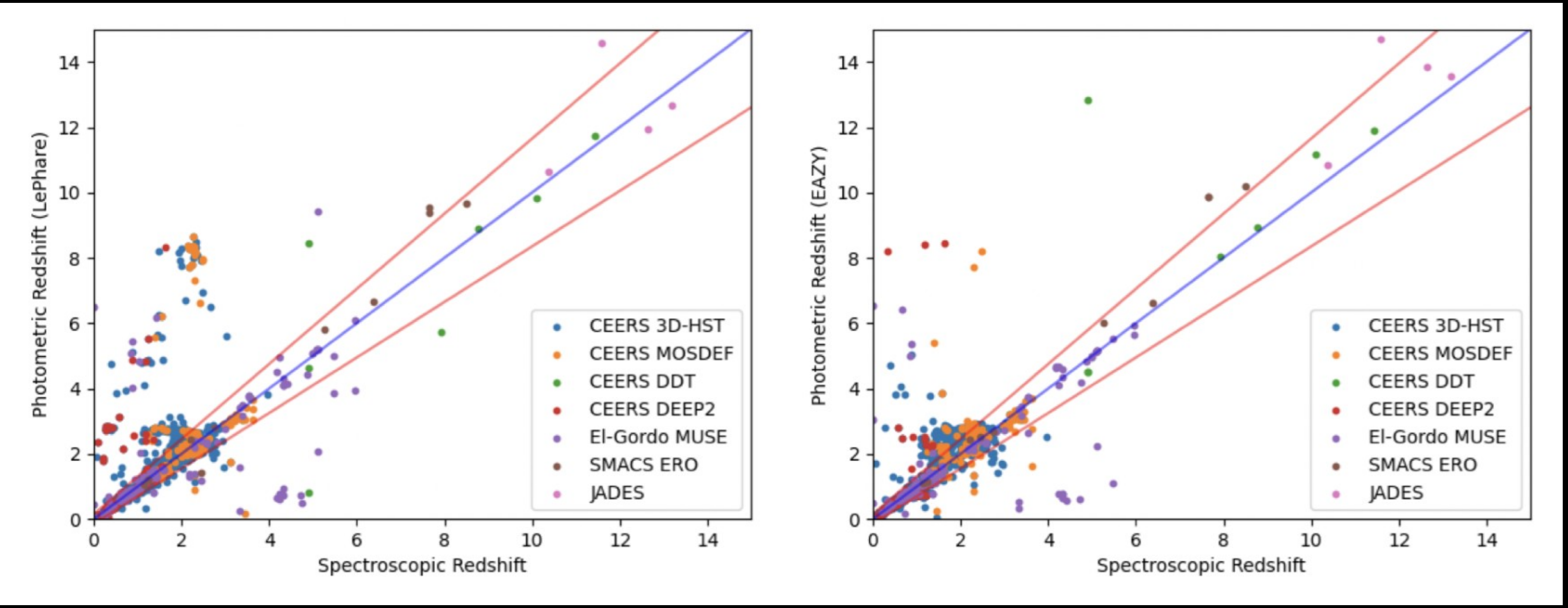
Even in early (July 2022) data we found many new distant galaxies

Adams+22

The EPOCHS Sample
6.5 < z < 20

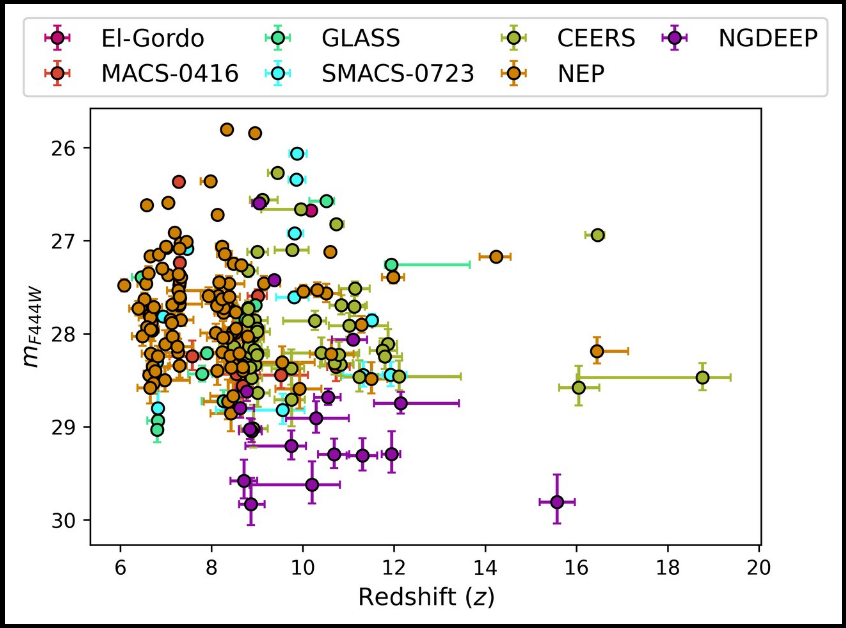
- Combined samples from PEARLS GTO (Windhorst+22), CEERS, GLASS, SMACS 0723, NGDEEP surveys
- Strict criteria for inclusion – 5 sigma detections, large Lyman-break
- In total ~200 galaxies (in prep)
- Largest sample of z > 6.5 galaxies with JWST to date

