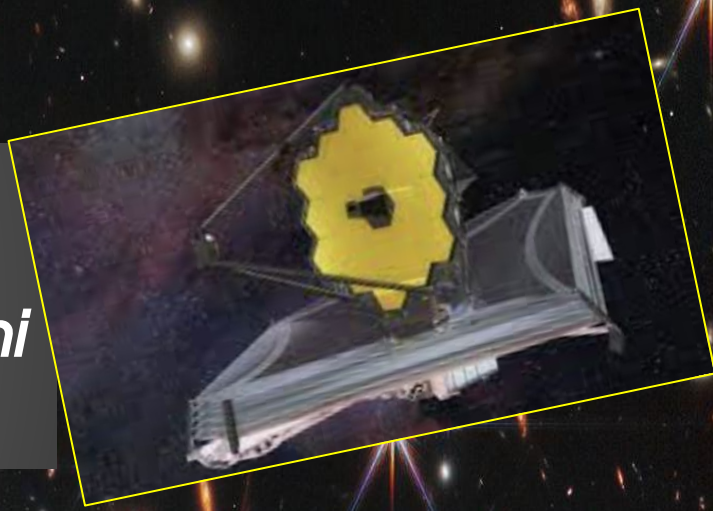
Looking for distant dusty galaxies with JWST

Giulia Rodighiero

with *Laura Bisigello, Andrea Grazian, Giovanni Gandolfi, Giorgia Girardi*

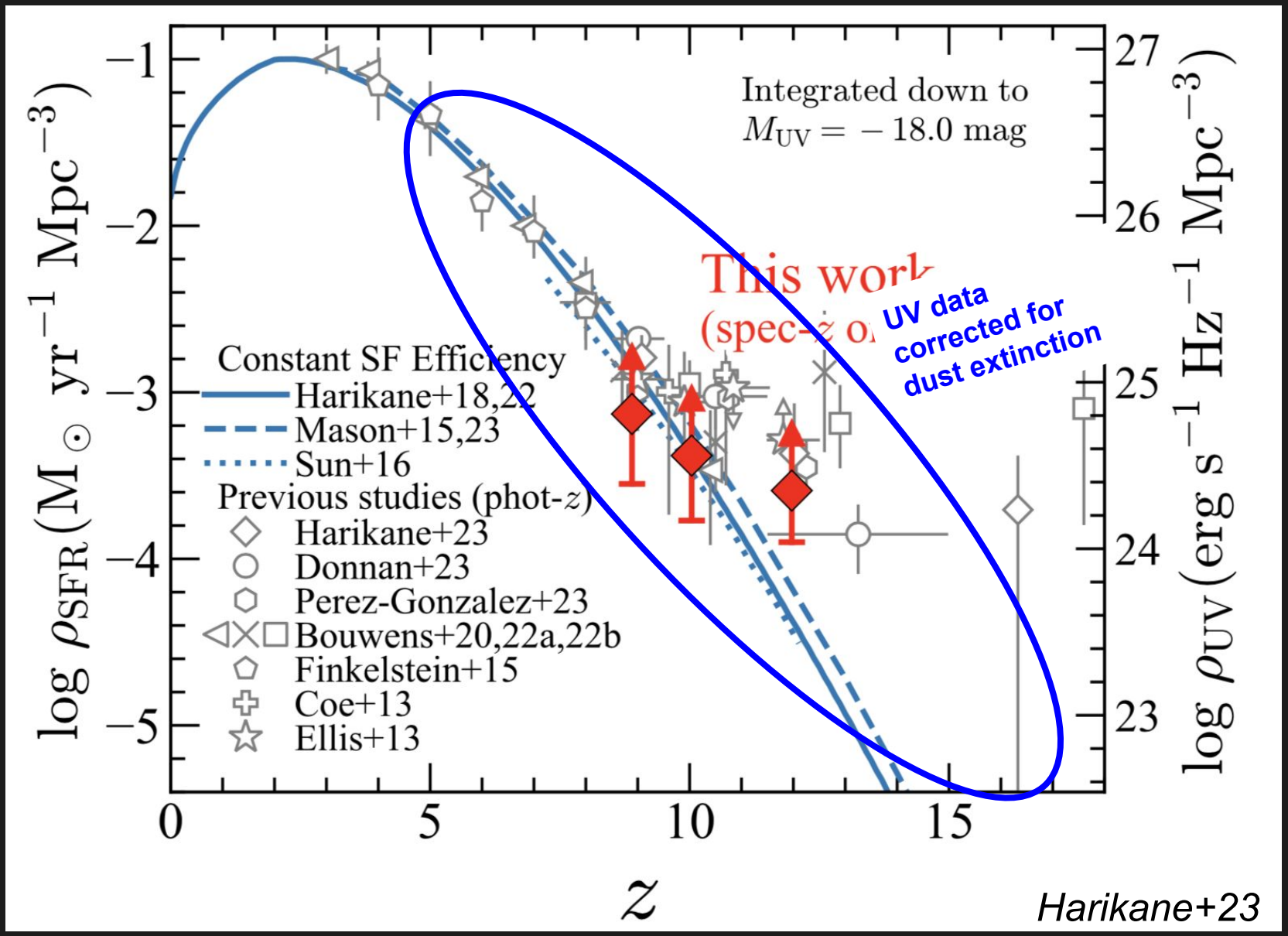


Dipartimento di Fisica e Astronomia
Università degli Studi di Padova

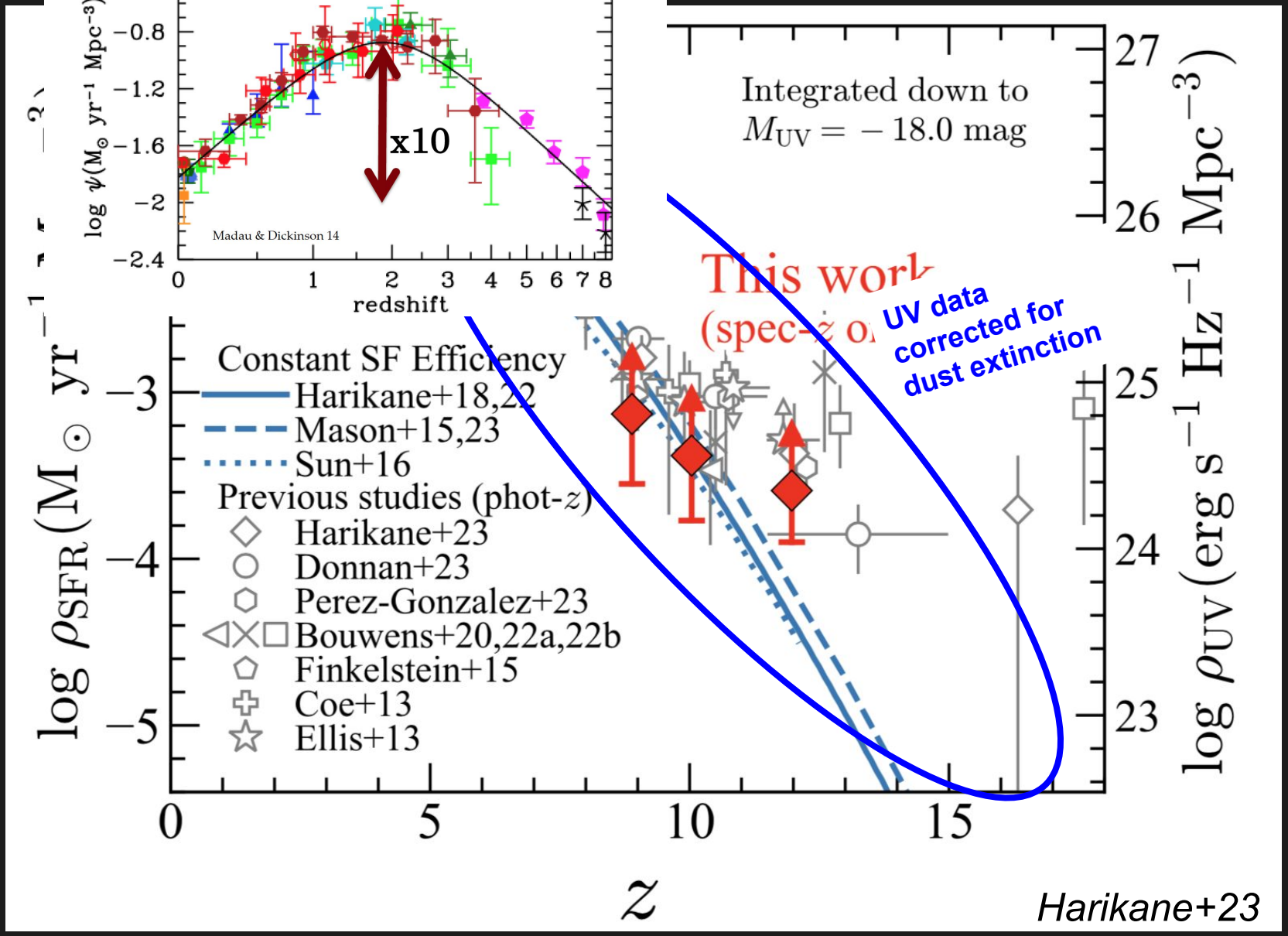
Bid4Best final conference

8th of February 2024, Southampton (virtual)

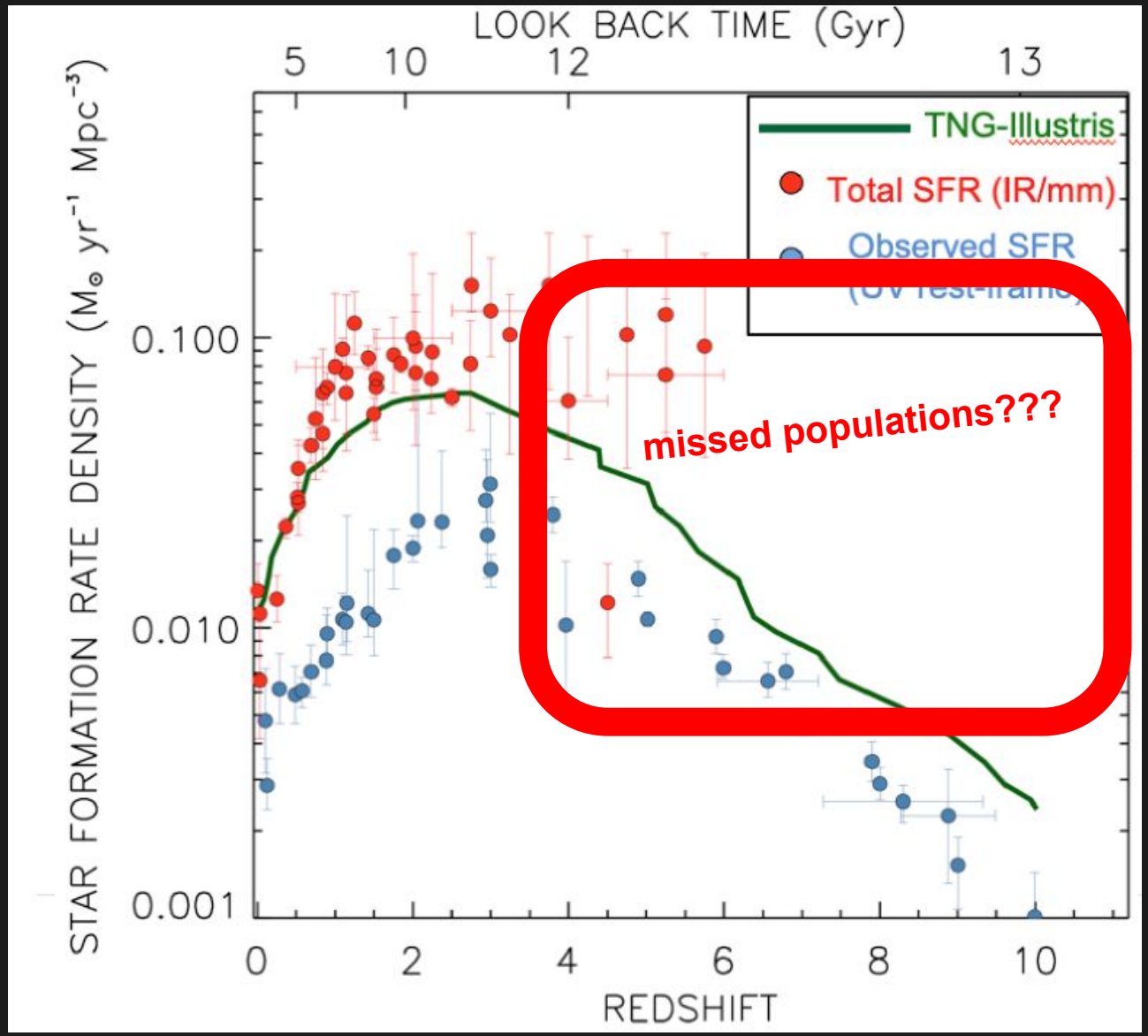
The cosmic SFRD in the *JWST* era



The [illegible] in the *JWST* era

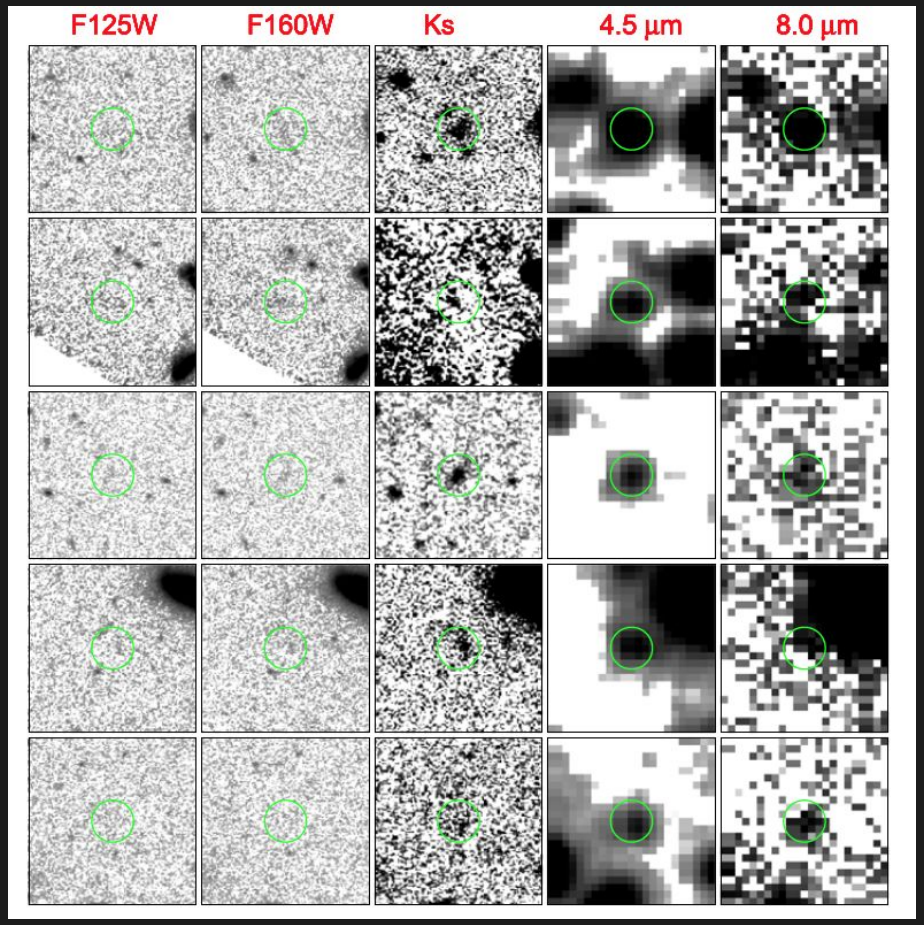


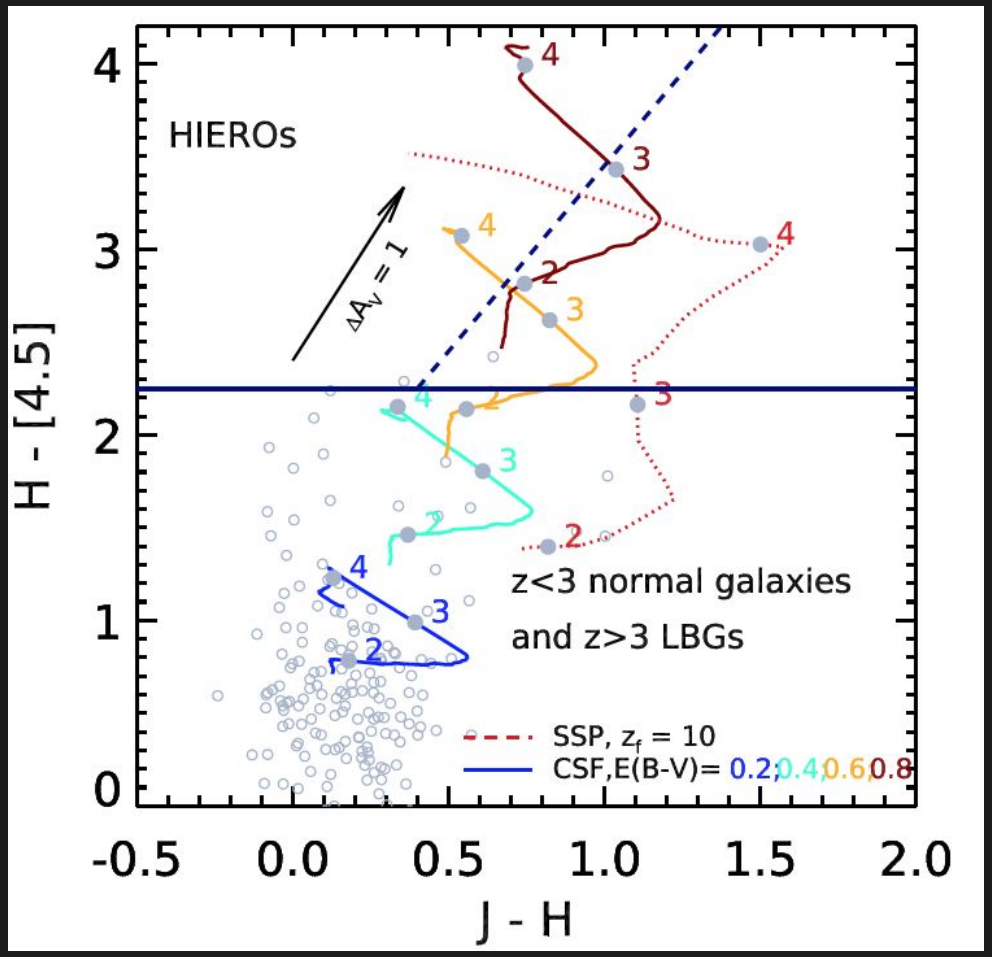
The cosmic SFRD in the *JWST* era



Courtesy, Carlotta Gruppioni

HST H-band dropouts in the CANDELS area have detected an analog population of dark massive sources: candidate massive Dusty SF Galaxies at 2<z< 3 and/or passive galaxies at z ~ 3–4



