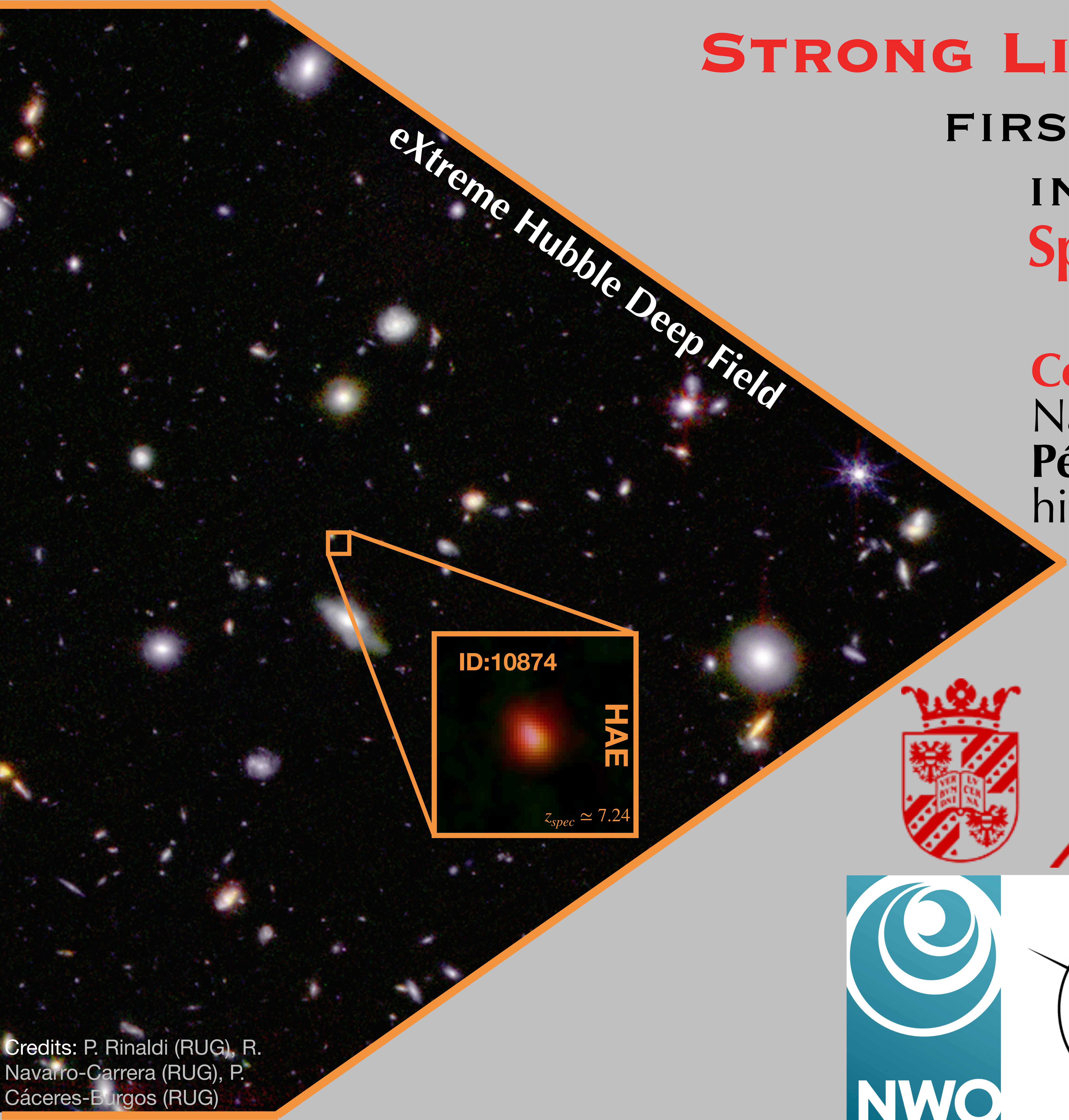
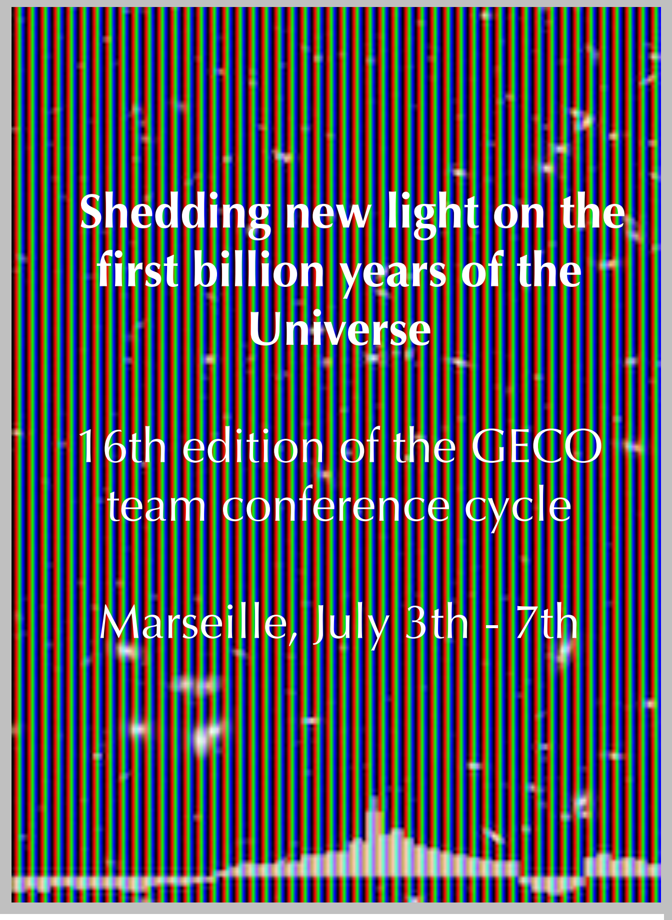
Strong Line Emitters at $z \simeq 7-8$: first detection of Hα emission in individual galaxies with JWST

Speaker: Pierluigi Rinaldi

Collaborators: **K. Caputi**, **E. Iani**, V. Kokorev, R. Navarro-Carrera, **L. Constantin**, **S. Gillman**, **P. Pérez-González**, **L. Colina**, **G. Östlin** & MIRI high-z team



rijksuniversiteit groningen



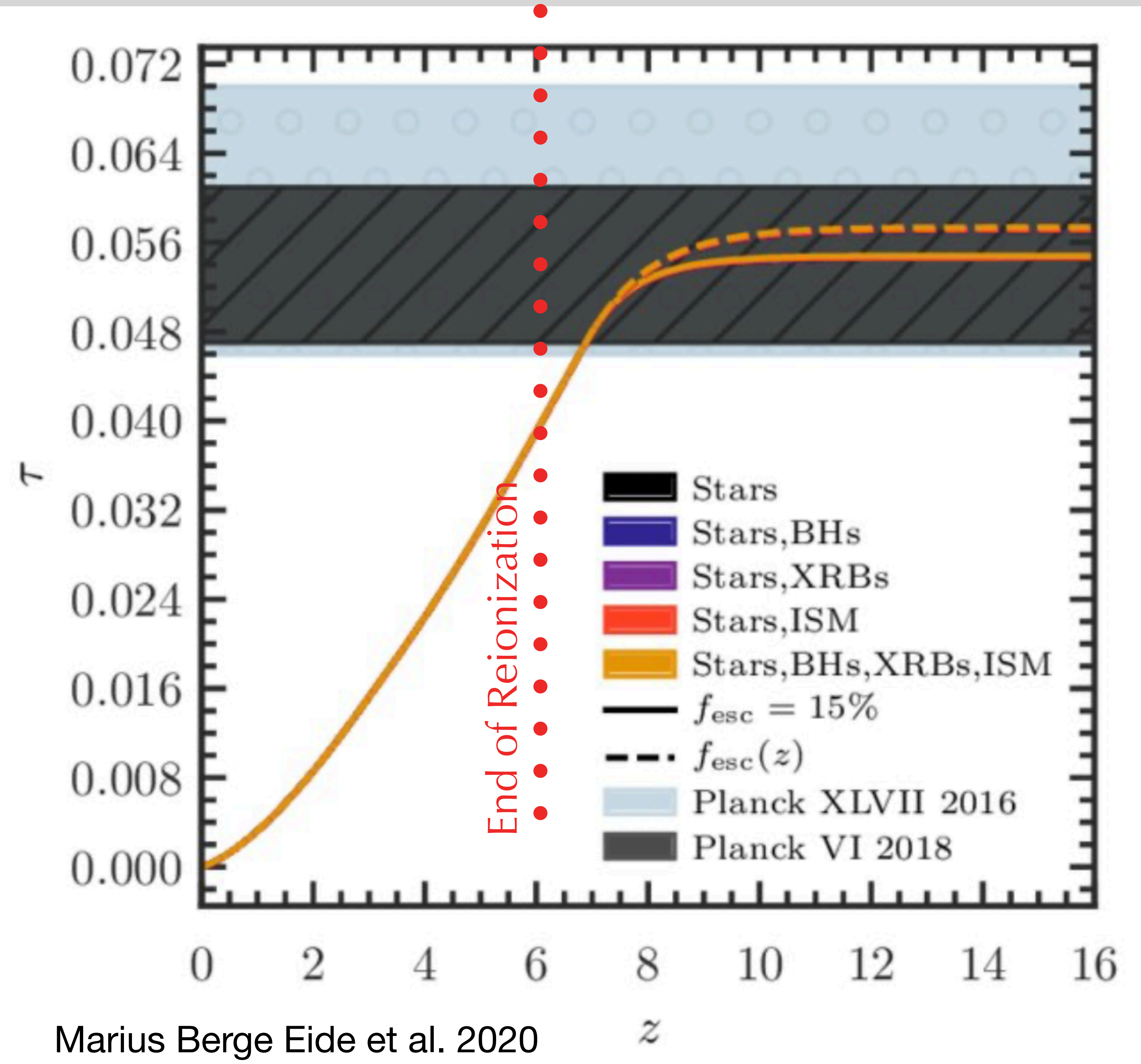
NWO

NOVA

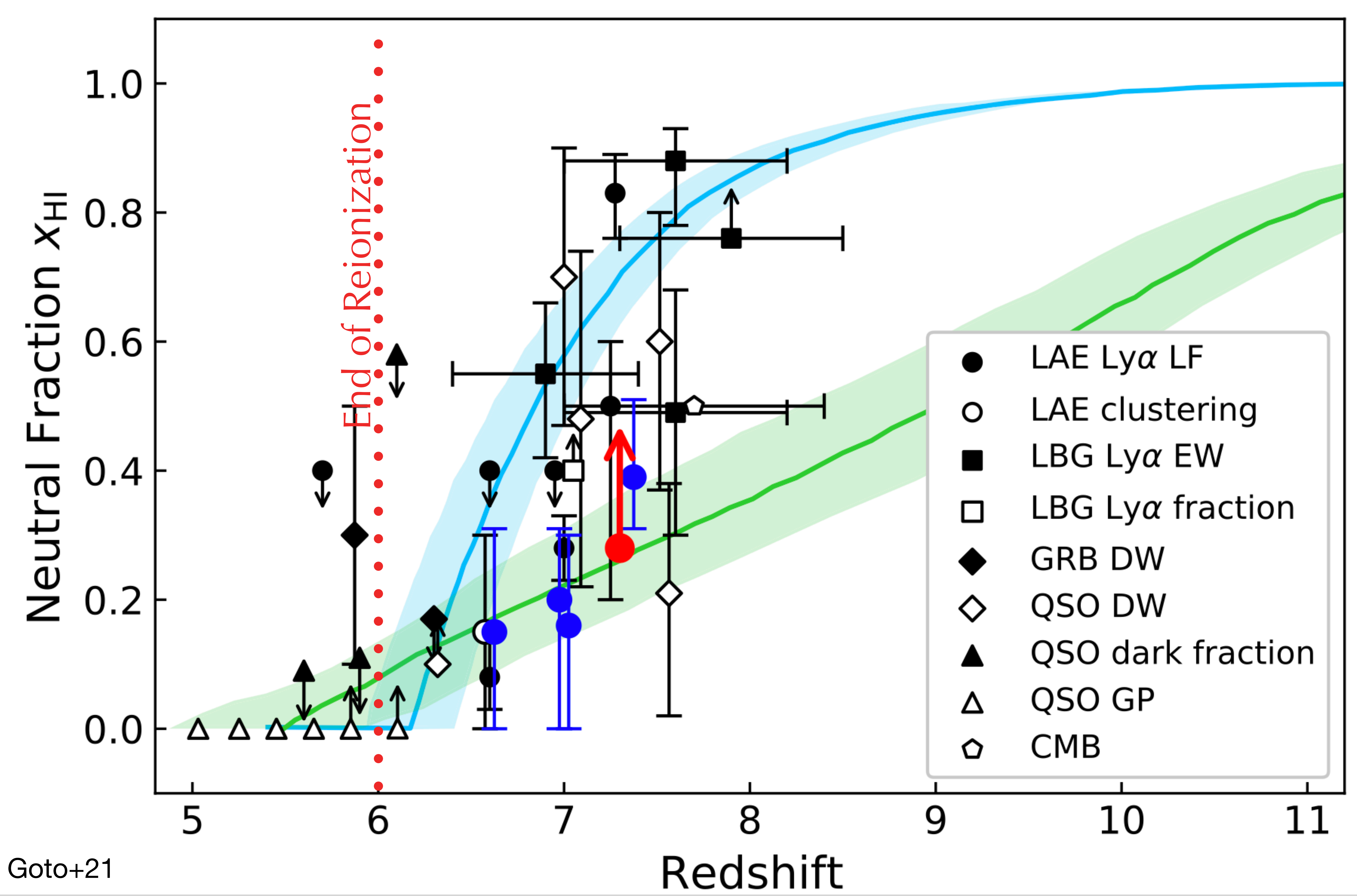
MIRI European Consortium

Strong Line Emitters at $z \simeq 7-8$

Strong Line Emitters at $z \simeq 7-8$



Marius Berge Eide et al. 2020



Goto+21

Tracers for neutral hydrogen (HI):

- Lyman Alpha Emitters;
- Lyman Alpha Forest;
- 21 cm emission;
- CMB background.

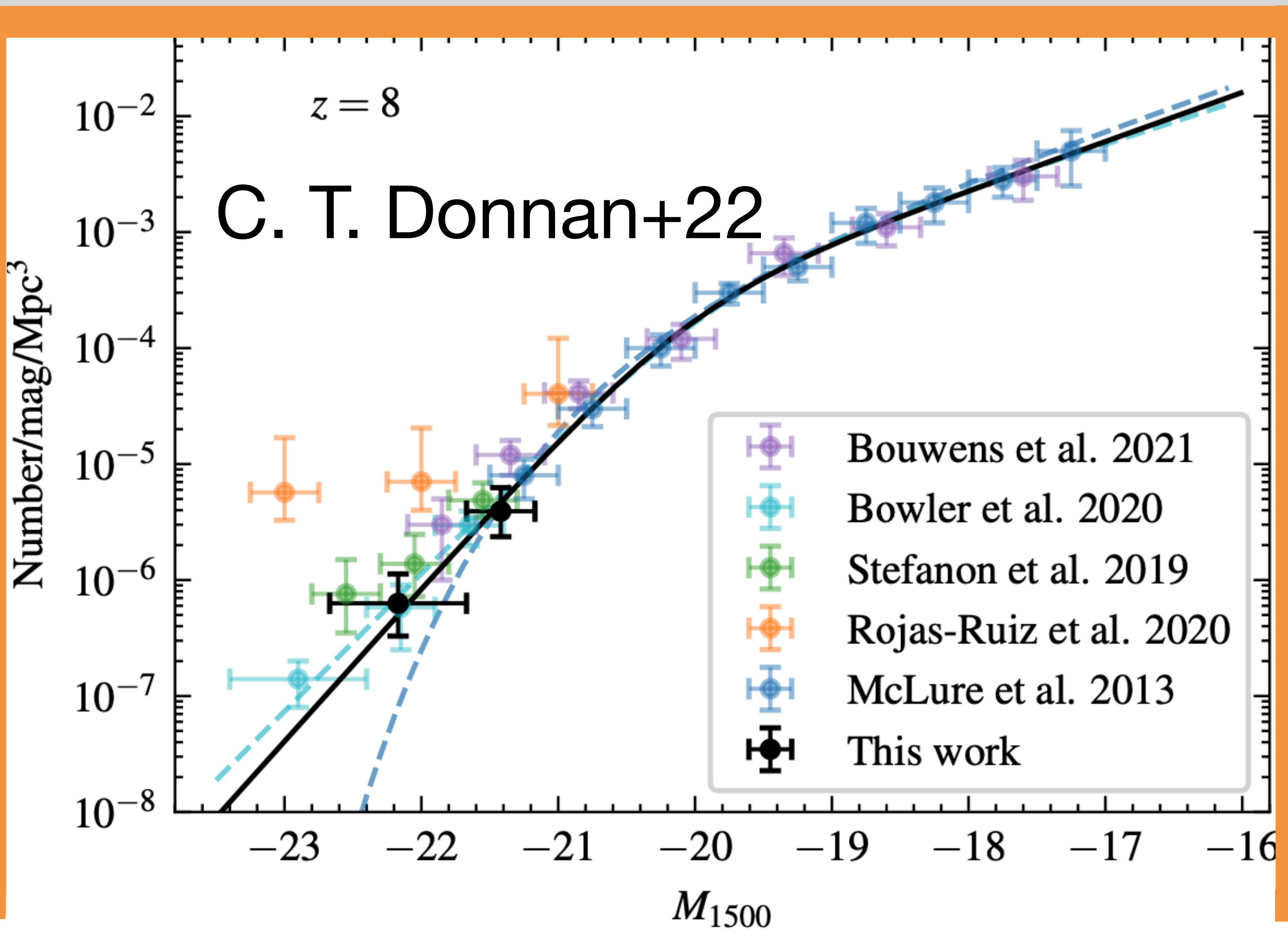
Which are the main sources of the Cosmic Reionization?

