# Reshaping the labyrinth
## The impact of galaxy mergers on Lyman radiation escape

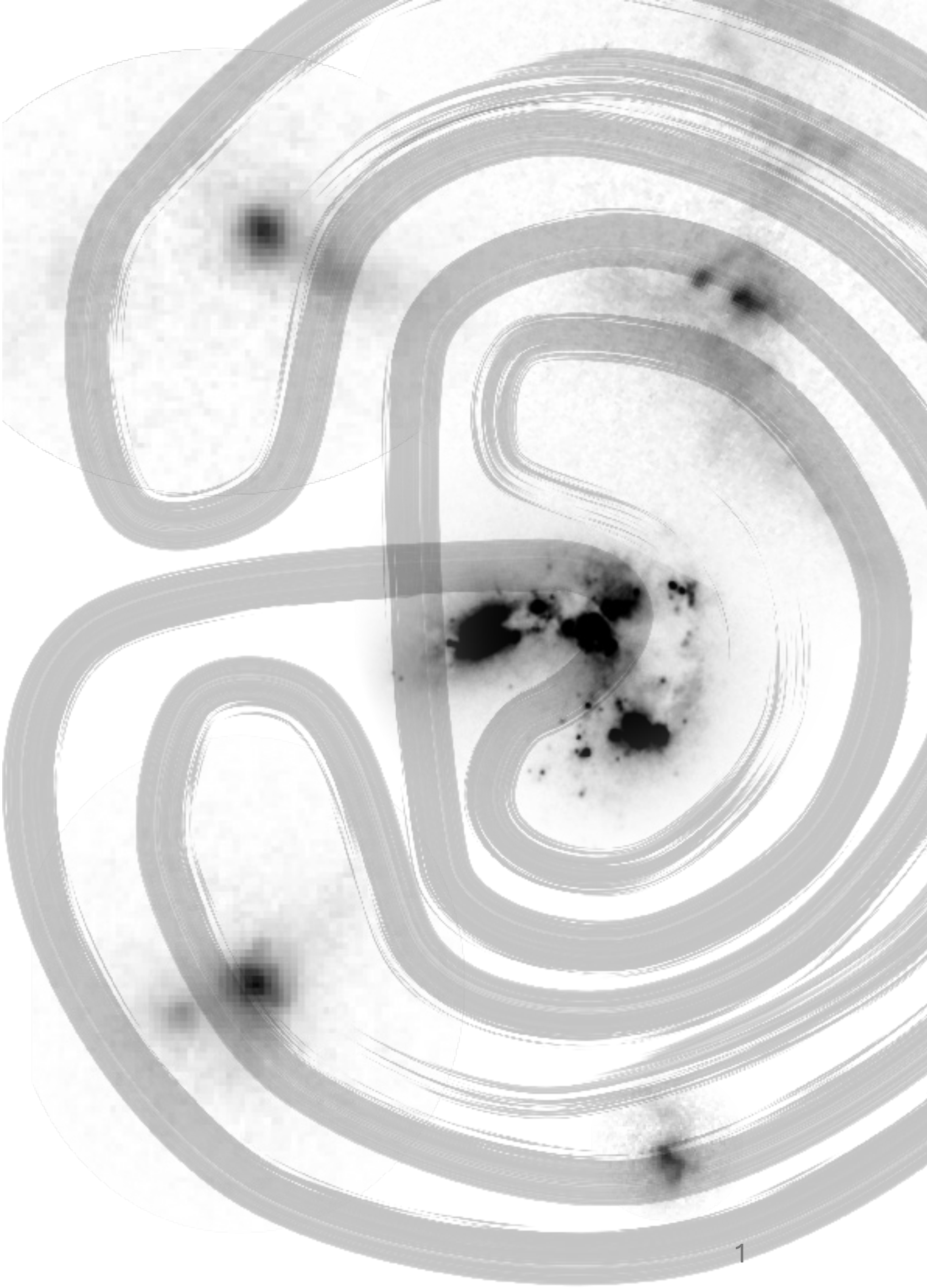
Alexandra Le Reste

Escape of Lyman radiation from galactic labyrinths

OAC, 2025

University of Minnesota

LaCOS



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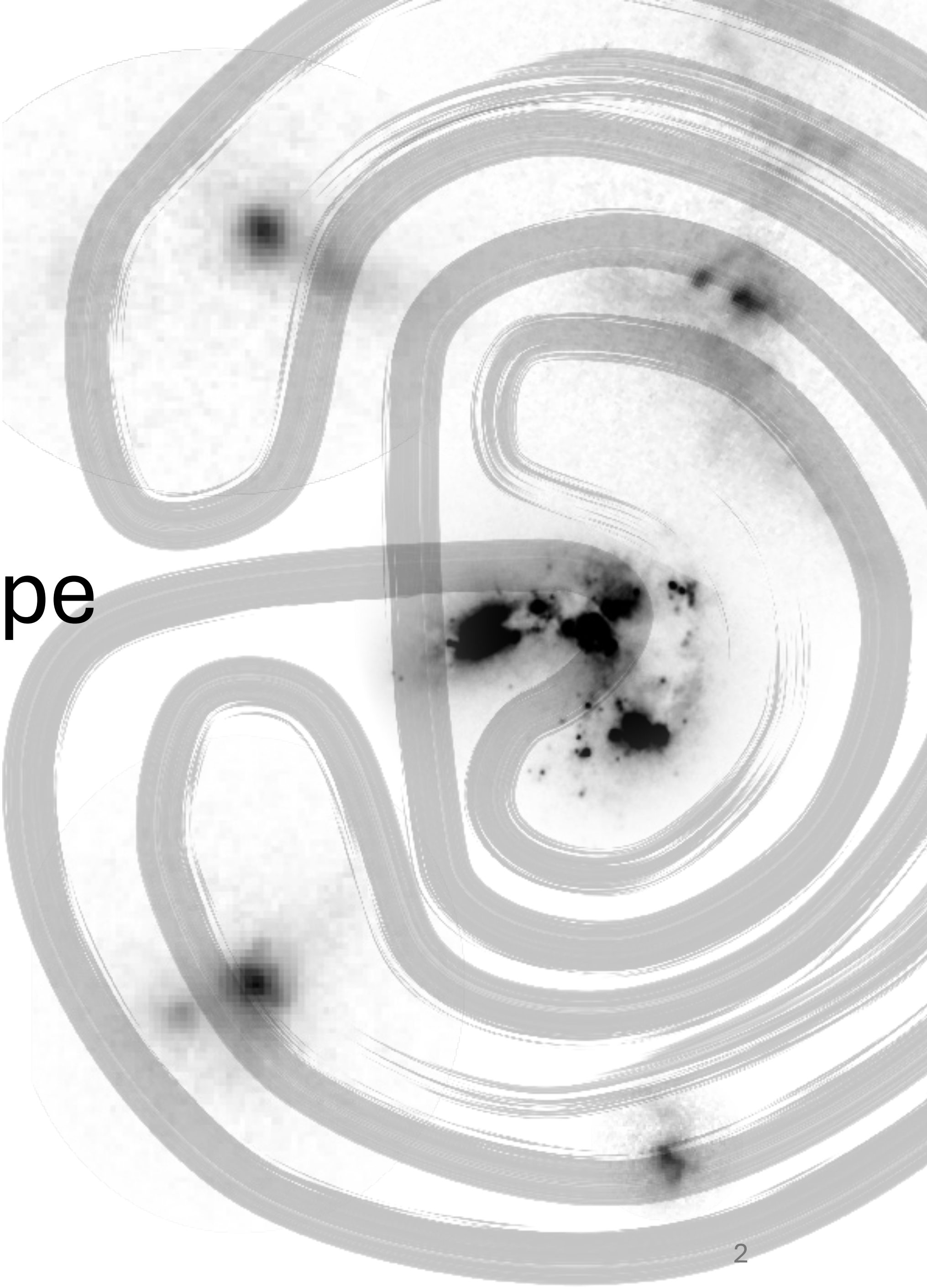

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OAC, 202

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# Investigating the link between Lyman-α and 21cm HI emission in nearby galaxies

Alexandra Le Reste[1,2], M. Hayes[1], J. Cannon[3], J. Melinder[1], A. Runnholm[1], T. E. Rivera-Thorsen[1], G. Östlin[1], A. Adamo[1], E. C. Herenz[4], D. Schaerer[5], C. Scarlata[2] and D.Kunth[6]

## 1 - Introduction

Lyman-alpha (Lyα, λ=1216 Å) emission serves as a crucial probe of galaxies across cosmic epochs, from the nearby Universe to the Epoch of Reionization. It has been proposed at a tracer of the neutral CGM, but despite its significance, the connection between Lyα emission and galaxy/CGM properties is not well calibrated. Here, we investigate the link between global Lyα emission and neutral hydrogen (HI) properties in nearby star-forming galaxies, leveraging multi-wavelength observations from the Lyman Alpha Reference Samples ((e)LARS). To do so, we compare 21cm HI observations obtained with the Karl G. Jansky Very Large Array (VLA) in D-array configuration (~38 kpc resolution) with Lyα properties derived from Hubble Space Telescope (HST) imaging and spectroscopy for 37 low-redshift (z~0.03) star-forming galaxies part of the (e)LARS sample.

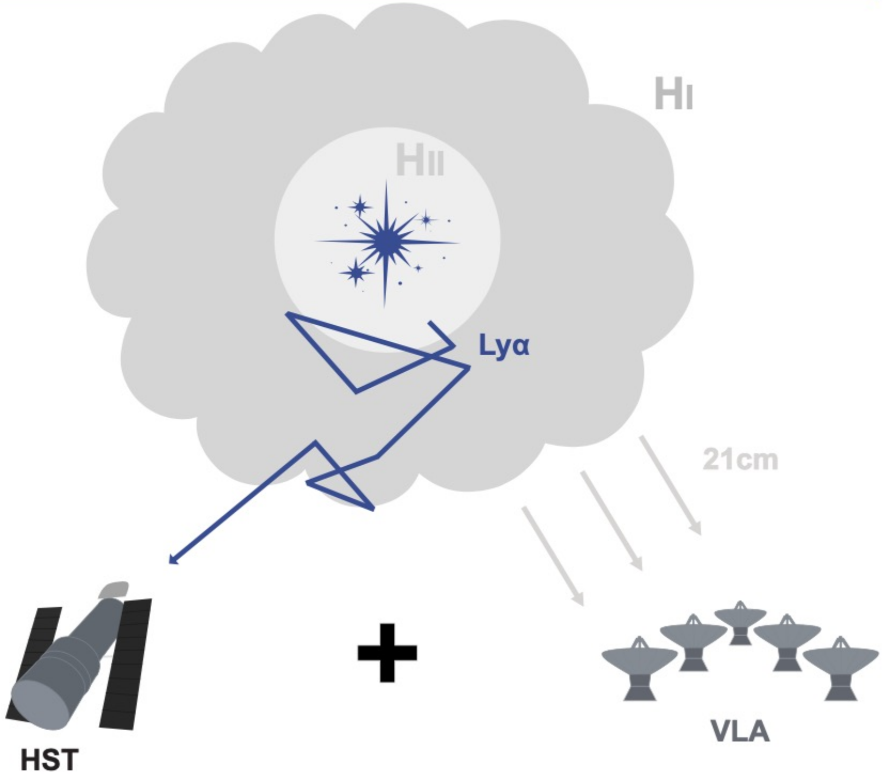
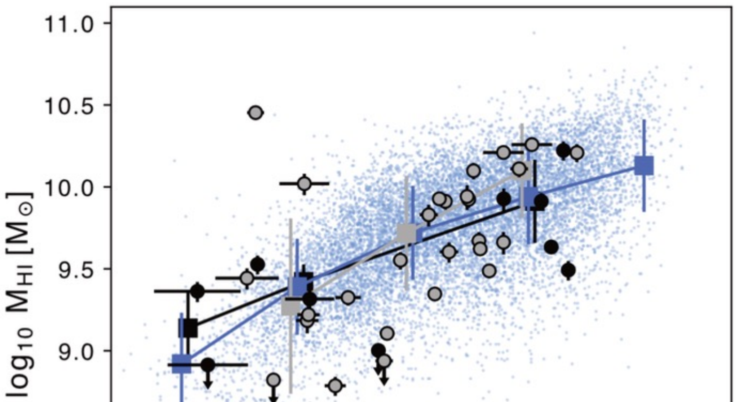
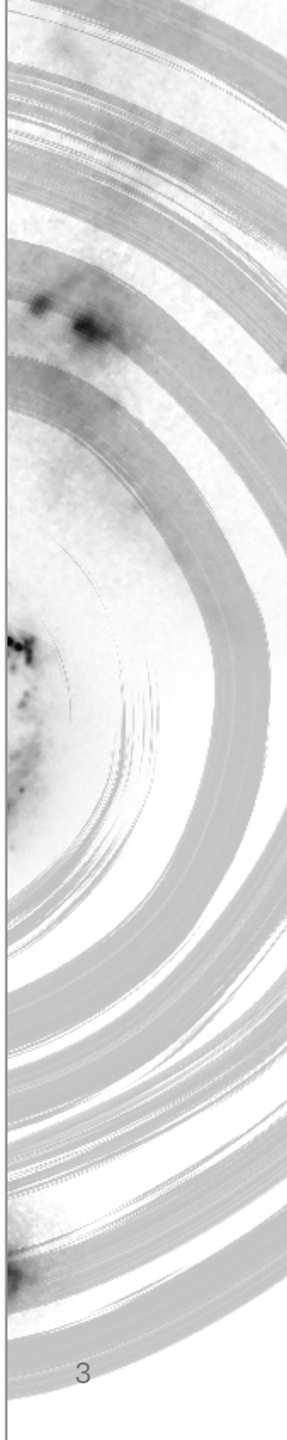



**Figure 1**
Lyα is a resonant line of hydrogen. In galaxies, it goes through a scattering-like radiative transfer in HI gas. 21cm emission spontaneously occur in hydrogen atoms, making it a direct tracer of the neutral ISM and CGM of galaxies. Here, we present a comparison of Lyα and 21cm observables, obtained respectively with the HST and the VLA, for a sample of 37 nearby star-forming galaxies.



