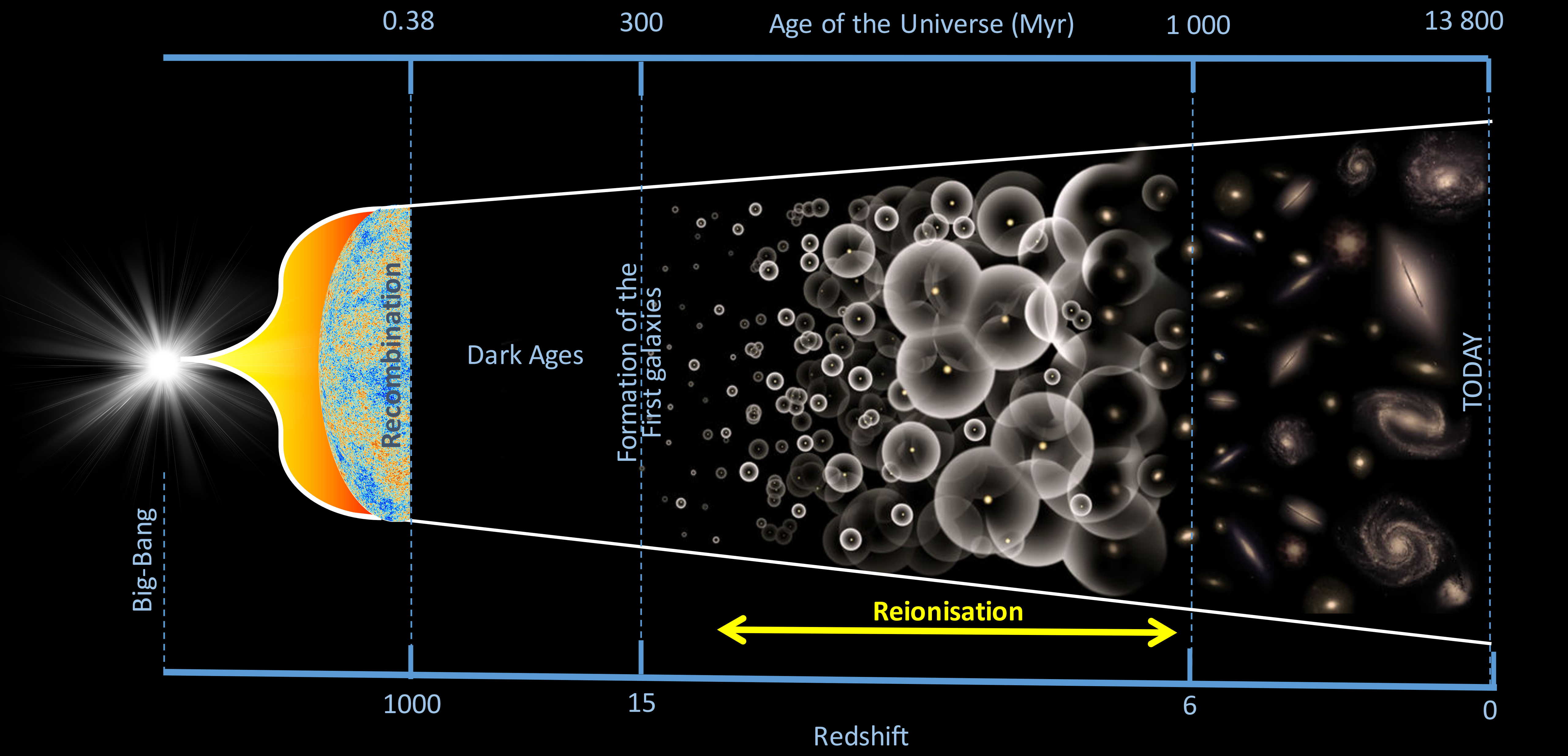
Probing Cosmic Dawn : the age of the most distant galaxies

Nicolas Laporte

11th September 2019 – Rome

G. Roberts-Borsani, R. Ellis, F. Bauer, F. Boone, T. Hashimoto, A. Inoue, H. Katz, S. Kim, G. Lagache, **R. Pelló**, B. Robertson, D. Stark, P. Troncoso-Irribaren, E. Zackrisson and A. Zitrin

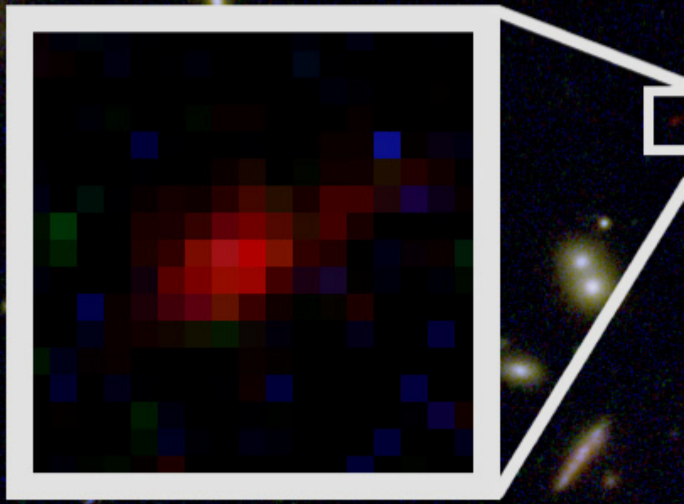


0.38
300
Age of the Universe (Myr)
1 000
13 800
Recombination
Dark Ages
Formation of the First galaxies
TODAY
Big-Bang
Reionisation
1000
15
6
0
Redshift

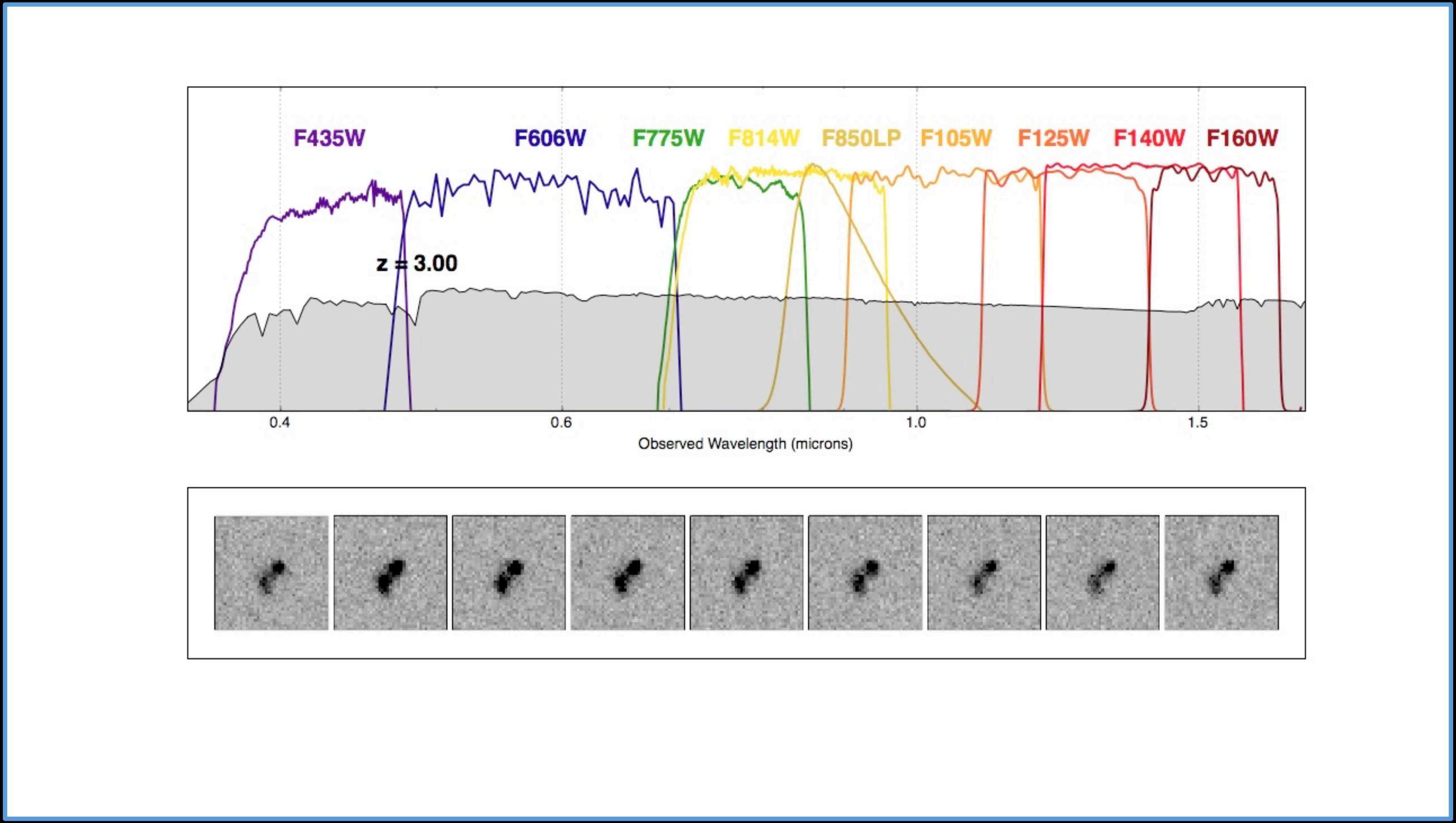
How can we probe observationally ‘Cosmic Dawn’ ?