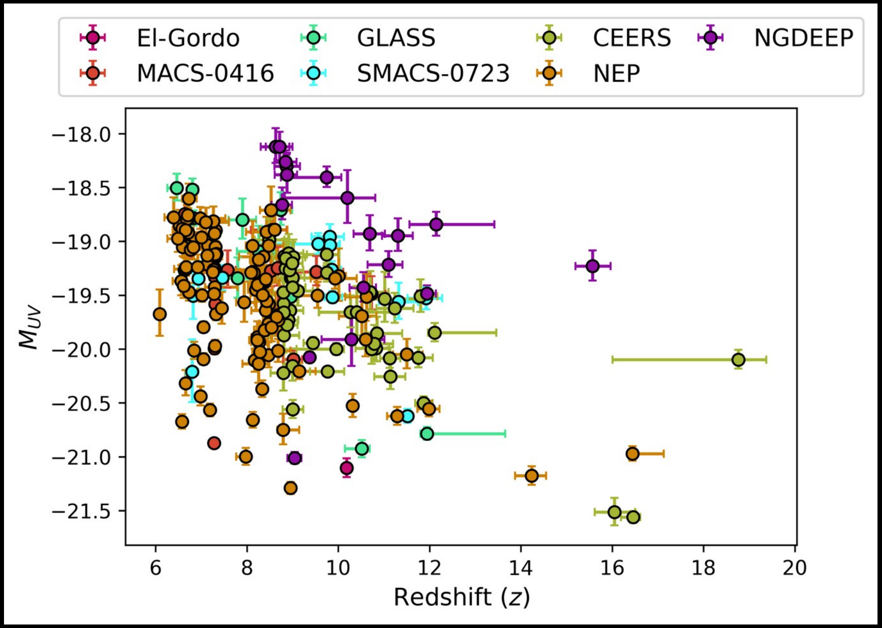
Photometric redshift measurements



Adams+23 in prep

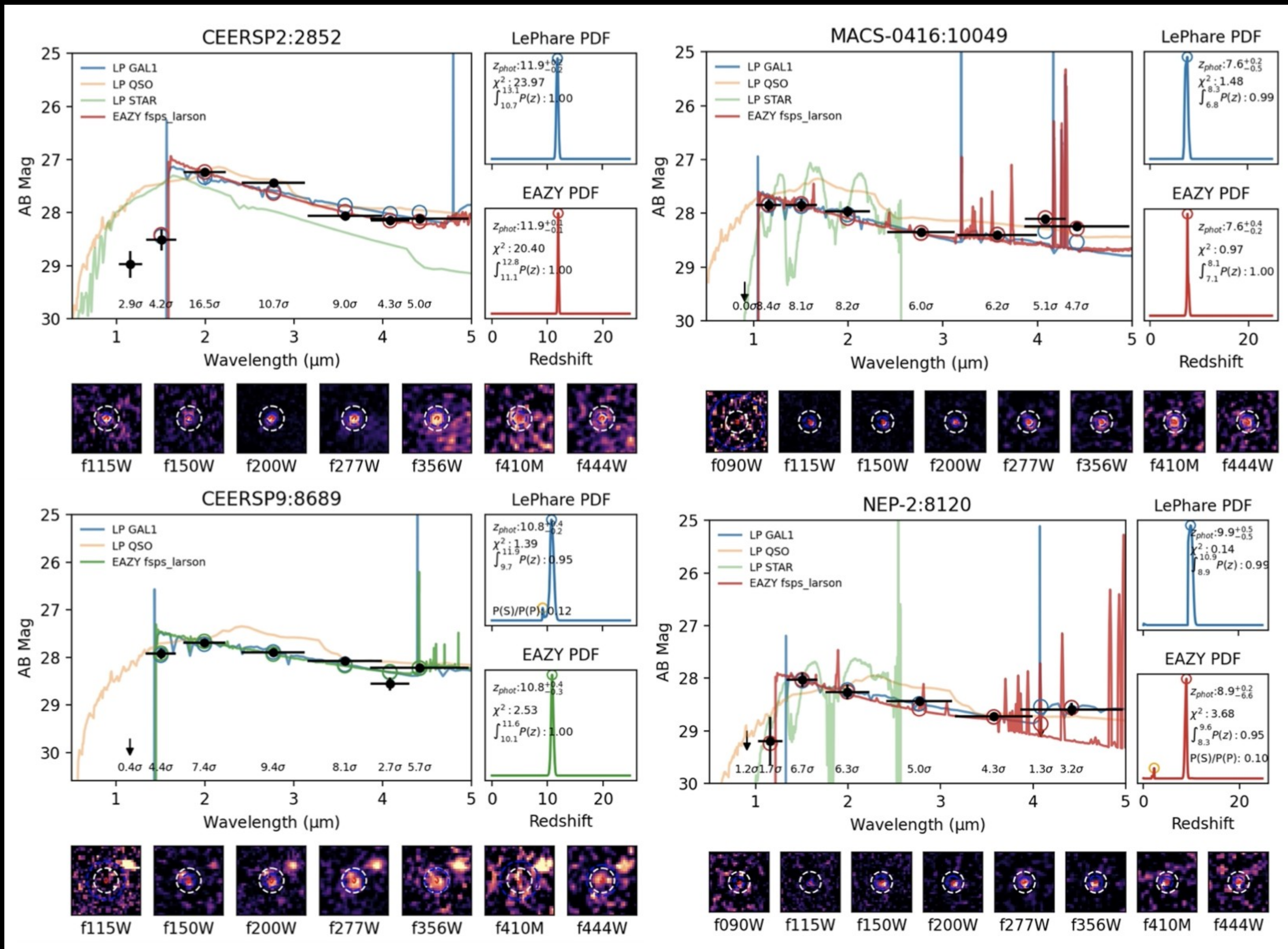
Properties of the EPOCHS Sample



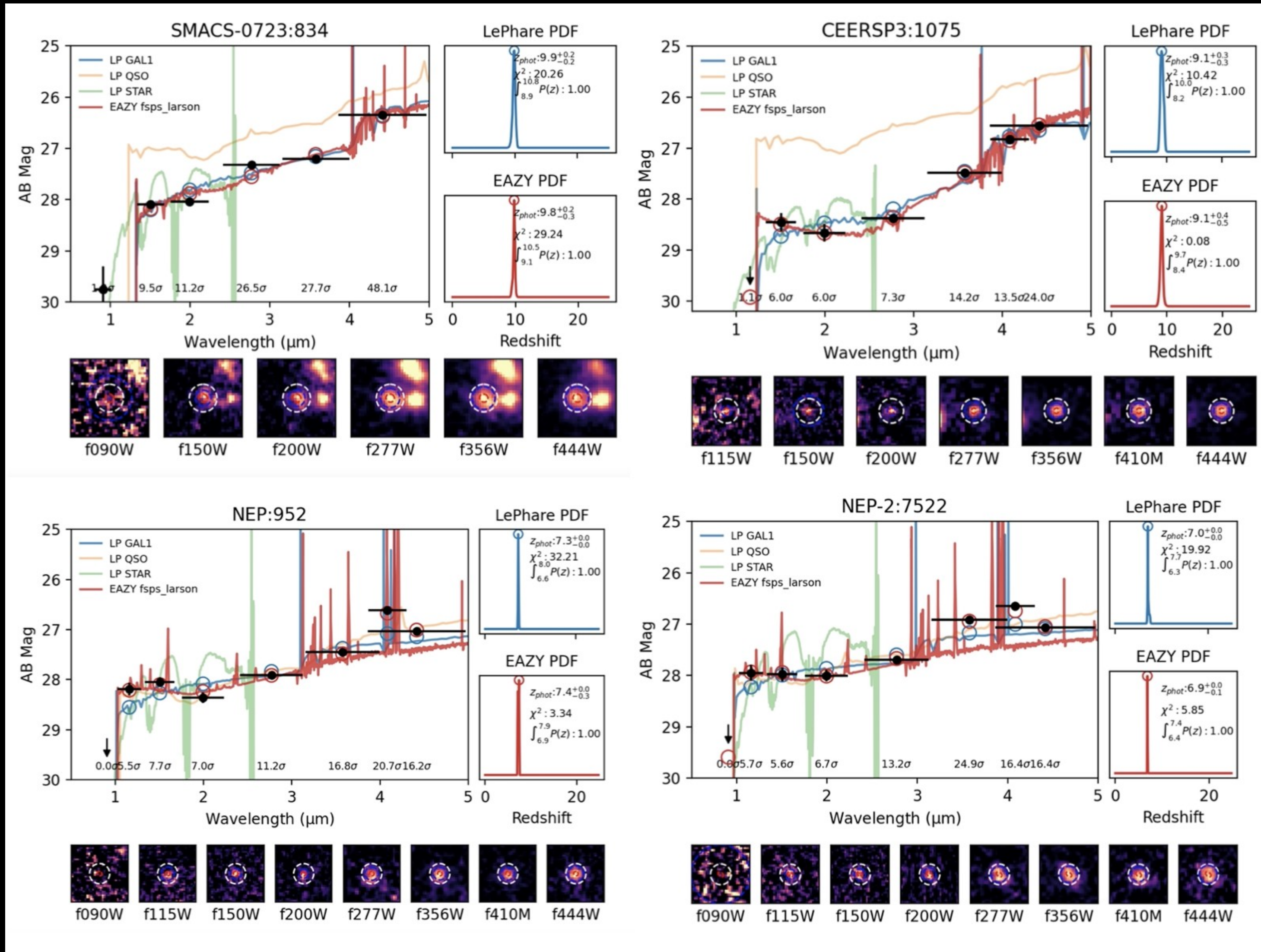


Conselice+2023 in prep

See many galaxies that are very blue

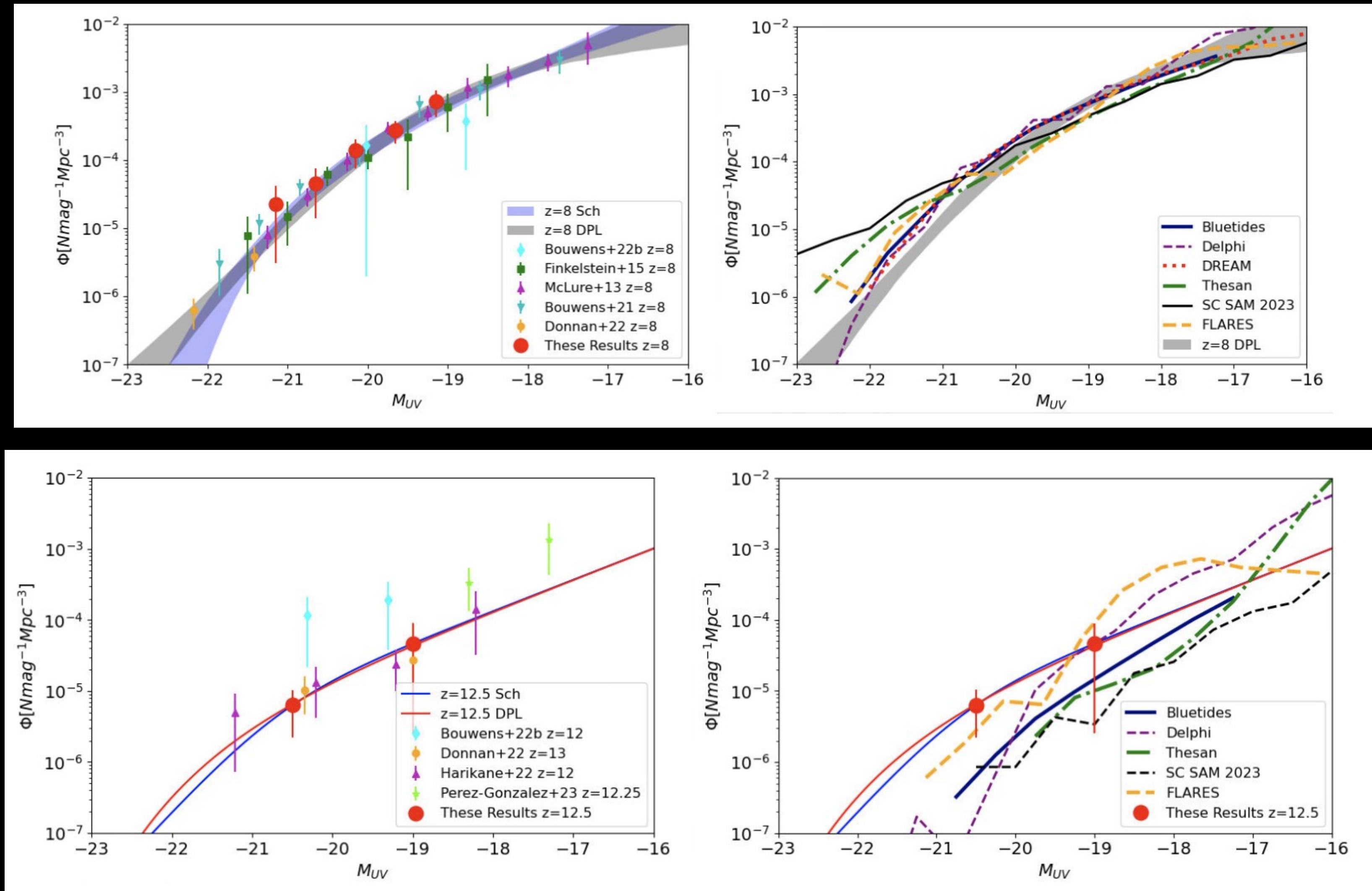


