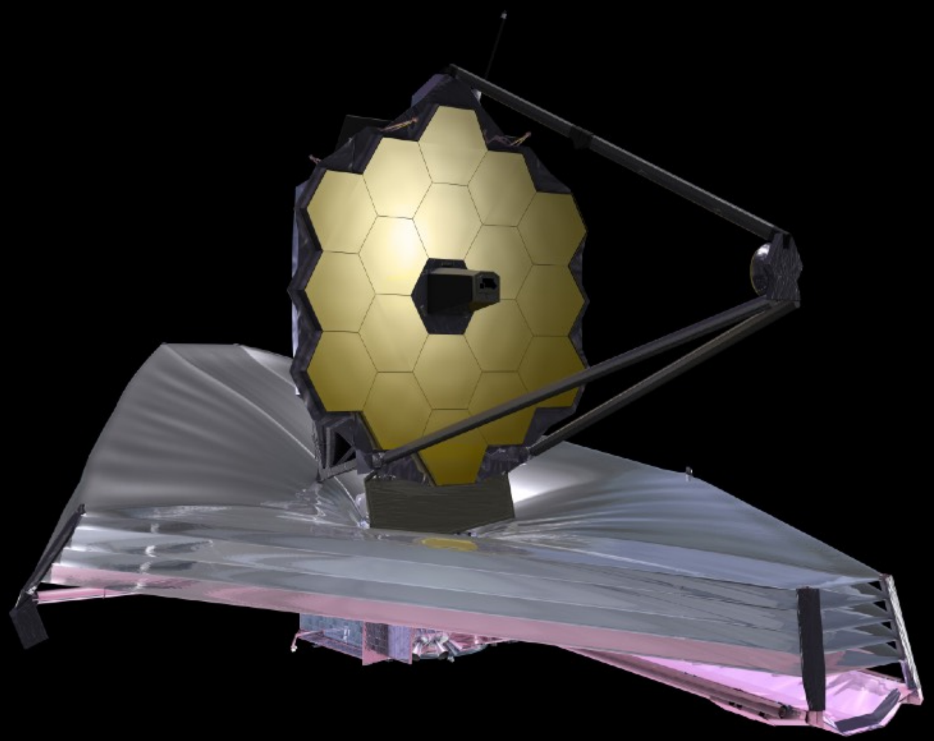
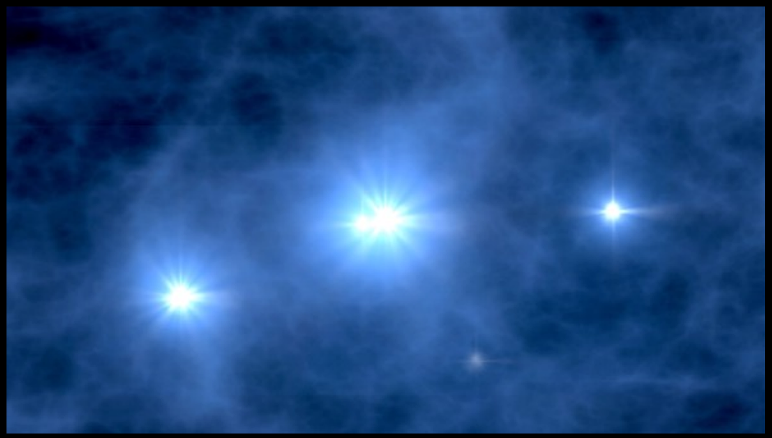
Finding and characterising the first galaxies in the Universe with JWST





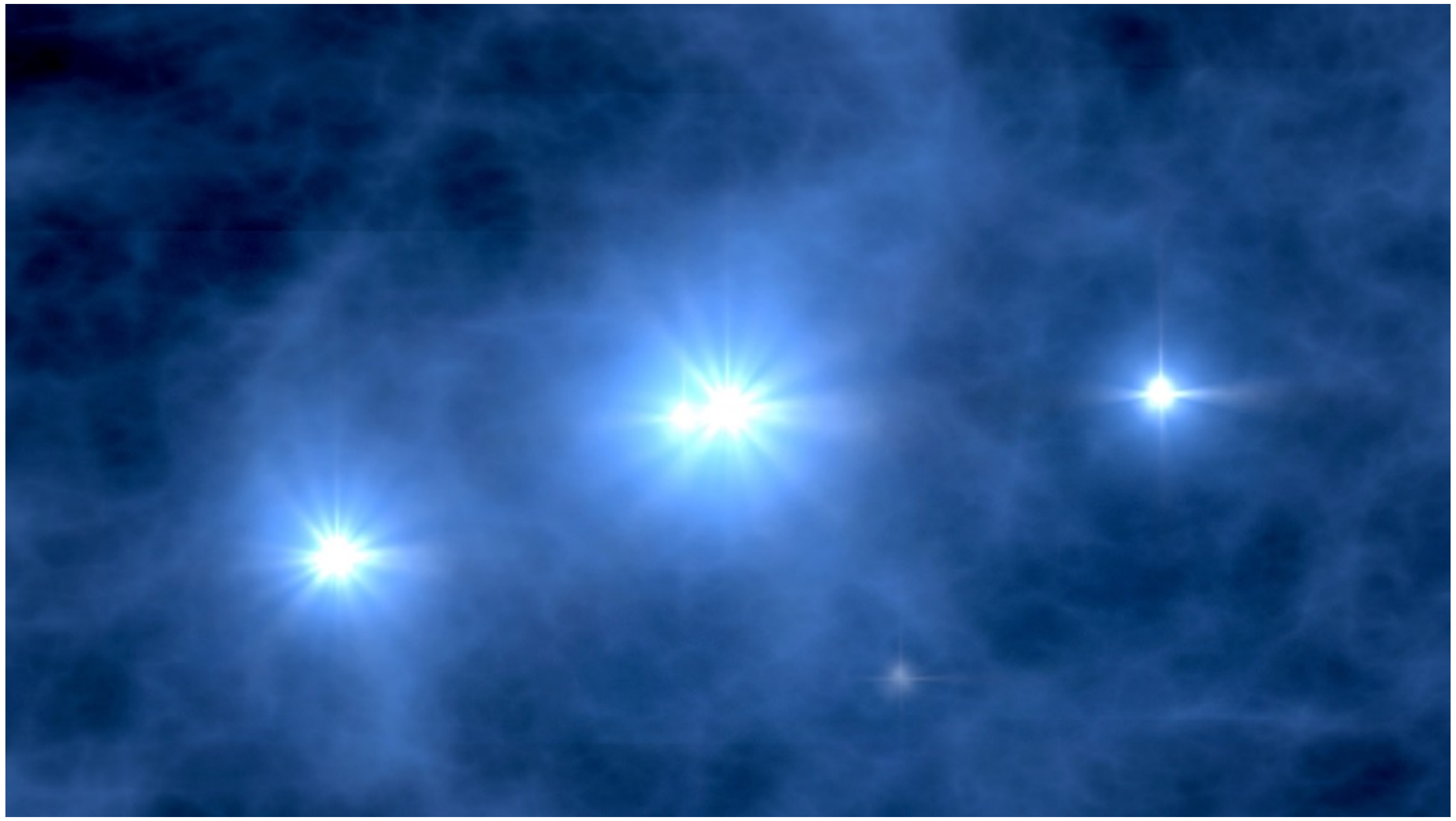
James Trussler

MANCHESTER 1824
The University of Manchester

C. Conselice, N. Adams, D. Austin, L. Ferreira, T. Harvey, Q. Li,
K. Nakajima, R. Maiolino, R. Windhorst, E. Zackrisson

erc
European Research Council
Established by the European Commission

First galaxies: Direct



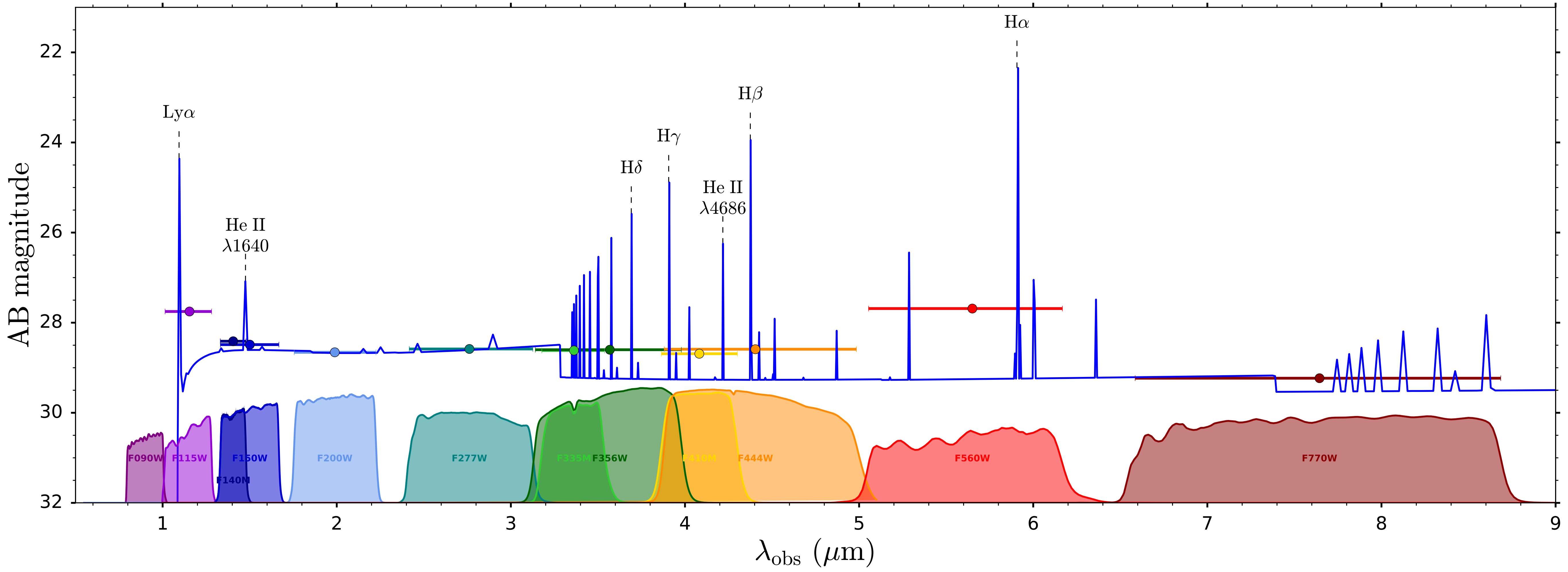
Pop III: the first stars
(pure hydrogen and helium)