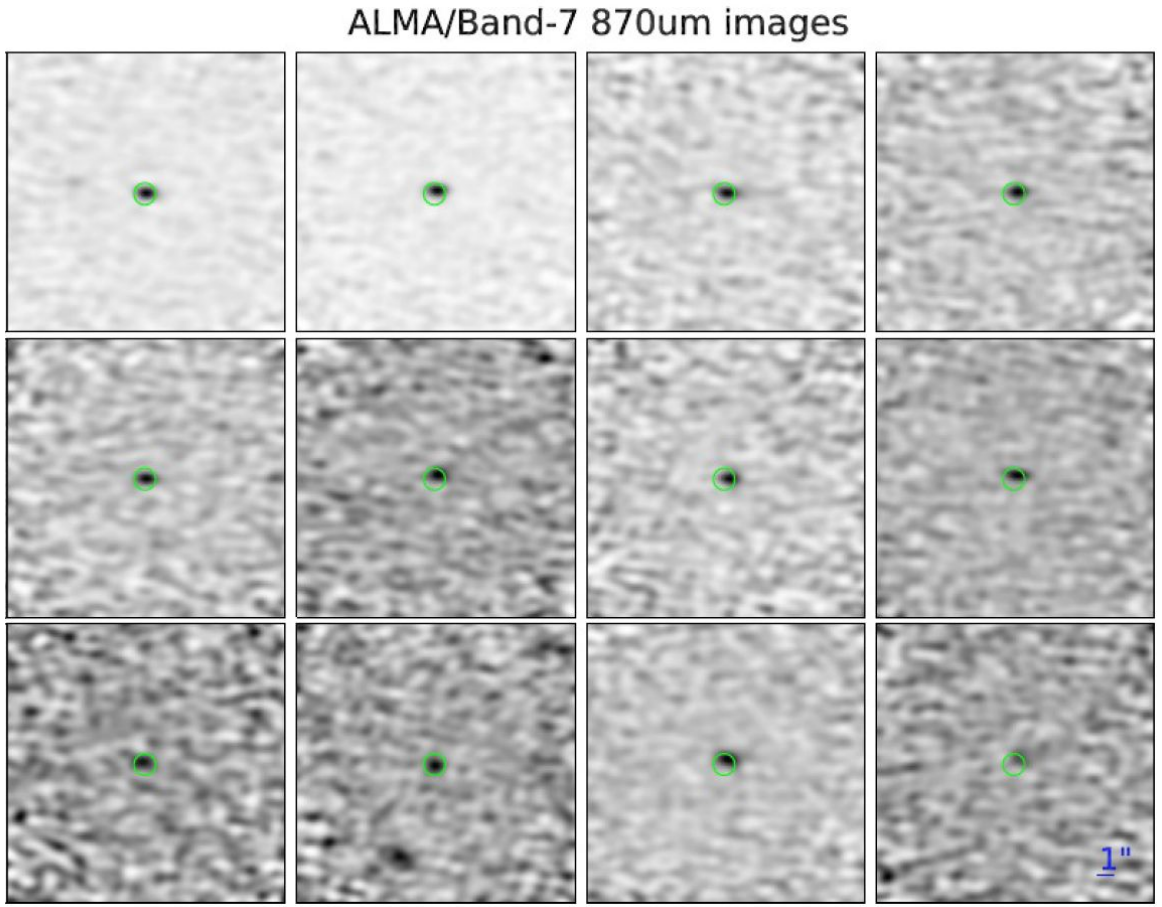


Wang et al. 2016, 2019, 2023

Most HST-dark dropout galaxies are detected in continuum by ALMA

- T. Wang: “H-dropouts” in the CANDELS catalogs
  → **62** galaxies (ch2 < 24)
- 17 of them were observed with ALMA (rest of the sample will come soon)
  → **80%** detection rate!

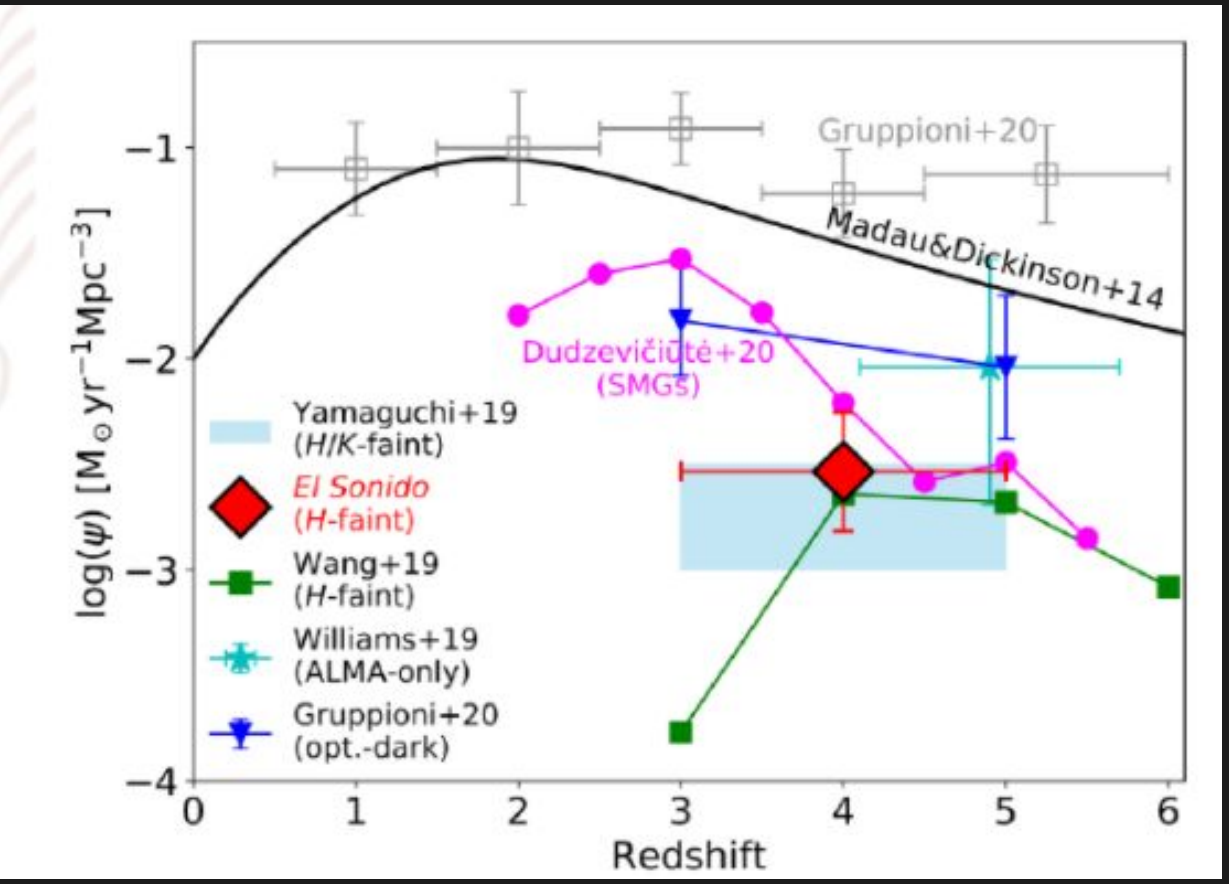
ALMA continuum detection favor the identification of a class of very extinguished dusty starforming sources



Wang+19 (Nature)

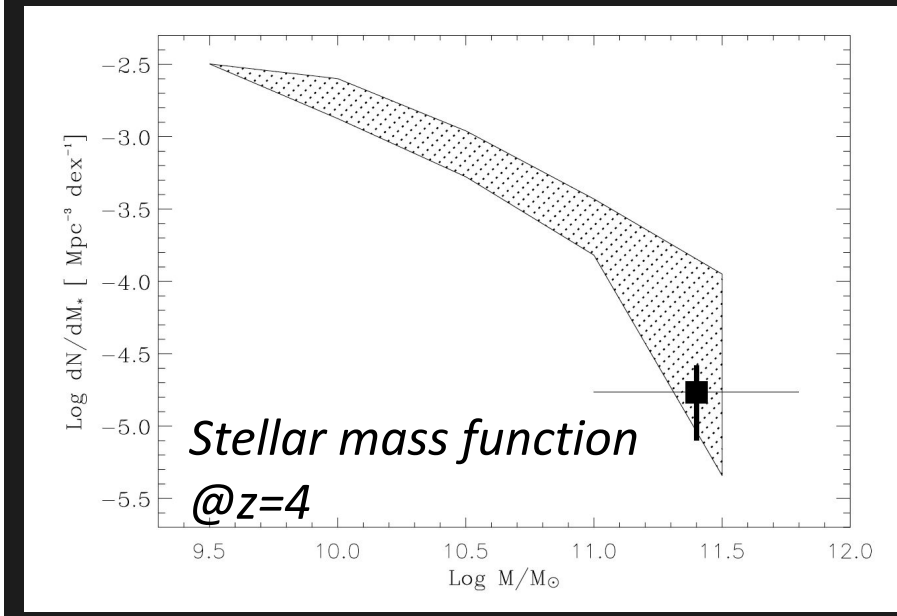
Unknown population, need to get redshifts!!!

Contribution of "HST" dark sources to the stellar mass density (selection from IRAC, ALMA, radio….):



Sun+20 (but see also Talia+20, Enia+22, Perez-Gonzalez+22,23)

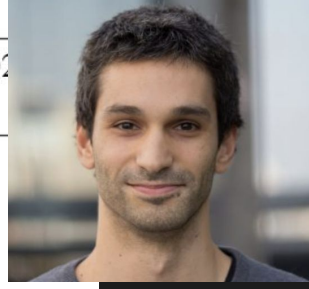
Different population from LBGs!



Rodighiero+07

These dusty and massive galaxies show remarkable star formation activity but are **very rare and faint ⇒ Need for Deep and Wide near-IR surveys to statistically recover this population**

Astronomy & Astrophysics manuscript no. aanda
February 8, 2024

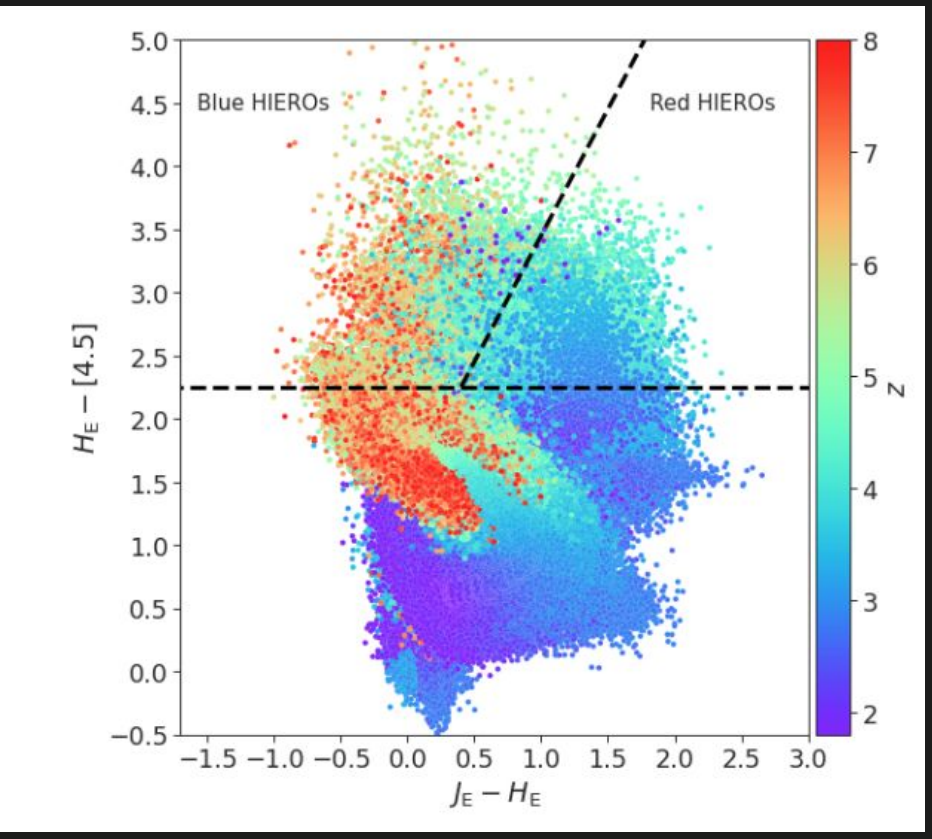


+Spitzer!