Also find many galaxies that are very red



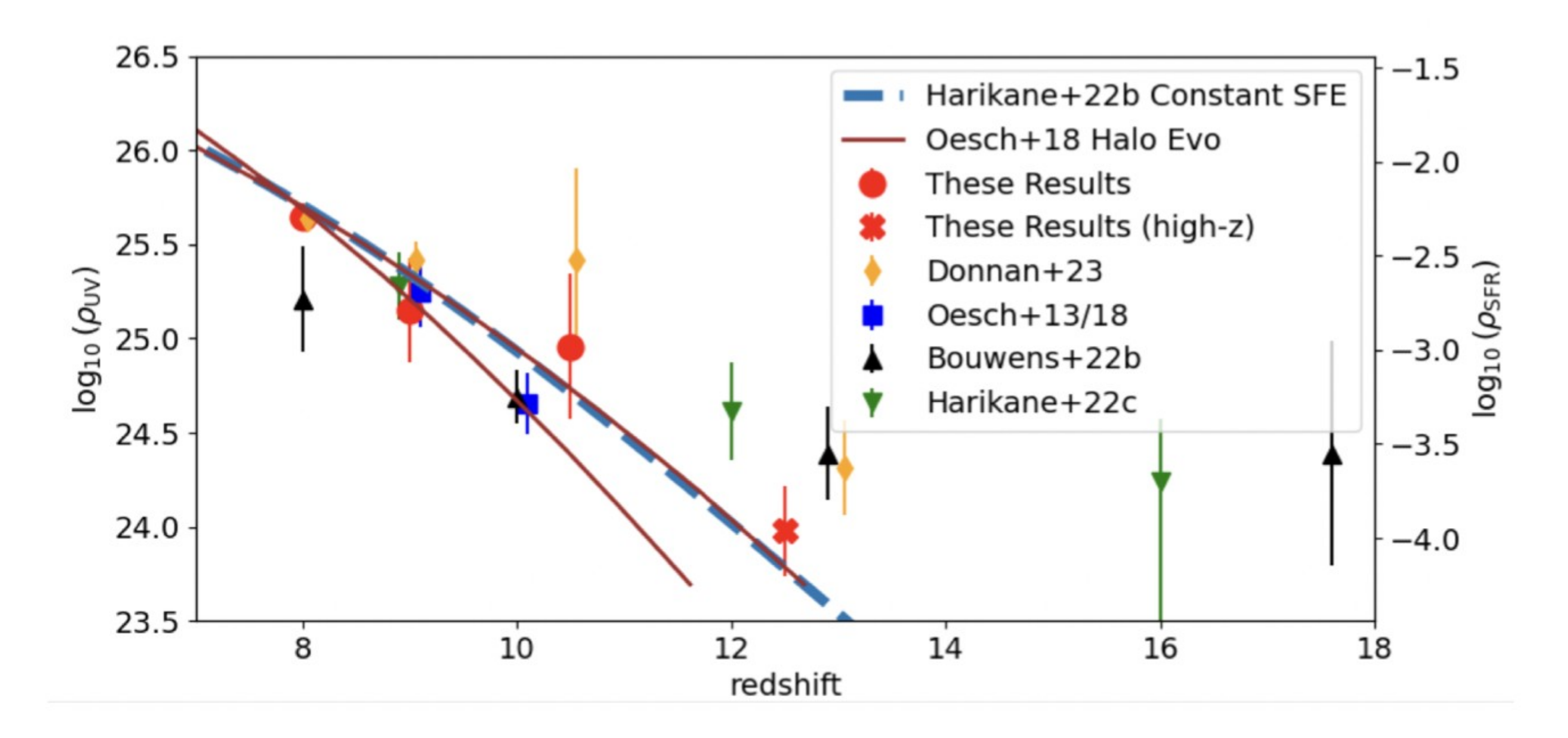
See a diversity in colours and SF histories at early times

We can now measure the UV luminosity function up to z~13



Adams+23

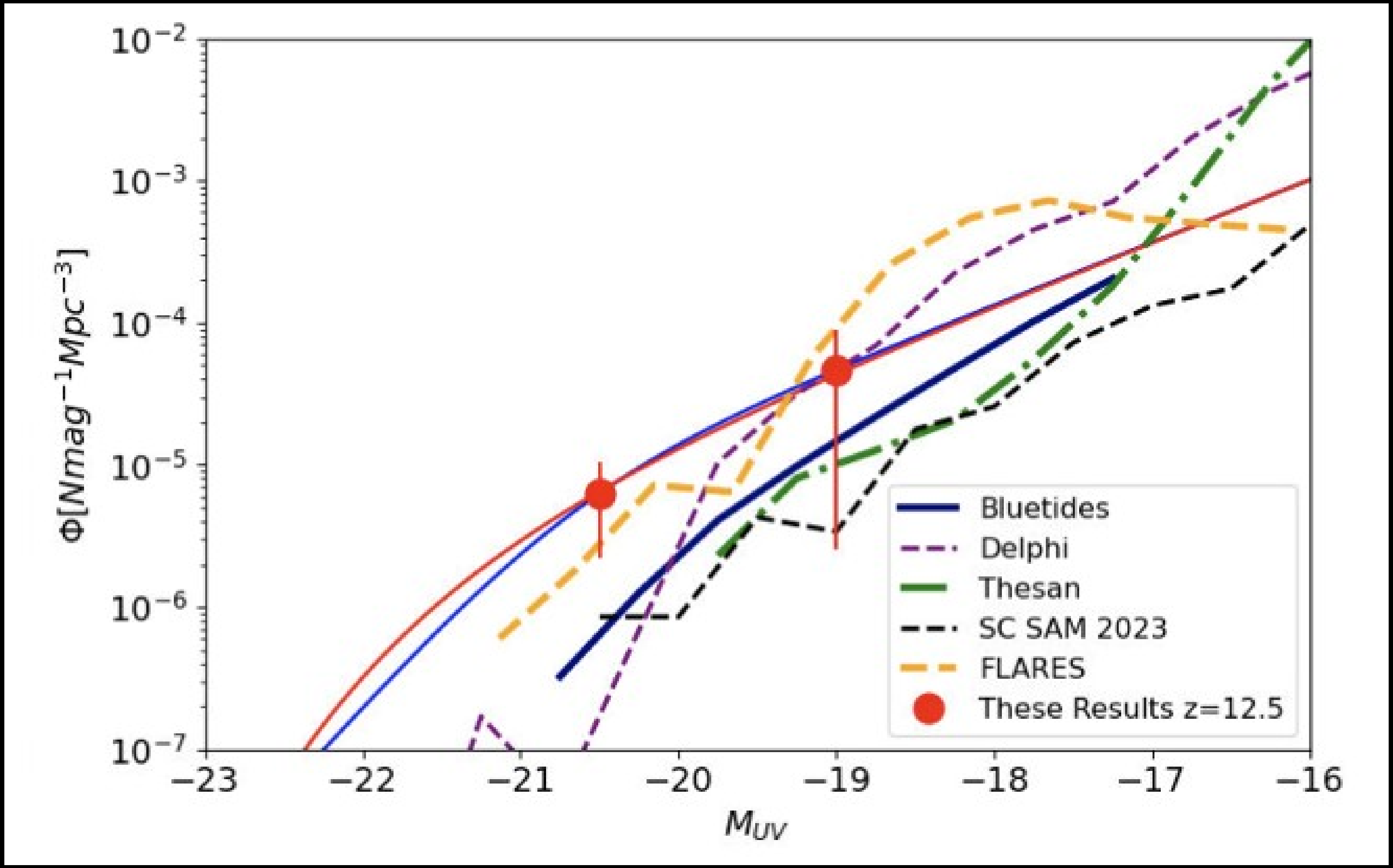
Allows us to measure the SFR history in the early universe