1. **Direct probe** : *Search for the galaxies at z>12*
   - What is the highest-z galaxy we can observe today ?
   - How the future ELTs will help probing Cosmic Dawn ?

2. **Indirect probe** : *Determine the age of the most distant galaxies*
   - What paramters can we used to determine their age ?
   - Can we measure the age of all galaxies at high-z ?
   - Is there any example of ”old” z>8 galaxy ?



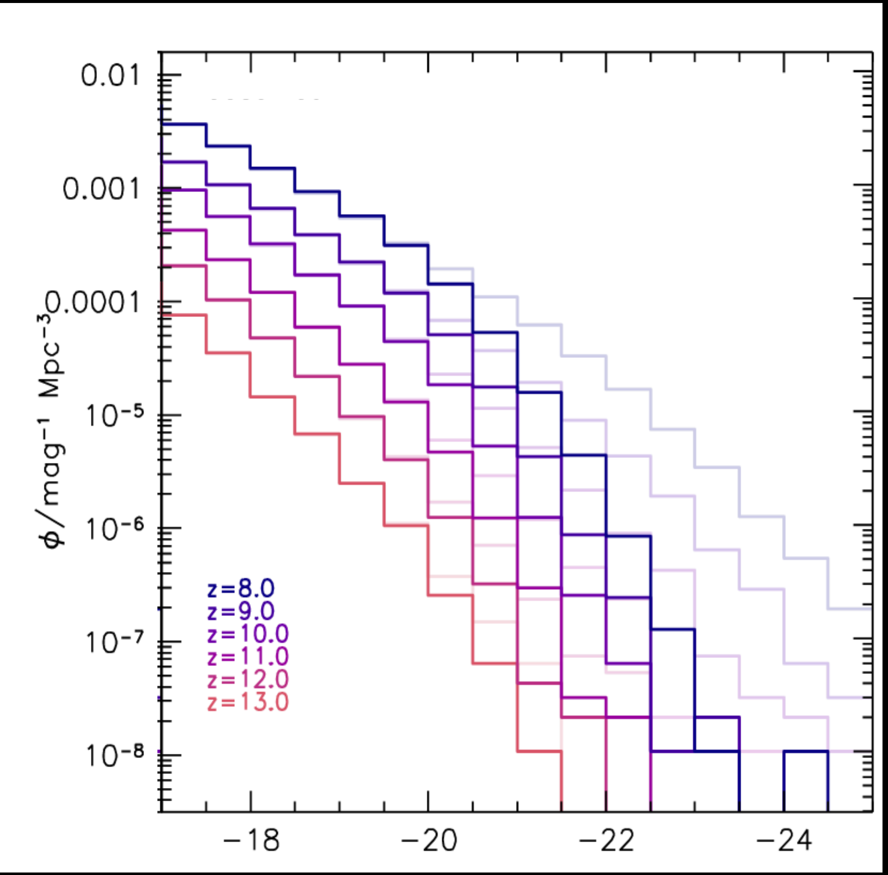
Direct probe : *Search for the most distant galaxy*



The highest redshift we can get in 2019

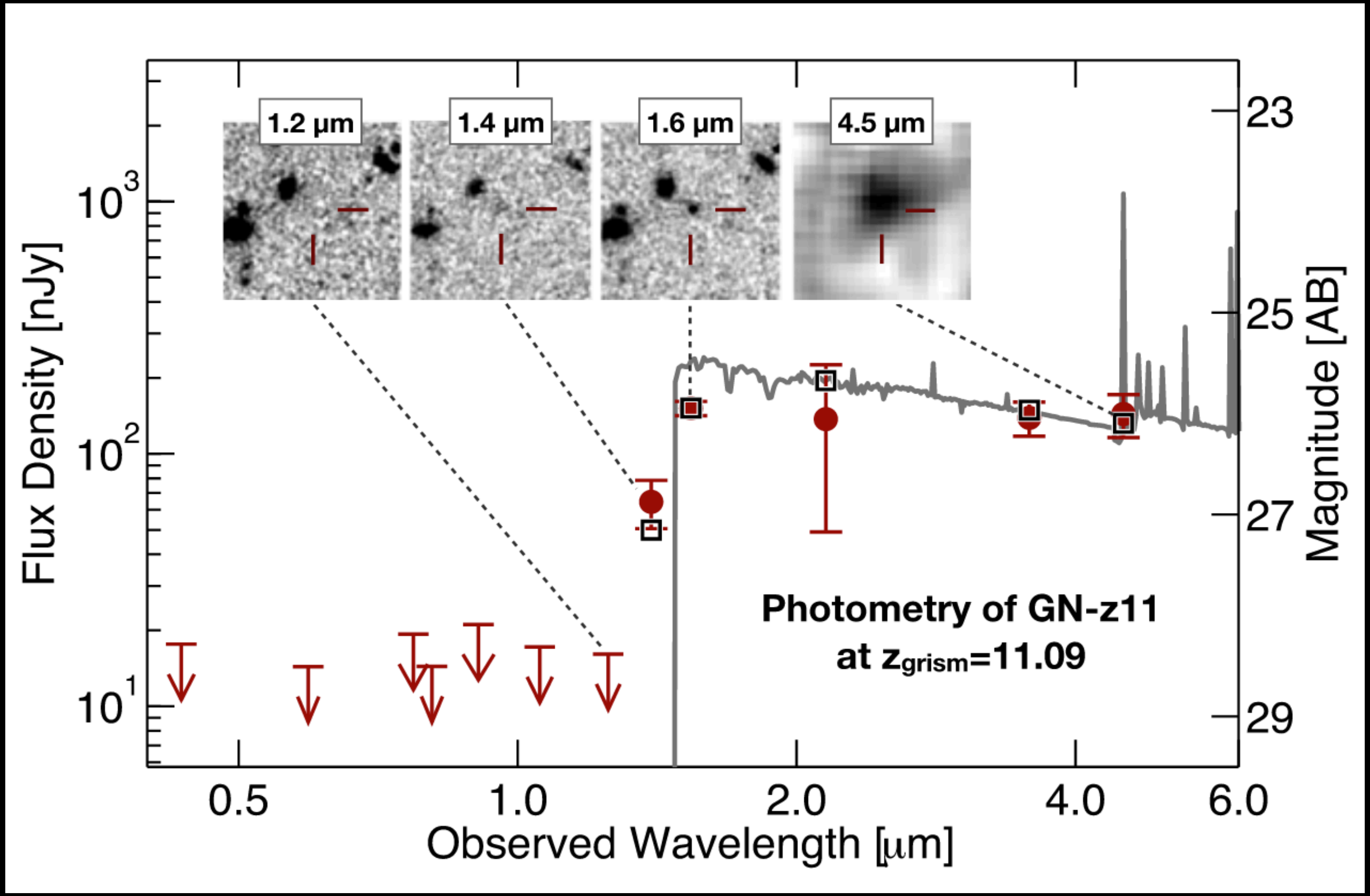
According to recent hydrodynamical simulations, the number of $z \approx 12$ objects expected in current surveys is :

Effective Surface	N(z≈12)
HUDF [4.7 arcmin^2]	**0.5**
CANDELS [668 arcmin^2]	**0.5**
UltraVISTA [1.5 degres^2]	**0.0**



Wilkins et al. (2017)

And there is at least one z≈11 galaxy



Oesch et al. (2016)