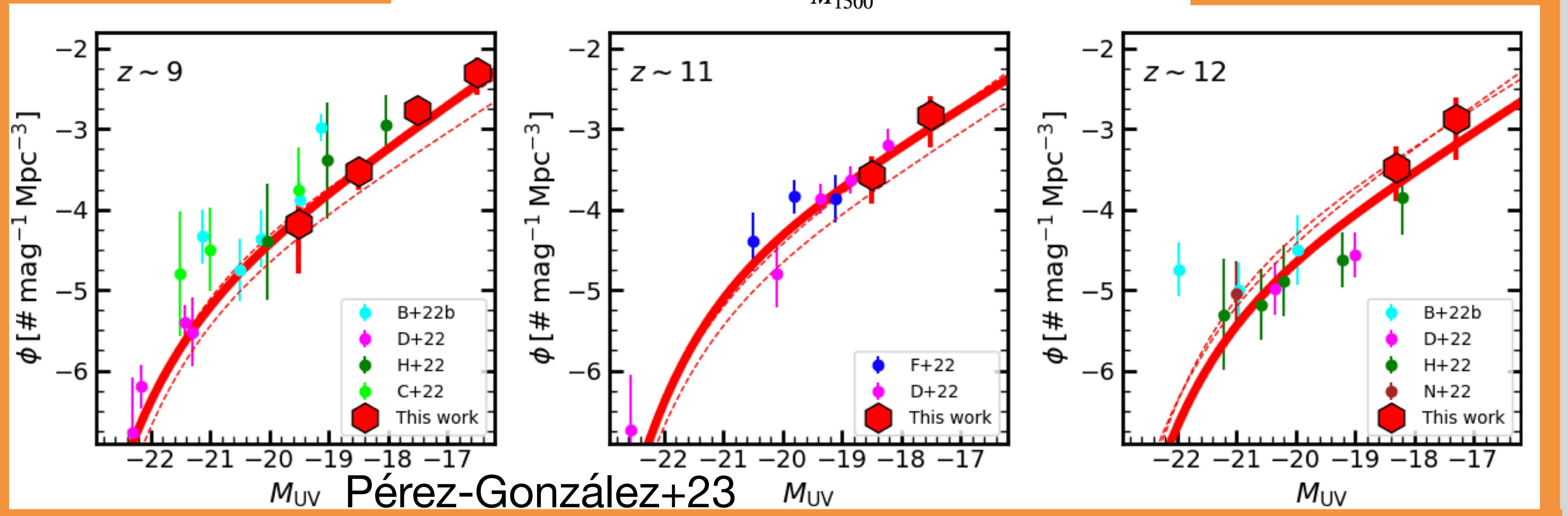
- **Stars (in galaxies);** → They represent the main source of H Reionization

- **QSOs.**

They represent the main source of He^+ Reionization

Why do we think that galaxies have mainly driven the Cosmic Reionization?





Other alternatives have been discussed in the literature

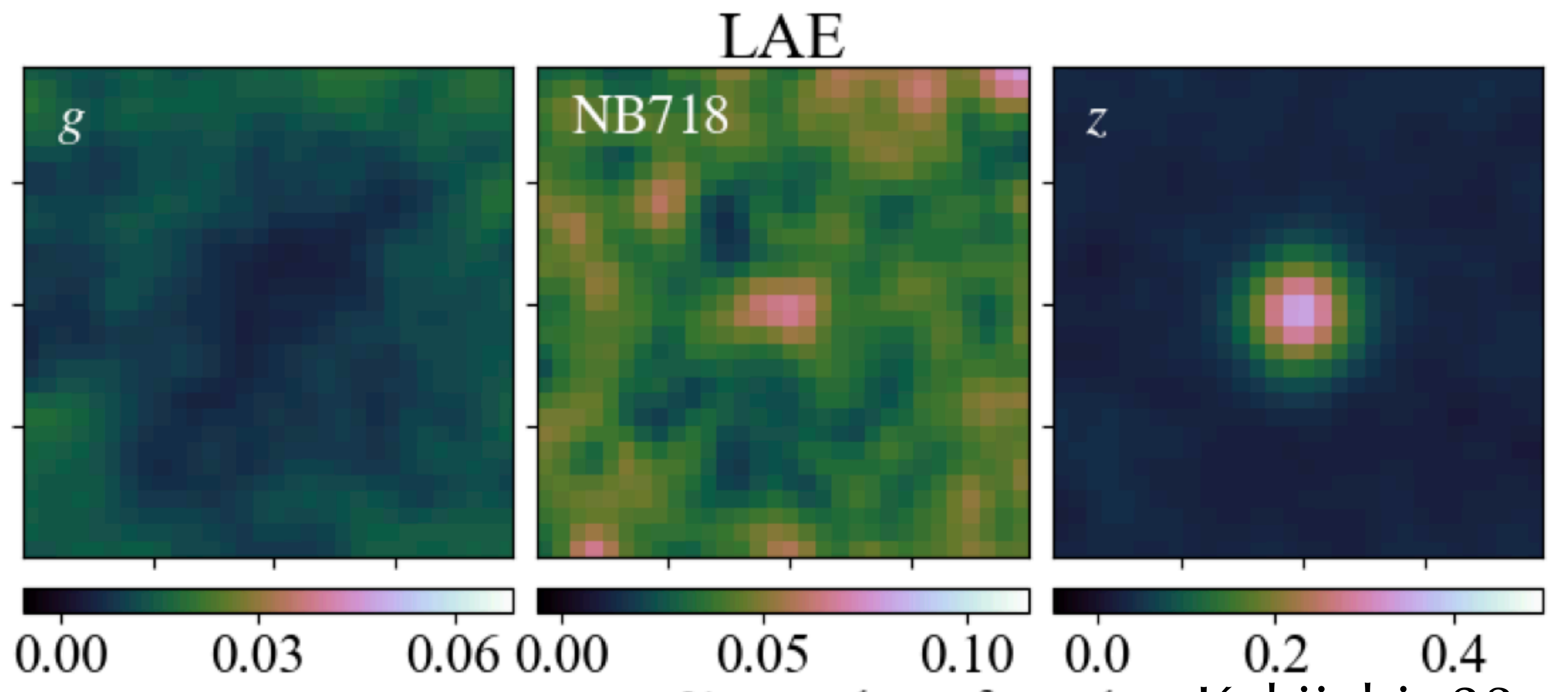
- SNs;
- X-ray binaries;
- Dark Matter decay.

Strong Line Emitters at $z \simeq 7-8$

Why do we look for **line emitter galaxies** and **how** do we look for them?

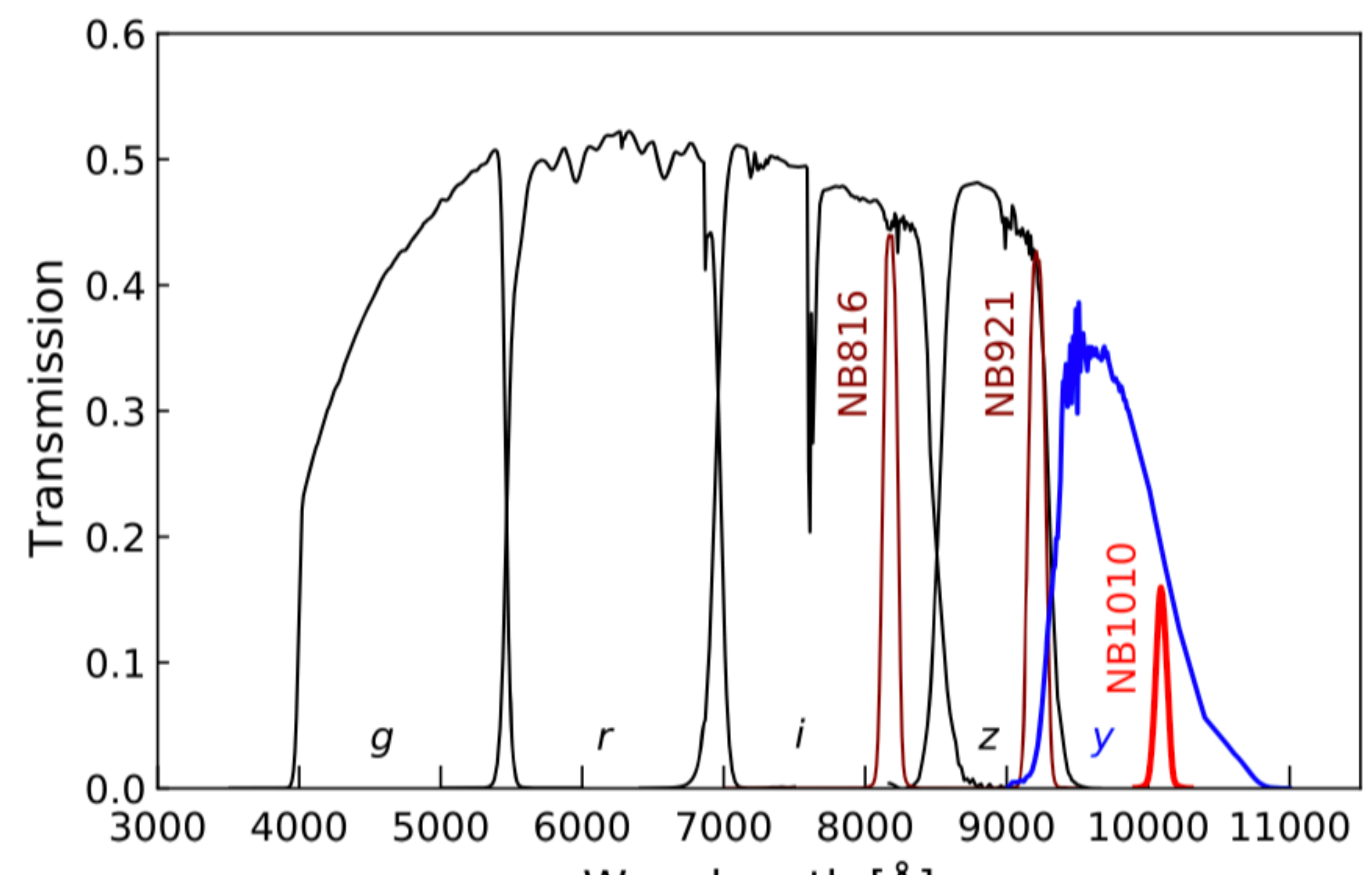
High-redshift galaxies can be **detected** and identified **using strong emission lines** (e.g., **LAEs** have been extensively used as **lighthouses** to study the high redshift Universe)

- Narrow band imaging;
- Blind spectroscopy.



Kakiichi+23

Subaru gave us an amazing opportunity to do that (look at the **SILVERRUSH** project)!



Goto+21

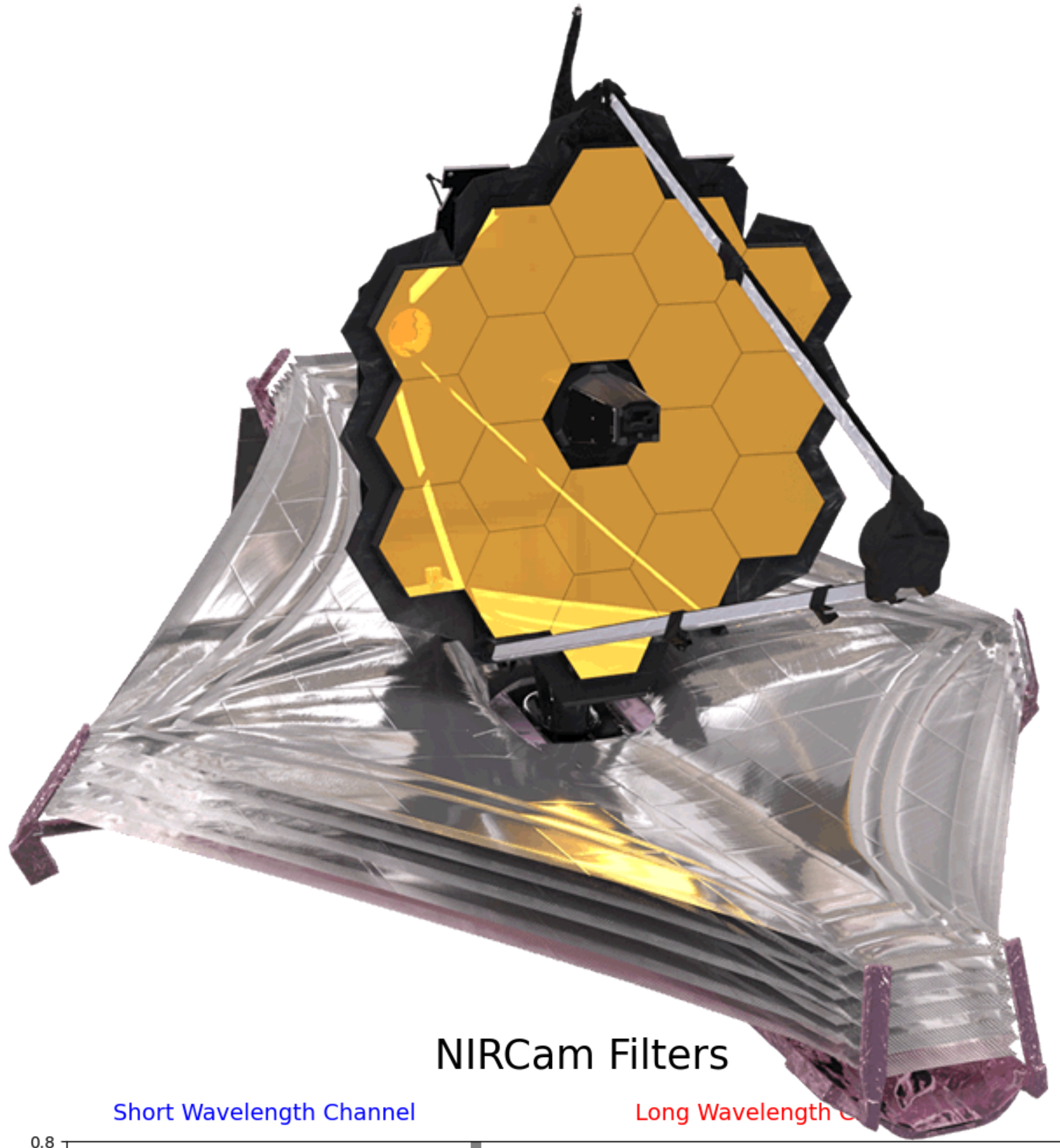
Understanding the formation and evolution of the **first galaxies** at high redshift!