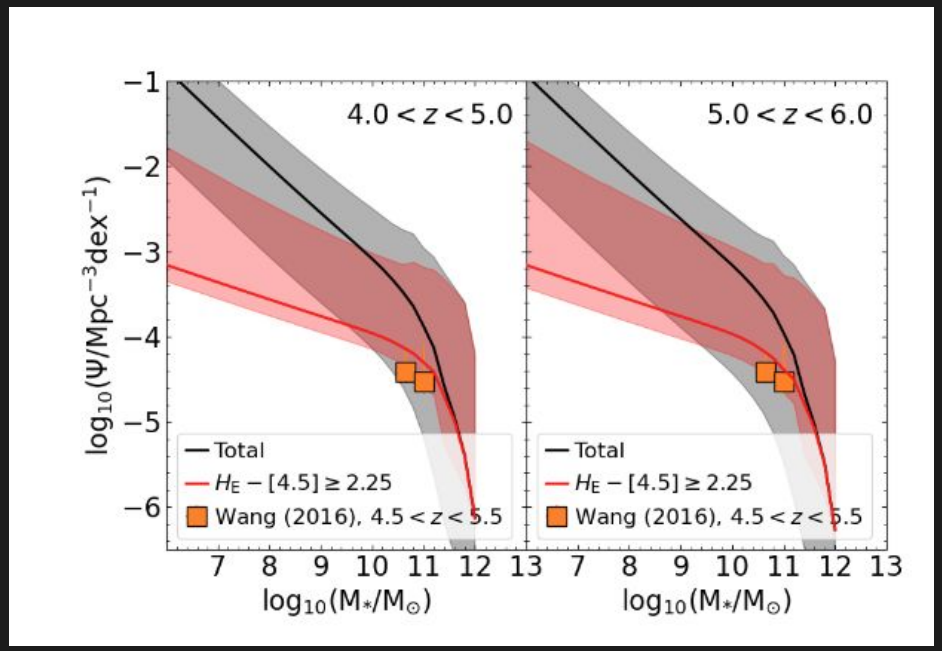
Euclid: Identifying the reddest high-redshift galaxies in the Euclid Deep Fields with gradient-boosted trees*

T. Signor[1,2,3], G. Rodighiero[3,4†], L. Bisigello[3,4], M. Bolzonella[5], K. I. Caputi[6,7], E. Daddi[8], G. De Lucia[9], A. Enia[10,11],

COLOR SELECTION



MASS FUNCTION



today on arXiv:2402.04800

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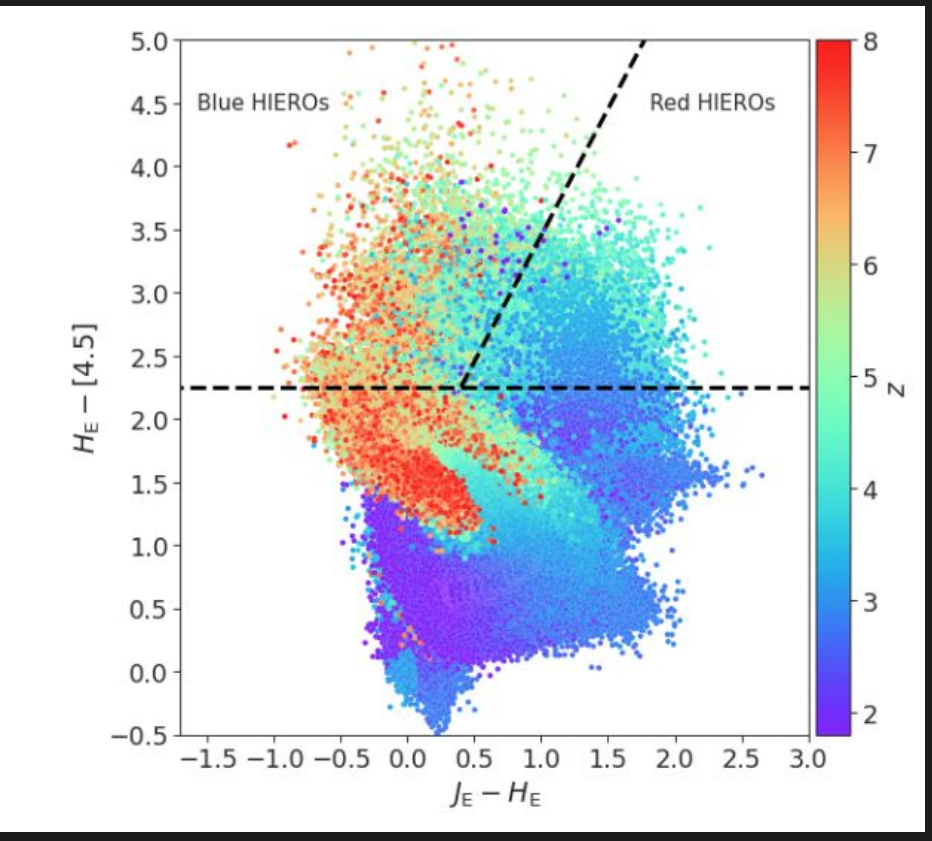

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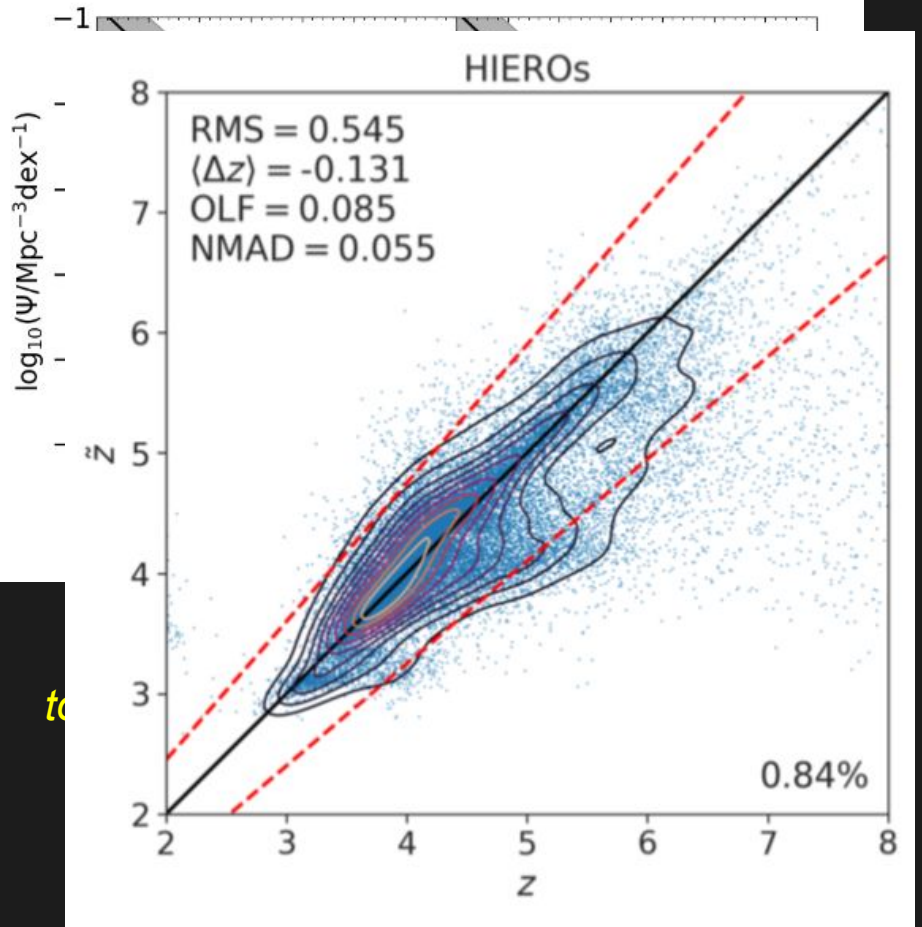


JWST unveils heavily obscured (active and passive) sources up to $z \sim 13$

Giulia Rodighiero[1,2]★, Laura Bisigello[1,2], Edoardo Iani[3], Antonino Marasco[2], Andrea Grazian[2], Francesco Sinigaglia[1,2], Paolo Cassata[1,2] and Carlotta Gruppioni[4]

METHODOLOGY

Field: SMACS0723 NIRCAM + MIRI ⇒ magnification complicates but helps!

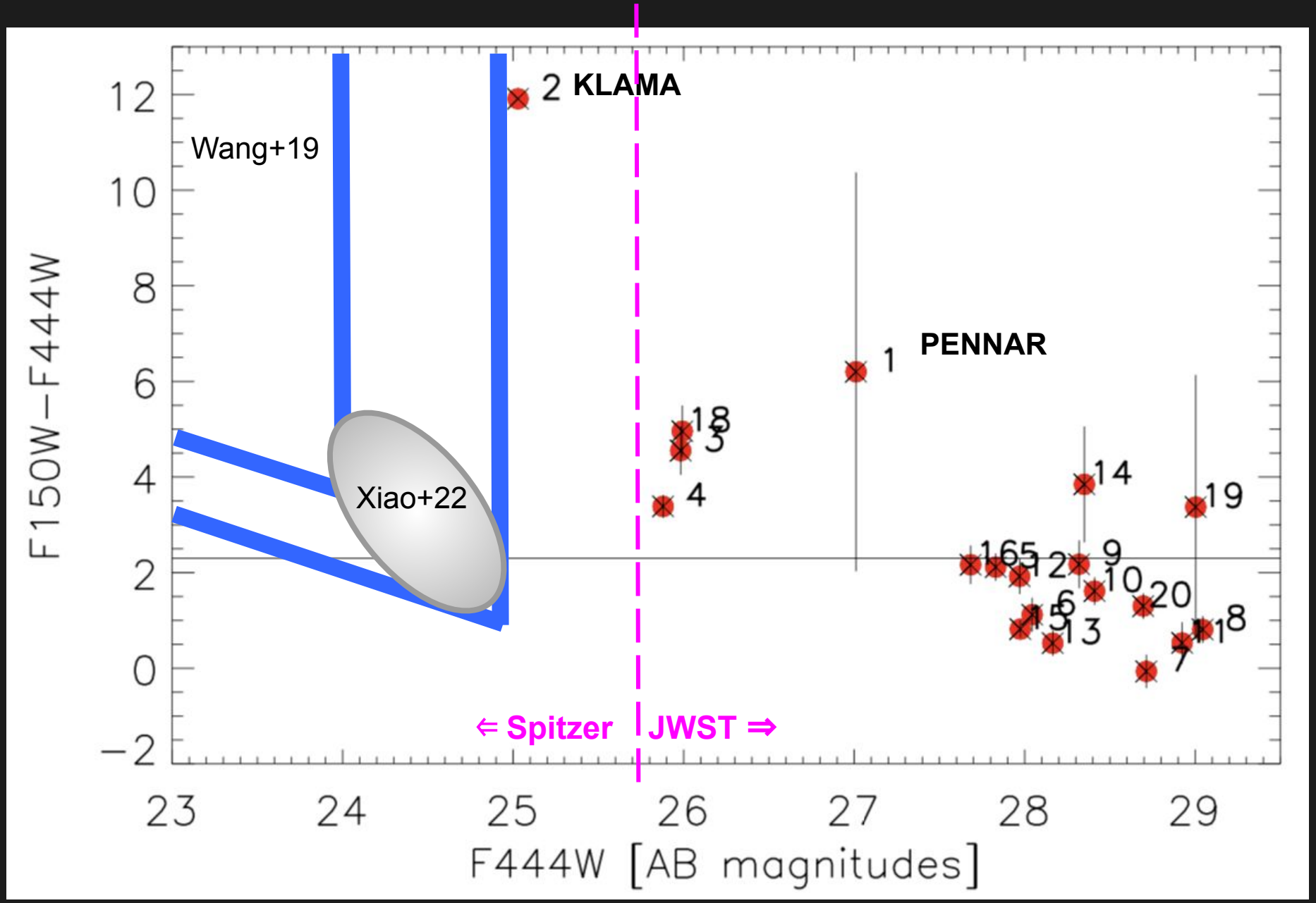
Selection: F444W detection / F200W non-detection in blind SExtractor matched catalogs (any a priori color cut). Final sample of 20 sources.

Ad hoc photometry: refined photometry accounting for local background and contamination around each source ⇒ Marasco+22
Some no-detections might become very faint detections!

SED fitting: BAGPIPES (Carnall+18) with parametric SF histories (delayed declining + rising), wide range of parameter space: Av → 6mag

Position in the M*-SFR plane with redshift

COLOR-mag diagram: comparison to Wang+19 ~HIERO selection



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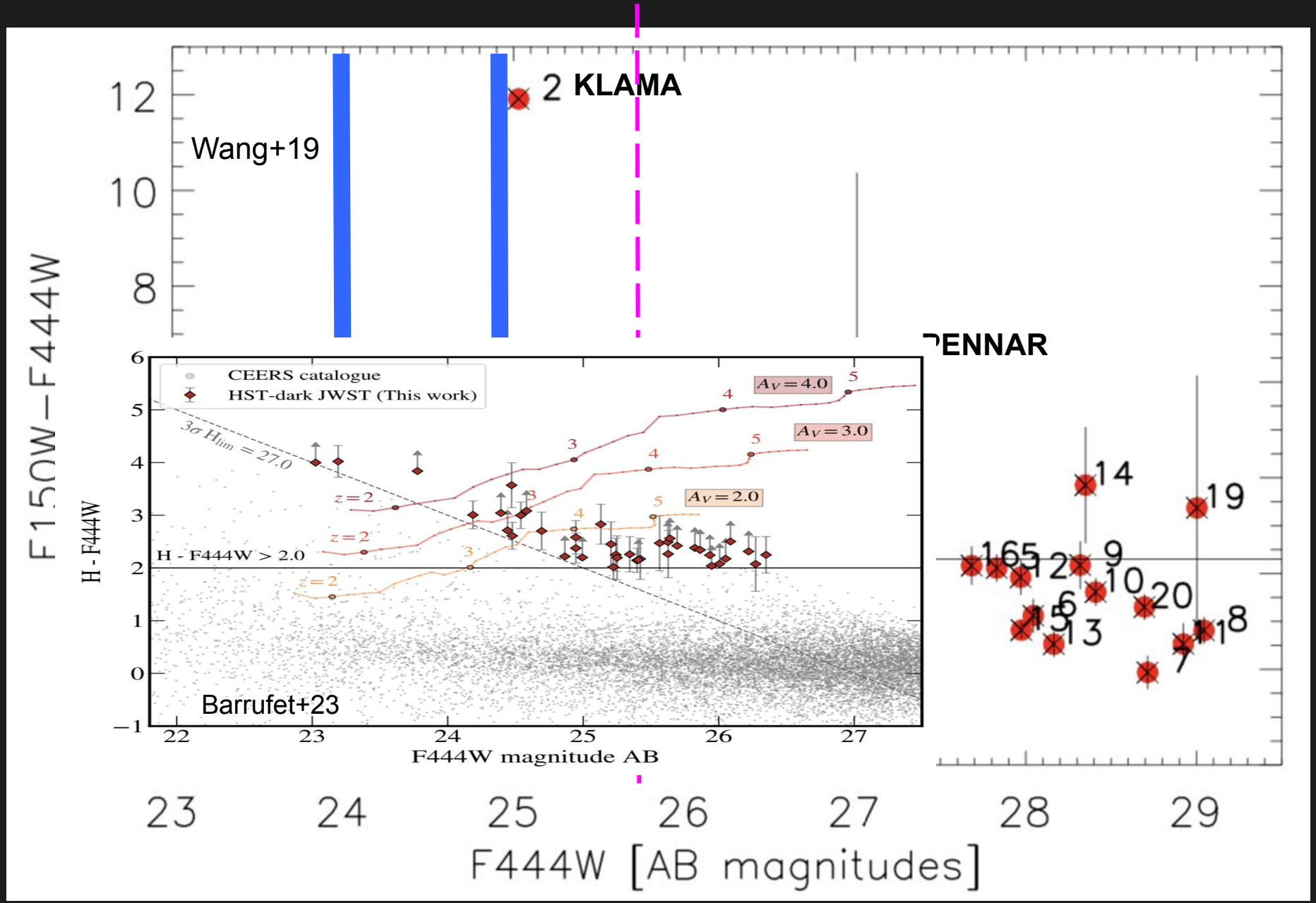
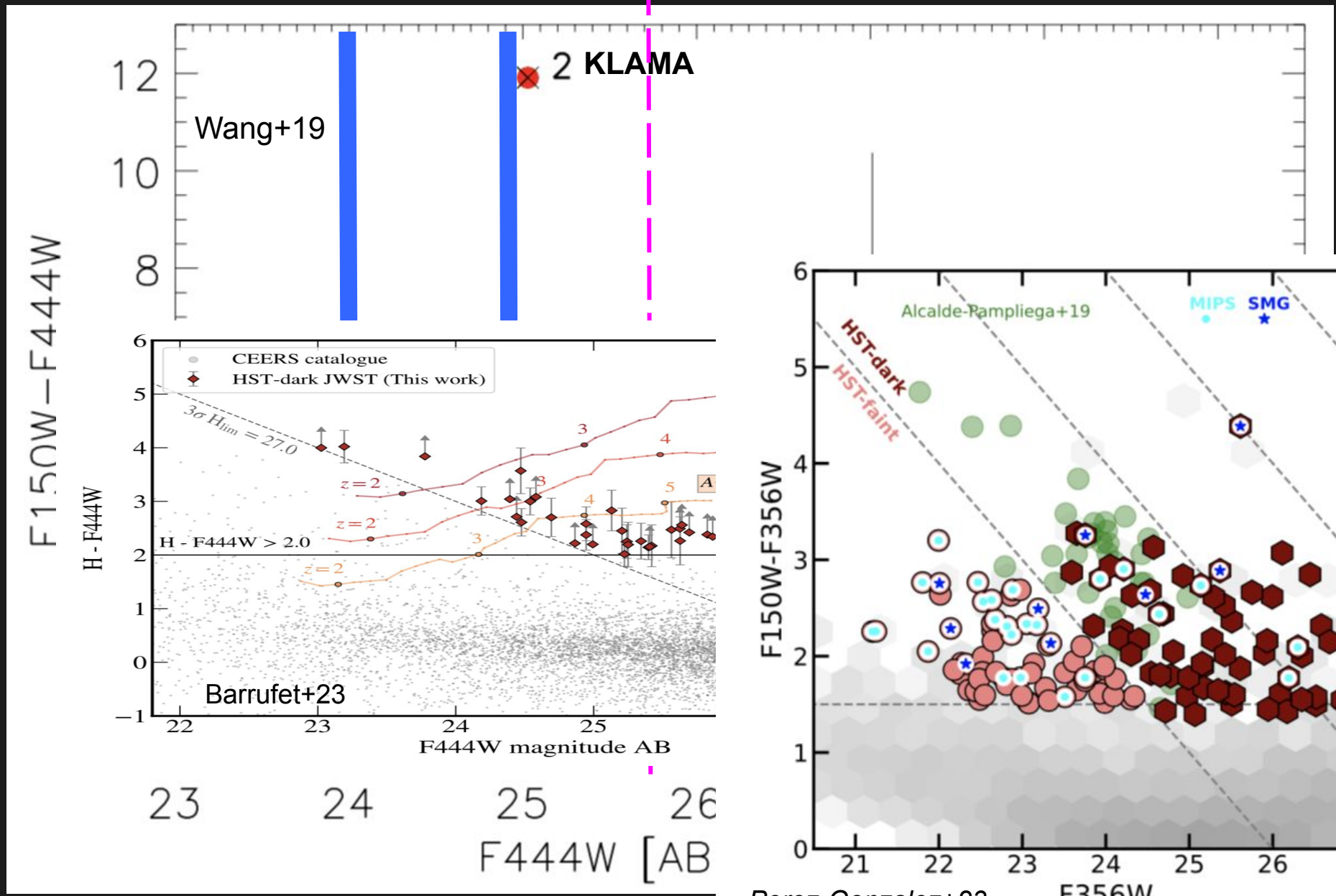
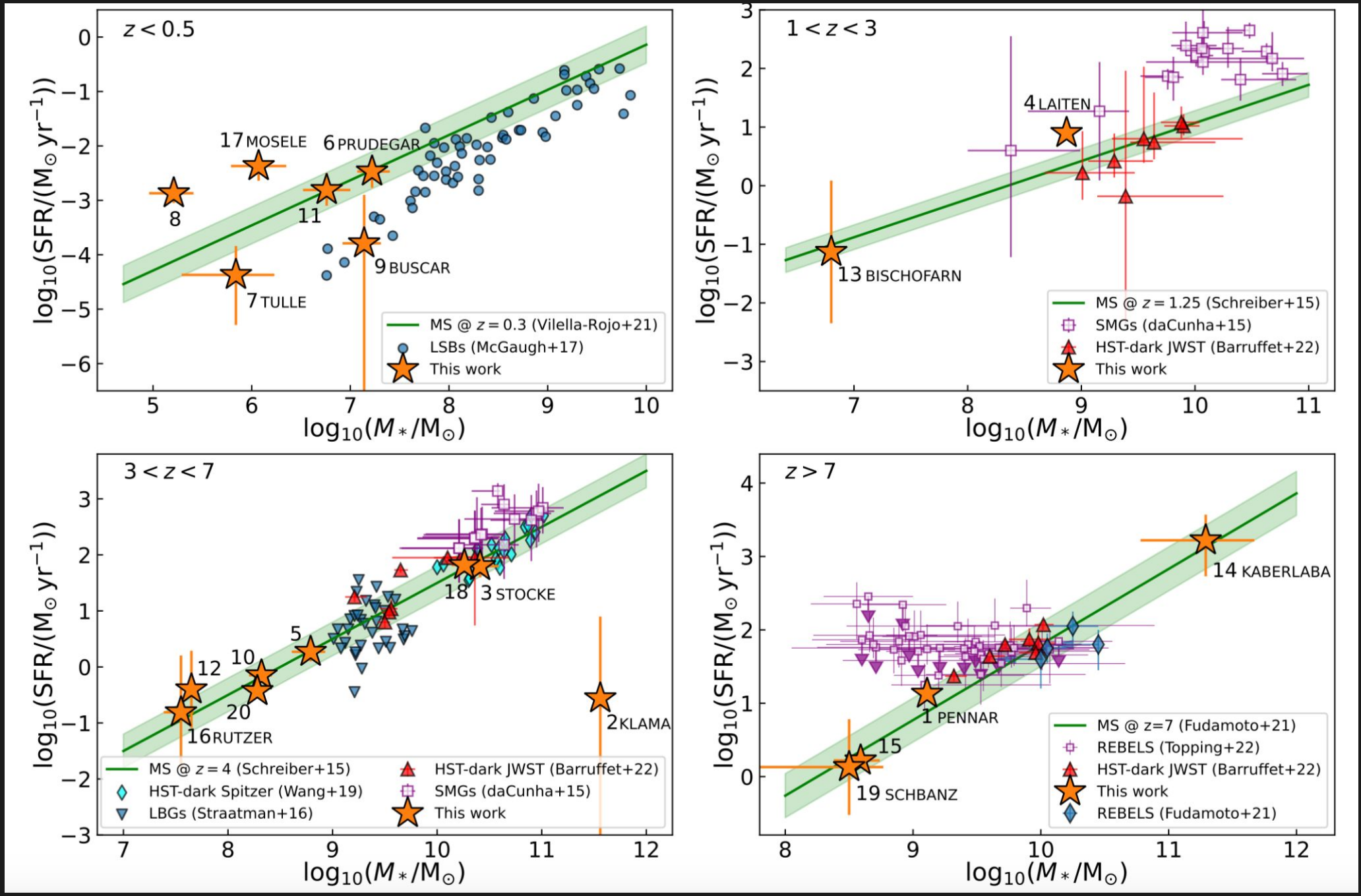