- Object selected in GOODS-North
- Photometric redshift of z=10.2 ± 0.4

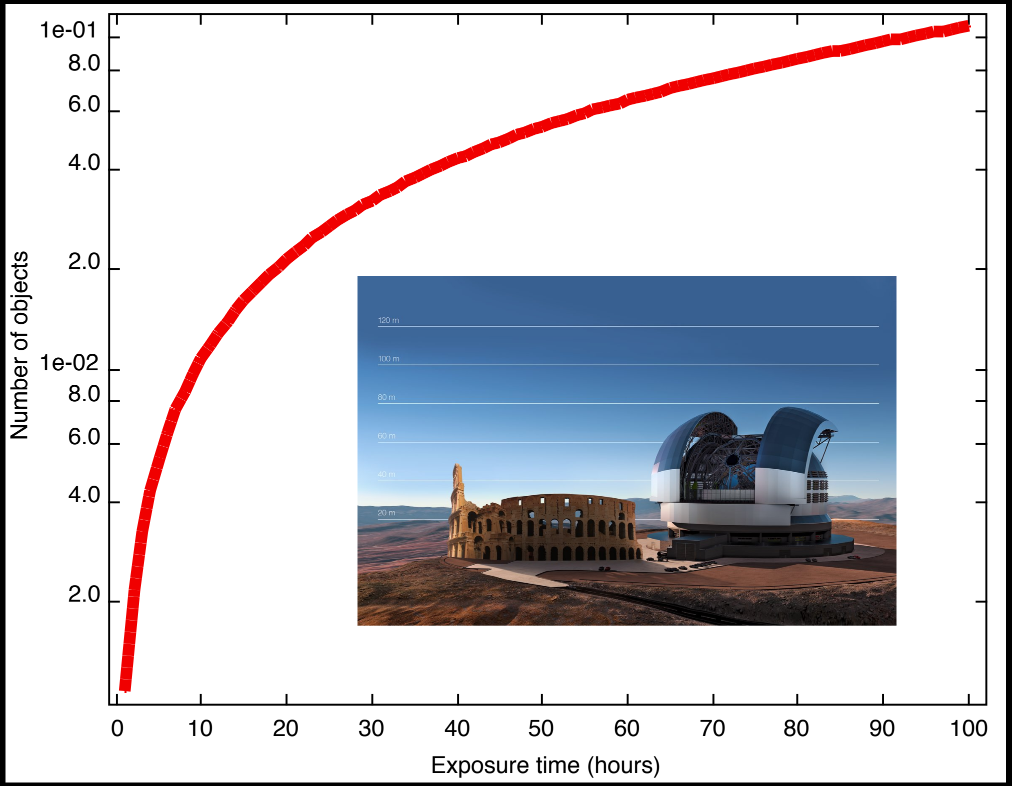
- Lyman continuum détection with HST
- **Spectroscopic redshift of z=11.09 ± 0.12**

(new spectroscopic confirmation soon)

- Partial coverage of the rest-frame UV due to its extremely high-redshift
  ➔ ***few constraints on the stellar population***

- JWST/ELTs are clearly needed to reveal the properties of this object.

Direct probe with future ELTs ?



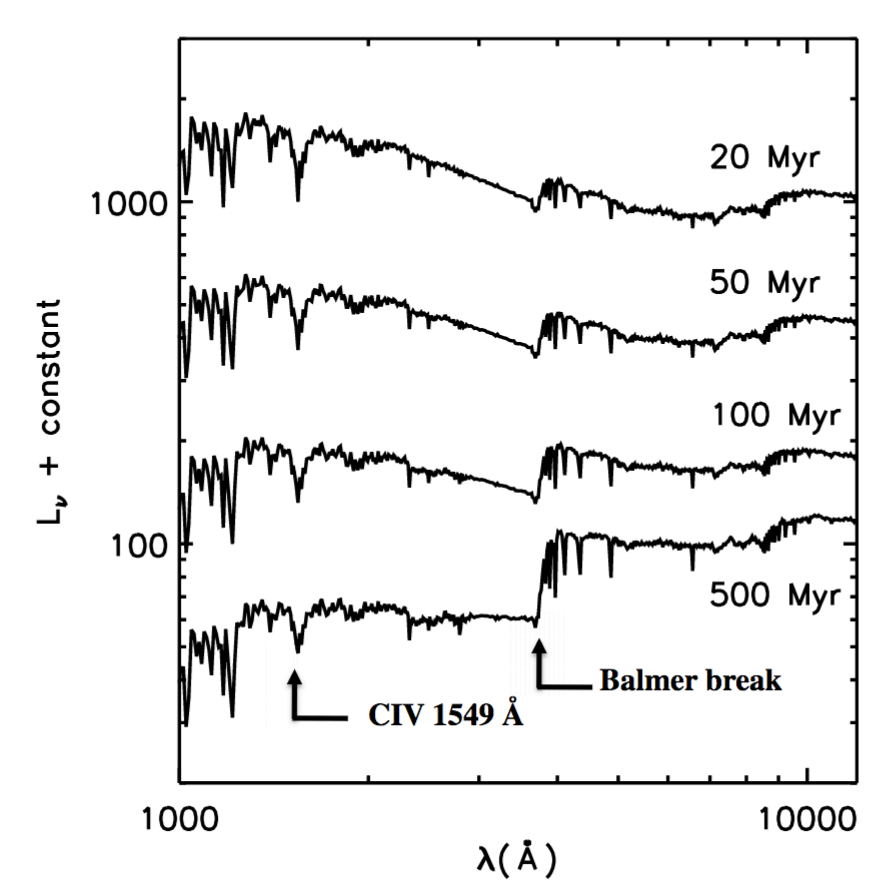
- Because of the Ks band, we will be able to detect z≈15 galaxies !
- But the sensitivity of the instruments will not be sufficient to detect z≈15 galaxy in < 100 hrs … in blank field

ELT SURVEY EXAMPLE

- Assuming the capabilities of MICADO/ELT
- Observing a RELICS like survey (Coe et al. 2019 - 41 clusters) with a 2’x2’ observed surface
- After 4hrs per filter and per cluster, ≈10 z≈15 galaxies are expected !
- **12hrs per cluster (J / H/ Ks) => TOTAL of 500 hrs**

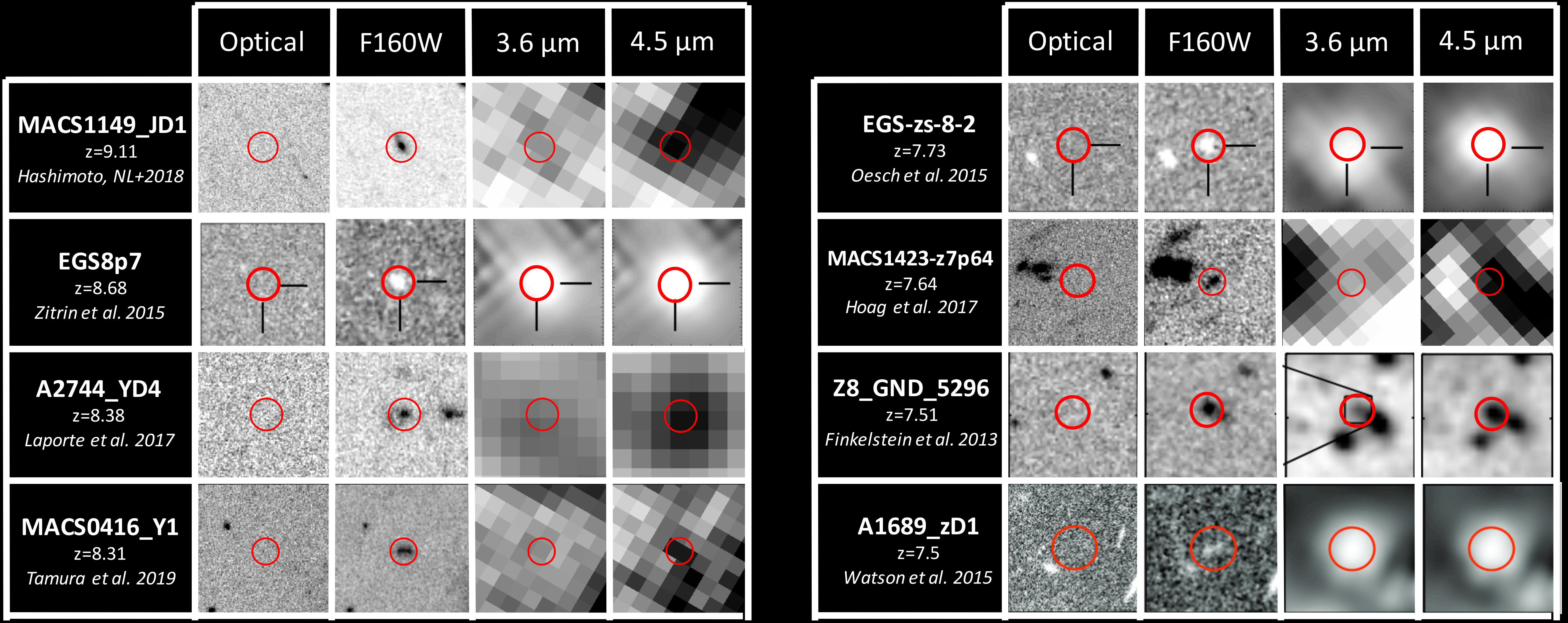
Indirect probes : the age of the most distant galaxies

- The shape of the Balmer break depends on two things :
  (1) the age of the stellar population
  (2) the dust content of the galaxy
- At $z > 7.5$, the Balmer break (4000Å) is seen in the two first IRAC channels

