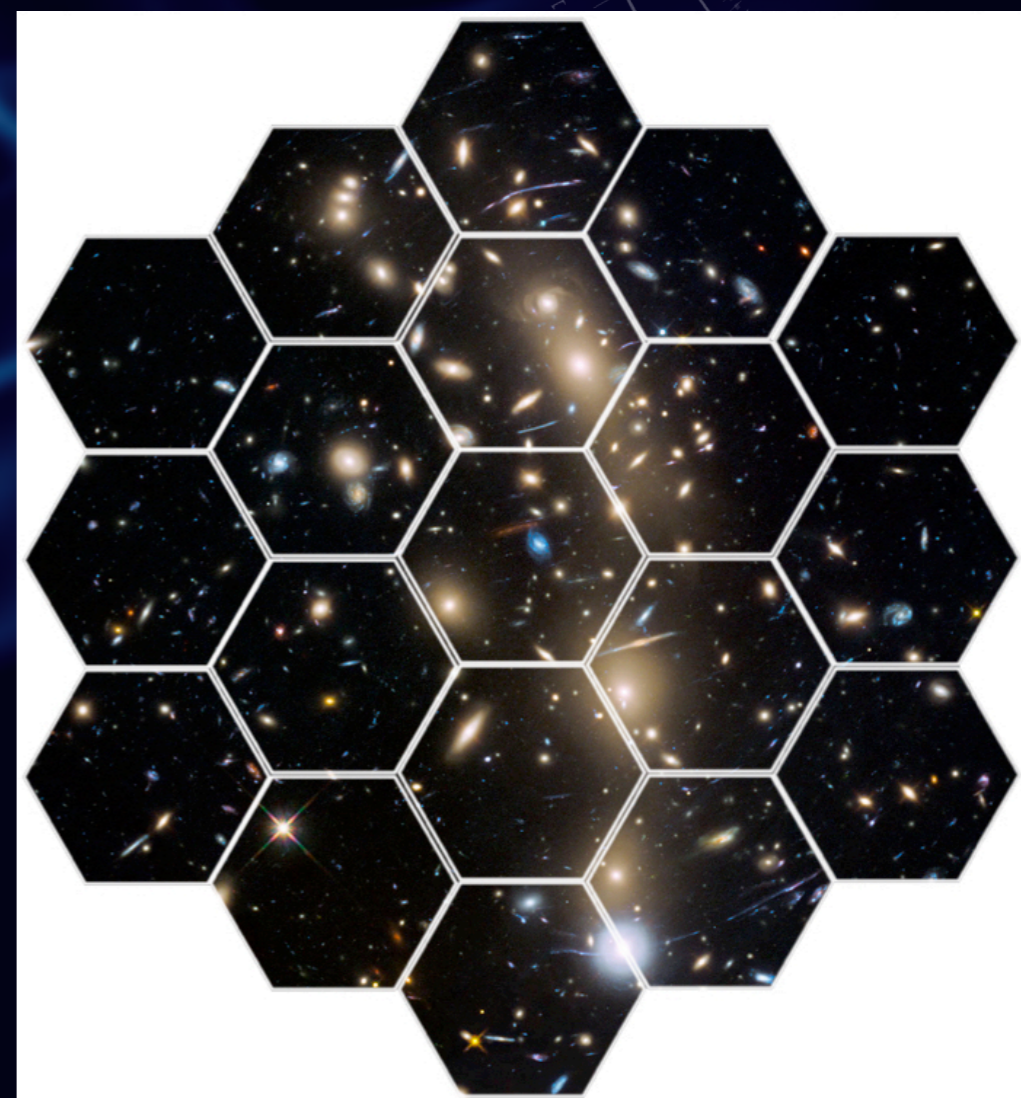


First Galaxies with James Webb Space Telescope

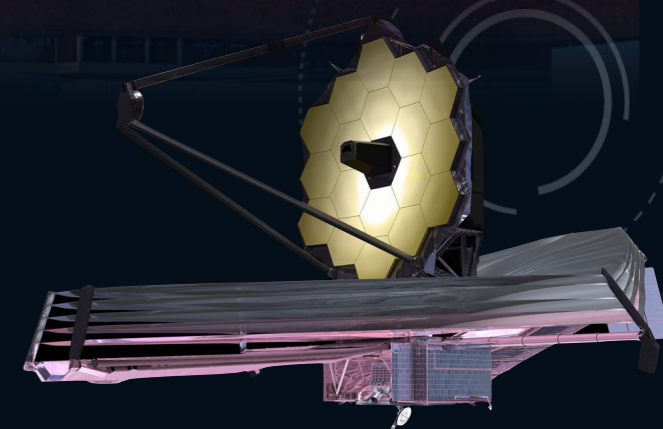
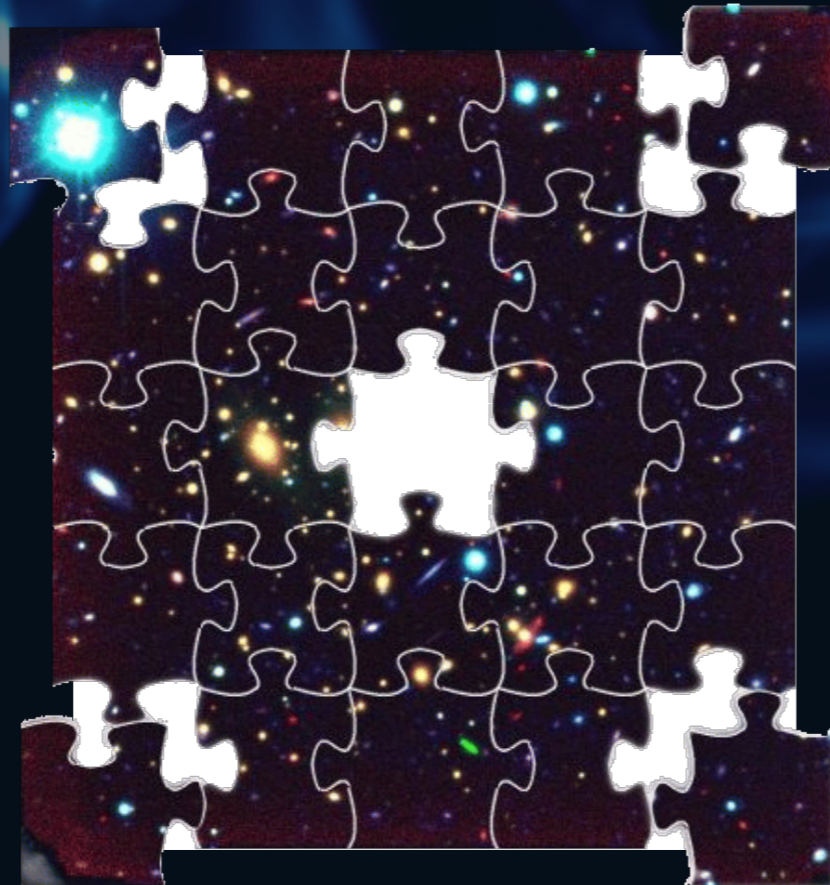
MARUŠA BRADAČ