Trussler+22

Pop III Spectrum

z=8, 10⁶ M⊙ Pop III galaxy

Trussler+22

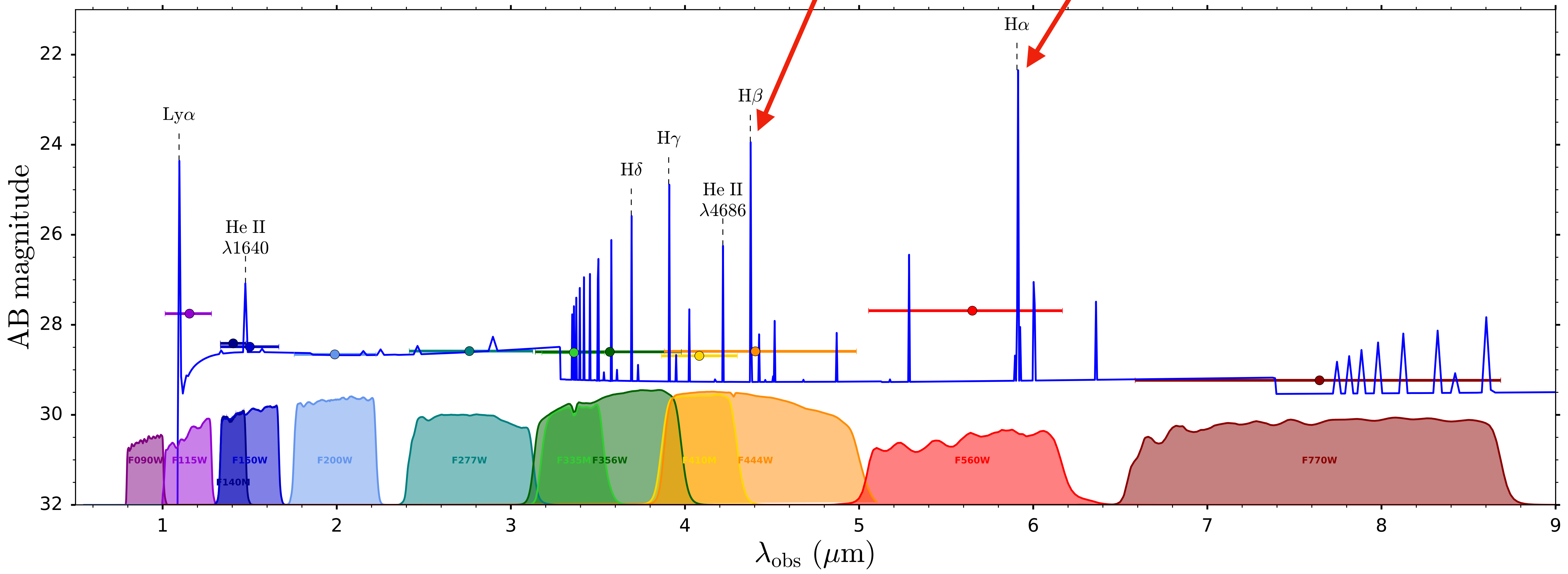


Zackrisson+11 models

James Trussler

Pop III Spectrum

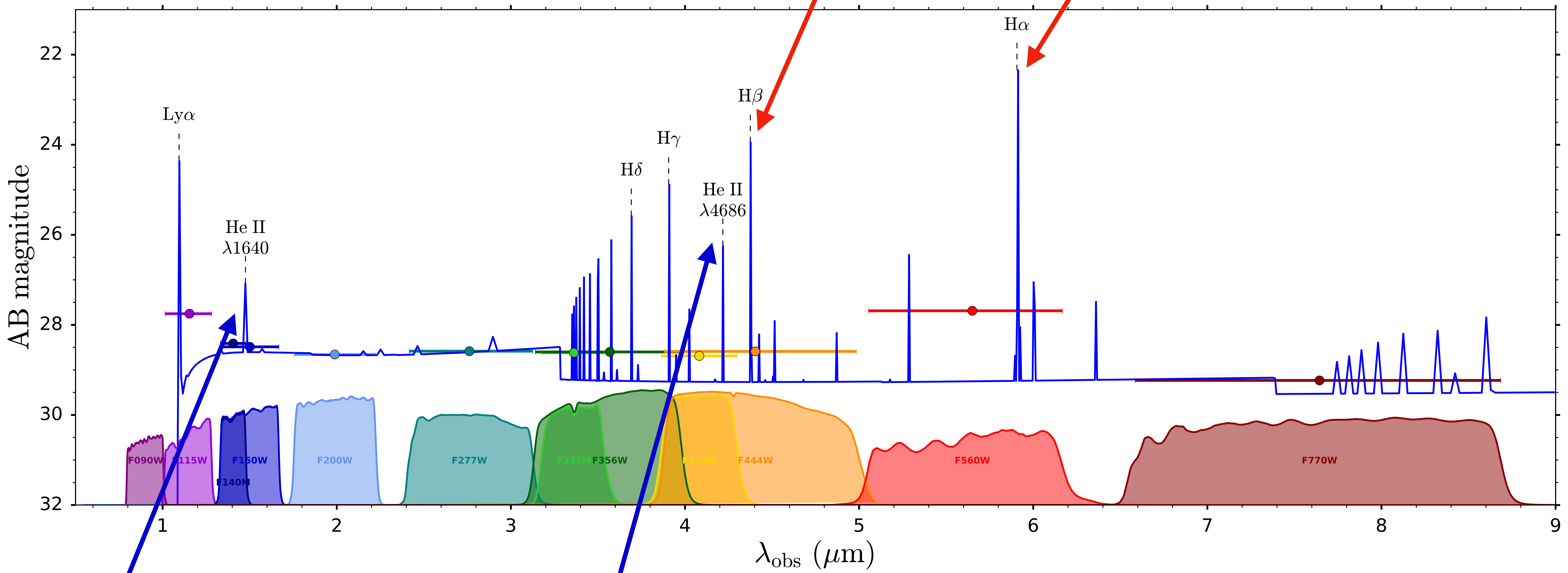
Strong Hydrogen recombination lines



James Trussler

Pop III Spectrum

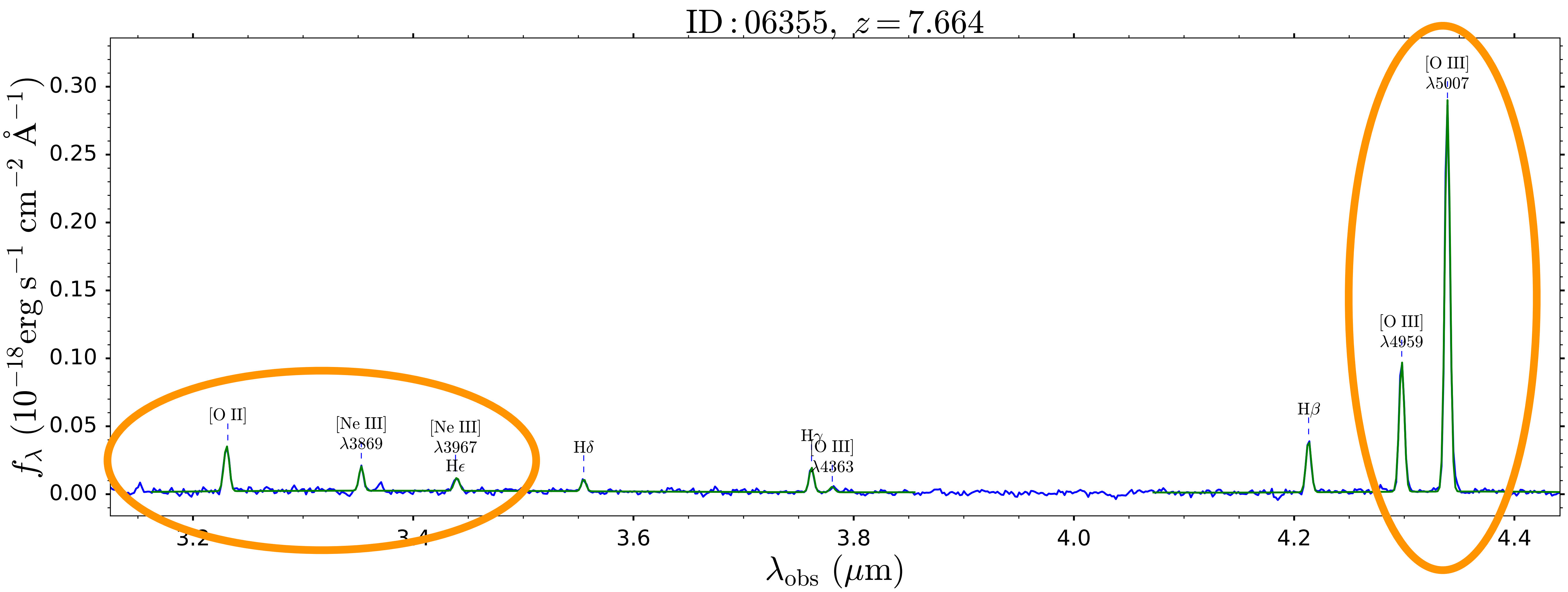
Strong Hydrogen recombination lines



Strong He II recombination lines

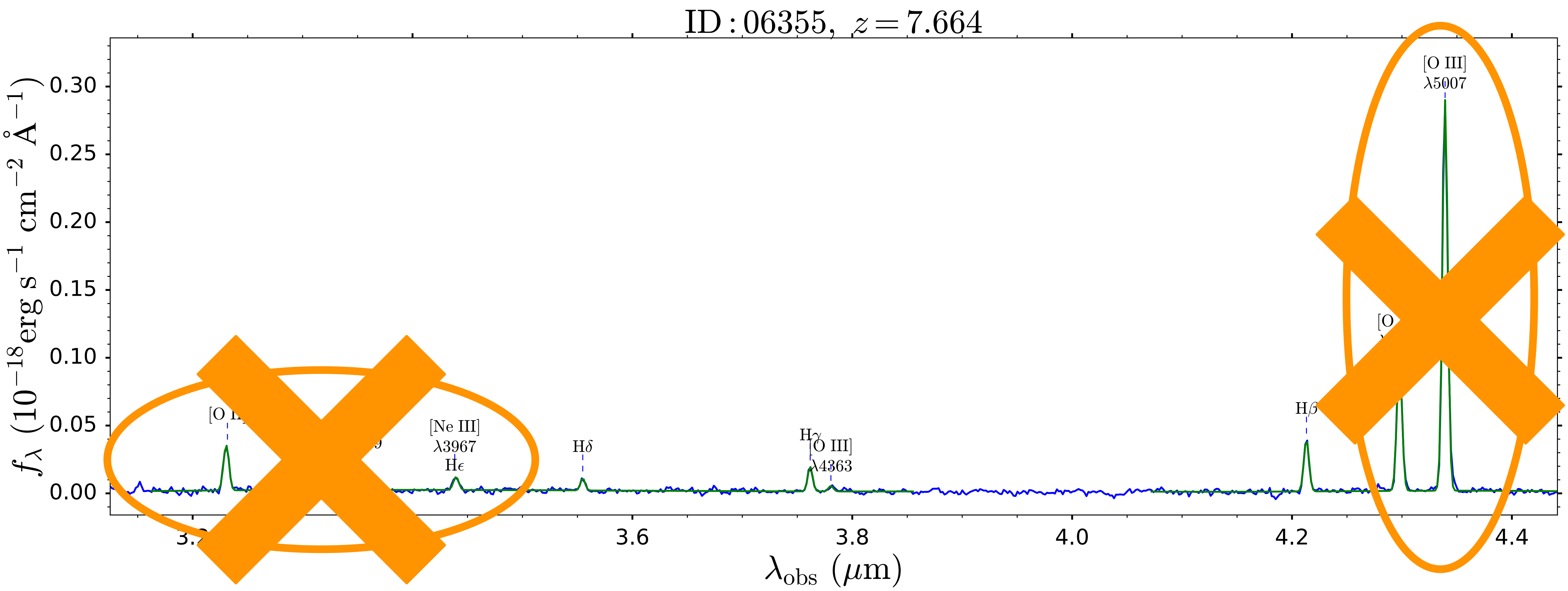
James Trussler

Non-Pop III Spectrum



Trussler+23

Pop III Spectrum

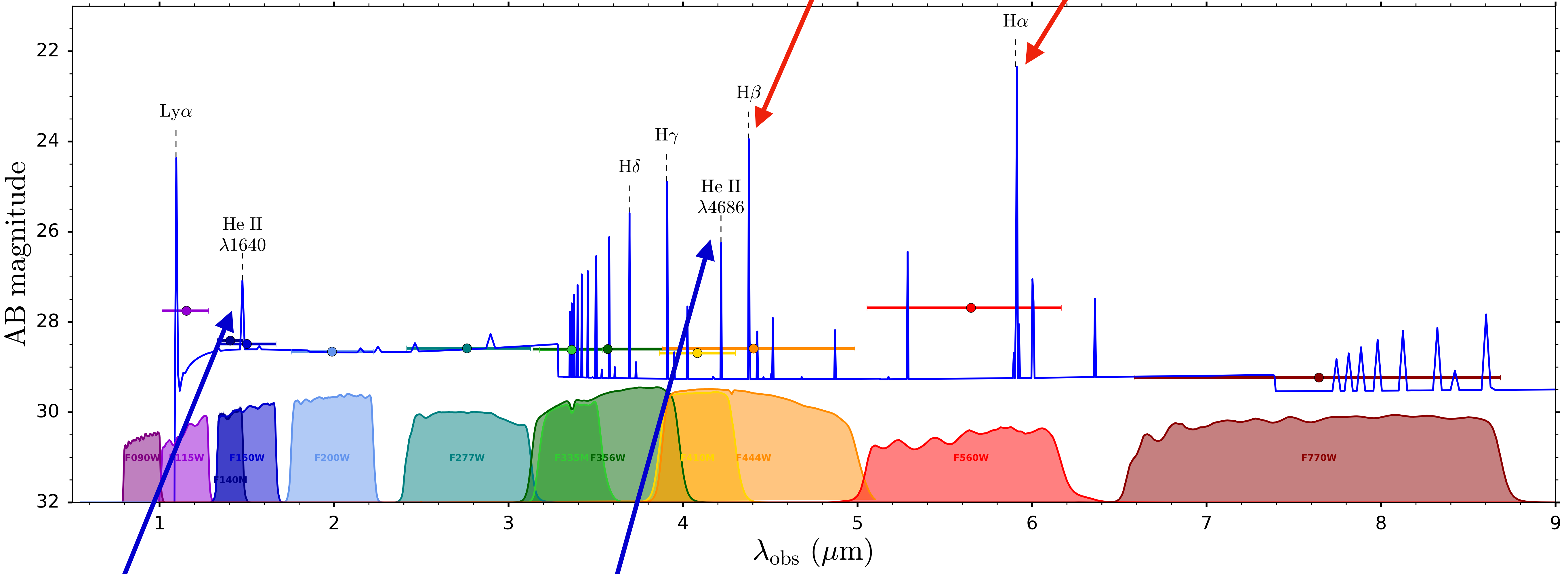


Lack of metal lines

James Trussler

Pop III Spectrum

Strong Hydrogen recombination lines



Strong He II recombination lines

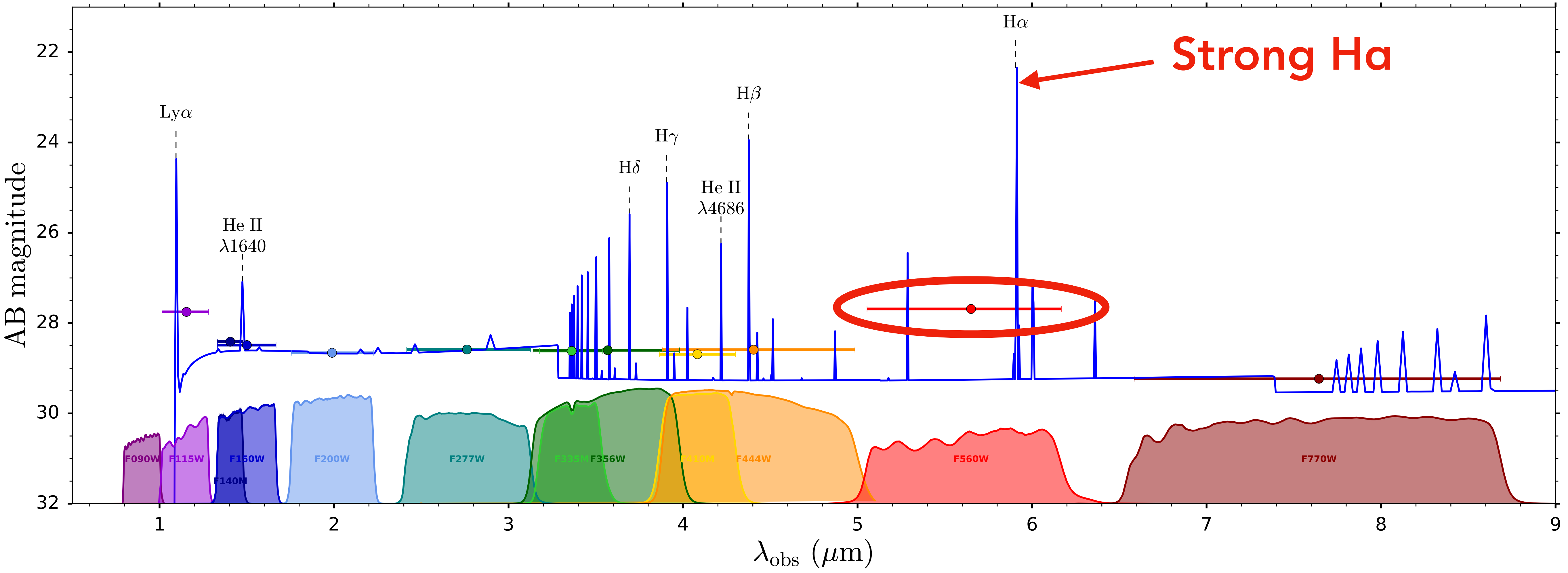
Lack of metal lines

James Trussler

Hα emission

z=8, 10^6 M$_\odot$ Pop III galaxy

Trussler+22

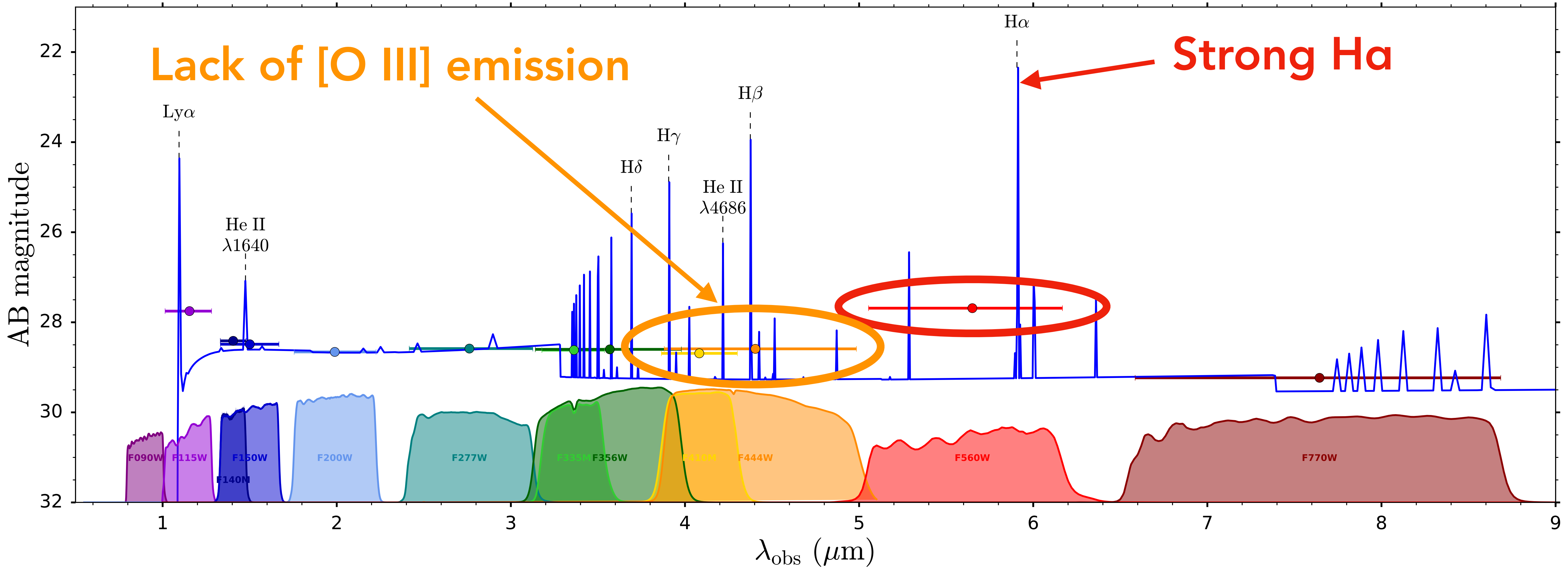


James Trussler

[O III] emission

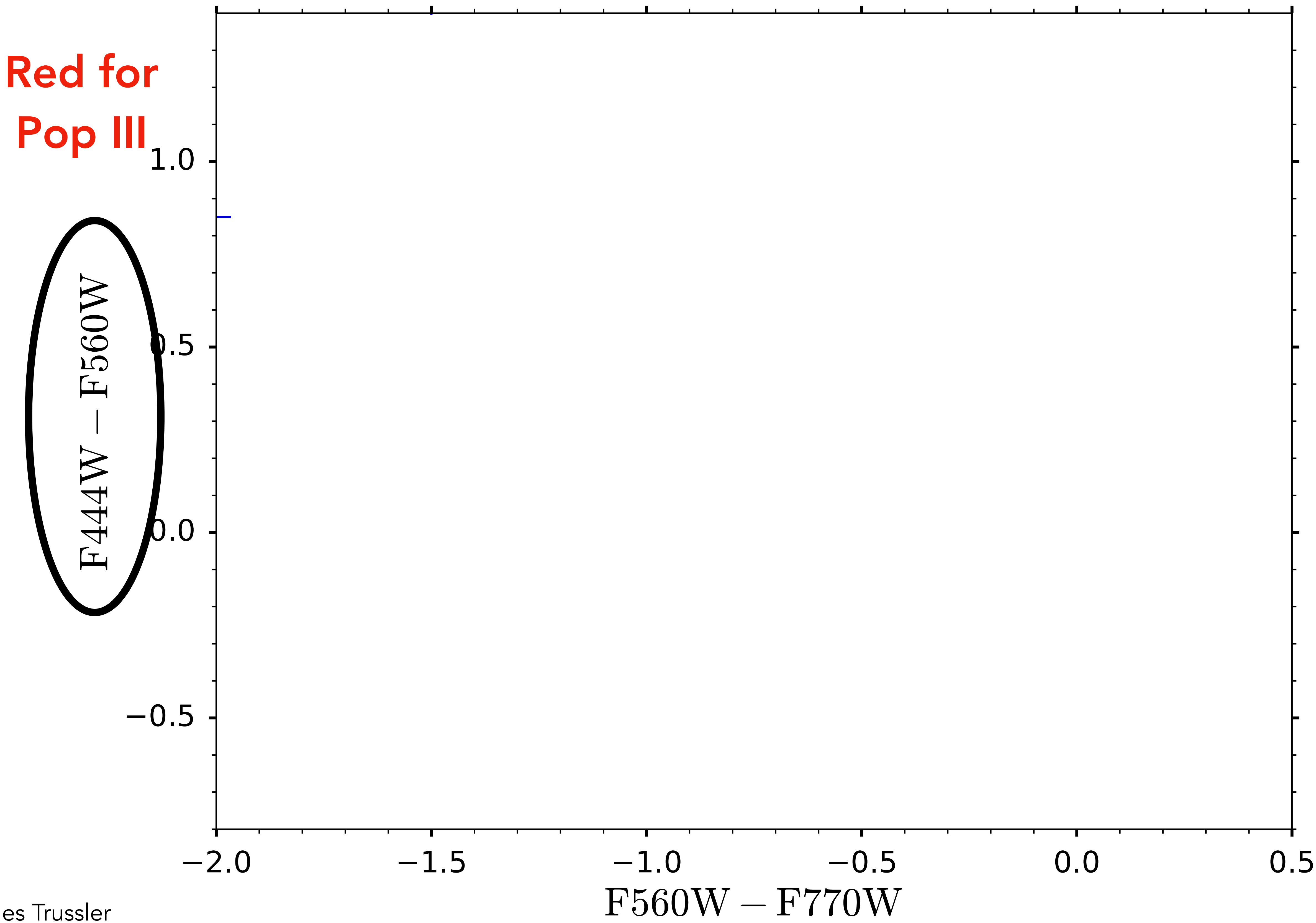
z=8, 10^6 M$_\odot$ Pop III galaxy

Trussler+22

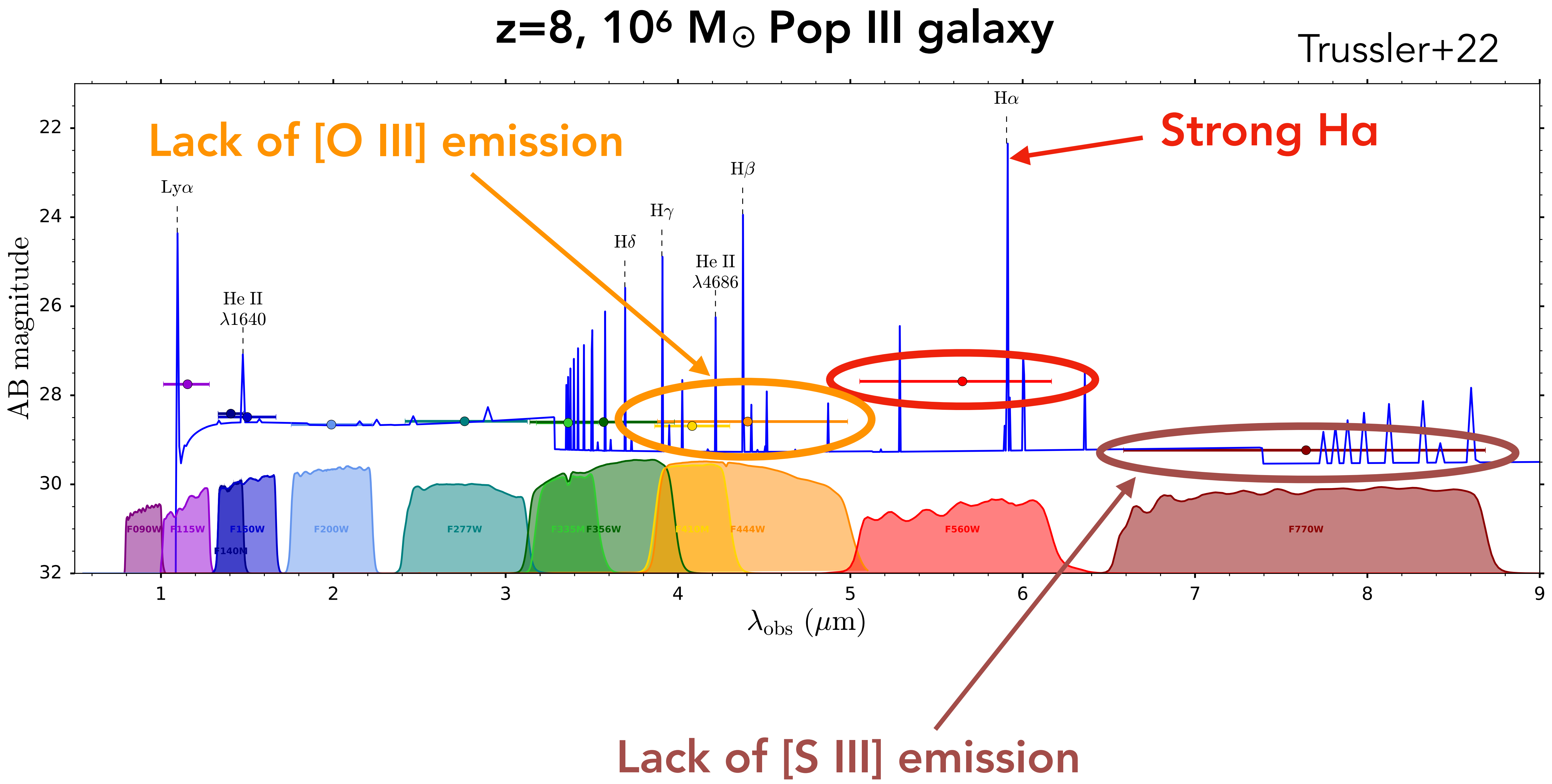


James Trussler