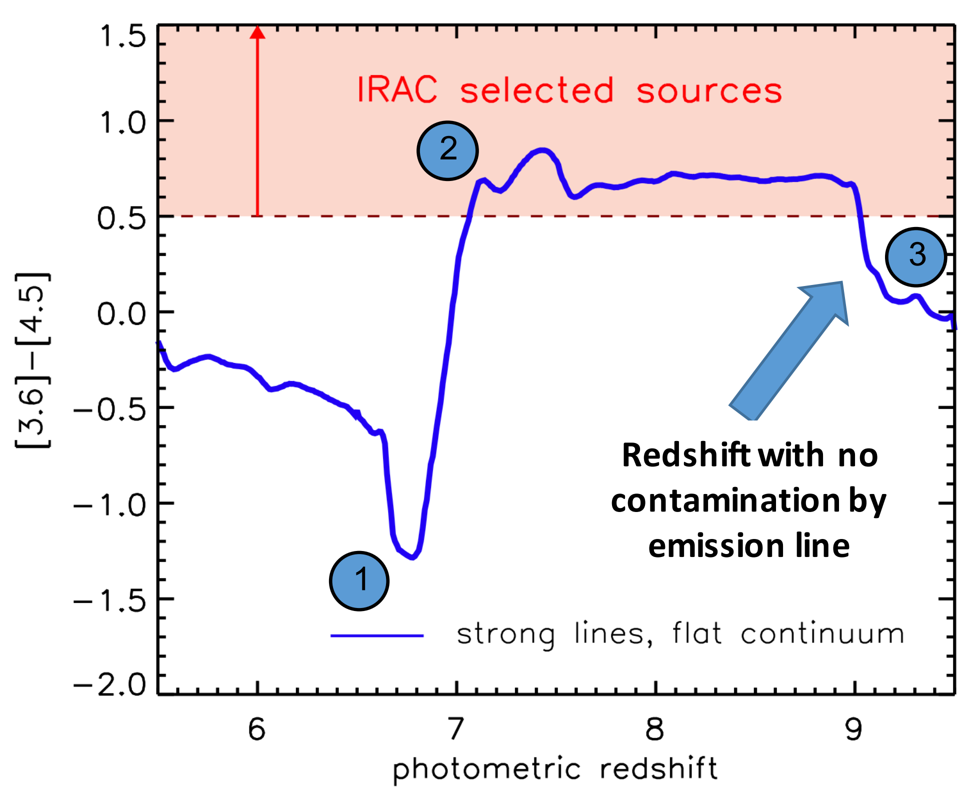


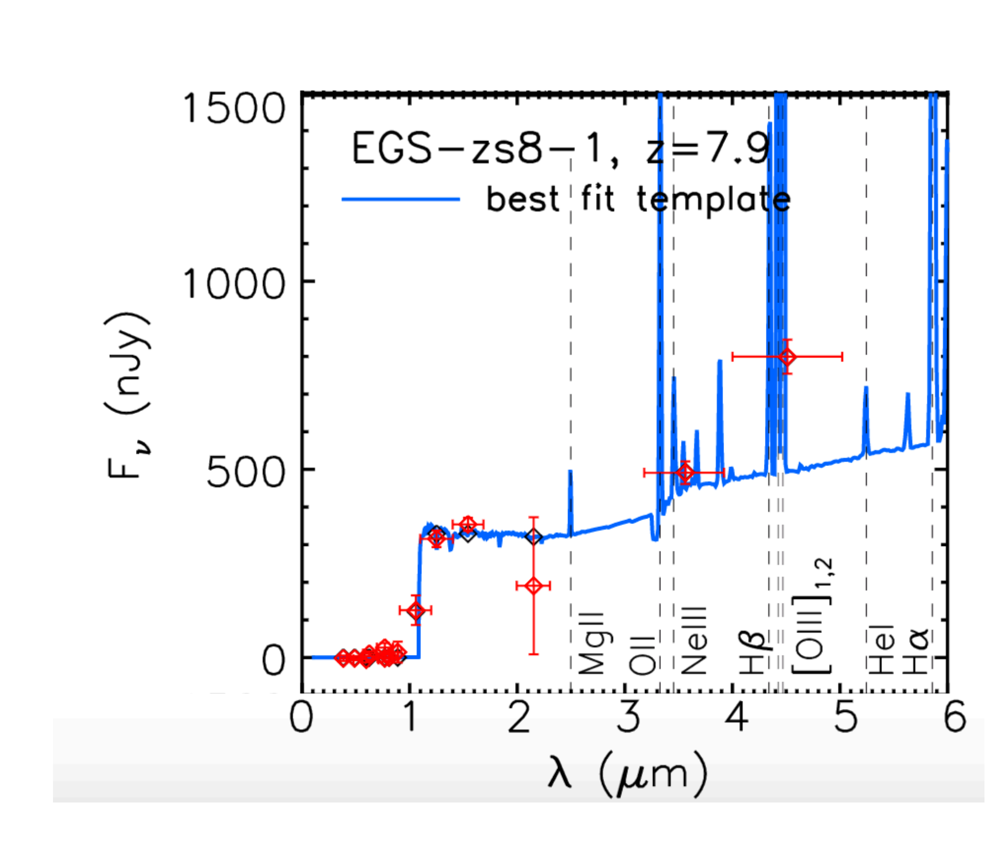
Scoville et al. (2015)

8 confirmed z>7.5 galaxies with red IRAC colors



But near 4000Å, there are [OIII] and Hβ lines

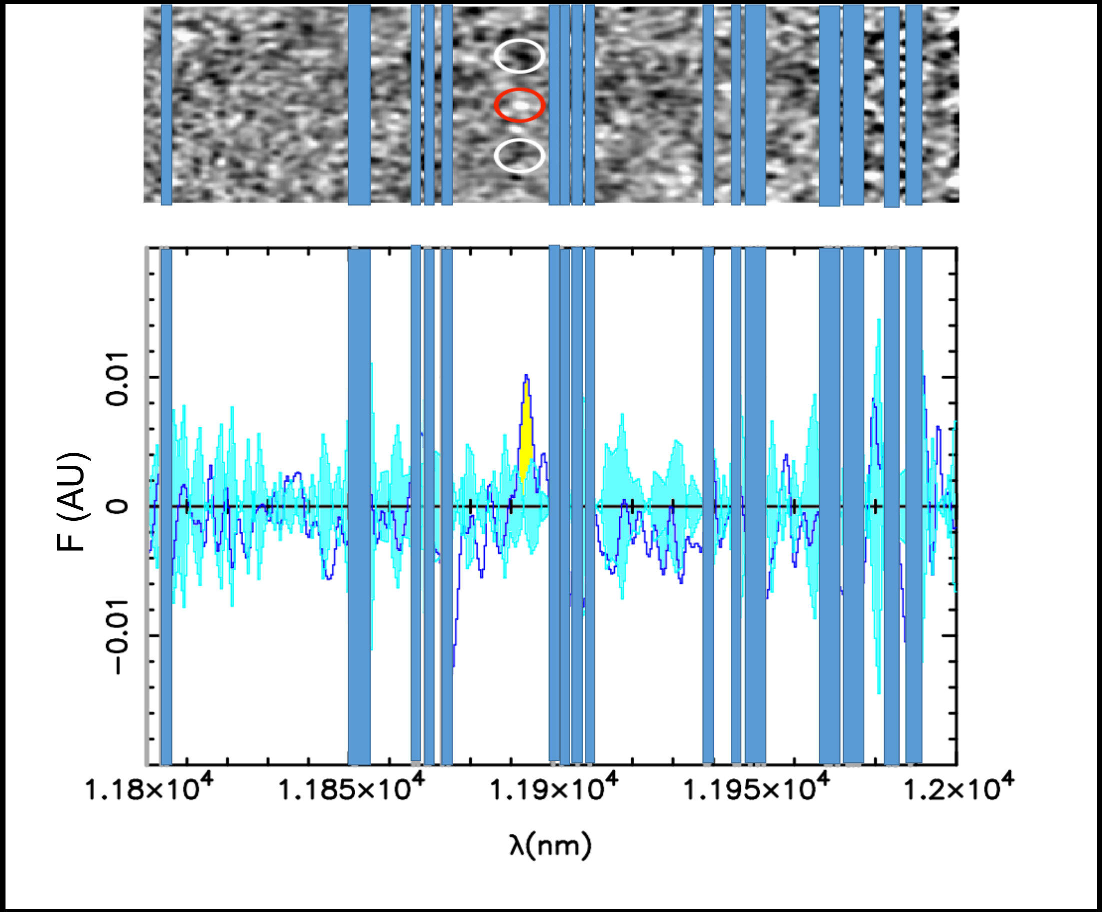


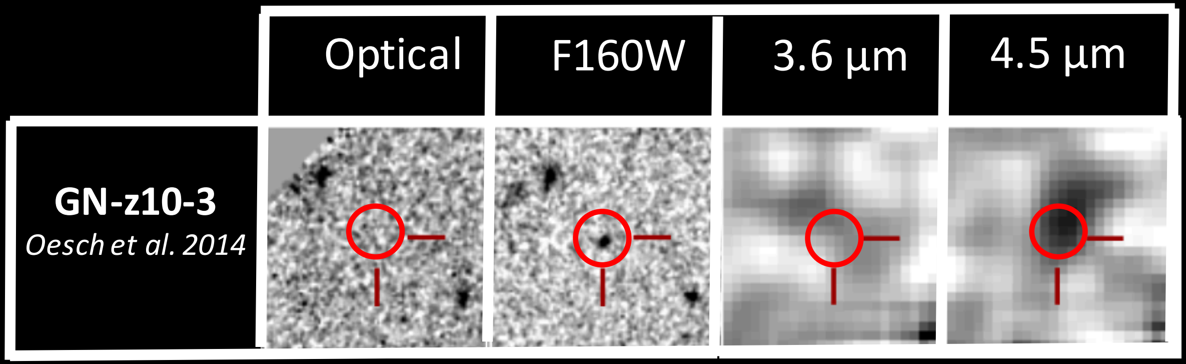


Roberts-Borsani et al. (2016)

