Unveiling the history of the Universe's re-ionisation

J.M. Rodríguez Espinosa (IAC), J.M. Mas-Hesse (CAB-INTA),
R. Calvi (IAC), and the ALBA team

Extremely Big Eyes on the Early Universe, Roma September, 2019

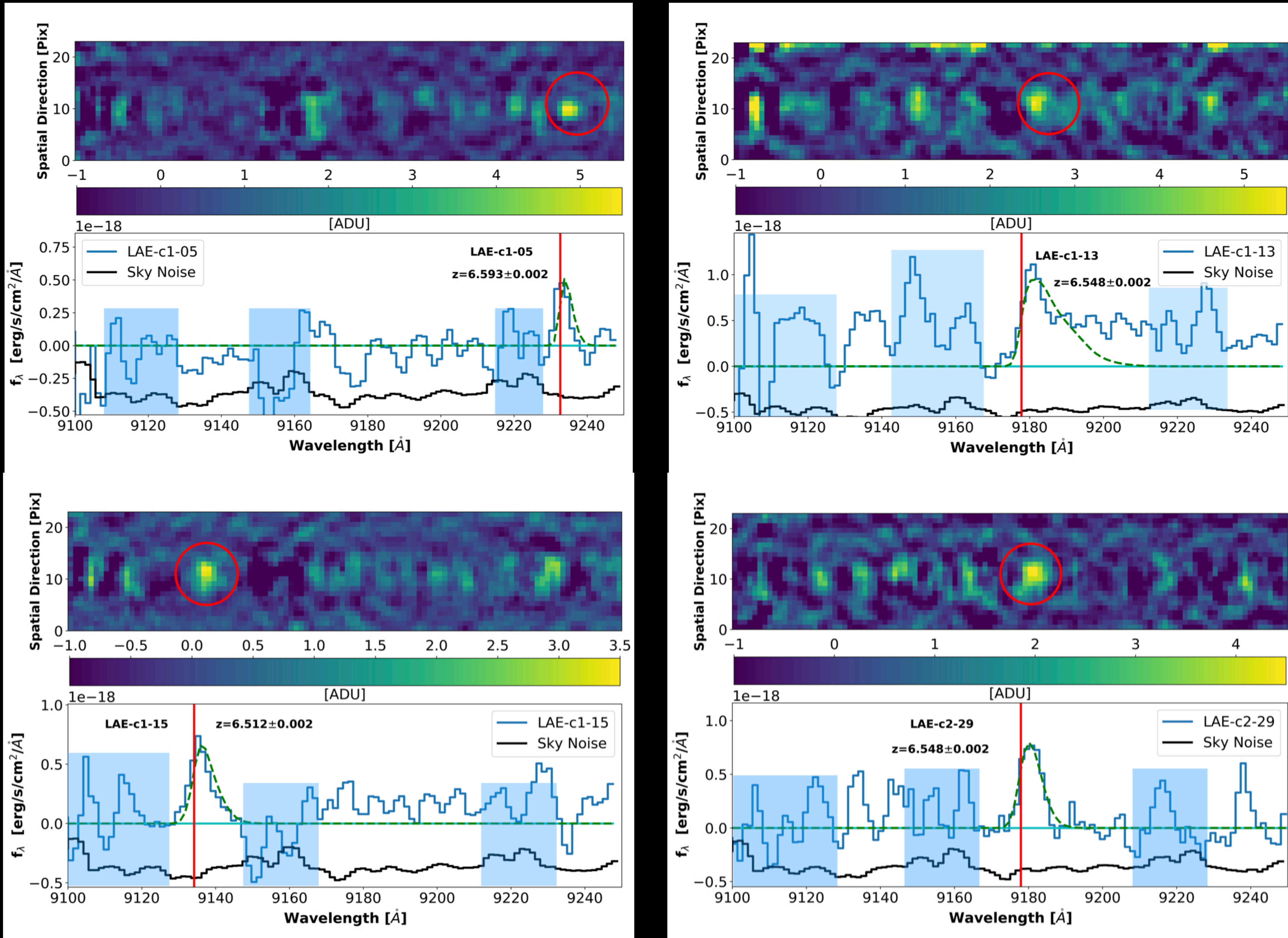
A proto-cluster discovered with GTC/OSIRIS

