Identifying Strongly Lensed High-Redshift Galaxies for JWST

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on behalf of Masami Ouchi, Masamune Oguri and the RELICS team

RELICS Reviews

Galaxy Evolution in Early Universe?

Q. When did the first galaxies form?

Q. How did they evolve?

Q. What were their properties?

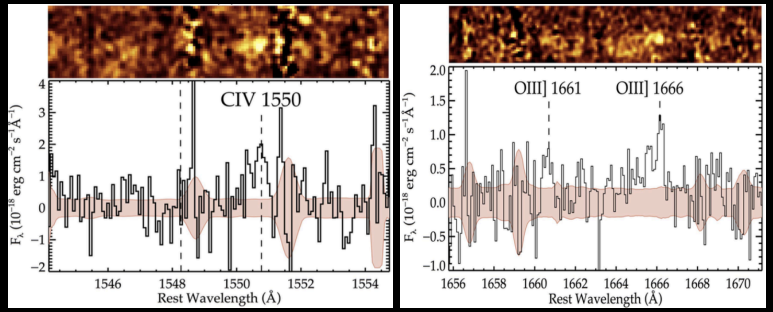
Q. Did they reionize the universe?

Necessary

- Galaxy Counting (Luminosity functions)
- Detailing individual galaxies in large samples

Brightly-Lensed Galaxies

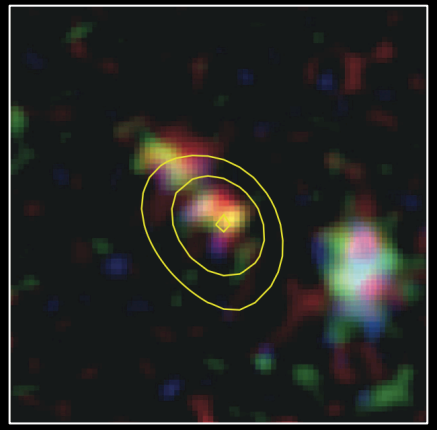
CIV



RXCJ2248.7-4431-ID3
(z=6.1, μ=5.5)

Mainali+17

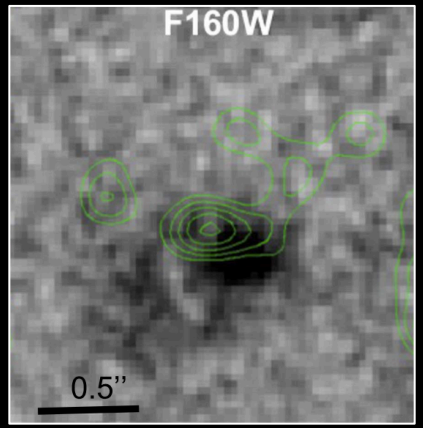
OIII]



A1689-zD1
(z=7.5, μ=9.3)

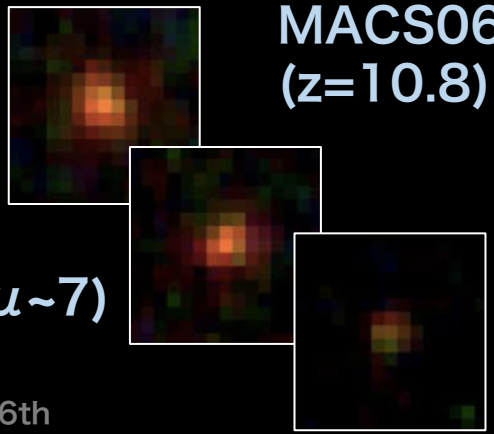
Watson+15

HST+ALMA



A2744-YD4
(z=8.4, μ=1.8)

Laporte+17



MACS0647-JD
(z=10.8)

Coe+13

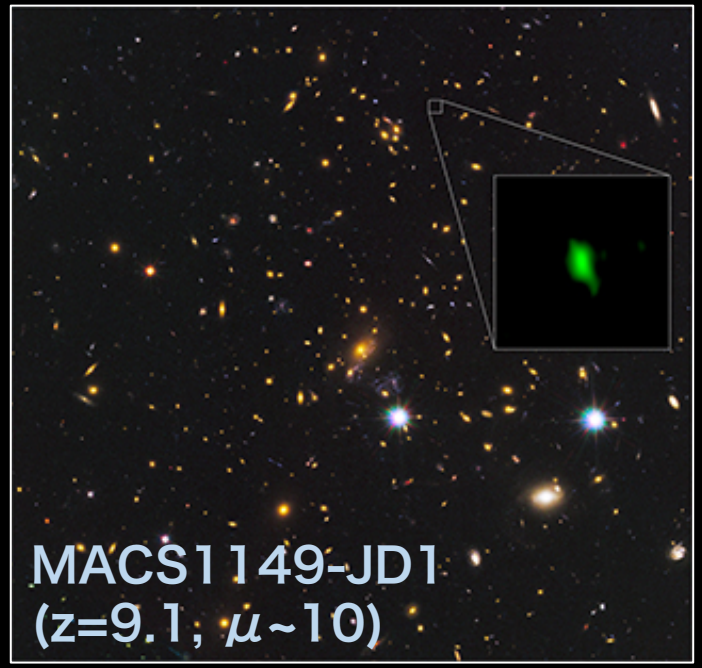
(μ~8)

(μ~7)