COLOR-mag diagram: comparison to Wang+19 ~HIERO selection

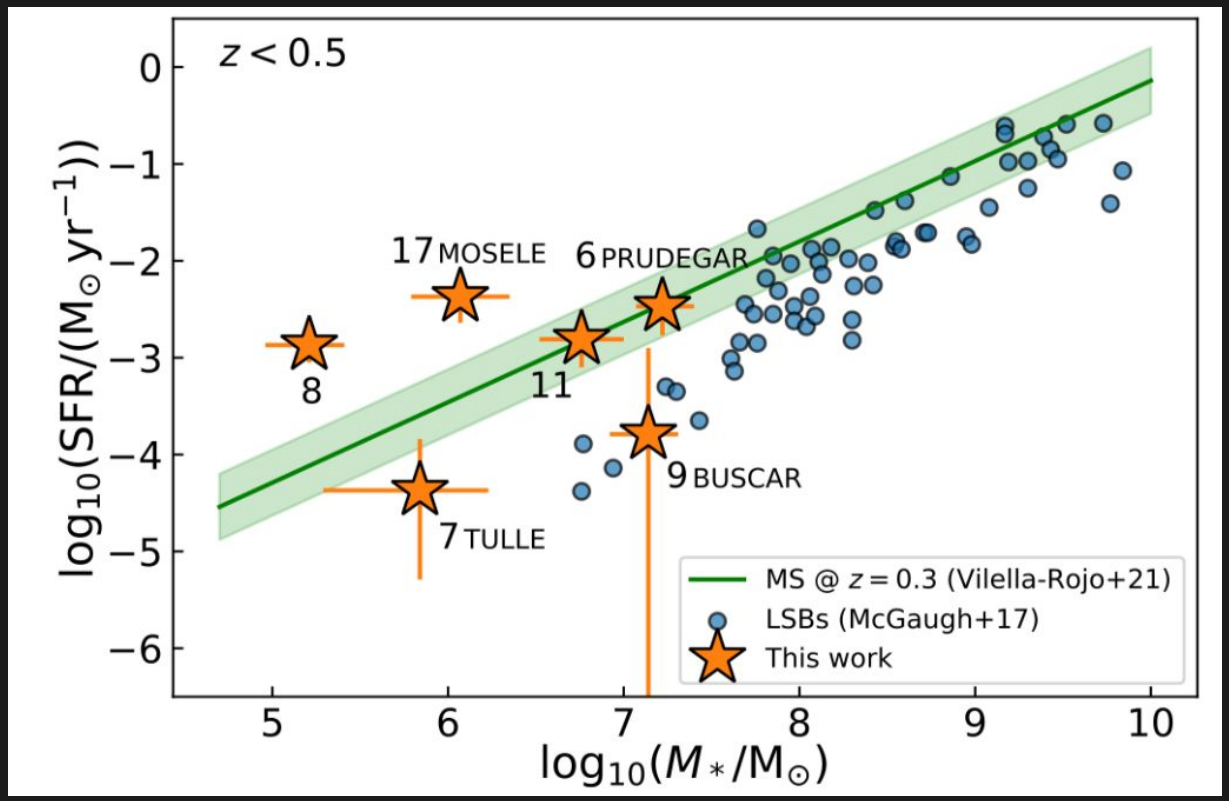


Comparison to the MS at different redshifts



Rodighiero+23

z<0.5

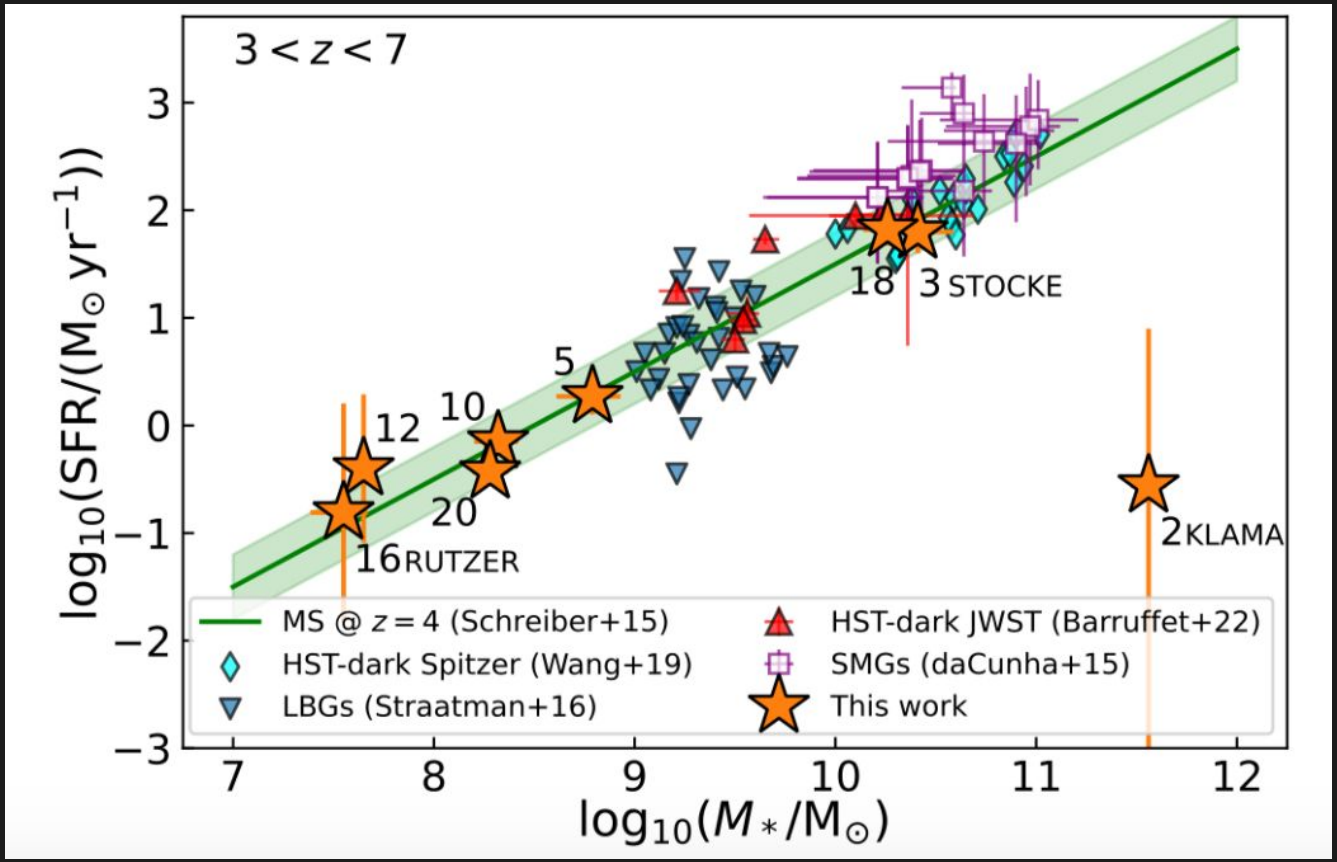


Red and dusty low-z dwarf galaxies:

JWST dwarves are much more extinguished than traditional UV selection, with AV up to ~5.5 mag

(see Bisigello+23)

3<z<7

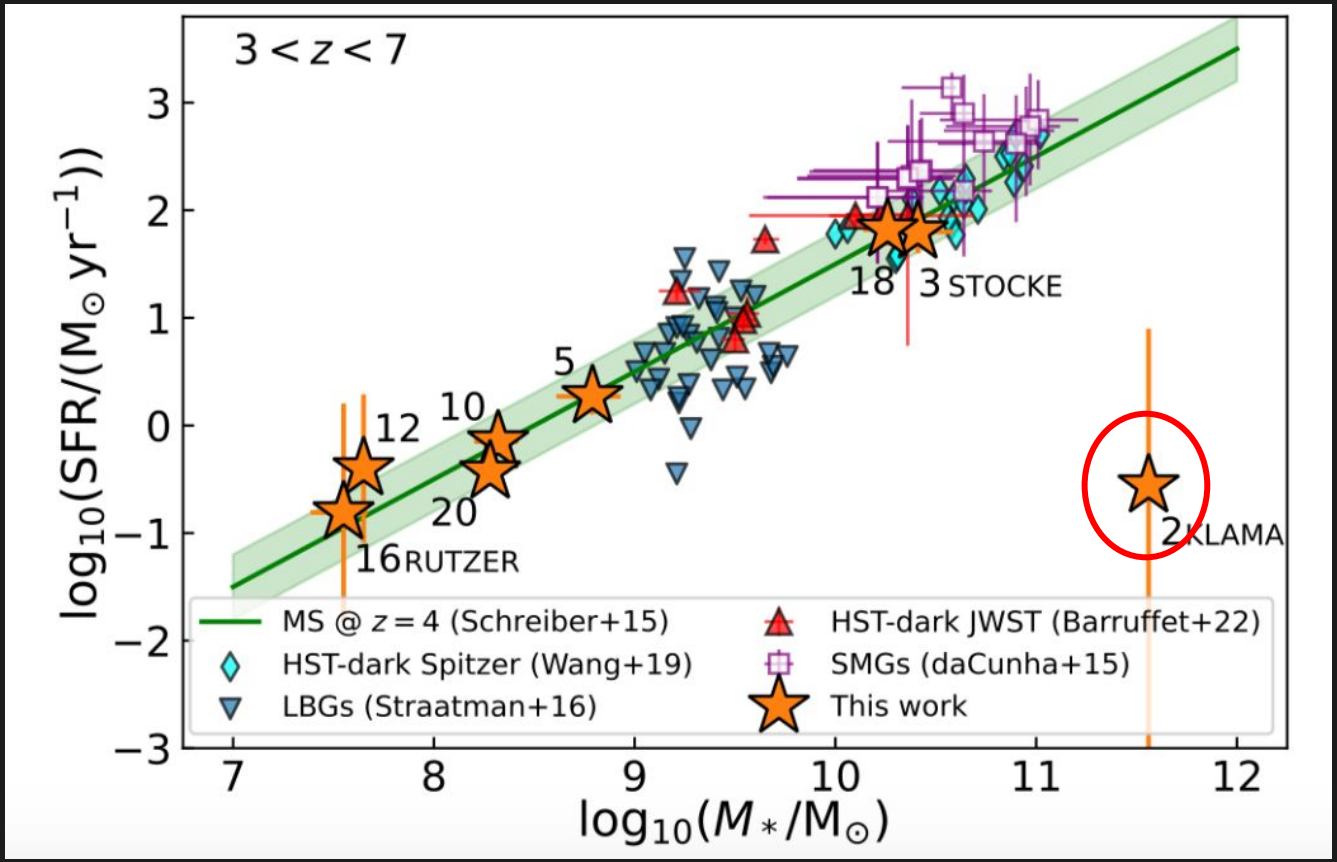


The HST-dark territory:

⇒ dusty star forming sources consistent with HIERO properties (highly extinguished up to Av~5)

⇒JWST probes a much lower stellar mass range!

