UNIVERSITY OF CAMBRIDGE

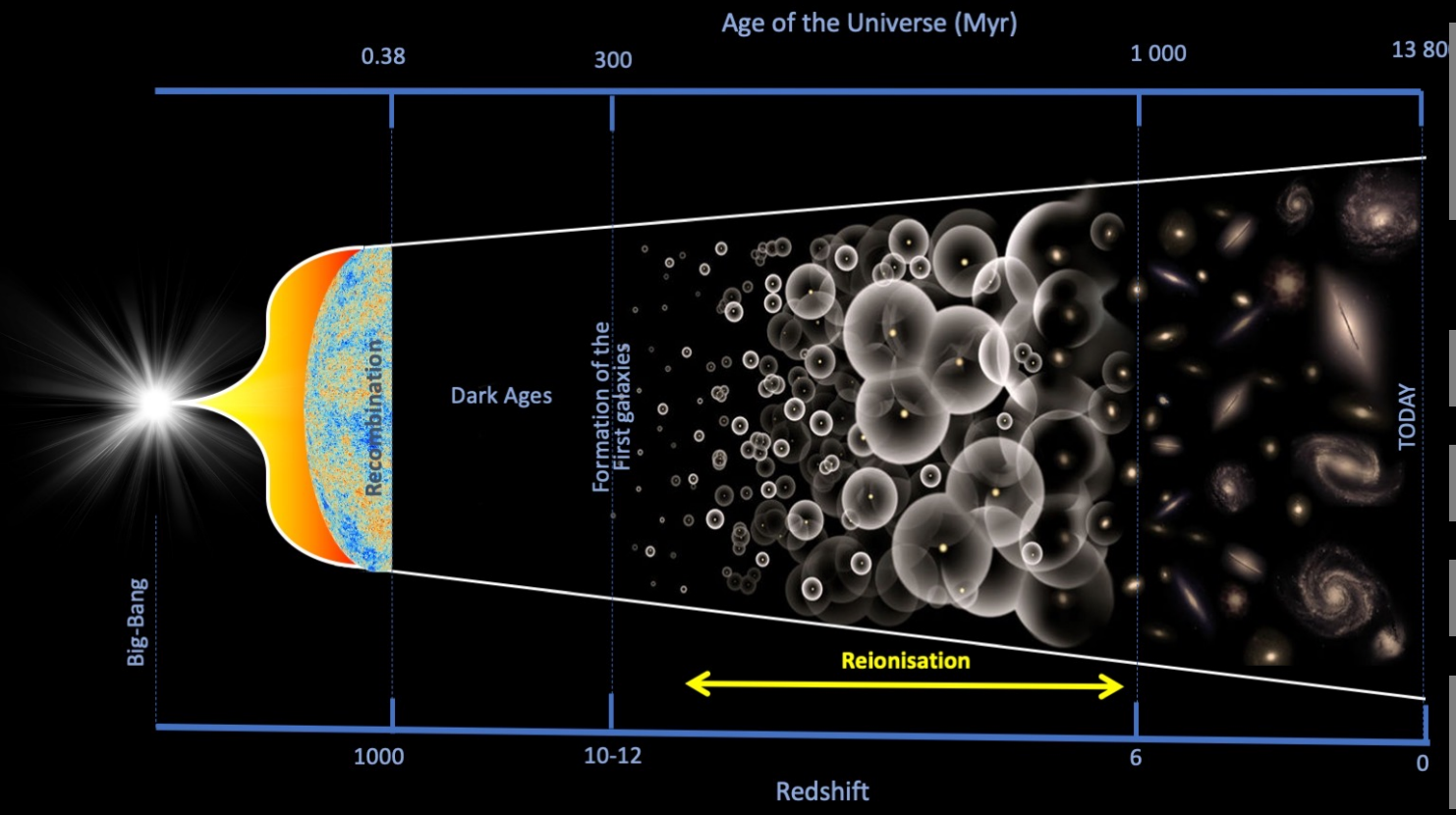
Kavli Institute for Cosmology Cambridge

KICC

New insights on the physical properties of the first galaxies

Nicolas Laporte – 15th September 2022

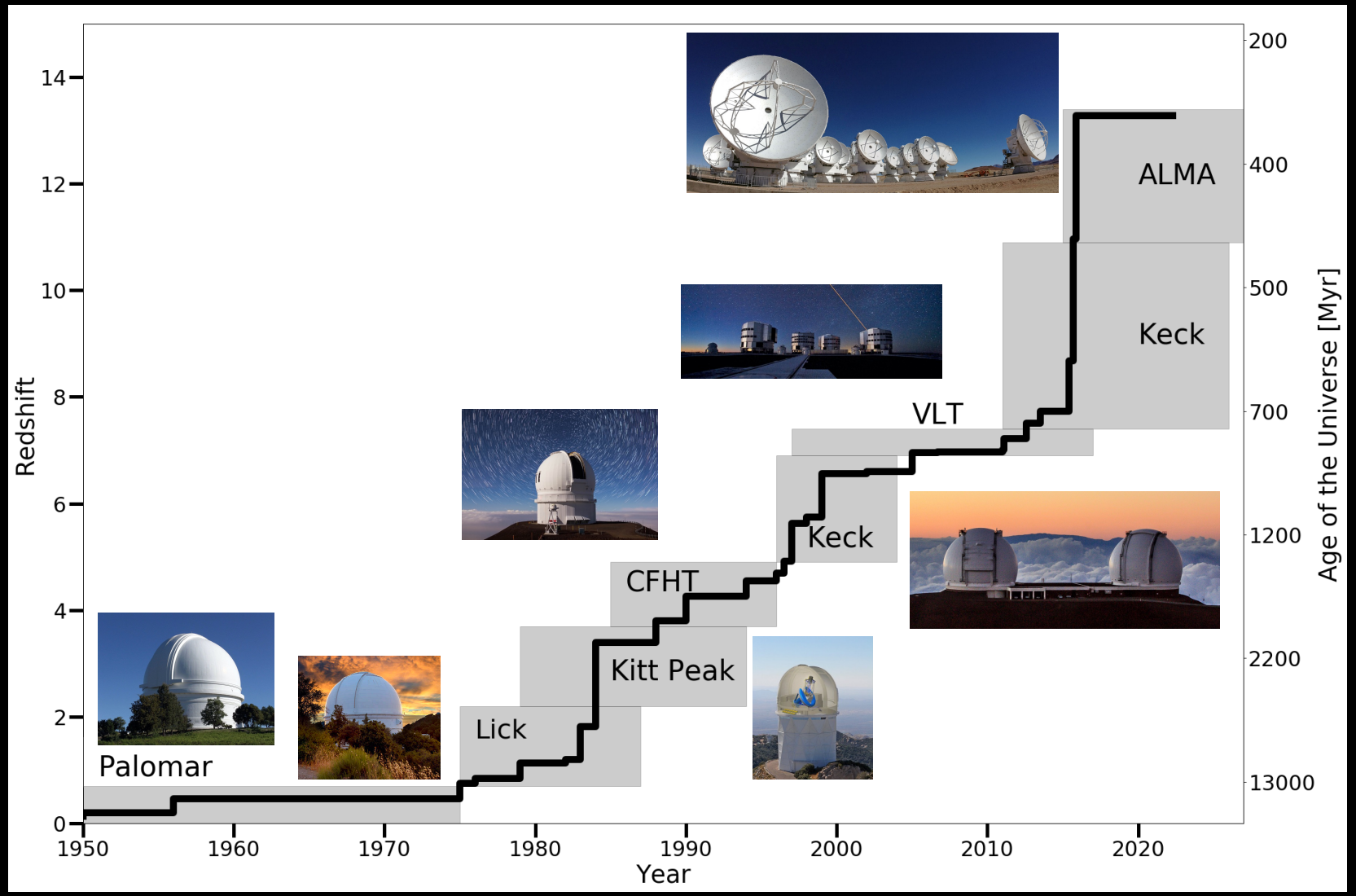
KICC Symposium

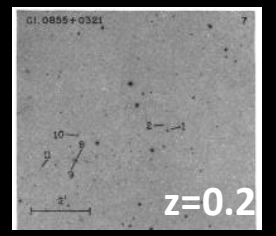


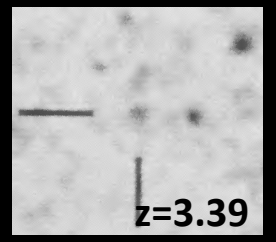
THE REMAINING UNANSWERED QUESTIONS

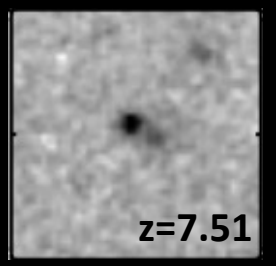
- When did the first galaxies form ?
- How did they form ?
- When did the first black holes form ?
- How did the first galaxies and black holes evolve over the first billion years ?

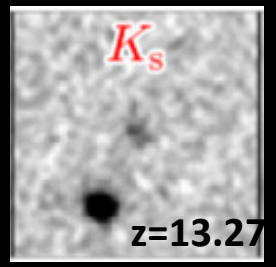
The "hunt" for the most distant galaxies since 1950