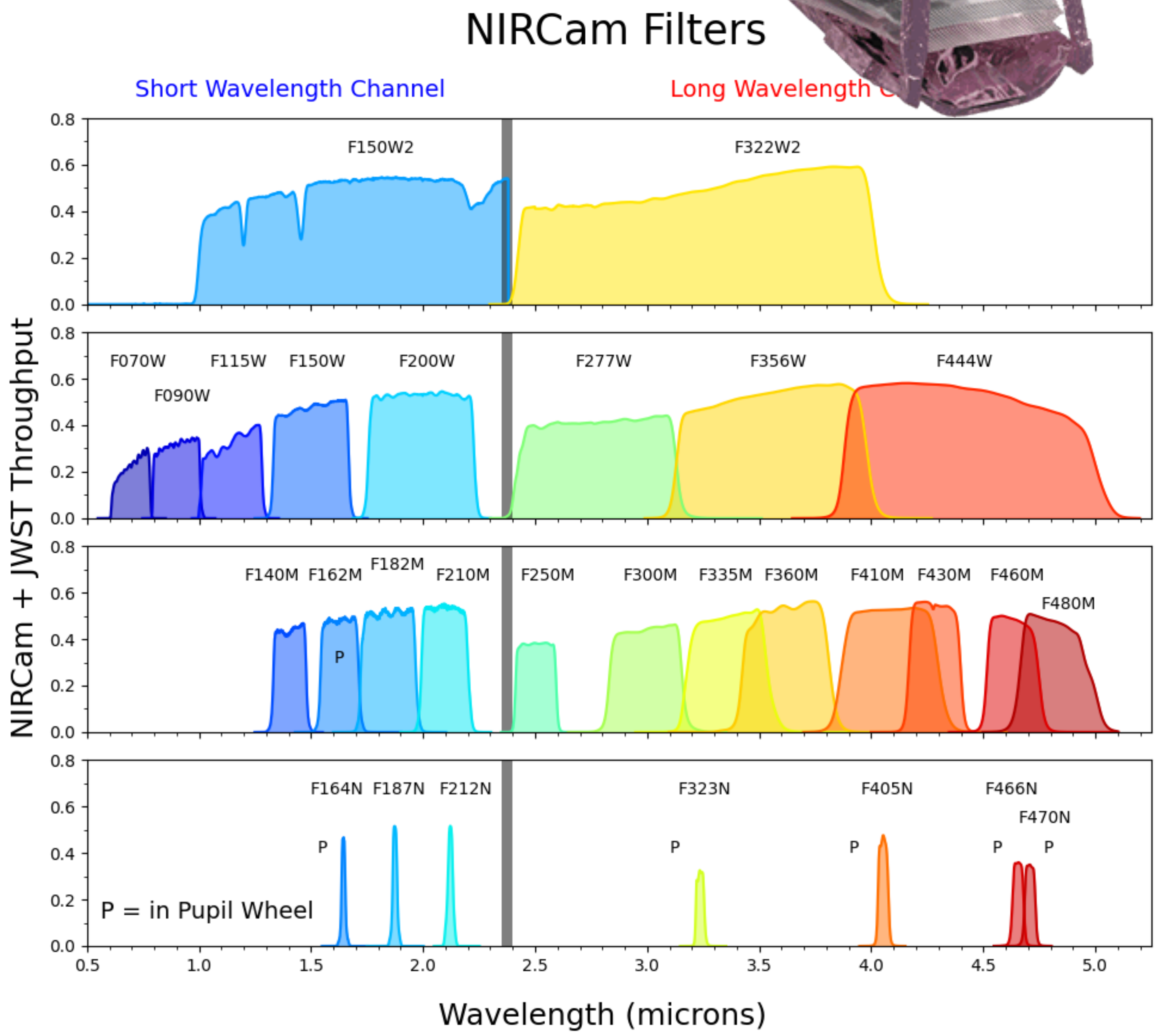
e.g., **MUSE** (LAEs at $z \simeq 2.8-6.5$, Bacon+23) or even **ALMA** observations targeting the [OIII] 88μm line (e.g., Hashimoto+18) => highest candidate at $z = 13.27$ (Harikane+22)

Strong Line Emitters at $z \simeq 7-8$

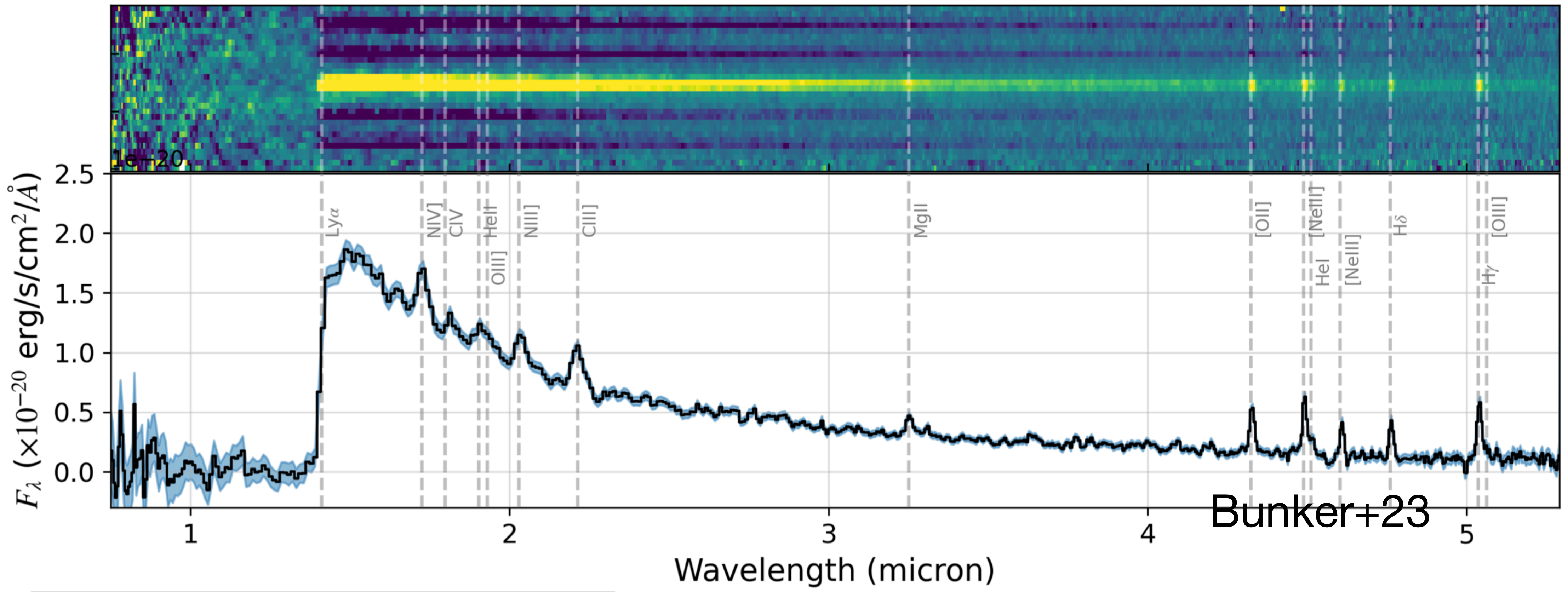
High-redshift g
detected and
strong emission
(e.g., **LAEs** have
used as lightho
high redshift Un

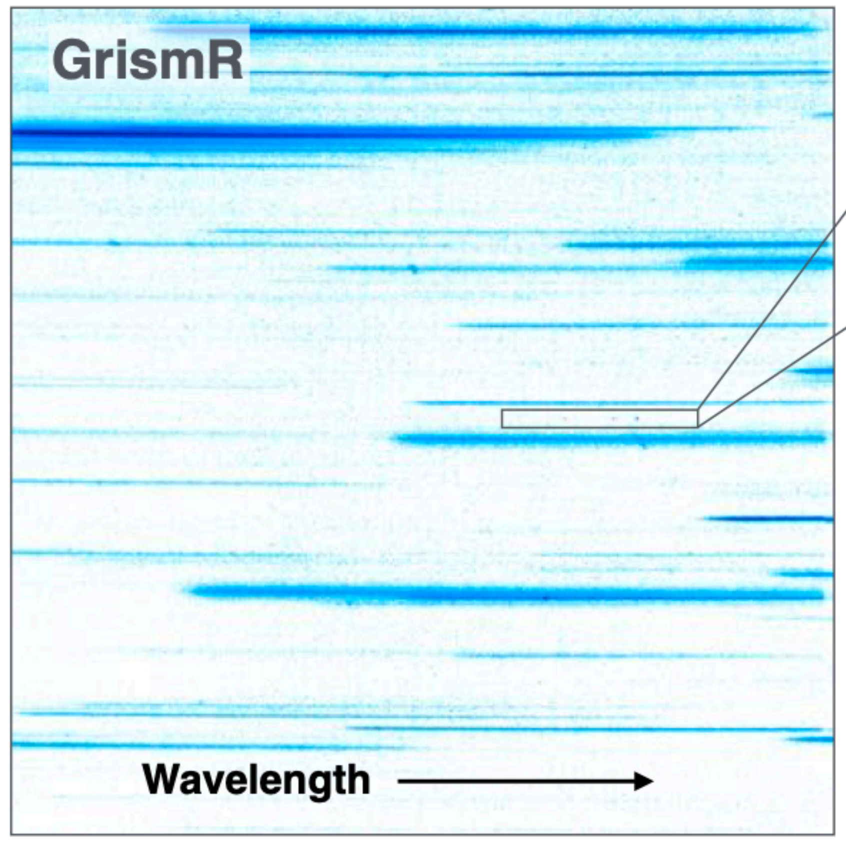
Understanding th
evolution of the
high redshift!

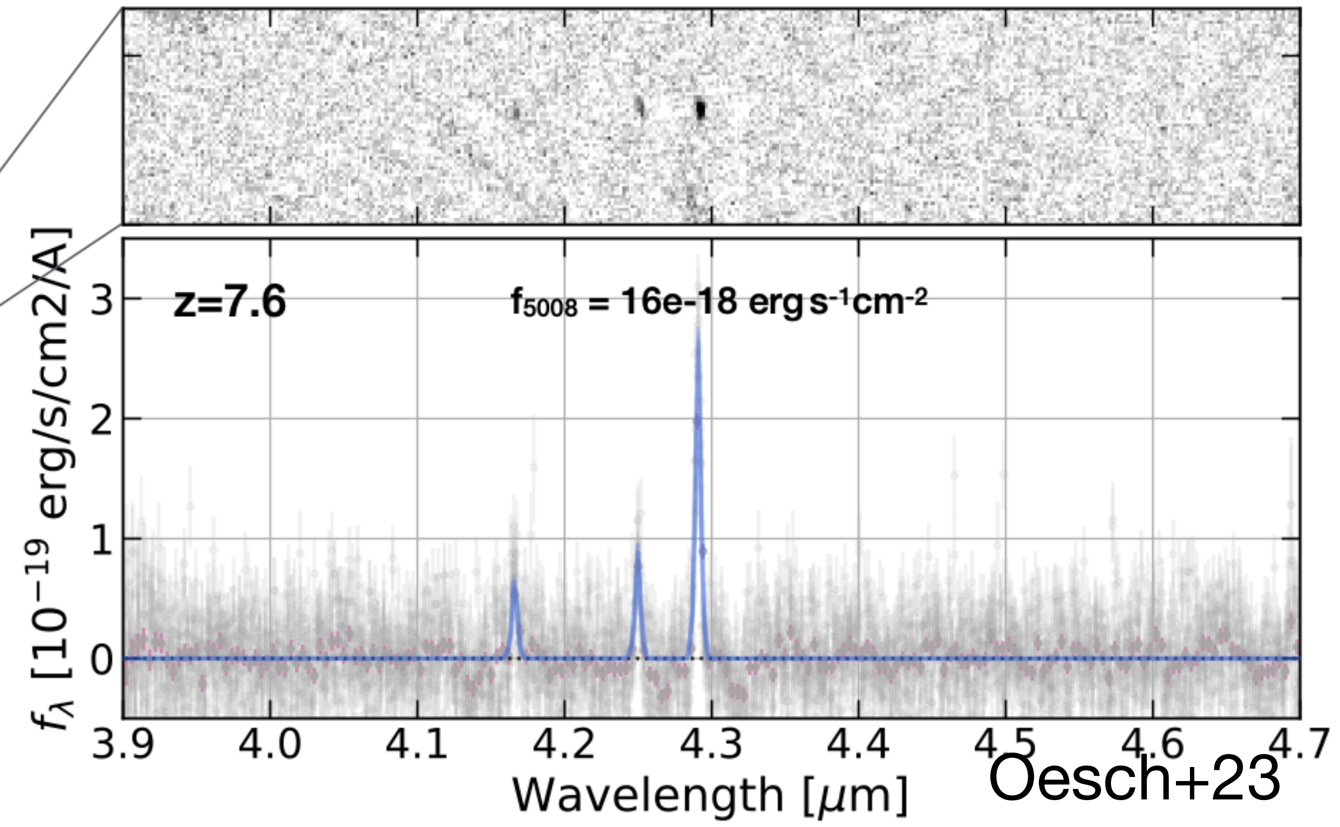


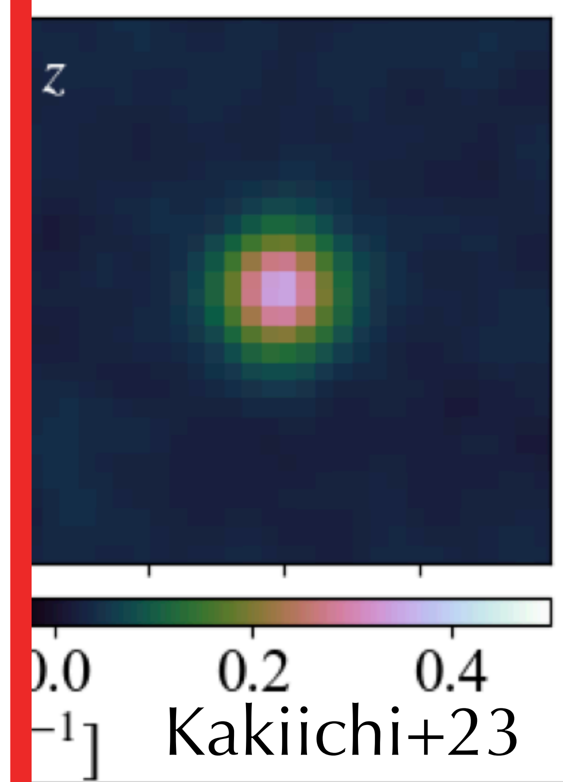


JWST is **finally operating** and is opening a **new window** into the **Early Universe** by detecting and identifying rest-frame **optical lines** such as: [OII] λ3727, Hβ λ4862, [OIII]$\lambda\lambda$4959, 5007, but also Hα λ6562…



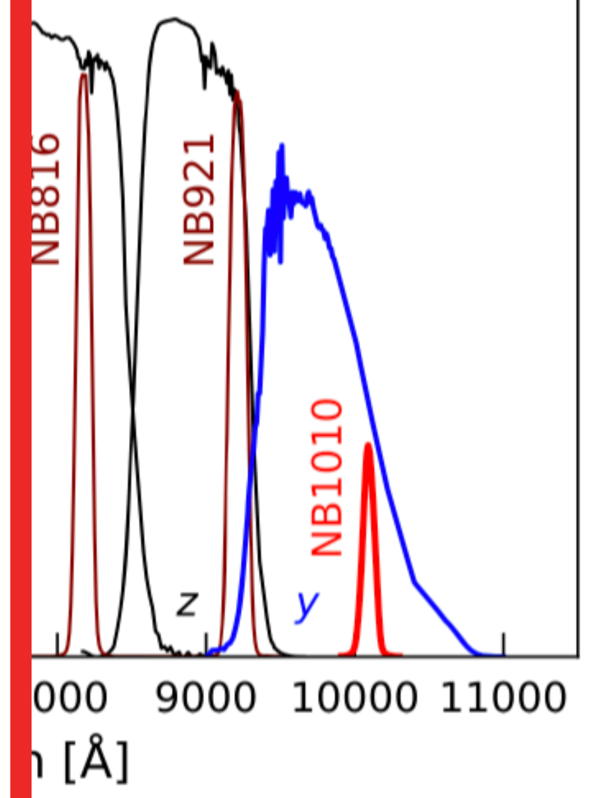






n amazing
!