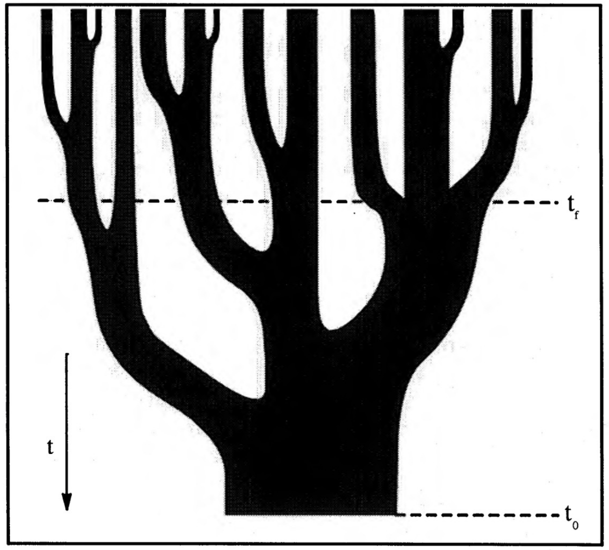

## 2 - Do Lyα emitters have special HI properties?



# An introduction to galaxy mergers

# Galaxy mergers in galaxy evolution

Mass growth




*Lacey & Cole 1993*

SFR

starburst triggers /

quenching agents

*e.g. Patton et al. 2013, Pearson et al. 2019*

AGN activity

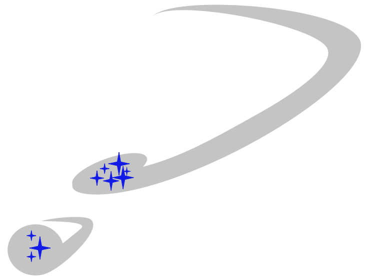
Centaurus A *(ESO,NASA)*

*e.g. Hopkins et al., 2010*

# A role in facilitating LyC escape?

- *Bridge et al. 2010, Bergvall et al. 2013:* Invoke major mergers as processes for elevated LyC escape via starburst + neutral gas clearing
- *Le Reste et al. 2024:* Haro 11: $10^8$ $M_{sol}$ of HI removed from our line-of-sight by tidal interaction
- *Maulick et al. 2024, Gupta et al. 2024, Yuan et al. 2024:* Detection of LyC from mergers

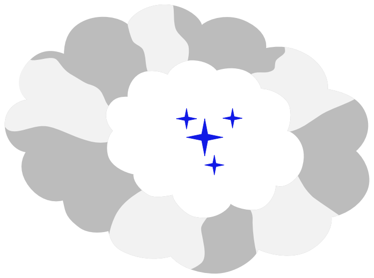
**Multi-stage burst:**



Efficient Lyman radiation production

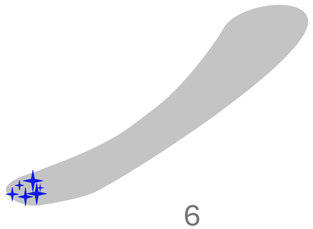
&

Clearing of the ISM



**+**

**Tidal offset of neutral gas**



# A role in facilitating LyC escape?

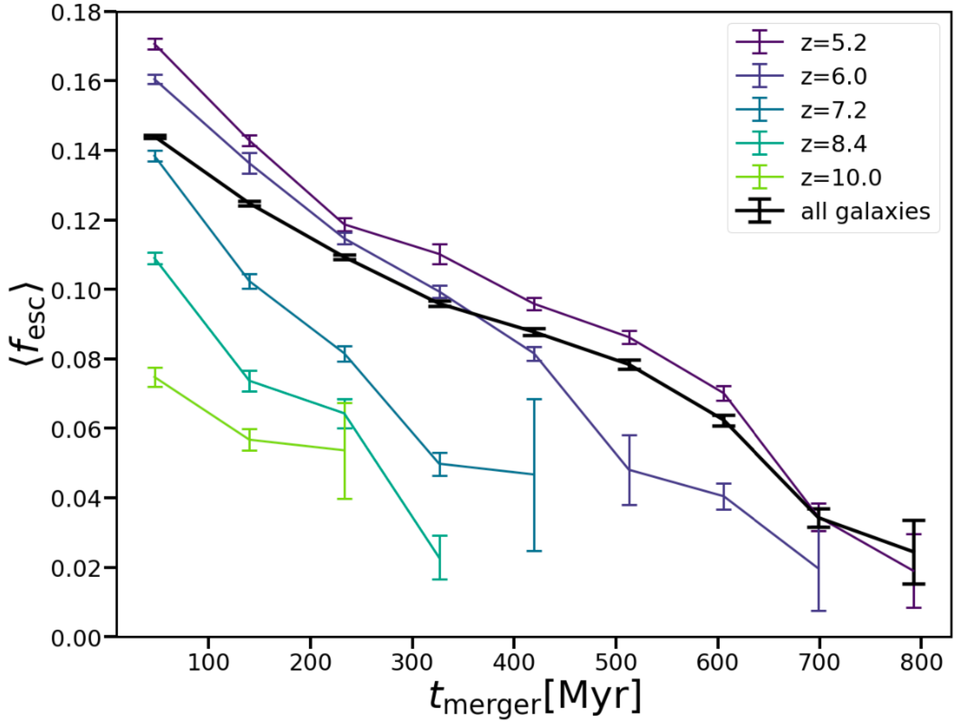
Questions:

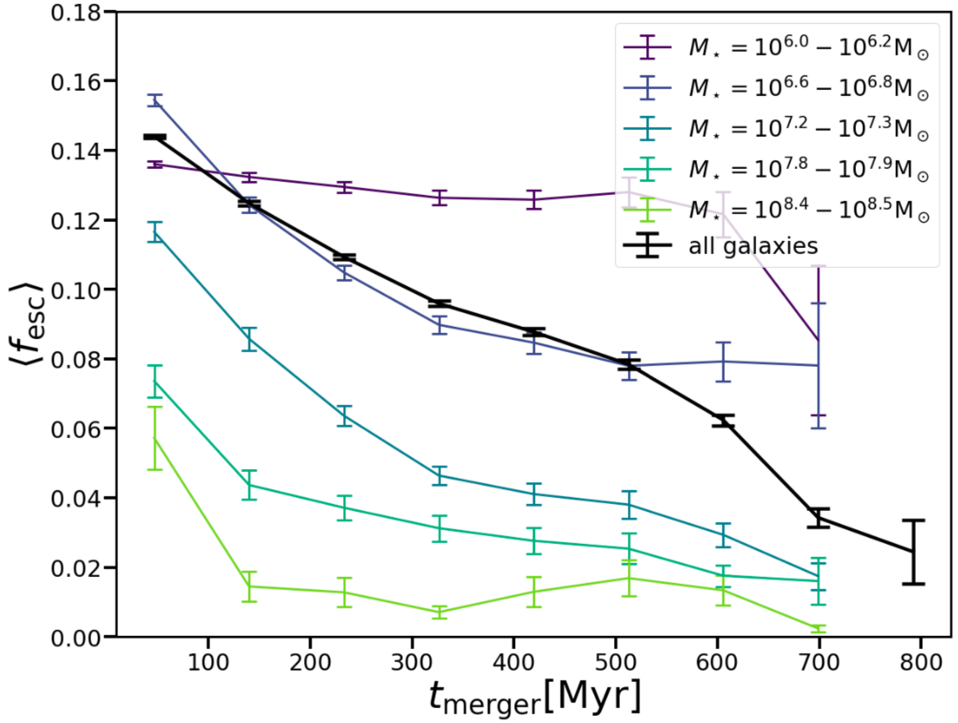
→ How common are galaxy mergers in LyC emitting samples?

→ At what point are in the LyC emitted/escaping in a merger?

# Characterizing mergers in LCEs

Simulations of galaxies at high-z: support for the idea of galaxy mergers facilitating LyC escape

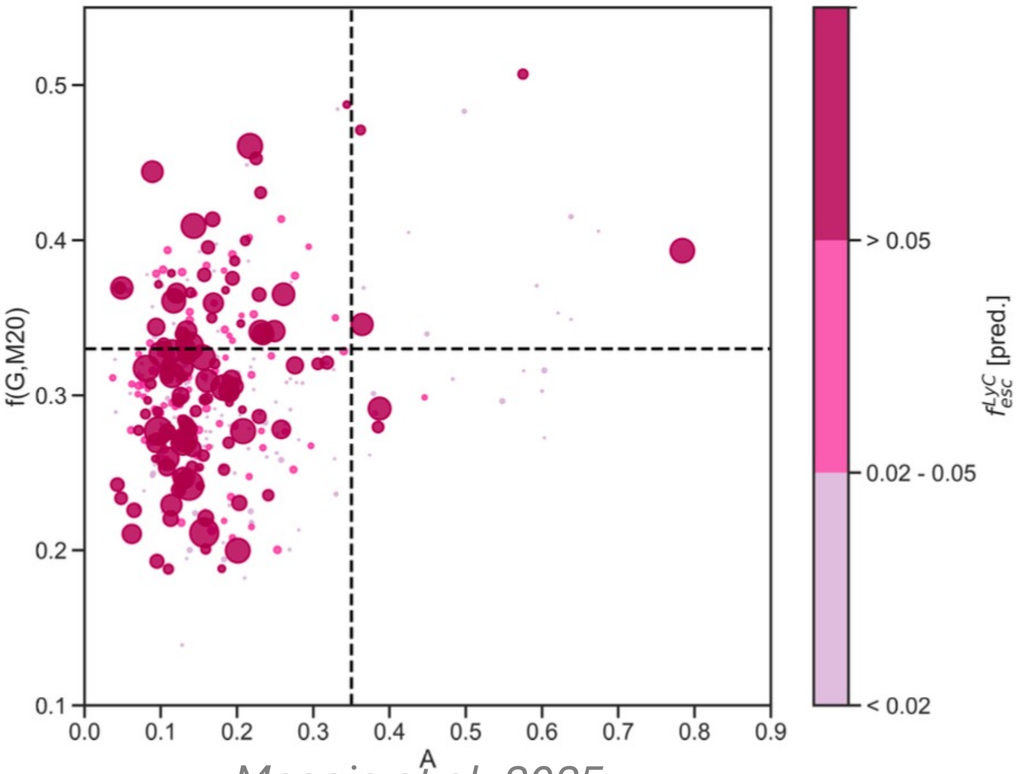


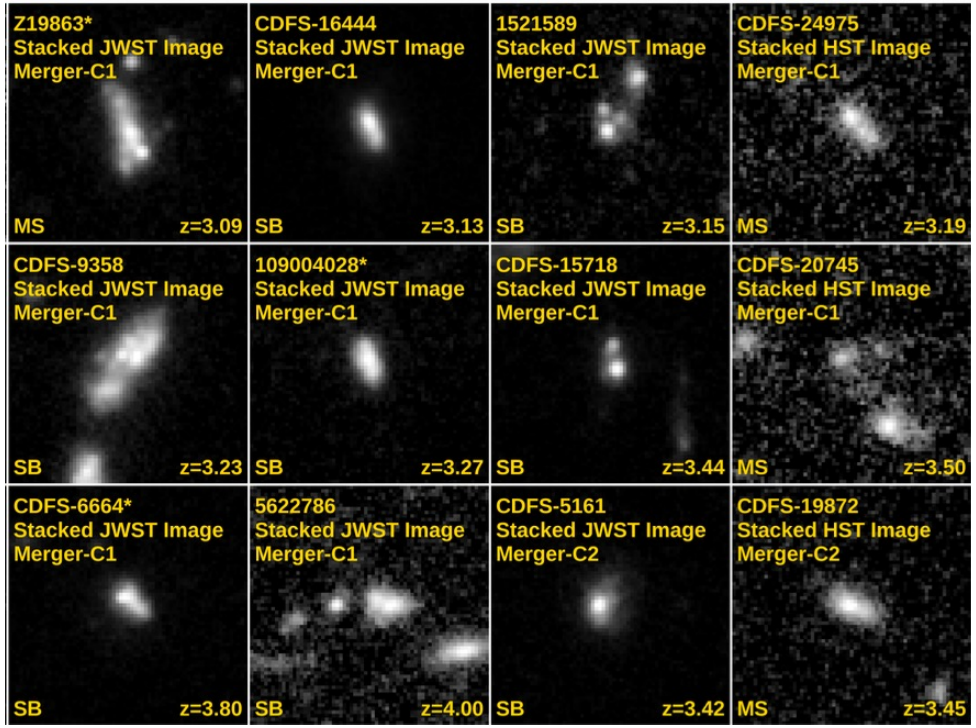

*Kostyuk & Benedetta, subm.*

# Characterizing mergers in LCEs

Observations have started systematically characterizing the merger fraction of observed and candidates Lyman Continuum Emitters at high-z




Mascia et al. 2025




Zhu et al. 2024

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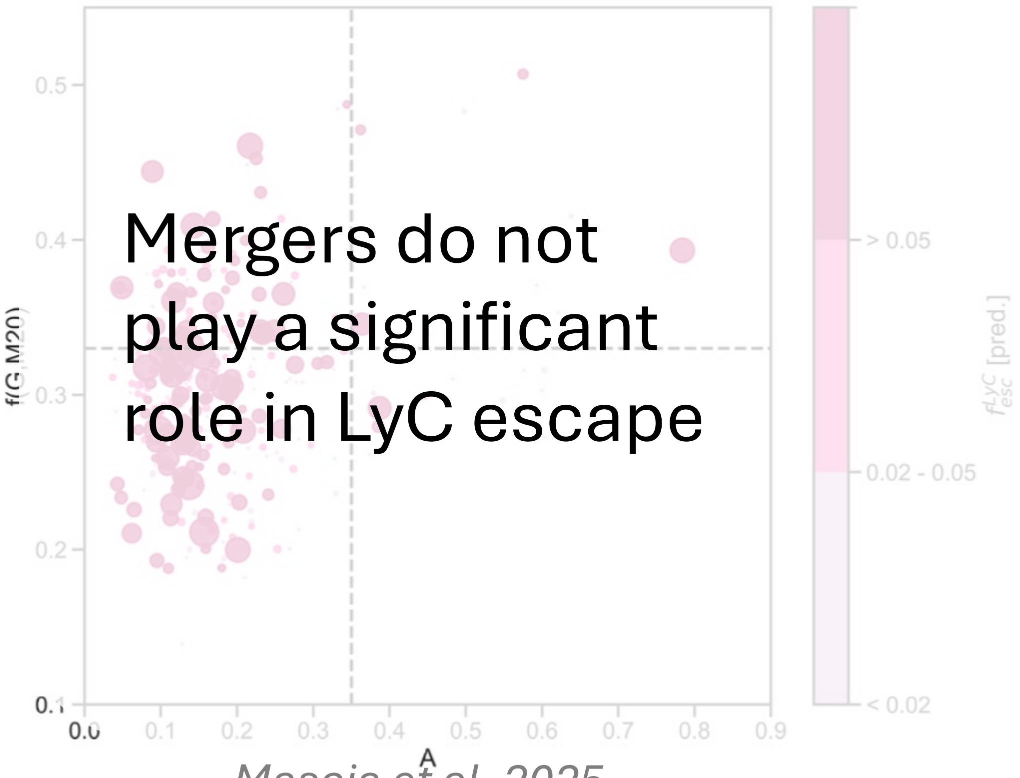
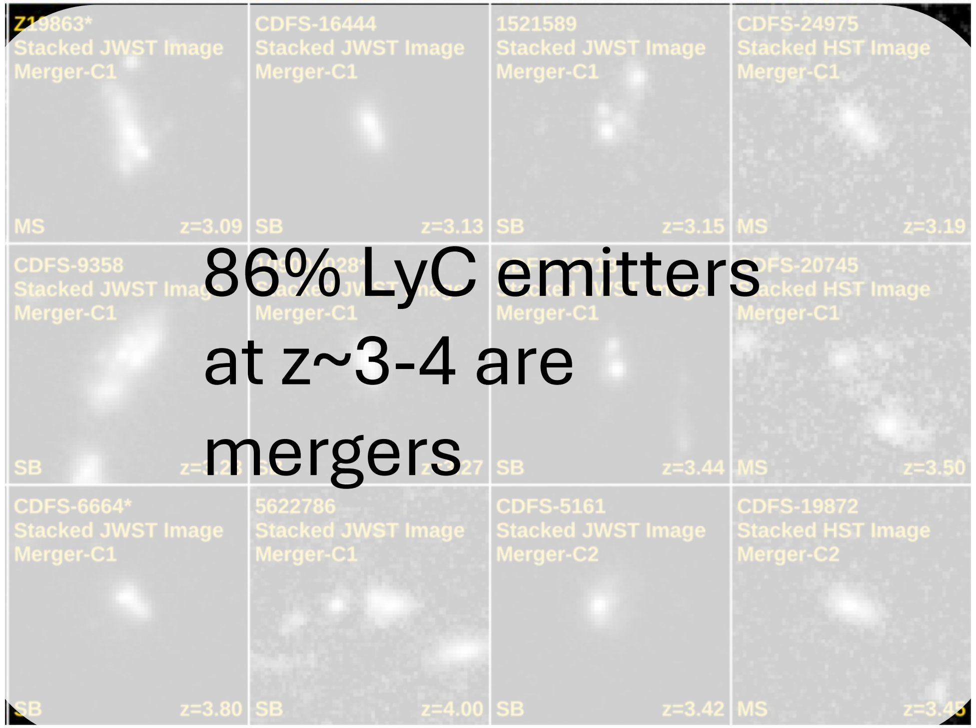