We find a higher density than some previous findings

Adams+23

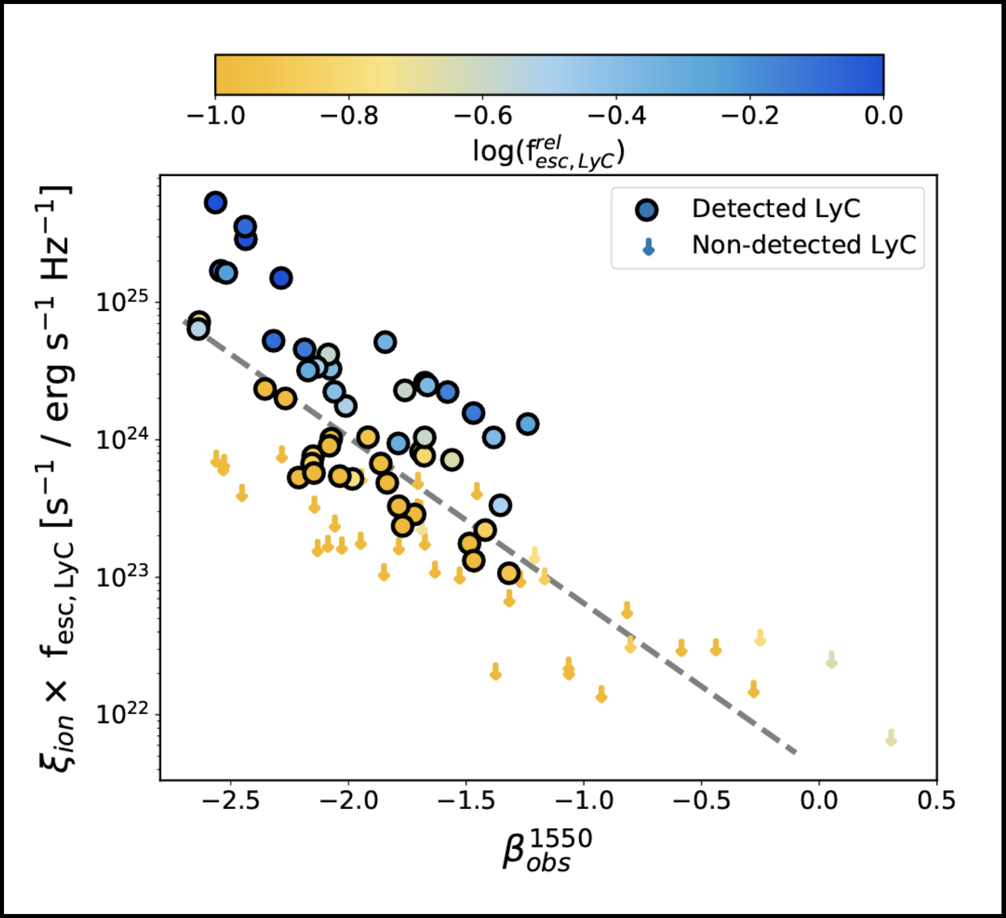
Comparison to models– more galaxies?



Adams+23

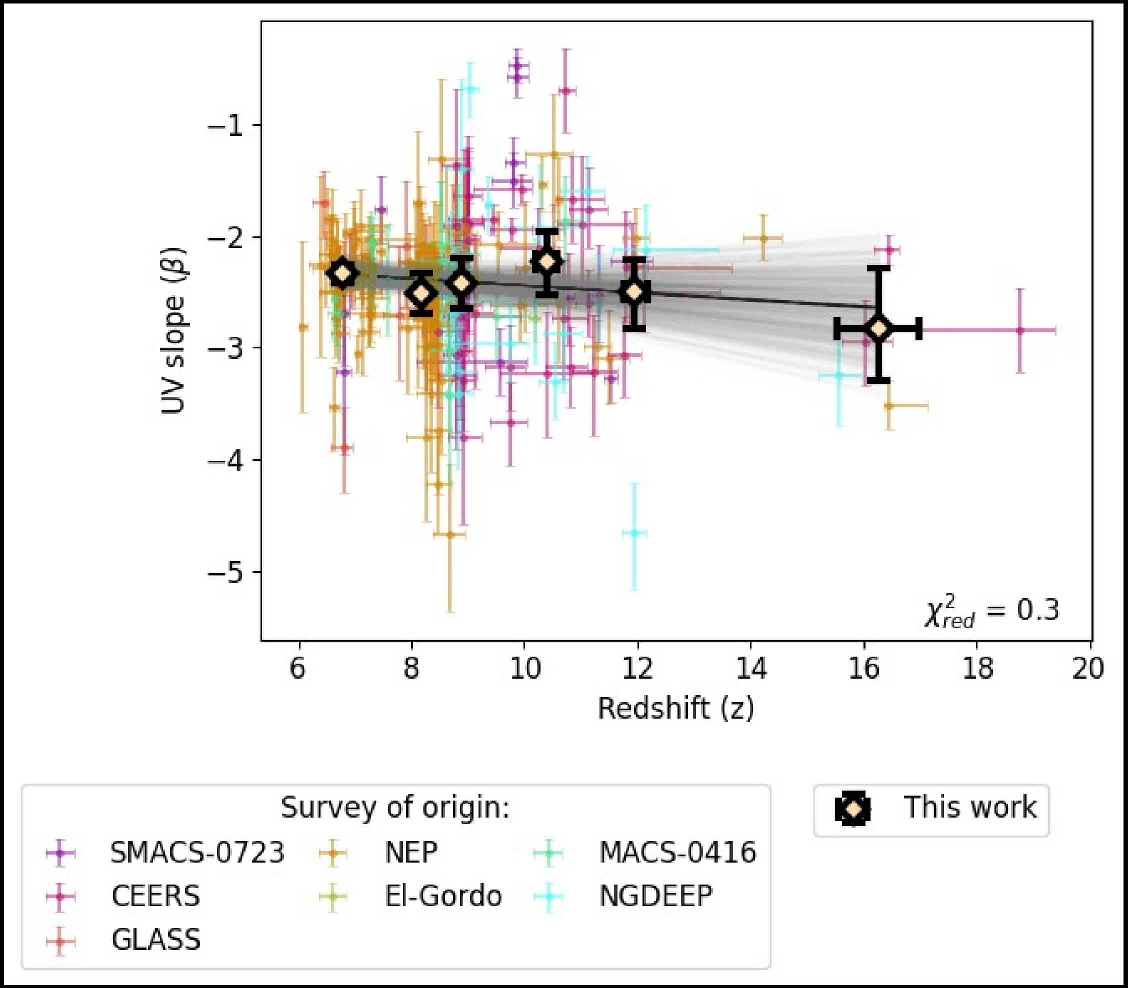
There may appear to be too many systems!