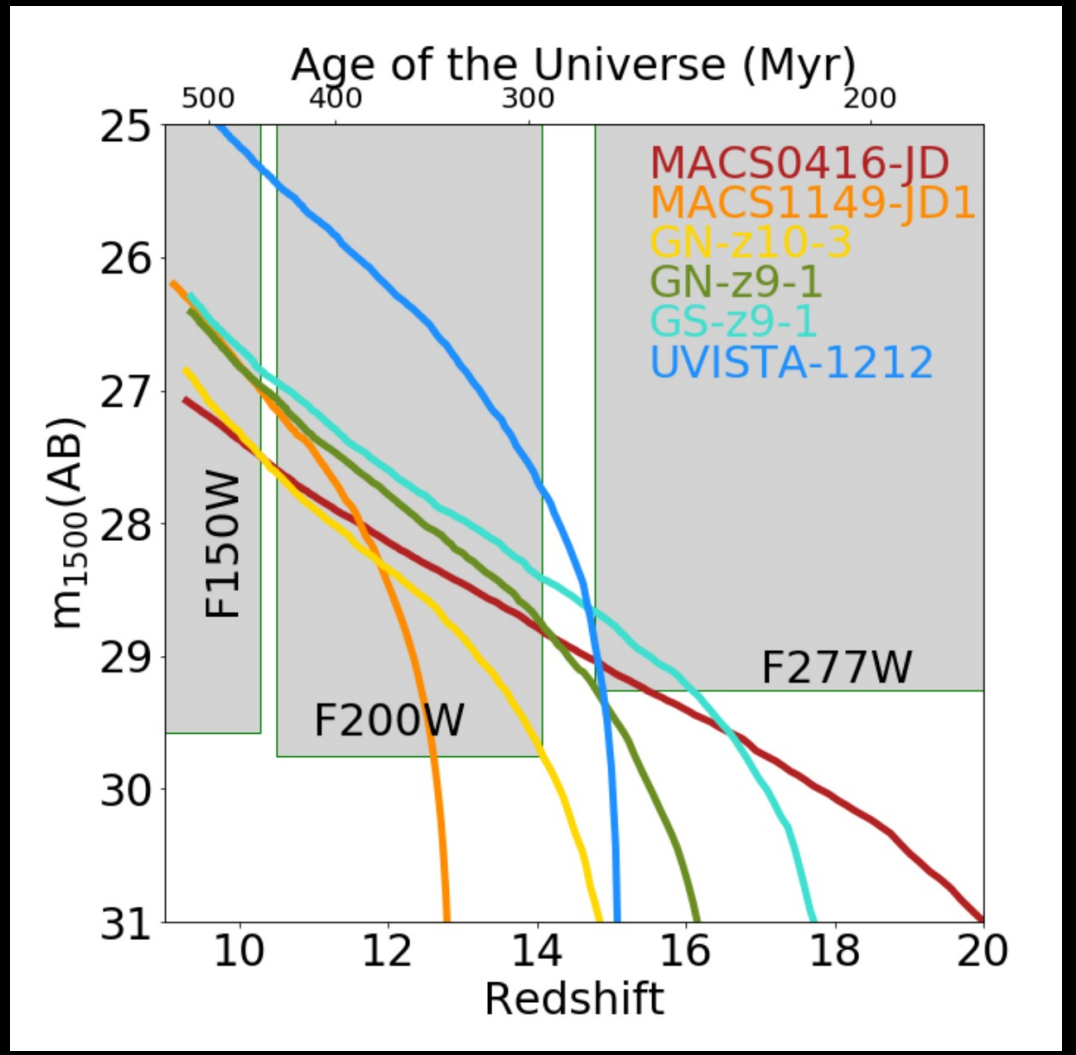
Humason et al. 1956
Minkowski 1960
Spinrad et al. 1975
Spinrad & Smith 1976
Smith et al. 1979
Spinrad 1982
Spinrad & Djorgovsky 1984
Lilly 1988
Chambers et al. 1990
Lacy et al. 1994
Petitjean et al. 1996
Franz et al. 1997
Day et al. 1998
Hu et al. 1999, 2002
Iye et al. 2006
Fontana et al. 2010
Vanzella et al. 2011
Ono et al. 2012
Shibuya et al. 2012
Finkelstein et al. 2013
Oesch et al 2014
Zitrin et al. 2015
Oesch et al. 2016
Harikane et al. 2022

When did the first galaxies form in the early Universe ?

Before July 2022, as far as our instruments/telescopes can see we still detect galaxies.

To probe the epoch when the first galaxies have been formed in the Universe, one has to measure the age of the most distant galaxies we can currently detect.

We did this exercise for the most distant galaxies spectroscopically confirmed and demonstrated that most of them have started to form stars at z>15.



Laporte et al. (2021)

When did the first galaxies form in the early Universe ?

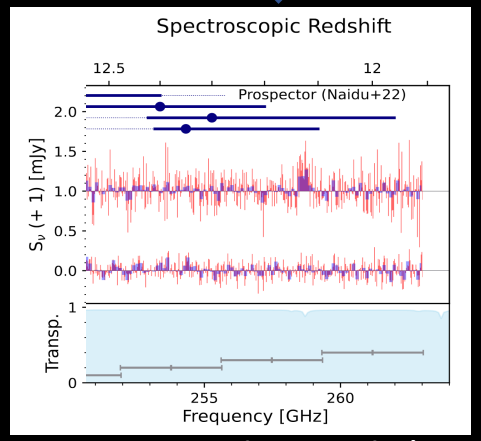
25th December 2021 – Kourou (French Guyana)

12th July 2022

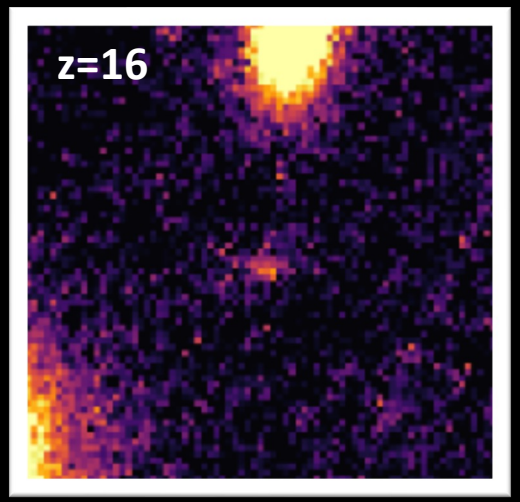
When did the first galaxies form in the early Universe ?

z=13

GLASS-z13 (Naidu et al. 2022)



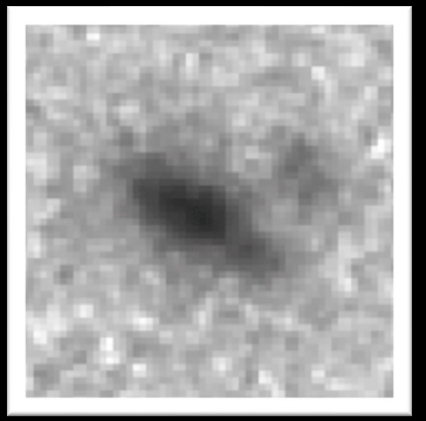
Bakx et al. (2022)