To avoid contamination by strong emission line, we should target red-IRAC colors galaxies with a photometric redshift z>9.1

MOSFIRE/Keck : a galaxy at z=8.78





λ=11891 A

z_{phot} = 9.5±0.4 **z_{spec}= 8.78**

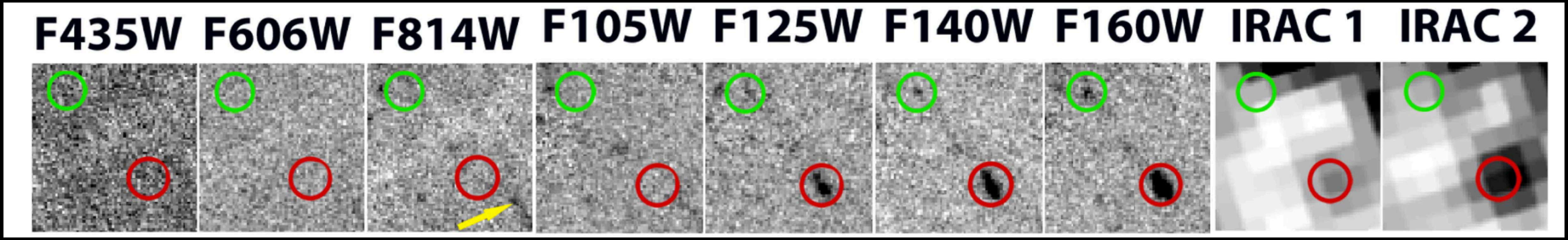
T_{exp} = 6hrs

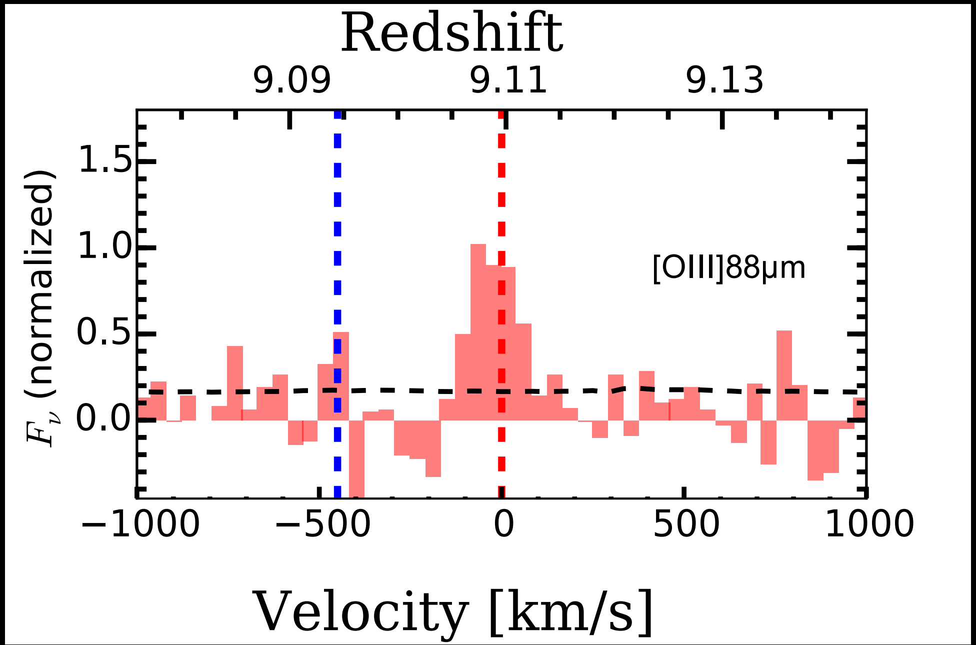
FWHM≈150km/s

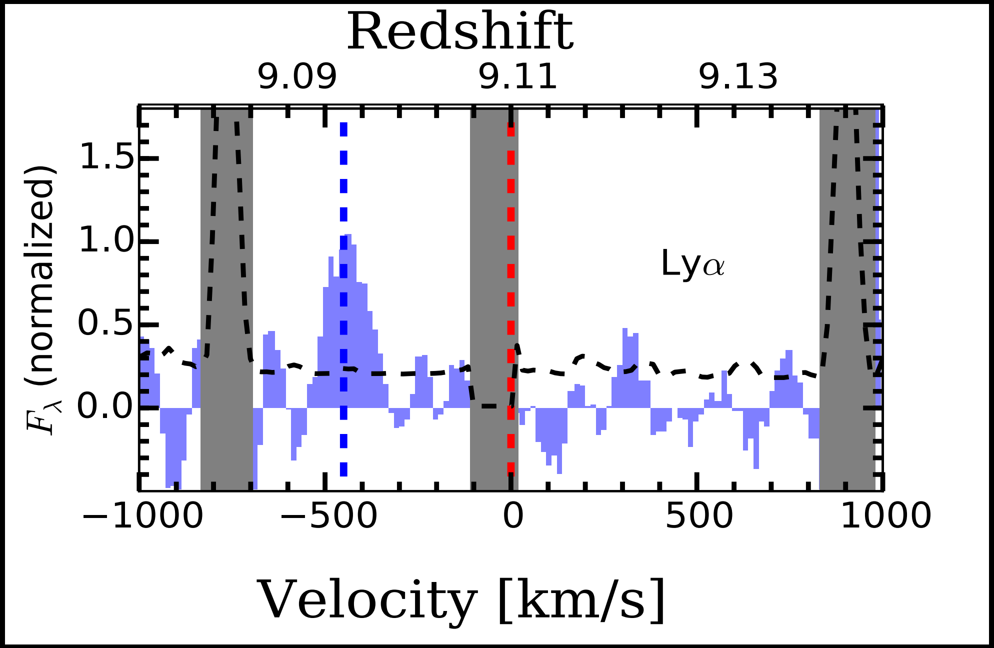
S/N ≈ 6

A strongly magnified candidate at z=9.11

Zheng et al. 2012, 2017



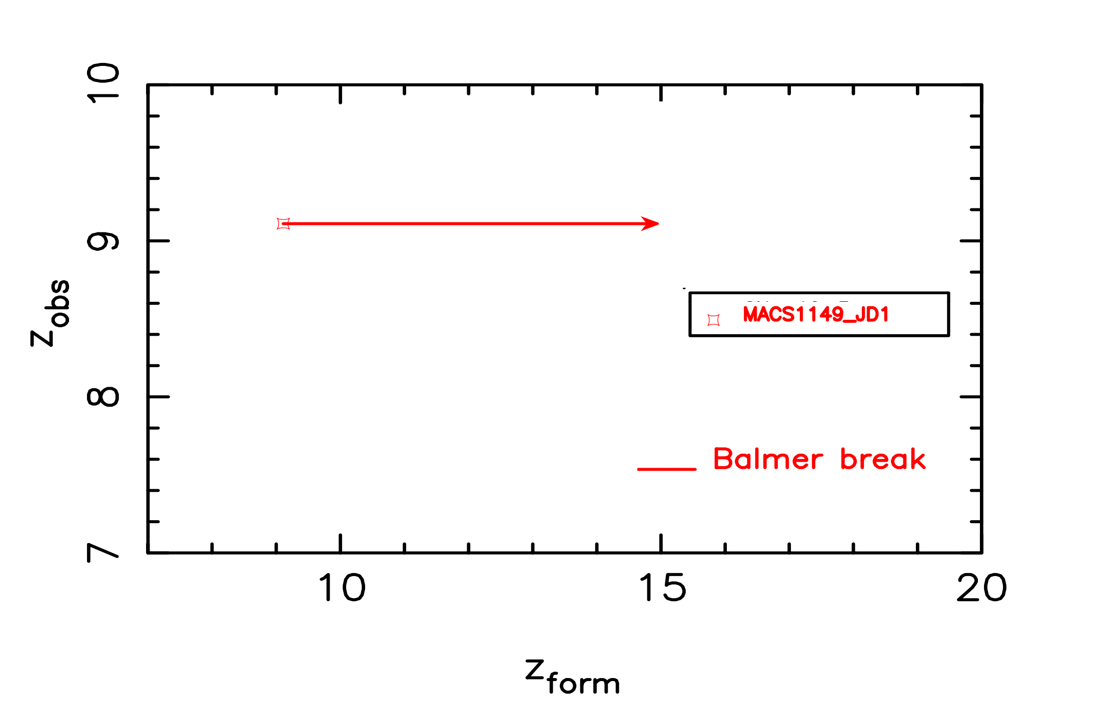




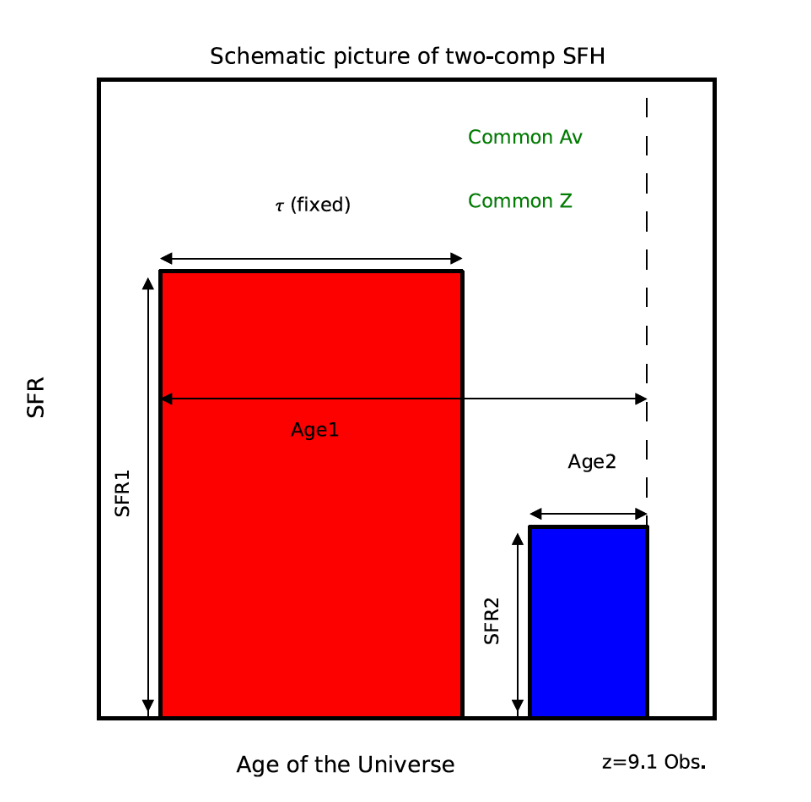