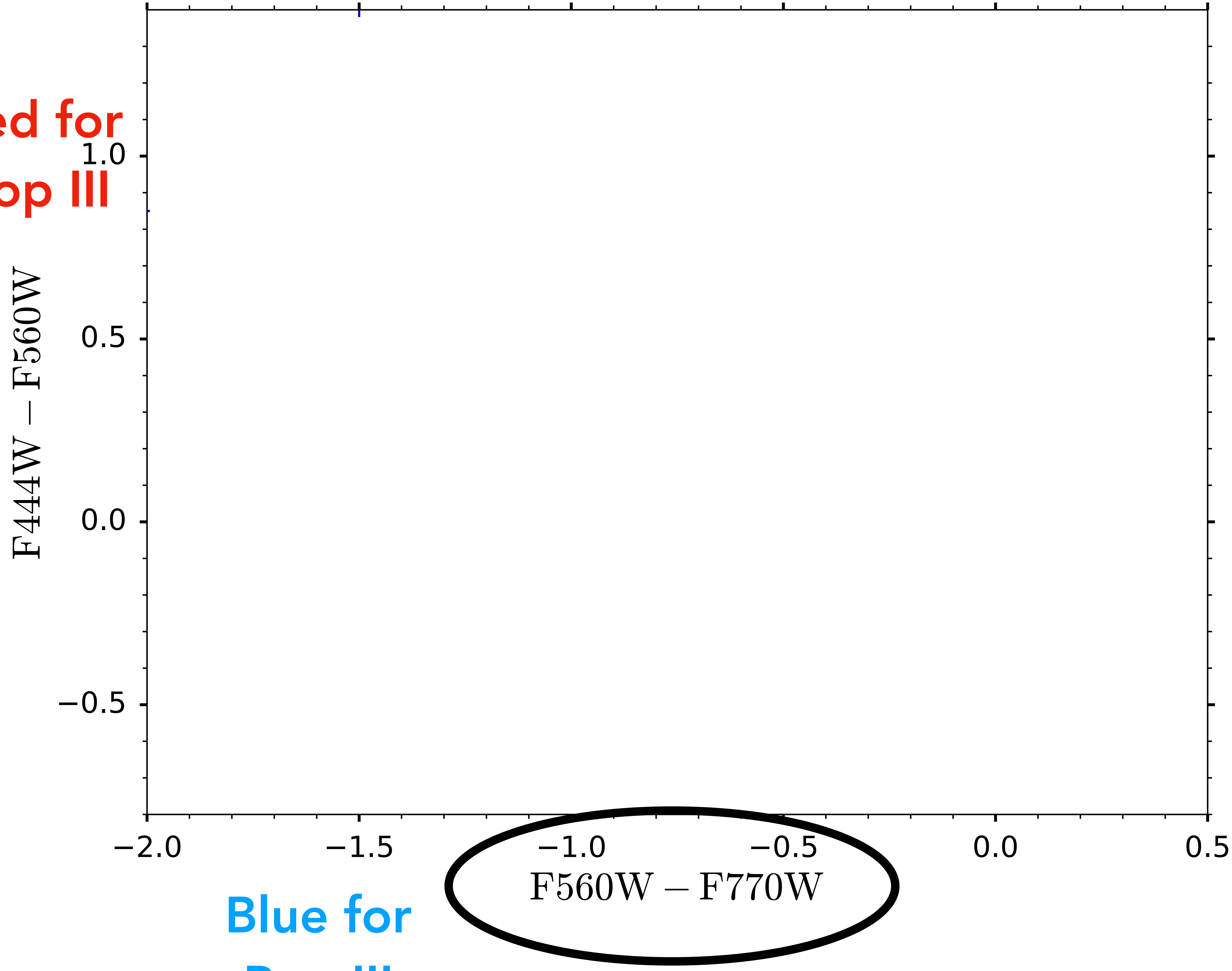
Colour–Colour selection



[S III] emission



Colour–Colour selection

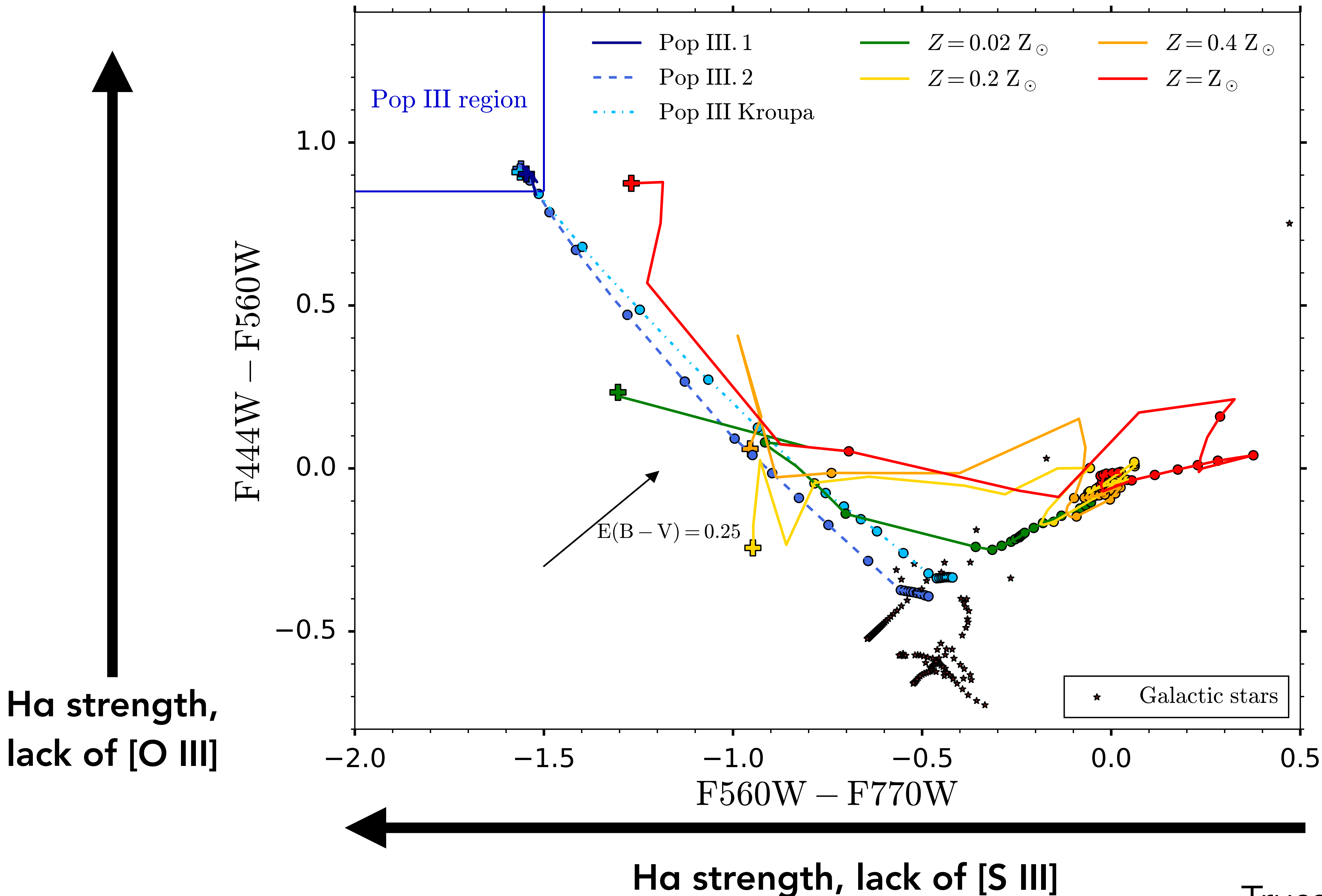


Red for Pop III

Blue for Pop III

James Trussler

Colour–Colour selection

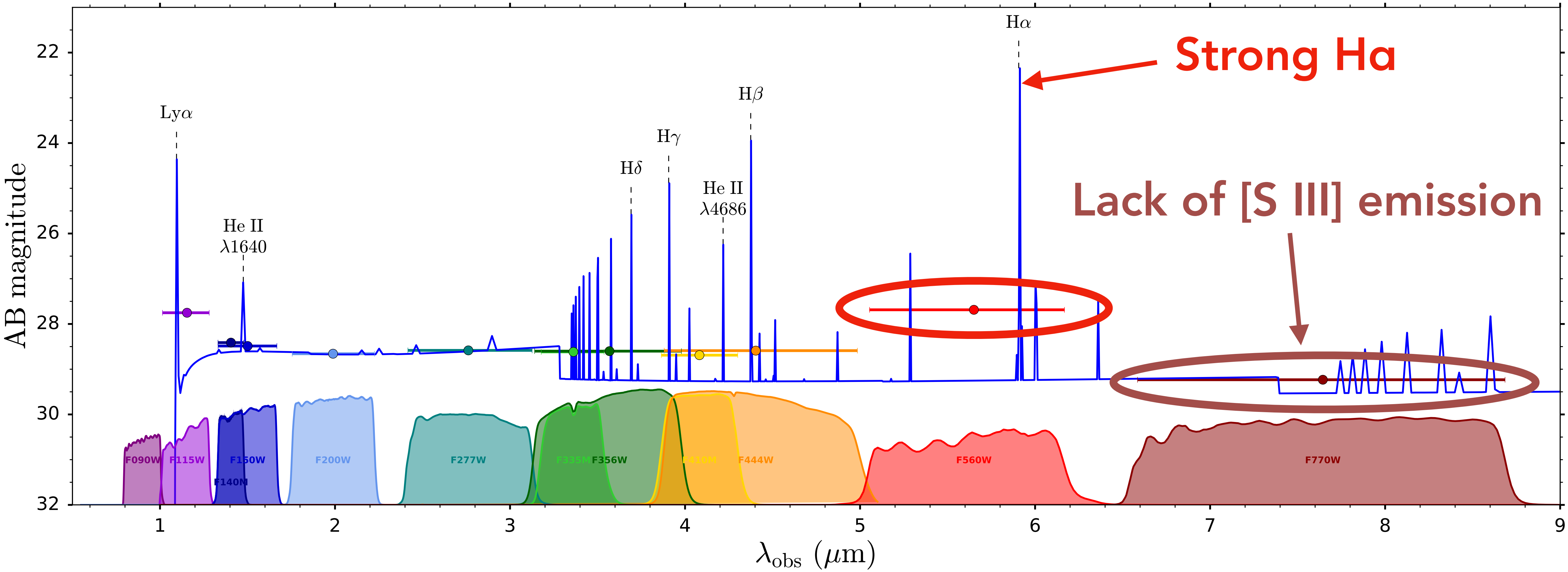


Trussler+22

MIRI imaging Hα, [S III]

z=8, 10^6 $M_\odot$ Pop III galaxy

Trussler+22



← NIRCam → ← MIRI →

James Trussler

NIRCam vs MIRI

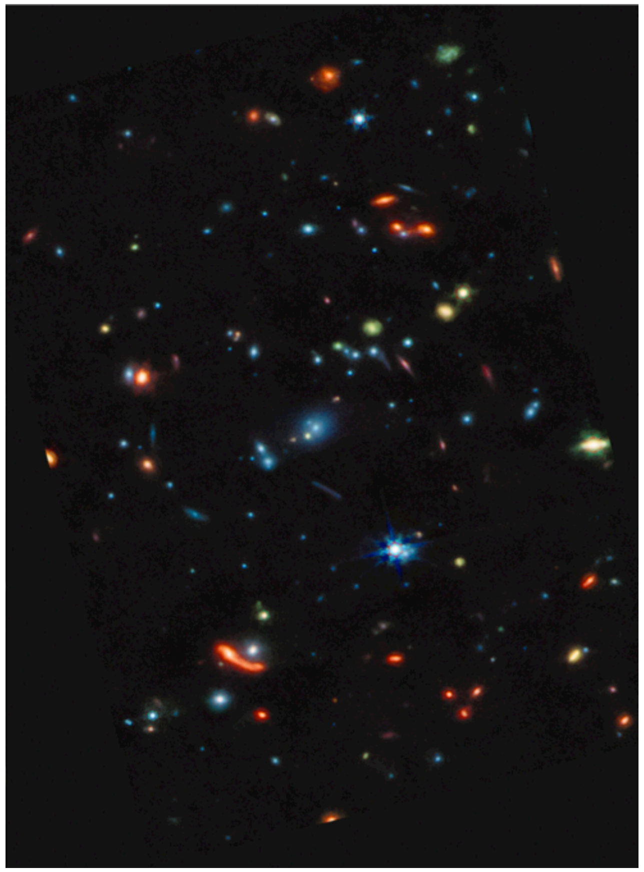
What **NIRCam** can detect in **1 hour**…

…**MIRI** detects in **50 hours**

NIRCam vs MIRI

What **NIRCam** can
survey and detect in **1 hour…**

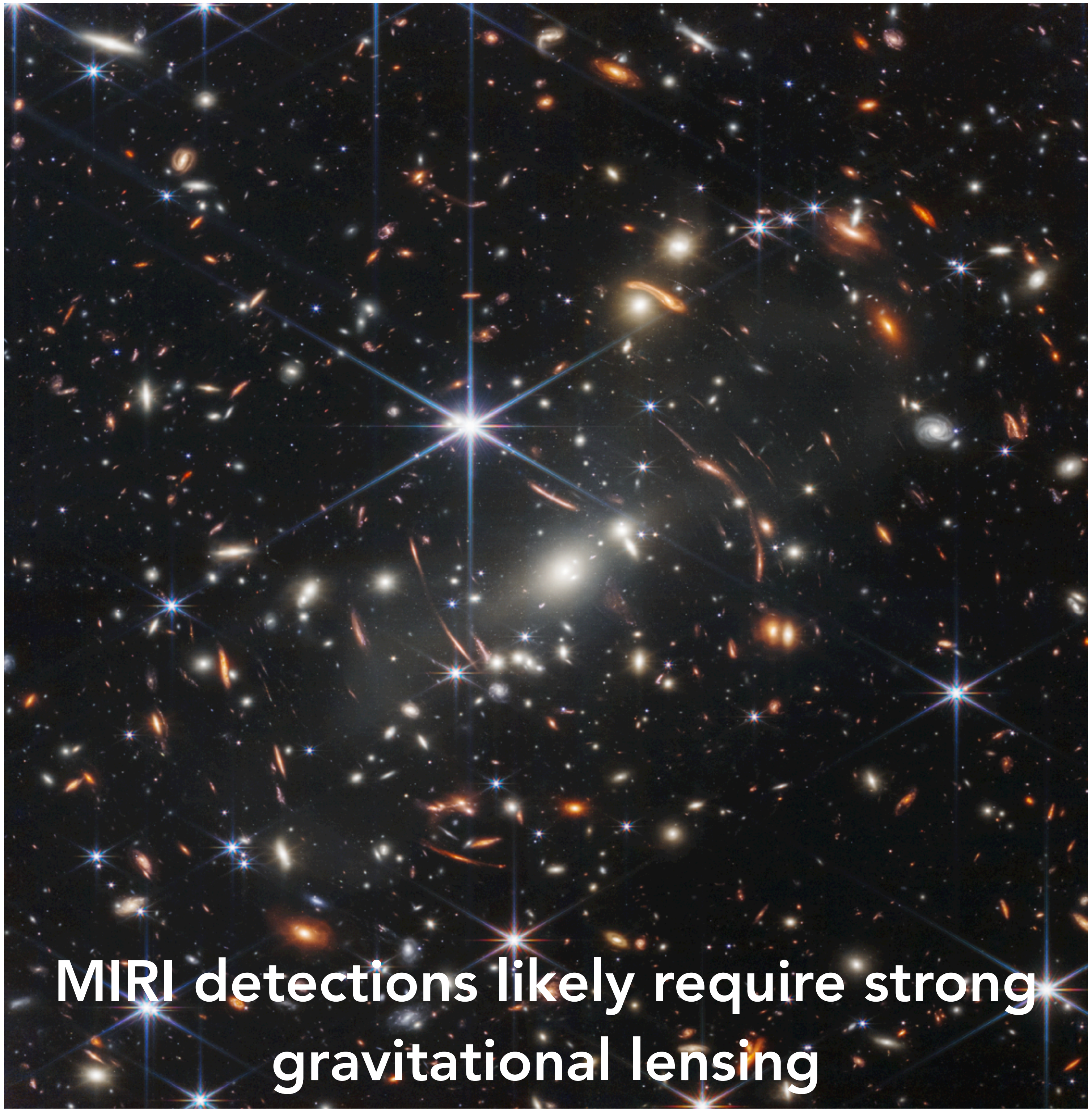
NIRCam vs MIRI



…MIRI surveys and detects in 200 hours

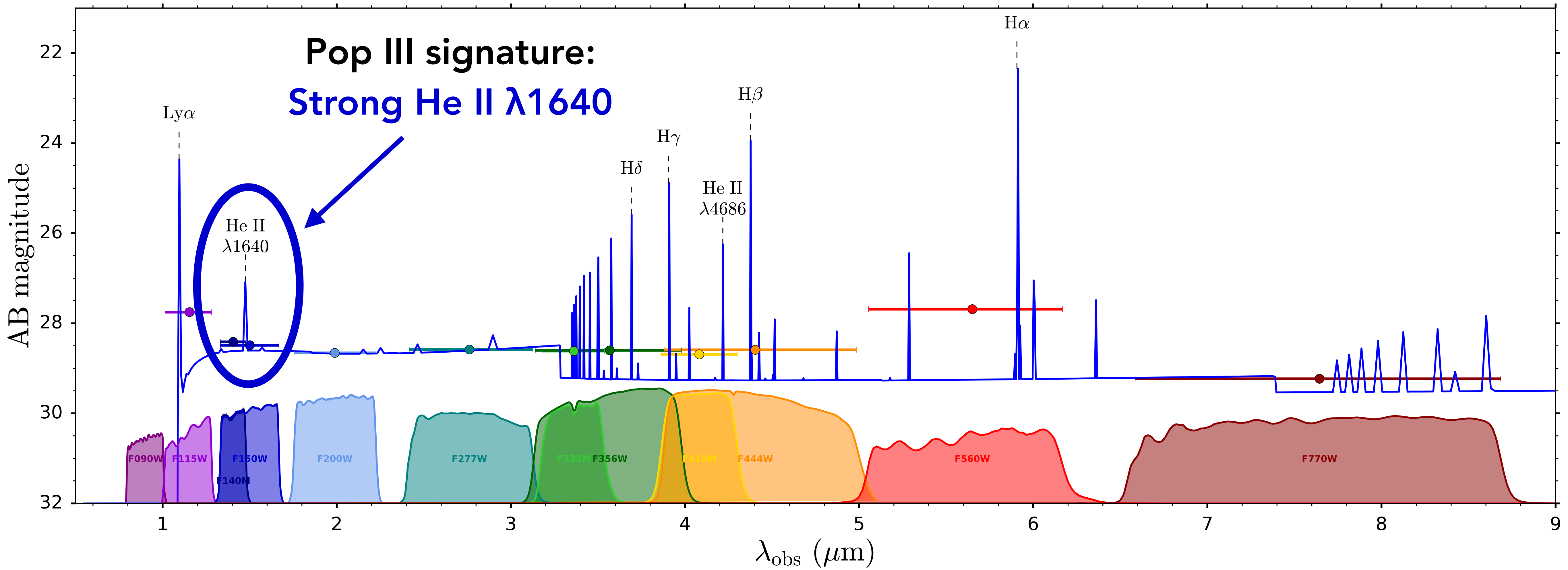
Credit: NASA, ESA, CSA, STScI and Webb ERO Production Team

MIRI: gravitational lensing



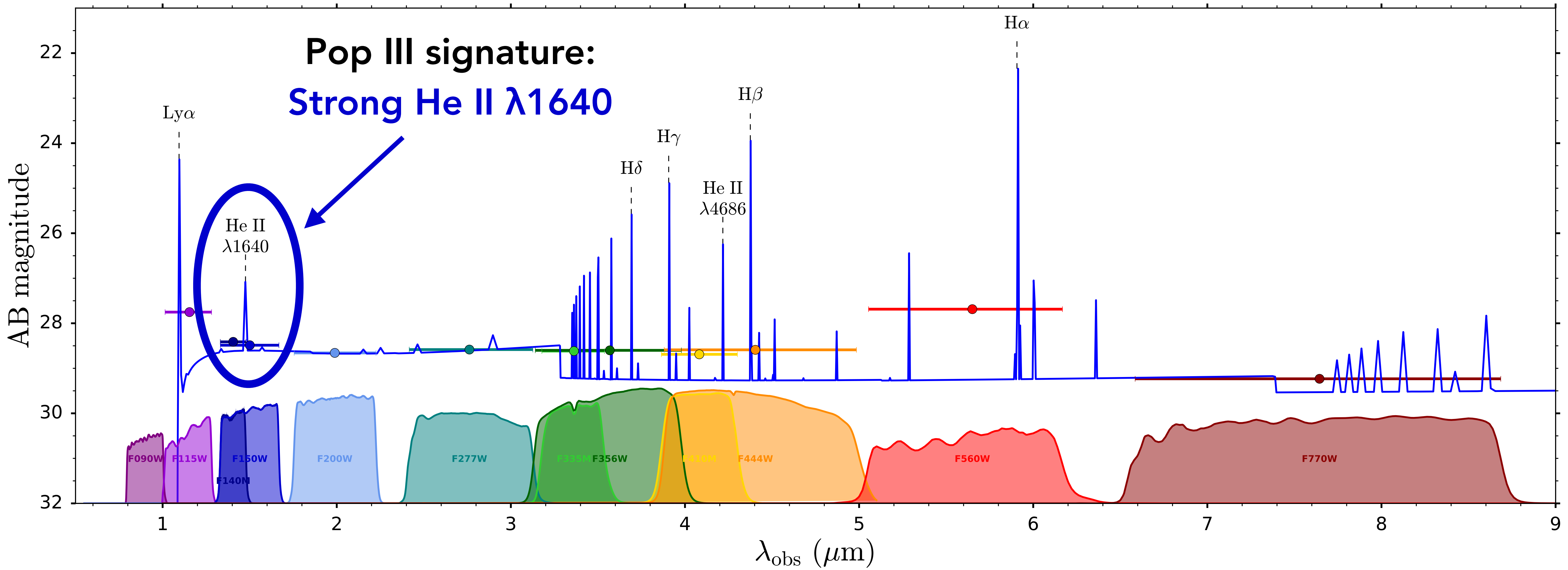
Credit: NASA, ESA, CSA, STScI

He II λ1640 emission



James Trussler

He II λ1640 emission



NIRCam medium-band imaging surveys that search for **strong He II λ1640 emitters:**