- Pratica Dayal made en excellent introduction to this talk

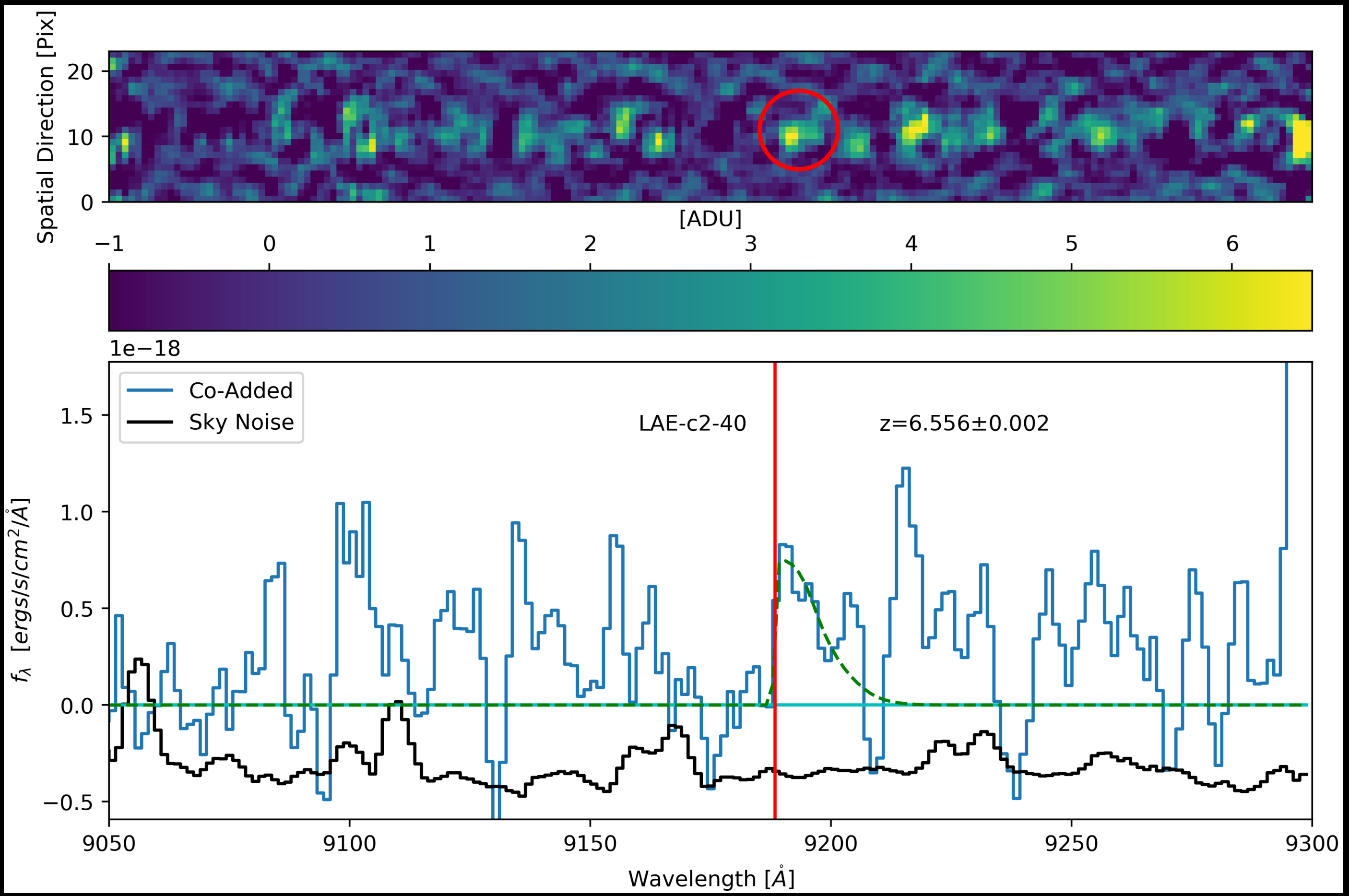
- Indeed the best way to follow the history of reionisation is with proto-clusters

The proto-cluster

- We have discovered a proto-cluster at z~6.5 in the SXDX, consisting of 45 sources (Chanchaiworawit+2018, 2019)
- We have confirmed the proto-cluster spectroscopically
    - We securely detected 12 out the 17 sources we could fit in one mask (Calvi+2019, in press).