University of Ljubljana
Faculty of *Mathematics and Physics*



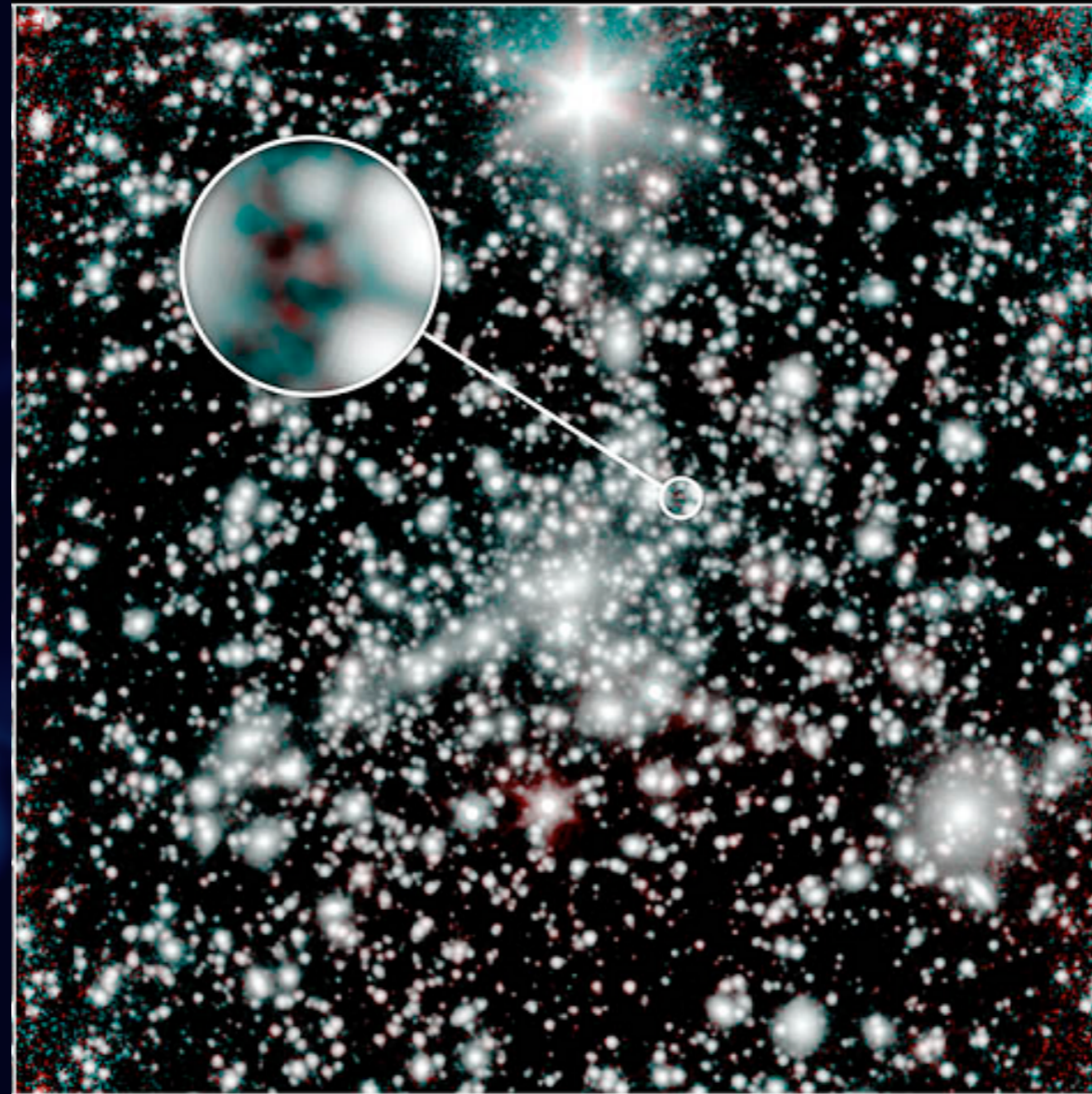
Puzzles of early star formation

- WHEN?
- HOW?



When?

MACS 1149 Cluster



Foreground Clusters Magnify Distant Galaxies

NASA / JPL-Caltech / R. E. Ryan, Jr. (STScI)