Mergers do not play a significant role in LyC escape

Mascia et al. 2025




86% LyC emitters at z~3-4 are mergers

Zhu et al. 2024

# Characterizing mergers in LCEs

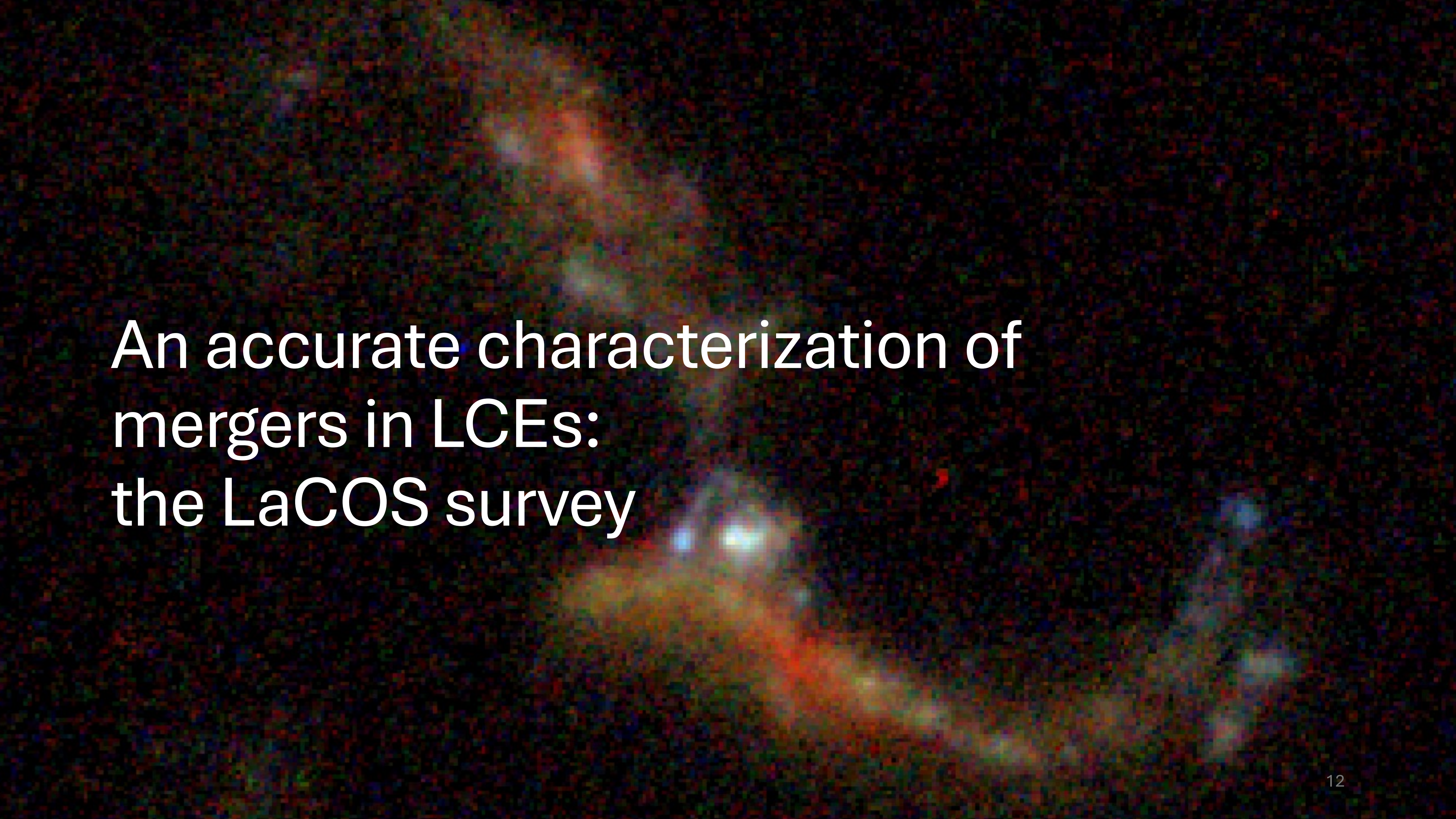
High-z studies *(z>2)*: several caveats when it come to identifying galaxy mergers.

1) High-z galaxies are clumpier, large number of non-interacting star-forming galaxies could masquerade as mergers

*e.g. Guo et al. 2015*

2) Low-surface brightness feature disappear very quickly with redshift: $(1+z)^4$ Many mergers are missed

*e.g. Mantha et al. 2019*



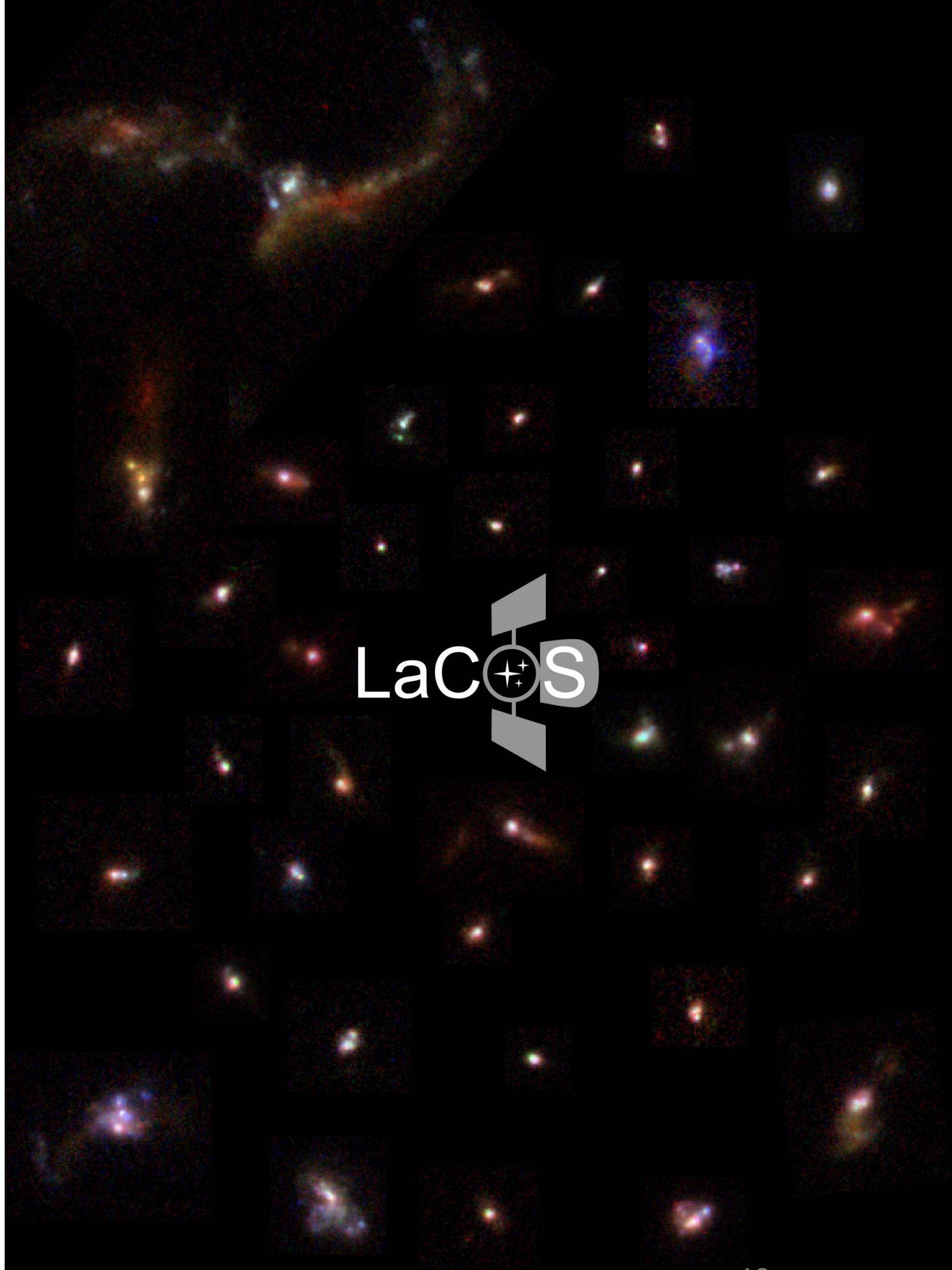
# An accurate characterization of mergers in LCEs: the LaCOS survey

# The Lyman alpha and Continuum Origins Survey

LaCOS: HST cycle 32 program imaging 42 galaxies part of LzLCS+ in five filters, sampling the UV and optical.
*(Le Reste et al., subm)*

**Goal:** Determine the link between resolved galaxy properties and LyC escape.

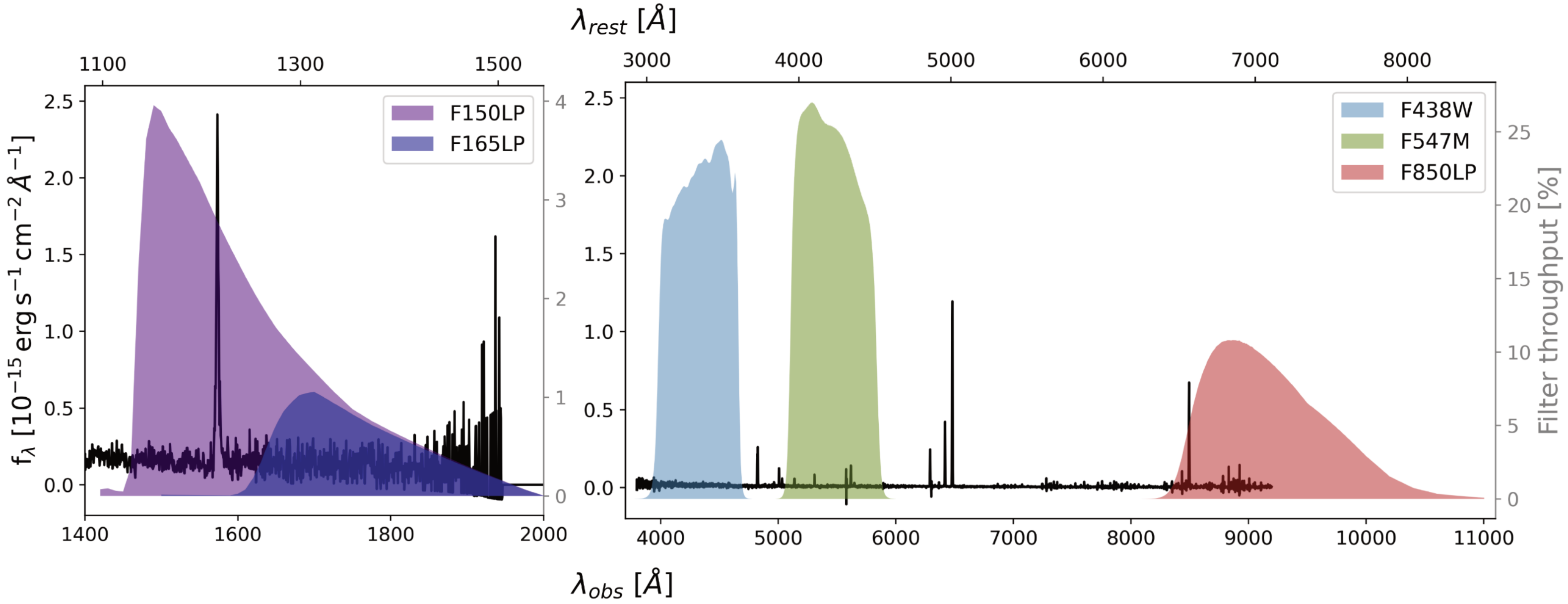
Lyα halo morphology *(Saldana-Lopez et al., subm)*, *Resolved* UV beta properties *(Jung et al. in prep)*



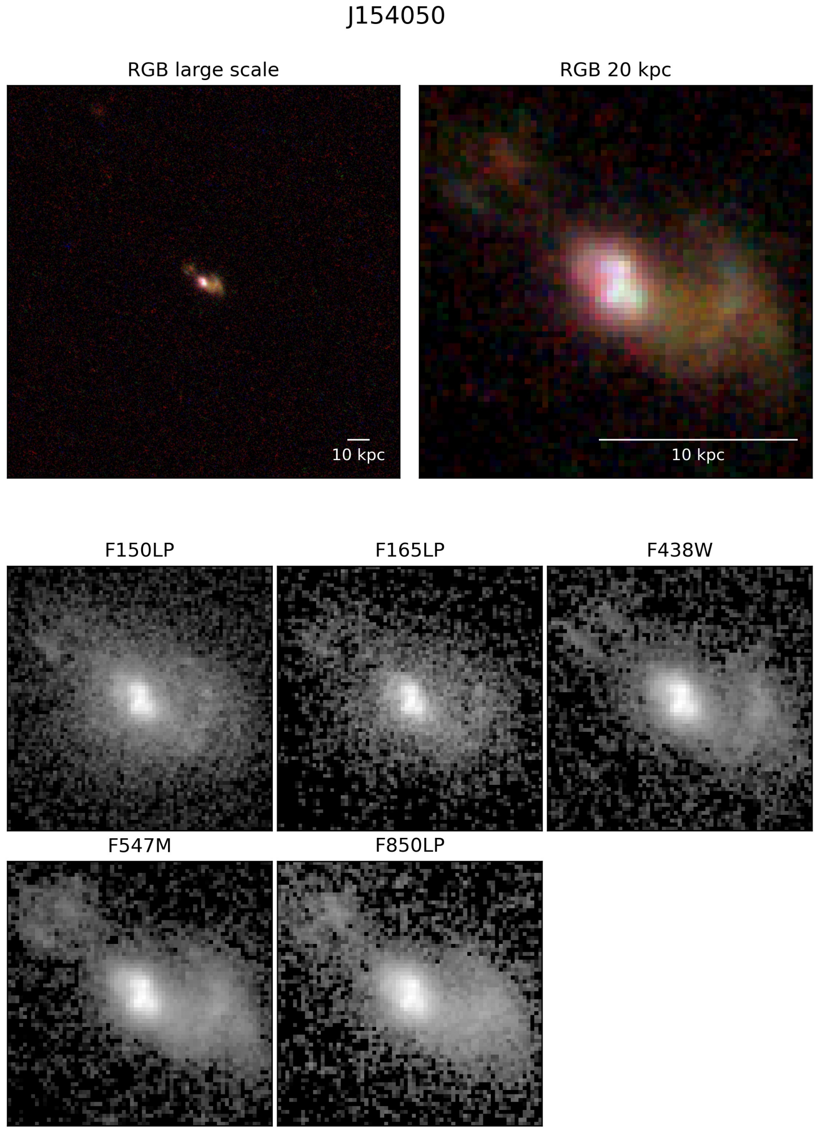
# Identifying mergers in LaCOS

- z~0.3
- Deep coverage across five bands (B~)
- High-resolution imaging: (0.1” PSF / 400pc)
- 22 Lyman Continuum Emitters / 20 non-emitters

→ The ideal survey to identify and characterize mergers in LCE



# Identifying mergers in LaCOS




LaCOS: 42 galaxies → Visual classification

$$P_{merg} = \frac{N_{vote,merg}}{N_{vote,merg} + N_{vote,nonmerg}}$$

$P_{merg} \geq 75\%$: Merger

$P_{merg} = 25 - 75\%$: tentative merger indication

$P_{merg} < 25\%$: no merger indication

# Identifying and *timing* mergers in LaCOS

Not a merger

?