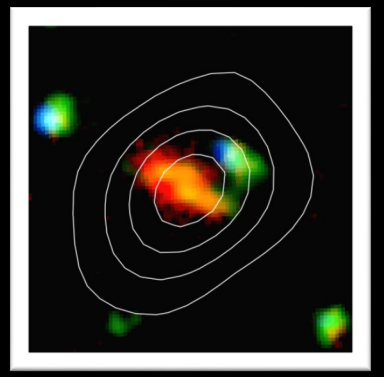
SMACS-z16a (Atek et al. 2022)

Within a week, 11 papers have been submitted using the first dataset from the JWST to search for the first galaxies.

z=17

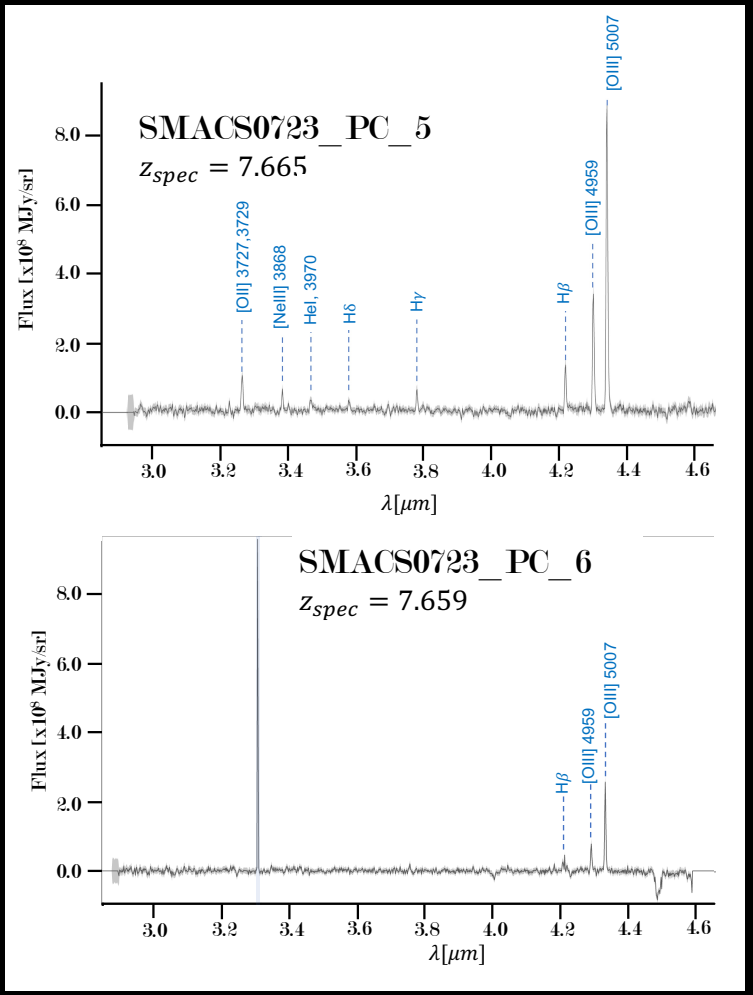


CEERS-DSFG-1 (Finkelstein et al. 2022)



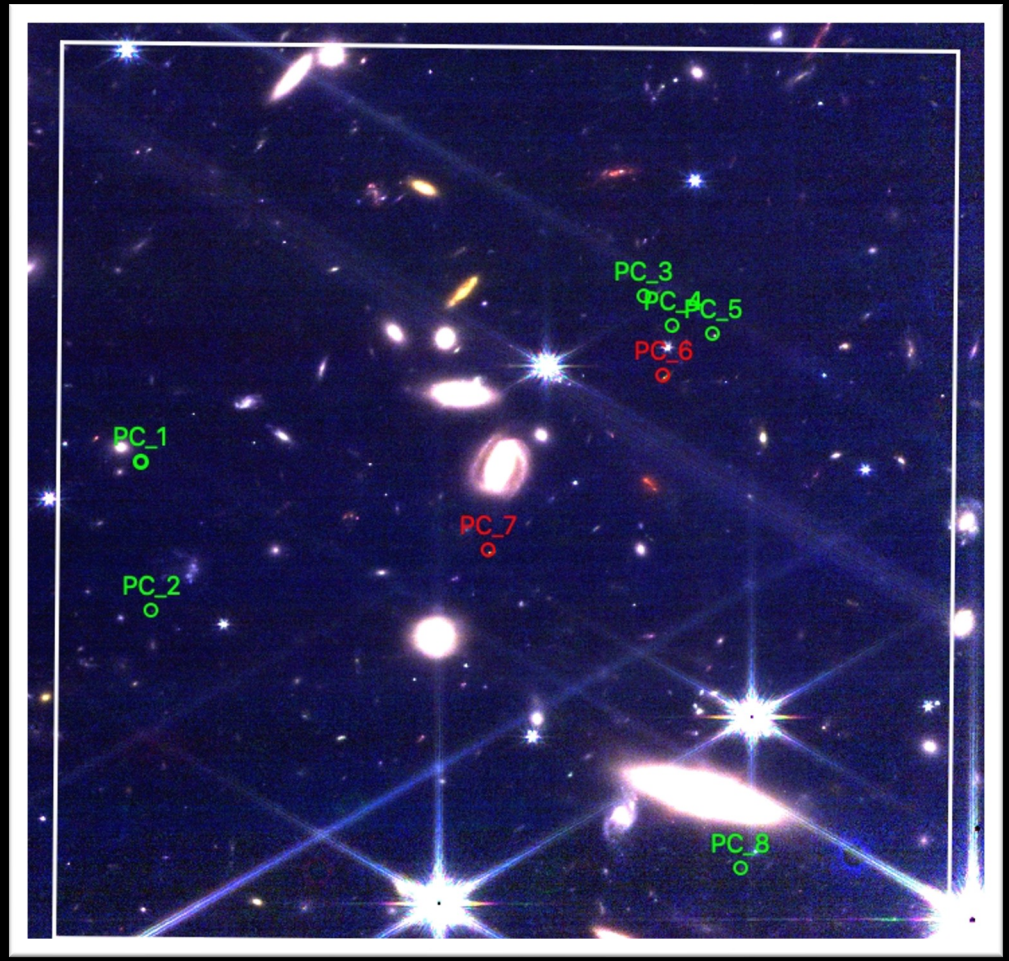
Zavala et al. (2022)

How did the first galaxies form in the early Universe ?