Spitzer Space Telescope • IRAC

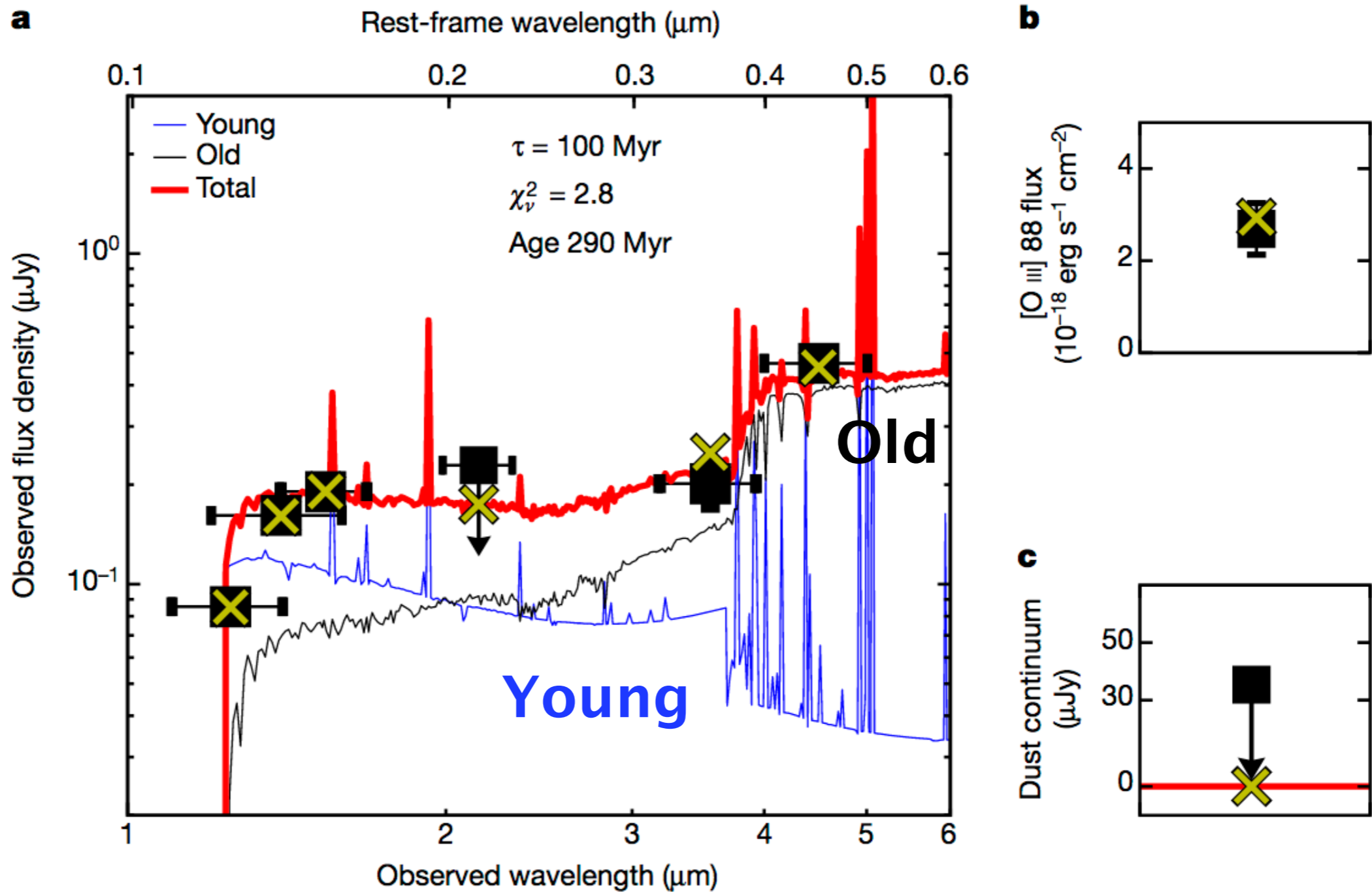
sig14-015

Zheng et al. 2012, Bradač et al. 2014, Ryan et al. 2014, Huang et al. 2016



SURFS UP

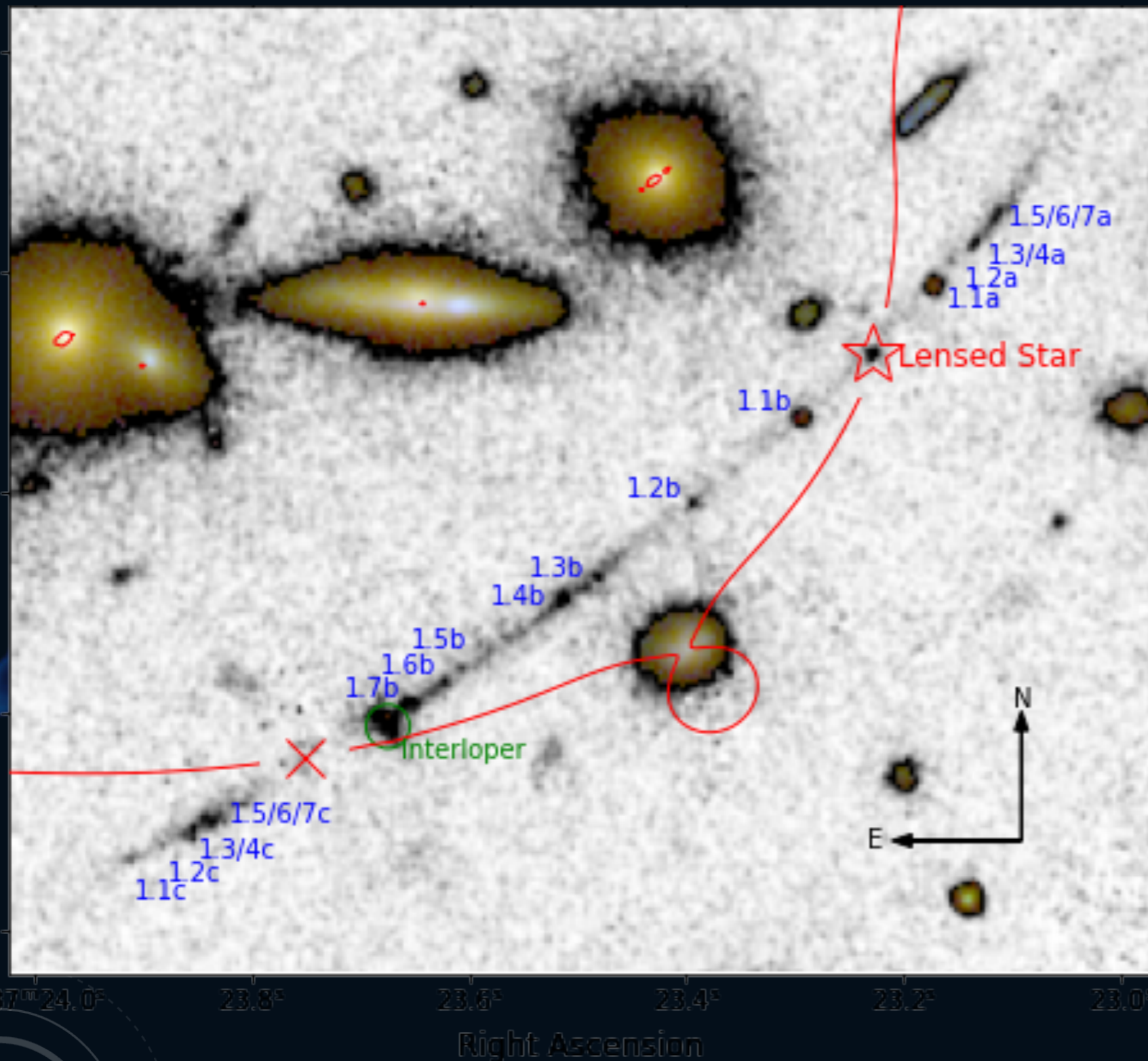
Balmer break or nebular emission lines? Balmer break at $z \sim 9.1$