A-type sources



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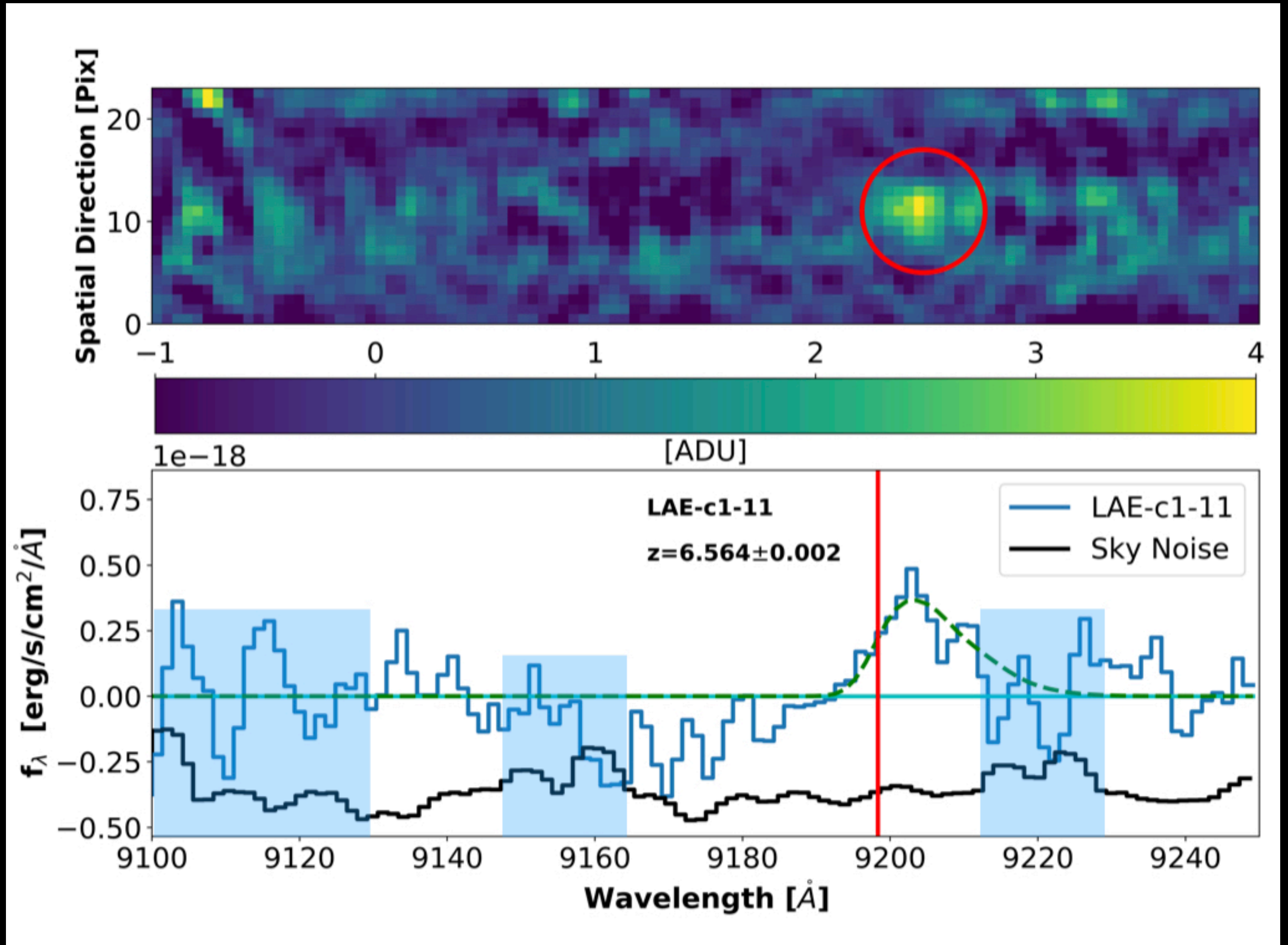
f_λ [ergs/s/cm^2/Å]
Wavelength [Å]