USH project!

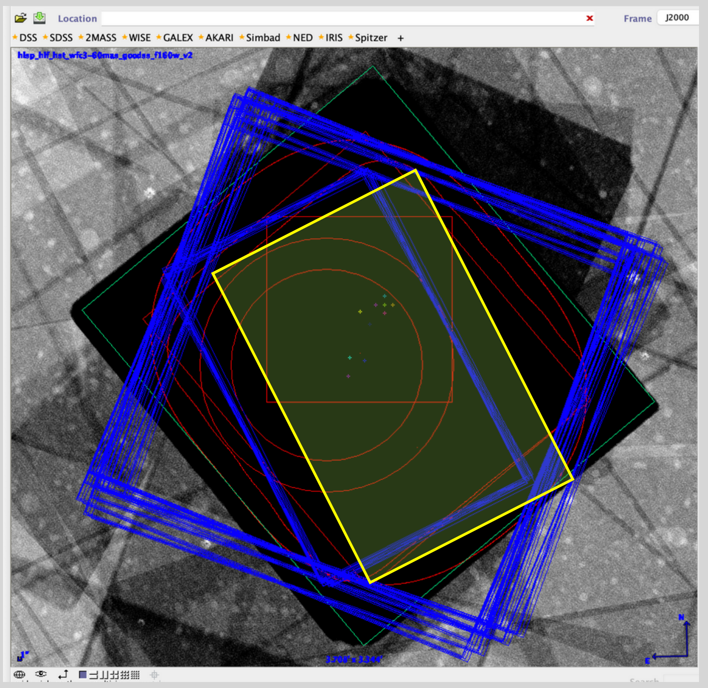


The MIRI Deep Imaging Survey observations

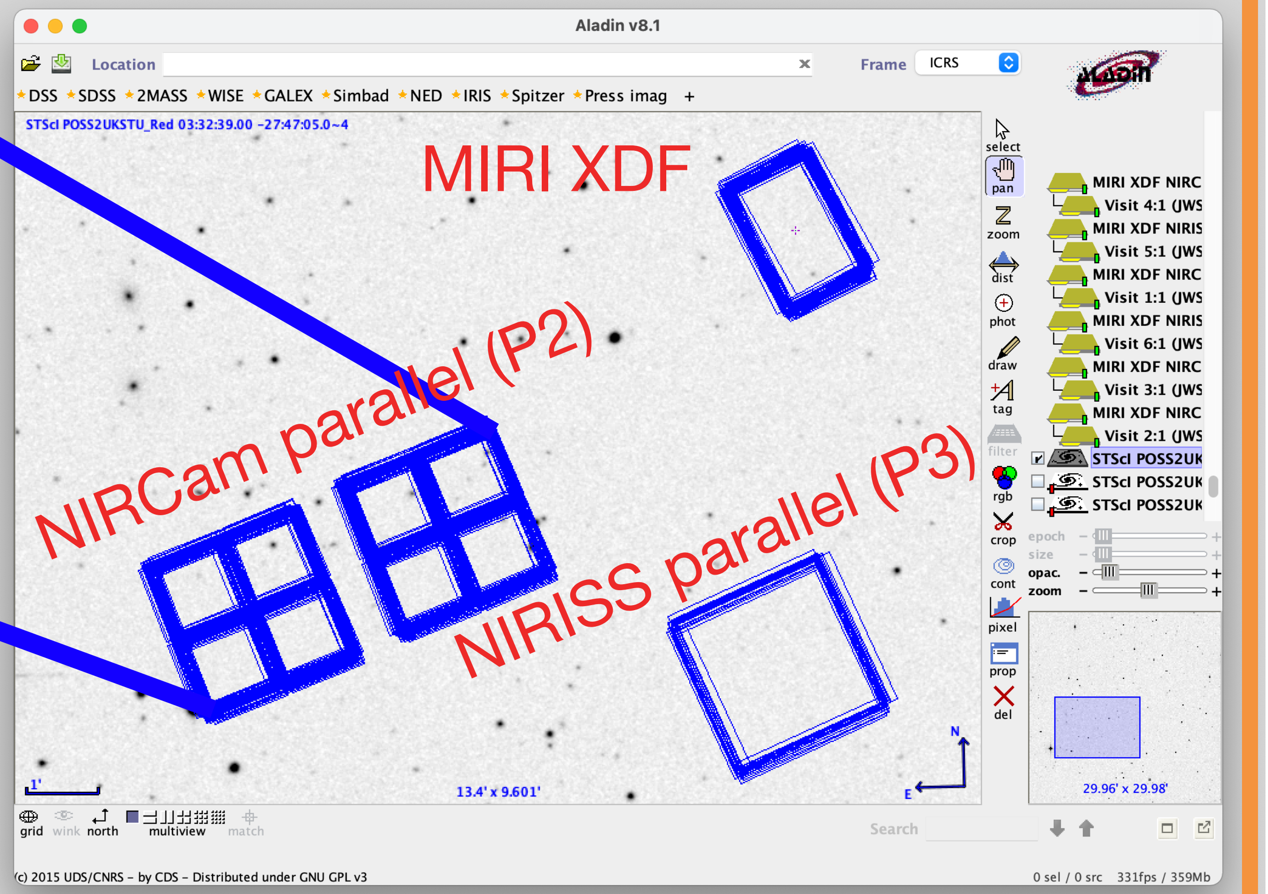
Credit: Göran Östlin

- 63 hours total (48.75h net exposure time) with F560W (**PID: 1283**) coordinated parallels: ~40h with NIRCam and ~20h with NIRISS
- Primary MIRI field has deep HST, X-ray, ALMA and MUSE etc + deep NIRCam, NIRISS
- Parallels fall in areas with deep HST imaging (GOODS-S, P2, P3)

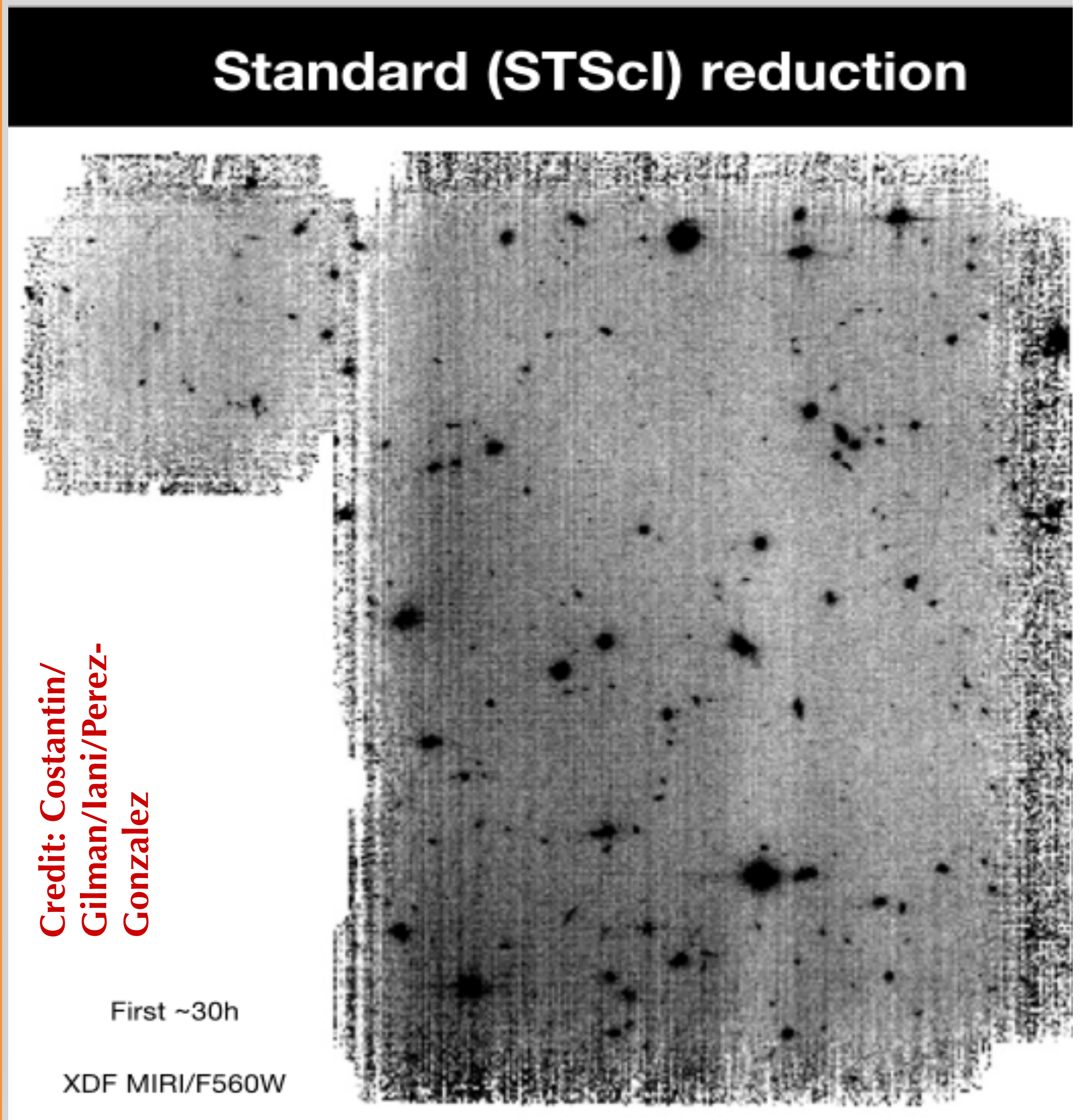
Pérez-González+23



MIRI UDF field (white) overlaid on HST exposure depth.
Blue square contours show NGDEEP/NIRISS pointing.
Red contours show deep MUSE and ALMA coverage



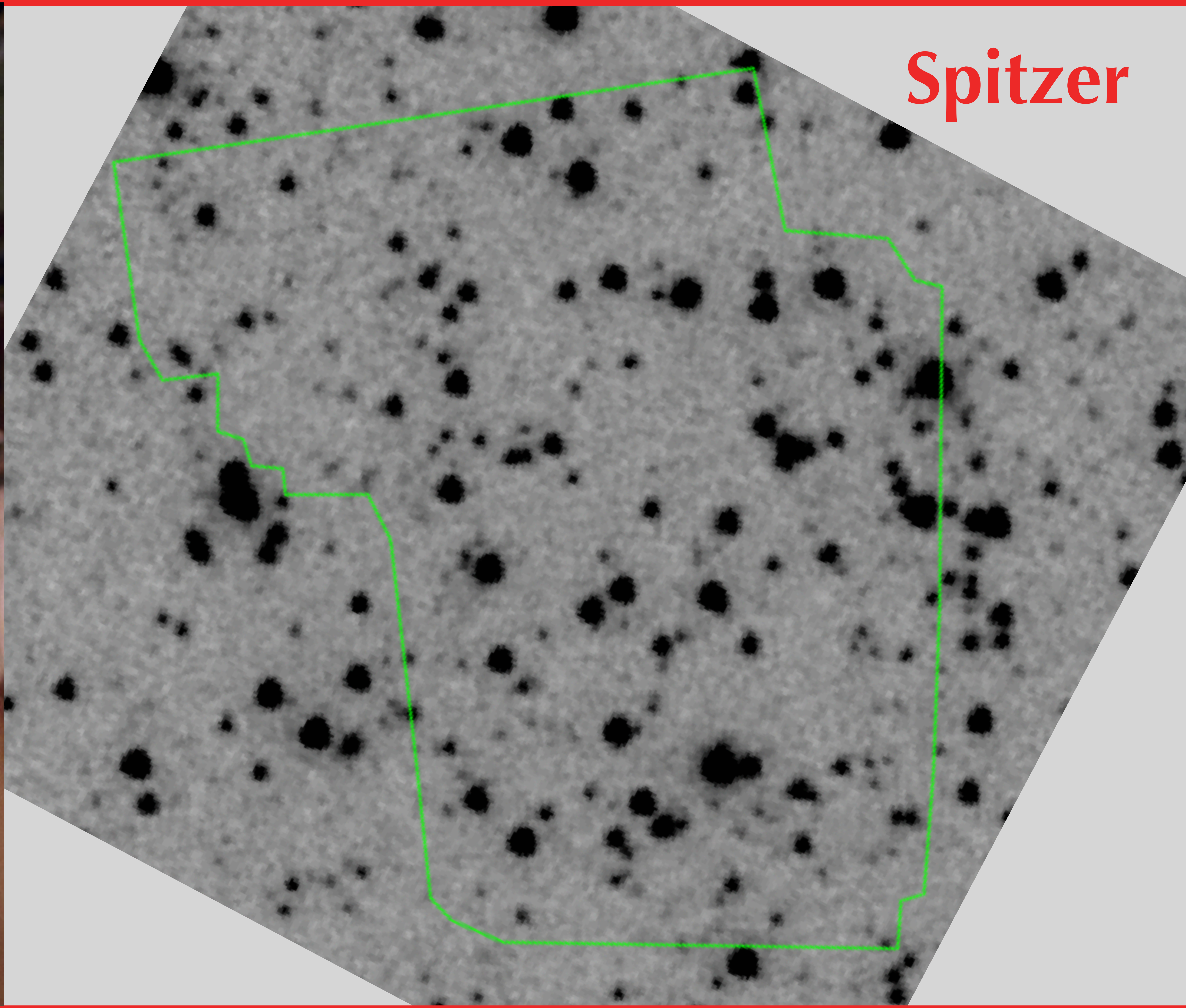
3 different teams (Copenhagen, **Groningen**, and Madrid) worked on the data reduction by adopting three different data reduction techniques in order to maximize the quality of the final product. A modified version of the official JWST pipeline has been adopted.



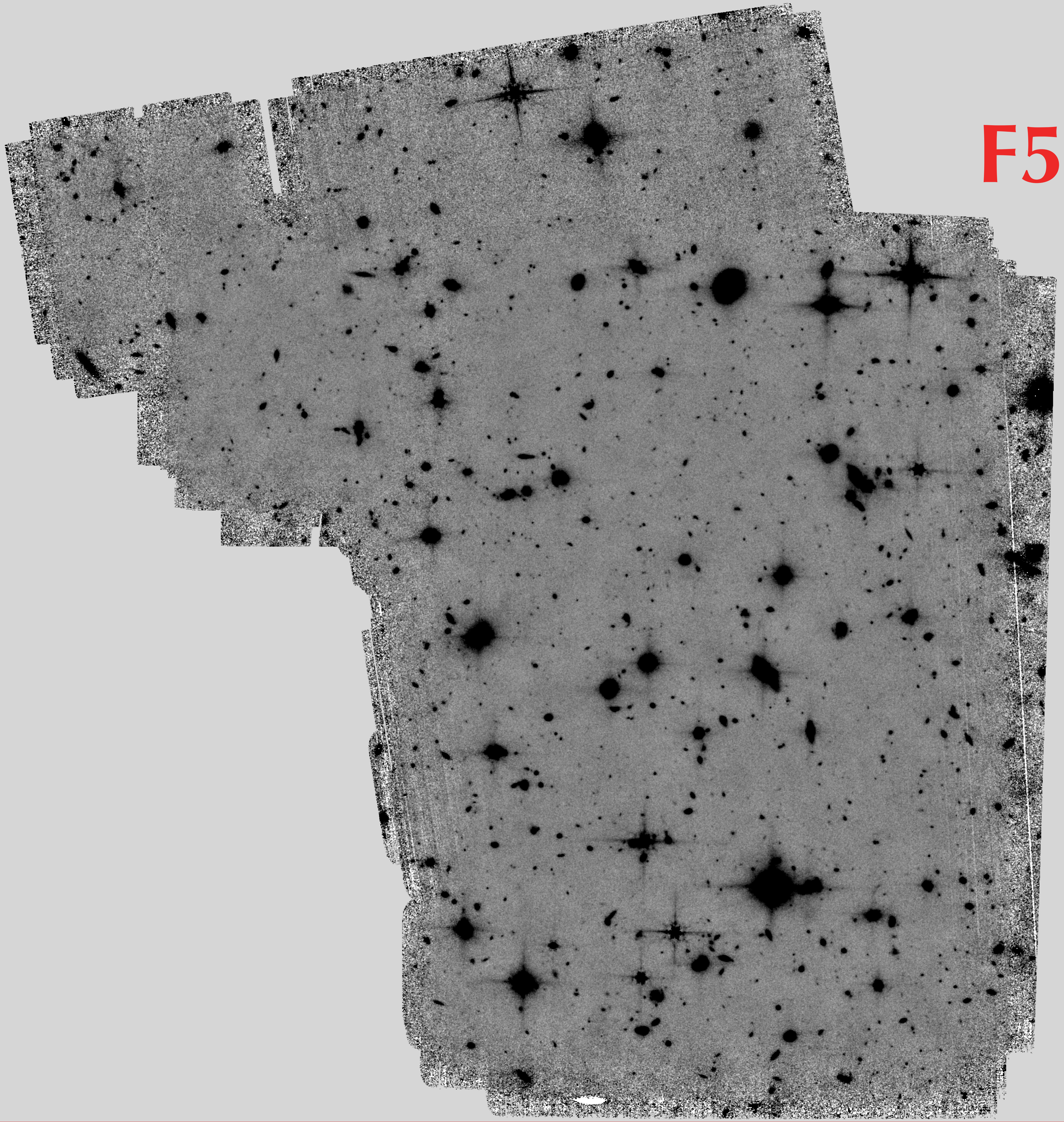
Several artifacts from the official JWST pipeline:

- Vertical and horizontal stripes;
- Strong background gradient;
- Strong background inhomogeneities;
- "Concentric waves" patterns.