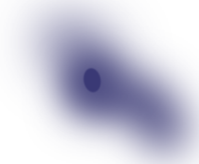
Not sure



Merger:
1 - pre-interaction

Merger:
2 - post-interaction

Merger:
3 - pre-coalesence

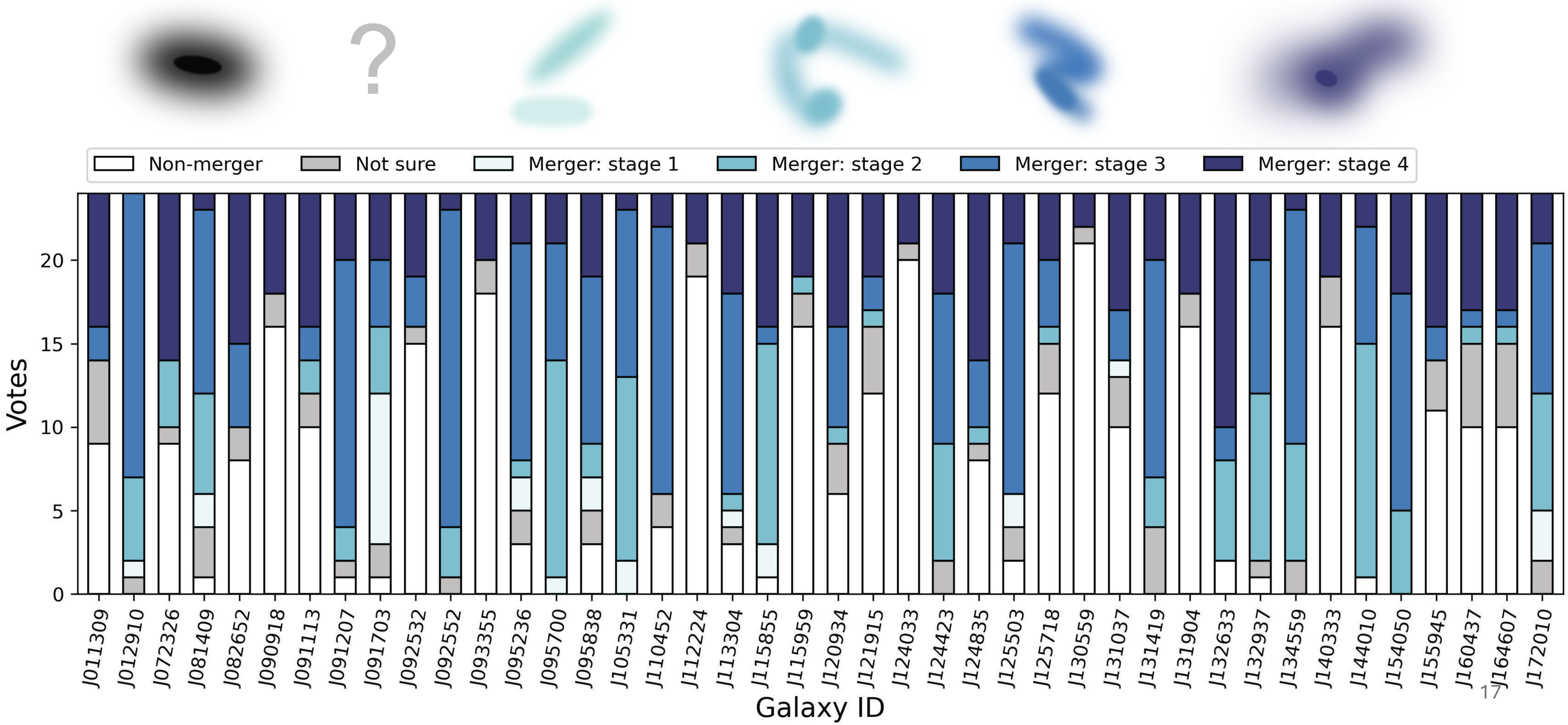


Merger:
4 - post-coalesence

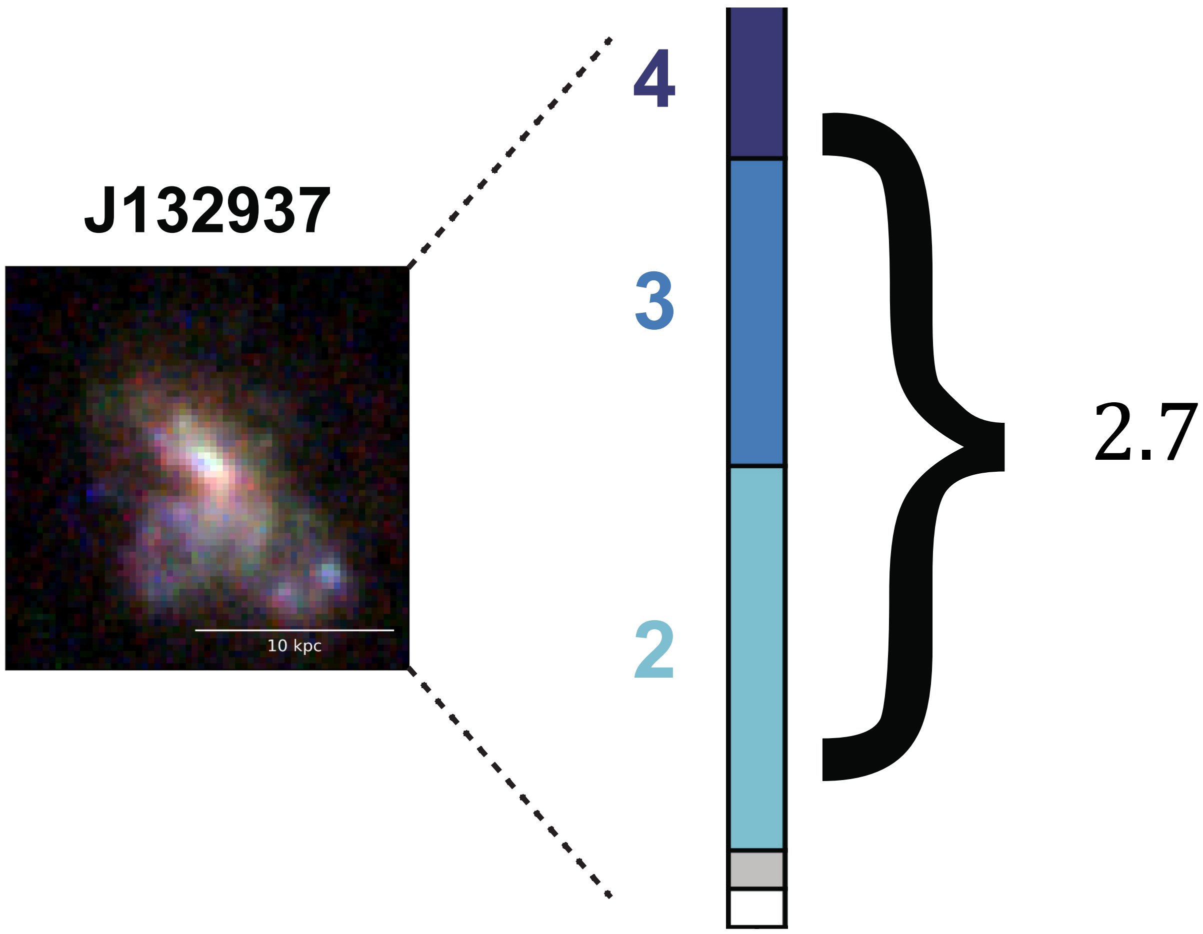
In addition to classifying the galaxies in merger/non merger, we classify the mergers in **broad timescale categories** according to their morphologies

For mergers votes, we assign a score $s_{merg}$ ranging from 1(pre-interaction) to 4 (post-coalescence)

# It is difficult to classify mergers



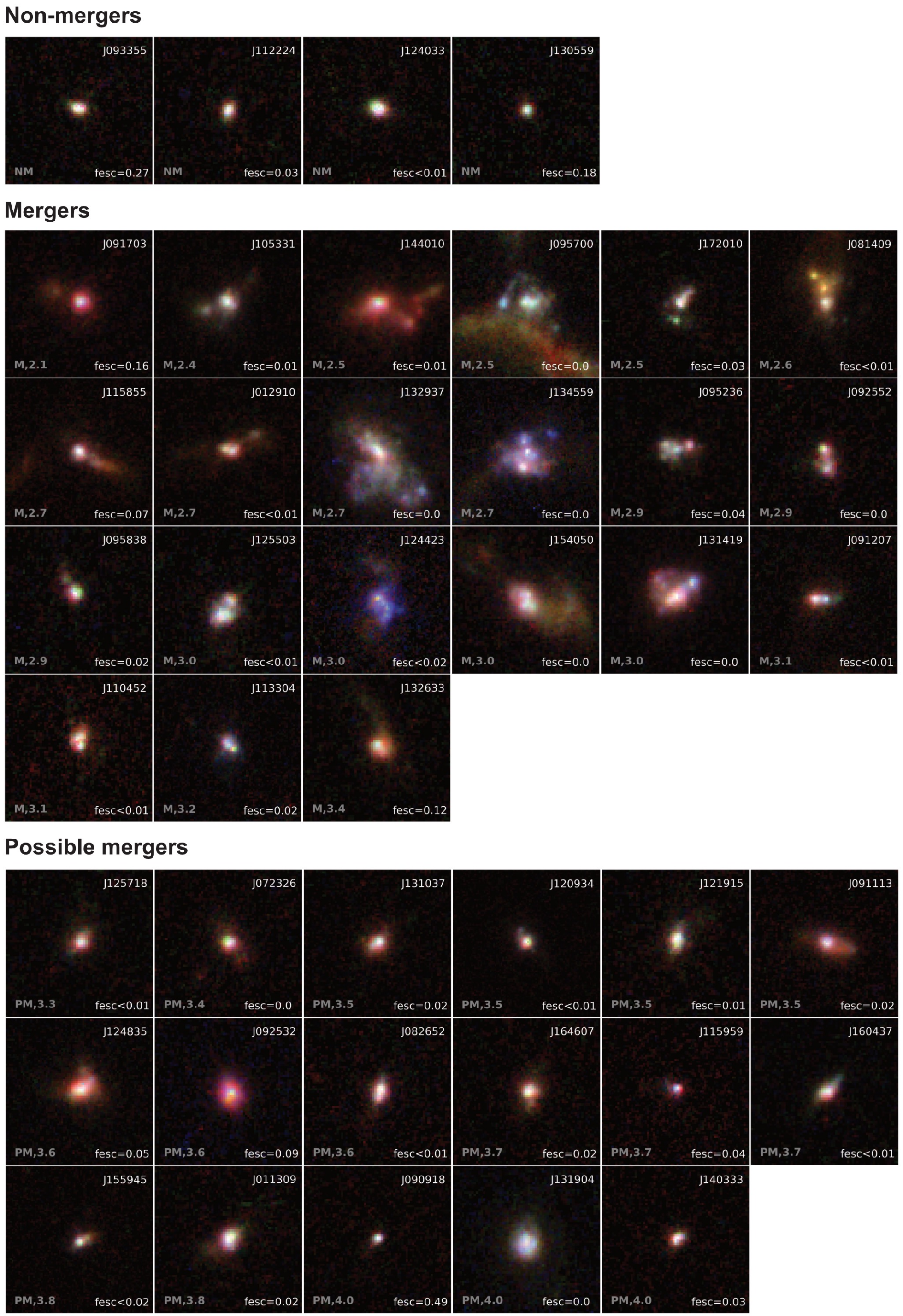
# Timing the mergers




Merger timescale:

$$T_{merg} = \frac{\sum s_{merg}}{N_{vote,merg}}$$

Broad measure of the temporal evolution of a galaxy interaction



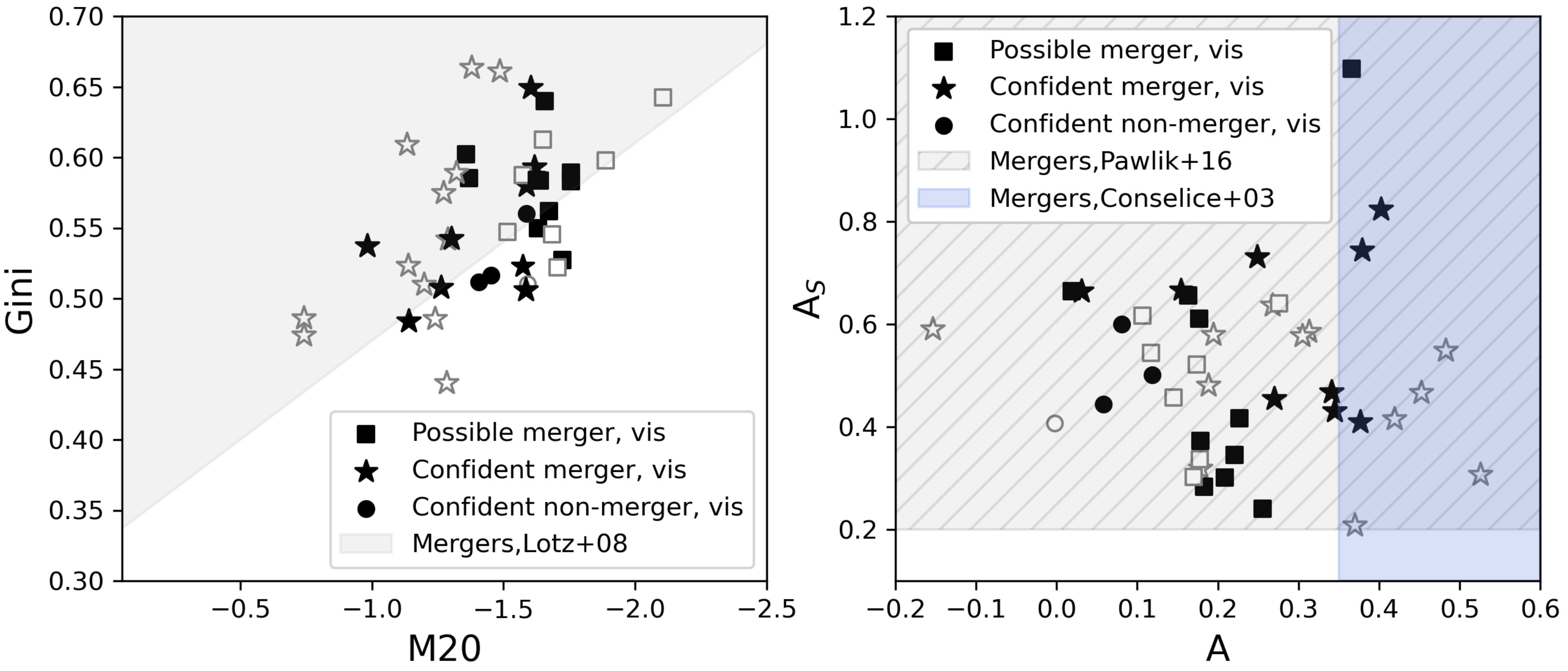

# Mergers in LaCOS with visual identification

50% : mergers
(40% LCE/60%nLCE)