~0.15–0.30 mag signal

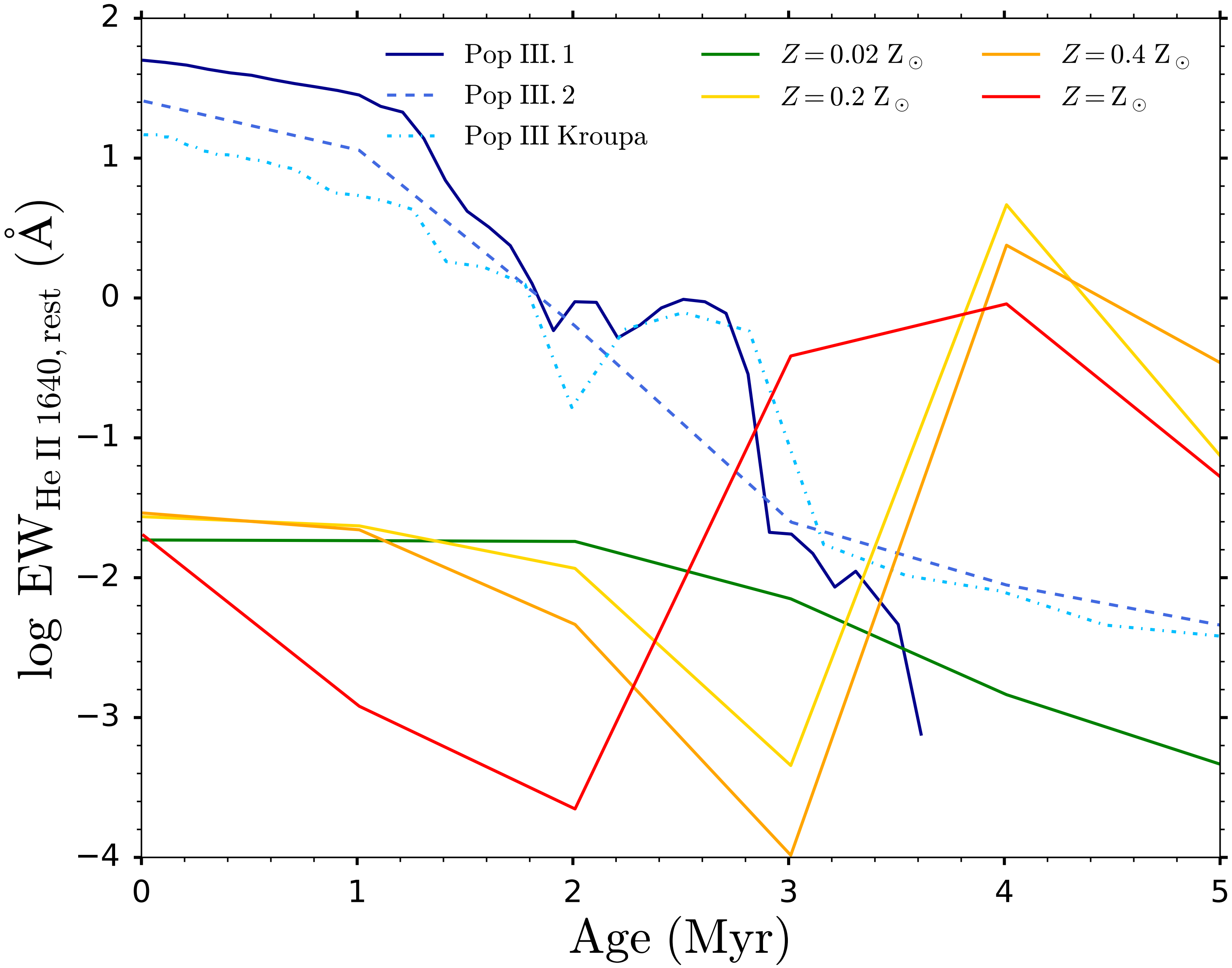
1–16 h for 5σ detection

Trussler+22

James Trussler

He II λ1640 equivalent width

Pop III: Substantially higher He II λ1640 EW

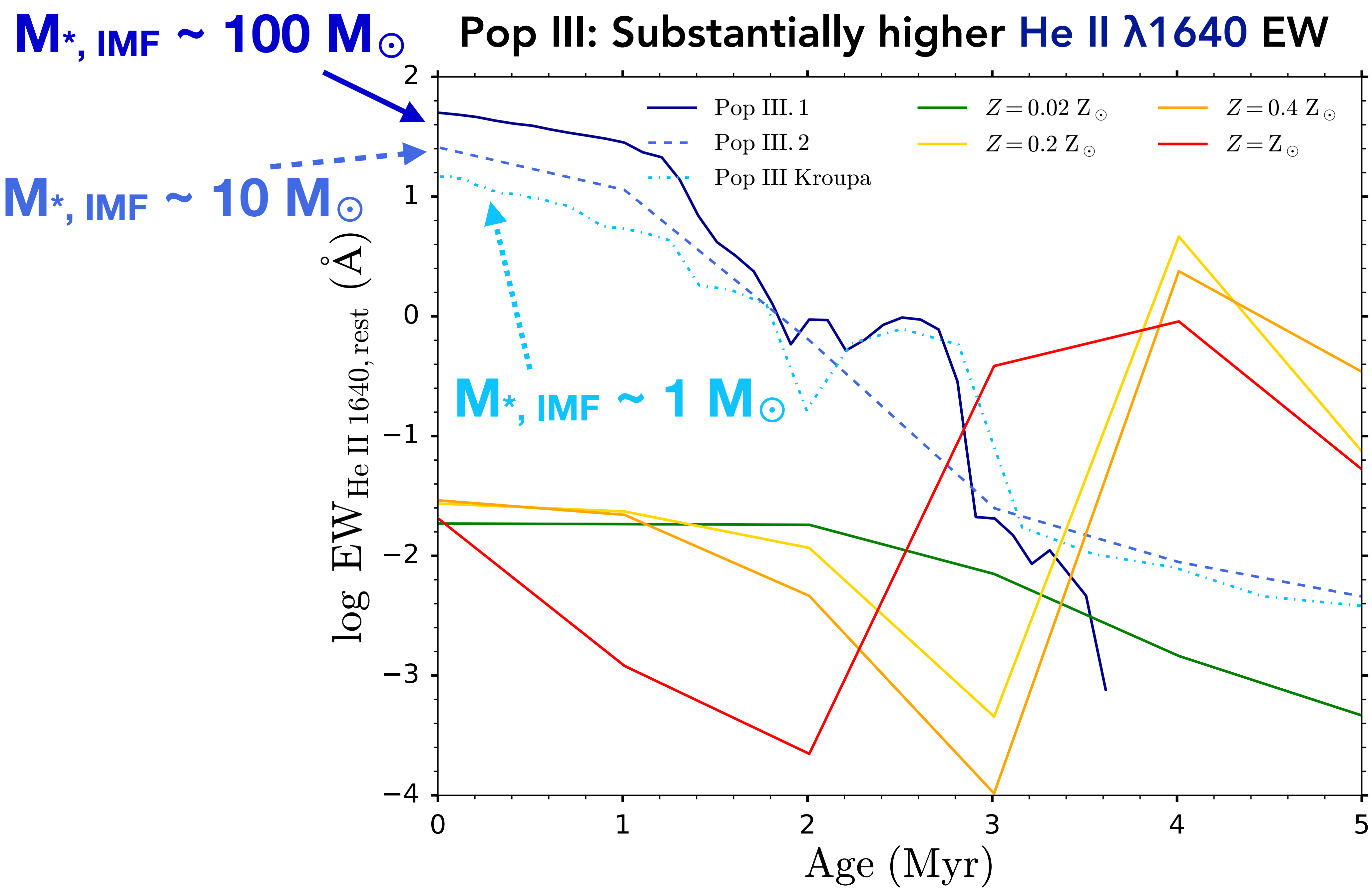


This diagnostic is the definitive Pop III indicator

Trussler+22

James Trussler

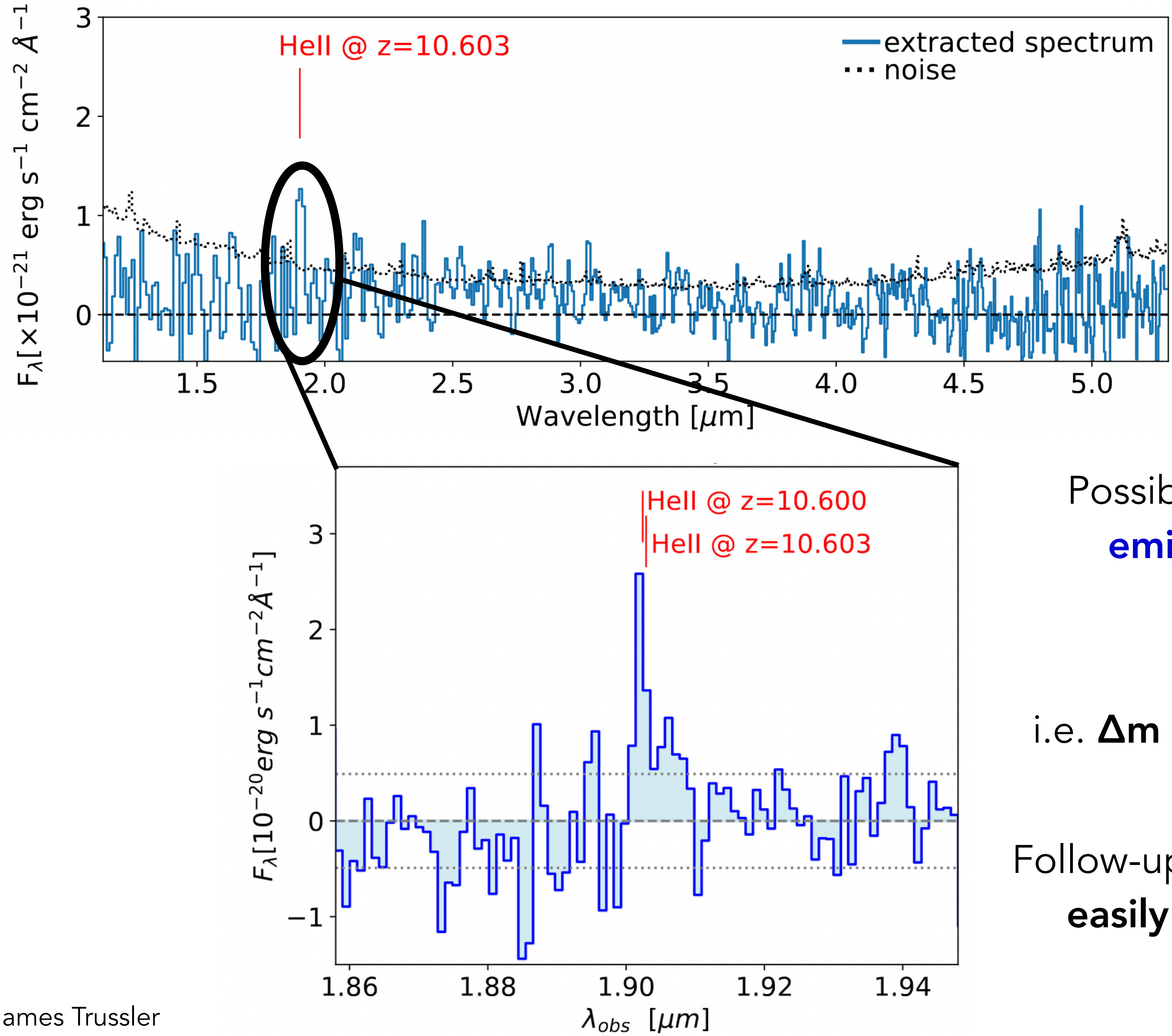
He II λ1640 equivalent width



This diagnostic is the definitive Pop III indicator

Trussler+22

Have we found Pop III candidates?



Maiolino+23

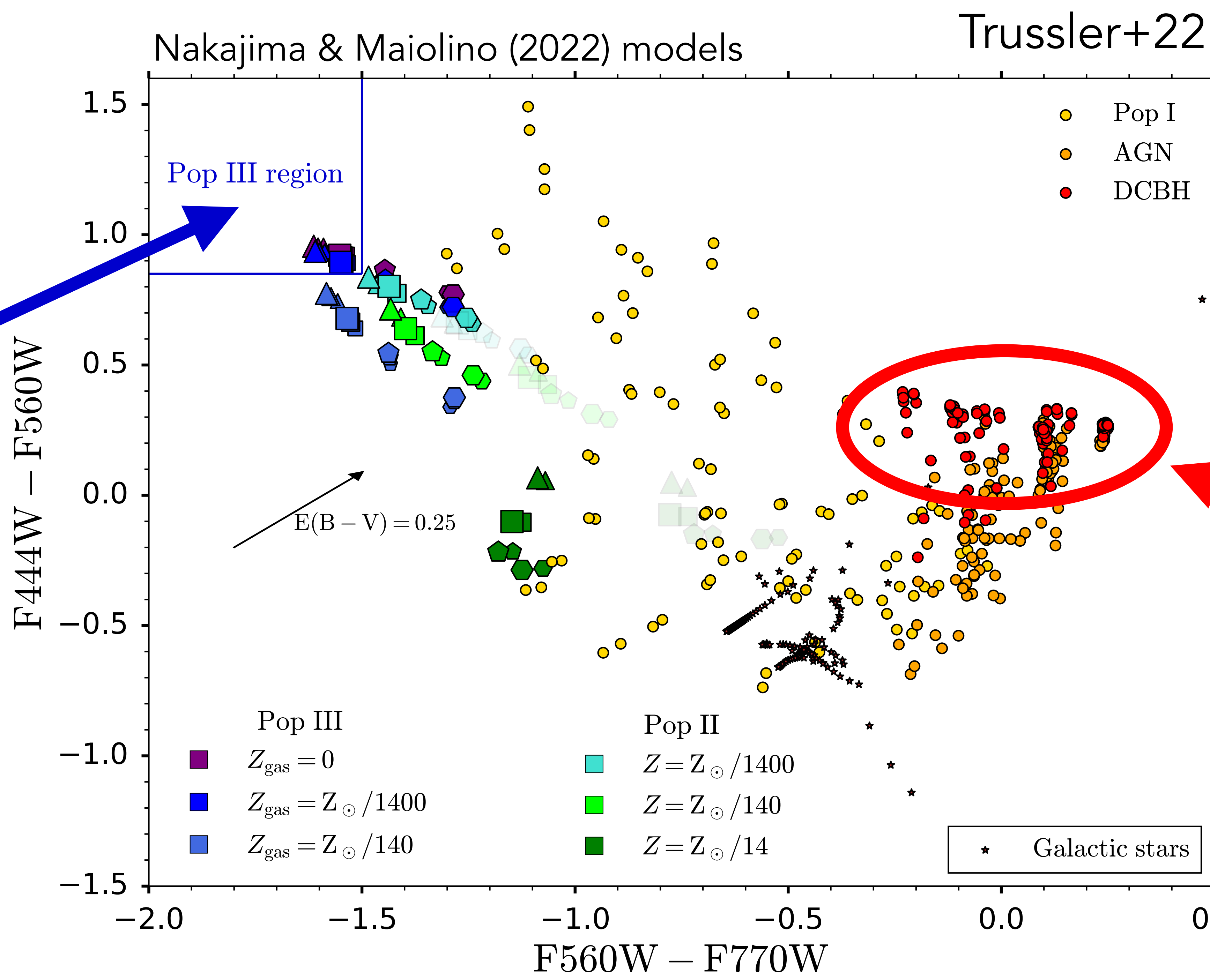
Possible **strong He II λ1640 emission** near **GN-z11**?

EW = 170 Å,

i.e. **Δm ≈ 0.65 mag for F182M!**

Follow-up, **deeper imaging**, could **easily confirm** this emission!

Distinguishing between Pop III and DCBH



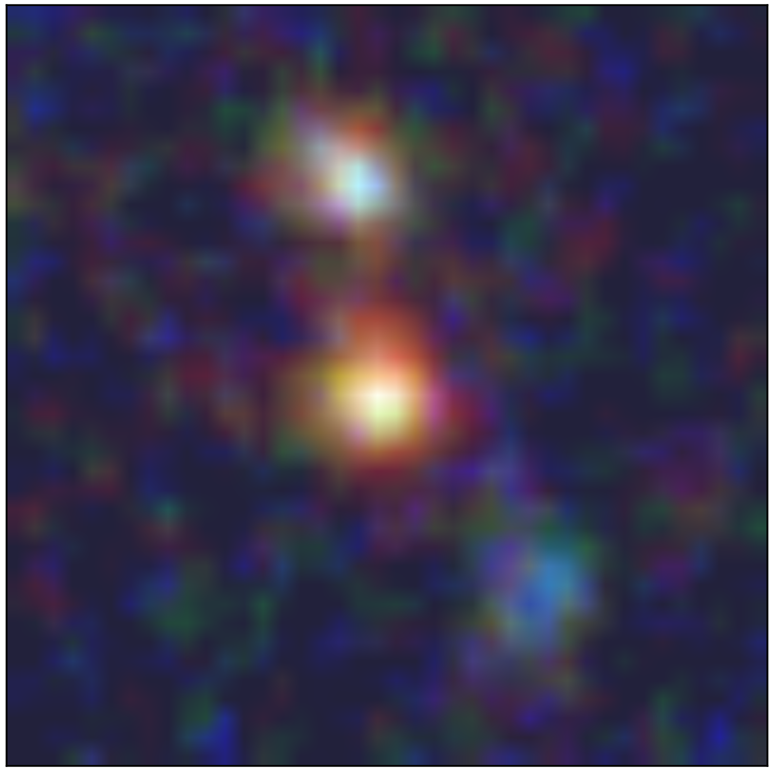
Pop III

DCBH
($f_\nu \sim \nu^{-\alpha}$)

Pop III galaxies and **DCBH** have **distinct colours**

James Trussler

First galaxies: Indirect



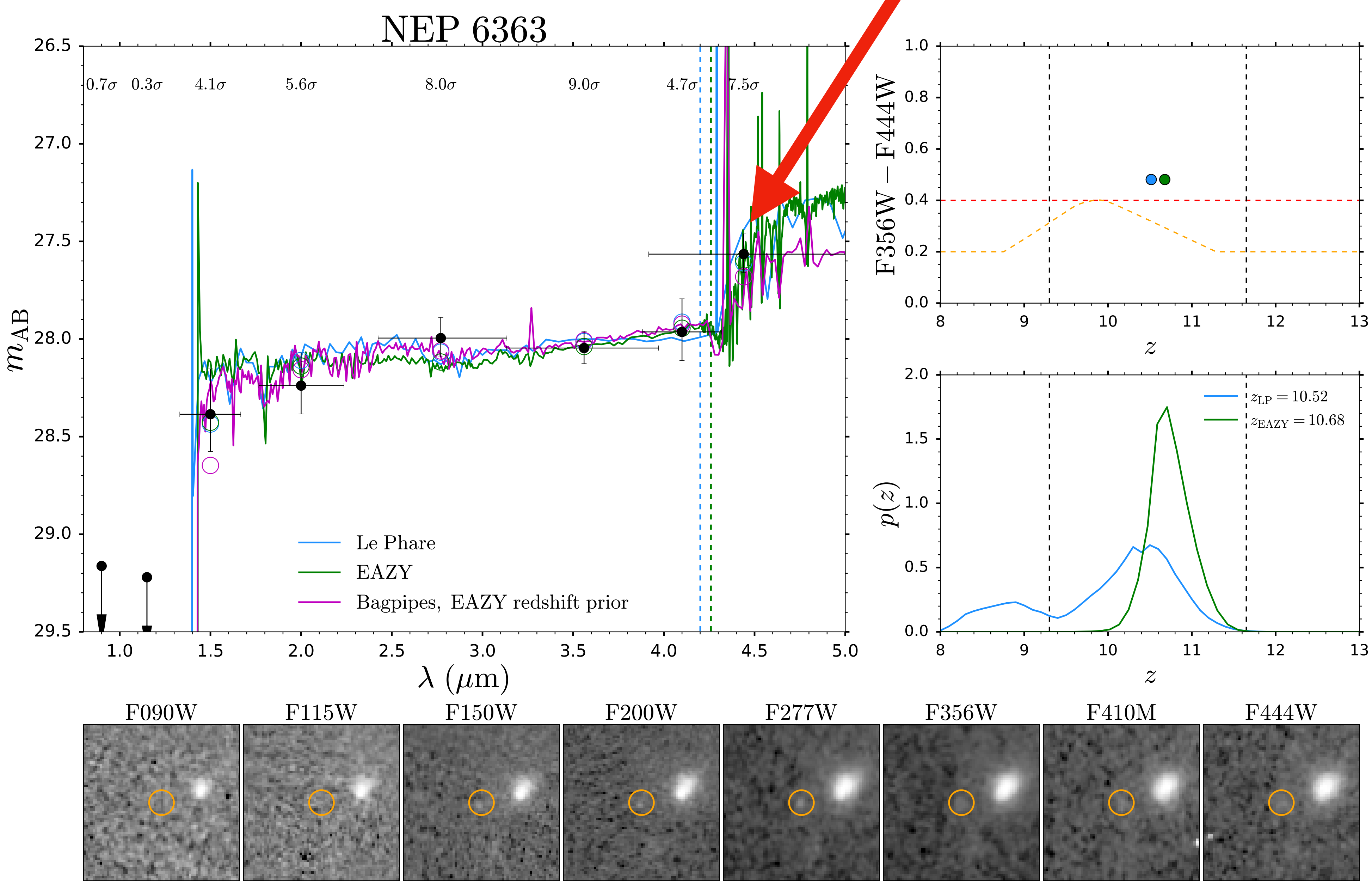
When cosmic dawn **breaks**:

Evidence for **evolved** stellar populations in **7 < z < 12 galaxies**

Trussler+23, in prep.