Hashimoto, NL et al. 2018

The age of a z=9.11 galaxy

Assuming a simple SFH model (period of constant SF with a recent burst) we estimated an age of ≈300 Myr, corresponding to a formation redshift of 15)



Parameters	Values
Age_{old} [Myr]	290^{+190}_{-120}
Age_{young} [Myr]	3^{+2}_{-1}

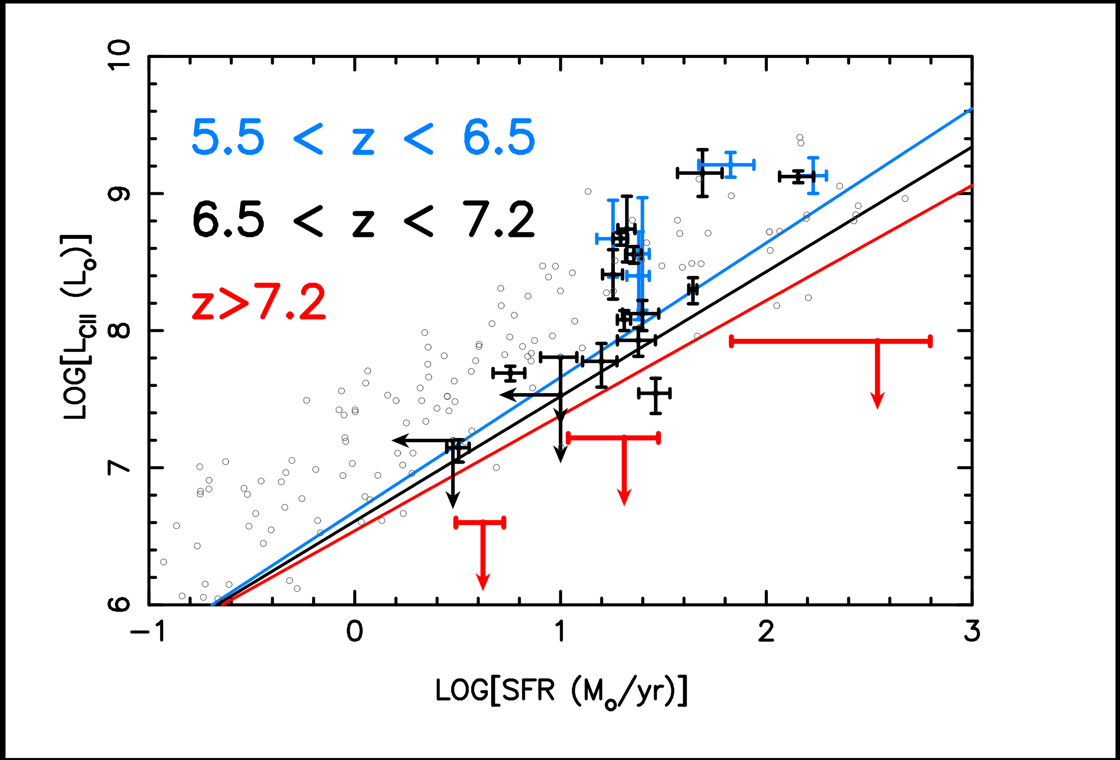


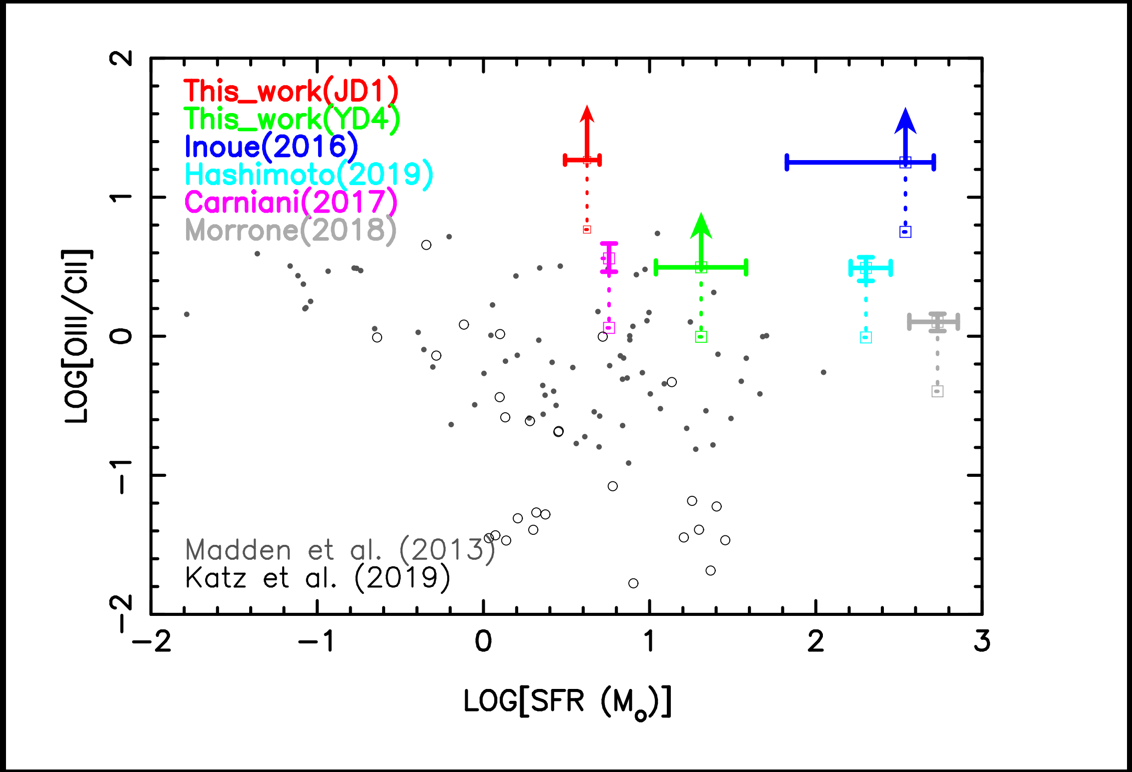
Hashimoto, NL et al. 2018

An absence of neutral gas at z>7.5 ?

ALMA Band 5 observations of 3 galaxies in this sample show no [CII] 158µm detection at z>7.5.