40%: tentative merger indications
(45% LCE/35%nLCE)

10%: no merger indication
(14% LCE/5%nLCE)

# The pitfalls of classification with morphological parameters
(even at z~0.3 ....)

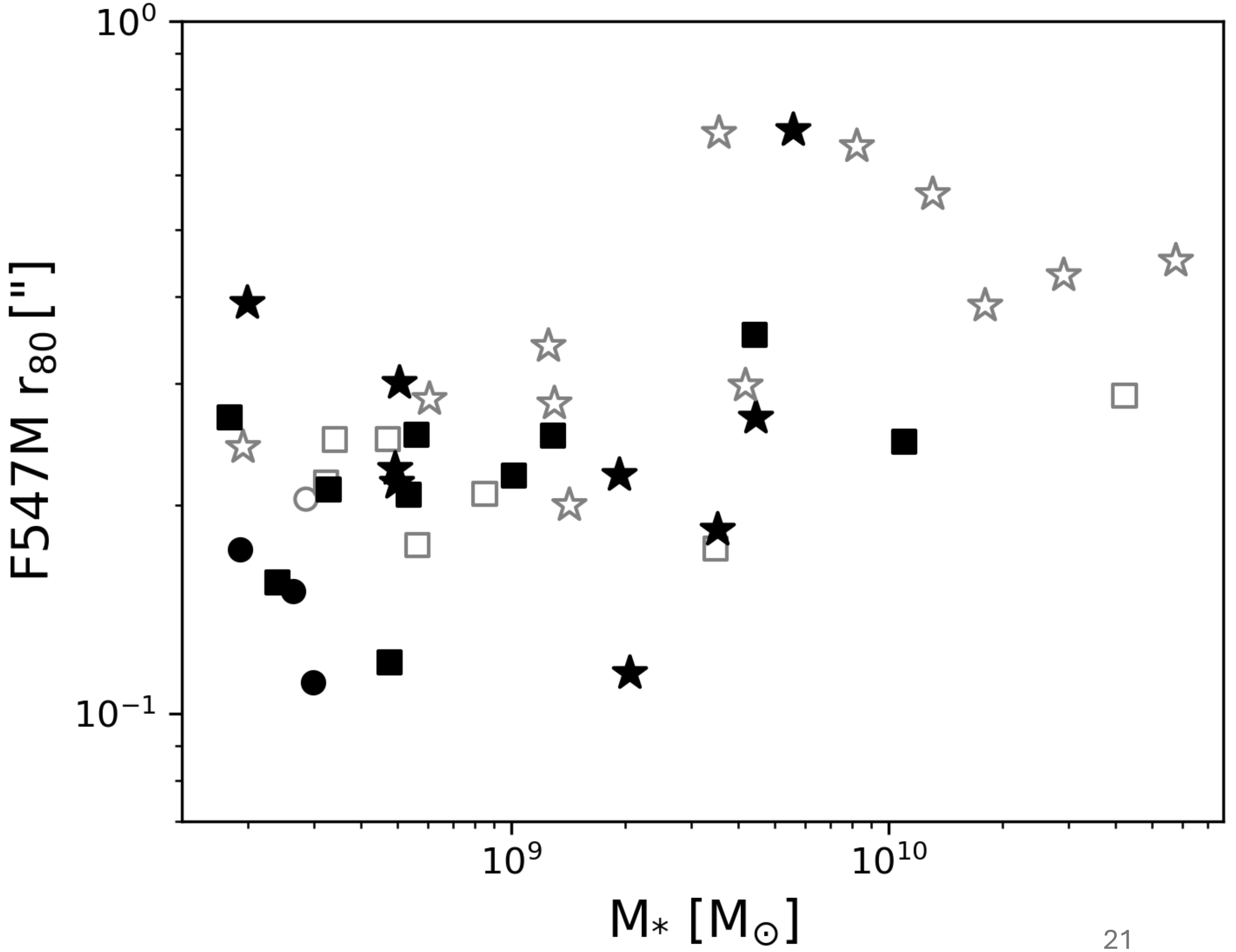



Morphological parameters calibrated at z~1 on massive galaxies are *not necessarily adapted to LyC emitters*

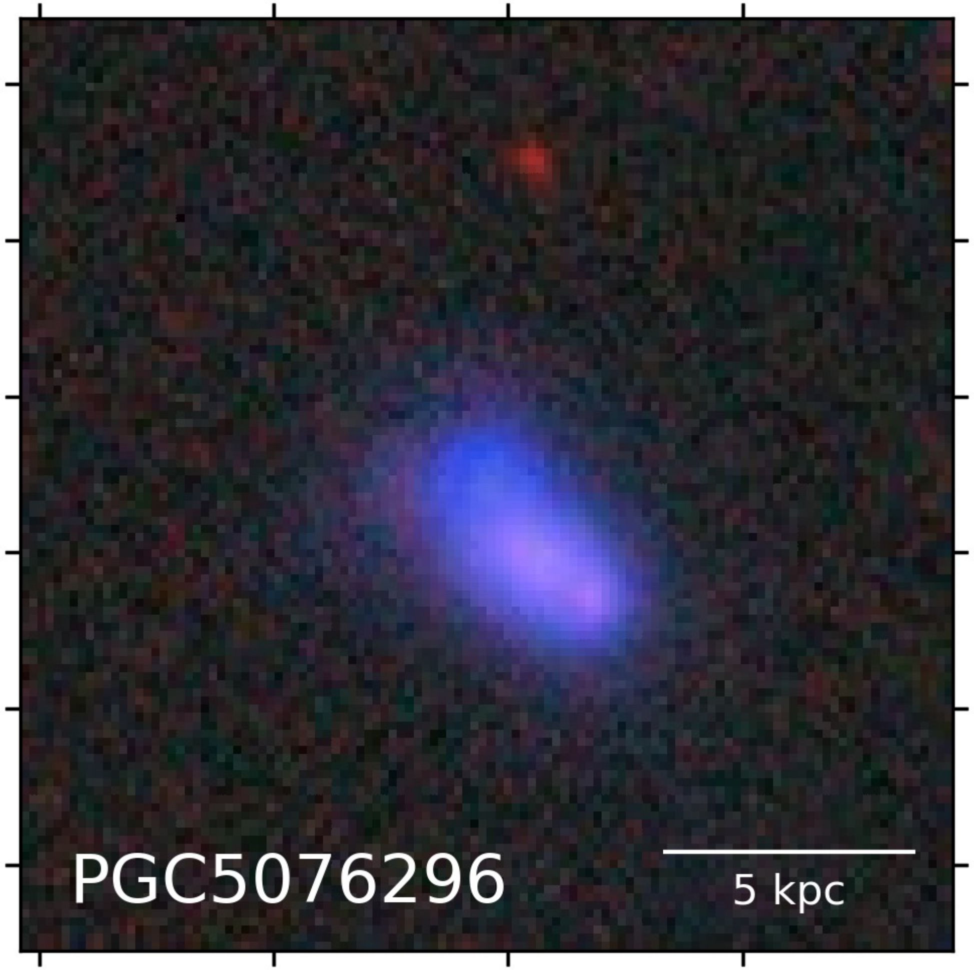
# The pitfalls of visual classification

Visual identification and classification of mergers can only be as good as the data

→ **Spectacular mergers are easier to identify:** High mass, intermediate stages of interaction



# Is this a merger or a dwarf galaxy?

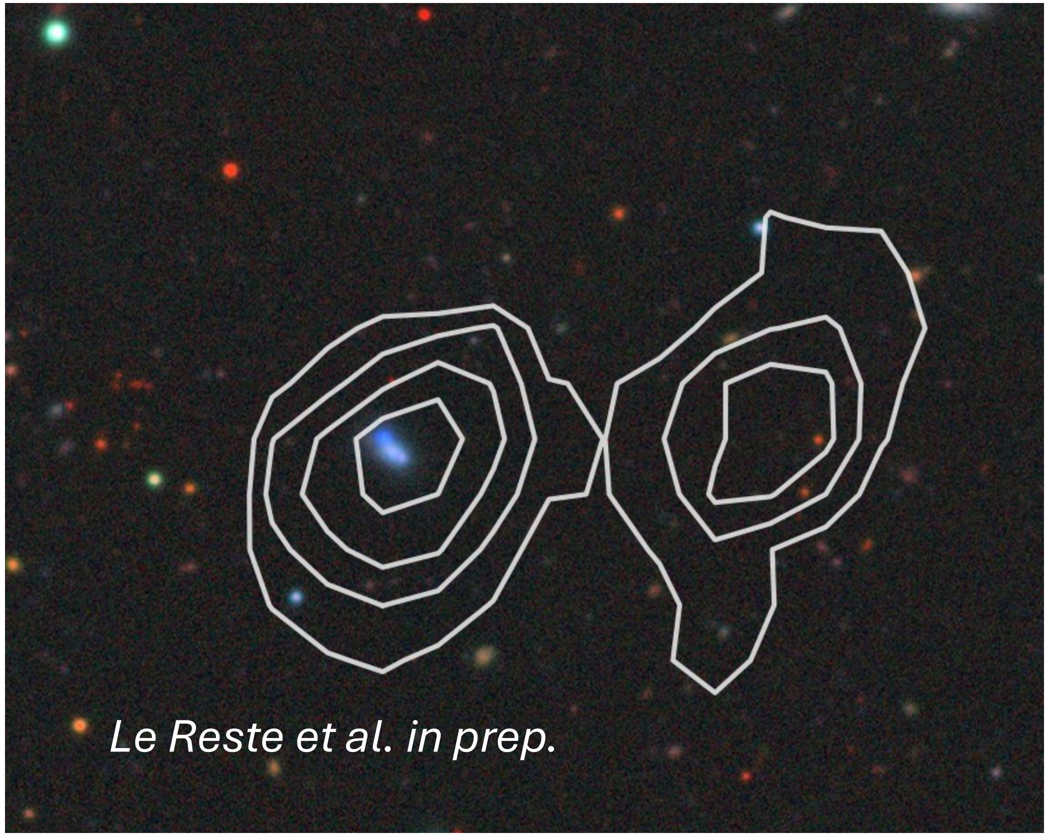



Blueberry galaxy z=0.029

O32 = 33

Mstar=$10^6$ $M_{sun}$

# Is this a merger or a dwarf galaxy?



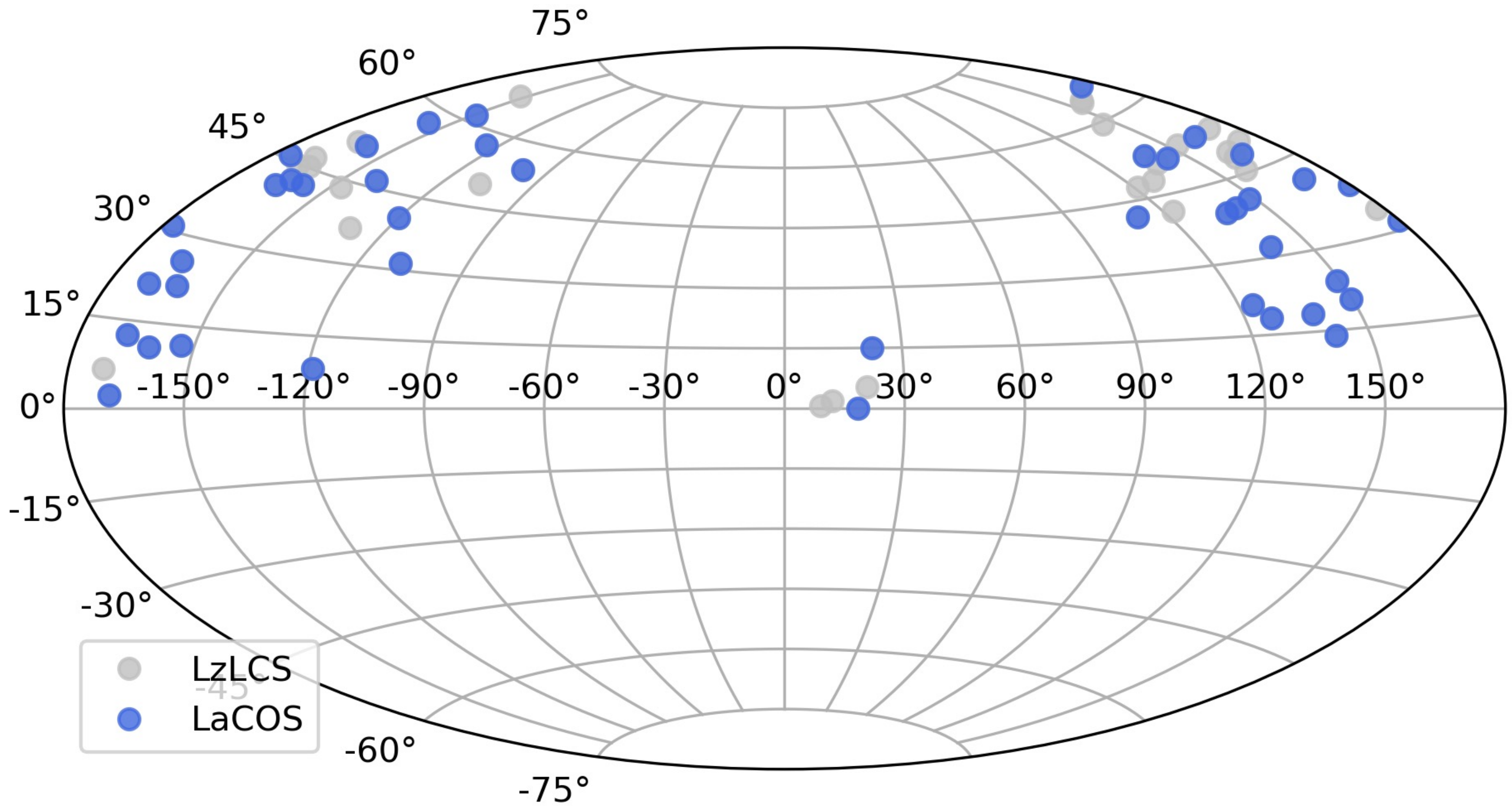

Tentative detection (2σ) of 21cm around the galaxy + possible tidal material with 1/3 of MeerKAT time allocated.

Compactness in the optical does not rule out a merger, and it says nothing about the shape of the labyrinth (HI morphology).