Almudena Alonso-Herrero (CAB)
Javier Alvarez-Márquez (CAB);
Marianna Annunziatella (CAB);
Leindert Boogaard (MPiA);
Karina Caputi (Groningen);
Luis Colina (CAB);
Luca Costantin (CAB);
Danial Langeroodi (DARK);
Daniel Dicken (STFC);
Macarena Garcia-Marin (STScI);
Steven Gilman (DTU);
Thomas Greve (DTU);
Edoardo Iani (Groningen);
Olivier Ilbert (LAM);
Iris Jermann (DTU);
Sarah Kendrew (STScI);
Mattia Libralato (STScI);
Jens Melinder (Stockholm);
Thibaud Moutard (LAM);
Göran Östlin (Stockholm Univers
Pablo Perez-Gonzalez (CAB);
John Pye (Leicester);
Pierluigi Rinaldi (Groningen);
Tuomo Tikkanen (Leicester);
Fabian Walter (MPiA);
Martin Ward (Durham);
Gillian Wright (STFC);
and the MIRI-EC high-z team.


Spitzer

Strong Line Emitters at $z \simeq 7-8$



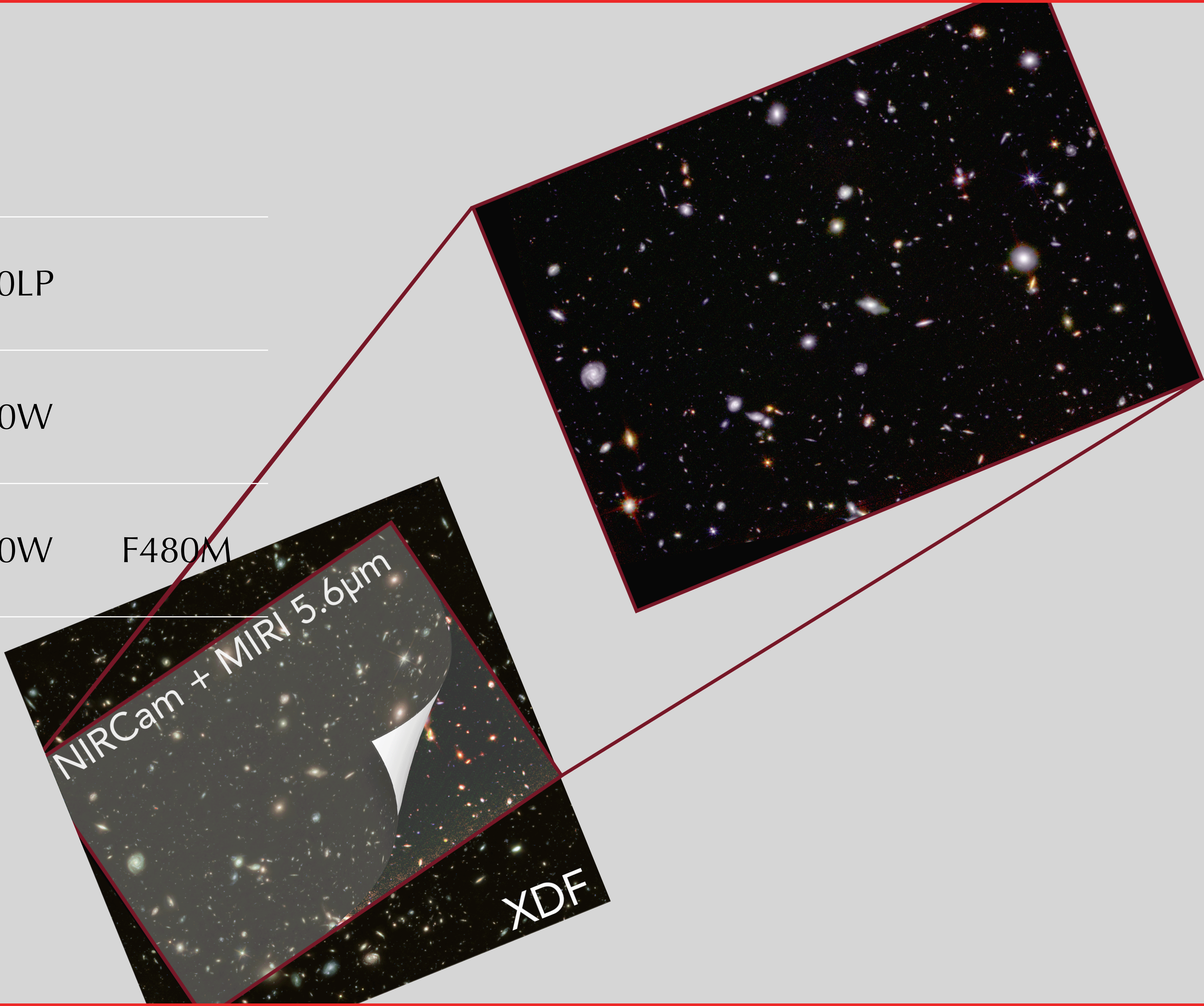
MIRI
F560W

Strong Line Emitters at $z \simeq 7-8$

Wavelength Coverage

HST/UVIS	F225W	F275W	F336W			
HST/ACS	F435W	F606W	F775W	F814W	F850LP	
HST/WFC3	F098M	F105W	F125W	F140W	F160W	
JWST/NIRCam	F182M	F210M	F430M	F444W	F460W	F480M
JWST/MIRI	F560W					

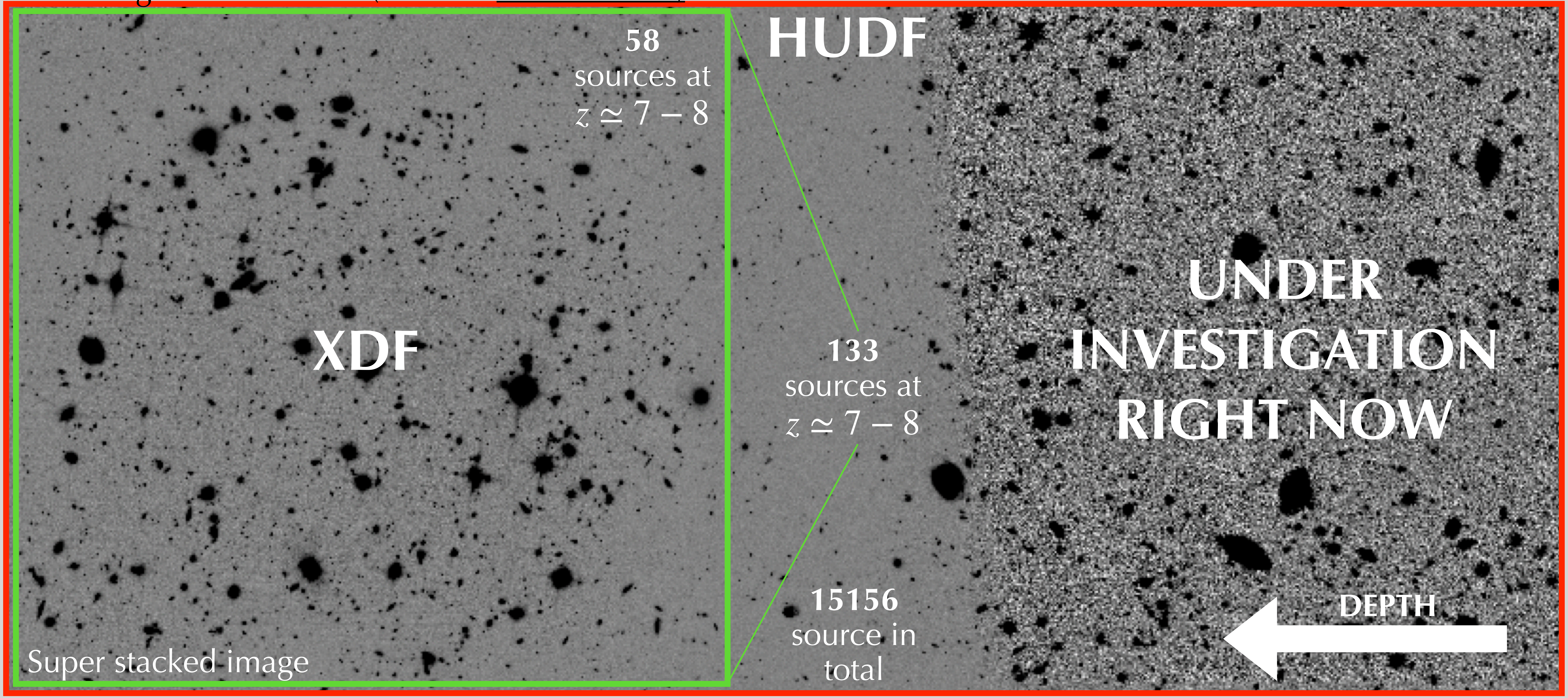
$$\mathrm{mag}_{5\sigma} \simeq 29.5$$



STRONG LINE EMITTERS AT $z \simeq 7 - 8$

SED fitting with **LePHARE** (BC03 & SB99 models)

SExtractor - hot-mode

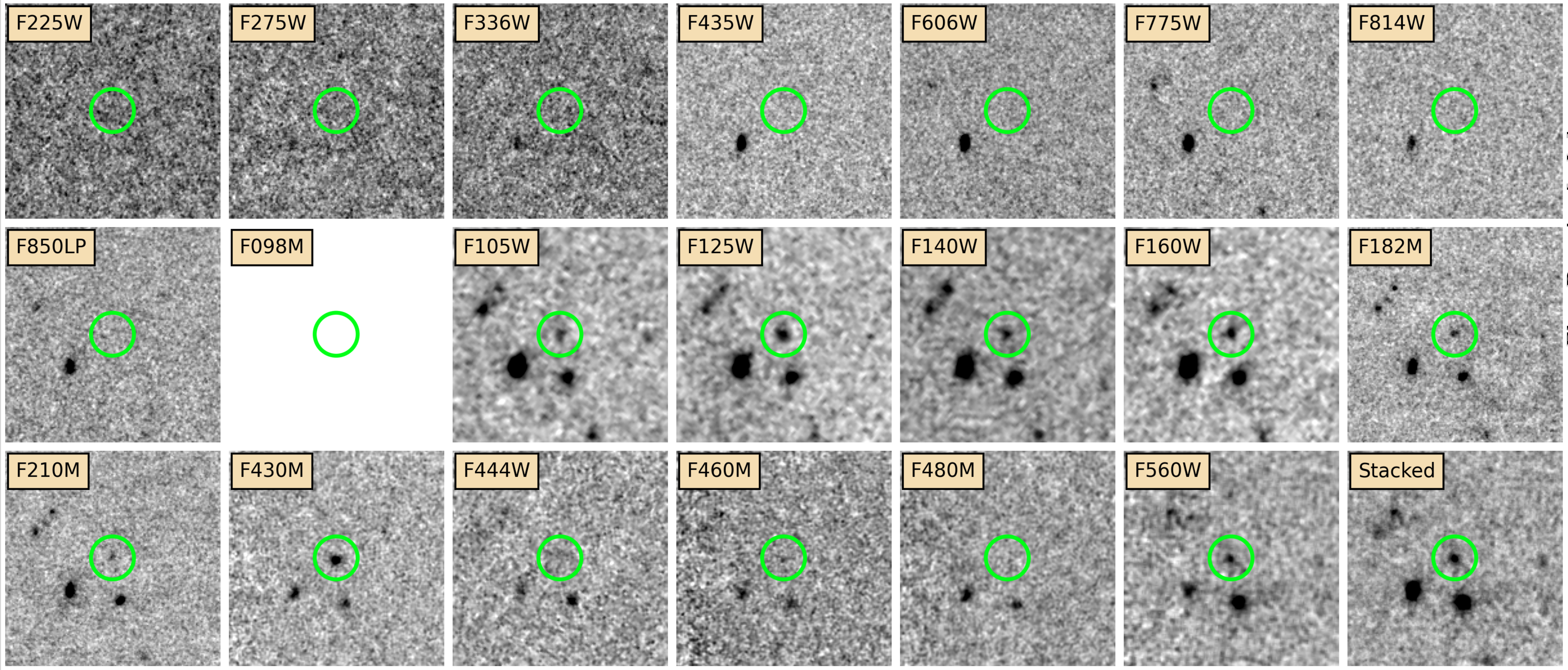


Strong Line Emitters at $z \simeq 7-8$

$$\Delta mag = mag_X - mag_{cont} < -0.2\ mag$$

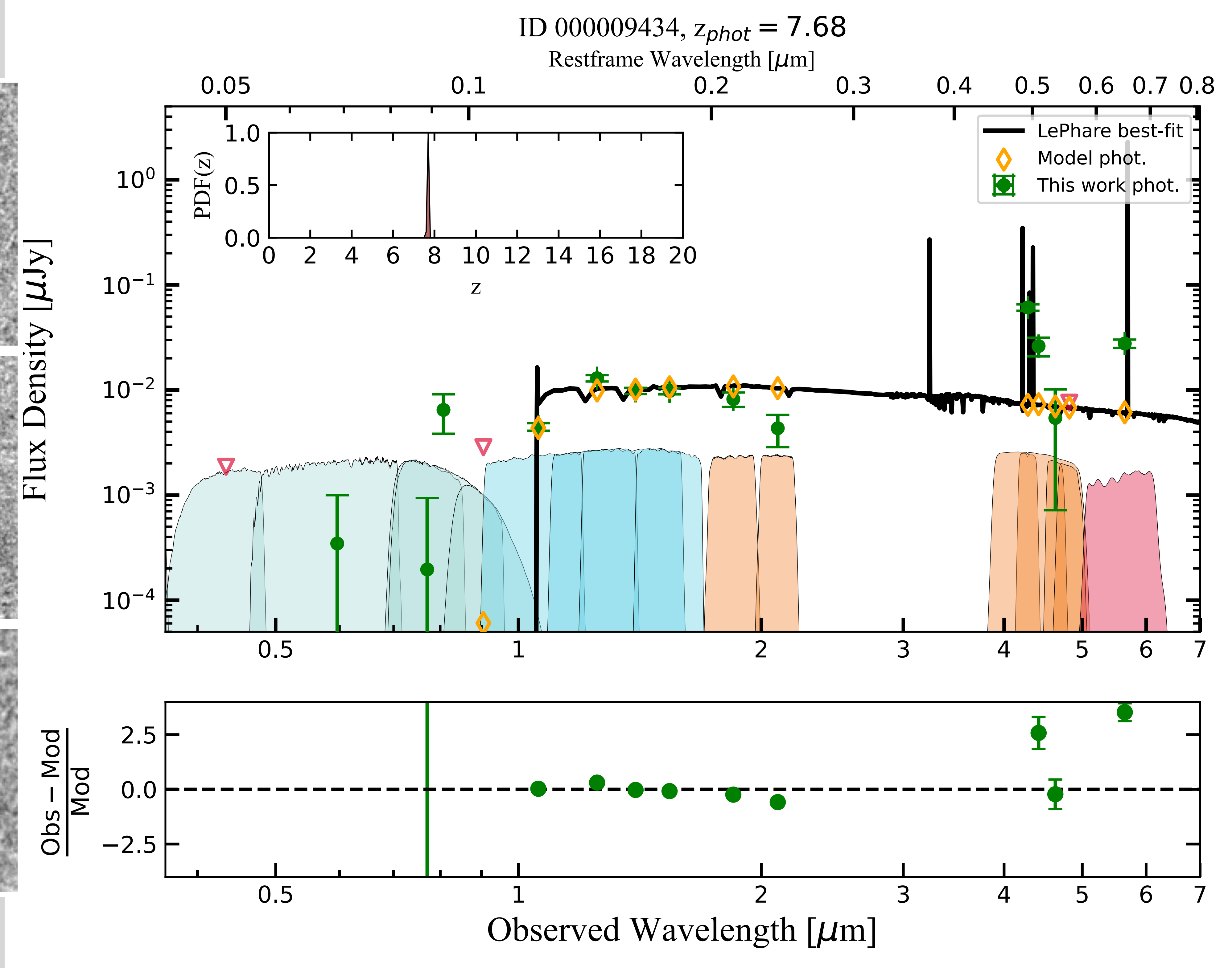
- 58 candidates at $z \simeq 7-8$;
- **18** sources show an excess in **F430M** or **F444W** => $(H\beta + [OIII])$ emitters;
- **12** of them show an excess in **F560W** => $H\alpha$ emitters;
- 40 sources classified as non-emitters.