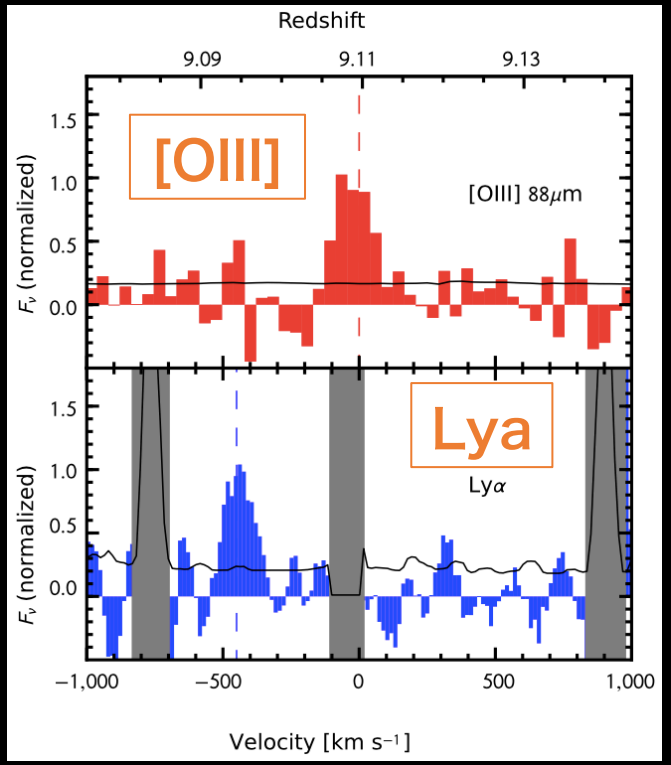
(μ~2)

LBG

Brightly-Lensed Galaxies

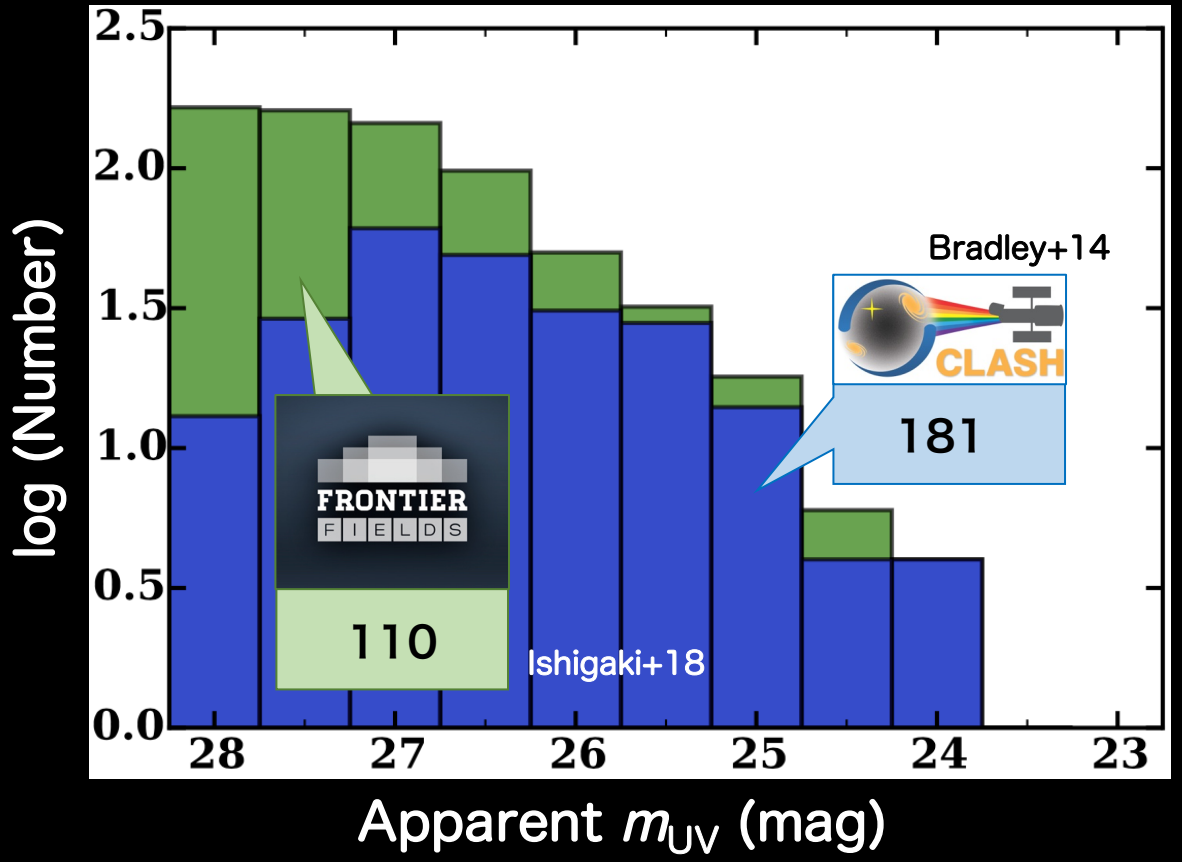


© ALMA (ESO/NAOJ/NRAO)