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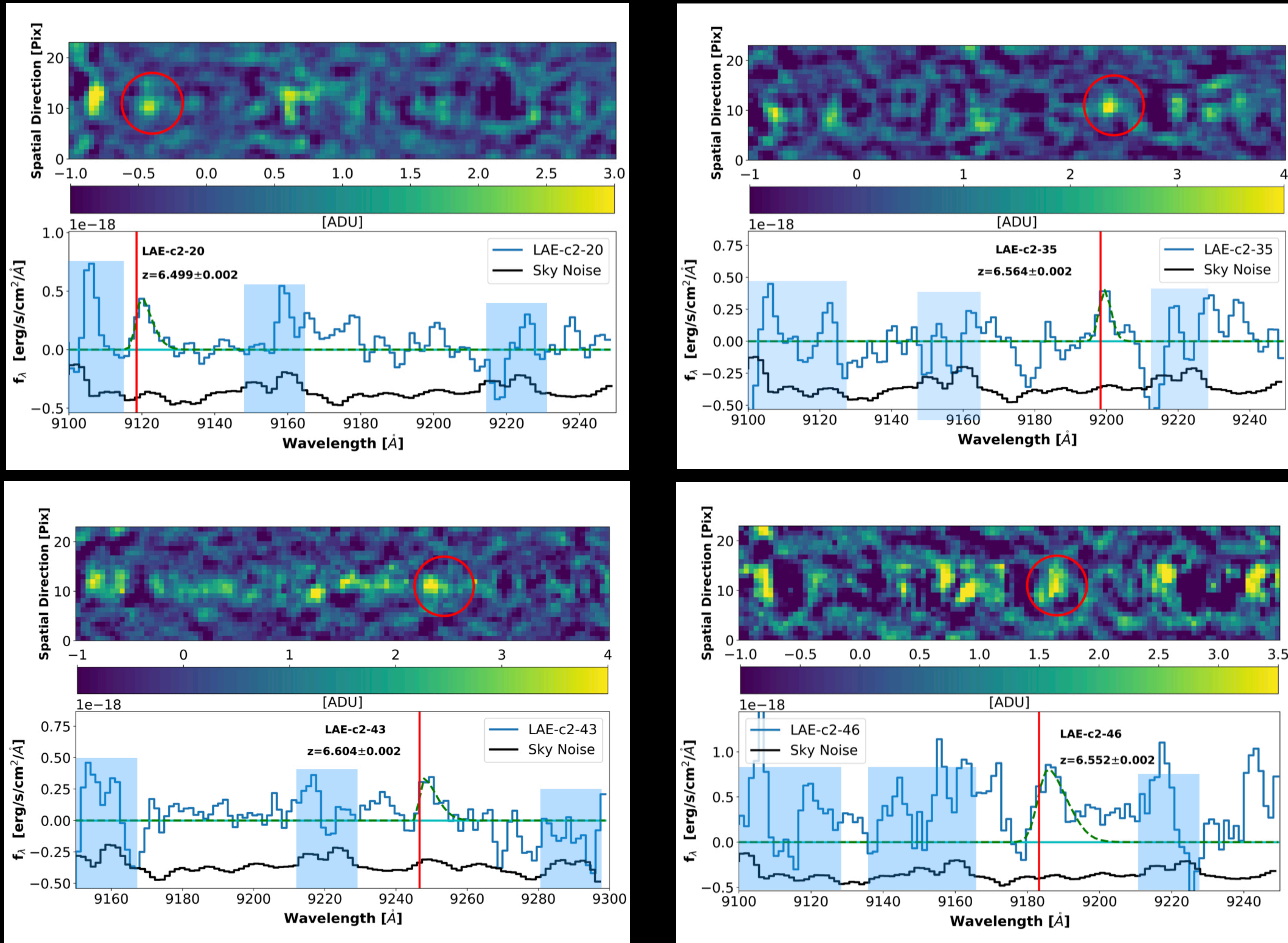


B-type sources

The data

- Lyα fluxes and observed luminosities from the spectra
- We derived $f_{esc,Ly\alpha}$ (Chanchaiworawit+2019)
- Then, the Intrinsic Lyα luminosities are Lyα_intr= Lyα_obs/$f_{esc,Ly\alpha}$
- From the intrinsic Lyα luminosities we derive the number of ionising continuum photons N_{ion} for typical HII regions
- We also derived the expected X-ray luminosities, coming from SN and stellar winds
- Then the mechanical energy produced by the proto-cluster is ~5% of X-ray production

Mechanical energy output

- The mechanical energy output is huge
- The mechanical energy is enough to pierce holes in the CGM
- Thus ionising continuum photons are able to escape

M 82 (NGC 3034) FOCAS (B, V, Hα)
Subaru Telescope, National Astronomical Observatory of Japan March 24, 2000

Assuming various $f_{esc,LyC}$

- We assume typical values for the escape fractions of LyC photons such as: 0.1, 0.15, 0.2 and 0.3