3<z<7



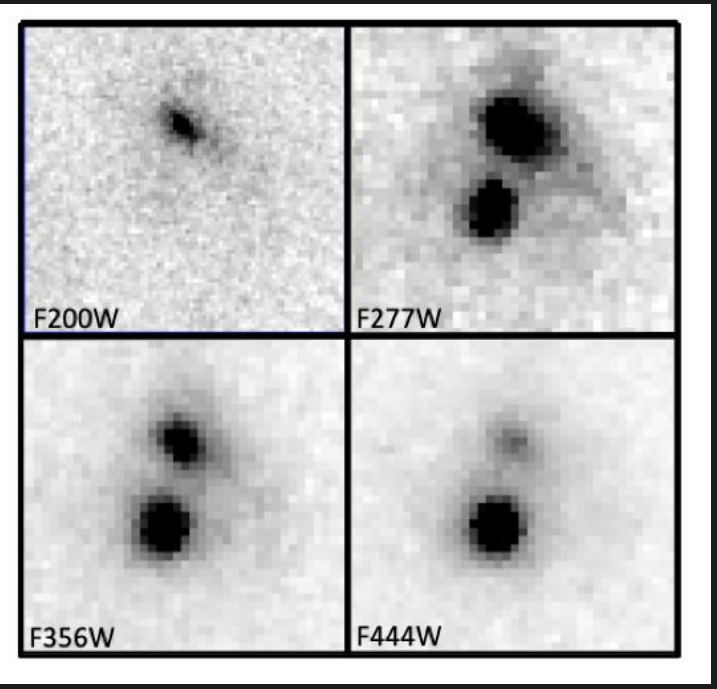
The HST-dark territory:

A quenched, dusty and massive galaxy at z~5? Av~4.7mag

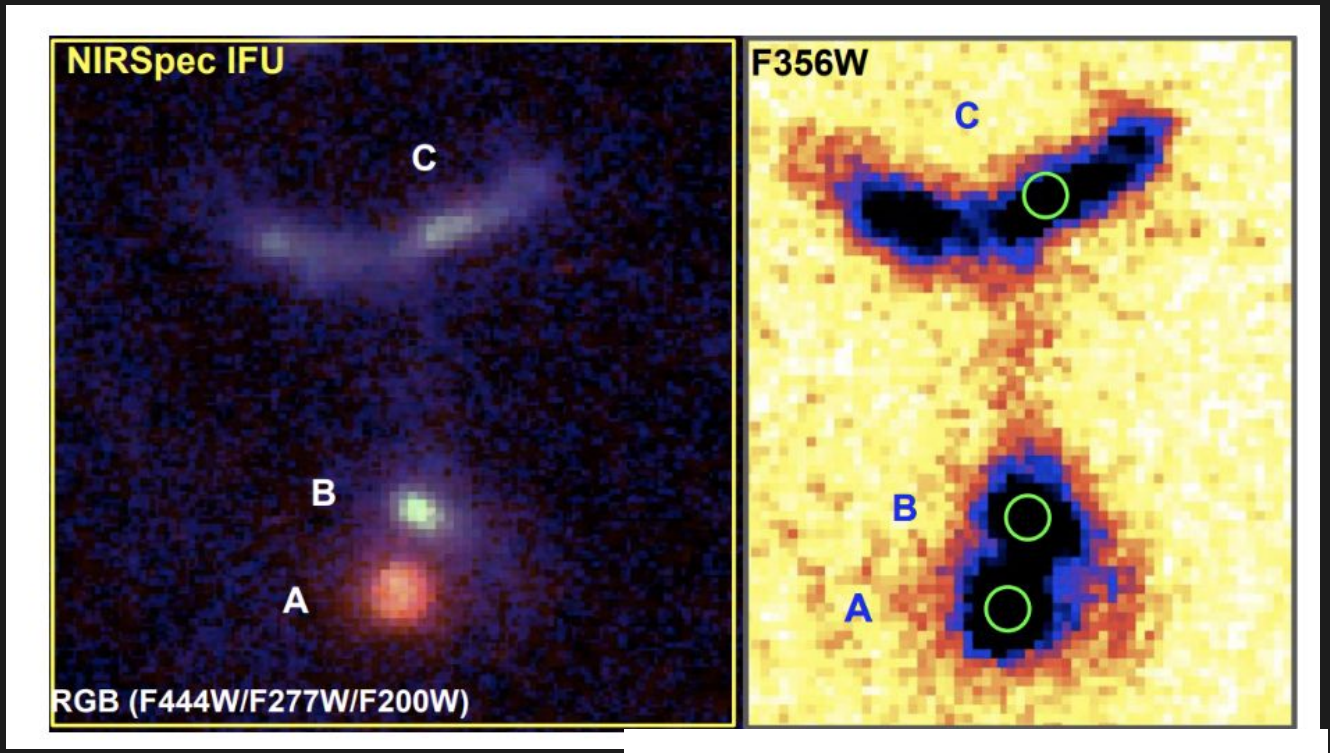
⇒A quiescent galaxy whose dust content has yet to be destroyed, a possible indicator of recent quenching??

(but see Valentino+23)

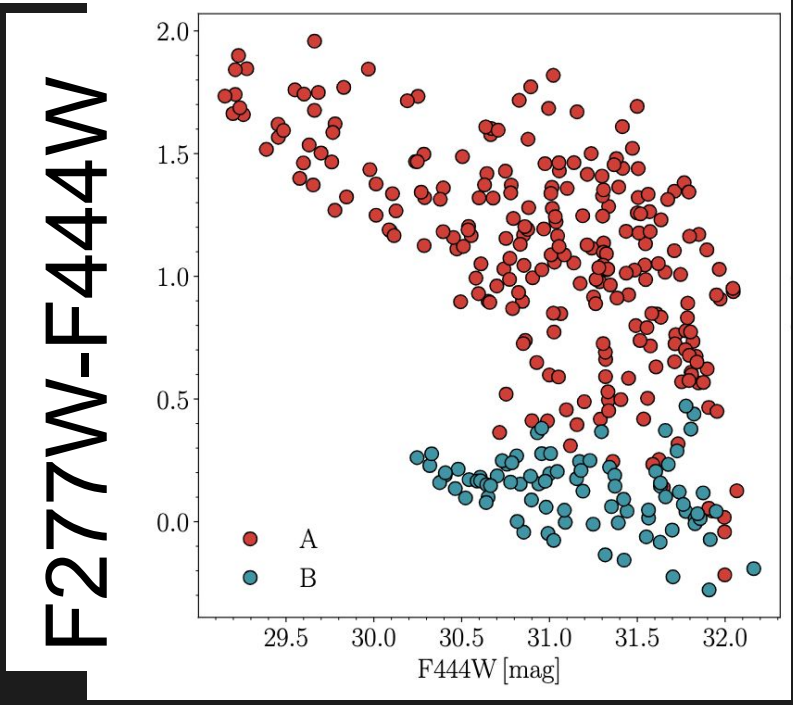
KLAMA: need for spatially resolved approach



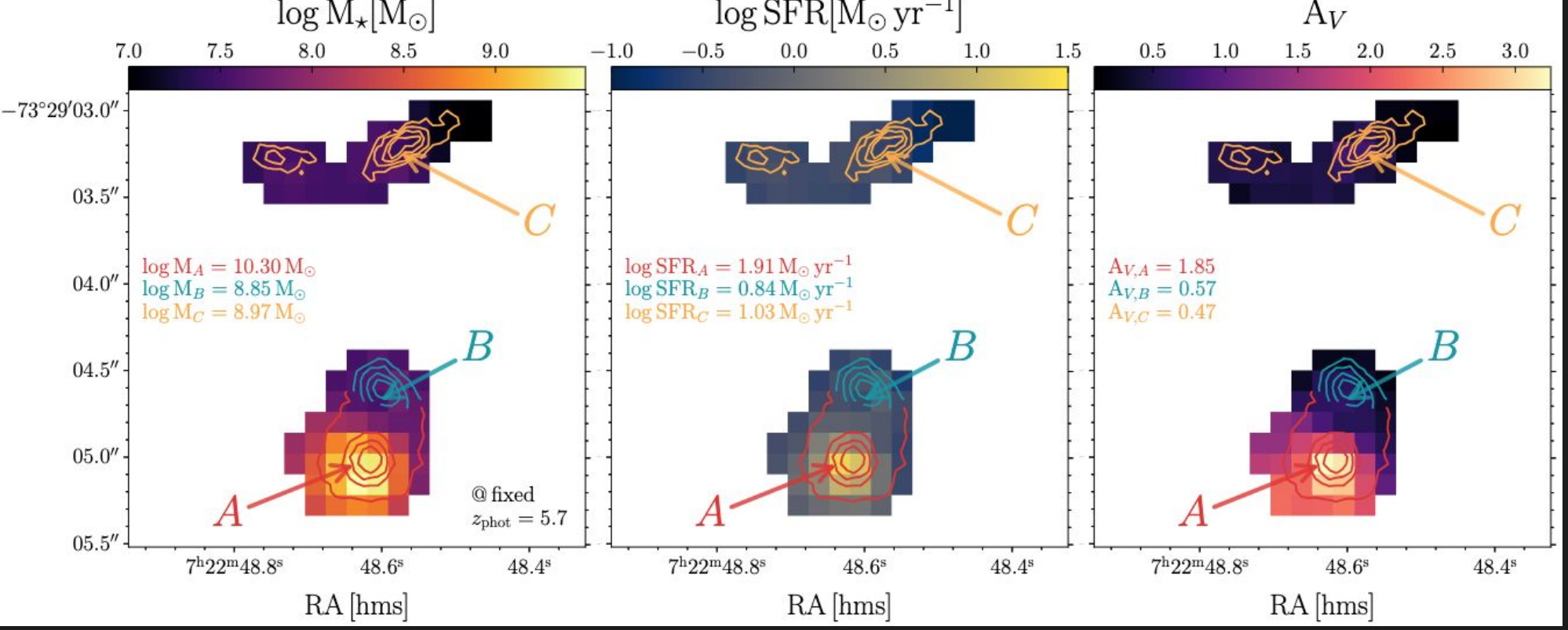
1.5”x1.5”

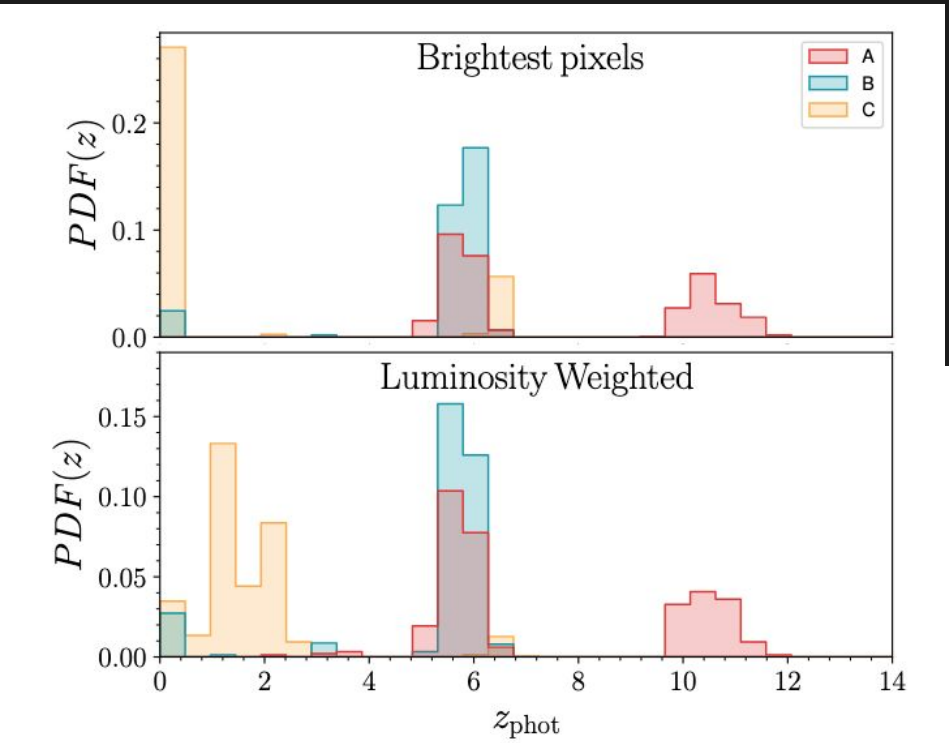


3”x3”



Rodighiero, Enia, Bisigello et al. in prep





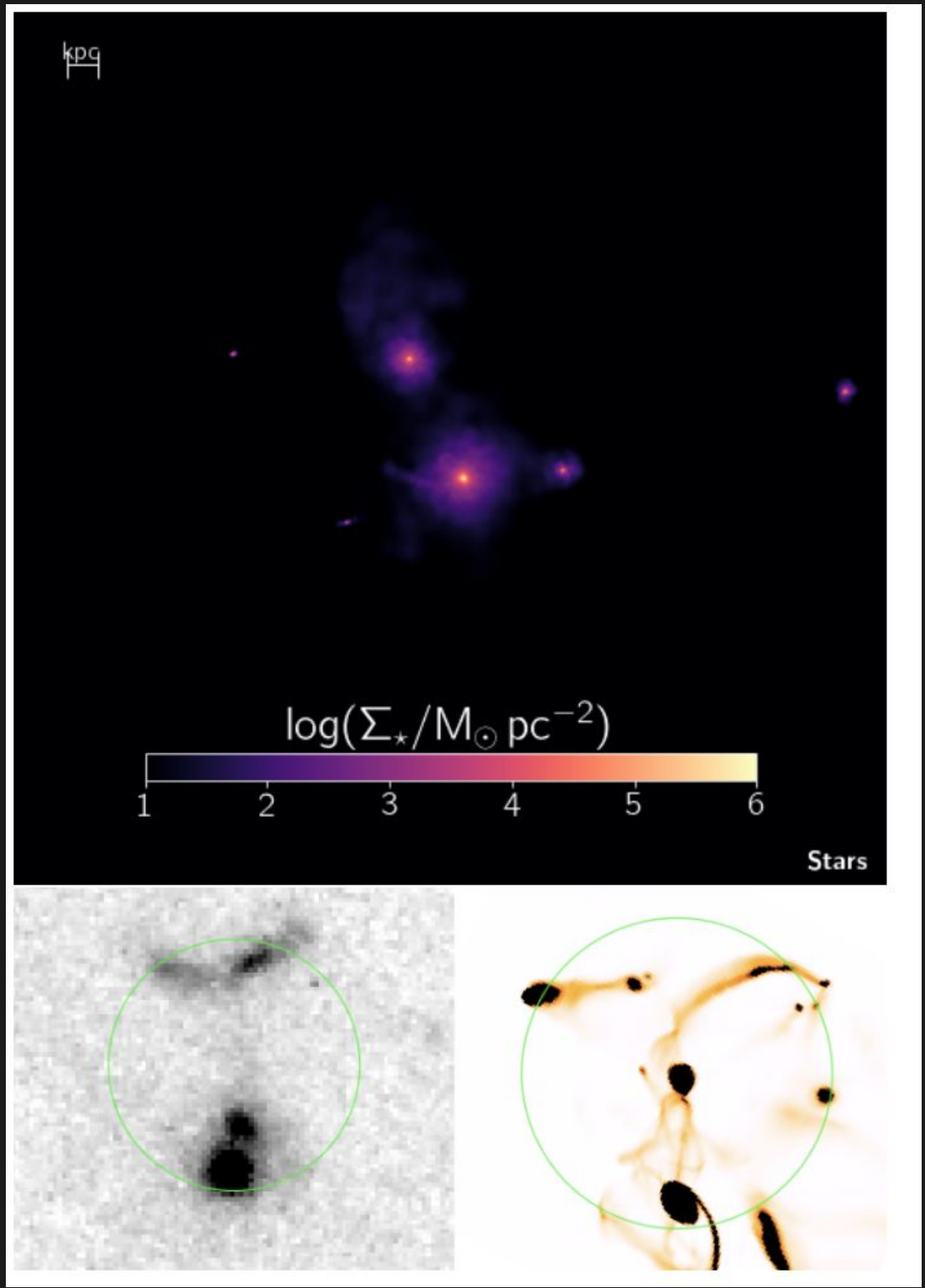
a z~6 group?