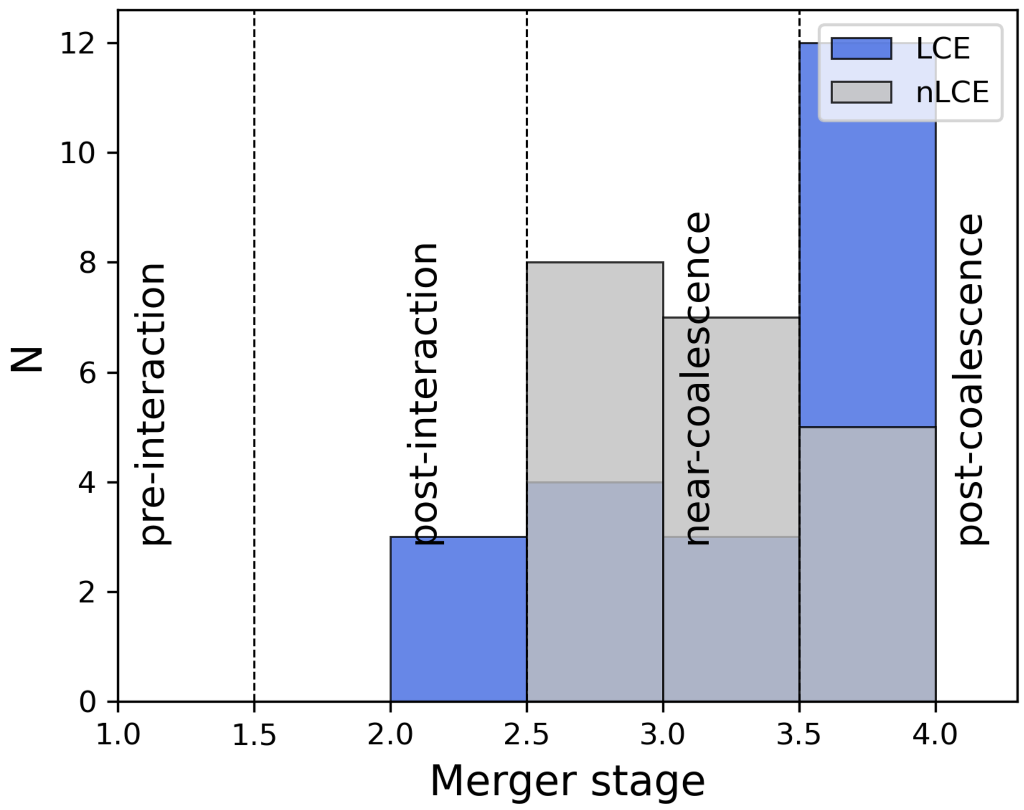
See also 21cm GMRT observations of blueberries in *Purkayastha et al. 2022, 2024*

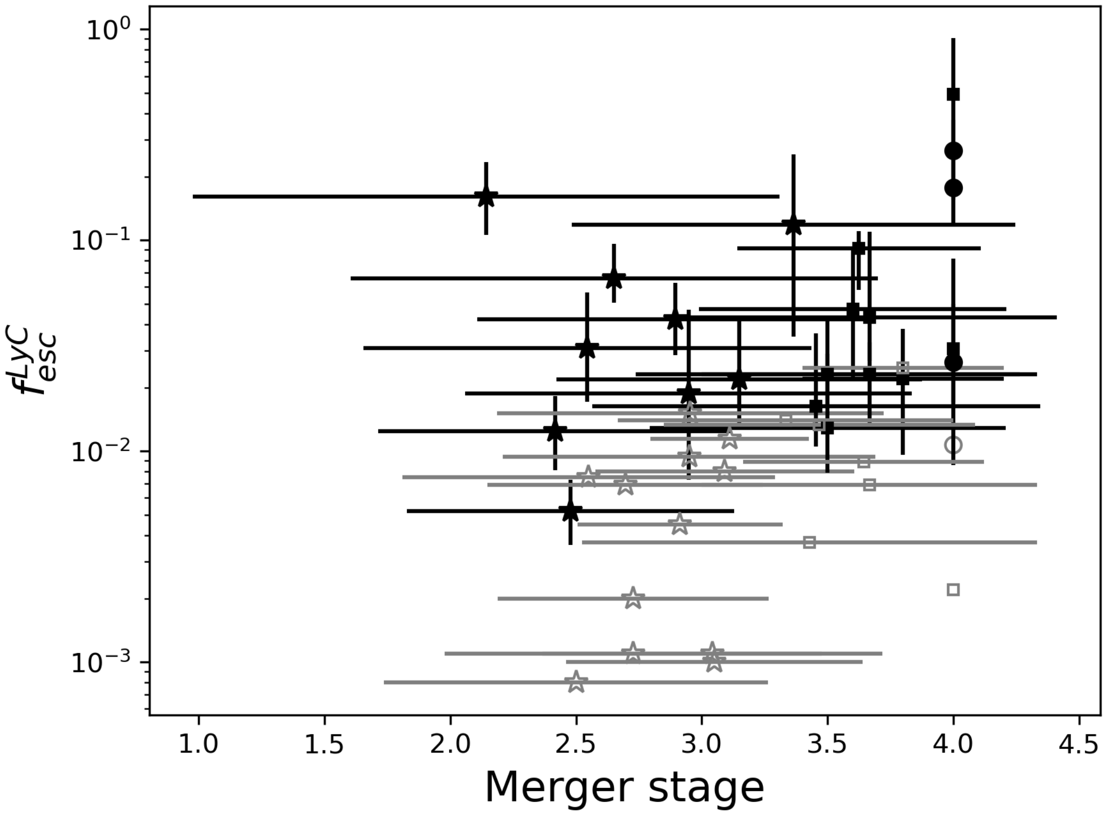
# Observing 21cm from LaCOS with SKA?

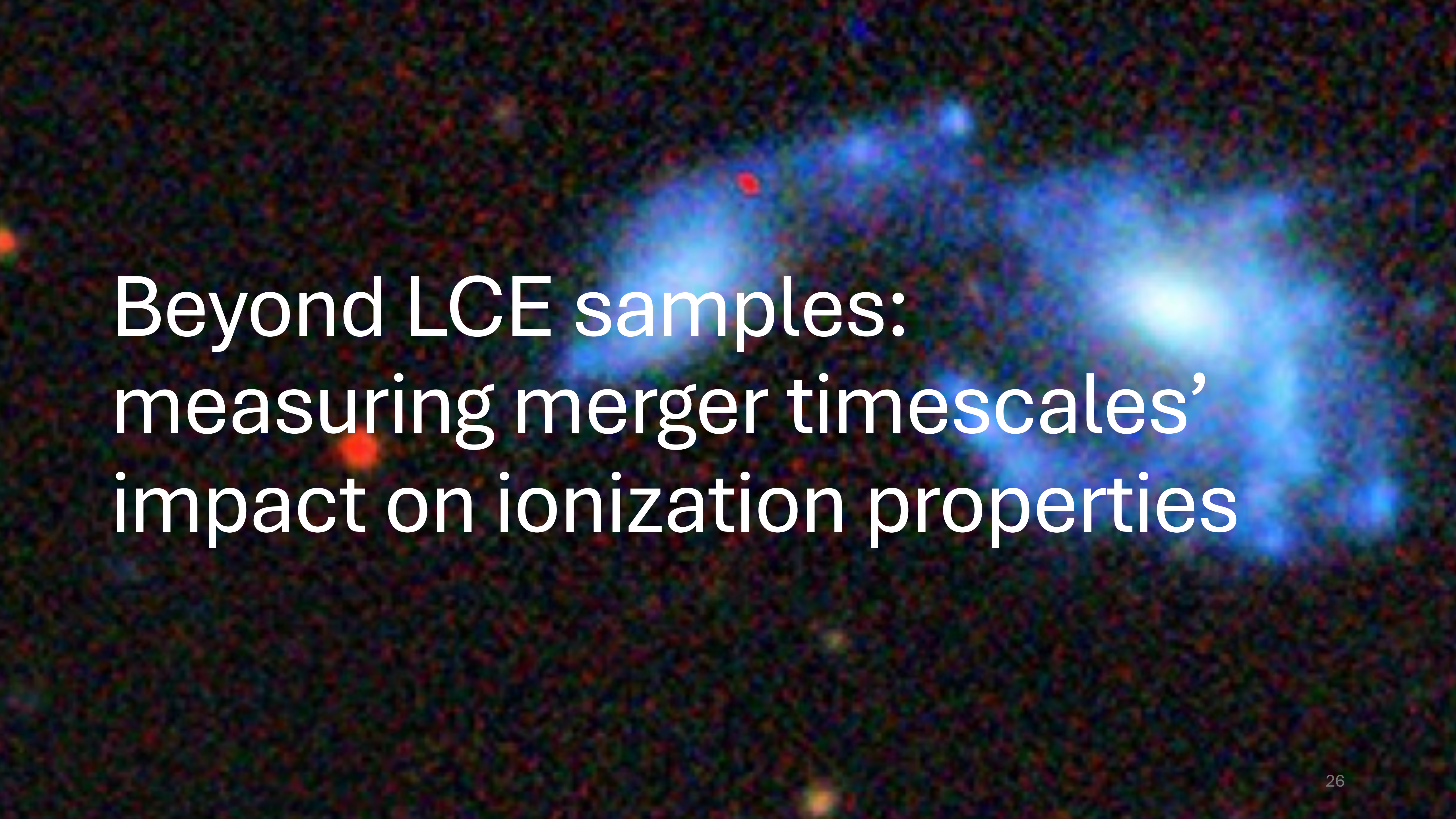
z~0.3 is within the reach of SKA, but LzLCS targets are mostly… in the North.



# Merger timescales

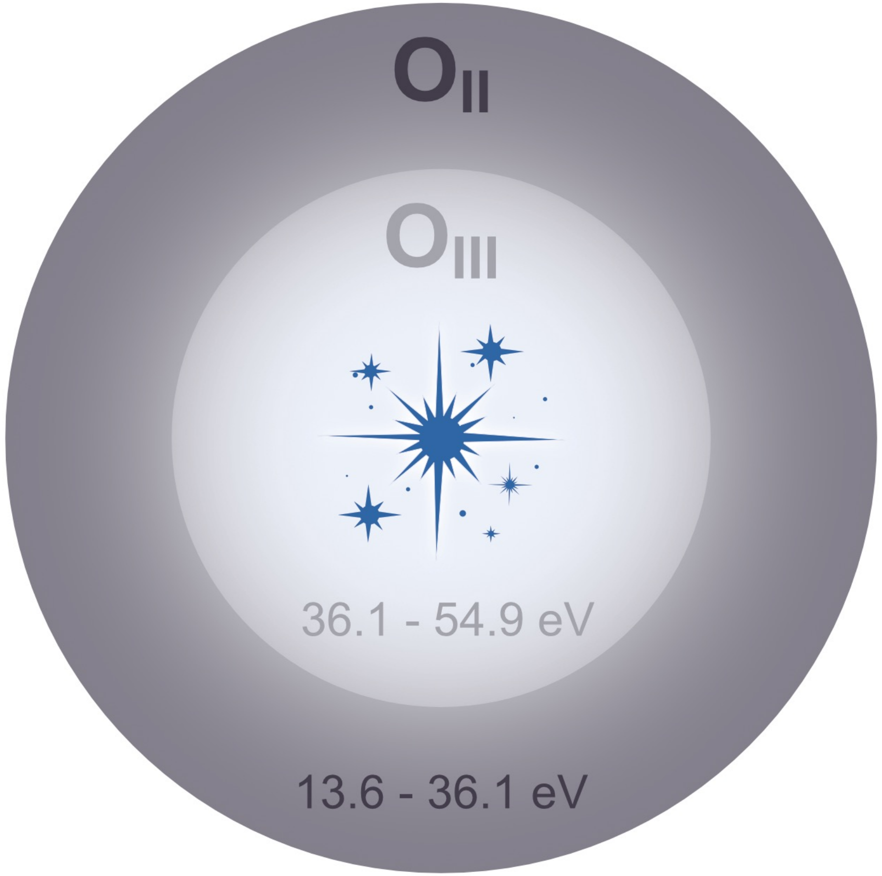




# Beyond LCE samples: measuring merger timescales' impact on ionization properties

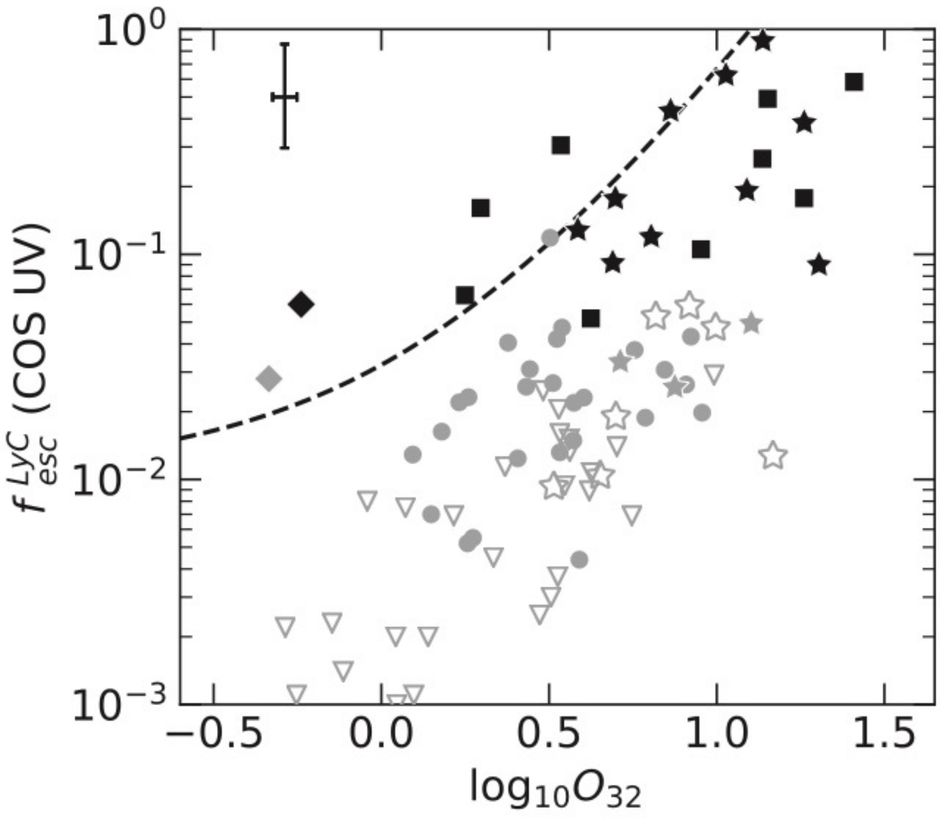
# The ionization state of galaxies in mergers




$$O_{32} = \frac{[O_{III}]_{\lambda 5007}}{[O_{II}]_{\lambda 3727}}$$

Traces the ionization state of a galaxy

# The ionization state of galaxies in mergers



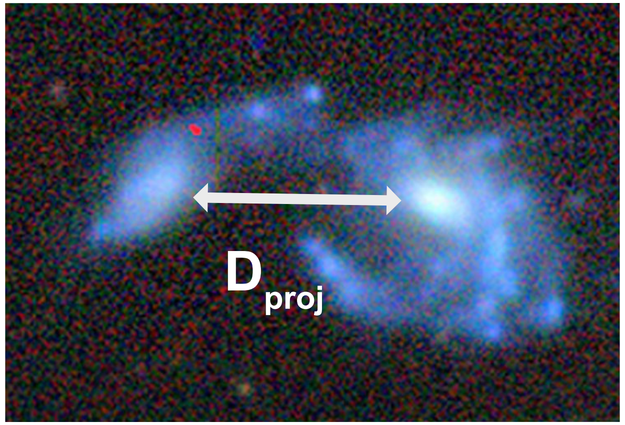

*Flury et al. 2022b*

⚠️ Stand alone galaxy properties are poor predictors of $f_{esc}^{LyC}$, and so is $O_{32}$ *(Jaskot et al. 2019)*

Nevertheless:

- Trend of increasing $f_{esc}^{LyC}$ with O32
- High O32 values : one of the criteria used to select LyC candidates (*Izotov et al. 2018,Flury et al. 2022a*)
- Can be easily calculated for large samples of galaxies