How can we obtain a measure of the LyC emission?



Chisholm+22

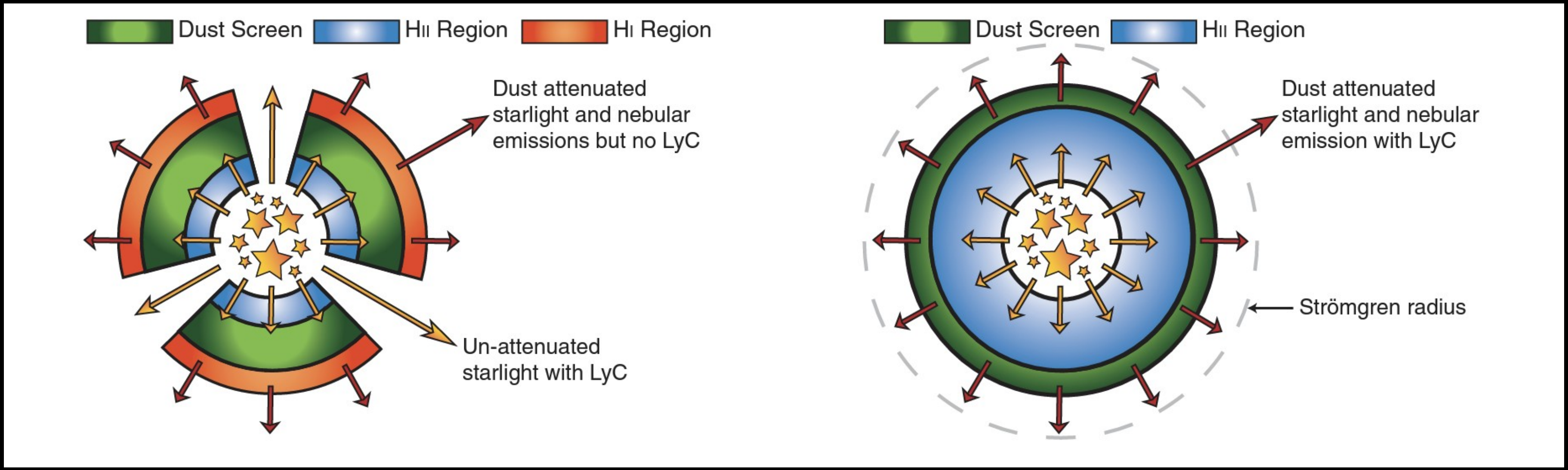
Measurement of Beta vs. Redshift



Find very little evolution

Austin+23

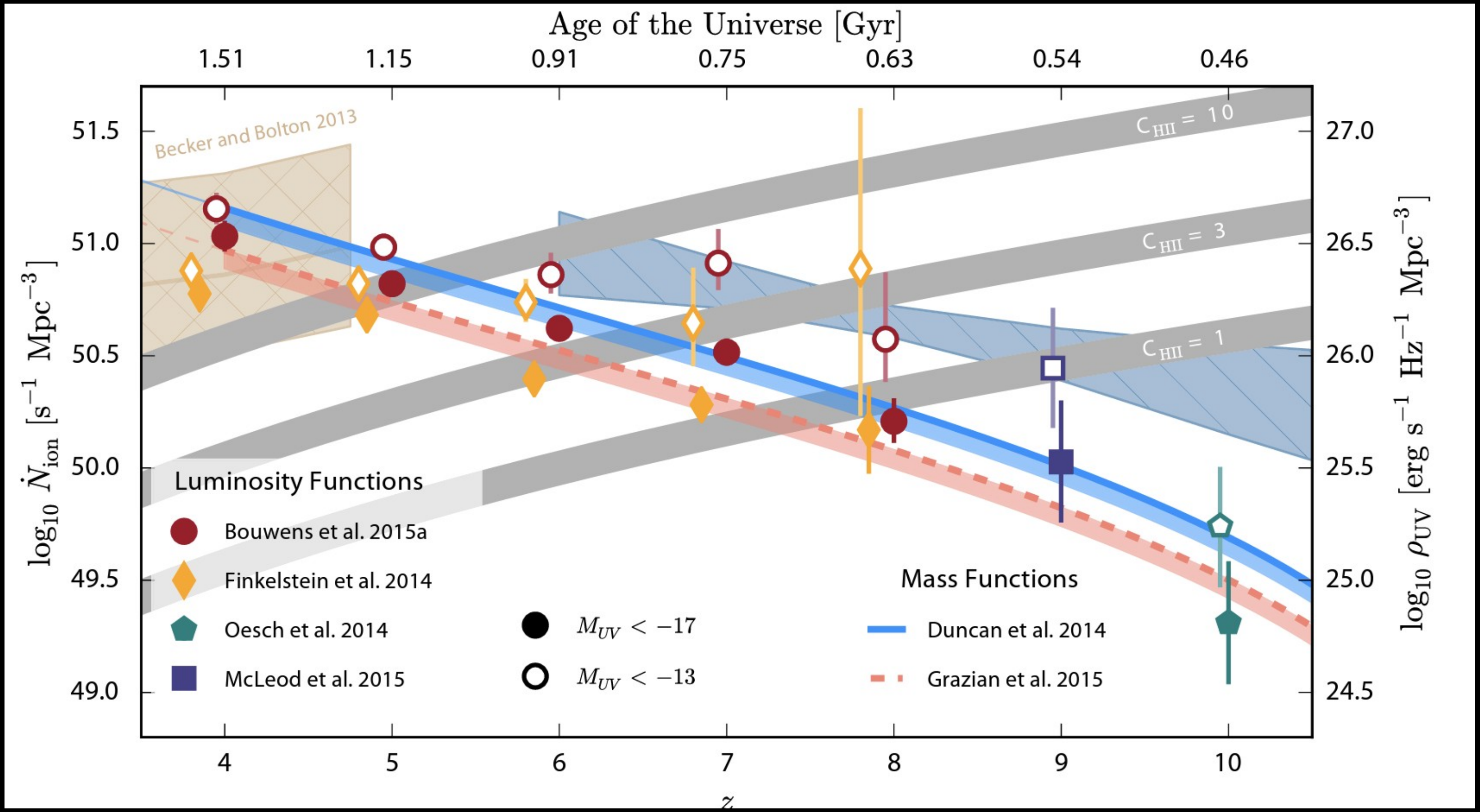
Reionization – escape fractions and emissivity



Depends on many factors! Escape fraction, geometry, etc.