Balmer break or nebular emission lines? Balmer break at $z \sim 9.1$

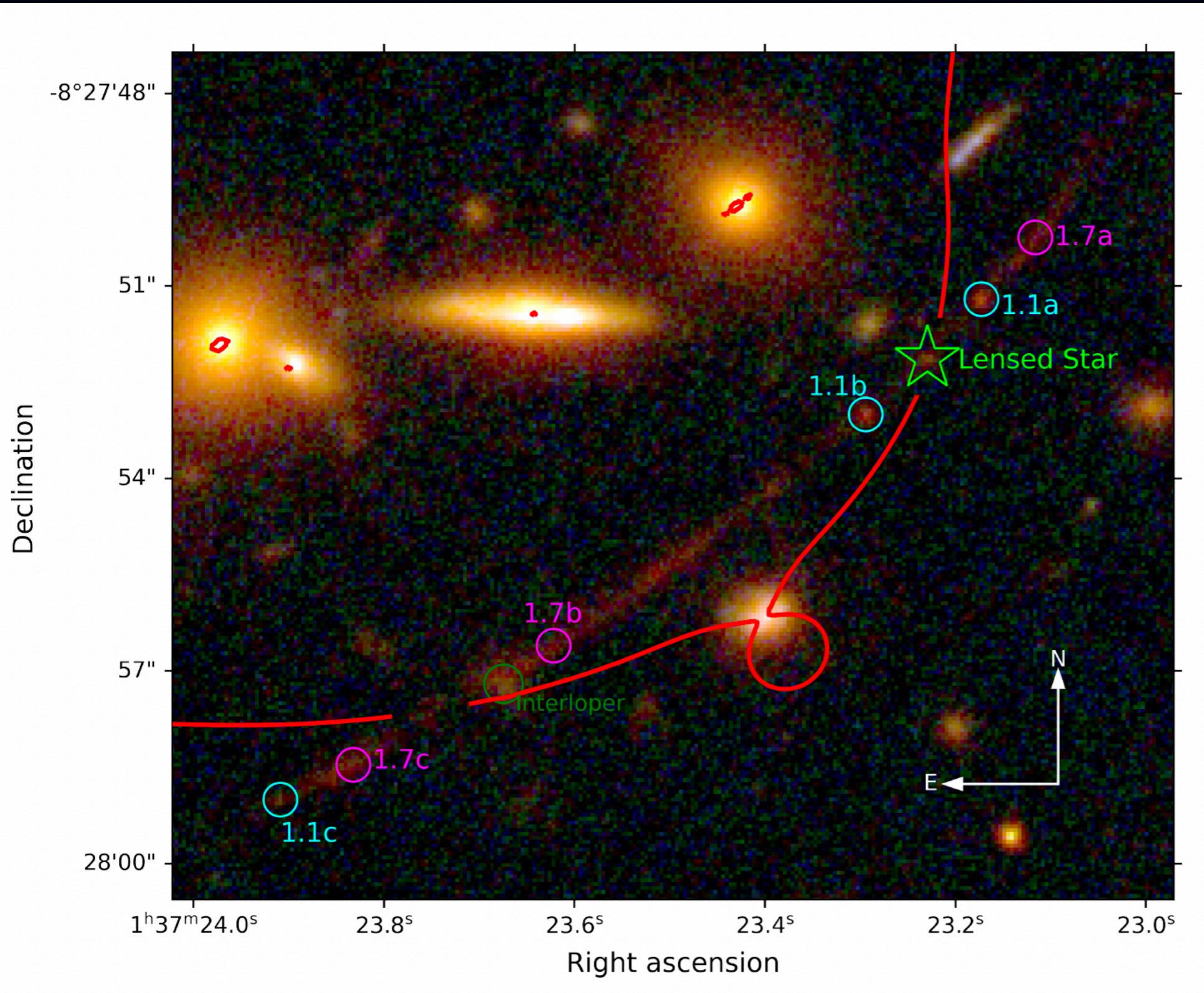
- Age of stellar population ~ 300 Myr indicate star formation @ $z \sim 15$
- Need to form $10^8 M_{\odot}$ in stars

How? Clumps of star formation



- Clumps
10–100pc
- Sunrise arc at
 $z=6.2$

Lensed star!



- Lensed object $< 0.3 \text{ pc}$
- $\mu > 1500$
- $z = 6.2$
- $L = 10^{6-7} L_{\odot}$

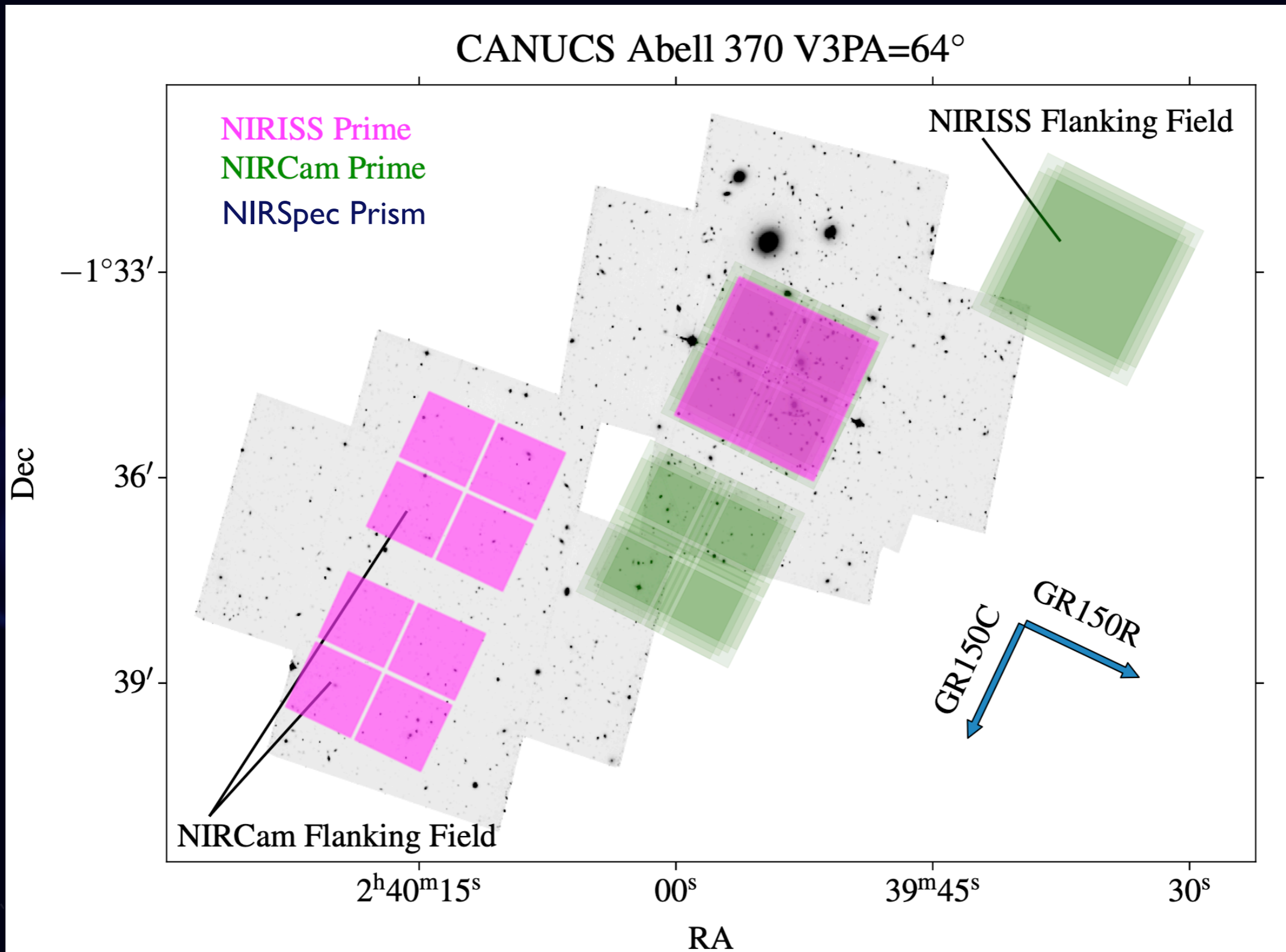
see Erik Zackrisson's talk

CANUCS: The Canadian NIRISS Unbiased Cluster Survey



- Observe five strong-lensing galaxy cluster fields at $0.37 < z < 0.55$.
- Provides large sample of distant, low-mass galaxies:
 - 2000 LBGs at $z > 7$ down to $10^5 M_{\text{sun}}$
 - ~ 200 at $z > 7$ spectroscopical detection down to $10^6 M_{\text{sun}}$