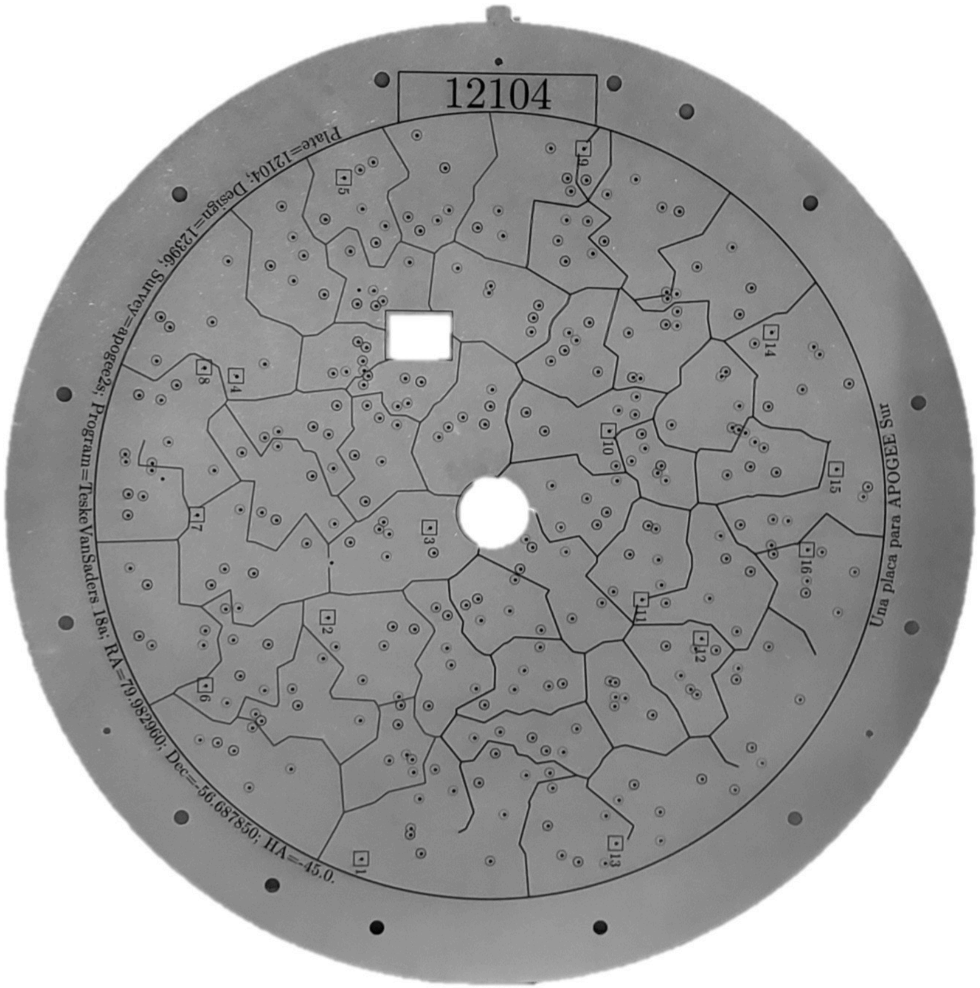
# Studying O32 in close pairs?




$D_{proj}$ = projected separation between close pairs

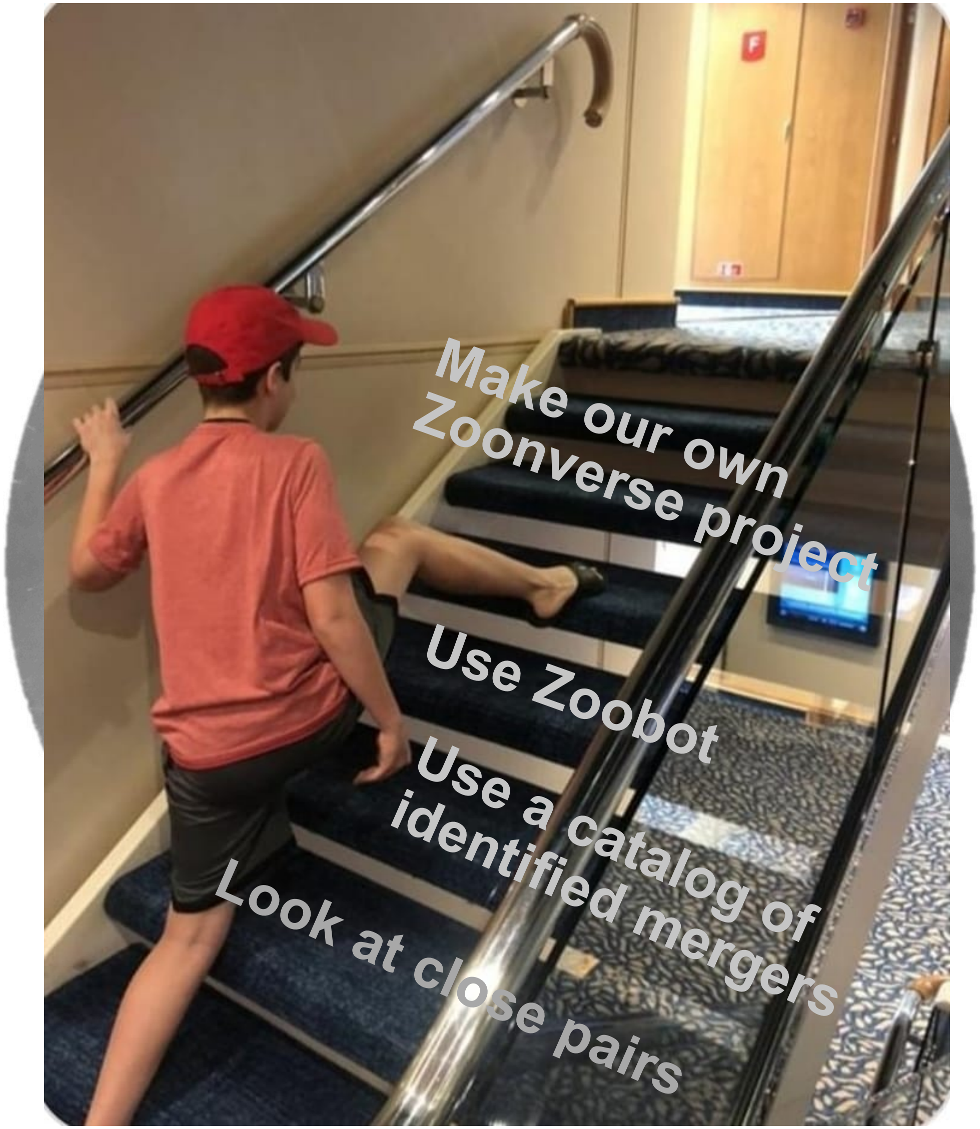
Used as a proxy for temporal evolution of a merger.

But... fiber collisions in SDSS




Example SDSS plate

# Studying O32 in close pairs?

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But… fiber collisions in SDSS

# Cosmic Disco: characterizing galaxy collisions

*Mantha, Le Reste et al, in prep.*

- Zooniverse project measuring **the impact of broad merger timescales** onto galaxy properties
- Sample pre-selected from SDSS with high quality spectral line measurement (Hα, Hβ, OIII, OII, NII, SII, etc…)
- Cosmic Dico: galaxies with a relatively large chance of being mergers according to Zoobot (CNN trained on Galaxy Zoo classifications): **7244 galaxies**

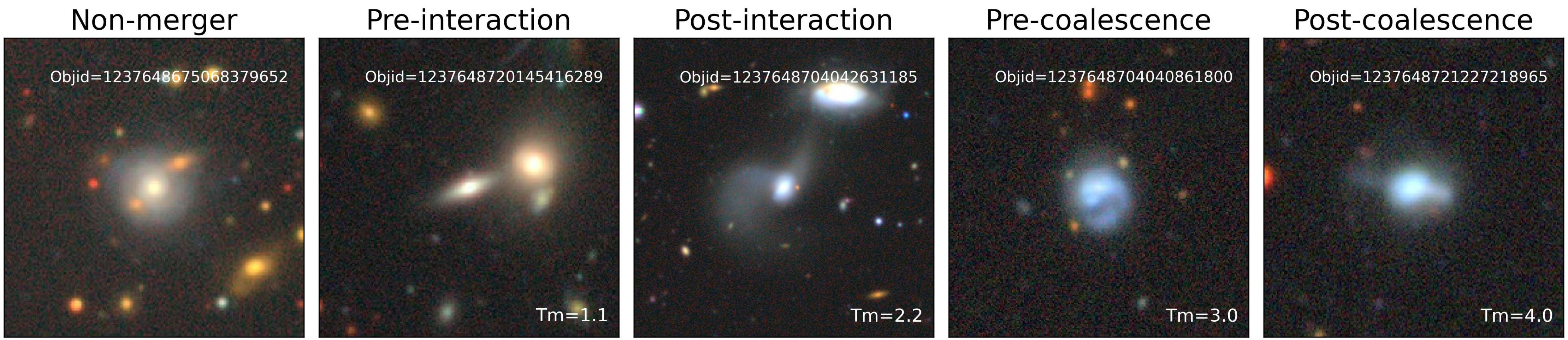
COSMIC DISCO: CHARACTERIZING GALAXY COLLISIONS STATISTICS

100% Complete

| 1,099 | 148,771 | 7,244 | 7,244 |
| --- | --- | --- | --- |
| Volunteers | Classifications | Subjects | Completed Subjects |

# Cosmic Disco: characterizing galaxy collisions

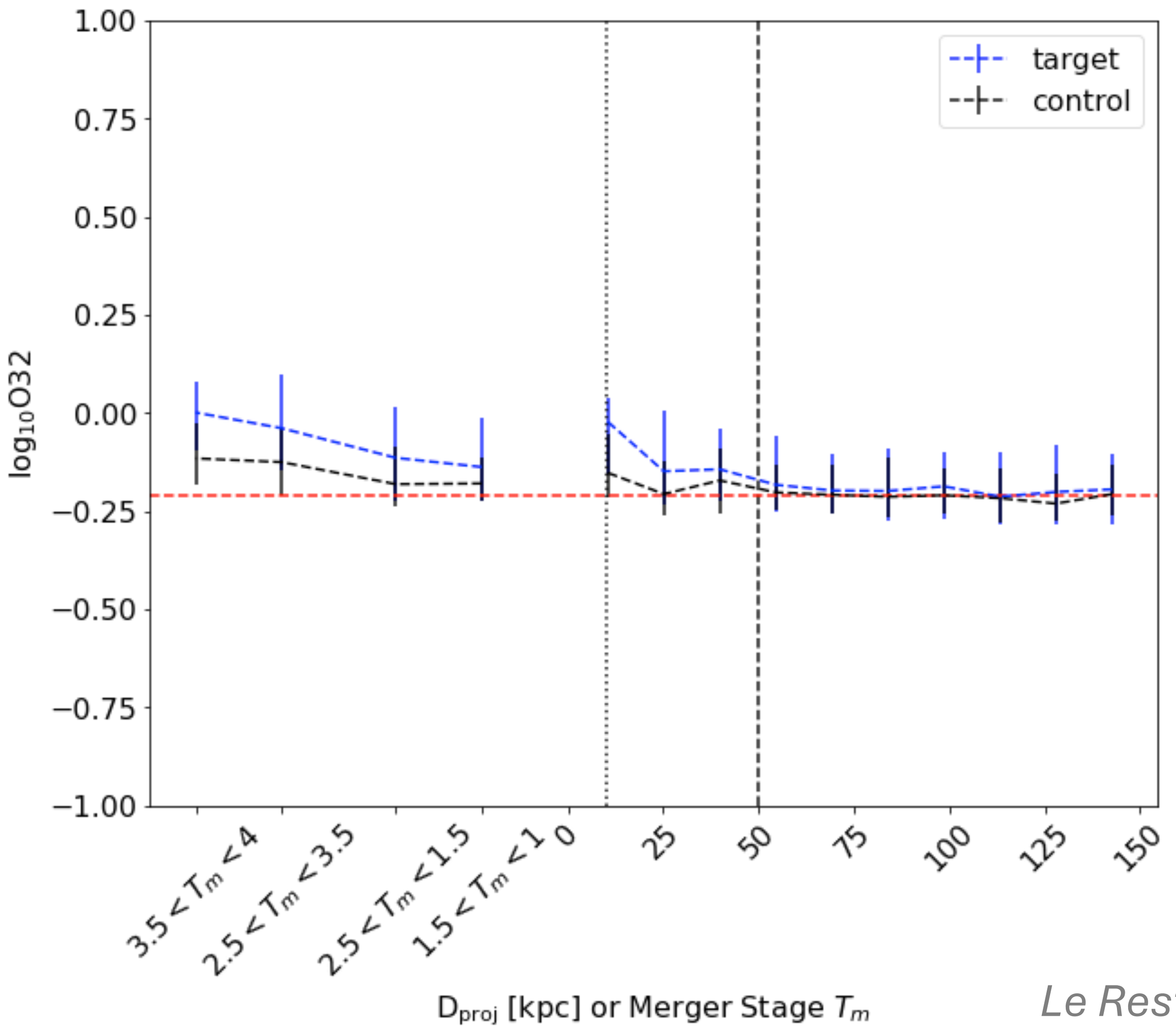
*Mantha, Le Reste et al, in prep.*




- We ask volunteer to place these galaxies in broad merger categories to estimate merger timescales

- The project will result in a public catalog

# The ionization states of galaxy mergers




Increase in O32 (as compared to control sample) as a function of galaxy merger timescale

*Le Reste & Mantha, in prep.*

# Conclusion

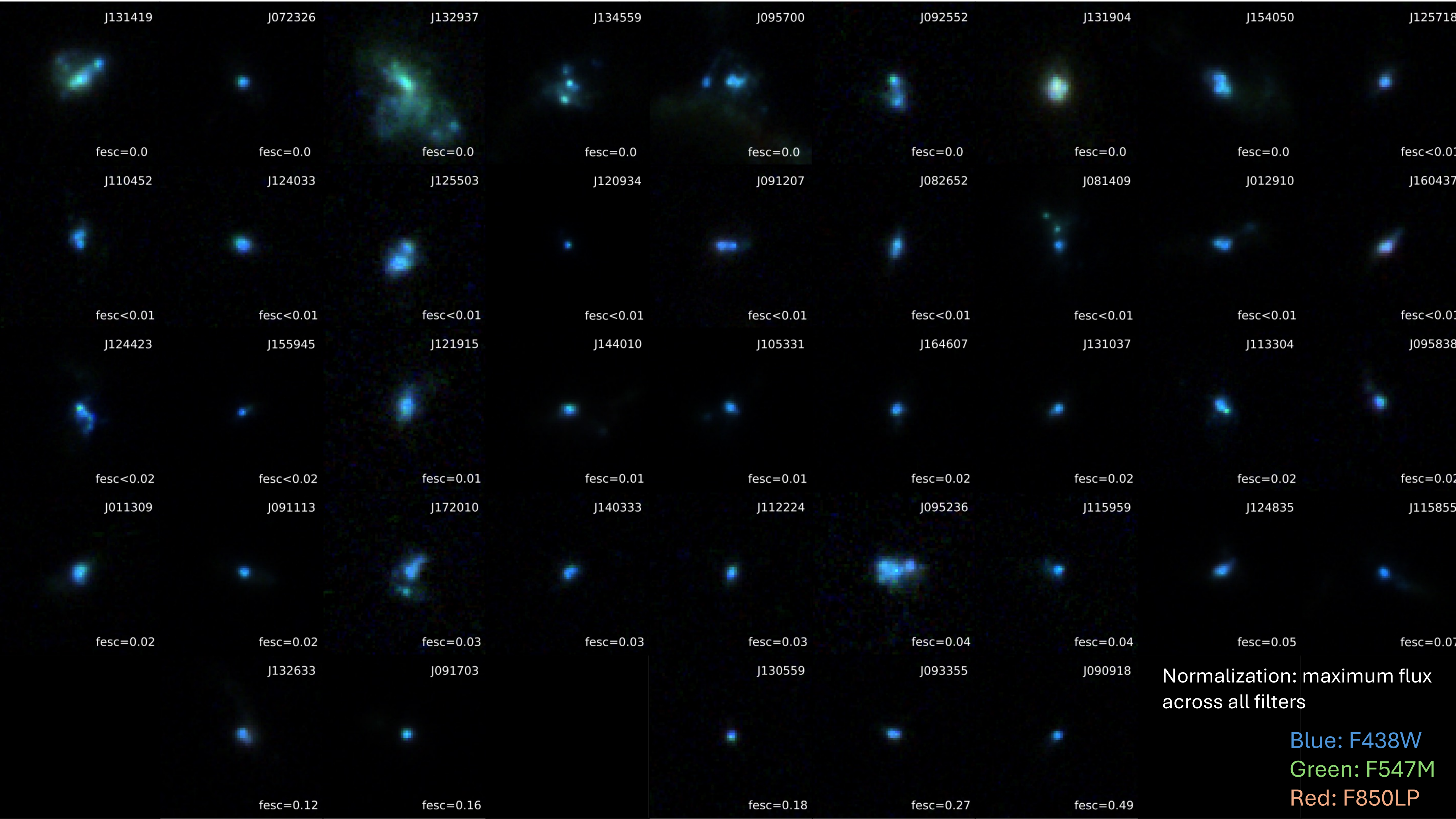
- Galaxy mergers represent a large fraction of both LyC (>45%) and Lyα emitting (84%) samples at low-z.