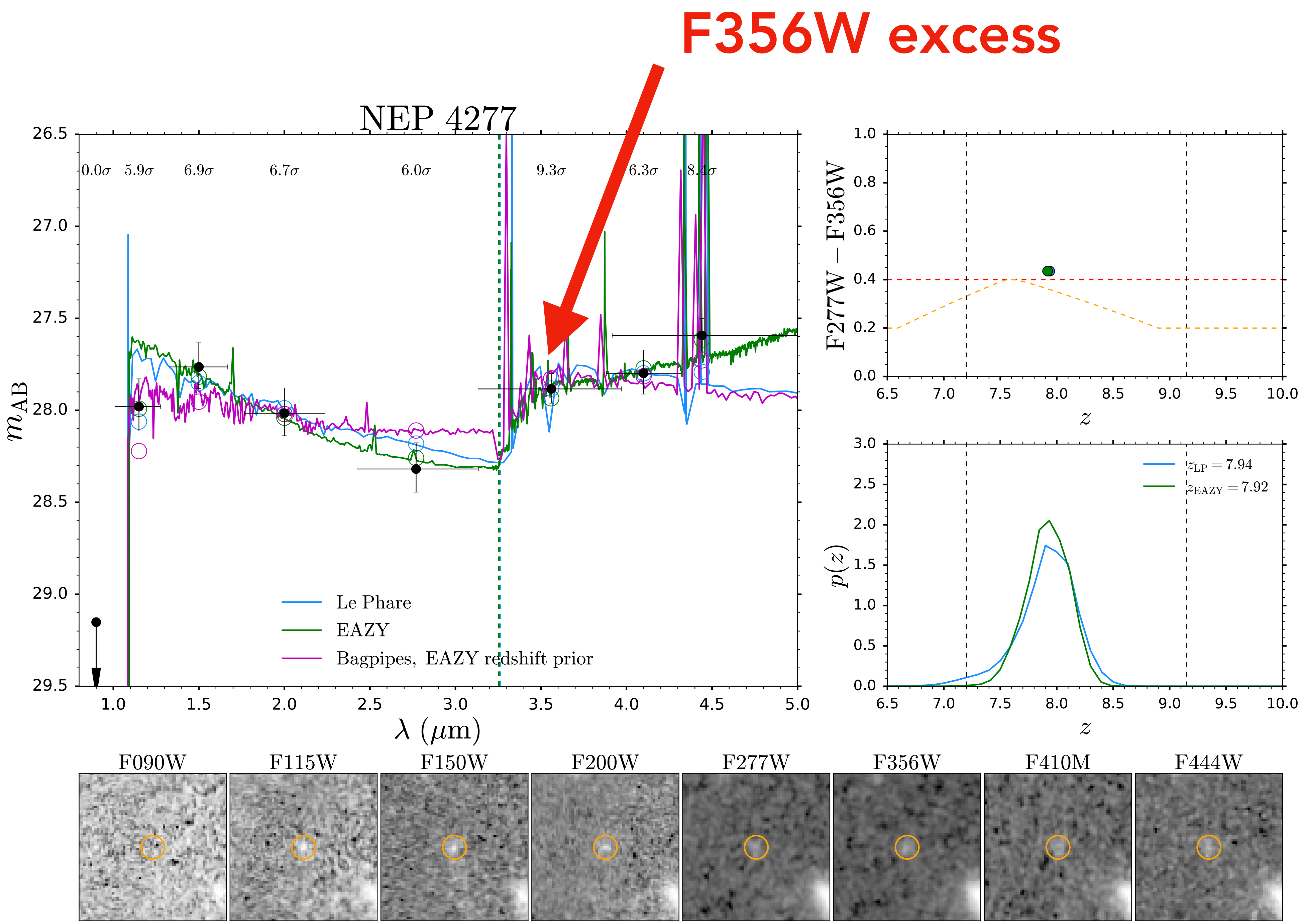
z~10.5 Balmer break candidate

F444W excess



Trussler+23, in prep.

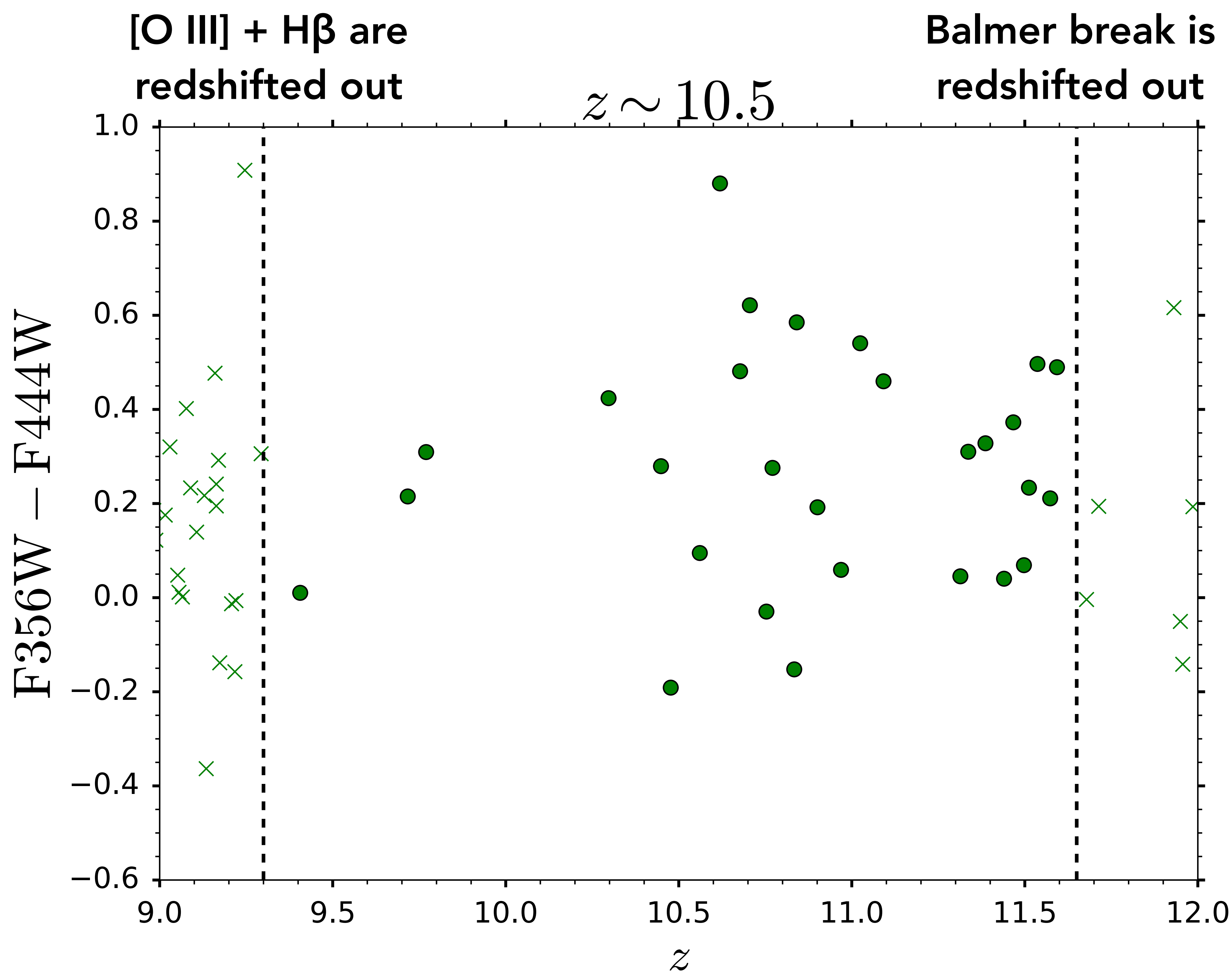
z~8 Balmer break candidate



James Trussler

Trussler+23, in prep.

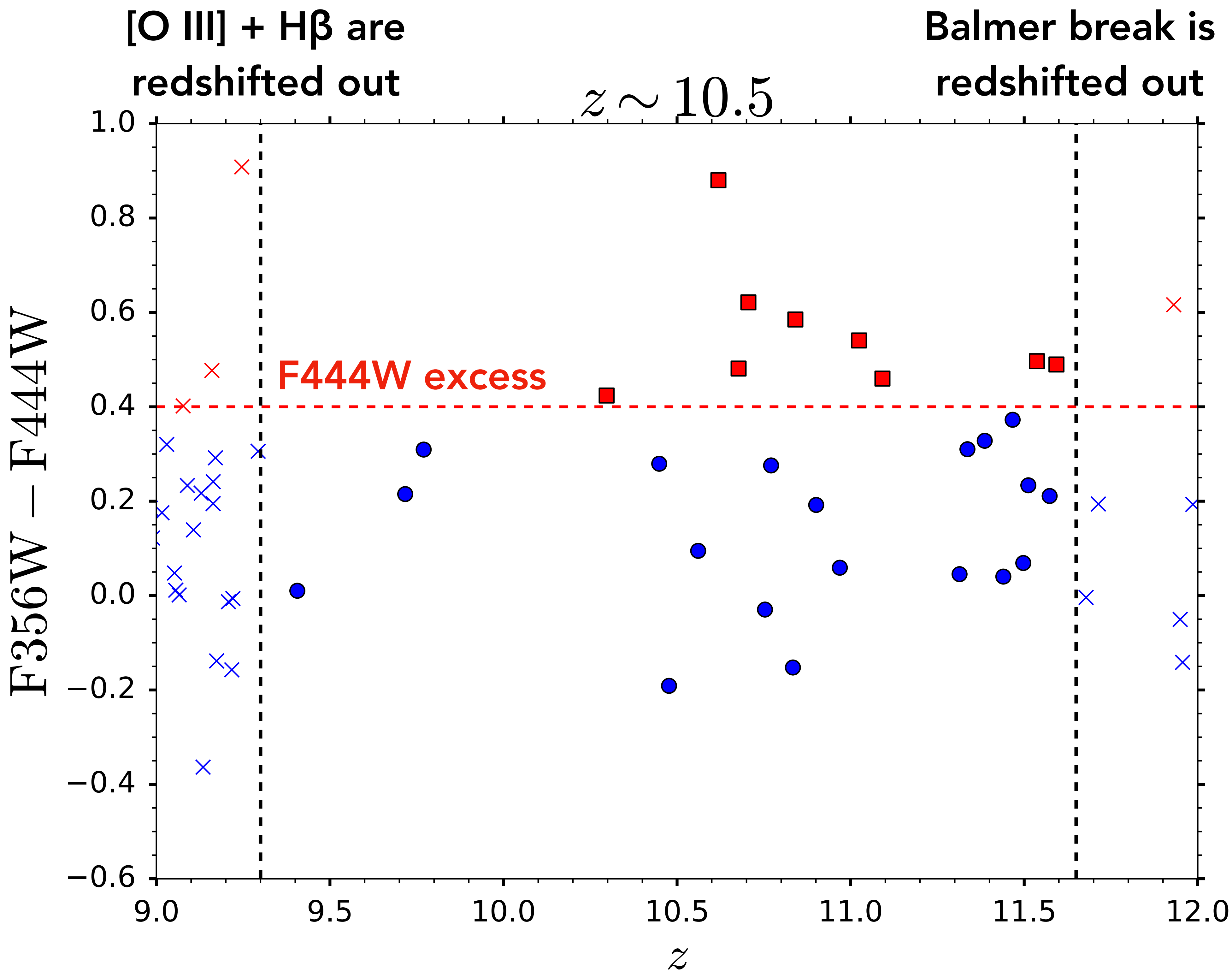
Balmer break selection



See also Laporte+21

Trussler+23, in prep.

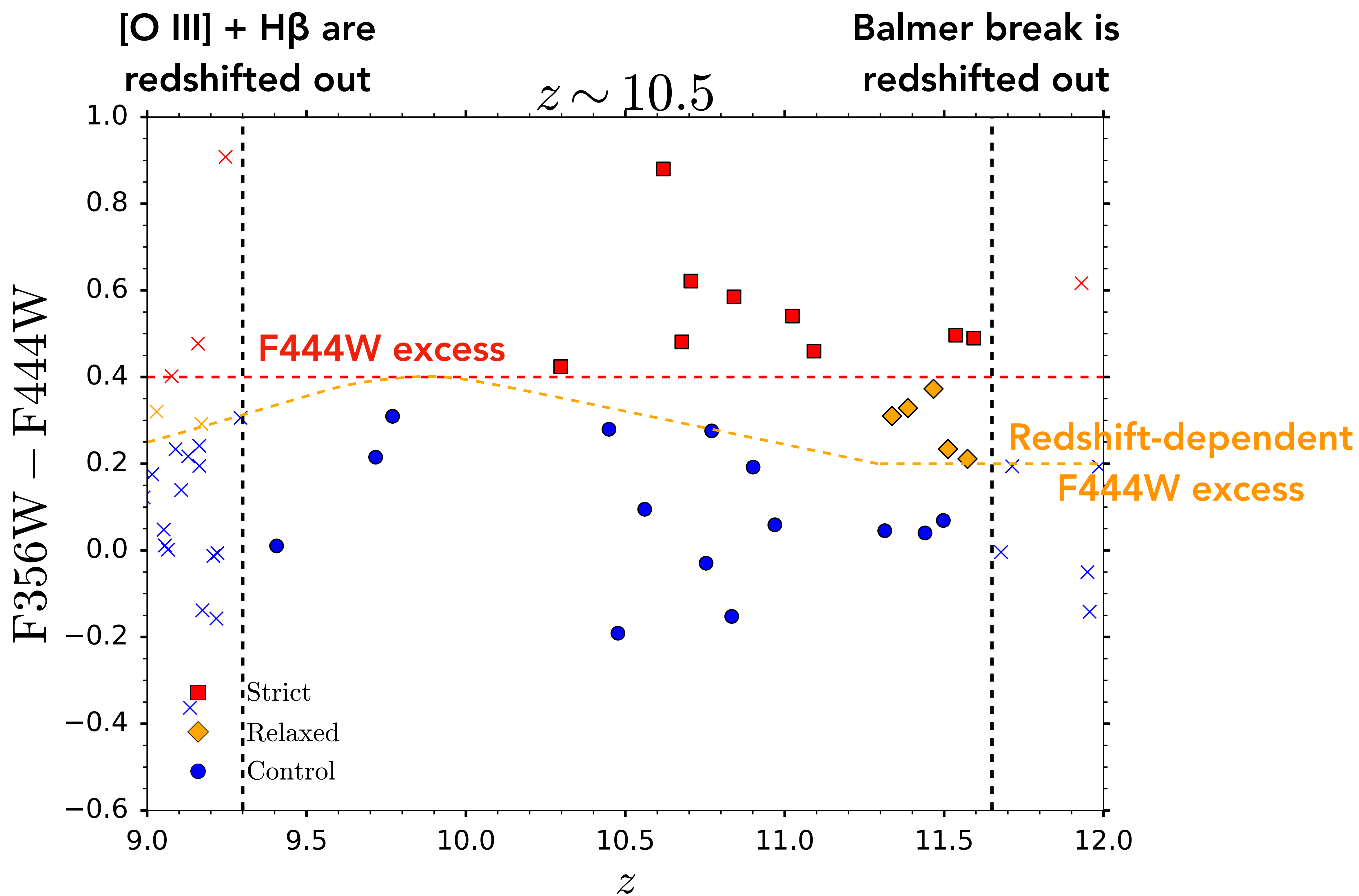
Balmer break selection



See also Laporte+21

Trussler+23, in prep.

Balmer break selection



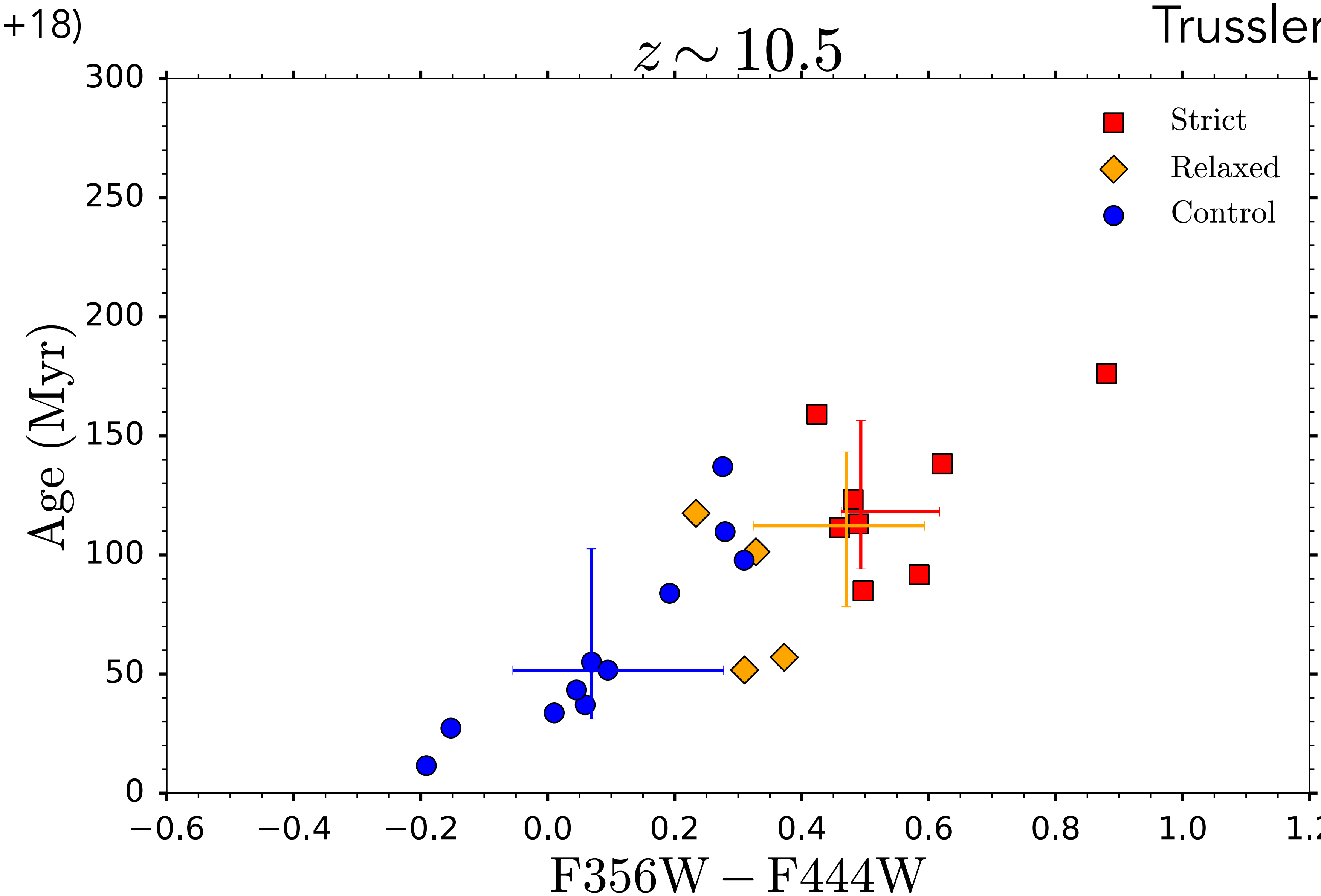
See also Laporte+21

Trussler+23, in prep.