$$EW_0 = \frac{W_{rec}(10^{-0.4\Delta mag} - 1)}{1+z}$$

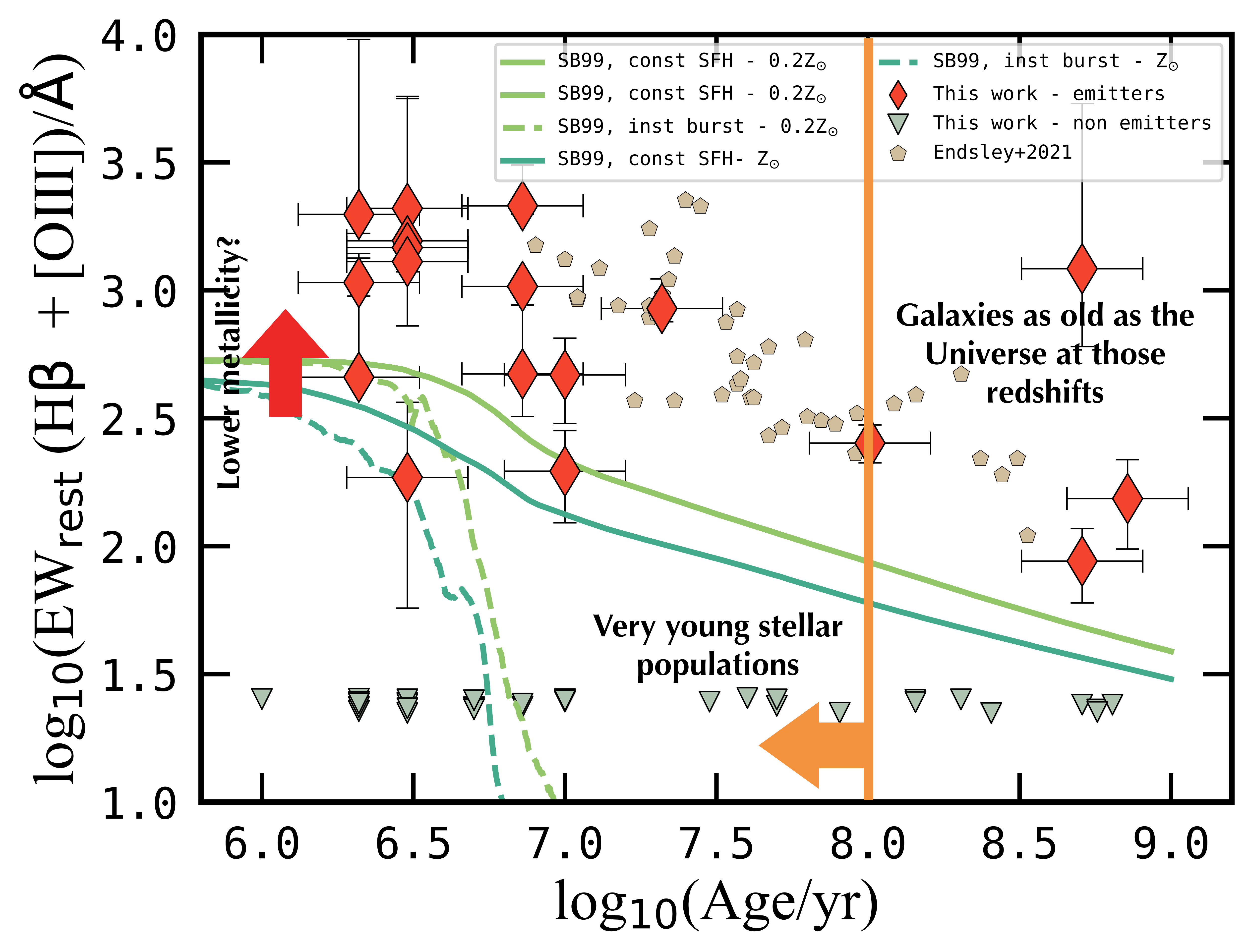


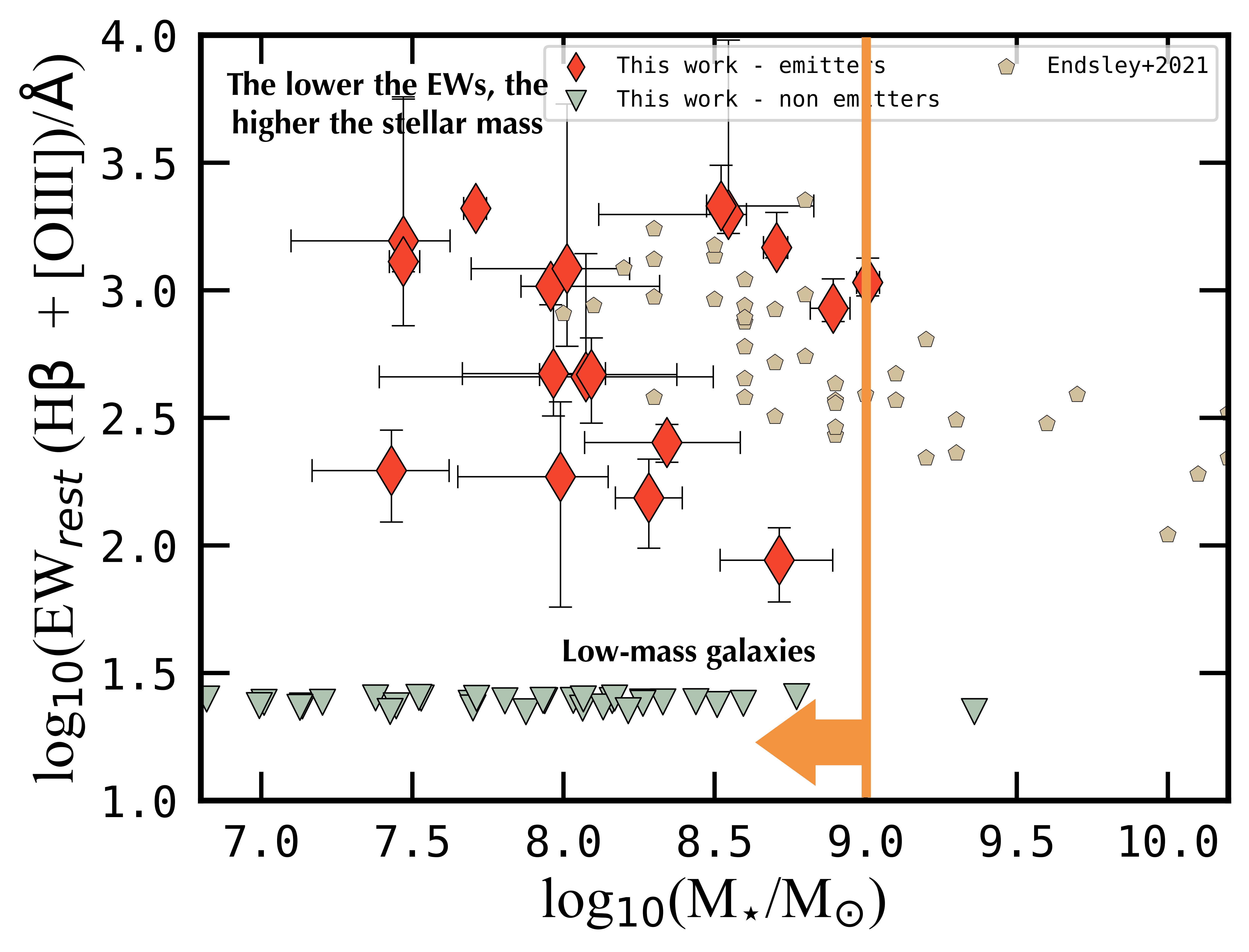
$(H\beta + [OIII])$

$(H\alpha + [NII] + [SII])$



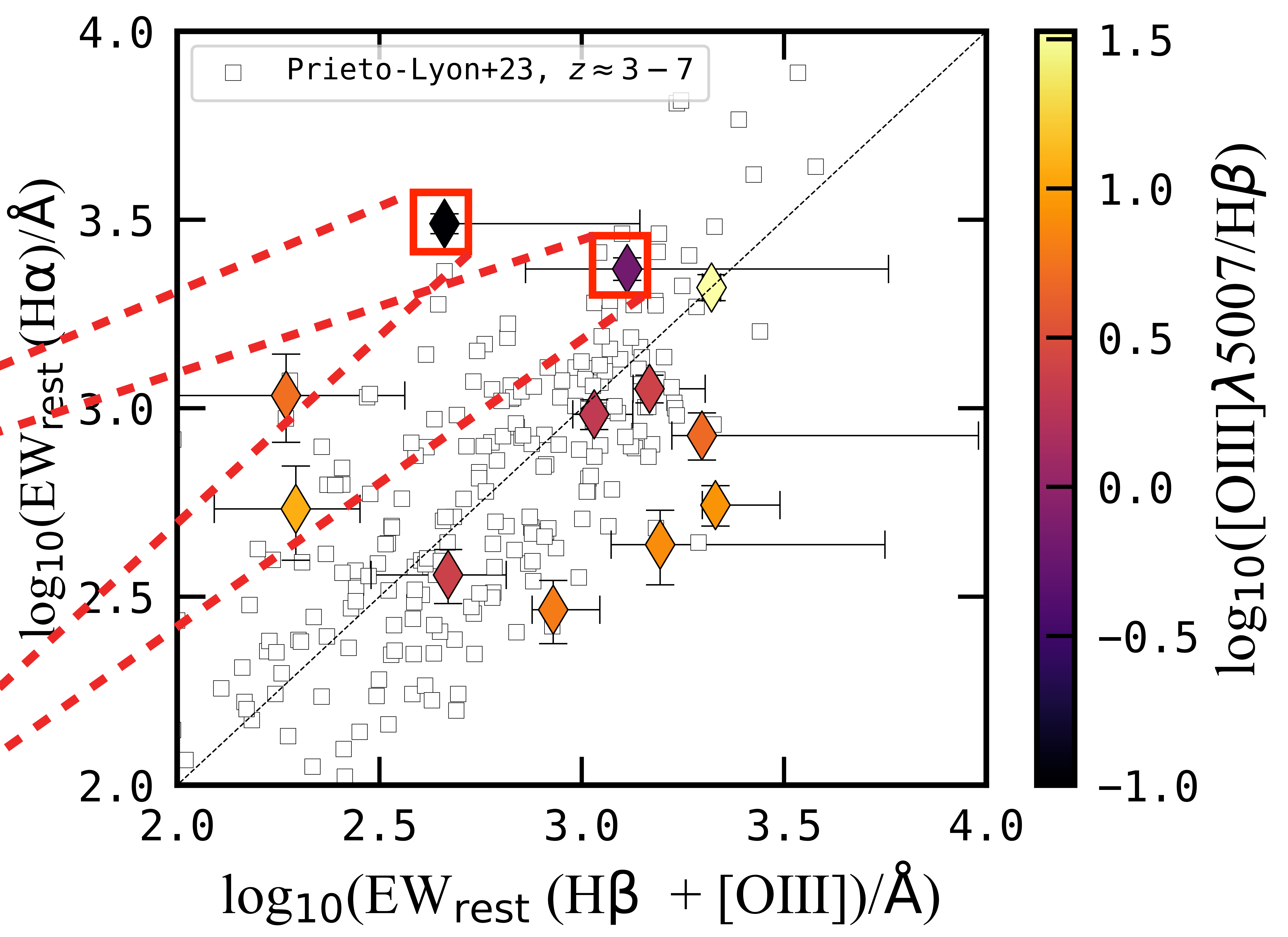
$$\langle \mathrm{EW}_0 \rangle \simeq 943^{+737}_{-194}\ \text{Å}$$