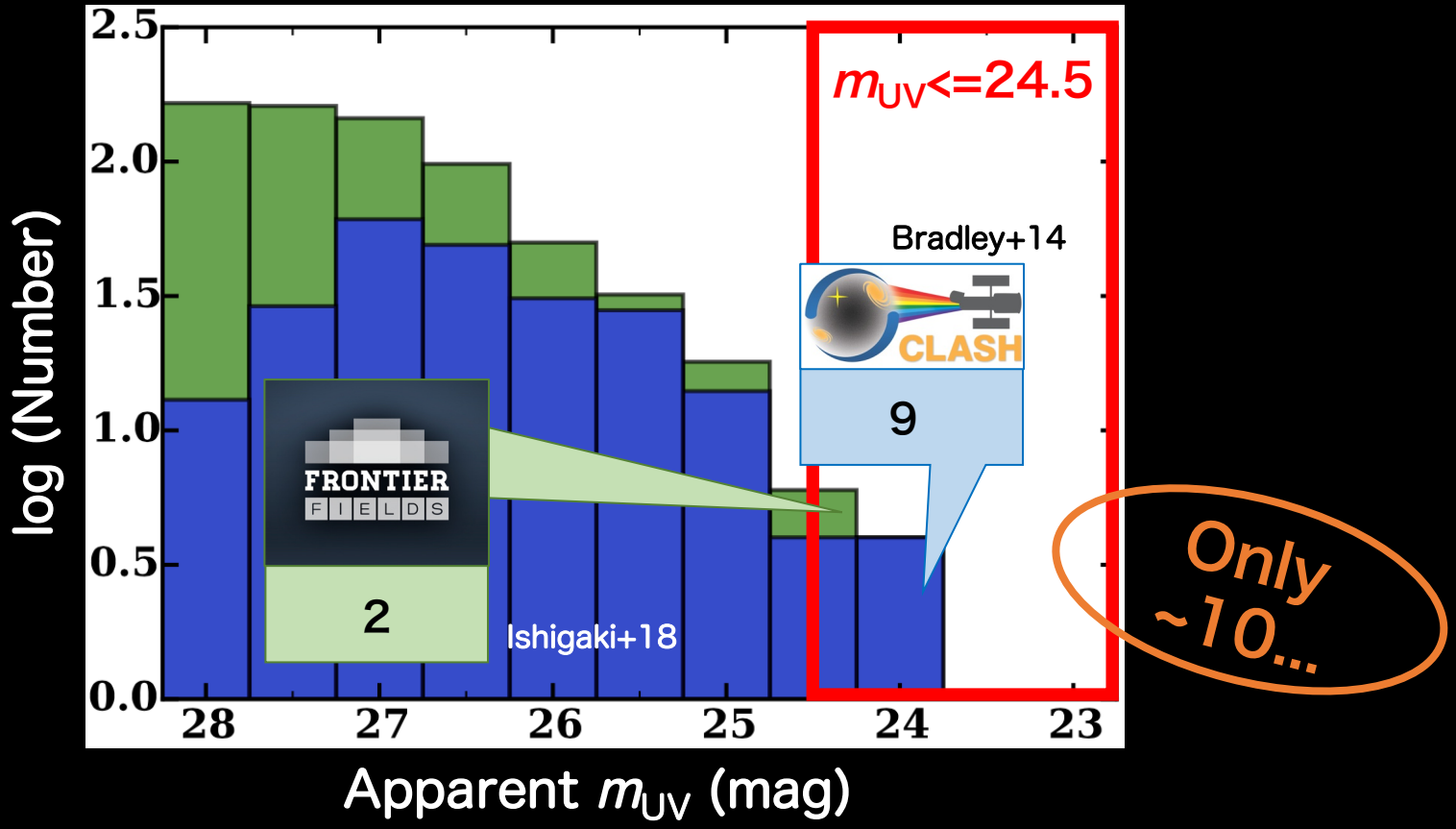


Hashimoto+18

Lensed Galaxy Candidates



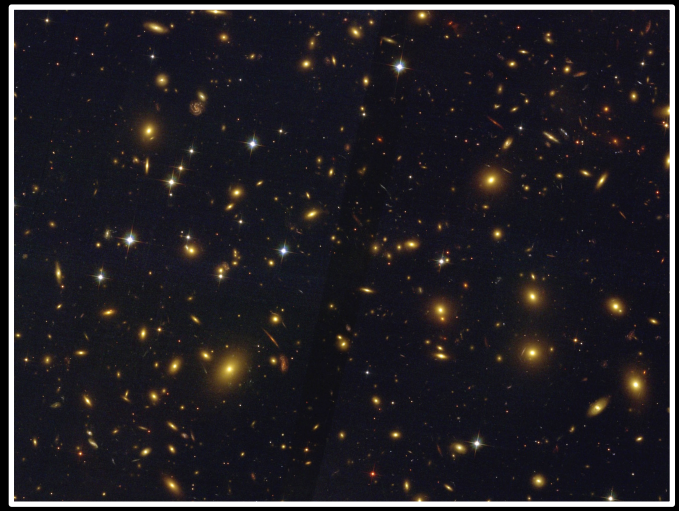
“Brightly”-Lensed Galaxy Candidates



RELICS Overviews

- REionization LensIng Cluster Survey
- HST Treasury Program
- PI: Dan Coe (STScI)
- Oct. 2015 – April 2017
- ~7 bands (ACS/WFC + WFC3/IR)
- 190 orbits (5σ depth = 26-27 mag)

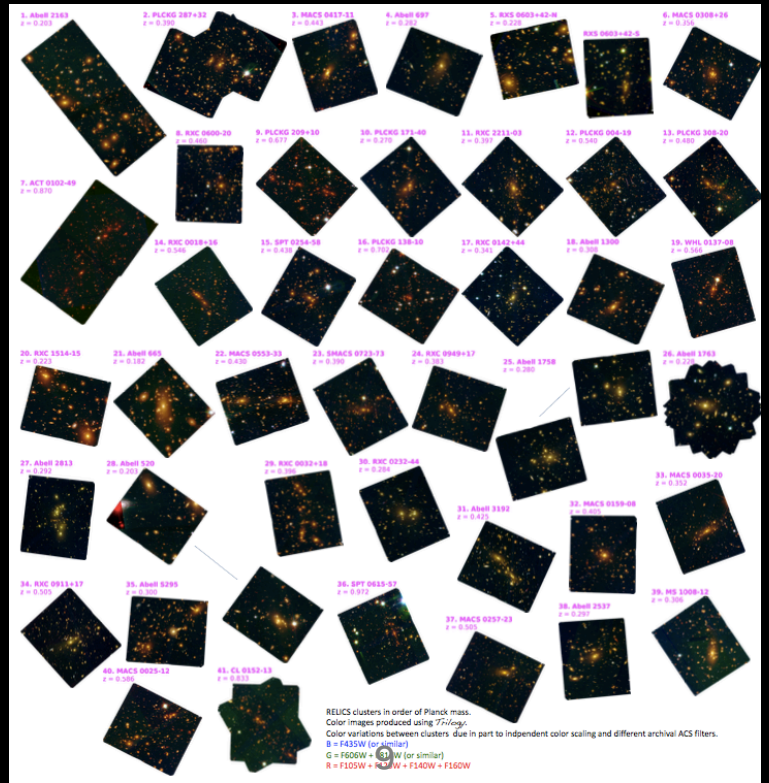
Abell 2163
(ACS falsecolor)