- Merger-driven enhancement $f_{esc}^{LyC}$ and O32 seem to happens predominantly **close to coalescence.**

- The timescale on which mergers leak LyC might be relatively short (~100Myr or less).

- Multi-wavelength, and especially 21cm observations, may be the only way to accurately classify the most compact leakers
  → we need samples in the south

Ευχαριστώ !



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J072326
fesc=0.0
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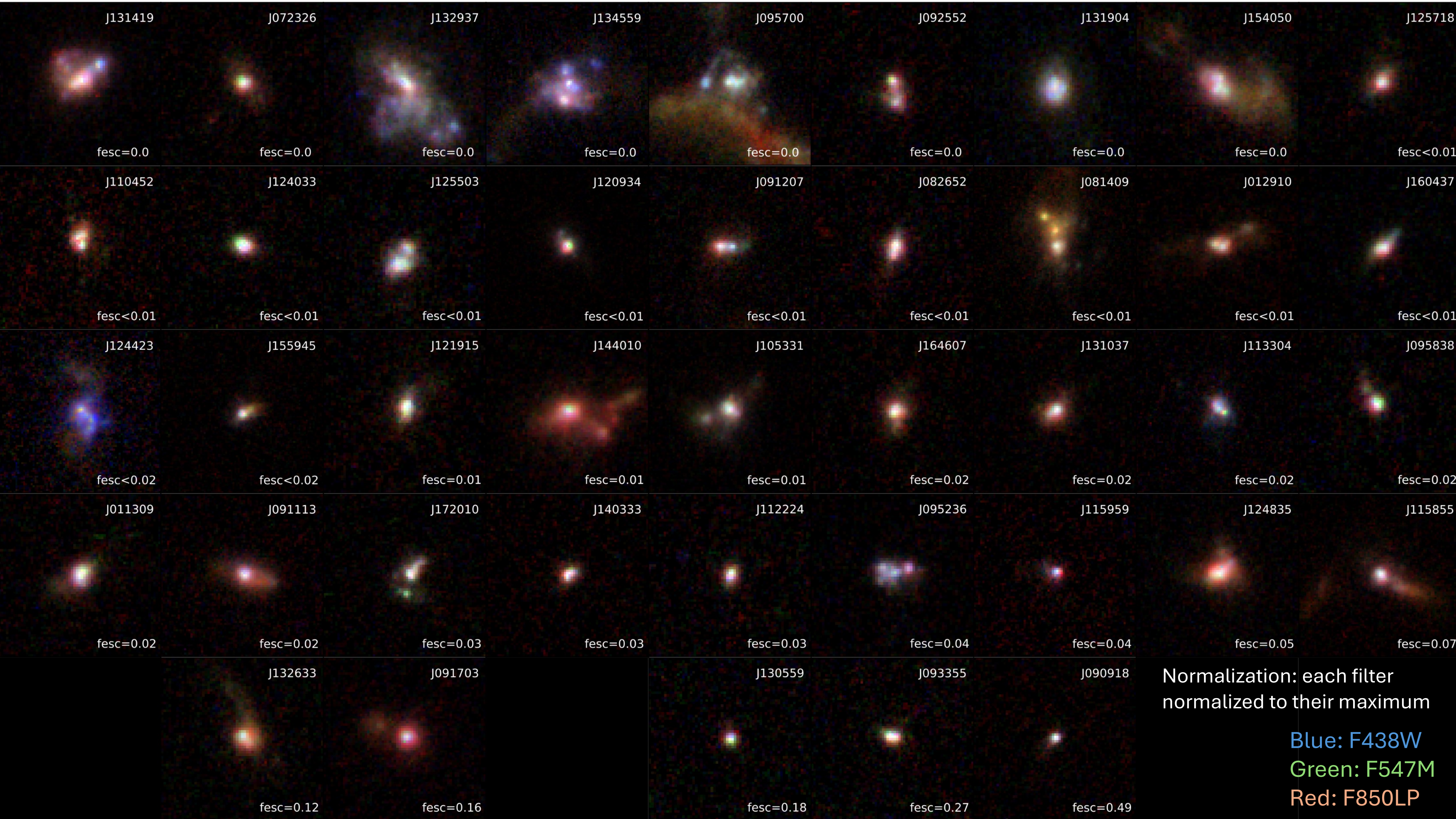
Normalization: maximum flux across all filters
Blue: F438W
Green: F547M
Red: F850LP



J131419
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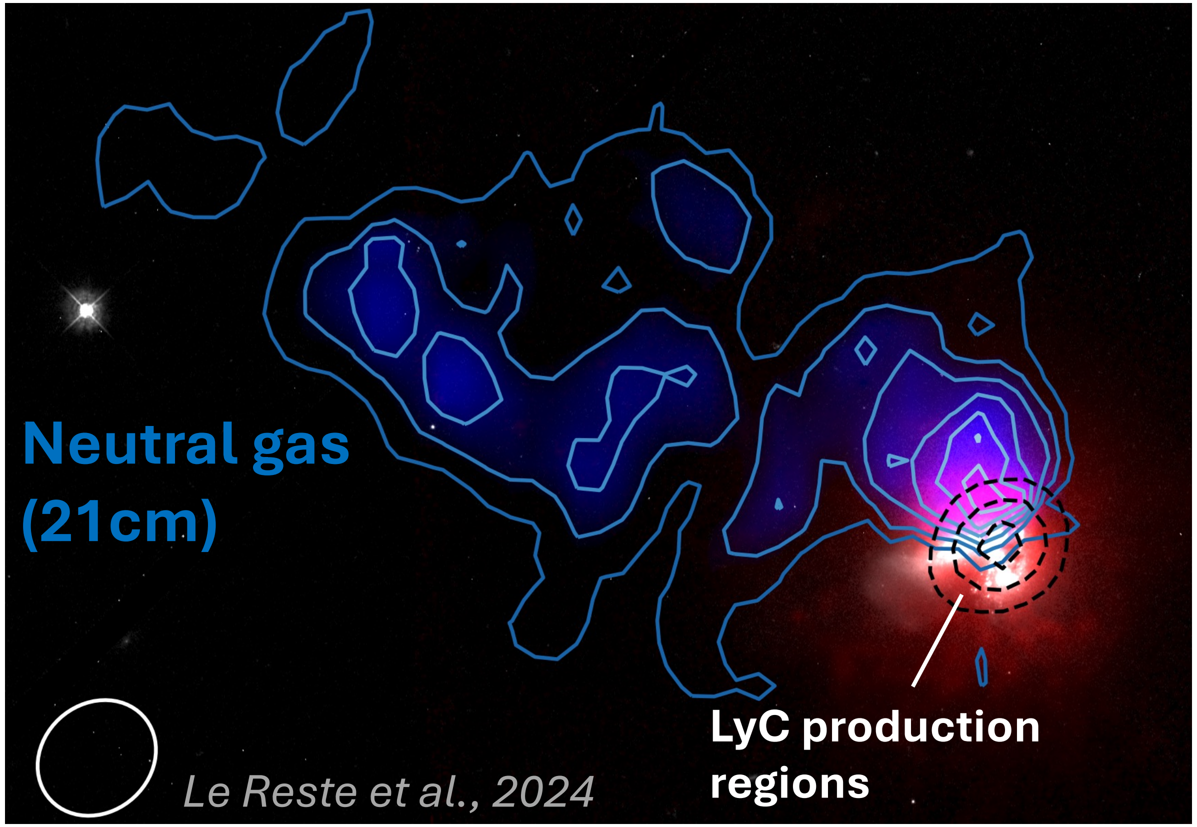
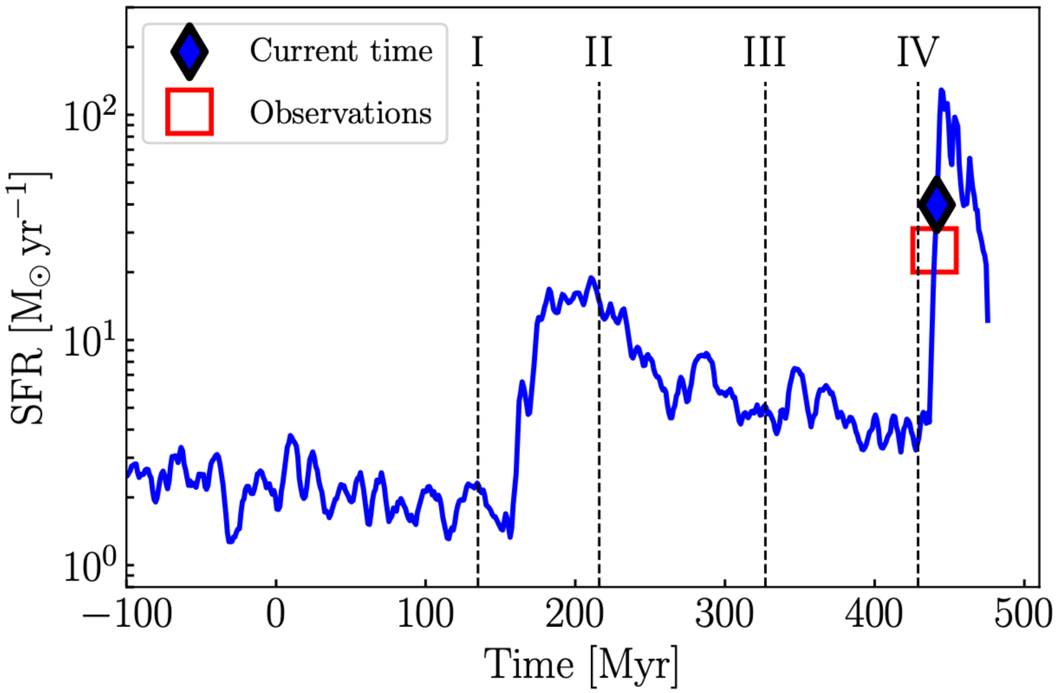
J091703
fesc=0.16
J130559
fesc=0.18
J093355
fesc=0.27
J090918
fesc=0.49
Normalization: each filter normalized to their maximum
Blue: F438W
Green: F547M
Red: F850LP

# Reshaping the labyrinth: MeerKAT observations

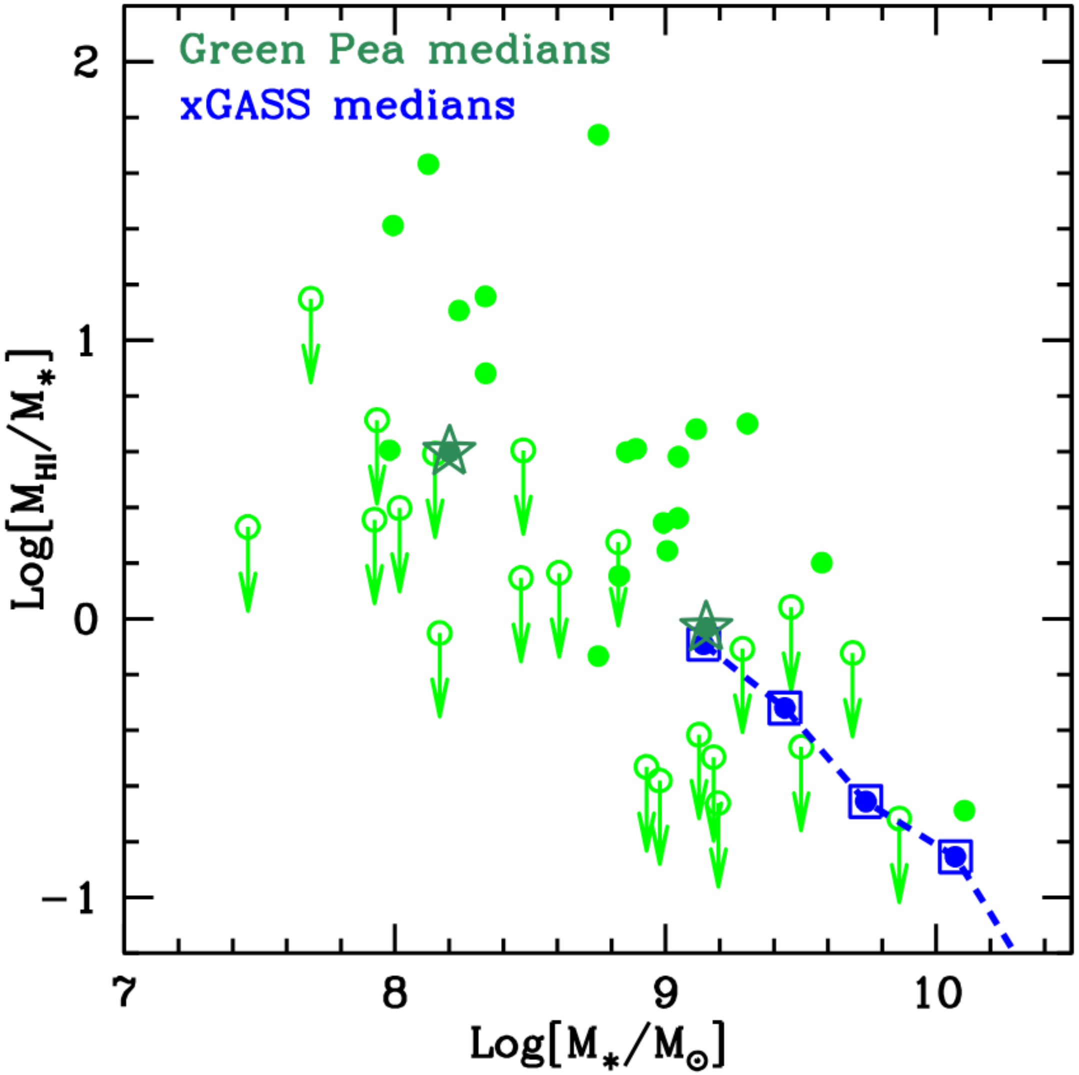
Haro 11: $10^8$ $M_{sol}$ of HI removed from our line-of-sight by tidal interaction




*Ejdetjärn et al. 2025, subm*

# HI in green peas/blueberries




No obvious indication that these objects have lower HI content than z~0 objects.