Duncan & Conselice 2015

Reionization – escape fractions and emissivity

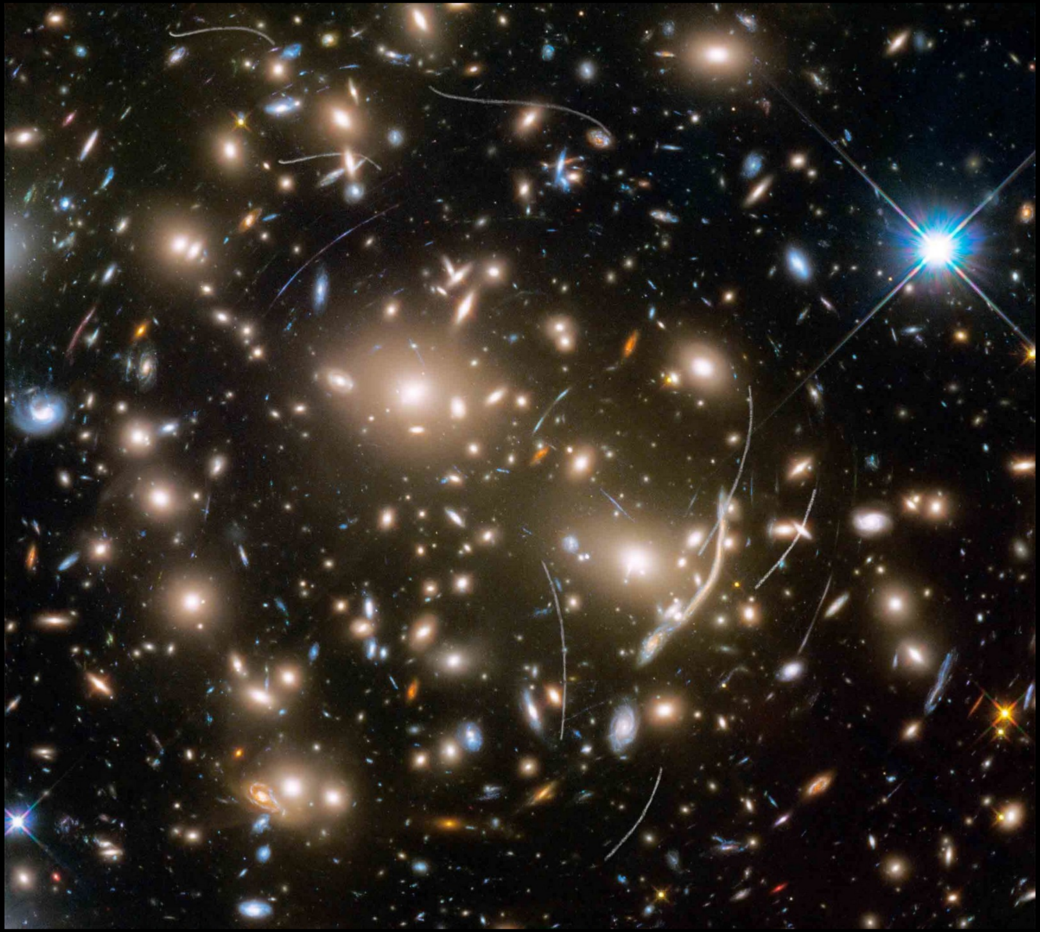


Can potentially reionize the universe with known galaxies

Duncan & Conselice 2015

Analog of reionization sources

Narrow line search for lensing galaxies – SHARDS survey

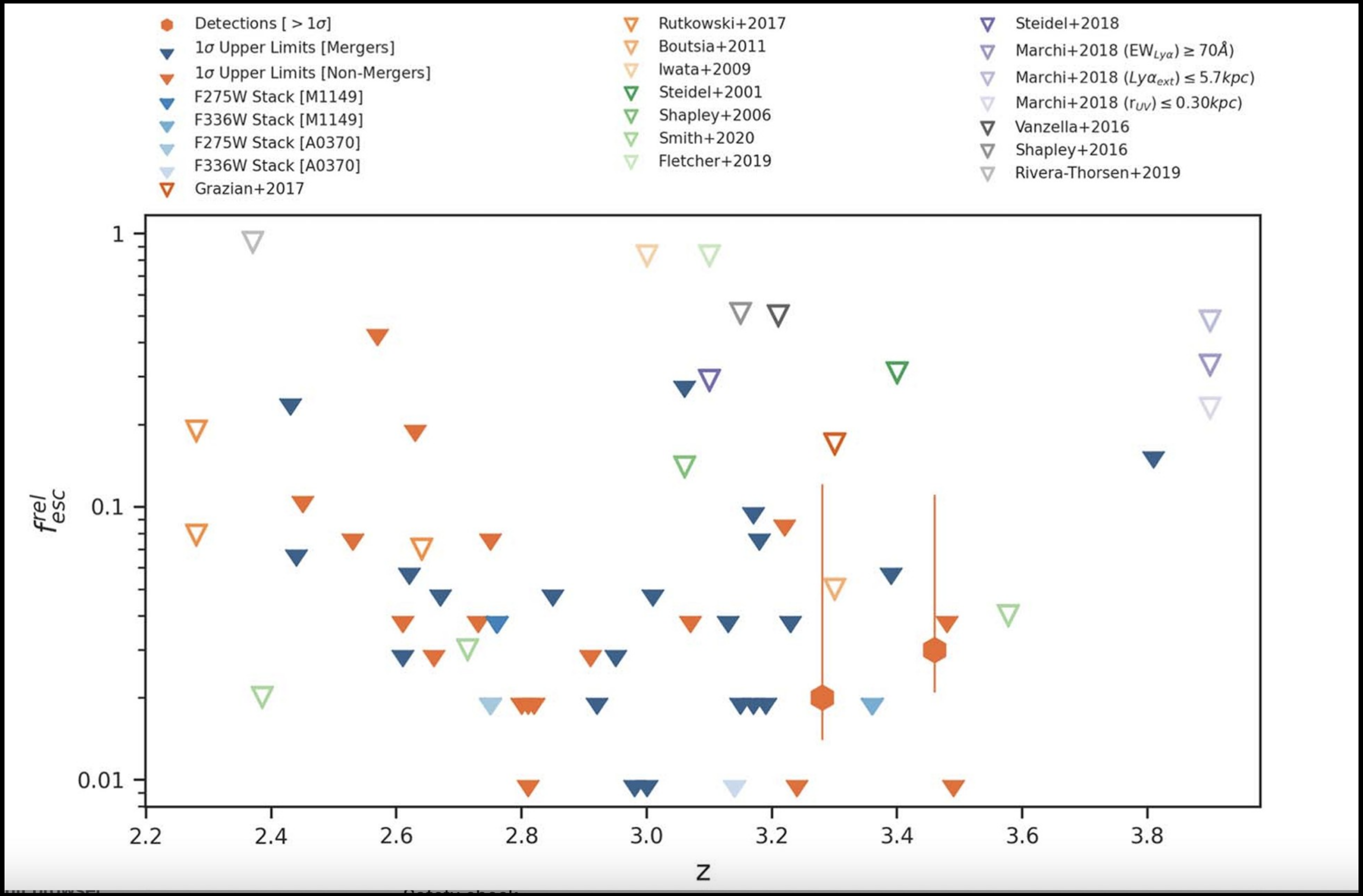


Abell 370

Griffiths, Conselice+2022

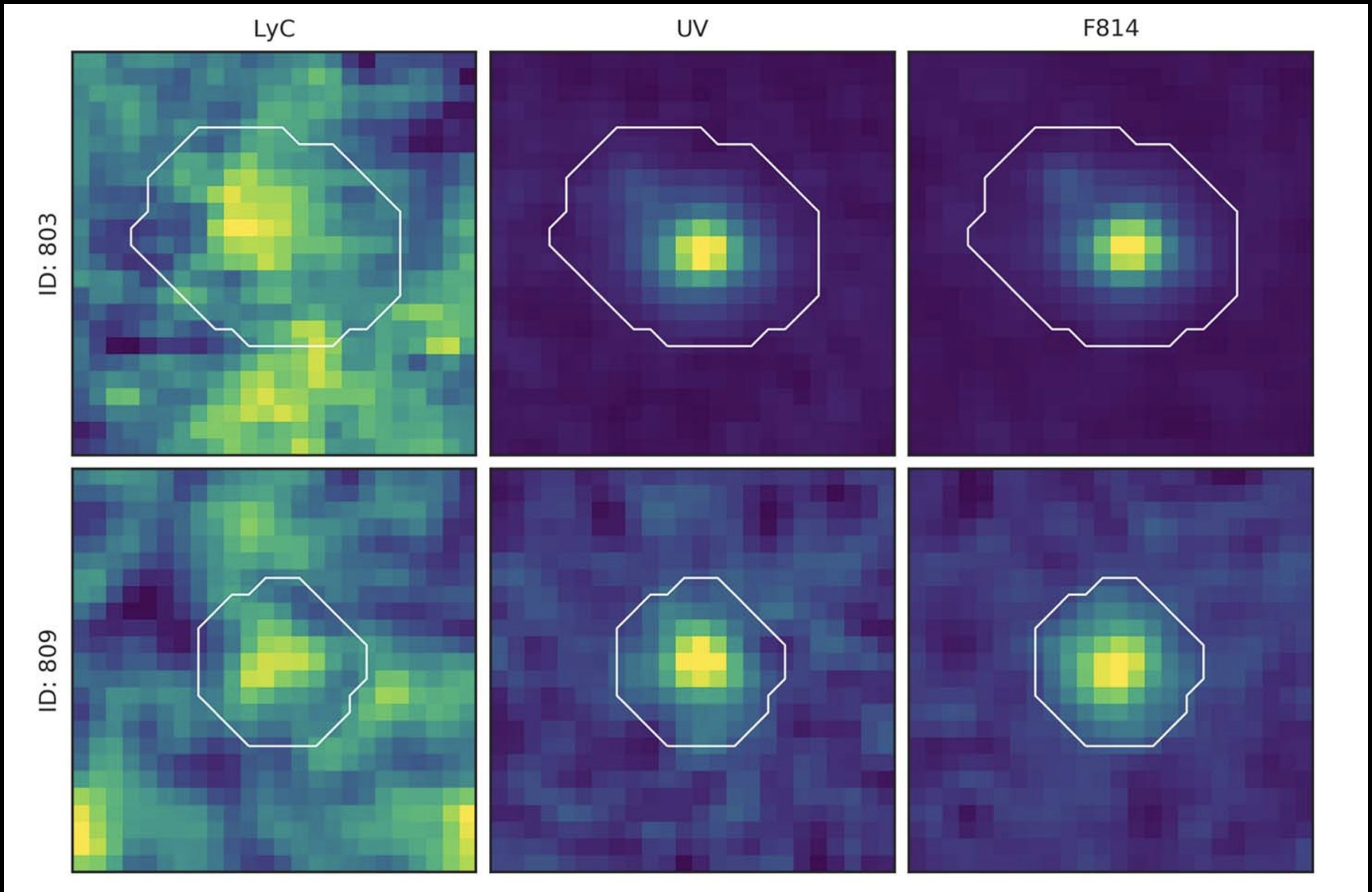
Very faint and low mass line emitters

Reionization – escape fractions



Griffiths, Conselice+2022

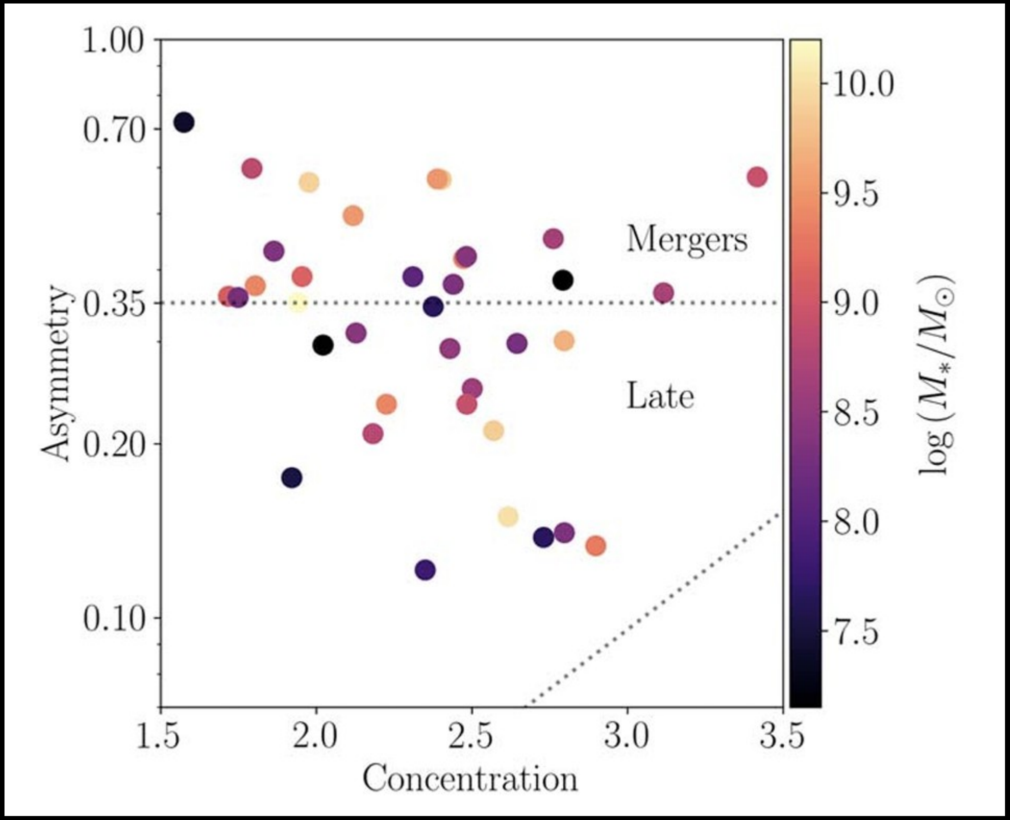
Faint low mass emission line sources with LyC



However, these systems have low escape fractions f = 2 - 3%

Only 2 out of 42 detected

Do we see a difference in structure/mergers?



Mergers have a escape fraction limit < 7% non-mergers < 4%

Can we find the first galaxies? How?

On the observability and identification of Population III galaxies with JWST

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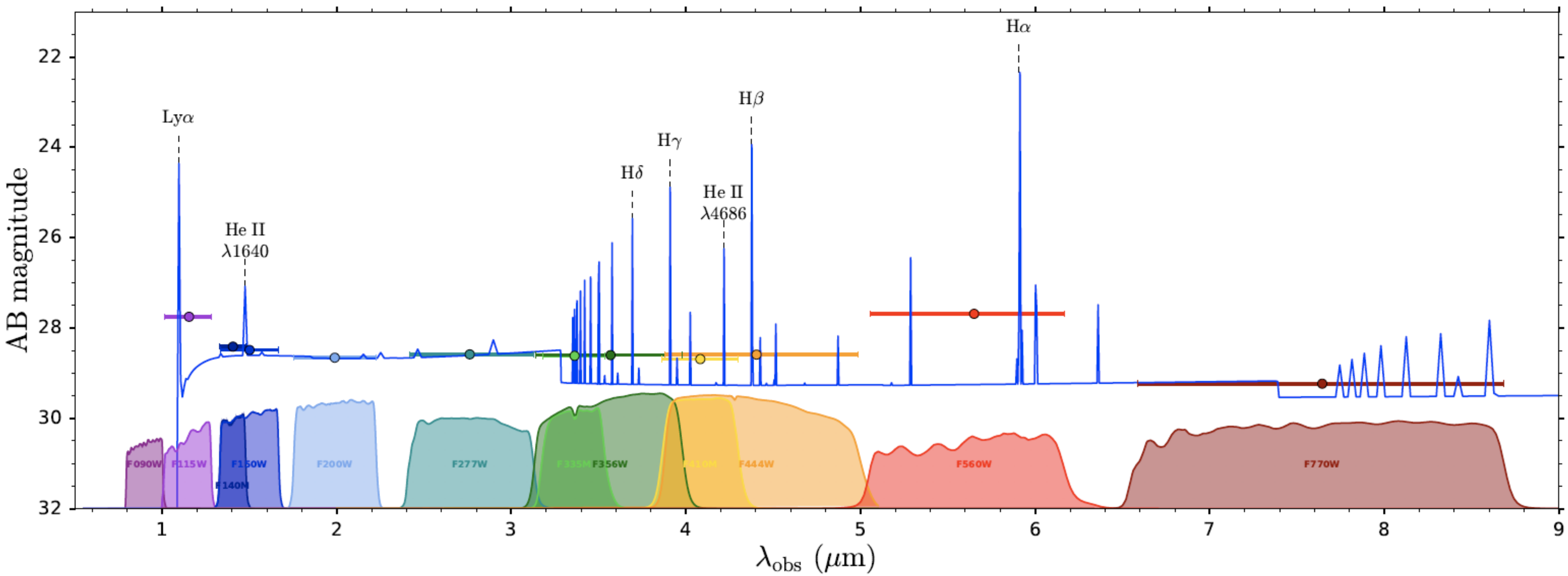
ABSTRACT

We utilise theoretical models of Population III stellar+nebular spectra to investigate the prospects of observing and accurately identifying Population III galaxies with *JWST* using both deep imaging and spectroscopy. We investigate a series of different colour cuts, finding that a combination of NIRCam and MIRI photometry through the F444W−F560W, F560W−F770W colours offers the