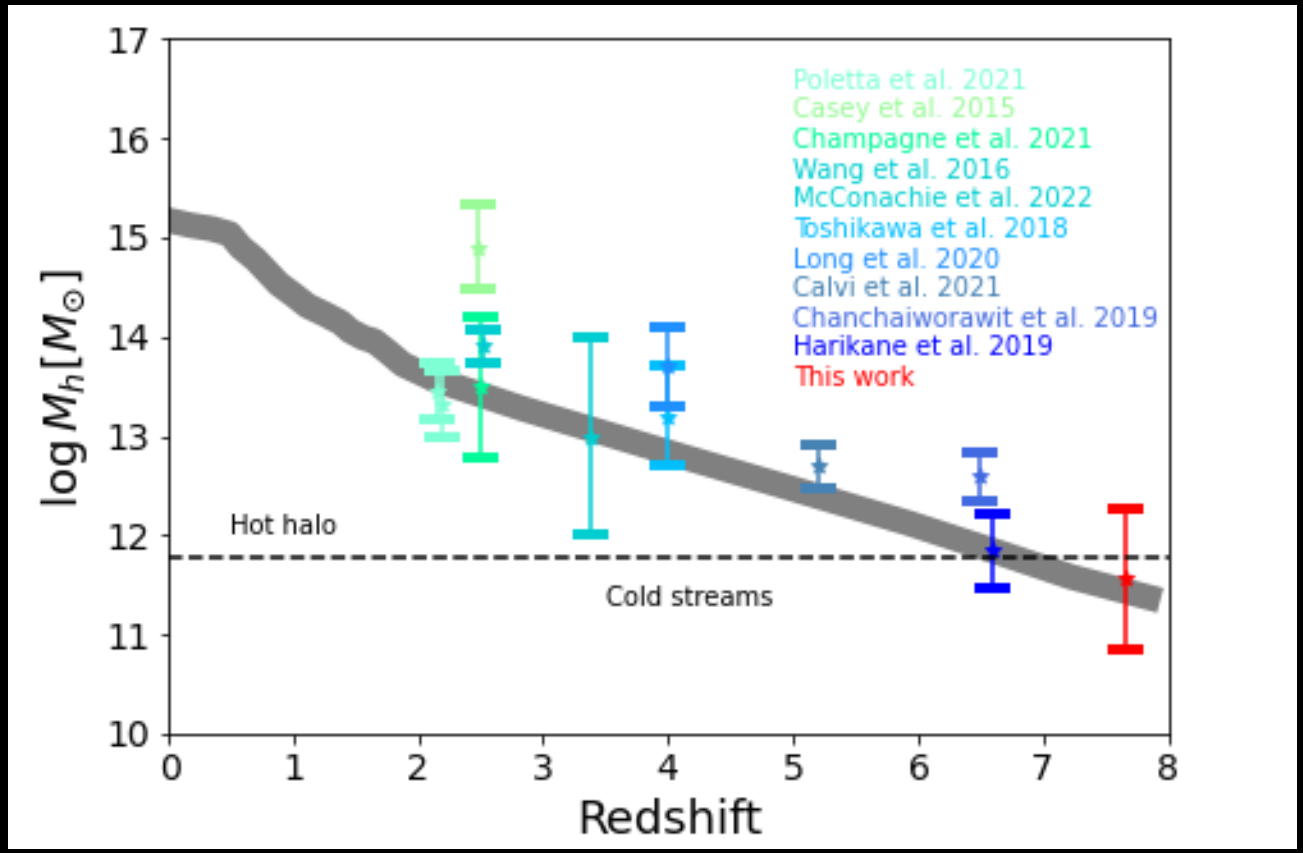


Two galaxies separated by 10'' are at the same redshift (z=7.66)

Looking for galaxies with similar properties in the entire field, we identified 25 objects including 8 in a 40''x40'' region

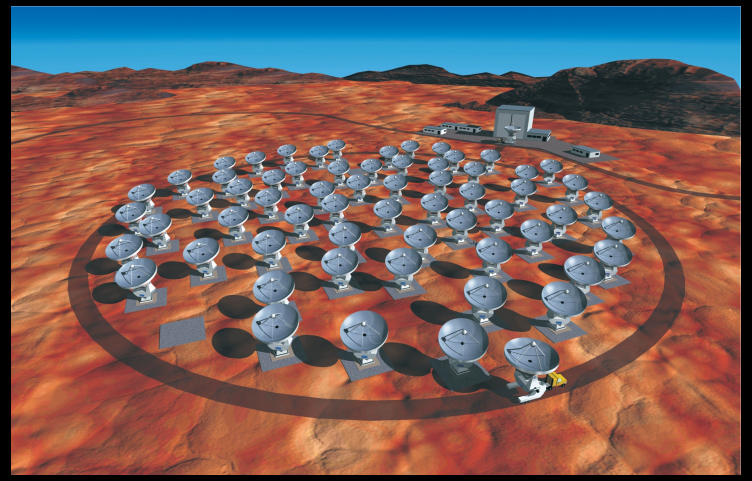


Laporte et al. (2022)