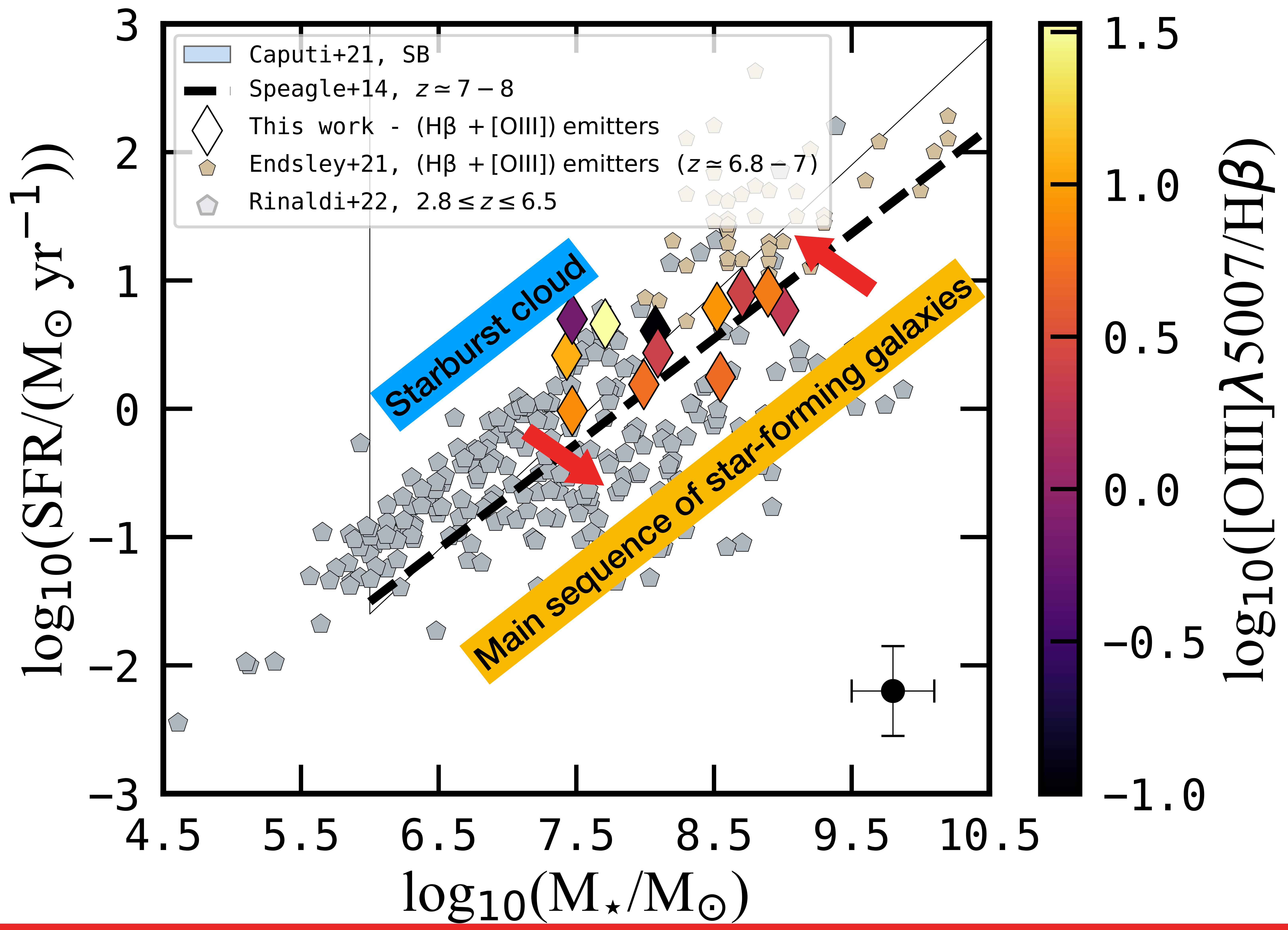
Strong Line Emitters at $z \simeq 7-8$

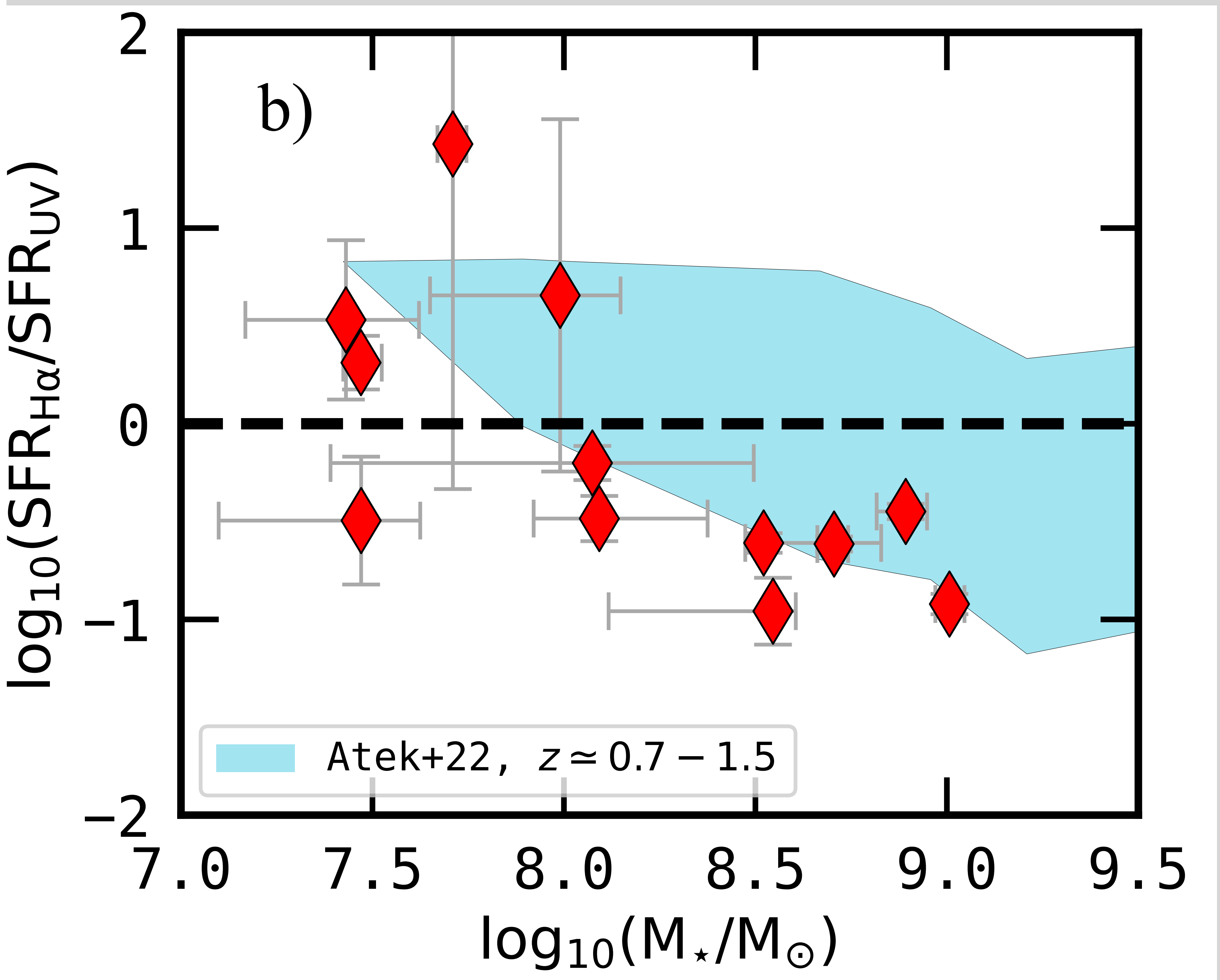
We retrieve the expected correlation between both nebular emission lines $H\alpha$ and ($H\beta$ + [OIII]), since these lines are all generated by the effects of stellar ionizing radiation



The NIRCam flux excess is **mainly driven** by $H\beta$, these sources correspond to cases with **nonnegligible** dust extinction.

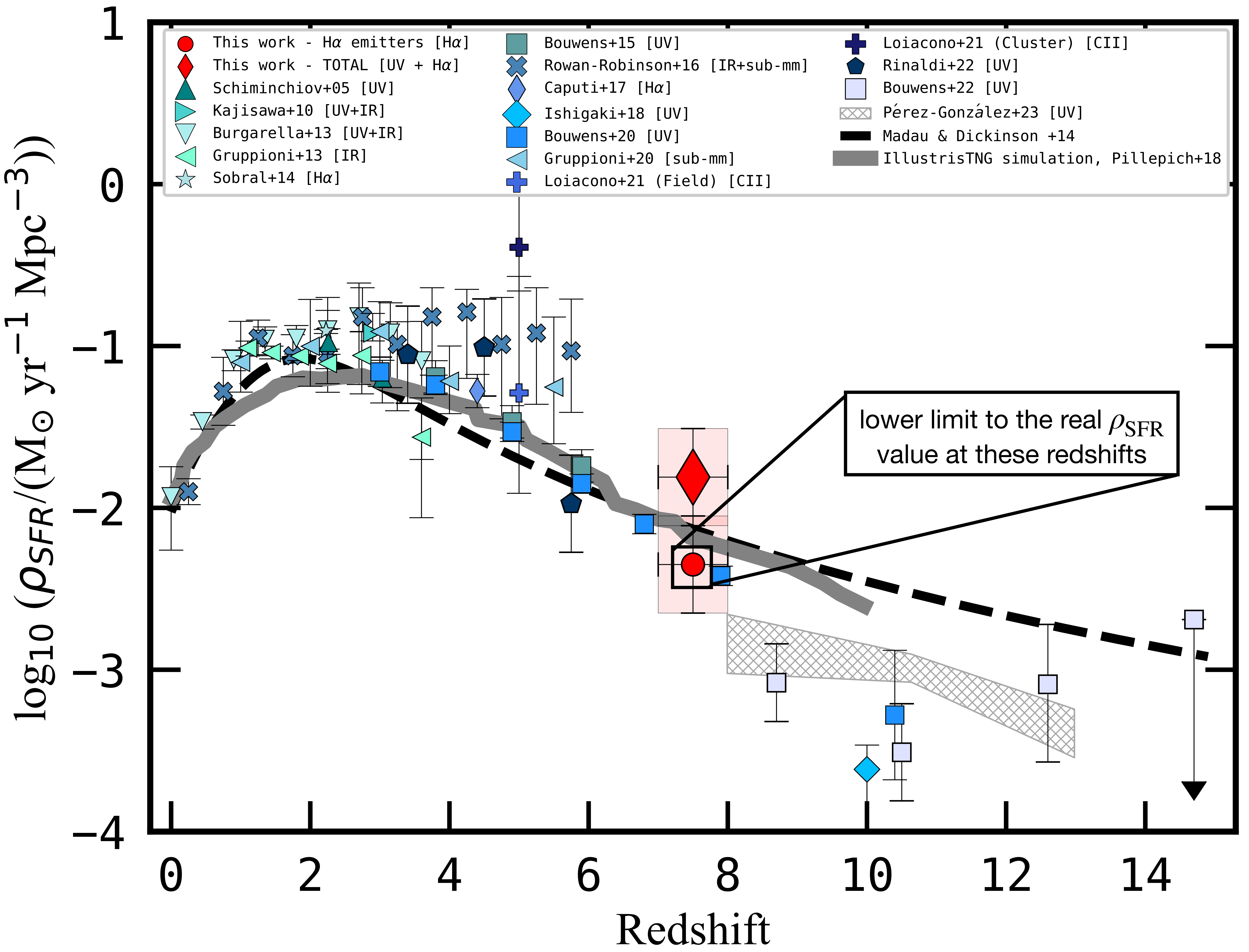
Strong Line Emitters at $z \simeq 7-8$





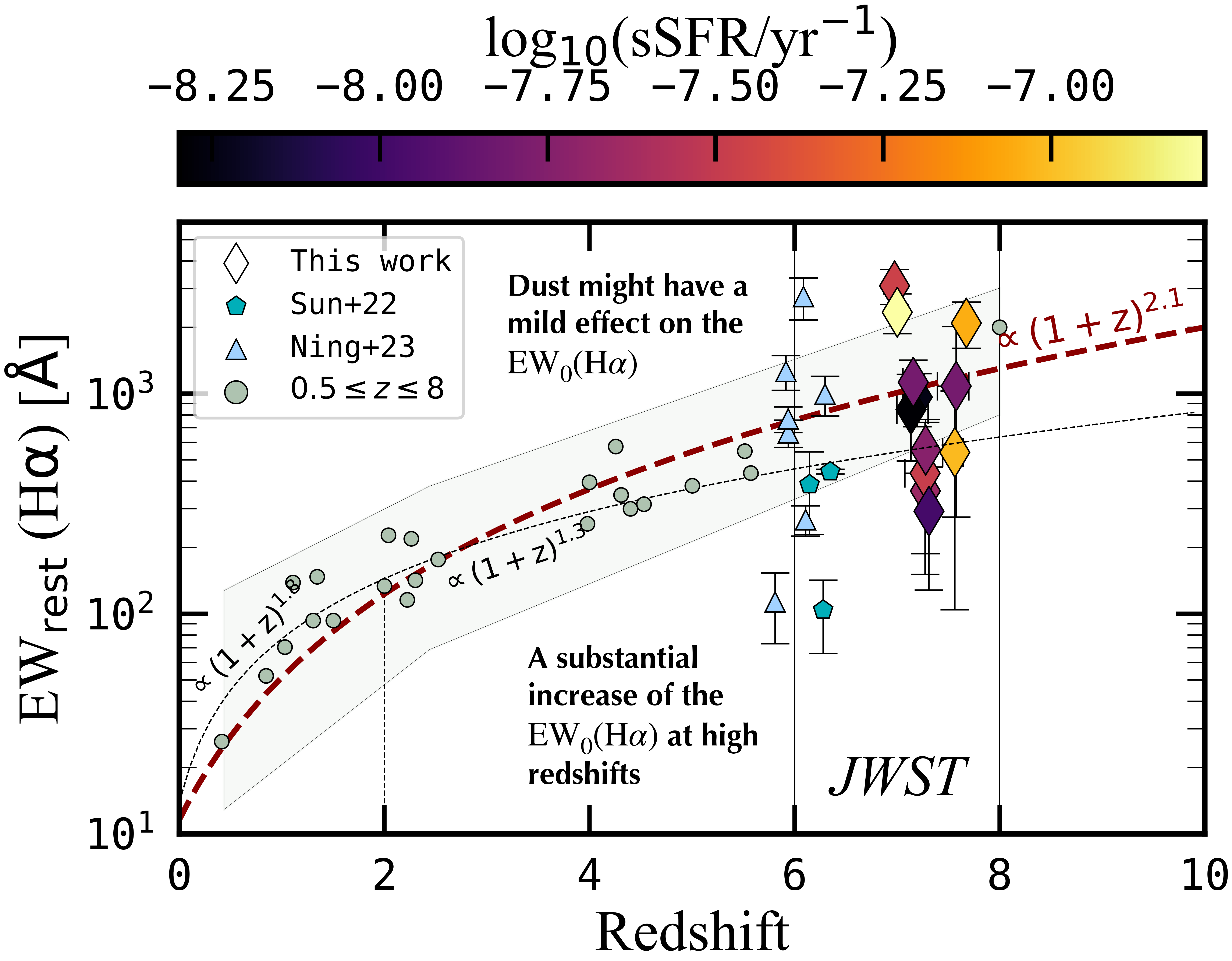
- Given the timescales traced by Hα and UV, the distribution of $\mathrm{SFR_{H\alpha}}/\mathrm{SFR_{UV}}$ and its dispersion can be used as a proxy to study the SFH parameters;
- Another possible source for the variations in the $\mathrm{SFR_{H\alpha}}/\mathrm{SFR_{UV}}$ ratio, especially in low-mass galaxies as in our sample, is a stochastic sampling of the IMF;
- However, both SFR indicators use conversion factors from Hα and UV luminosities assuming a constant star formation.

Strong Line Emitters at $z \simeq 7-8$



Strong Line Emitters at $z \simeq 7-8$

The evolution $EW_0(H\alpha)$ with redshift can be assumed as an observational proxy (i.e., which does not depend on models) for the sSFR – z relation, therefore it can help us to constrain the star formation history of galaxies at very high redshift.



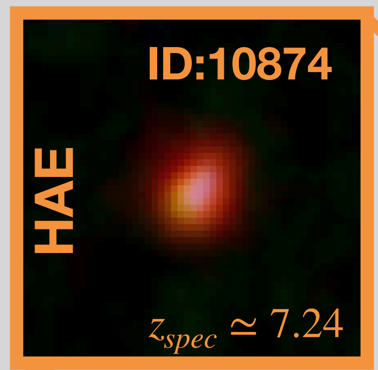
CONCLUSIONS AND NEXT STEPS   STRONG LINE EMITTERS AT $z \simeq 7-8$

In less than one year, JWST has demonstrated its capability the unfold the high redshift Universe giving us the opportunity to better constrain how galaxies formed and evolved over cosmic time.

- Huge advantages by combining **medium-band** and **broadband** from JWST => unique opportunity to look for **high redshift (strong) emitters**;
- Over 58 sources at $z \simeq 7-8$, 18 show $(\mathrm{H}\beta + [\mathrm{OIII}])$ excess. Among them 12 show an "Hα excess" (a quarter of **all** the MIRI-detected galaxies at $z \simeq 7-8$);
- **4** HAEs have been spectroscopically confirmed ([OIII] doublet) with FRESCO data. **A further analysis will help to confirm the rest of the sample**;
- **Most** of the **HAEs** we studied are **starburst galaxies** or on the way to/from the starburst cloud;
- **Majority** of the our $(\mathrm{H}\beta + [\mathrm{OIII}])$ emitters **are very young galaxies** (best-fit ages $< 10^7$ yr) => **first major star formation episode**. A **few others are almost as old as the universe at their redshifts** with significant stellar mass ($> 10^8\ \mathrm{M}_\odot$), **suggesting that they may be experiencing a rejuvenation effect**;
- The **identified** Hα **emitters** show a variety of EW_0 values ($200-3000$ Å**).** We also find that $\mathrm{EW}_0(\mathrm{H}\alpha)$ **should evolve as** $\propto (1+z)^{2.1}$ => **larger samples of galaxies to confirm this result**;
- **MIRI** has demonstrated that we can **systematically observe** Hα emitters at very high-z ($z > 7$), offering us the opportunity to better constrain the **star formation history** at those z.

What's next?!

We want to study the Hα emission from a spectroscopical point of view - aka we need spectra!



What's next?!

Understanding the properties of the HAEs in the context of the Epoch of Reionization. Which role did they play? Could the strong emitters have played a **key role** in reionizing the Universe?