RELICS
Reionization Lensing Cluster Survey

RELICS Targets

- 41 galaxy-cluster regions
  - ~200 arcmin^2

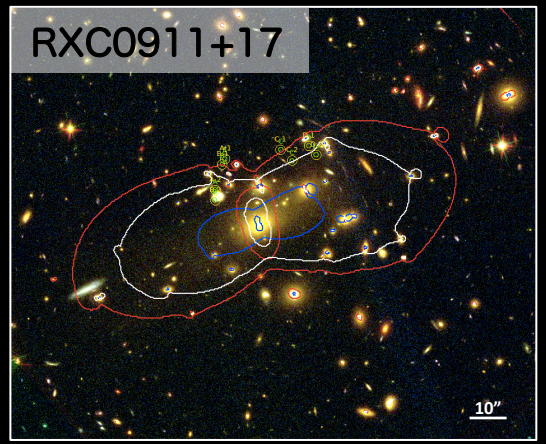


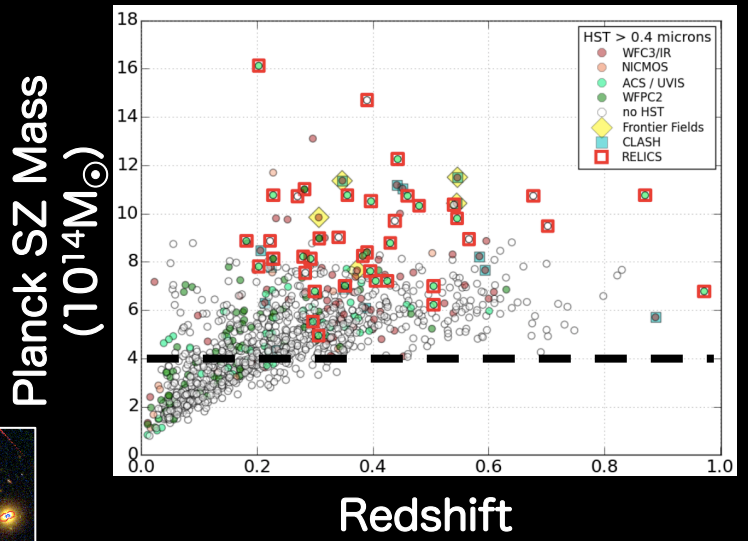
Credit: Coe

RELICS
Reionization Lensing Cluster Survey

RELICS Targets

- 41 galaxy-cluster regions
  - ~200 arcmin^2
  - most massive (> 4x10^{14} M$_\odot$), causing *'powerful'* strong-lensing
  - mass-modeling is ongoing (currently 20/41 released)