ID	log $M_\star$ $M_\odot$	log SFR $M_\odot$ yr^{-1}	<A_V> mag
A	10.30 ± 0.51	1.91 ± 0.49	1.85 ± 0.72
B	8.83 ± 0.10	0.84 ± 0.15	0.57 ± 0.16
C	8.93 ± 0.23	1.03 ± 0.24	0.47 ± 0.17

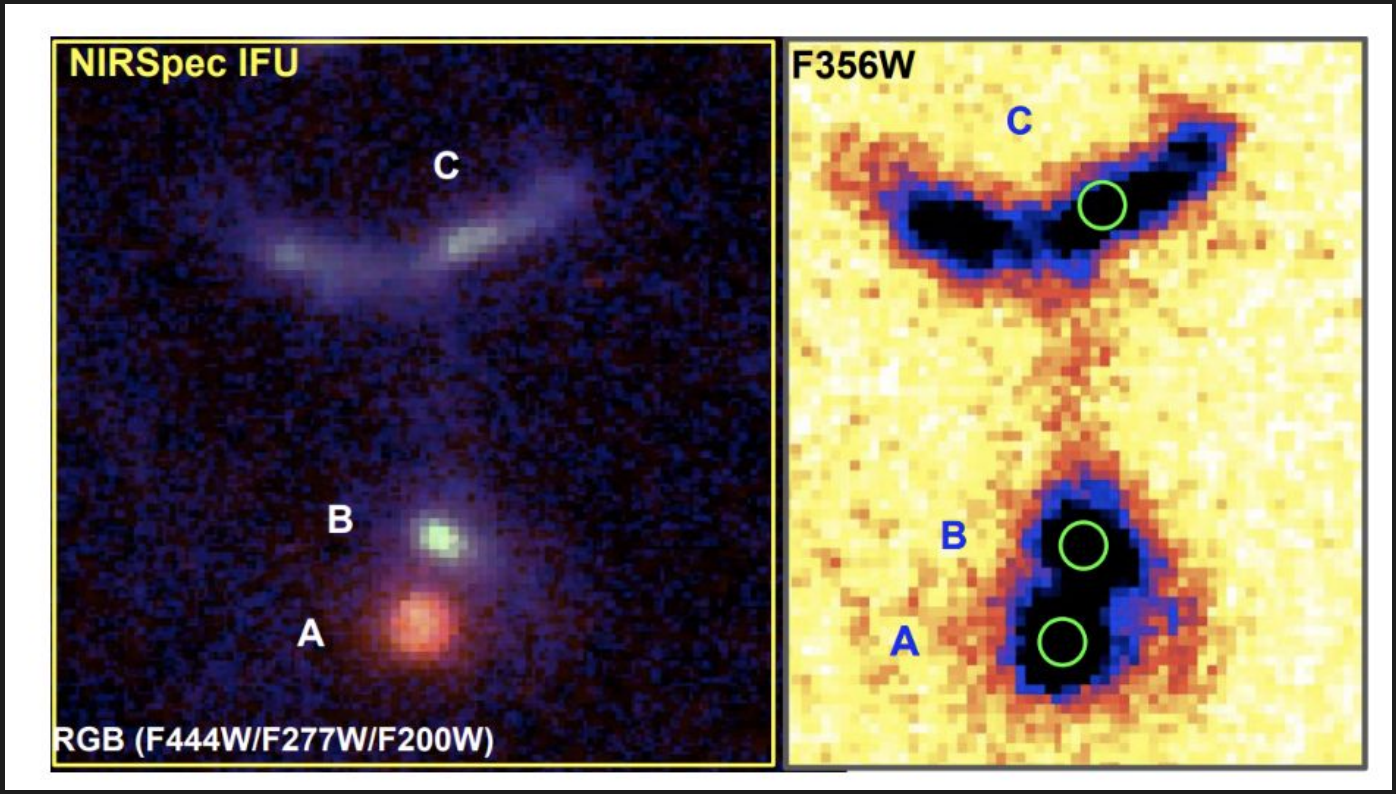
similar dusty systems in the SERRA simulation
(courtesy M. Kohandel, A. Pallottini, A. Ferrara)

⇒
looking to the past and future
merger history

10kpc

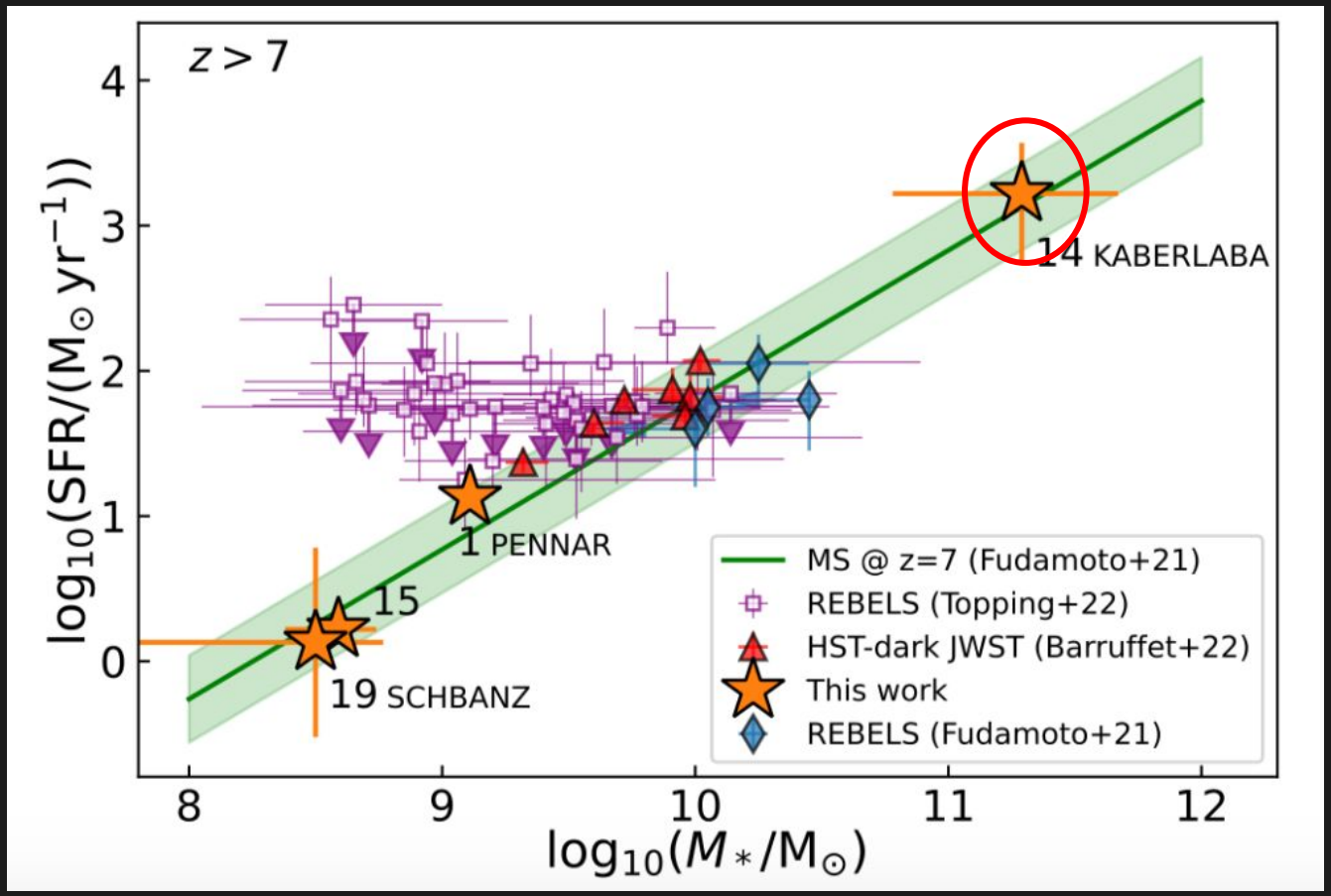


the true nature: the cosmic whale



⇒ need for a statistical sampling of merger events among HST/optically dark sources (JWST+EucliD)
(==> Giorgia Girardi, PhD)

and finally, high-z! (really????)



tension with LambdaCDM? (Lovell+22)

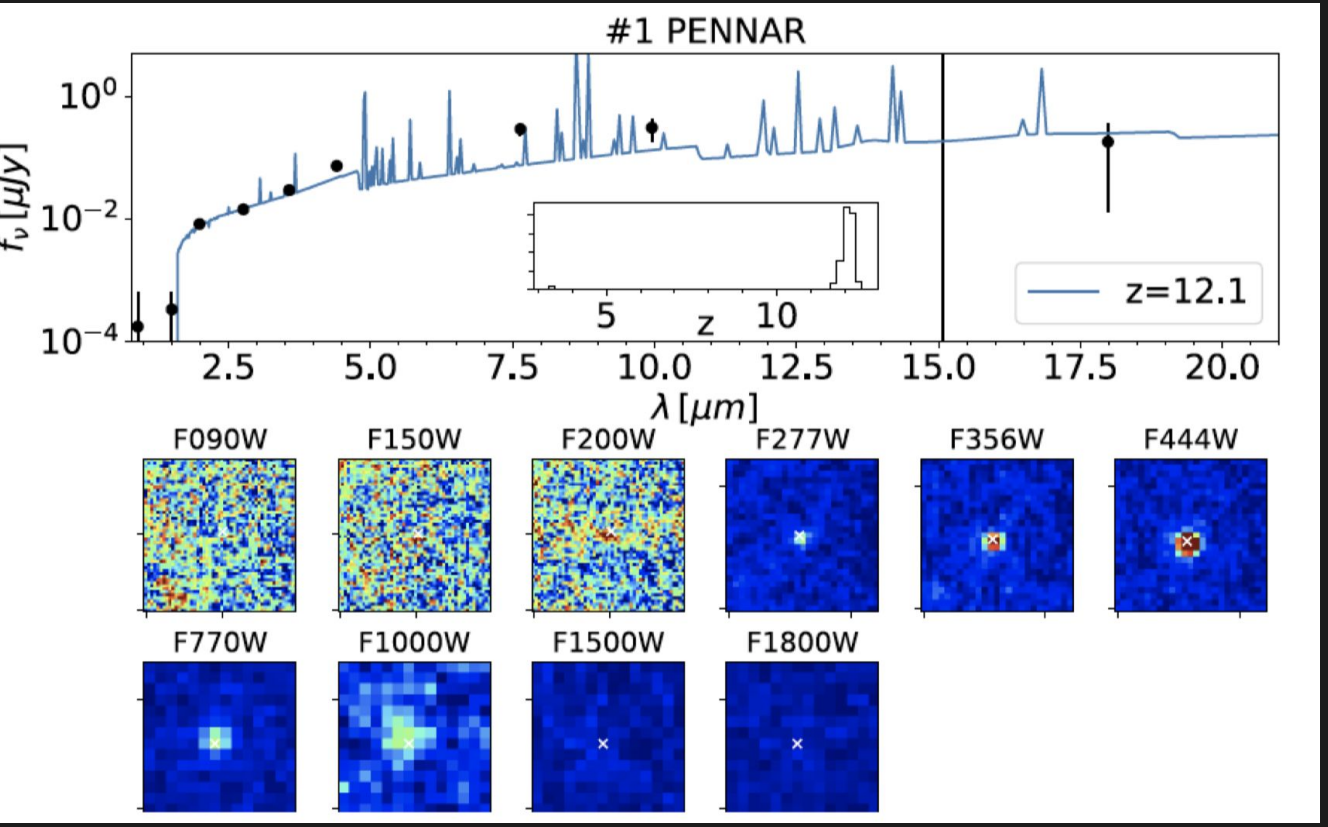
Extinguished high-z star-forming sources:

We classify four objects at z > 8, with mature stellar populations, that differ from already detected JWST sources at similar cosmic epochs for their extreme dust content (Av = 0.4−5.8mag)

⇒

unexplained by current theoretical model

(but see Ferrara+22, Fiore+22, Nath+22, Ziparo+23, Kohandel+23)



PENNAR at z~12: the highest redshift dusty galaxy?
Detected by MIRI

but see Zavala+22 (secondary low-z solution implies Av~4.4mag! still an extreme object)

A point like source

Where's the dust?

Stars have the time to produce dust.
Why it is not observed in JWST blue monsters? (observational bias?)

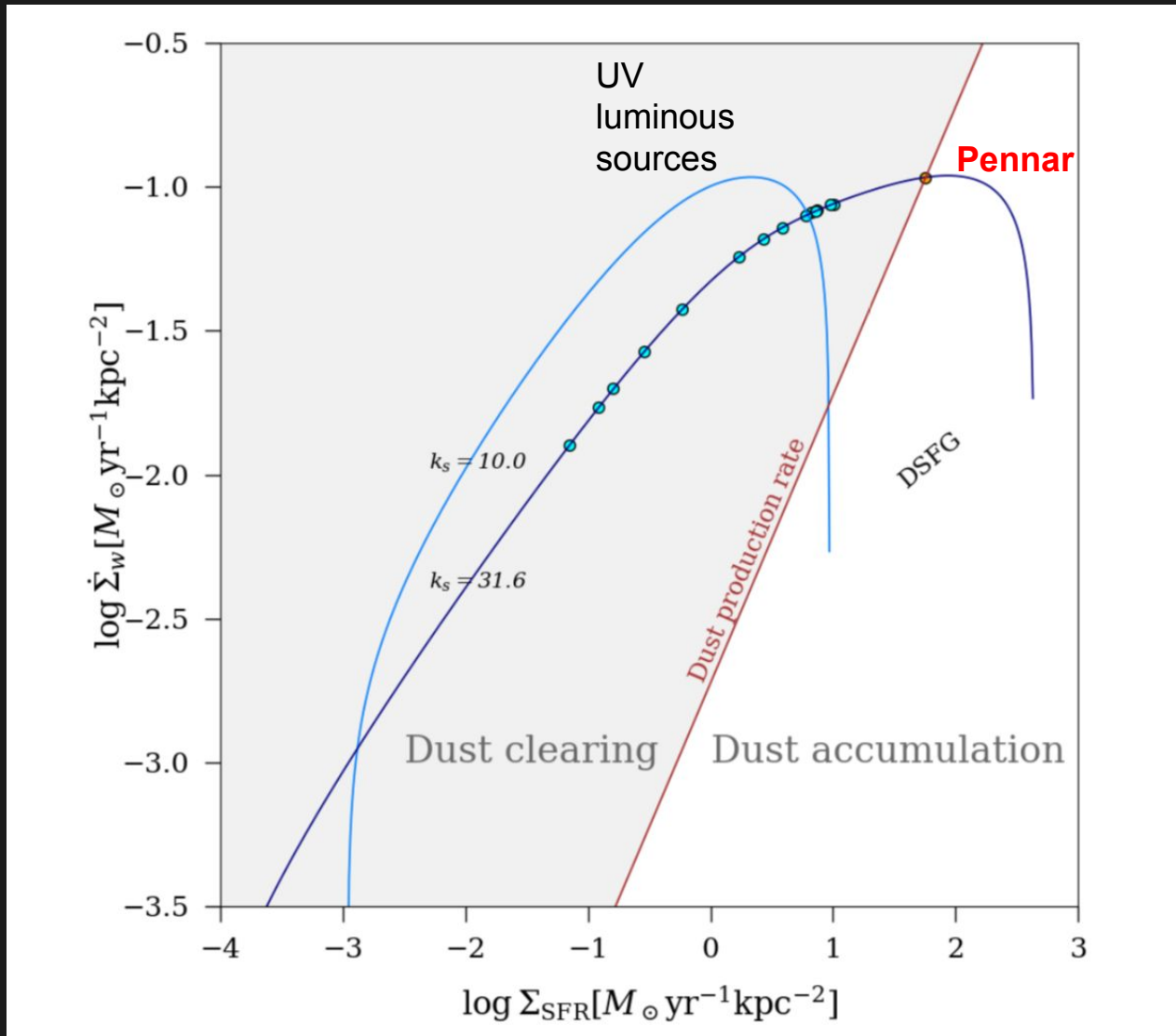
(a) ejected by radiation pressure;

(b) segregated with respect to UV-emitting regions.

the dust ejection rate is faster than the production rate (red curve) and the galaxy is cleared

in the opposite case (white region) dust accumulates as a result of a too slow ejection rate.