CANUCS: Observing Plan



Lensing is fantastic!!!

MARUŠA BRADAČ

Strong lens

Frontier Fields
"footprints":
Galaxy Cluster
Abell 2744

MACSJ0416.1-2403

Galaxy cluster
observation

Parallel
observation

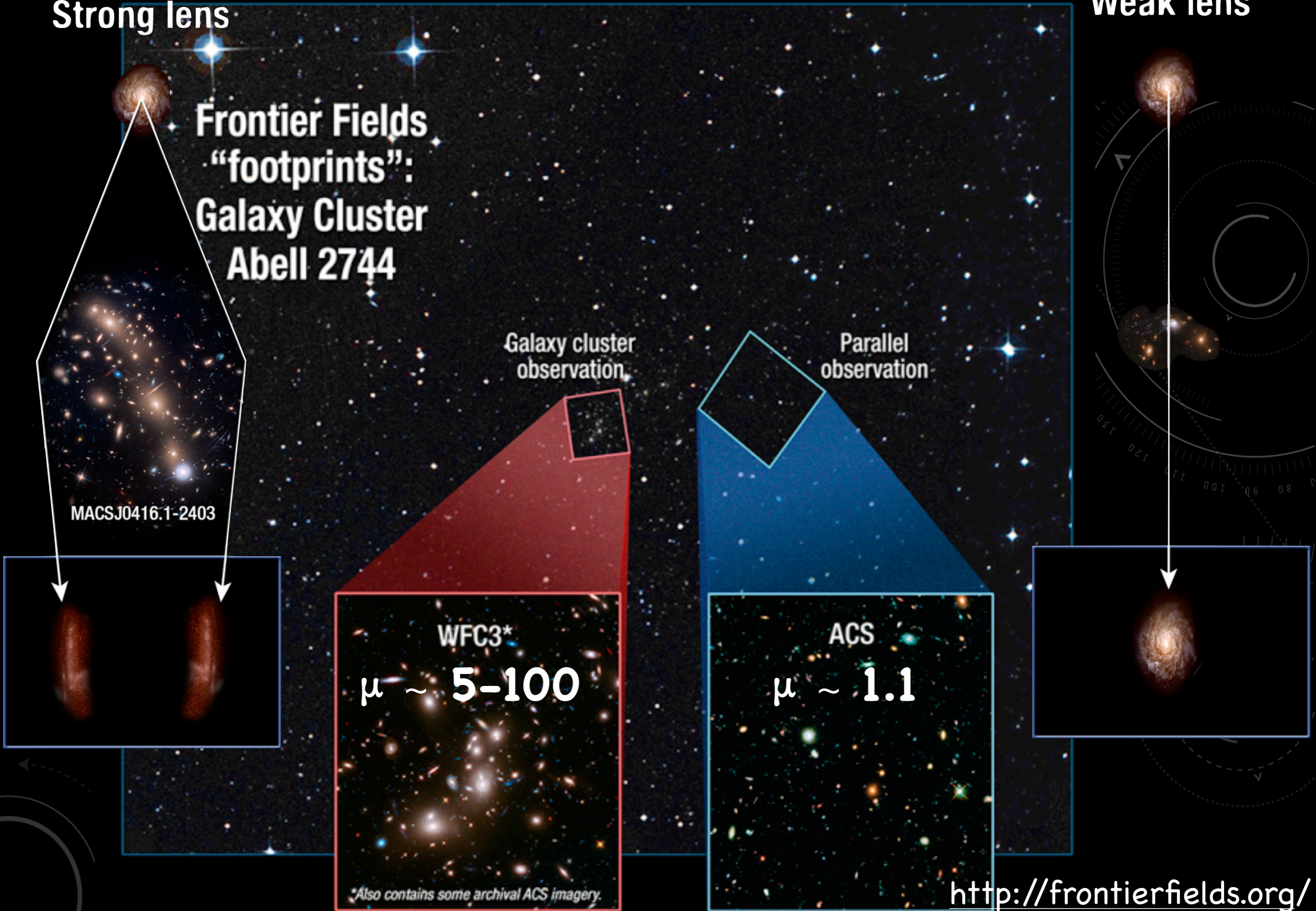
Weak lens

WFC3*
 $\mu \sim 5-100$