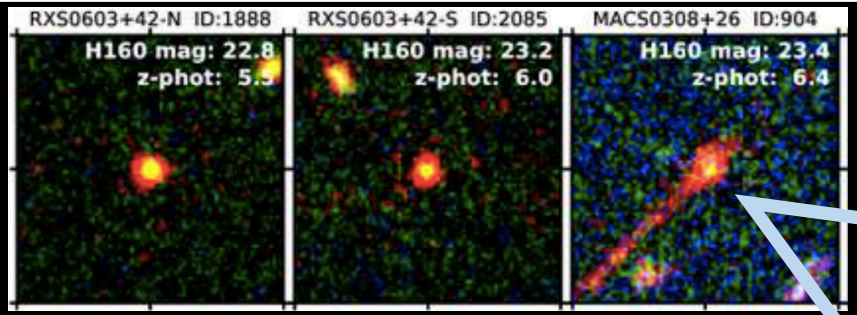
Credit: Coe

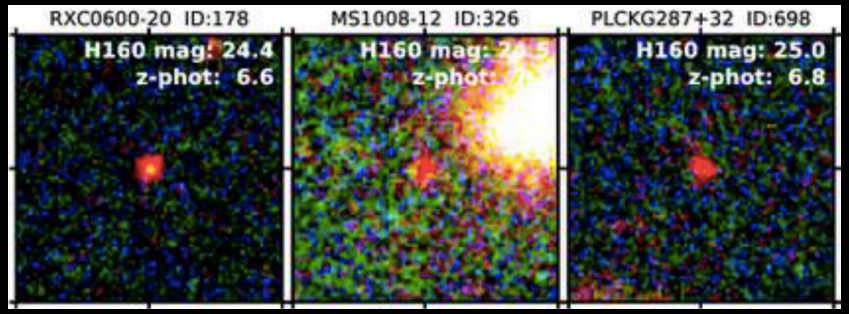
Kikuchihara+

RELICS
Reionization Lensing Cluster Survey

321 galaxy candidates at z=6-8

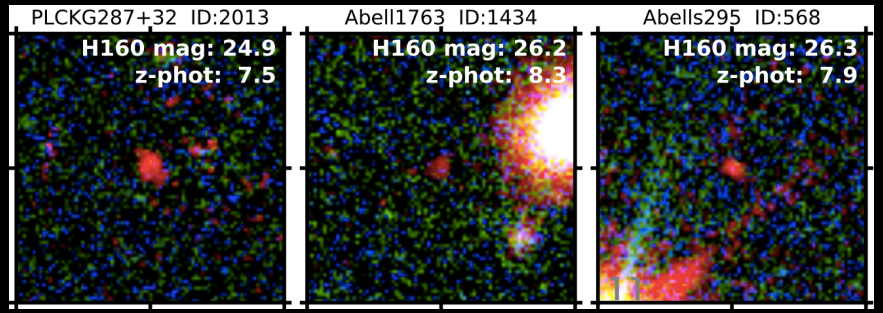
Brightest candidates at z=6





at z=7

at z=8



intrinsic (delensed): 25.4 mag

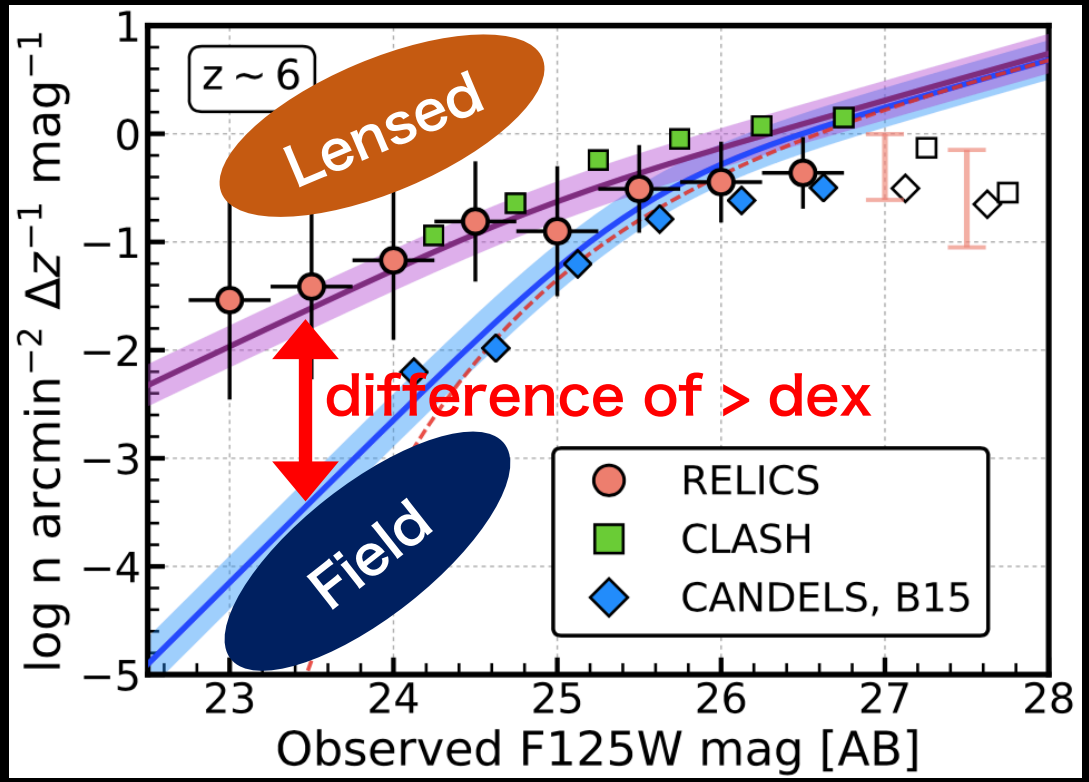
~ x23 magnified

apparent (lensed): 23.4 mag

Salmon+17

RELICS Reionization Lensing Cluster Survey

Lensing Advantage

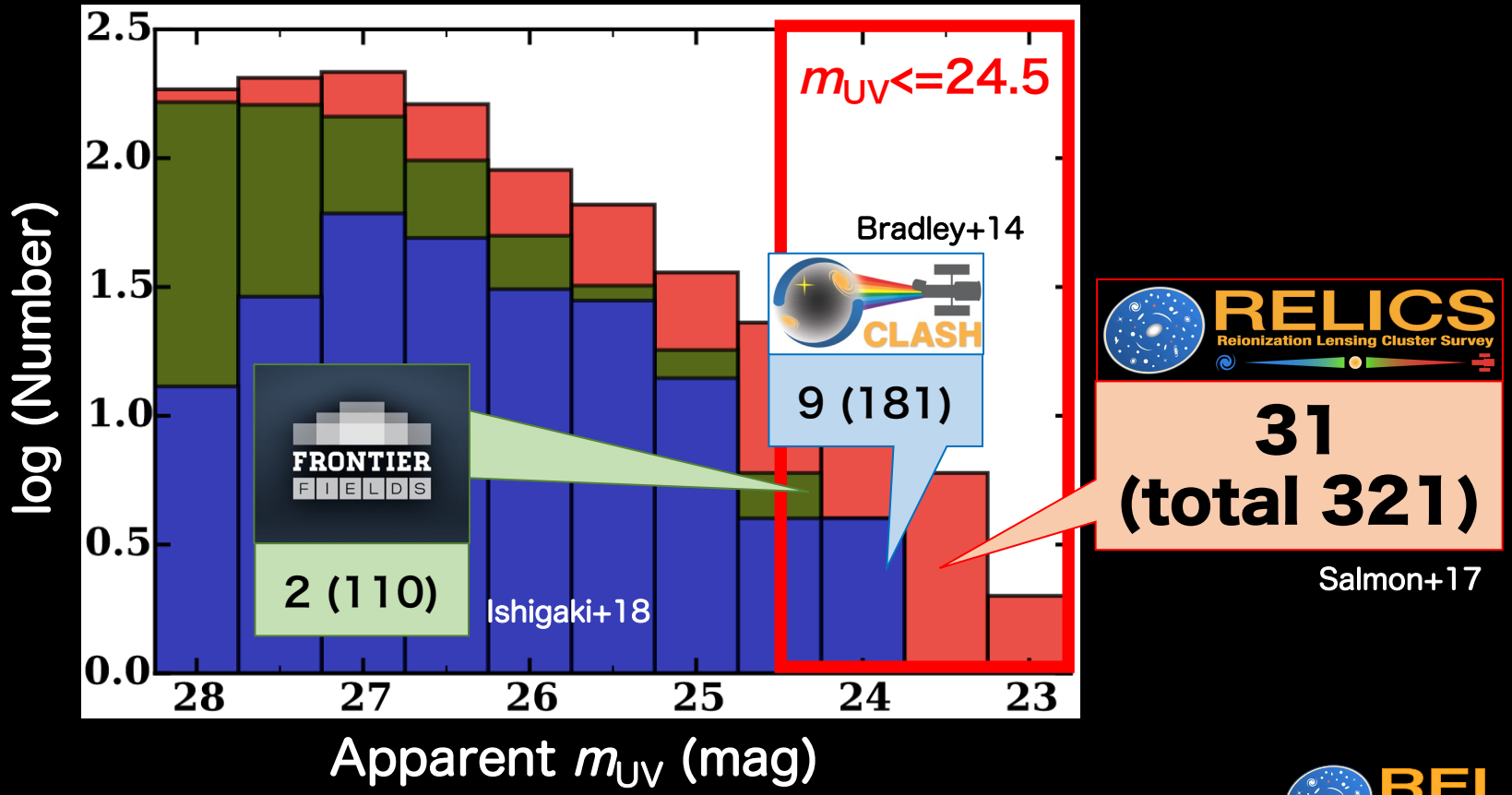


Bright high-z galaxy candidates detected efficiently owing to lensing

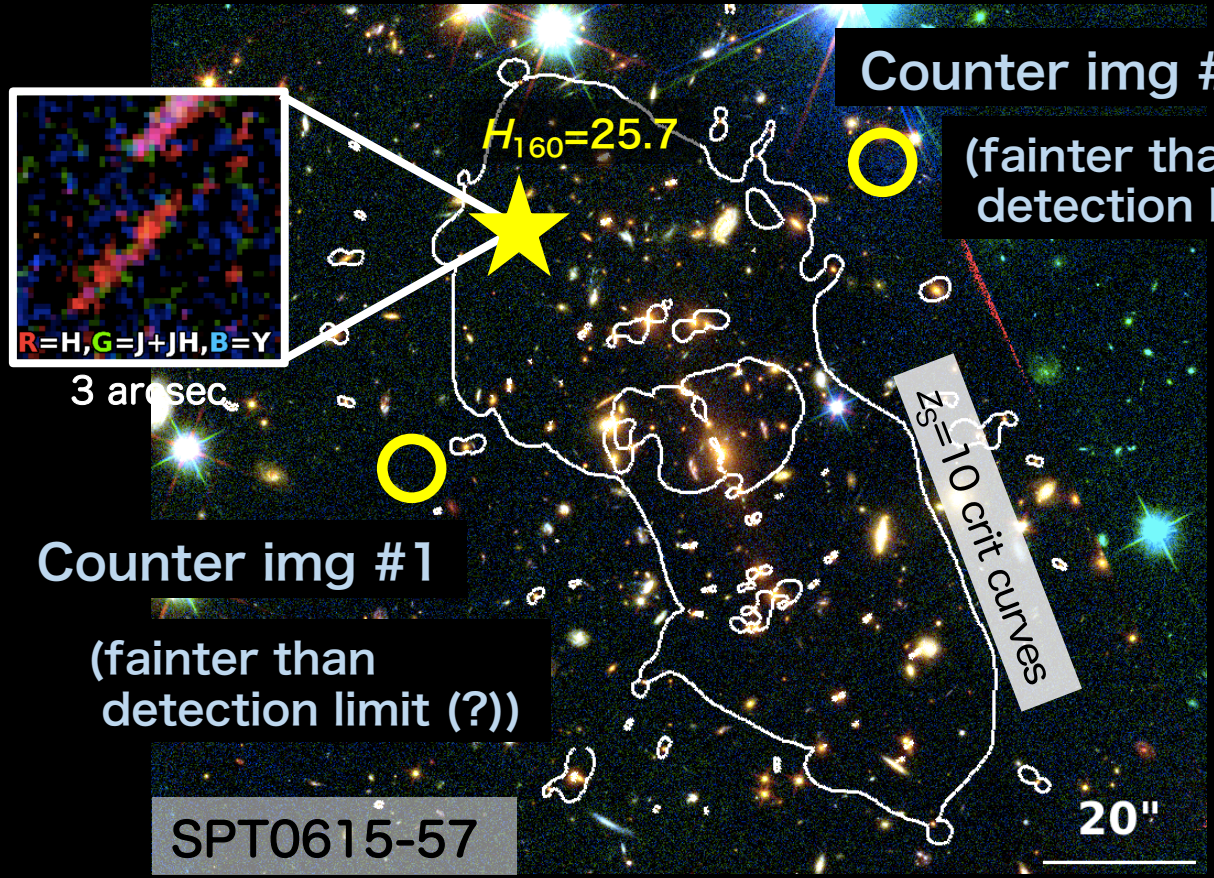
Salmon+17

RELICS
Reionization Lensing Cluster Survey