Ziparo, Ferrara et al. +22



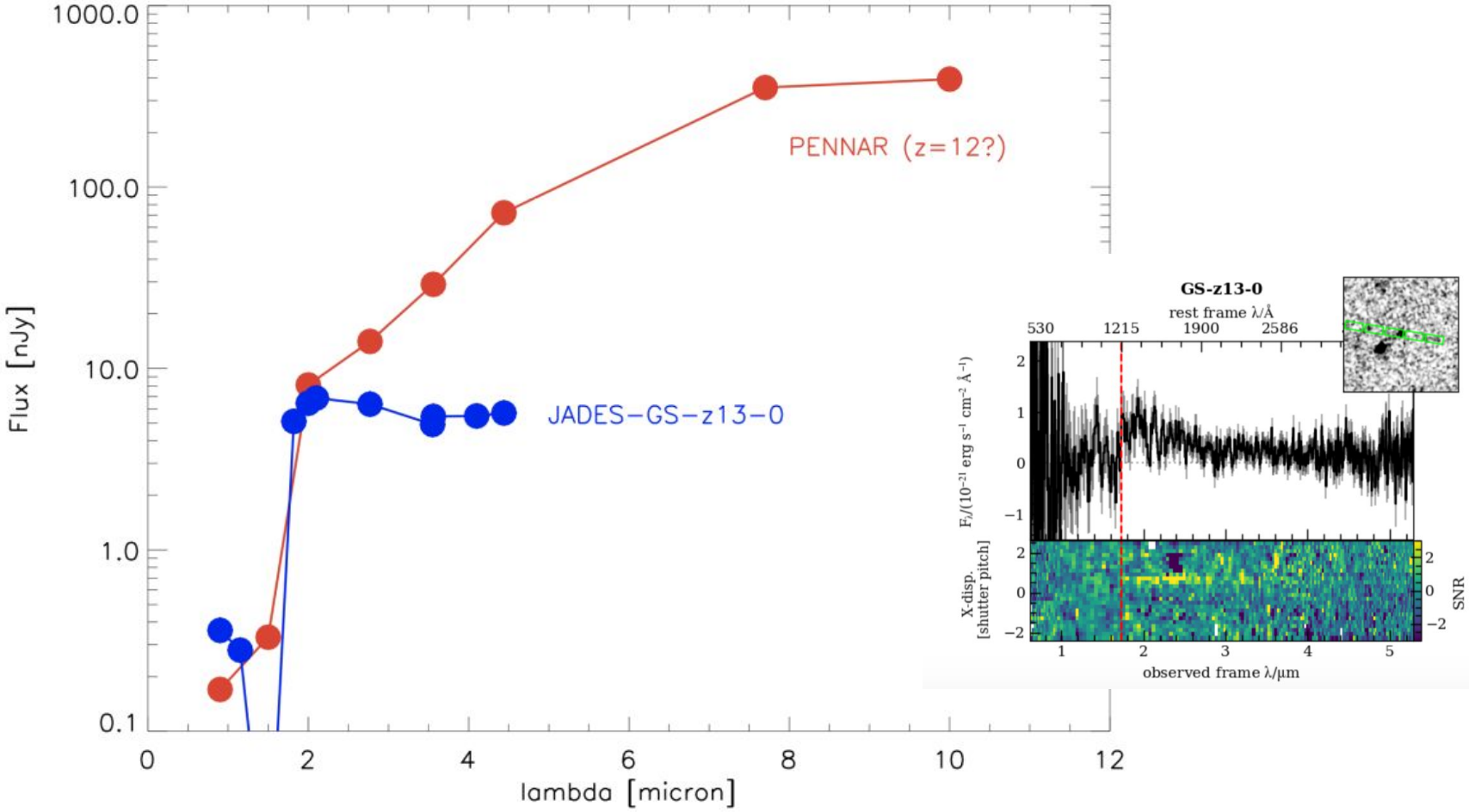
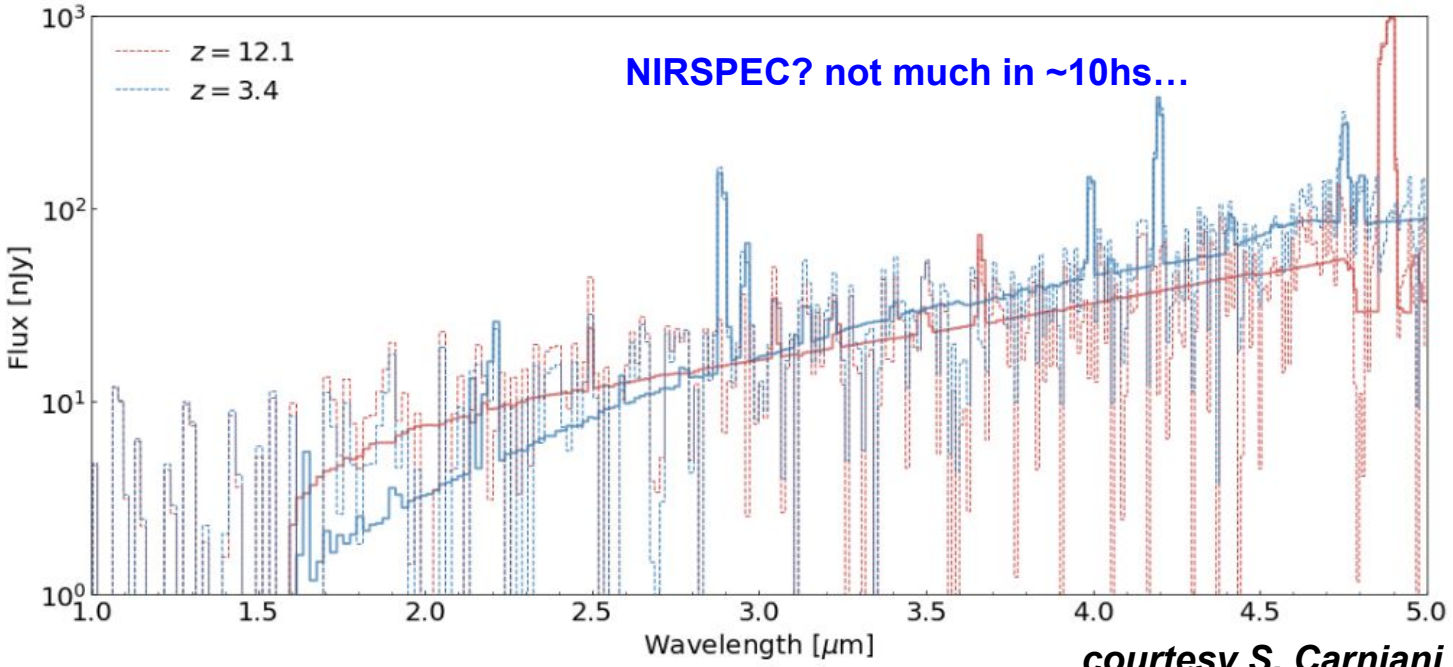


Figure 3: *Comparison between the observed broad-band photometry for the red dark PENNAR galaxy (red points) and JADES-GS-z13-0, the $z = 13$ Lyman Break Galaxy spectroscopically confirmed by NIRSpec (Curtis-Lake+23).*

Roberts-Borsani+22b, Curtis-Lake+22

Ar

NIRSpec@JWST



courtesy S. Carniani

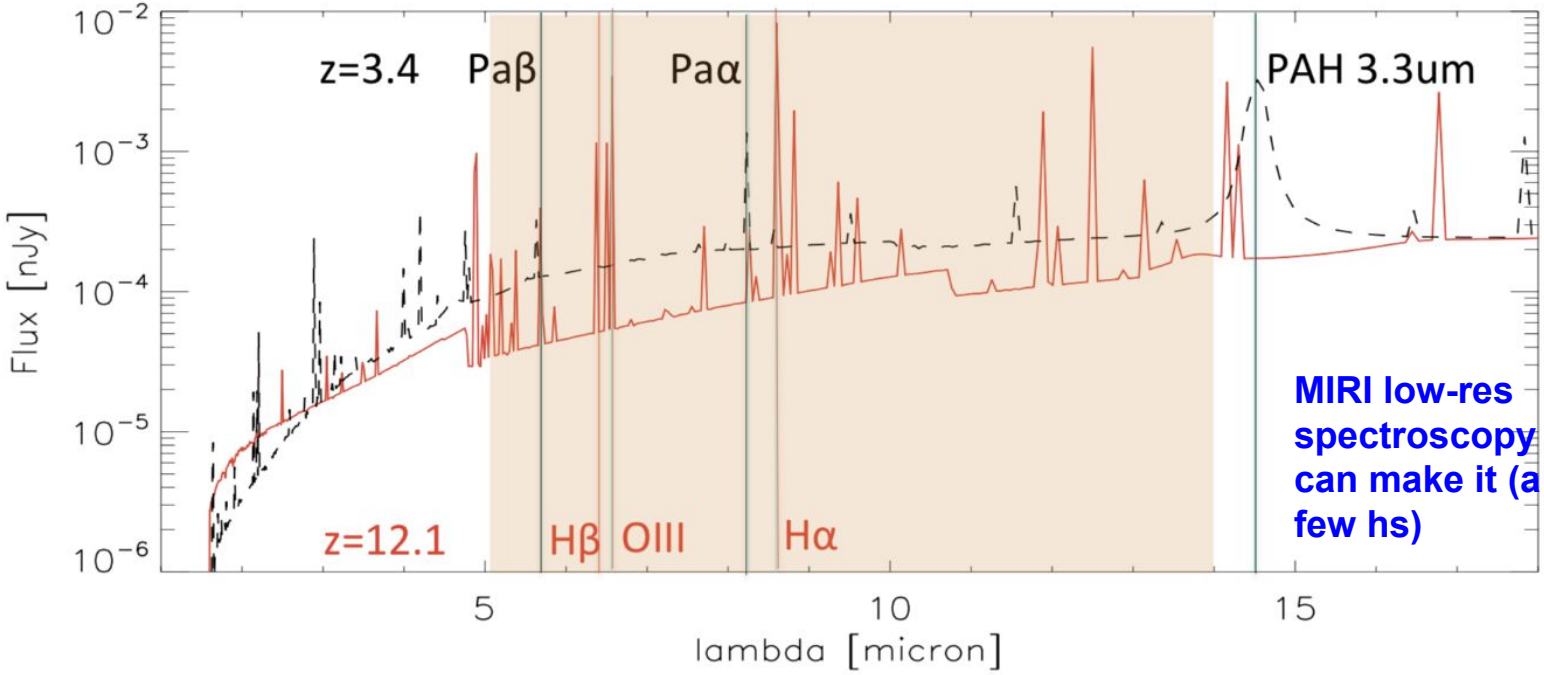
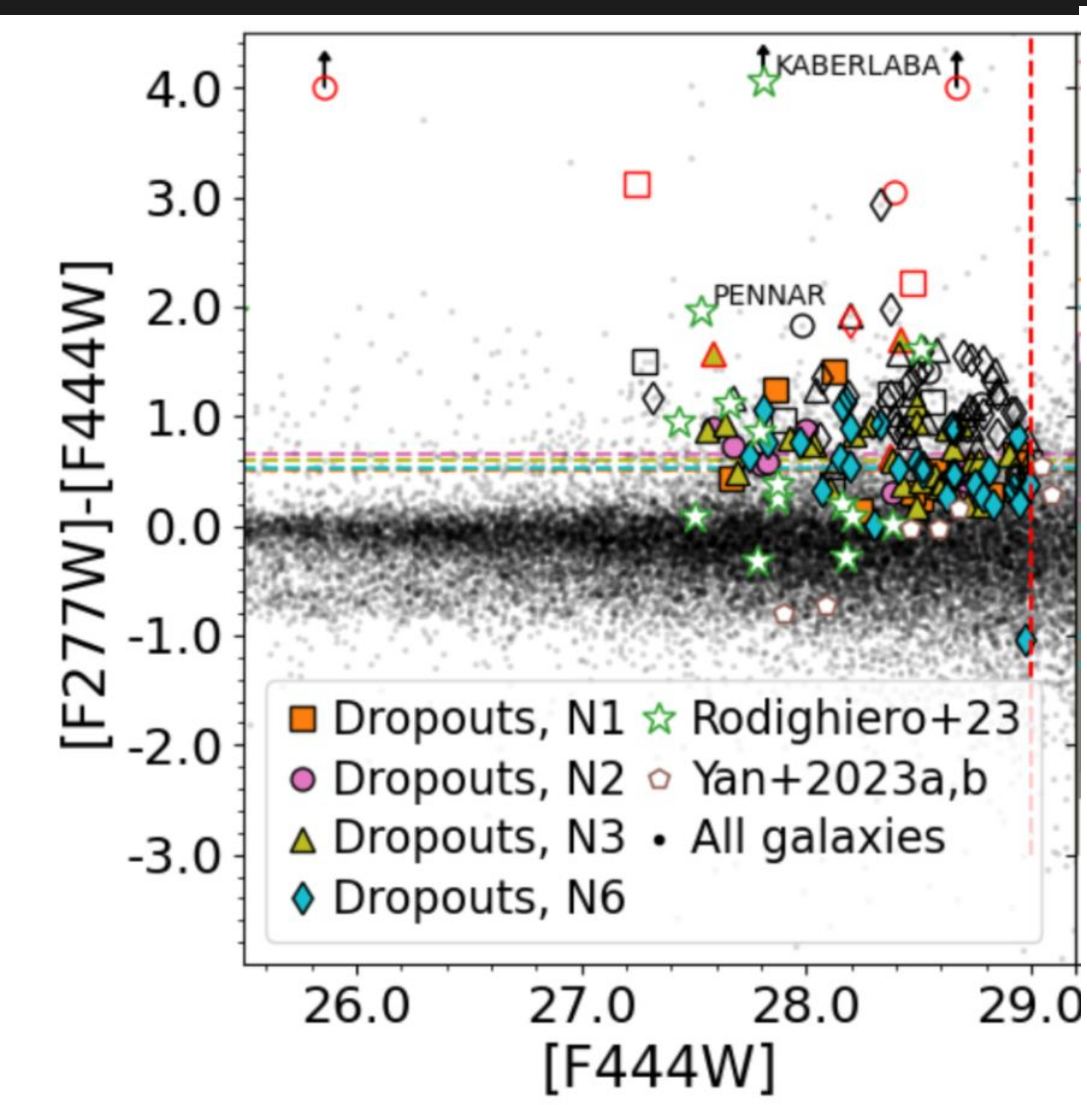
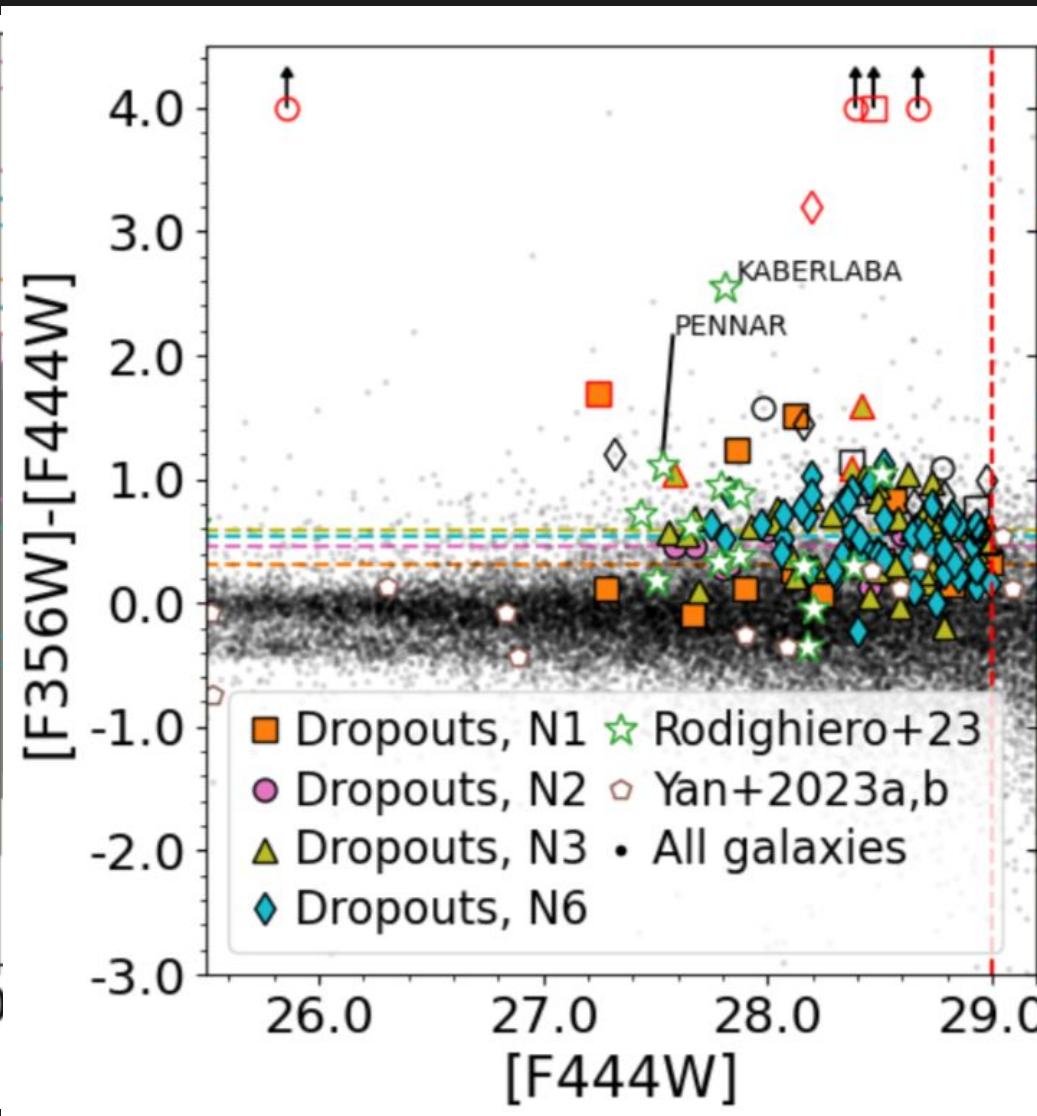


Figure 5: *The best fit model spectra at* $z = 12.1$ *(red lines and symbols) and* $z = 3.4$ *(black dashed lines and symbols) are reported, together with the main emission lines that will be eventually observed in the two different situations. The orange box marks the observed MIRI LRS spectral range.*

More statistics with ERS CEERS → *Bisigello+23*





Rouge & Rogue - looking for high-z/dusty objects in CEERS

Gandolfi et al., 2024 (in prep.): search all CEERS pointings to find **very red sources** previously missed in the collaboration's official catalogue (i.e., **"rogue" objects**) via NIRCam + HST + MIRI photometric data.