- N_{ion} produced by the proto-cluster: 36.38, 38.52, 40.92 & 46.77 x 10^{54} s^{-1}, depending on the $f_{esc,LyC}$

- And using the volumen calculated for the proto-cluster (9242 ± 1427 $cMpc^3$) and the ionising emissivities given by Finkelstein+2012, we derive the volumes ionised by the proto-cluster ($V = N_{ion}/\dot{N}_{ion}$)

Volumes derived

From Finkelstein+2012, at z~6.5

$f_{esc,LyC}$	$\dot{N}_{ion}$ 10^{51} $s^{-1}Mpc^{-3}$	Ionised volume $cMpc^3$
0.1	4.90	7410 ±841
0.15	3.02	12732 ±1467
0.2	2.32	17608 ±2000
0.3	1.74	26833 ±3046

- Note that for $f_{esc,LyC}$~0.15 the volume ionised is larger than the proto-cluster volume (Rodriguez Espinosa+2019, submitted)

Recently however

- Finkelstein+2019 has derived a model whereby they predict an ionising emissivity, $\log\dot{N}_{ion}$= 50.625 $s^{-1}Mpc^{-3}$, at z=6.5, for reionising the Universe with a very low escape fraction

- They assume a low escape fraction of LyC~0.05 through the bulk of the Epoch of Reionisation

- Using this scenario we get an ionising emissivity of $\log\dot{N}_{ion}$= 51.57s^{-1} Mpc^{-3} for the proto-cluster

- Which is an order of magnitud larger than required for reionising the whole proto-cluster plus the IGM around it

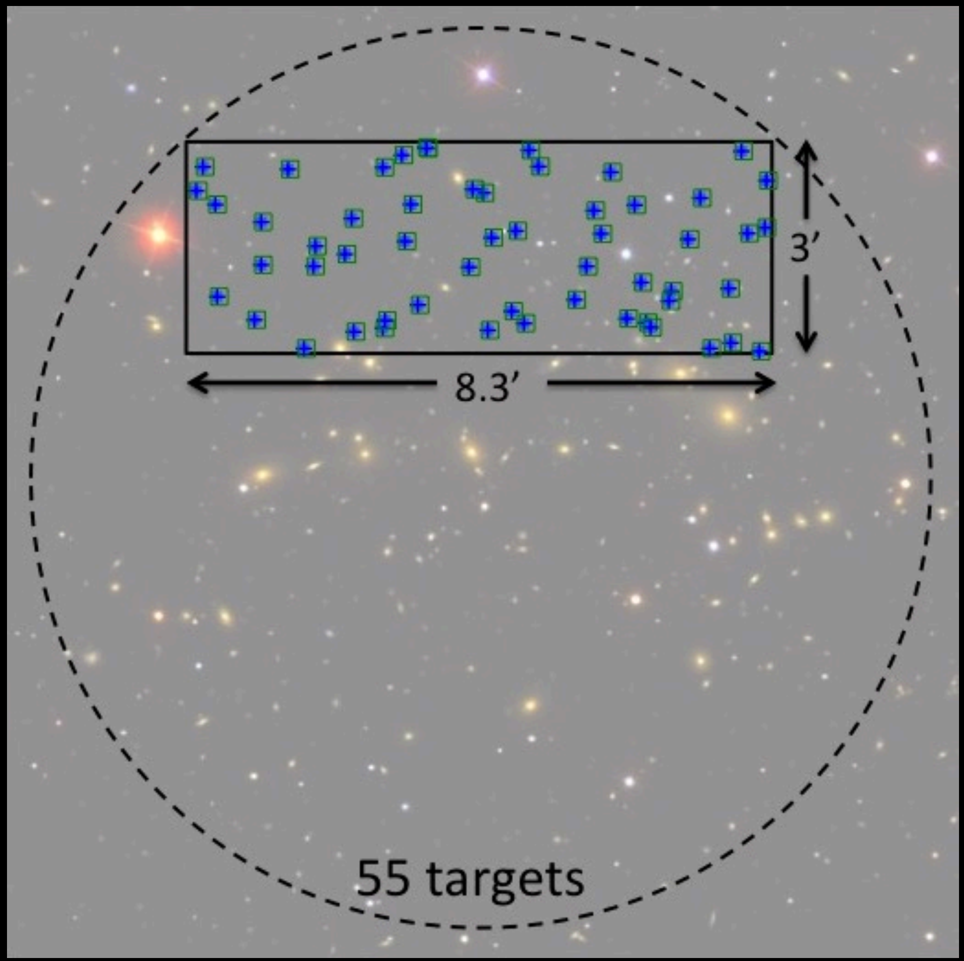
- So in this scenario of low escape fraction the ionised bubble is still there!