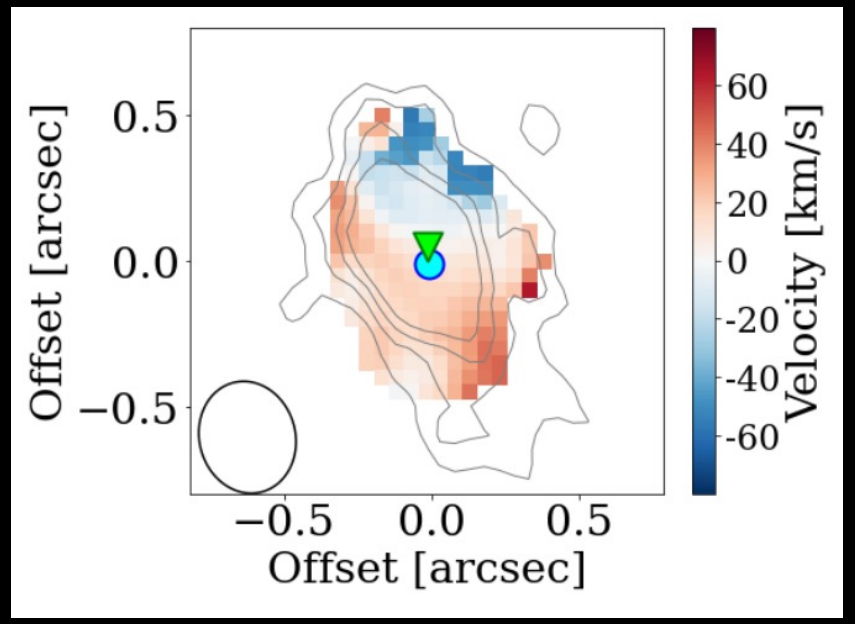


The total dark matter haloe mass of this protocluster agrees well with the expectation from the evolution of a Coma-like cluster.

How did the first galaxies evolve within the 1st billion years ?



- What are the properties of the most evolved galaxies at z>9 ?
- By using ALMA in its most extended configuration, we can get high-resolution data and therefore resolve the morphology of the first generation of galaxies.



Tokuoka,.., NL et al. (2022)

See also Smit et al. (2018), Tamura et al. (2019), Bakx et al. (2020)

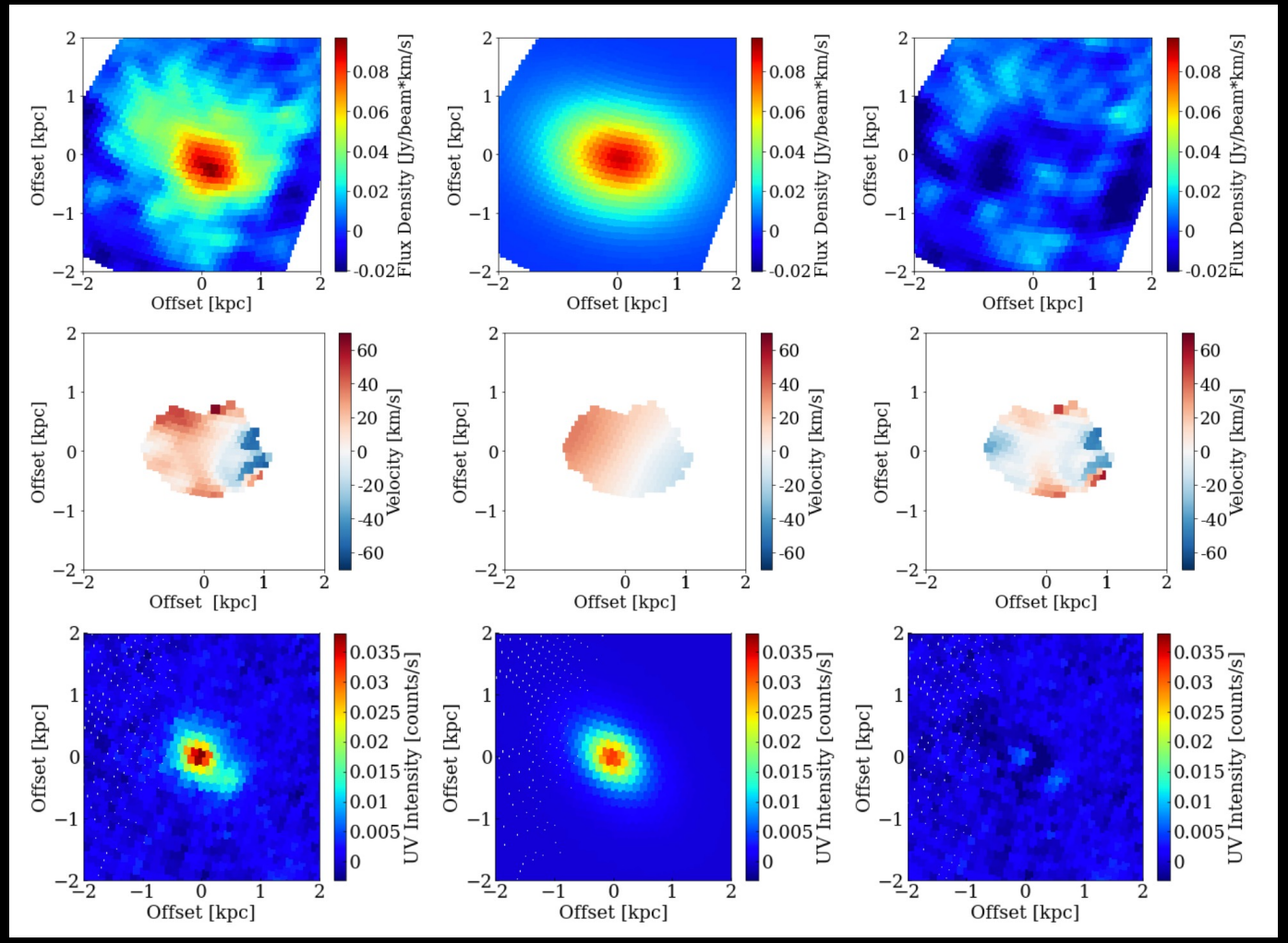
How did the first galaxies evolve within the 1st billion years ?