Inferred stellar ages

Bagpipes (Carnall+18)

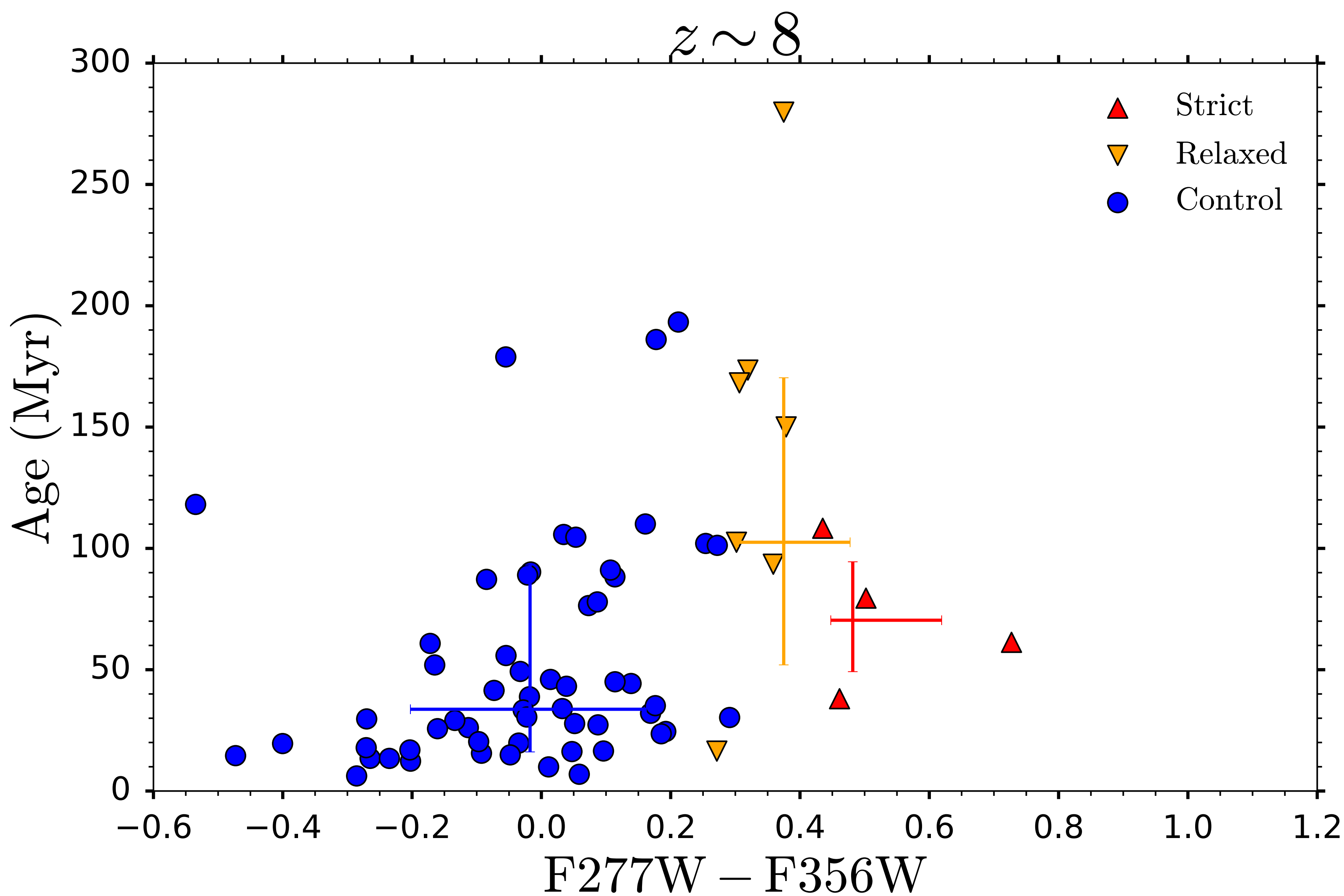
Trussler+23, in prep.



Balmer break seemingly a good predictor of the mass-weighted stellar age?

Ages_{MW}: ~75–175 Myr, i.e. z=13–14

Inferred stellar ages

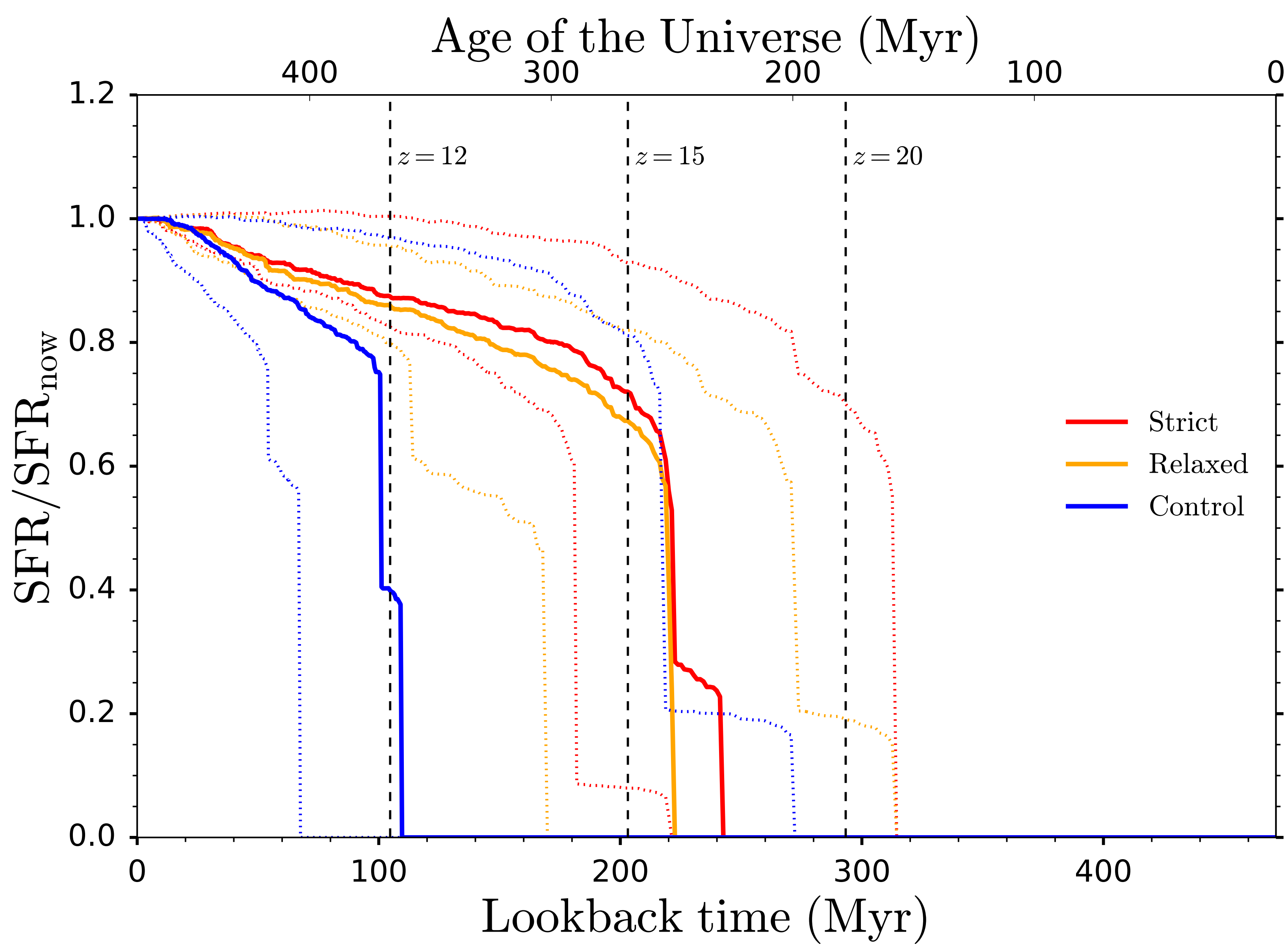


Weaker trends at z~8: **F444W** now probes **[O III] + Hβ**, thus providing additional **constraints** on the **current SFRs**

—> **MIRI F560W** needed at **z~10.5**

Trussler+23, in prep.

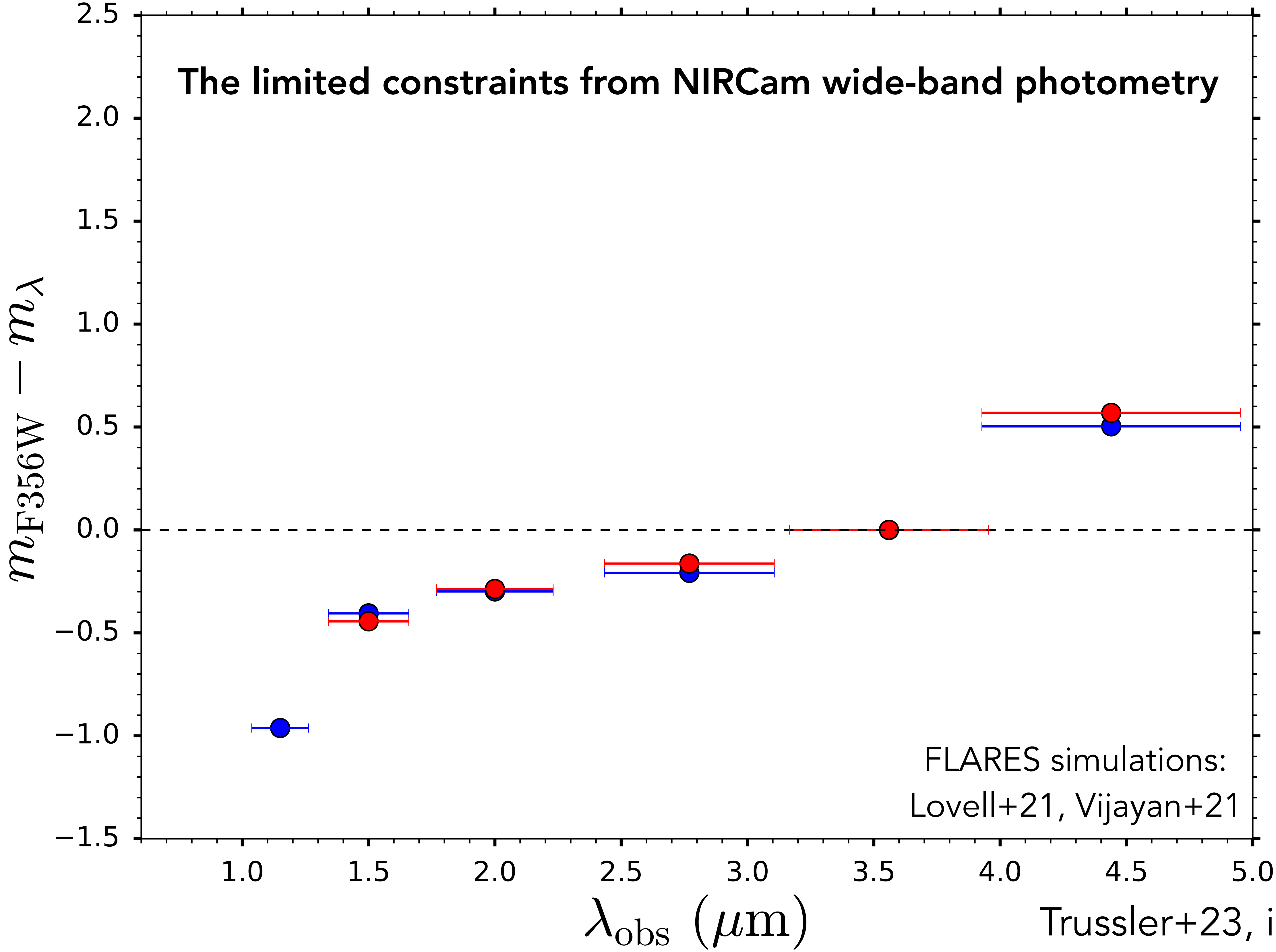
Inferred star formation histories



Deep NIRSpec continuum spectroscopy and **MIRI imaging** will provide the strongest indirect constraints on the onset of star formation in the Universe

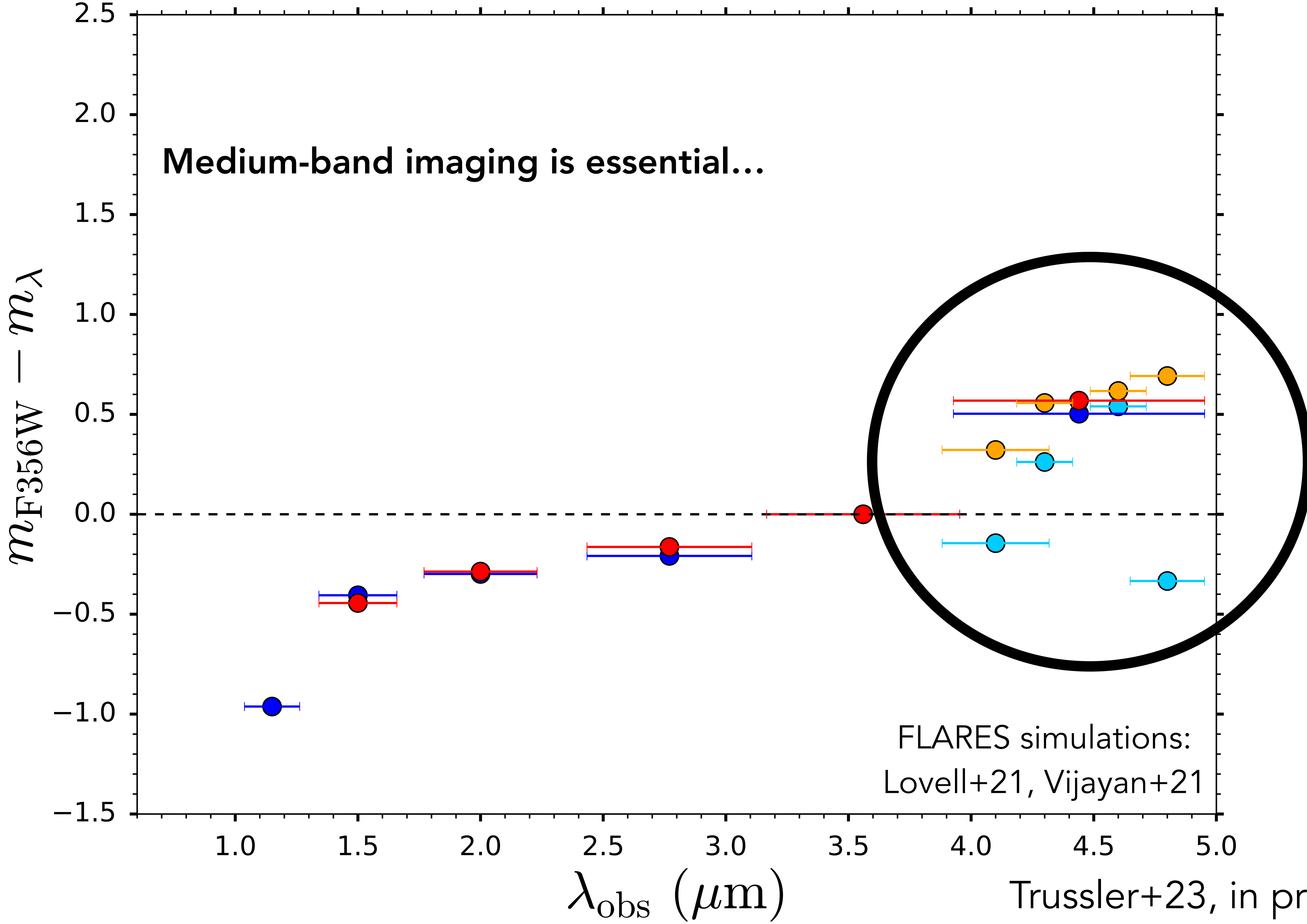
Trussler+23, in prep.

NIRCam wide-band photometry



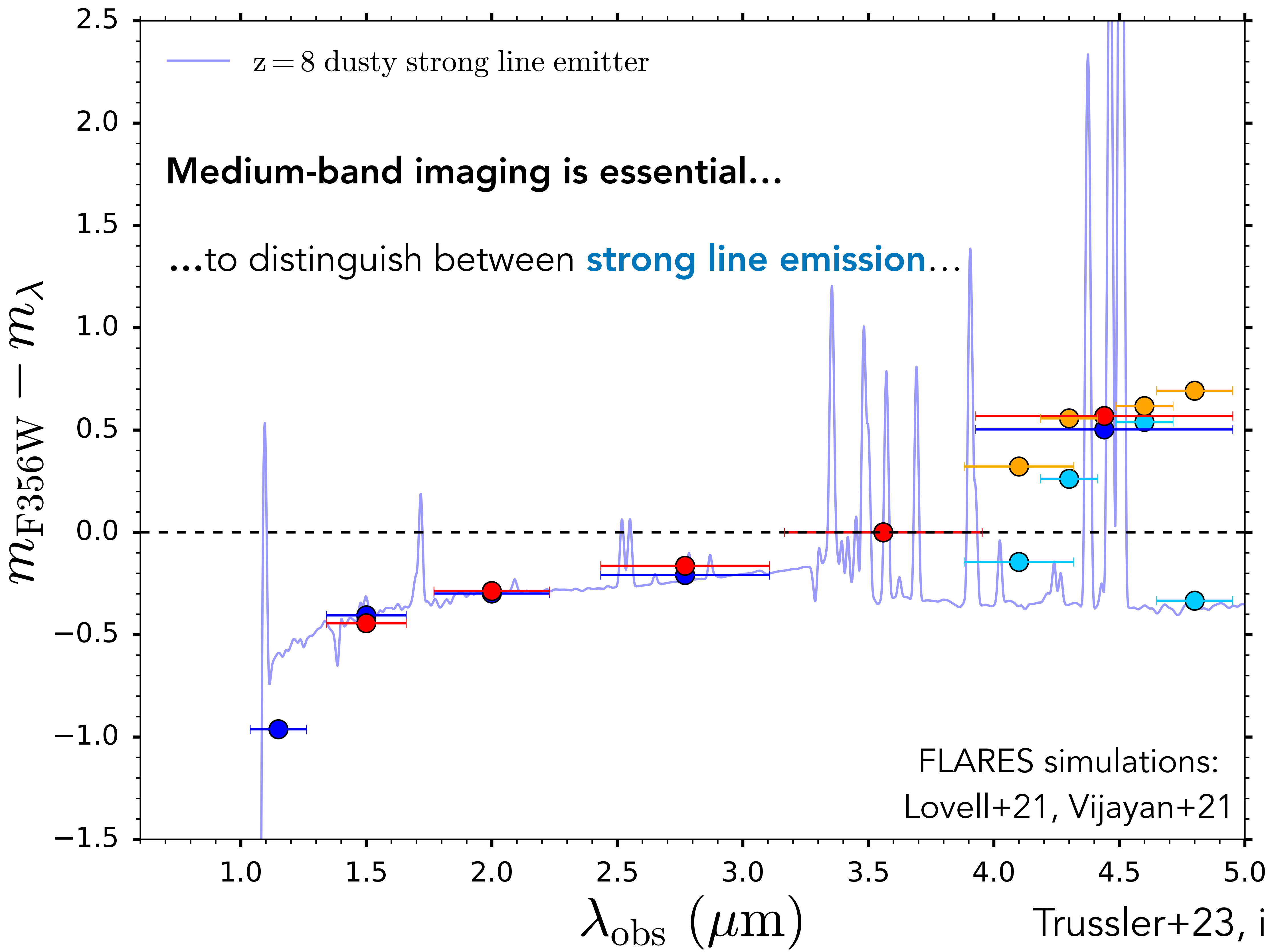
Trussler+23, in prep.