TMT could perform a census of Ionised bubbles

- WFMOS could be used in slit-less (substituting the mask with several narrow band filters) to search for groups of Lα sources

- Large field (25.5 arcmin^2) and low res spectroscopy would be ideal

- Could patrol a cosmological Field (i.e. GOODS-N, the SXDX, etc.) searching for Lyα proto-clusters at redshifts 6 to 7.25



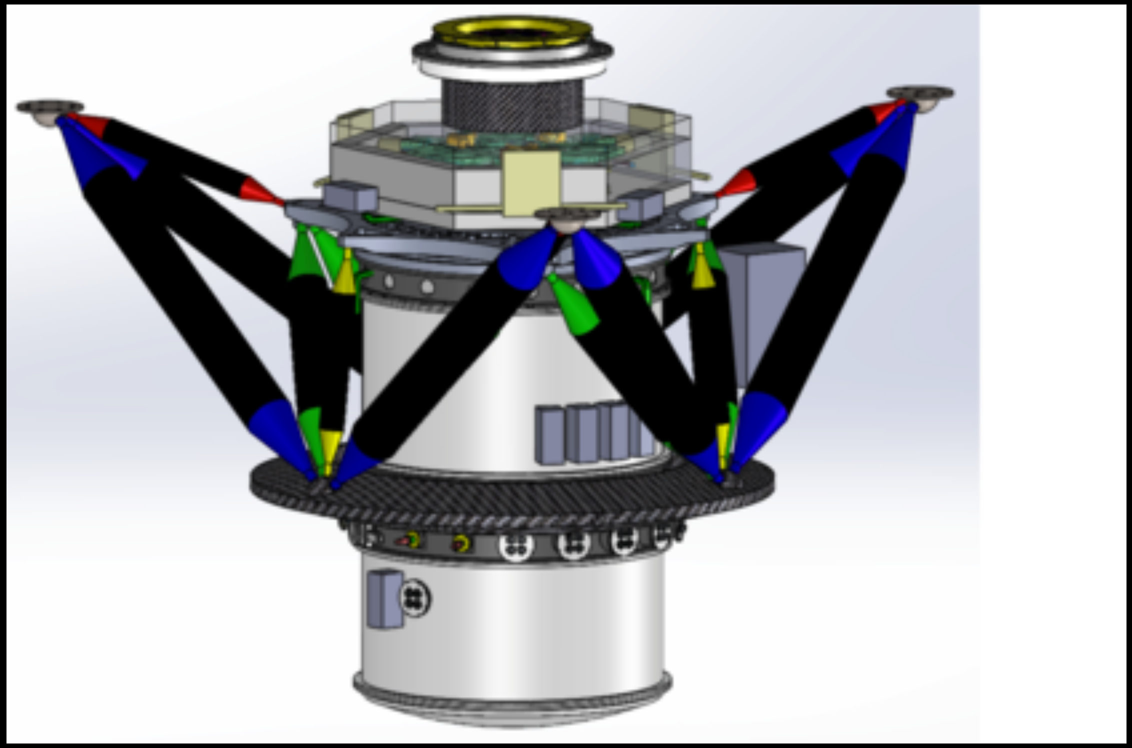
- For instance for the GOODS-N field we require 5 positions to cover entire field

- If using NFIRAOS, 0.5 hour is needed for each pointing and for each narrow band filter.

- So if 5 narrow band filters are used, 12.5 h would be needed with the TMT!

The field can from now on be narrowed to use TMT/IRIS

- IRIS, in its imaging mode with narrow band filters could also be used at a lower survey pace (given the smaller field)



Searching for protoclusters at high redshifts

- These proto-clusters most probably will have produced ionised bubbles.
- The number of ionised bubbles at each redshift will tell the history of the Universe’s reionisation
- So we need to follow the number of ionised bubbles versus z
- In the future ARISE/TMT would be very useful (5’x5’ field; 0.31-4.8μ range)

Summary for ELTs

- Large FoV instruments to make blind surveys in the optical and Near IR are required!
- A census of high-z proto-clusters will unveil the history of the Universe’s reionisation
- Proto-clusters such as the one we have found