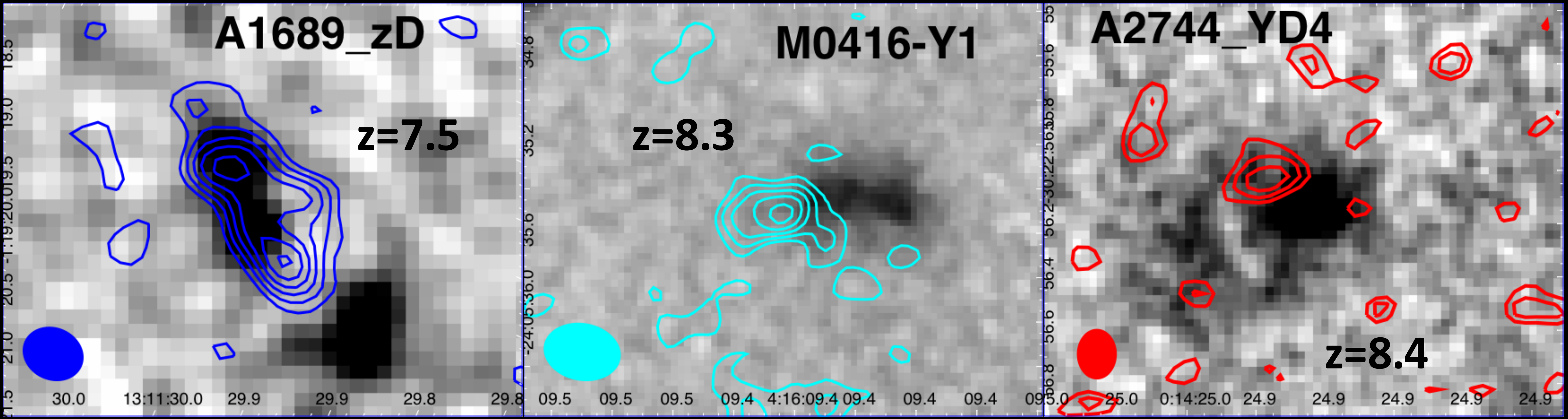
➔ Small amount of neutral gas or diffuse emission ? (*see Seiji's talk*)





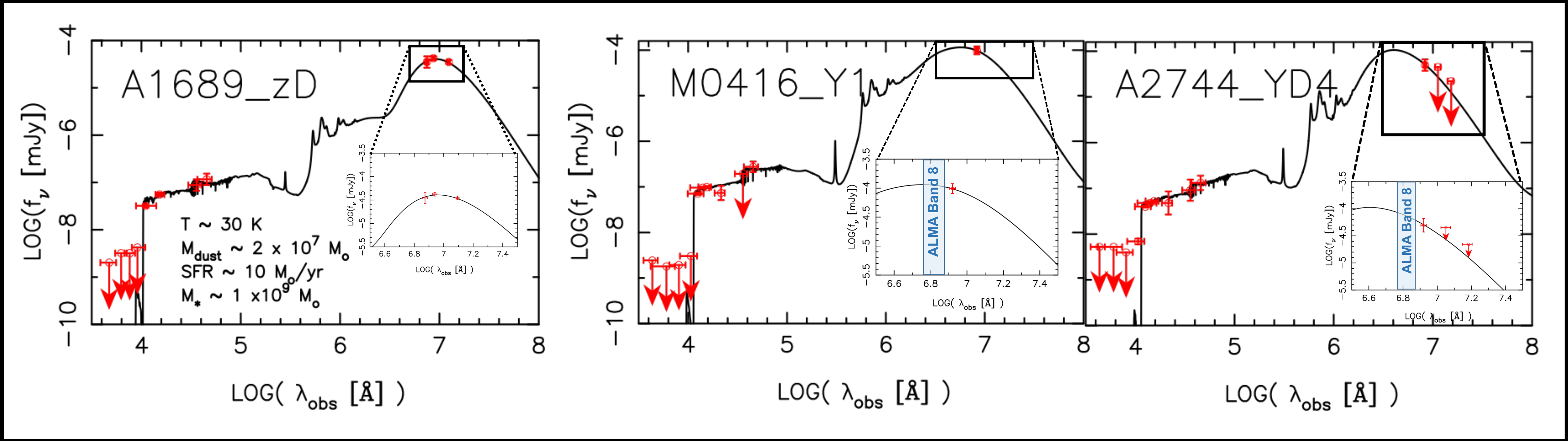
Laporte et al. (2019)

For galaxies at z<9.1, the crucial parameter is the dust detection



Watson et al. (2015) Tamura et al. (2019) Laporte et al. (2017)

From dust light to the age of the galaxy



F_{peak} = 730 μJy

T_{dust} = 30K

M_{dust} = 4×10^7 $M_\odot$

F_{peak} = 167 μJy

T_{dust} = 30K

M_{dust} = 7×10^6 $M_\odot$

F_{peak} = 122 μJy

T_{dust} = 30K

M_{dust} = 5×10^6 $M_\odot$

The production and destruction of dust

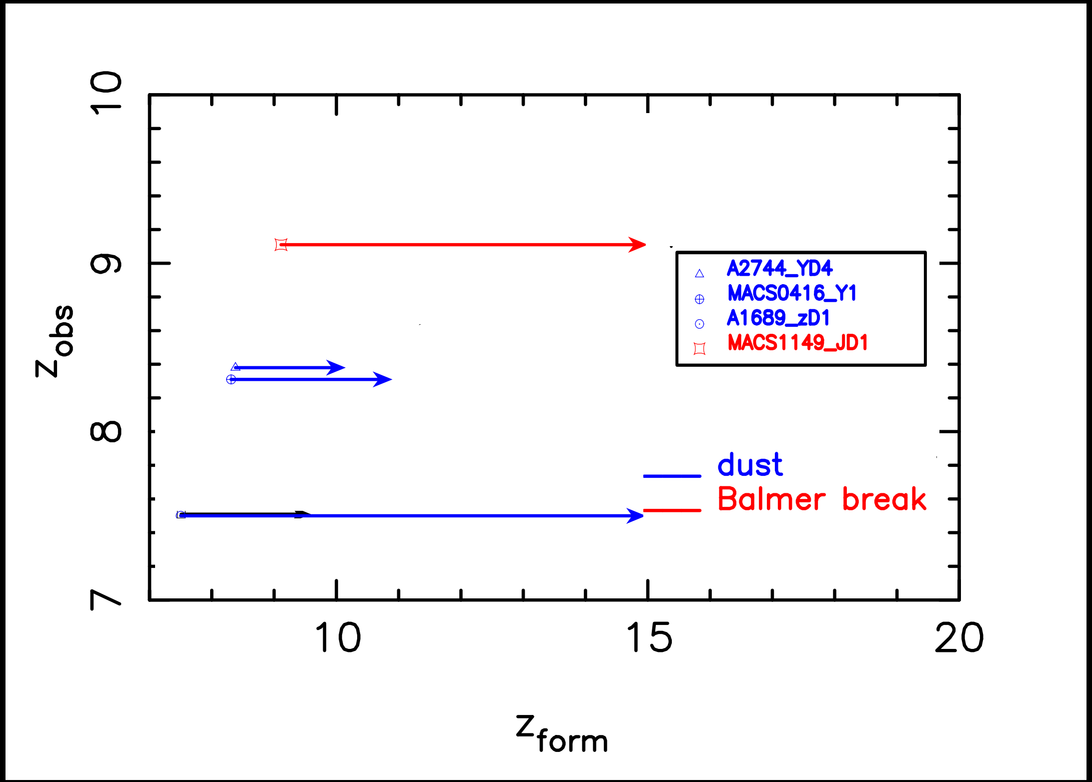
- Production (*see also Aleksandra's talk*) :
  - up to 1 M_o per SNe (Gall et al. 2015)

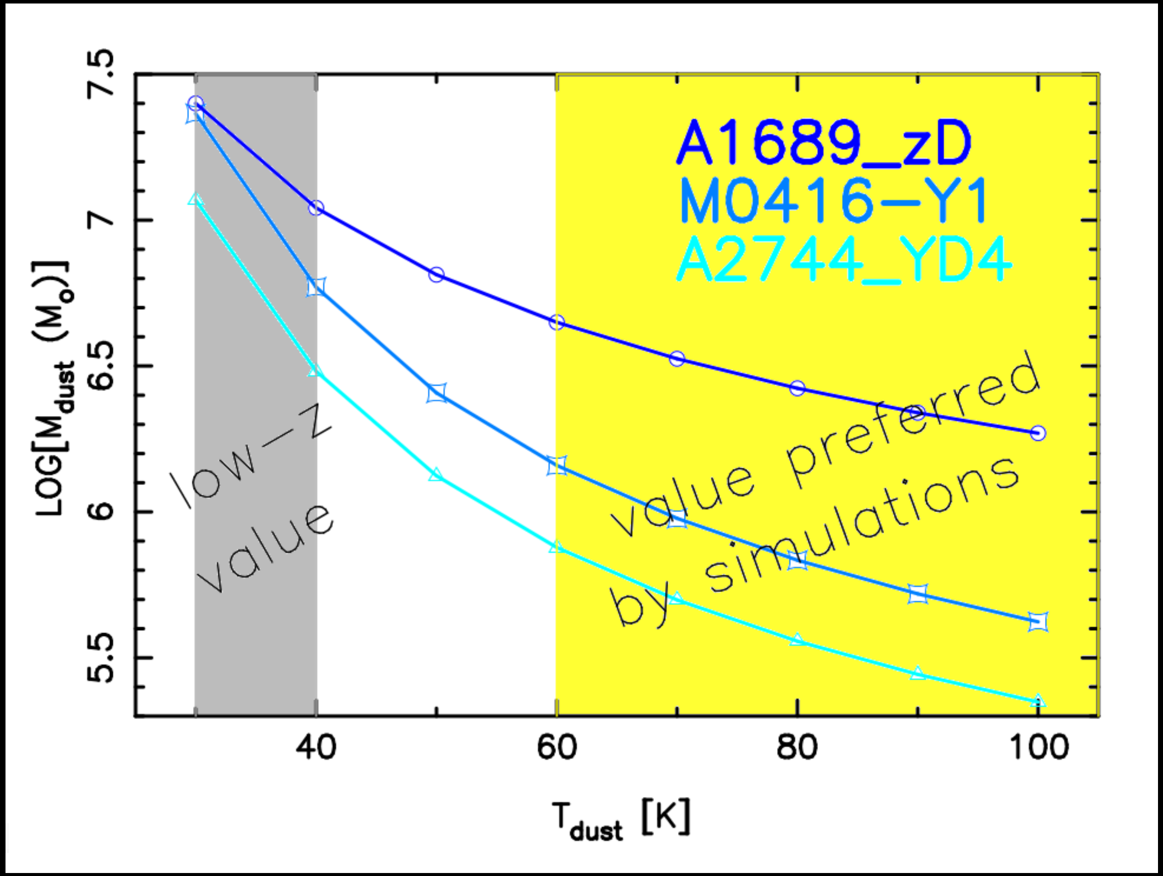
- Dust destruction timescale (Slavin et al. 2015) :
  - 1.6 ± 0.7 Gyr (for carboneous grain)
  - 0.9 ± 0.4 Gyr (for silicate)