most robust identifier of potential $z = 8$ Pop III candidates. We calculate that NIRCam will have to reach ~28.5–30.0 AB mag depths (1–20 h), and MIRI F560W must reach ~27.5–29.0 AB mag depths (10–100 h) to achieve 5σ continuum detections of $M_* = 10^6$ $M_\odot$ Pop III galaxies at $z = 8$. We also discuss the prospects of identifying Pop III candidates through slitless and NIRSpec spectroscopic surveys that target Lyα, Hβ and/or He II λ1640. We find small differences in the Hβ rest-frame equivalent width (EW) between Pop III and non-Pop III galaxies, rendering this diagnostic likely impractical. We find that the detection of high EW He II λ1640 emission will serve as the definitive Pop III identifier, requiring (ultra-)deep integrations (10–250 h) with NIRSpec/G140M for $M_* = 10^6$ $M_\odot$ Pop III galaxies at $z = 8$. With moderate ($\mu = 2$–3) lensing and/or moderately massive ($M_* = 2$–3×10^6 $M_\odot$) Pop III galaxies, such line detections can be achieved in medium-sized *JWST* GO programs. However, MIRI F770W detections of Pop III galaxies will require substantial gravitational lensing ($\mu = 10$) and/or fortuitous imaging of exceptionally massive ($M_* = 10^7$ $M_\odot$) Pop III galaxies. Thus, NIRCam medium-band imaging surveys that can search for high EW He II λ1640 emitters in photometry may perhaps be a viable alternative for finding Pop III candidates.