NIRCam medium-band photometry



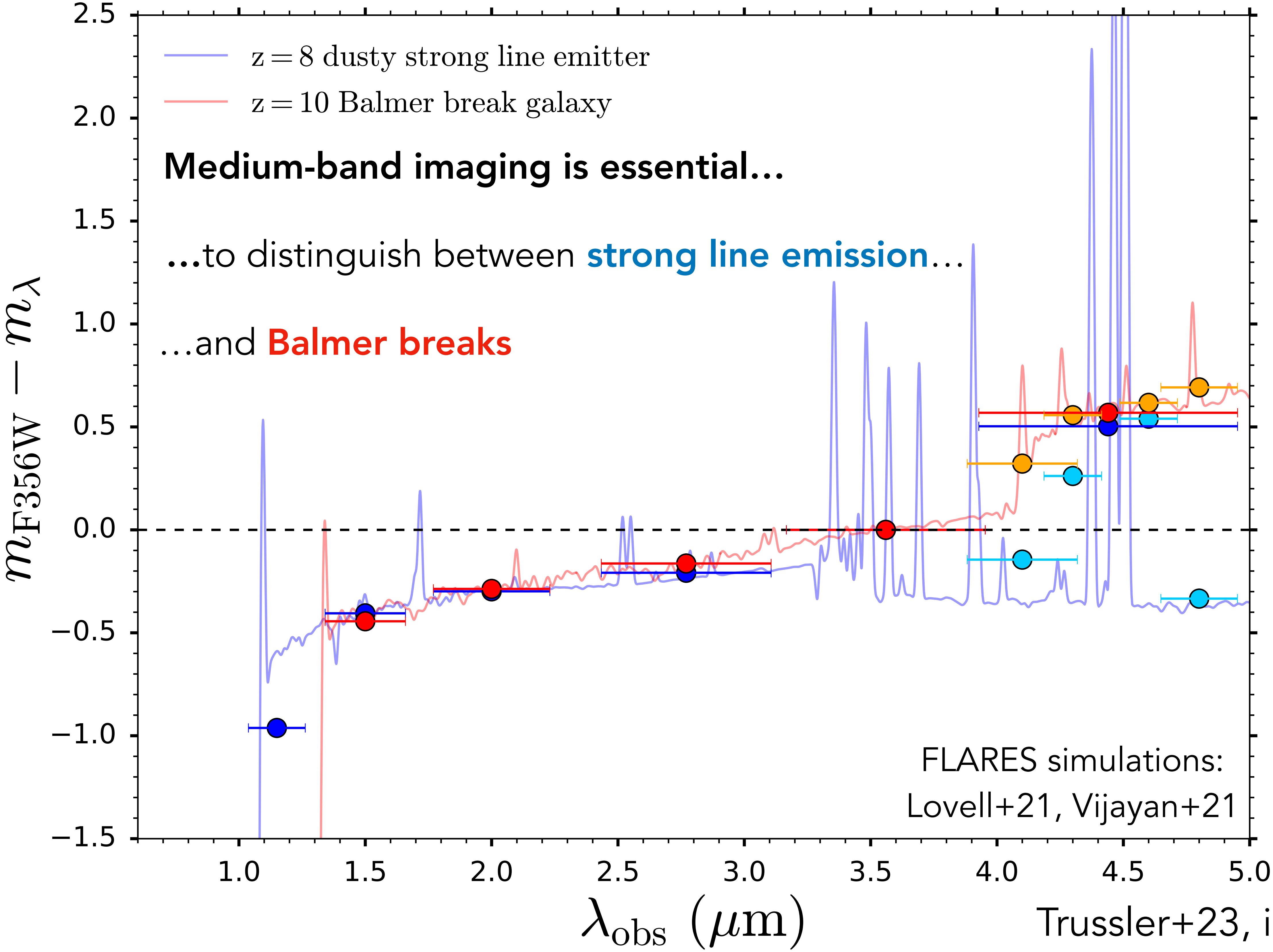
Trussler+23, in prep.

NIRCam medium-band photometry



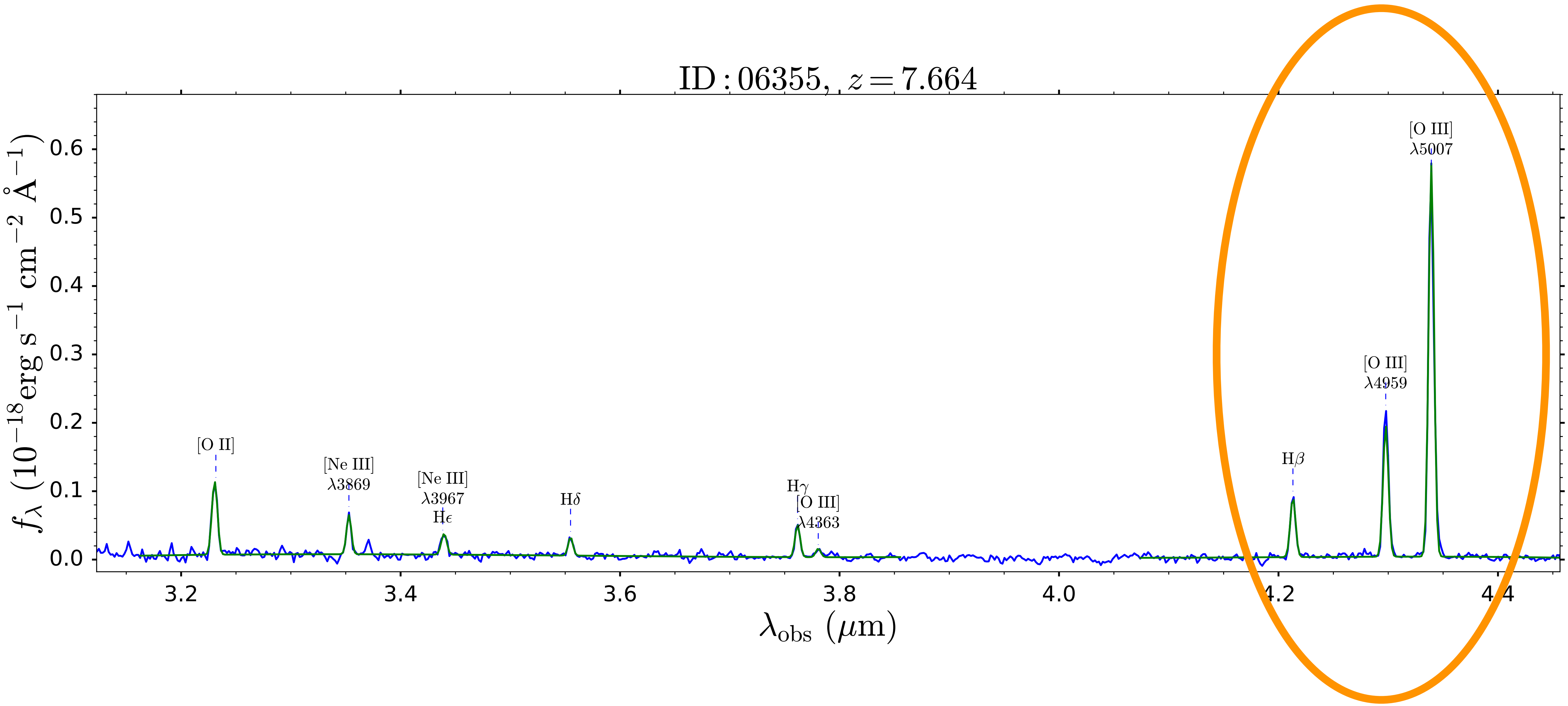
Trussler+23, in prep.

NIRCam medium-band photometry



Trussler+23, in prep.

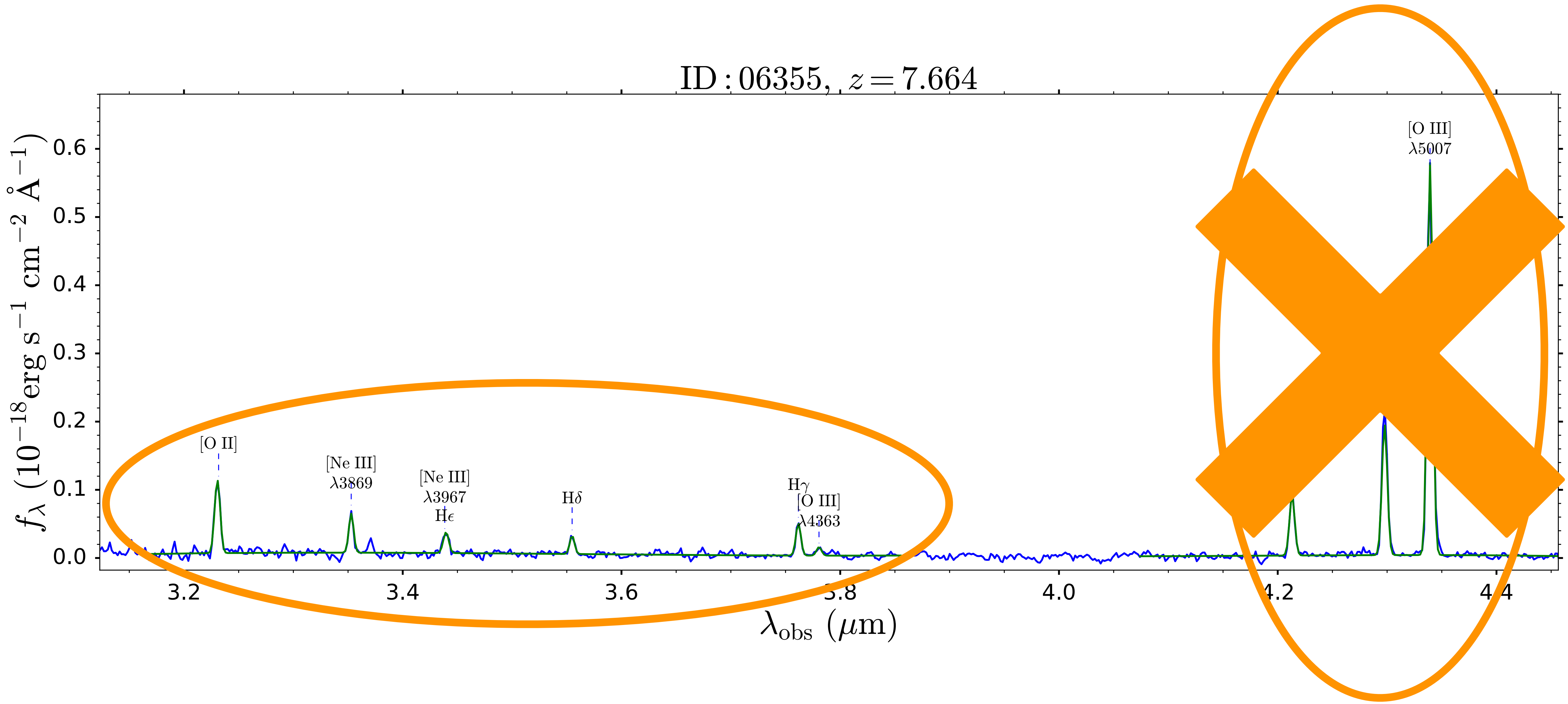
Strong emission lines



[O III], Hβ

James Trussler

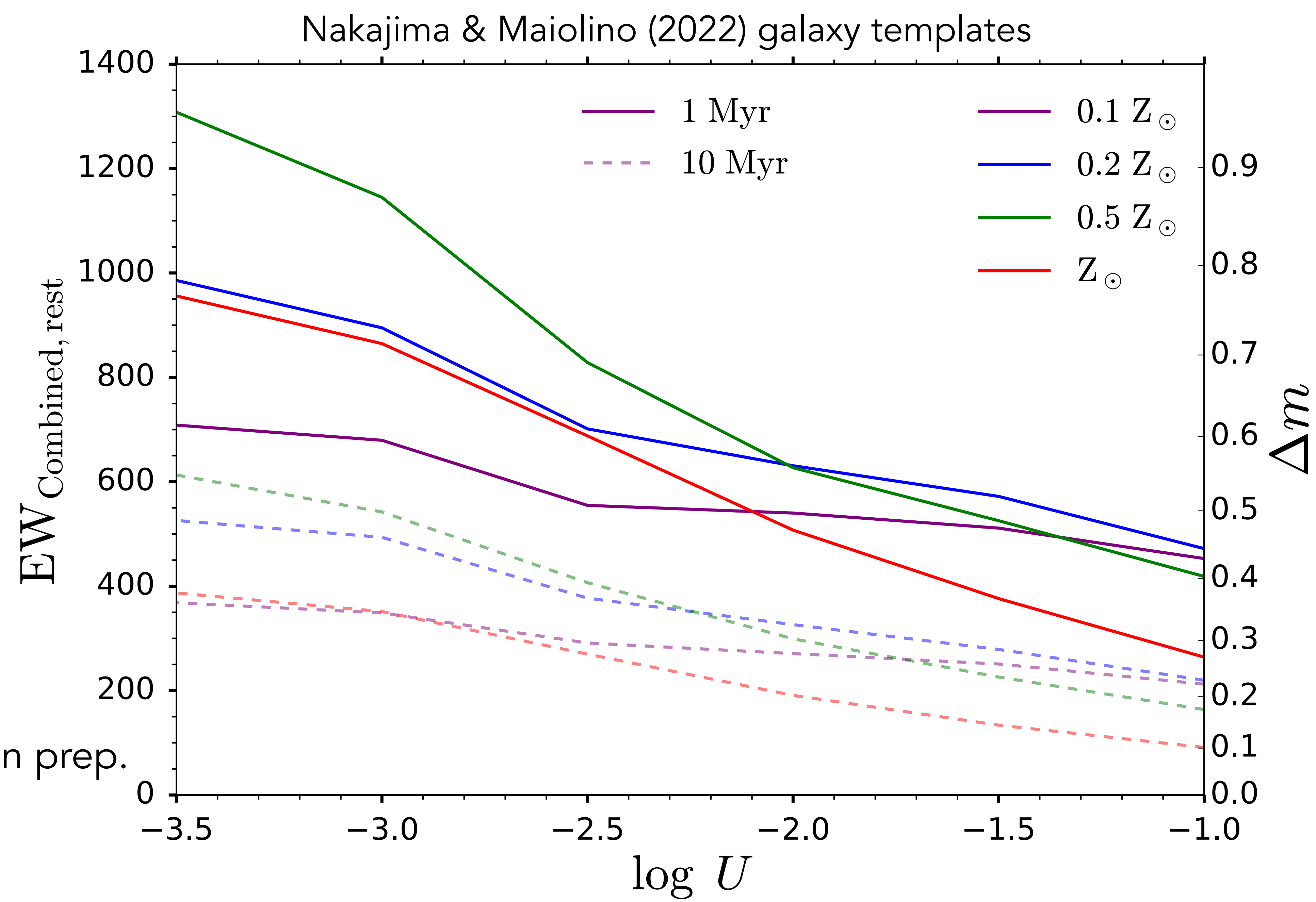
Weak emission lines



[O II], [Ne III], Hγ, Hδ etc.

James Trussler

Weak emission lines



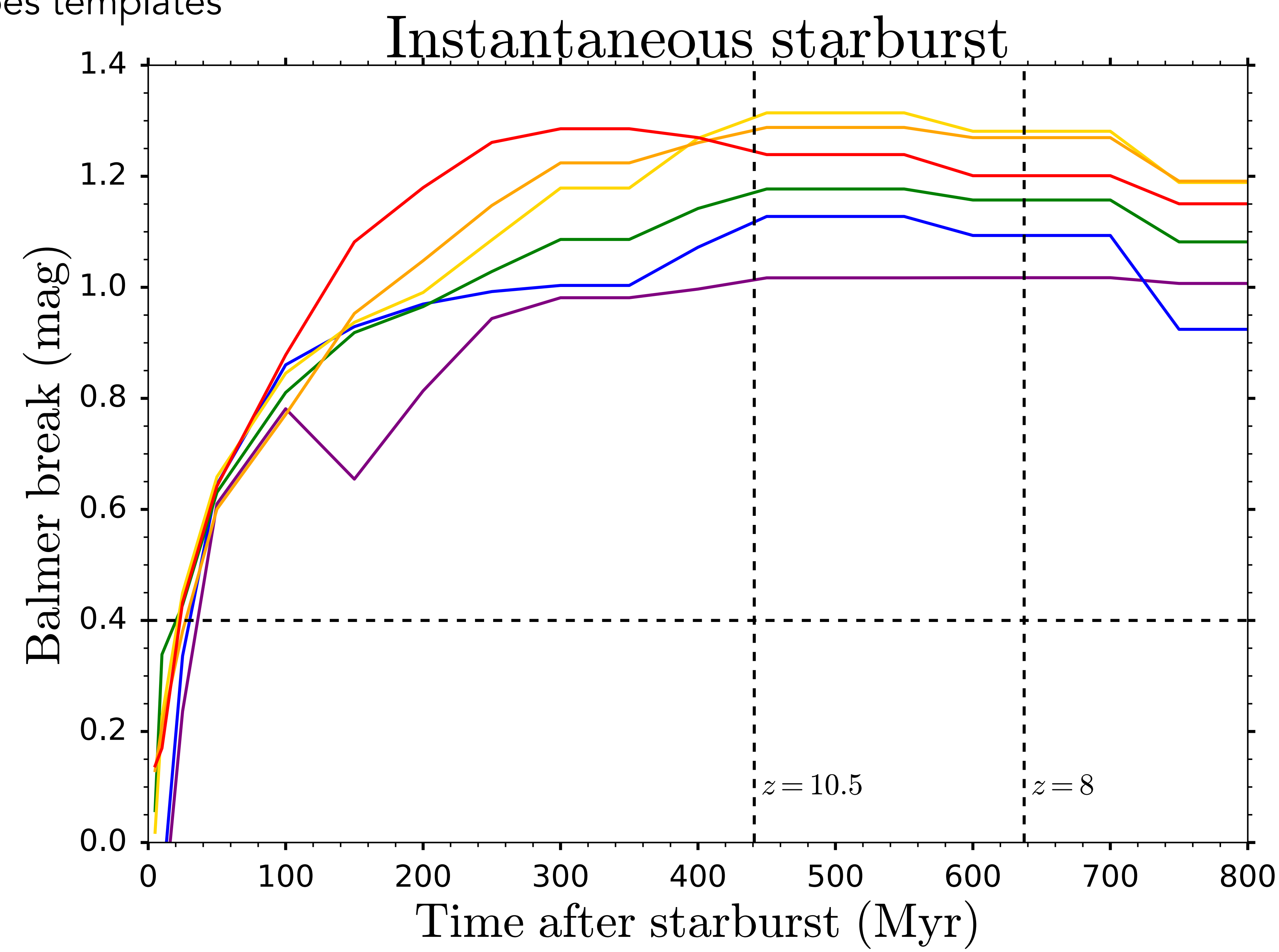
Trussler+23, in prep.