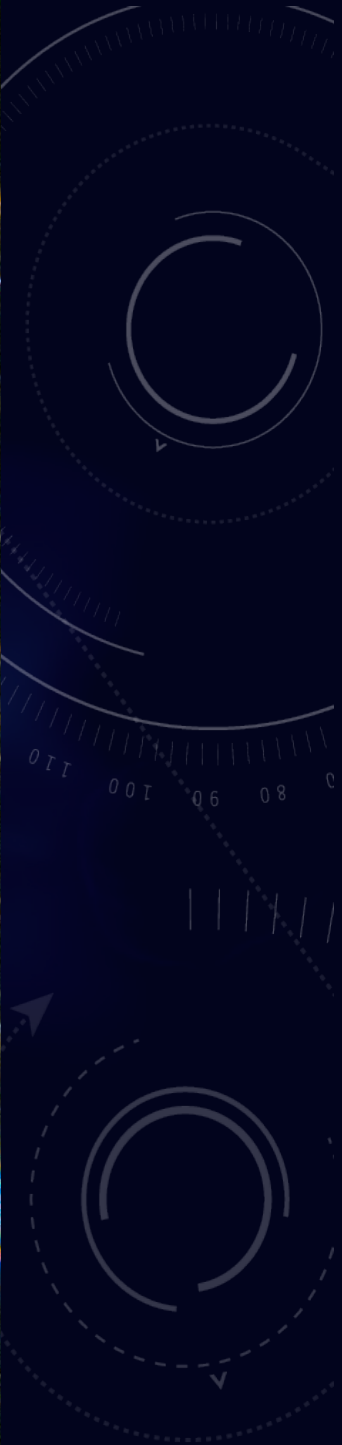
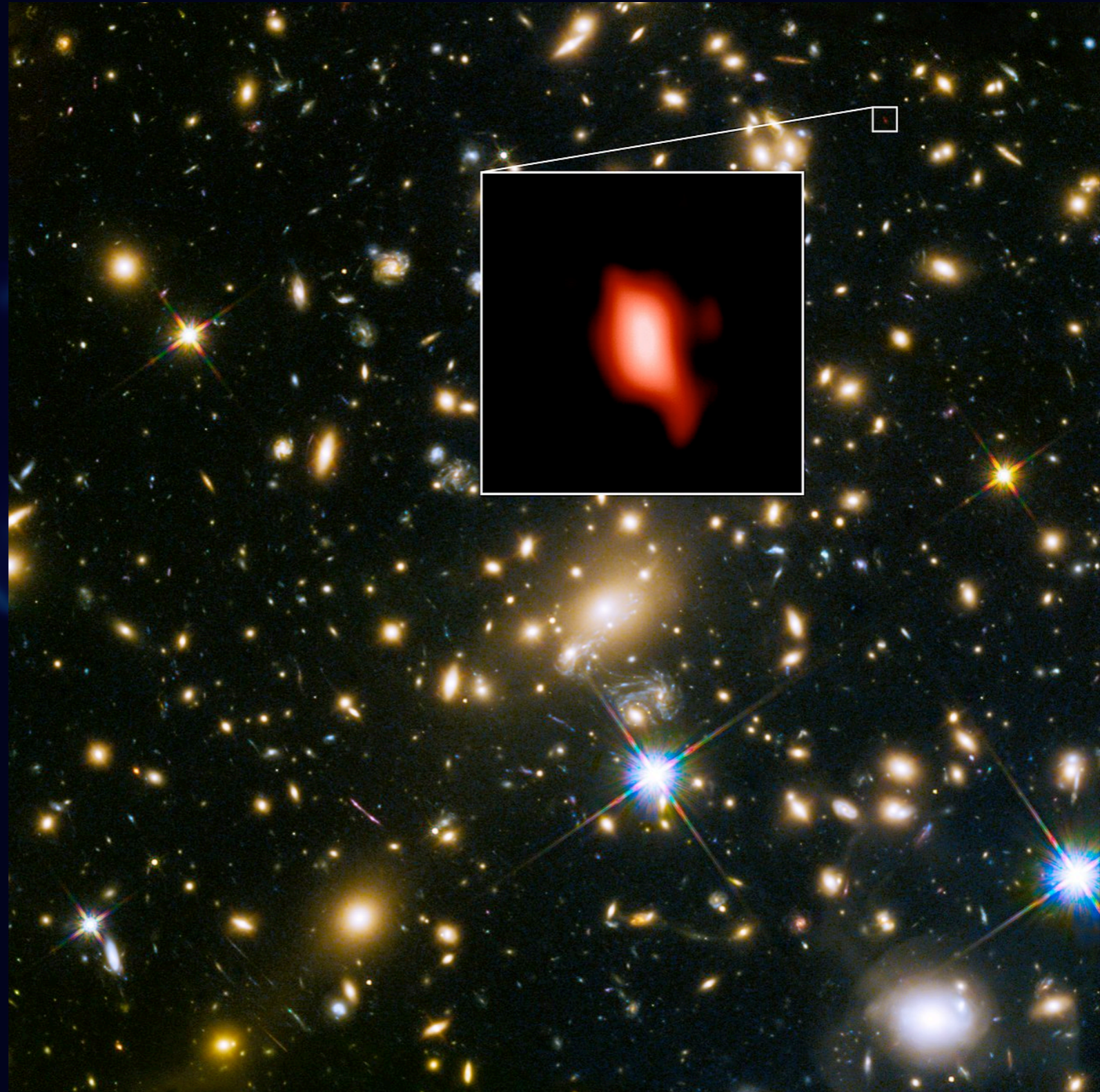
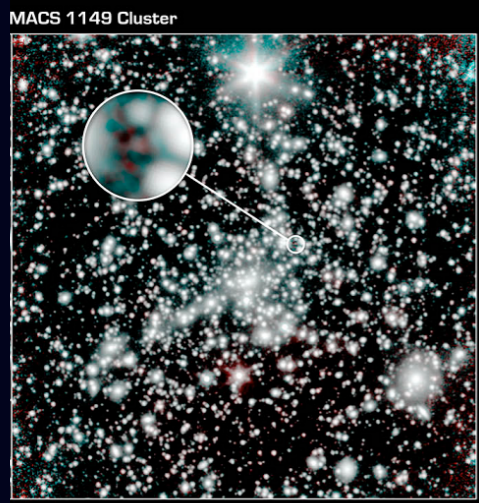
ACS
 $\mu \sim 1.1$

*Also contains some archival ACS imagery.

<http://frontierfields.org/>

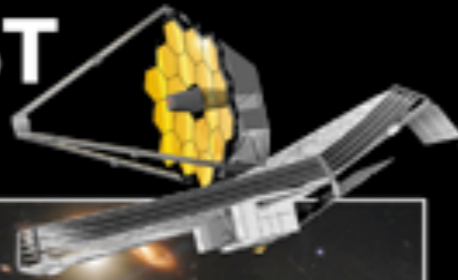


When? MACS1149-JD



When? Sparkles!