Brightly-Lensed Galaxies in RELICS



z=9.9 Arc (?)



Lens model constructed by Kikuchihara+ using GLAFIC

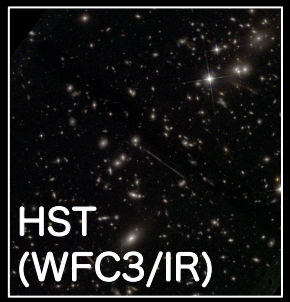
Prediction based on the lens model does not rule out z=9.9

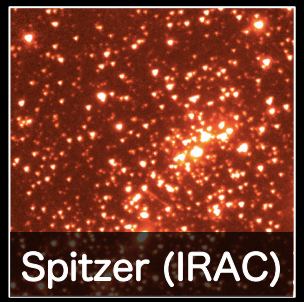
RELICS
Reionization Lensing Cluster Survey

Follow-up Observations

Spitzer

- 390 hr for all clusters (archive)





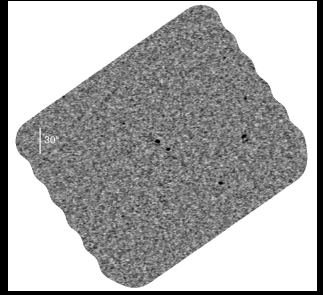
+

330 hr (proposal accepted; cy14)

➡ Redshift verification, stellar mass, A_V, etc.

ALMA

- 1 cluster-field survey (archive)



ACT0102-49
(ALMA/band 6)

+

15 more (proposed for cy6)

As part of the ALMA Lensing Cluster Survey
(PI: Kohno)

➡ Properties of faint SMGs, IRX-β, [CII]/CO LF, etc.