When **combined** together, these individually **weak** emission lines can have a **non-negligible contribution** to **broadband photometry, mimicking** the **Balmer break signature**

James Trussler

The Balmer break as a proxy for stellar age

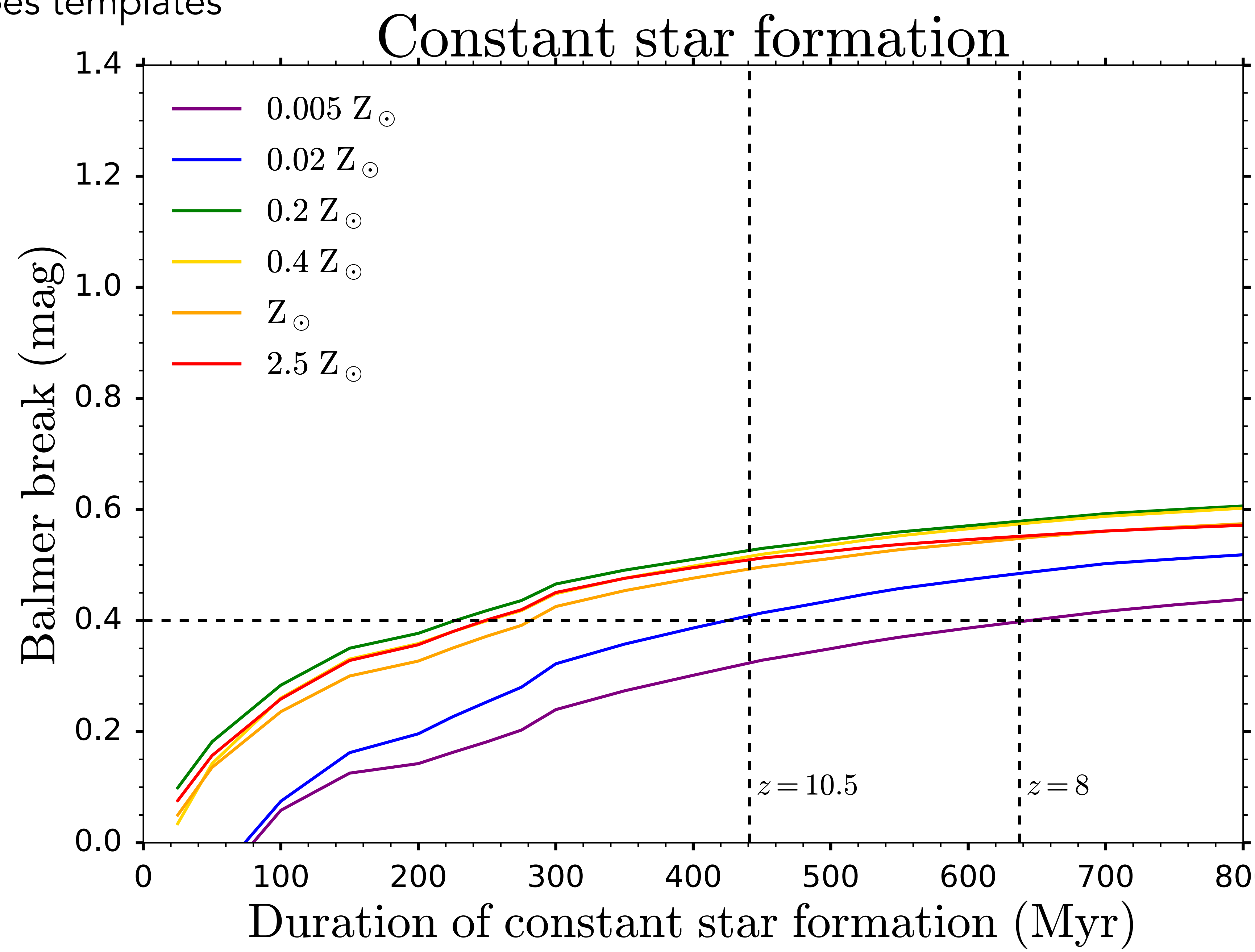
Carnall+18 Bagpipes templates



The Balmer break can grow **very quickly** after a **starburst**, reaching 0.4 mag in **less than 50 Myr**

The Balmer break as a proxy for stellar age

Carnall+18 Bagpipes templates

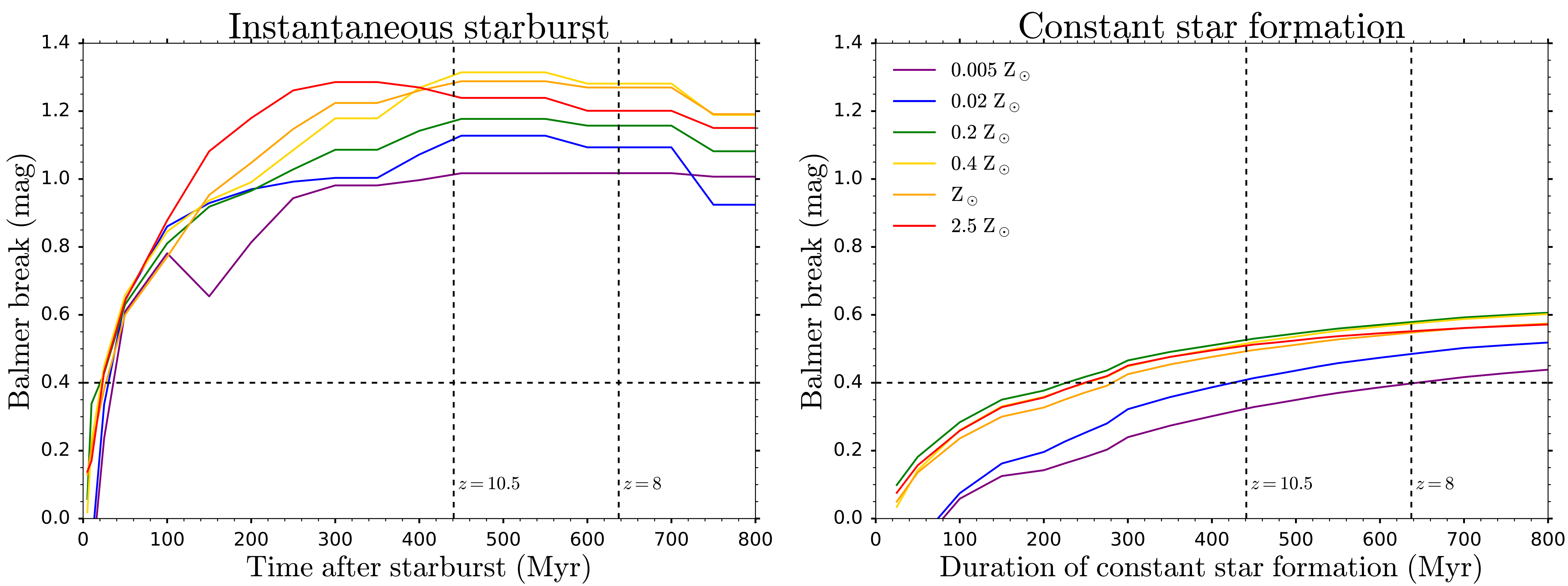


The Balmer break grows **much more slowly during a constant star formation history,** reaching 0.4 mag in > **250 Myr**

James Trussler

The Balmer break can't do it all

Carnall+18 Bagpipes templates

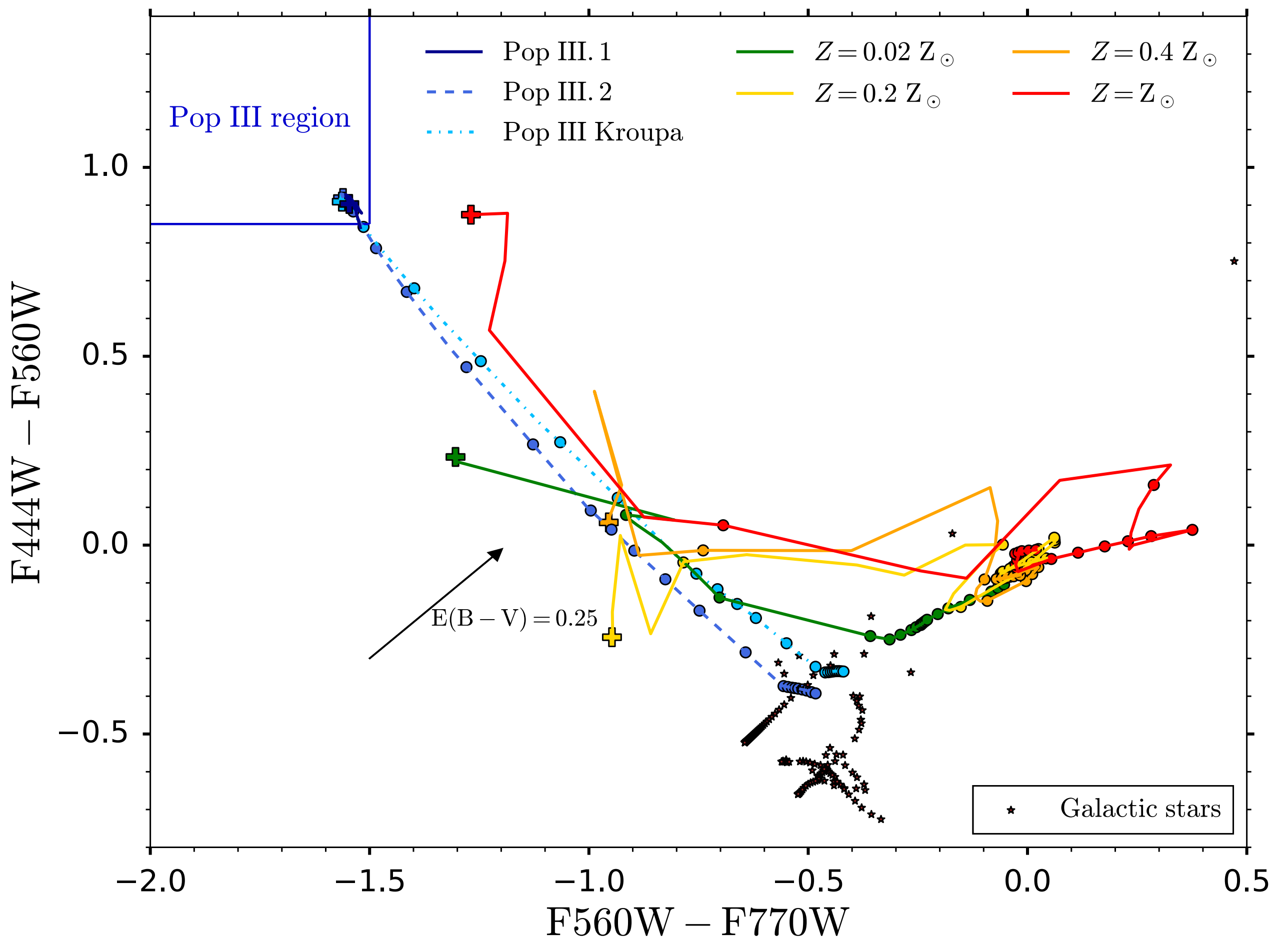


—> The Balmer break is **complexly dependent** on the **star formation history**

NIRSpec PRISM + MIRI imaging needed for best possible SFH constraints

Summary

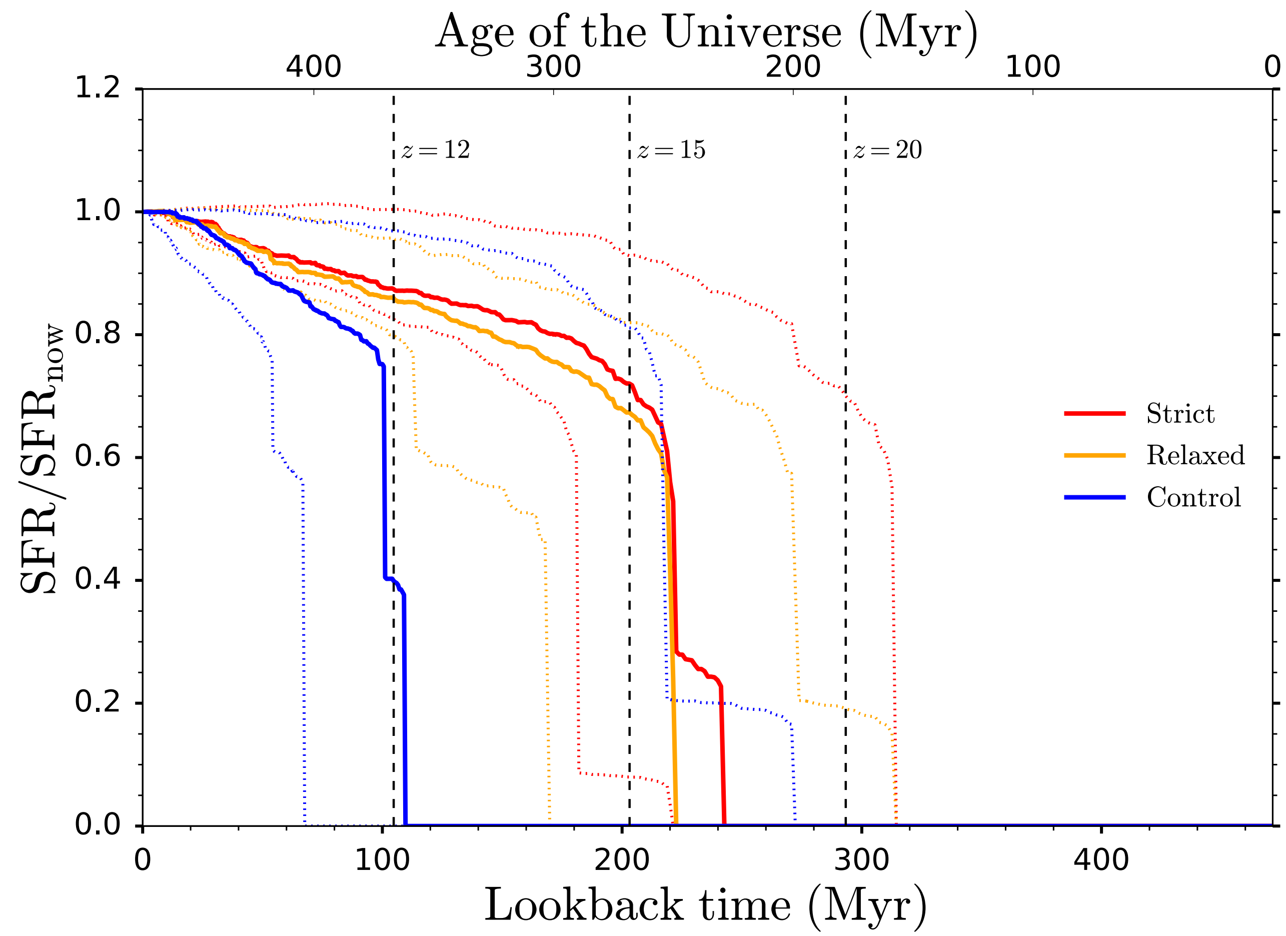
Direct



NIRCam + MIRI imaging will enable us to identify **Pop III candidates**

NIRSpec spectroscopy of **He II λ1640** will determine their Pop III nature

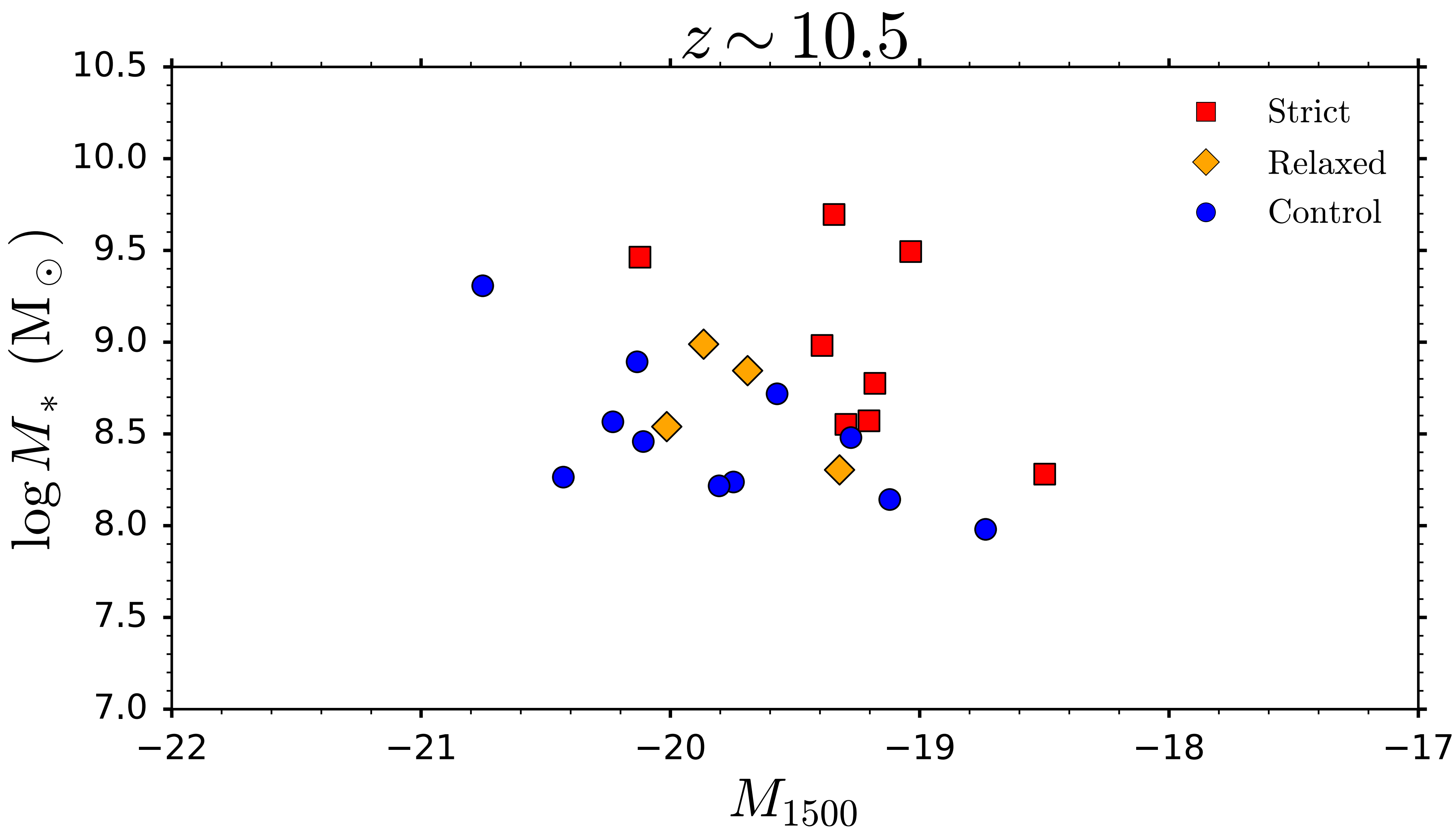
Indirect



Medium-band imaging is essential to reliably identify **Balmer breaks**

NIRSpec continuum spectroscopy + MIRI imaging will provide the best indirect constraints on the **onset of star formation in the Universe**

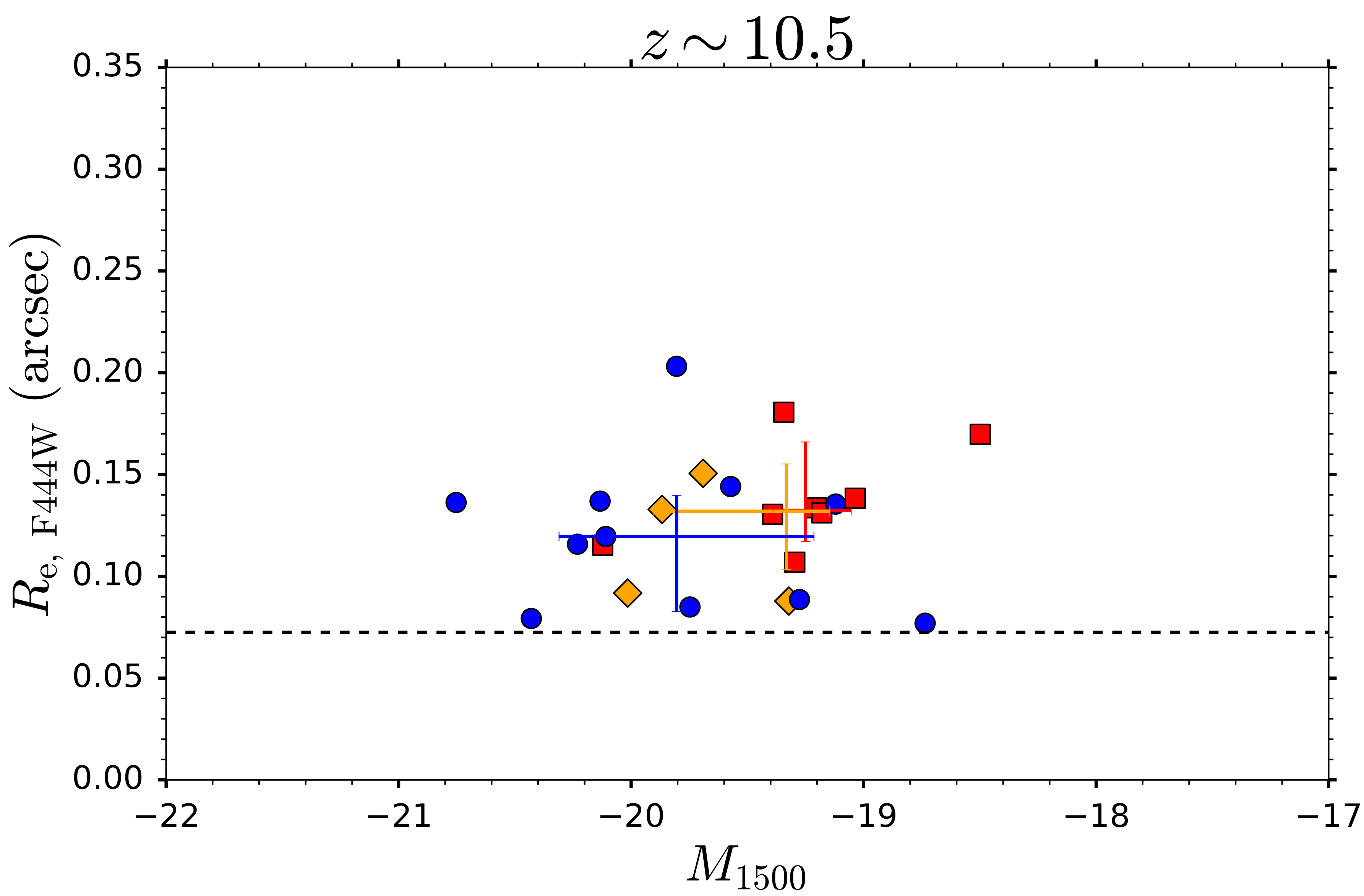
Magnitudes and masses



The **Balmer break candidates** are **comparable in brightness** to the **control sample**

The **higher stellar masses** inferred are therefore an outcome of the SED-fitting process (and the assumptions therein)

Galaxy sizes



We find **no indication** that any of our **Balmer break candidates** are **point sources,** thus none of these galaxies likely harbour a substantial **AGN component**