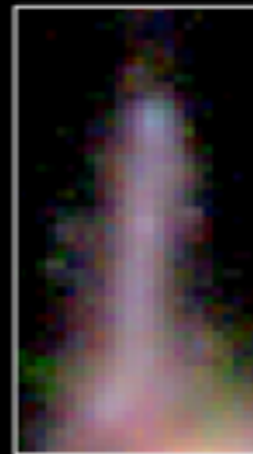
WEBB'S FIRST DEEP FIELD



THE SPARKLER GALAXY



WEBB



HUBBLE

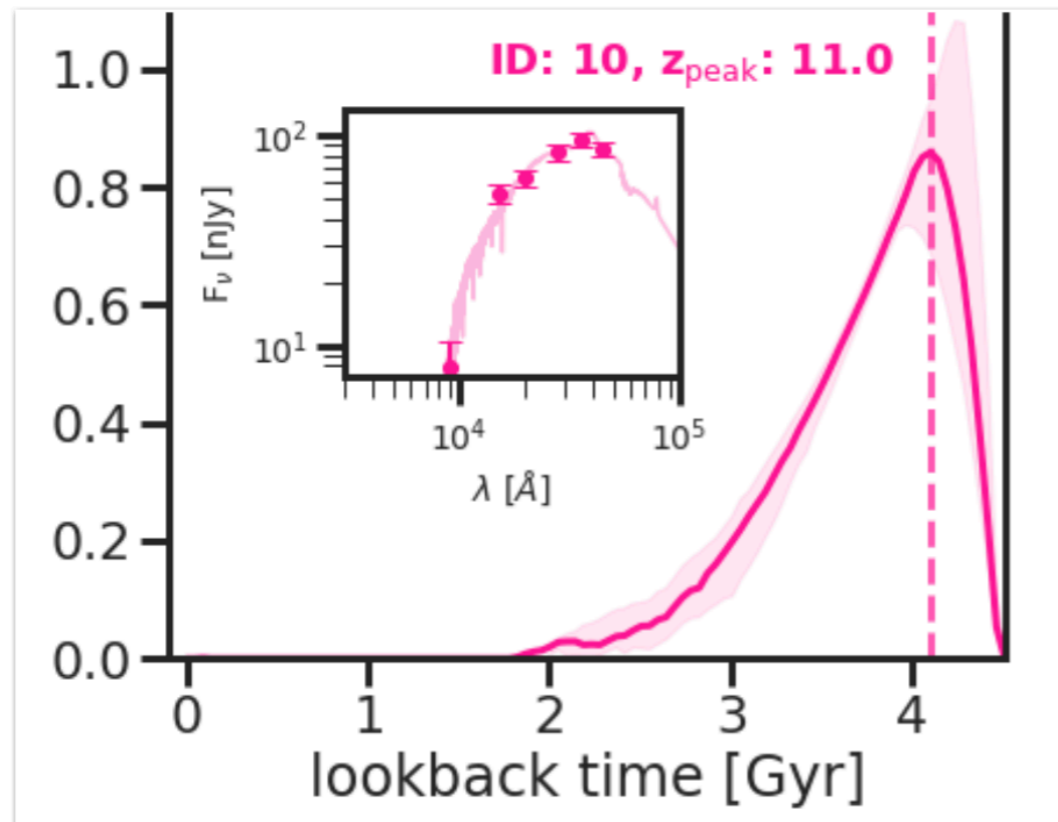


GLOBULAR CLUSTER?

- A magnified galaxy at $z = 1.38$ surrounded by bright star clusters

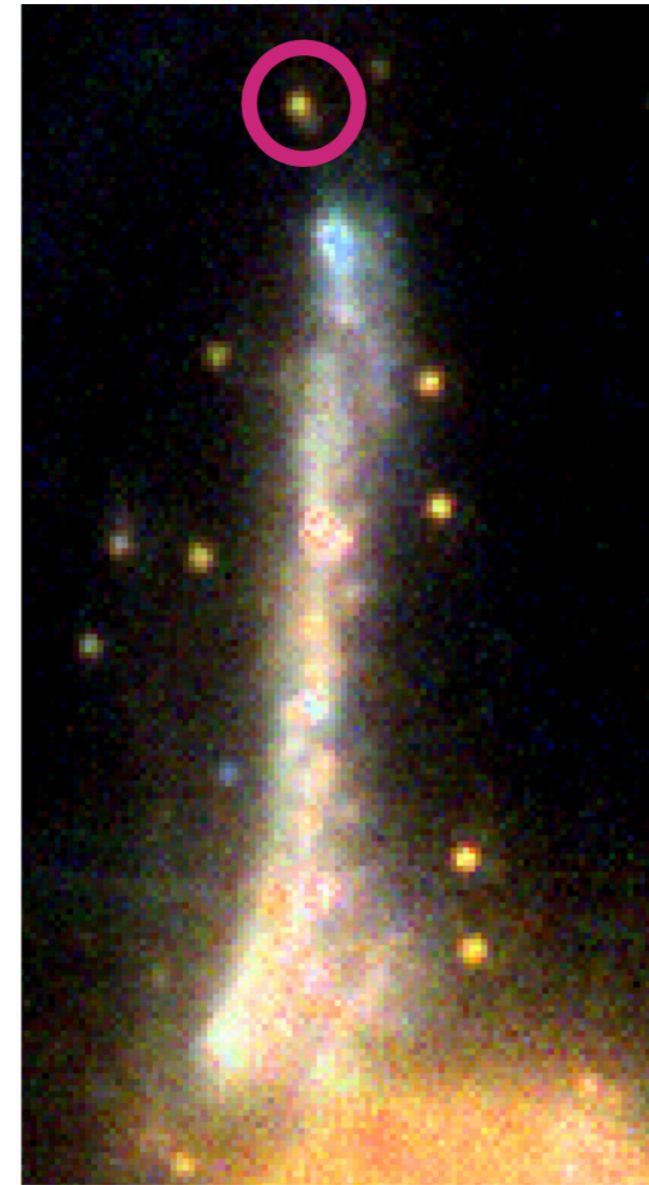
When? Sparkles at $z \sim 1$

Young or Old?