Such rogue objects are found exploiting the **F444W** as detection image (differently from CEERS' official catalogue which instead uses the coadded F277W+F356W image).

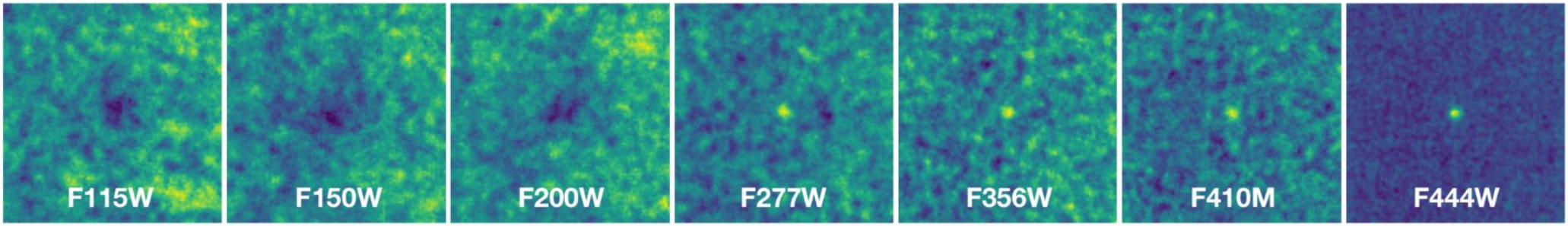
Then, the following selection is enforced:

$$\begin{cases} \text{S/N} > 3,\ \lambda = 4.4\ \mu\text{m} \\ \text{S/N} \leq 2,\ \lambda \leq 2\ \mu\text{m} \end{cases} \longrightarrow$$

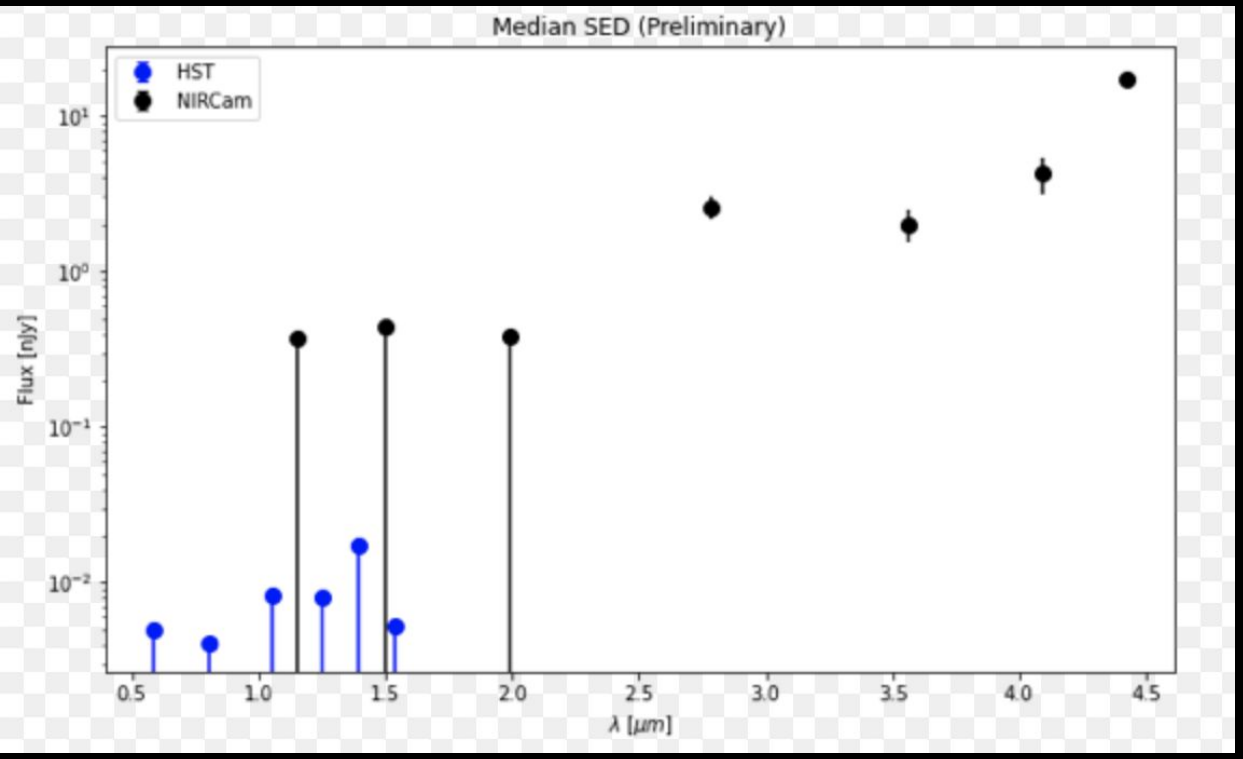
- Very dusty galaxies with $10^6\,M_\odot < M_s < 10^{10}\,M_\odot$ at $z < 5$
- More massive dusty galaxies at $z = 5$ - 18
- Galaxies at $z > 18$ independent from their dust extinction

Preliminary results: 70+ rogue objects (all pointings) --> what are their physical characteristics?

NIRCam median stacking

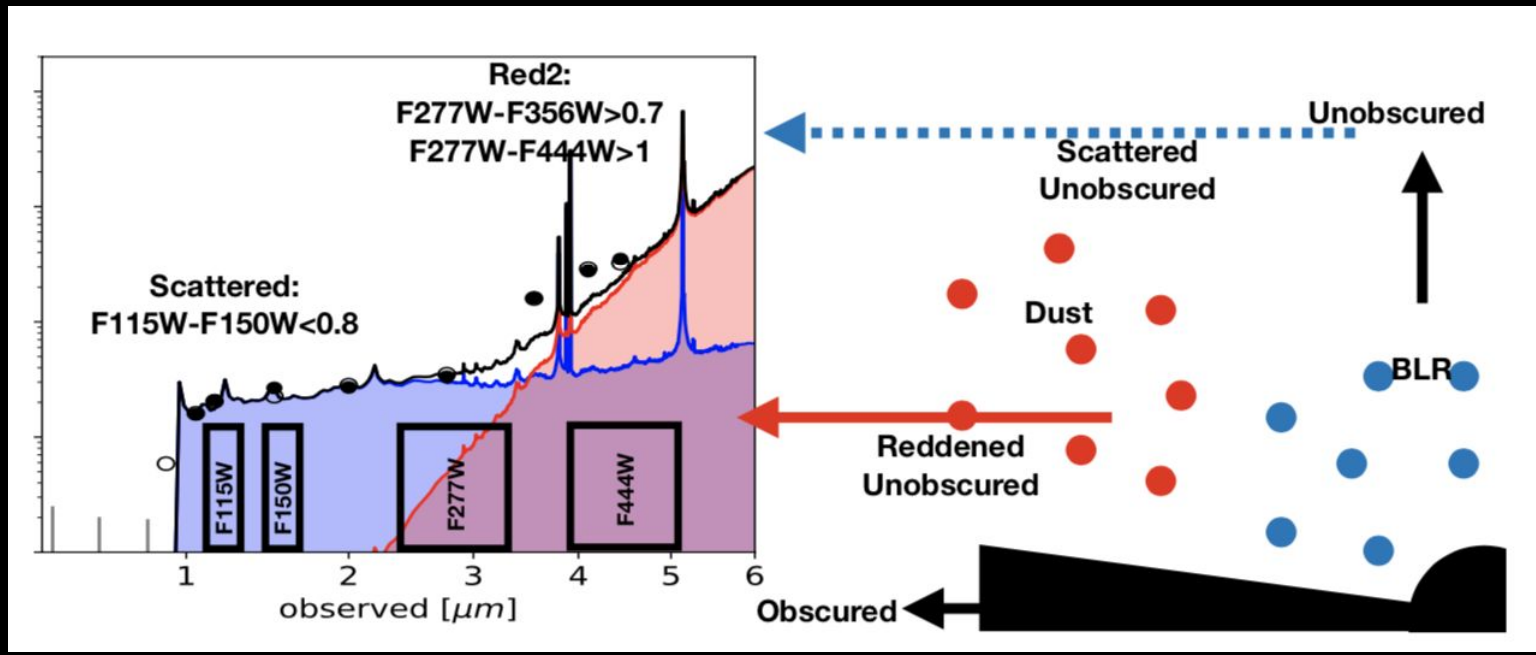


stacked average SED:



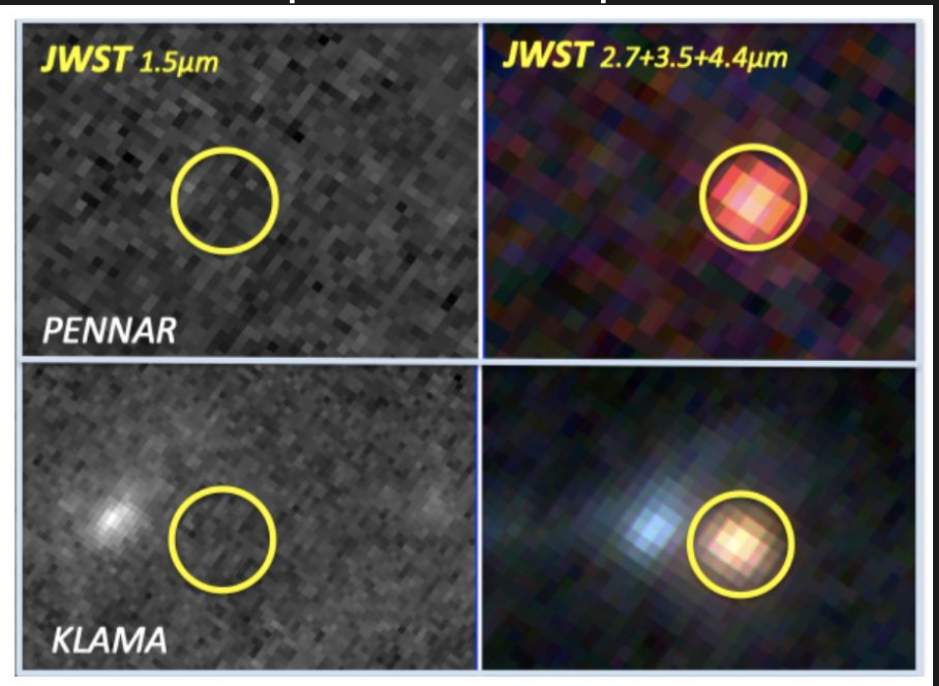
the rising long wavelength photometry reminds the shape of Little Red Dots (z~5-7 obscured AGN including a UV bright scattered light component)

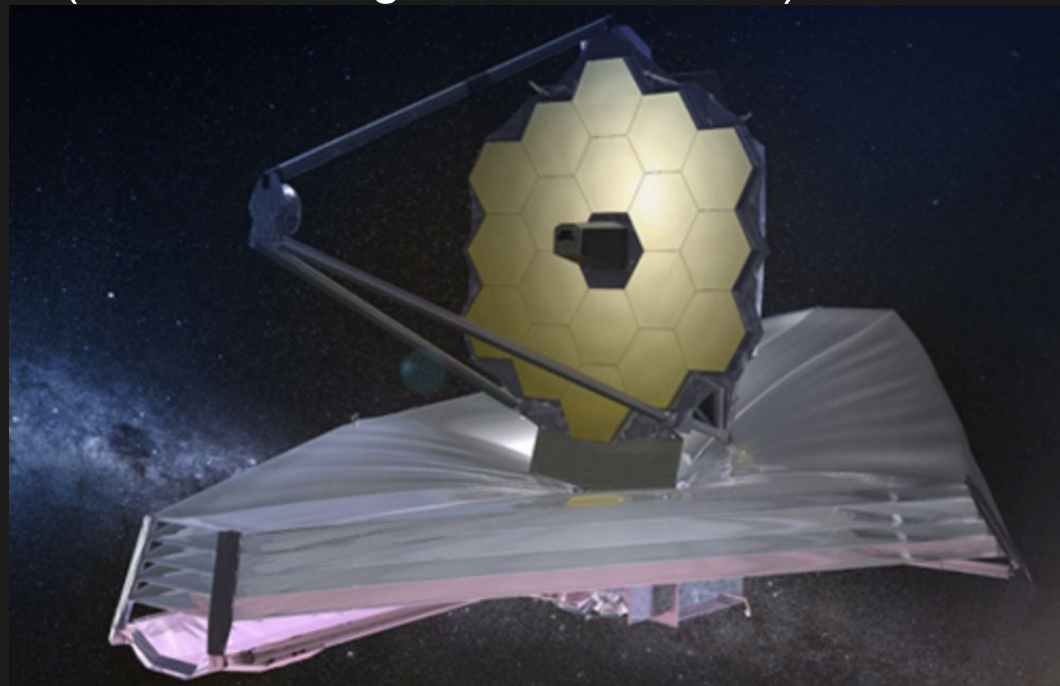
Labbe'+23, Furtak+23, Barro+23, Matthee+23, Akins+23



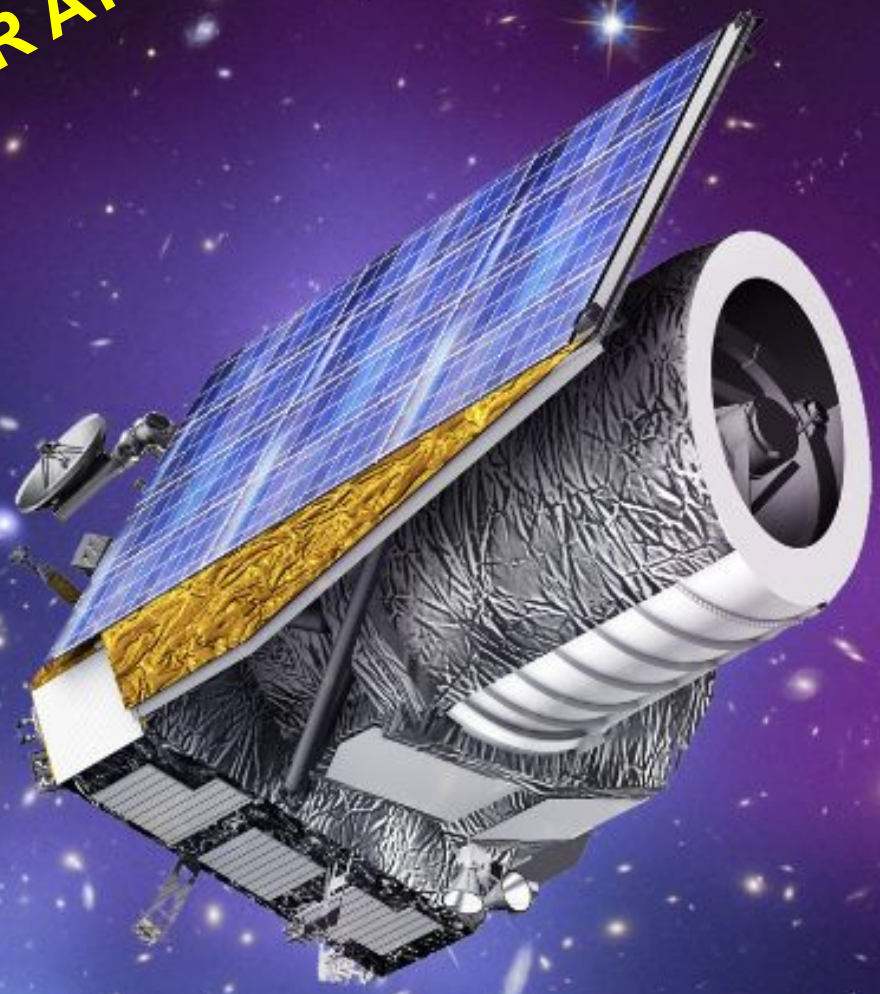
CONCLUSIONS

- All the preliminary JWST photometric candidates require an urgent confirmation
- However, it is clear that the dark and extremely dark sources detected by Webb should include at least a few very high-z objects
- LBG only technique loses the dustier side of dropouts
- Our results suggests that JWST very red sources represent a dust rich population at different redshifts, previously missed even by HST and Spitzer
- New parameters spaces are being filled (low mass, high-z, obscuration)





THANKS FOR YOUR ATTENTION!!



EUCLID:

LOOKING FOR THOUSANDS OF OPTICALLY DARK SOURCES