Observation | Model | Residual

[OIII]88μm

Velocity field

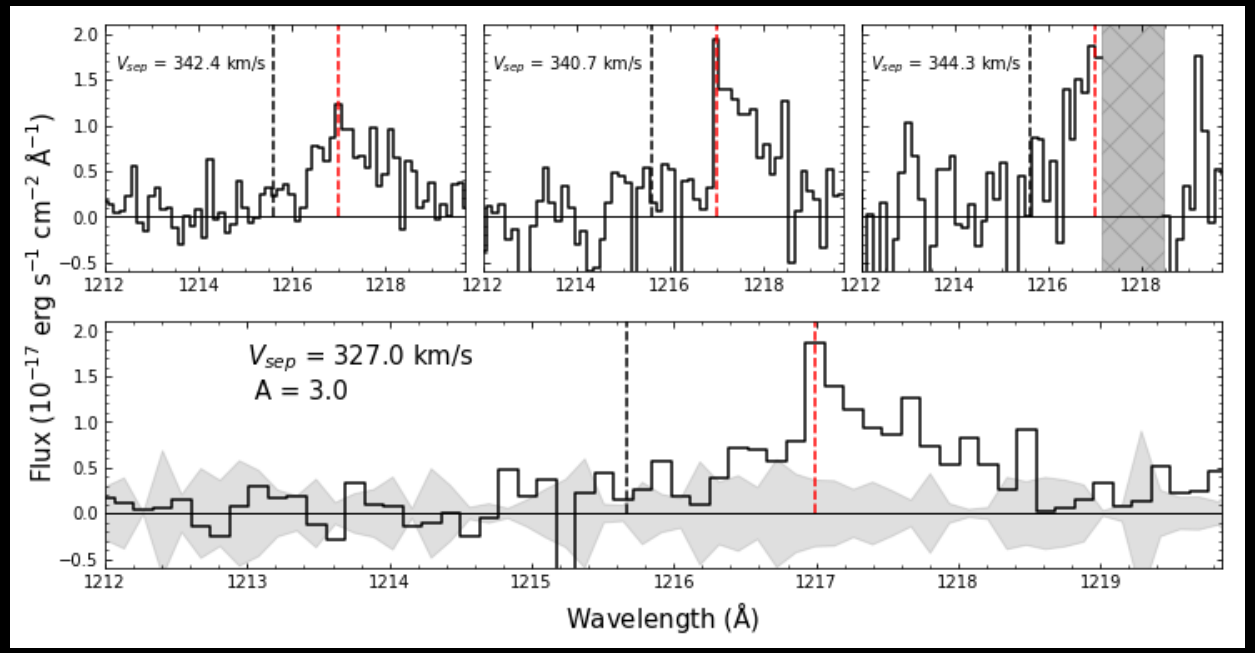
UV continuum



Tokuoka,.., NL et al. (2022)

- Modelling of the disk, assuming a thin rotating disk, gives good results
- BUT there is no positional agreement between the [OIII]88μm disk center and the peak of the velocity dispersion **which could be an indicator of a merger**
- The weaker Ly-α line shows a blueshift **which could also be another sign of a different component.**

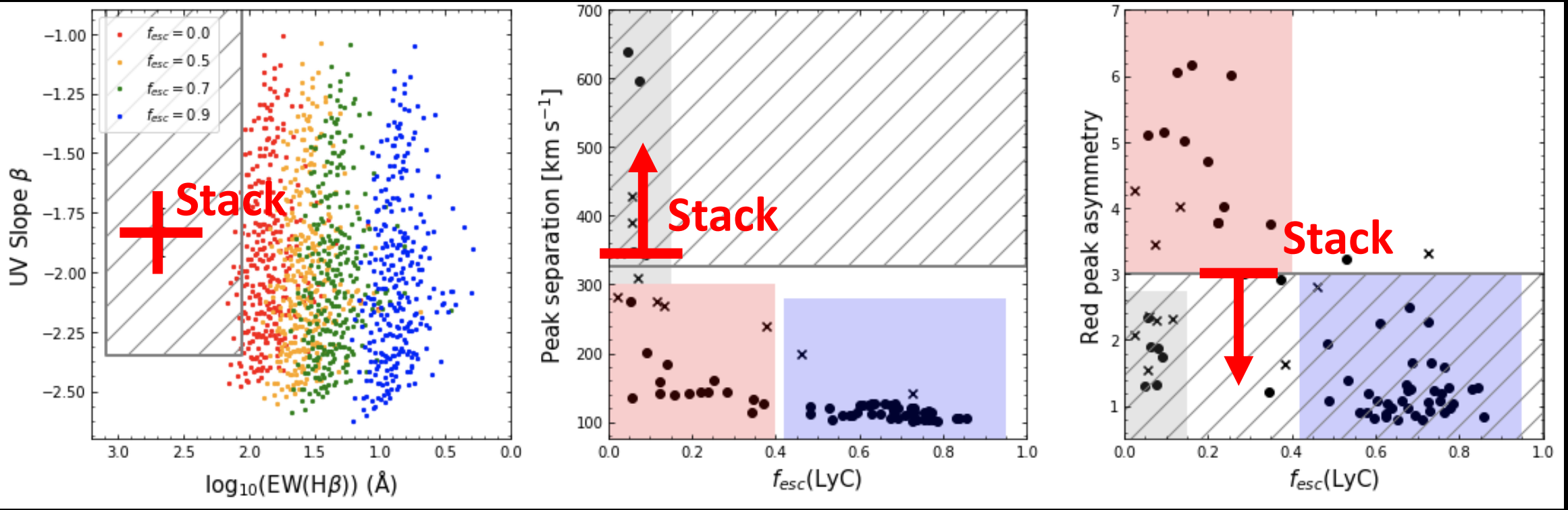
How did the first galaxies evolve within the 1st billion years ?