SCAN ME

The paper has been accepted for publication in ApJ and it is going to be published soon

MIDIS: The Role of Strong Hα Emitters at $z \simeq 7-8$ during the Epoch of Reionization - Constraints from JWST

P. Rinaldi,[1] K. I. Caputi,[1,2] and MIRI GTO

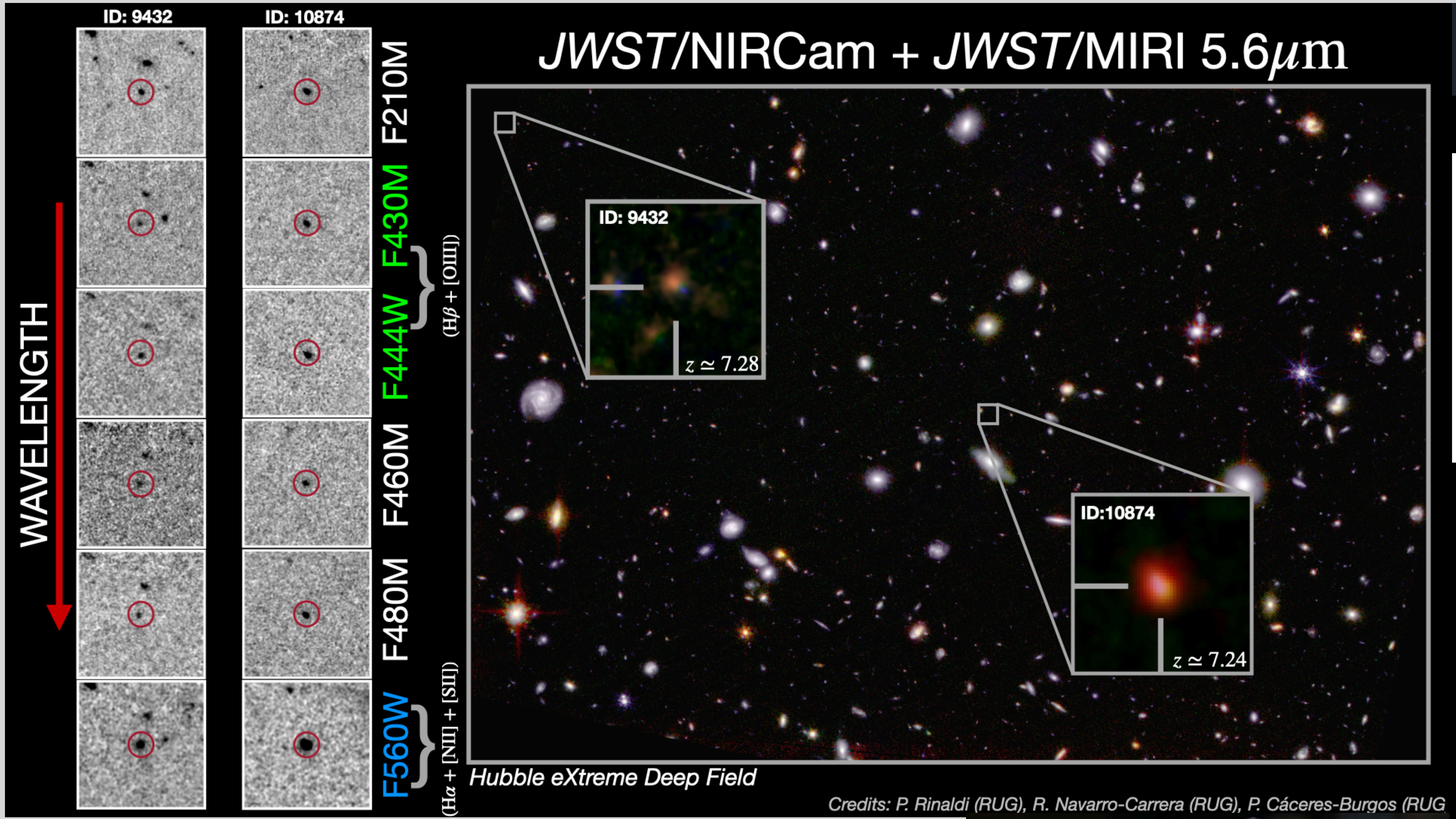
[1] Kapteyn Astronomical Institute, University of Groningen, P.O. Box 800, 9700AV Groningen, The Netherlands
[2] Cosmic Dawn Center (DAWN), Denmark

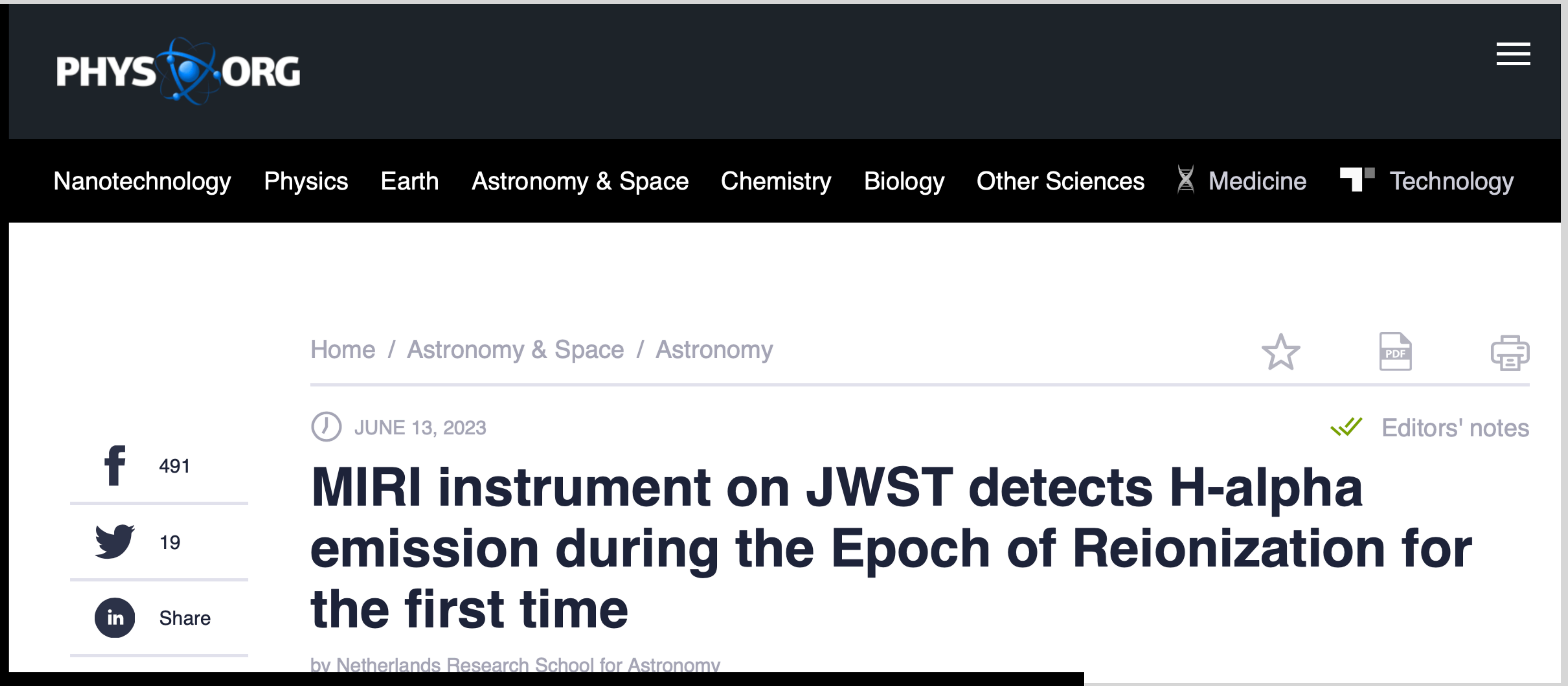
STAY TUNED

MIRI European Consortium

PRESS RELEASE

STRONG LINE EMITTERS AT $z \simeq 7-8$





PHYS.ORG

Nanotechnology Physics Earth Astronomy & Space Chemistry Biology Other Sciences Medicine Technology

Home / Astronomy & Space / Astronomy

JUNE 13, 2023

Editors' notes

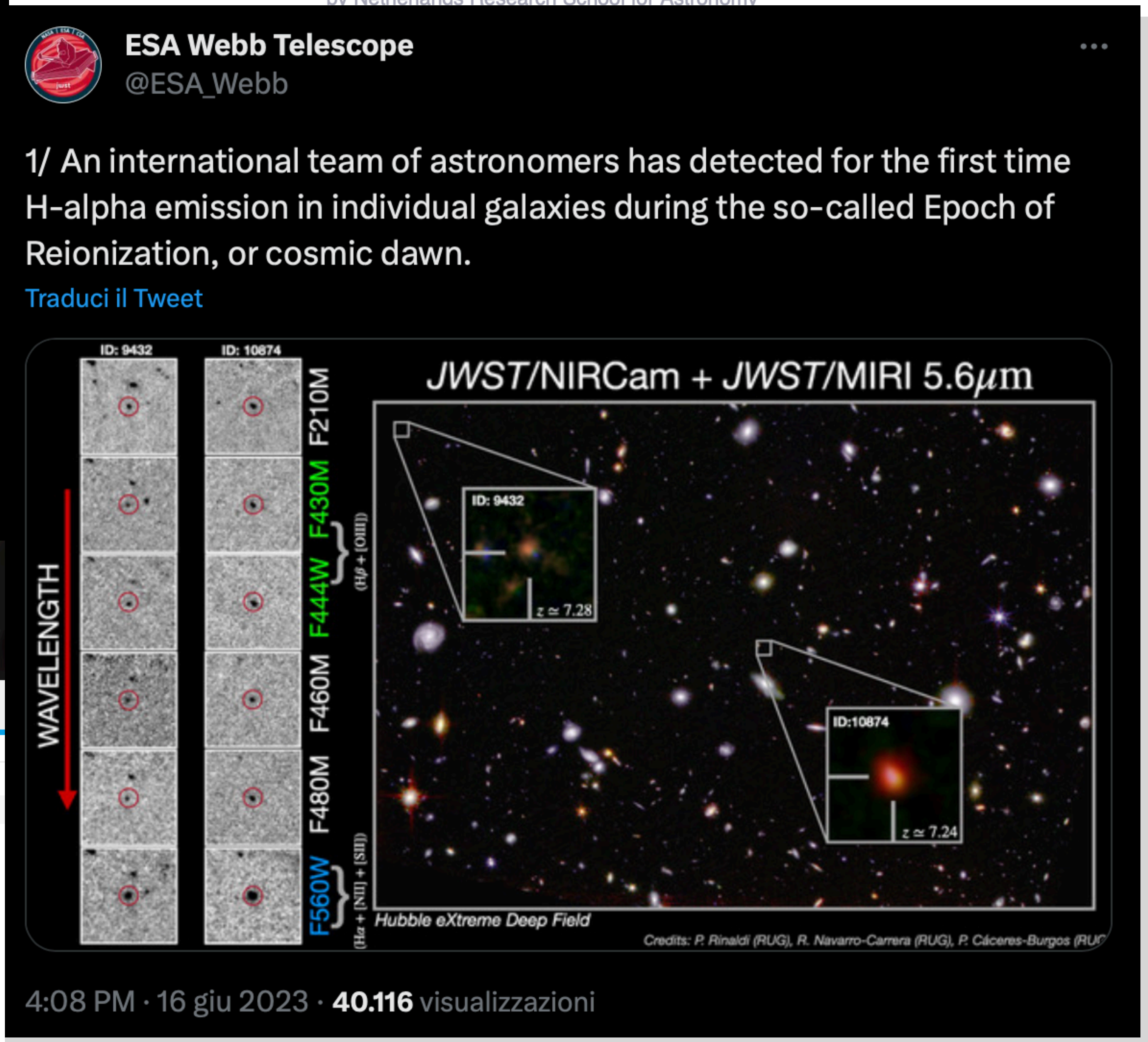
491

19

Share

MIRI instrument on JWST detects H-alpha emission during the Epoch of Reionization for the first time

by Netherlands Research School for Astronomy



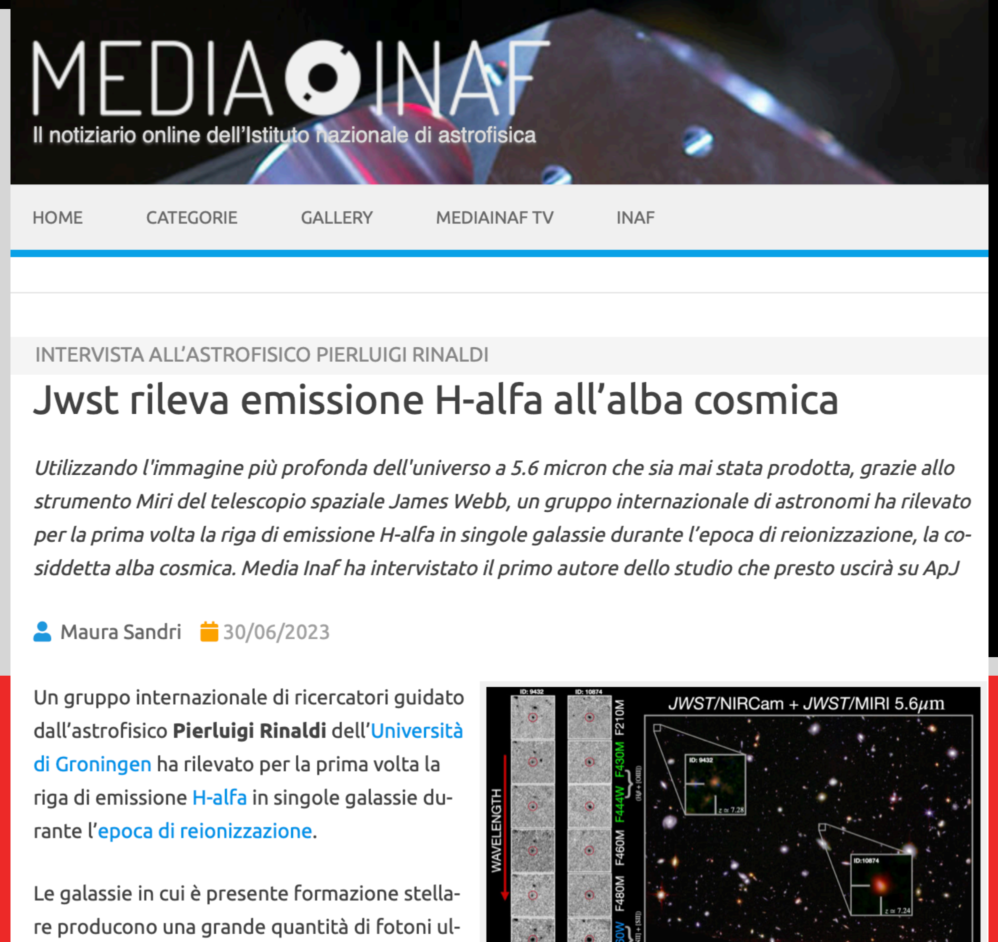
ESA Webb Telescope
@ESA_Webb

1/ An international team of astronomers has detected for the first time H-alpha emission in individual galaxies during the so-called Epoch of Reionization, or cosmic dawn.

Traduci il Tweet

4:08 PM · 16 giu 2023 · **40.116** visualizzazioni

SCAN ME



MEDIA INAF
Il notiziario online dell'Istituto Nazionale di astrofisica

HOME CATEGORIE GALLERY MEDIAINAF TV INAF

INTERVISTA ALL'ASTROFISICO PIERLUIGI RINALDI

Jwst rileva emissione H-alfa all'alba cosmica

Utilizzando l'immagine più profonda dell'universo a 5.6 micron che sia mai stata prodotta, grazie allo strumento Miri del telescopio spaziale James Webb, un gruppo internazionale di astronomi ha rilevato per la prima volta la riga di emissione H-alfa in singole galassie durante l'epoca di reionizzazione, la cosiddetta alba cosmica. Media Inaf ha intervistato il primo autore dello studio che presto uscirà su ApJ

Maura Sandri 30/06/2023

Un gruppo internazionale di ricercatori guidato dall'astrofisico **Pierluigi Rinaldi** dell'Università di Groningen ha rilevato per la prima volta la riga di emissione H-alfa in singole galassie durante l'epoca di reionizzazione.

Le galassie in cui è presente formazione stellare producono una grande quantità di fotoni ul-