RELICS
Reionization Lensing Cluster Survey

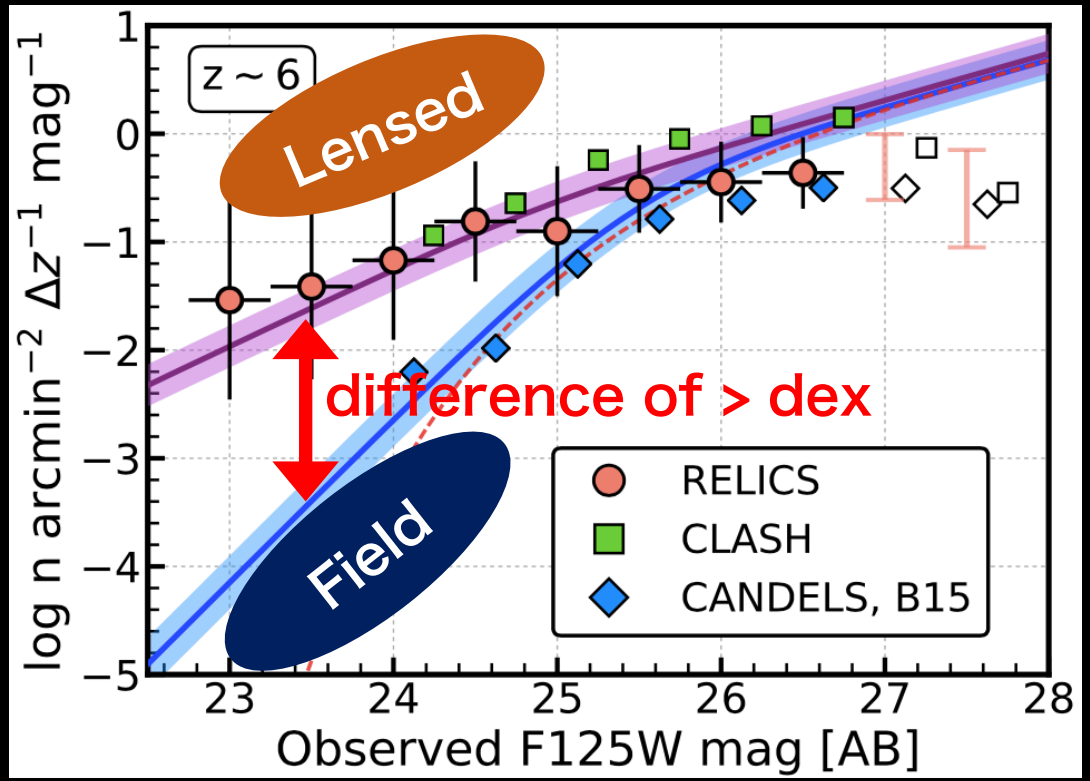
Summary of RELICS

- RELICS surveyed the 41 cluster regions with HST.
- 321 galaxy candidates were identified at z=6-8, including brightly-lensed sources (~23 mag).
- Mass-modeling is ongoing (20/41 released).
- Follow-up observations have been proposed to find the properties of the candidates (Spitzer, ALMA).

RELICS
Reionization Lensing Cluster Survey

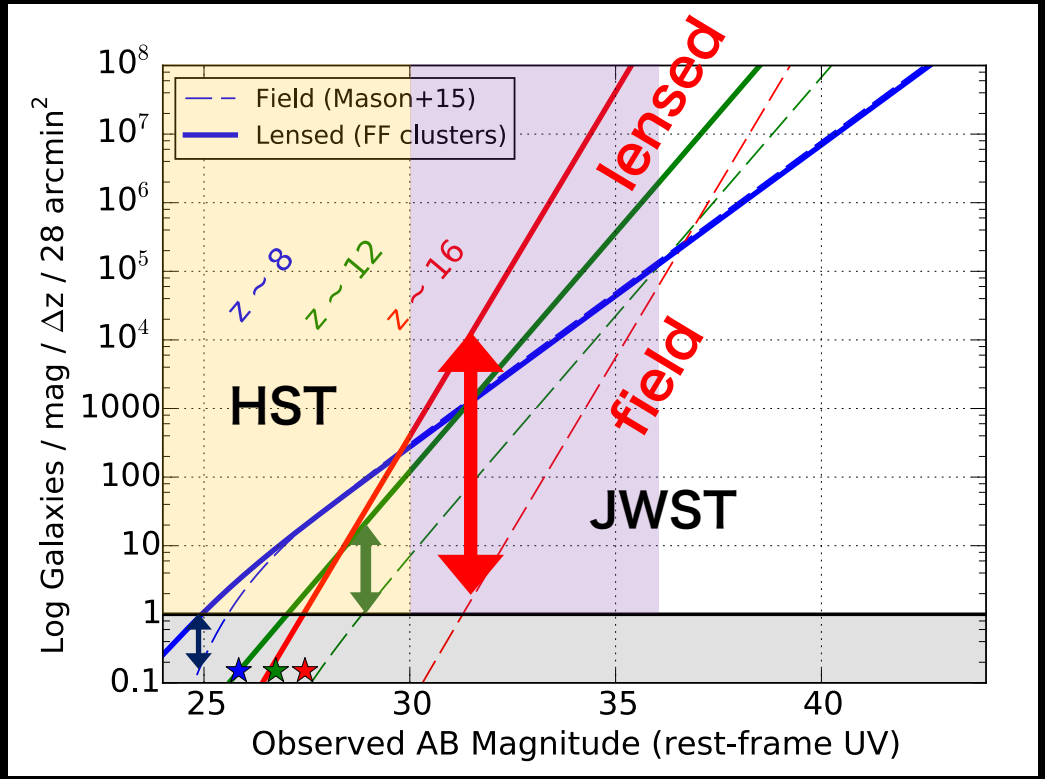
Future Observations with Lensing

Lensing Advantage (again)