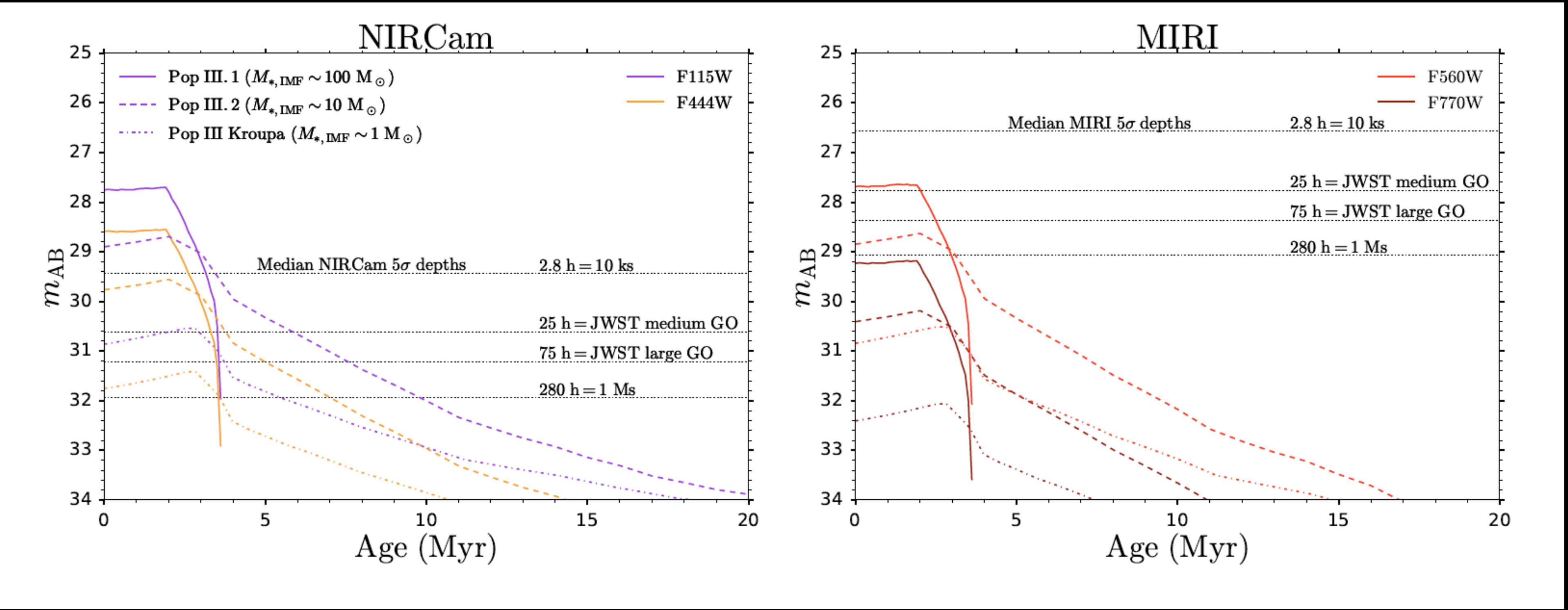
Can we find the first UV bright galaxies? How?



Pop III spectra – only contains hydrogen and helium lines

Trussler+2022

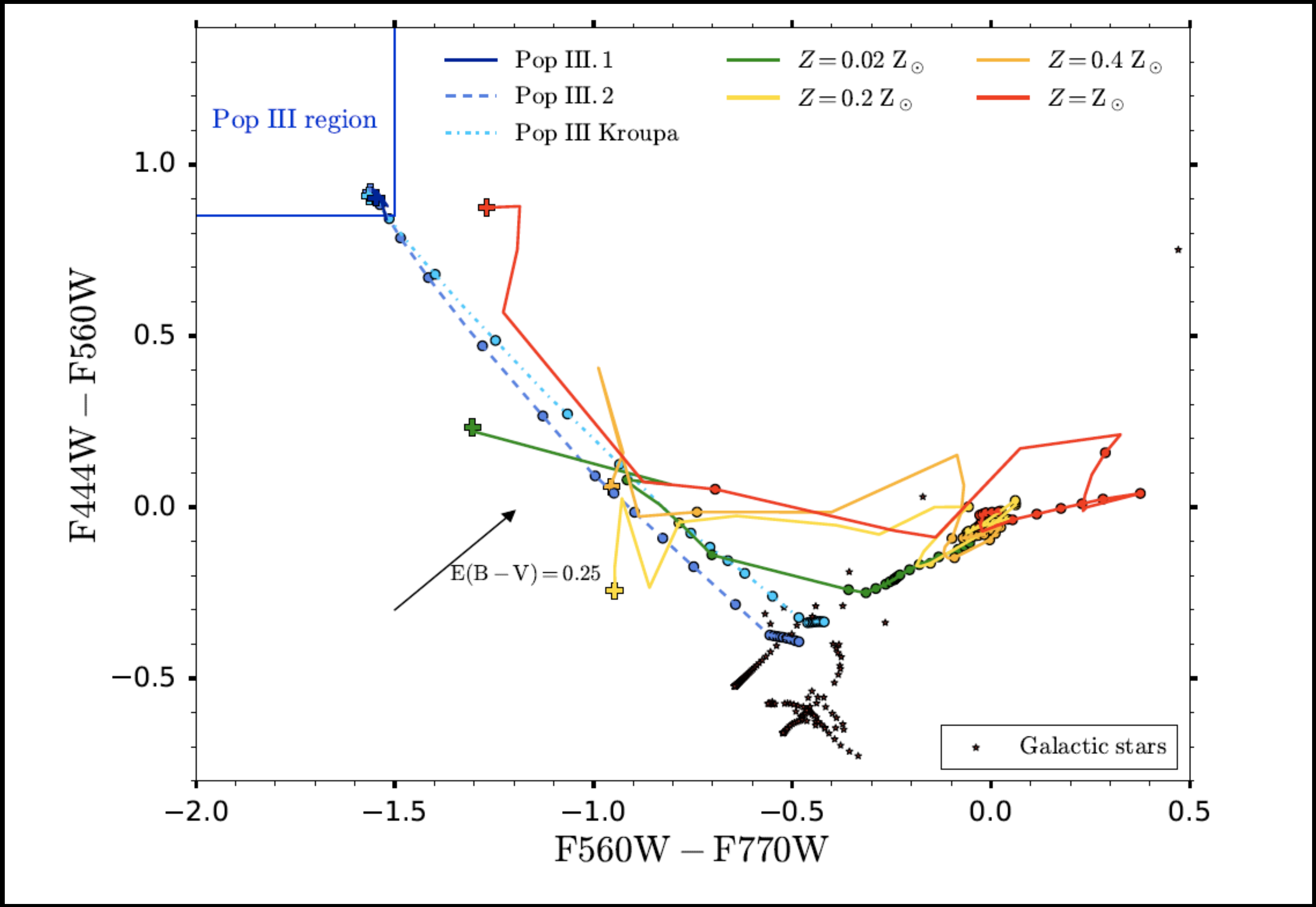
Can we find the first galaxies? How?



Pop III galaxies become too faint to detect very quickly

Have <5 Myr to find such systems

Can we find the first galaxies? How?



Occupy a unique part of parameter space

Will require deeper data than we have as well as spectra follow up

Summary

1. JWST is just starting to reveal the formation and evolution of galaxies, but has already changed understanding in a few months!

2. Disk galaxies are much more common than we thought based on previous HST data. Most of the star formation/reionization flux and mass are found in disk galaxies since universe was 1 Gyr old.

3. We are now finding distant galaxies at $z > 10$ that are unexpected. There is therefore a new epoch of early galaxy evolution that needs to be examined in more detail, or we have more contamination

   Future observations with NIRSpec and ALMA will help sort this problem out.

4. Finding the first galaxies or Pop III galaxies will be very hard, but possible