Witten, NL et al. (submitted)

- When the first galaxies formed in the early Universe they started to emit UV photons which ionised the neutral hydrogen formed after the Big-Bang.
- There is currently a debate to determine which galaxies have the larger contribution : the most massive or the smallest (less massive) galaxies ?
- To address this question, we stack the deepest spectra currently available in 8-10m class telescopes archive .

How did the first galaxies evolve within the 1st billion years ?



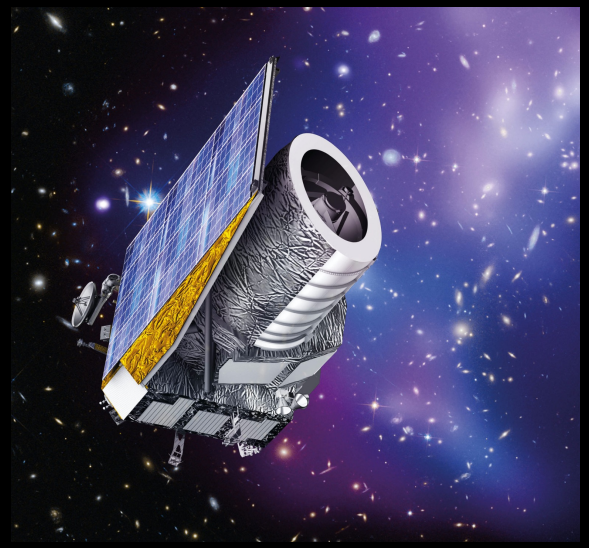
- **The galaxies in this stack are massive ($M_\star > 10^{10} M_\odot$) and it seems they are not strongly contributing to the ionization of the IGM**

- Caveat : this conclusion is only based on 3 galaxies at $z > 7$; more high-resolution spectra are needed to increase the sample size

Going further in the study of the properties of the first galaxies

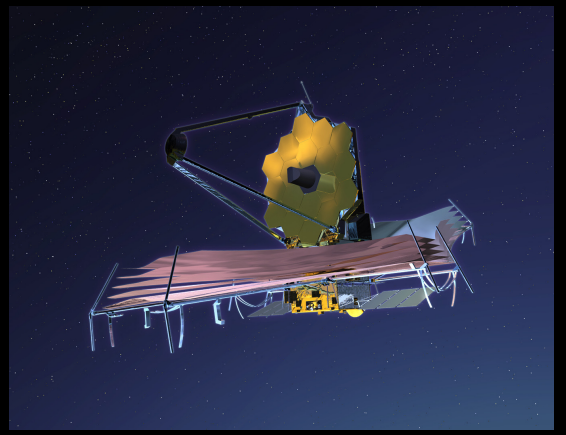
The continuum of z=6-7 galaxies by stacking 1000s spectra

Identifying AGN candidates at z>6 in its large surveys

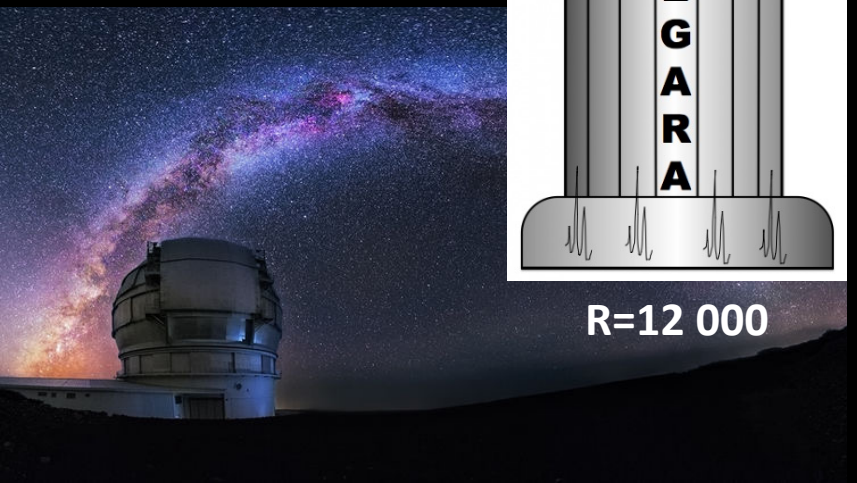


Direct observations of Cosmic Dawn

Number densities of the faintest galaxies at z>8



The shape of Ly-α at z=6-7 with high-resolution spectrograph



MEGARA

R=12 000

The spatial distribution of ionising sources by identifying ionised bubbles at z>6

SKA
SQUARE KILOMETRE ARRAY

MOSAIC

The metallicity of 1000s of z>6 galaxies with extremely Large Telescope