- From the shape of the IMF :
  - 0.2% of stars have $M>8M_O$
  - 7.2% of the mass is due to massive stars

- From the dust mass and the SFR, we can estimate the age of a galaxy :
  - A1689_zD1 : 431 Myr (z_{form} = 14.97)
  - M0416_Y1 : 190 Myr (z_{form} = 10.90)
  - A2744_YD4 : 139 Myr (z_{form} = 10.15)

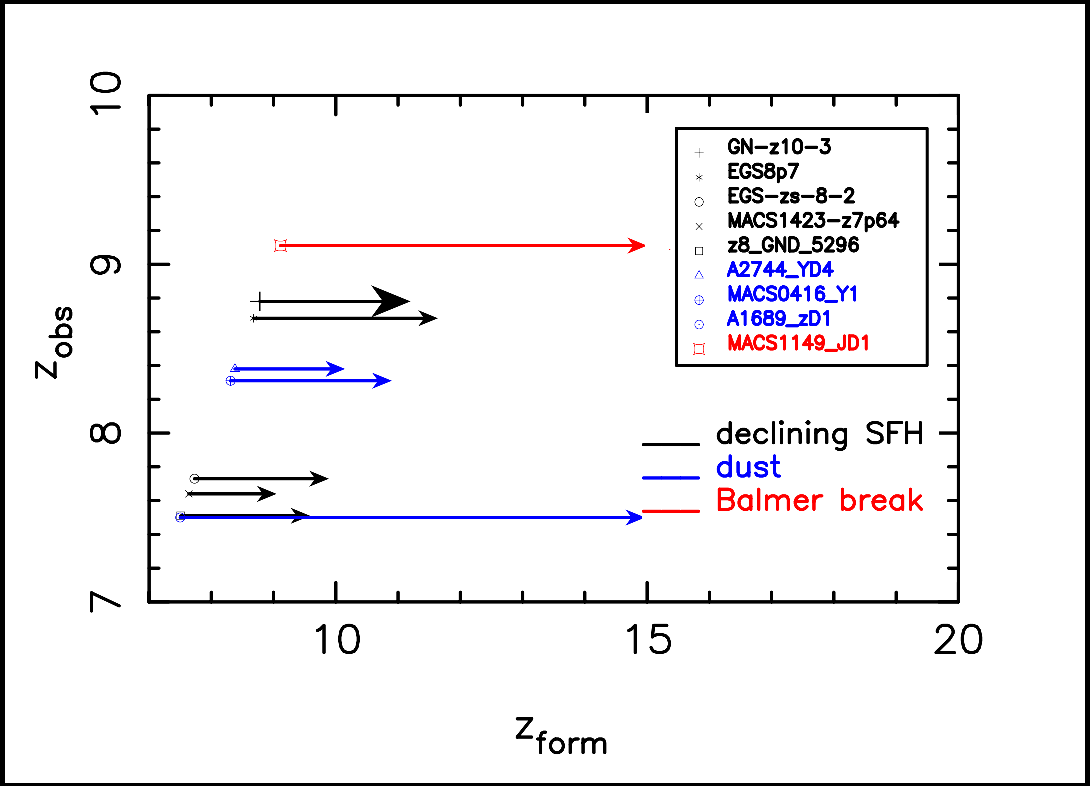
The age of galaxies from dust measurements

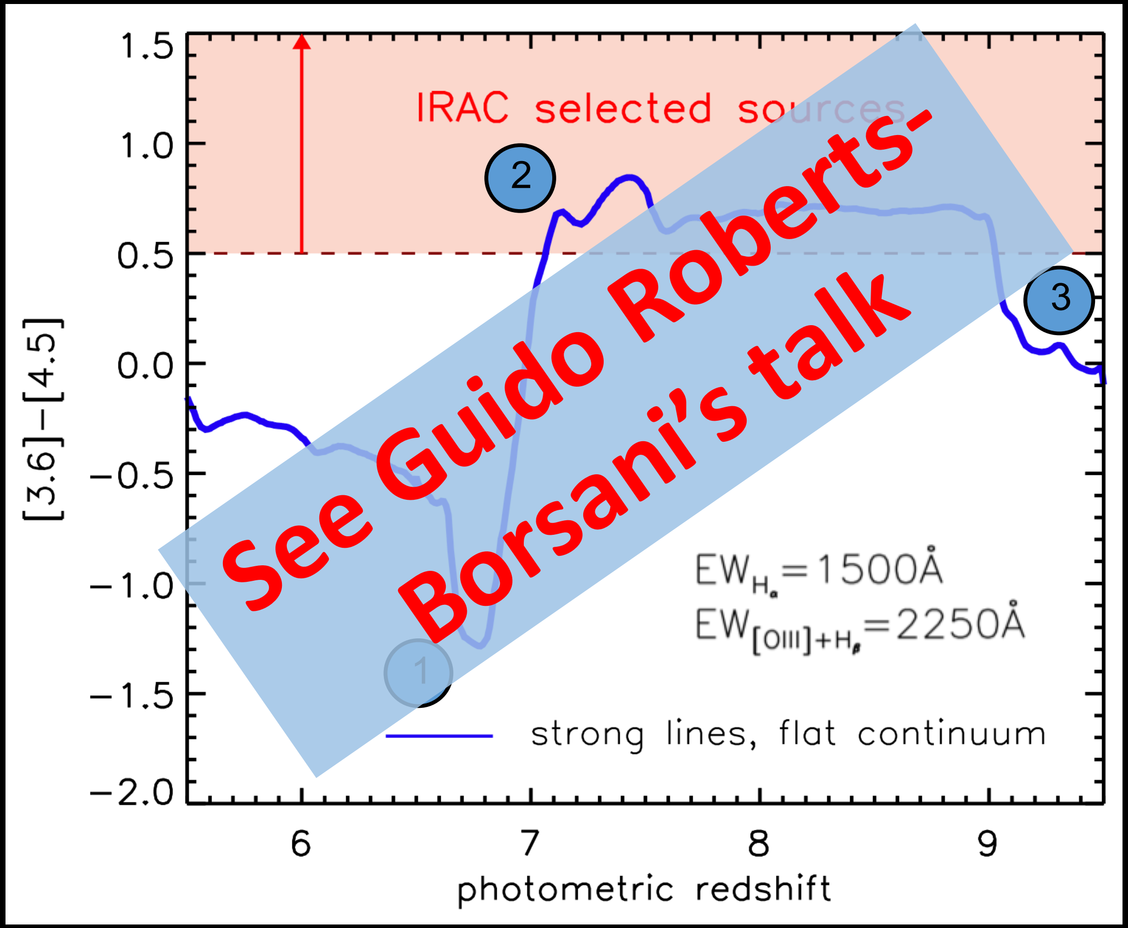




But dust mass strongly depends on the dust temperature. Recent simulations suggests that dust at z>8 could be as high as T=100K (eg. Behrens et al. 2017, Katz et al. 2018)

Galaxies without dust and at z<9.1





All we need is spectroscopic redshifts :
the role of future ELTs

MOSAIC

Sensitivity :
- $10\sigma \approx$ 1e-19 erg/s/cm^2 in 10hrs

Field of View :
- 32 arcmin^2

EMISSION LINE PROPERTIES
Ly-α, CIII

- $z > 9.1$
- EW < 25 A

In a 10hrs pointing : N(z=10 , EW=25A) ≈100 objects in a blank field …

… *but this number does not take into account IGM absorption for Lyman-α.*

The JWST will select objects with red 3.5µm-4.5µm, ELTs will have to conduct spectroscopic follow-up to confirm nature of the observed break.

Summary / Conclusions

- Observing directly the birth of the first galaxies is not possible with current telescopes, but this epoch will be accessible to future ELTs.
  ELT idea : *RELICS like survey (42 clusters) in 3 bands (J/H/Ks) => 500 hrs with MICADO*

- To probe Cosmic Dawn, one need to determine the age of the most distant galaxies :
  - By measuring the size of their Balmer Break (only for z>9)
  - By studying their dust content, but this depends on the dust temperature at very high-redshift

- To date, only 2 galaxies have a formation redshift z>12. We clearly need to increase the sample size via the spectroscopic confirmation of more z>9 candidates.