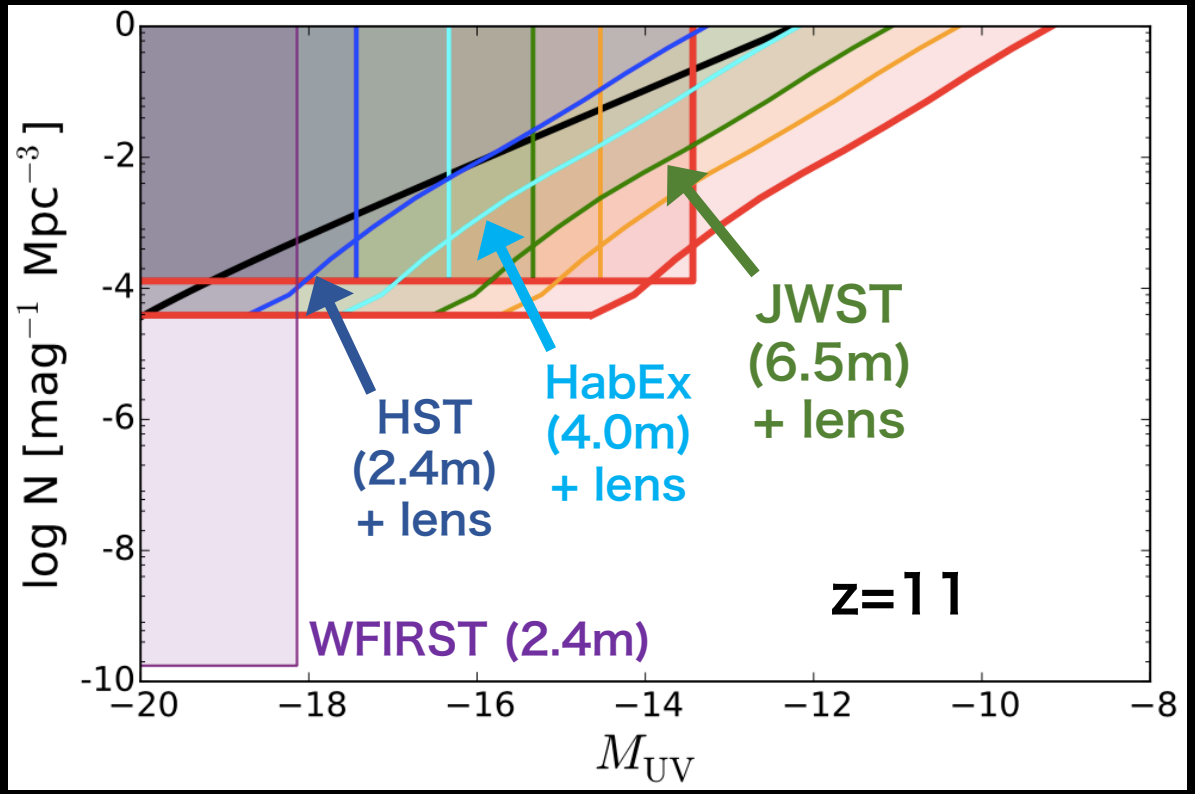
Salmon+17

Lensing Advantage increases at z>10



Credit: Coe

JWST and Beyond!

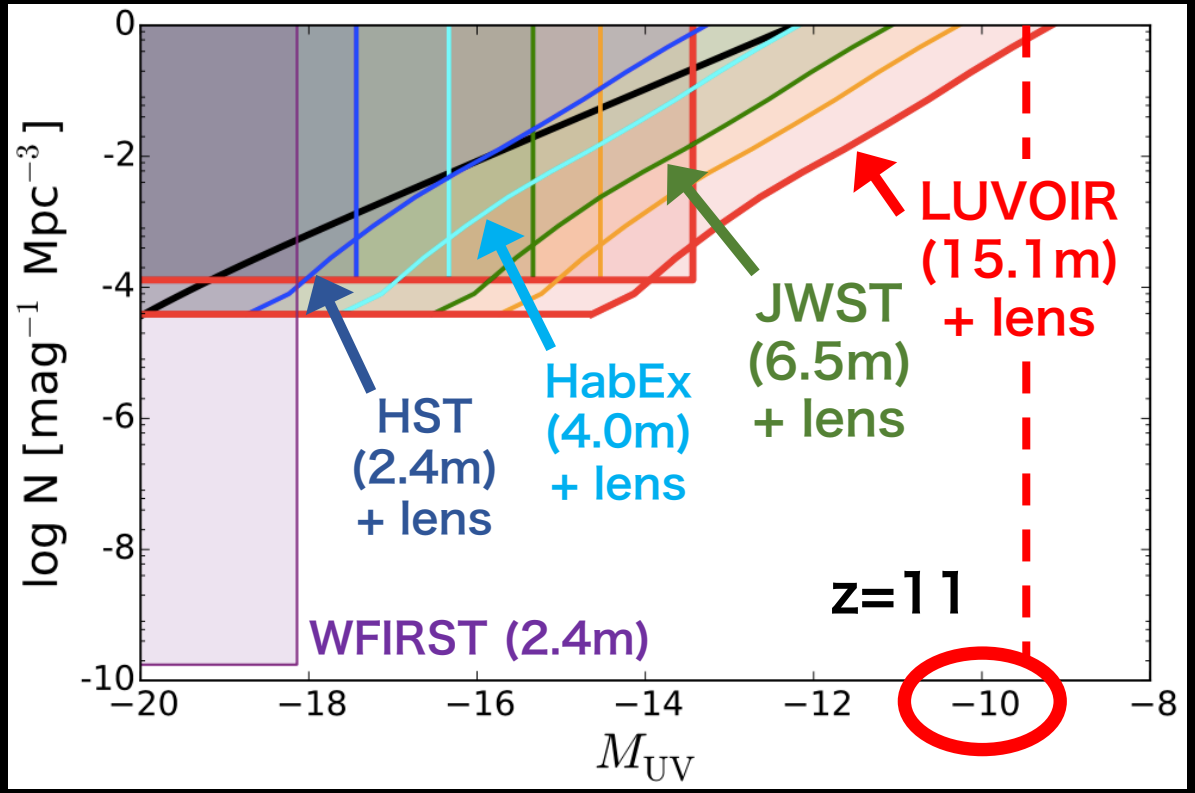


- JWST will identify high-z galaxies of ~ -17 mag

Taking advantage of cluster lensing!

O'Meara, Ouchi, Postman, Ishigaki, Kikuchihara

JWST and Beyond!



© NASA

- LUVOIR+lens will reach ~ -10 mag

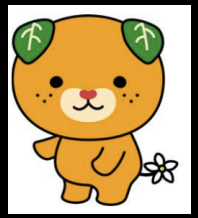
➡ First stars or star-clusters?!

O'Meara, Ouchi, Postman, Ishigaki, Kikuchihara

Future Observation Summary

- High-z galaxies are efficiently detected owing to cluster-lensing, especially at z>10.

- JWST will identify galaxies of ~ -17 mag at z~10. LUVOIR will reach ~ -10 mag at z~10, identifying the first stars or star-clusters (?!).



Thank you!