Mowla and Iyer et al. 2022

Lamiya Mowla

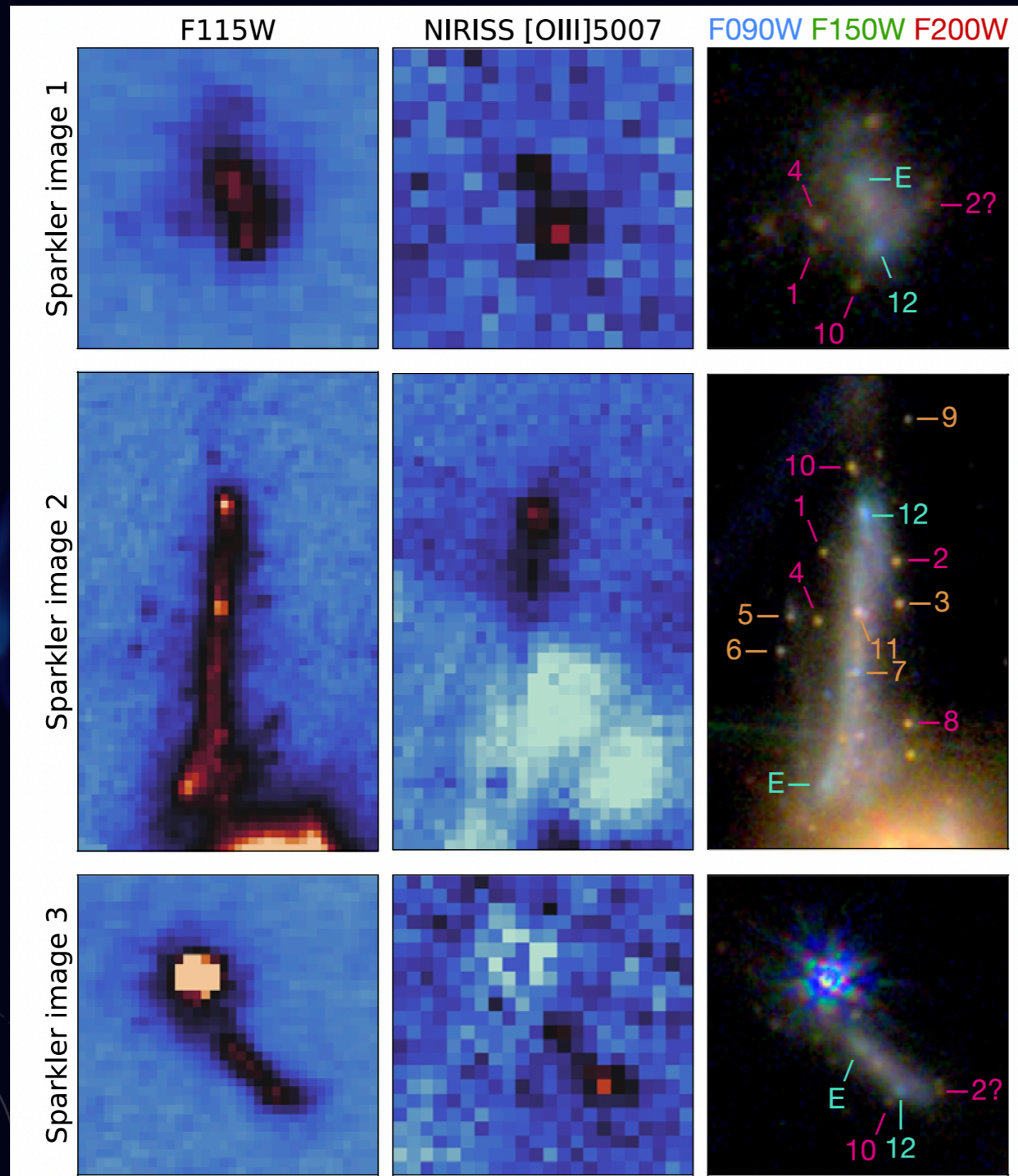


Age of the Universe ~ 4.7 Gyr
Age of the star clusters ~ 4 Gyr

Mowla (MB) et al. 2023



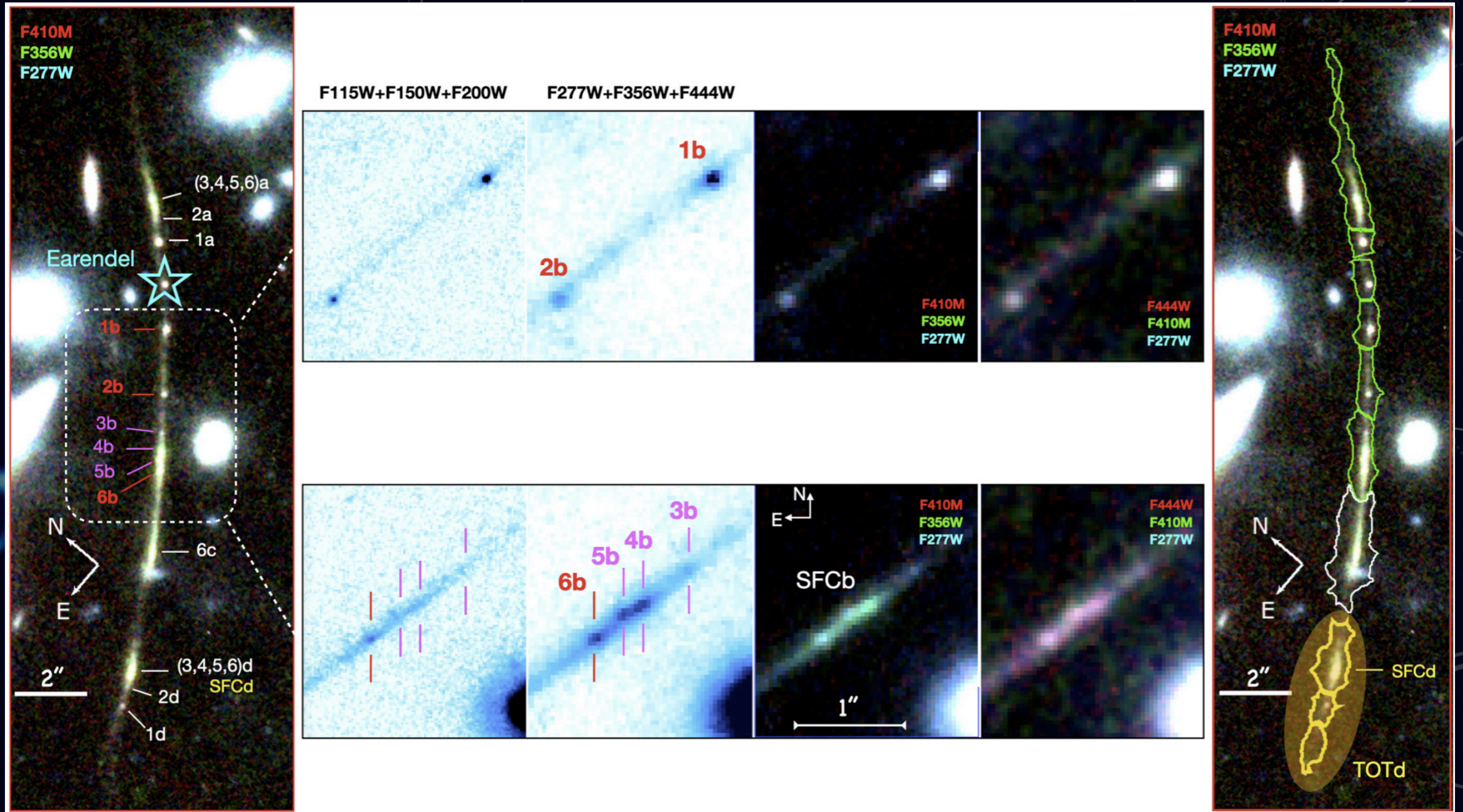
When? Sparkles at $z \sim 1$



- A magnified galaxy at $z = 1.38$ surrounded by bright star clusters with $z_{\text{form}} > 9$.
- Extremely dense star clusters with half-light sizes < 15 pc and stellar masses $\sim 10^7 M_{\text{sun}}$.

Mowla (MB) et al. 2023

When? Young sparkles at $z \sim 6$



See also talk by E. Vanzella!!

Vanzella et al. 2023

Future is bright, magnified by lensing, assisted by JWST

- First detailed studies of galaxies that are responsible for reionization are possible now. And they are showing an interesting picture:
 - star formation have likely started at $z > 15$
 - star formation is resolved in smaller clumps with intense UV radiation (high ξ_{ion} , extreme emission lines).
- CANUCS has just started, much more to come.

...to see the first light in the Universe...

