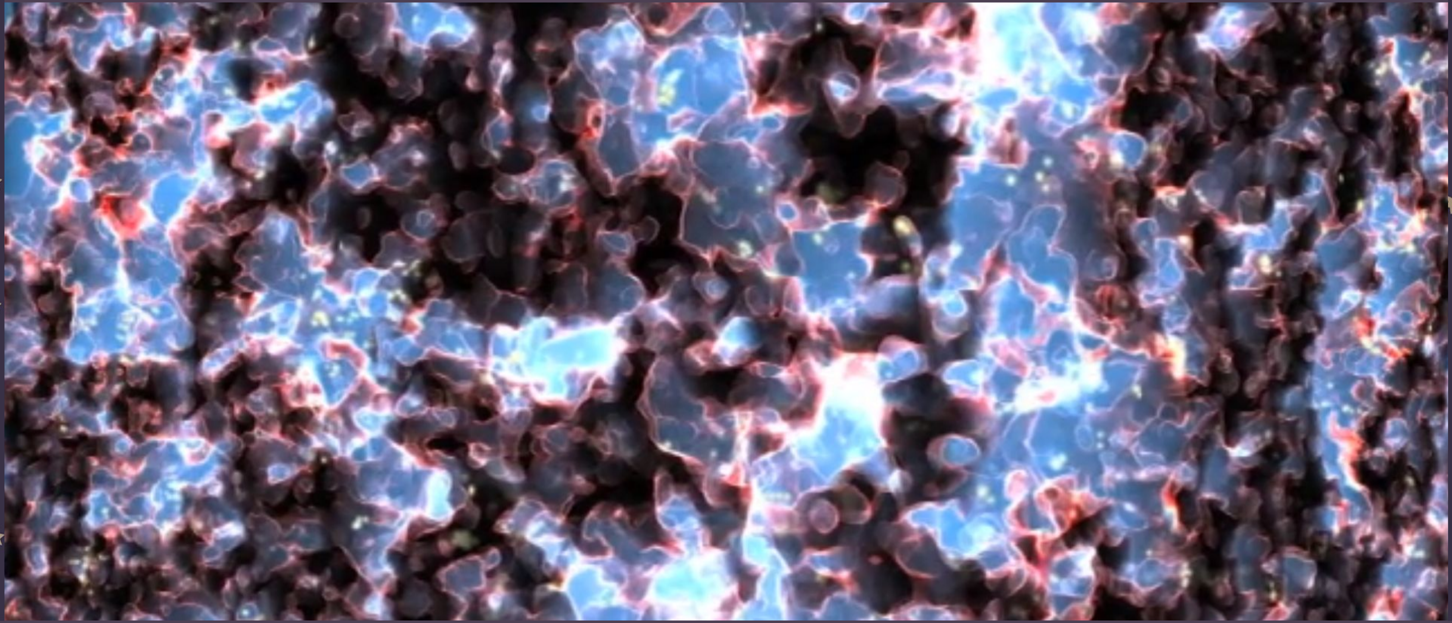
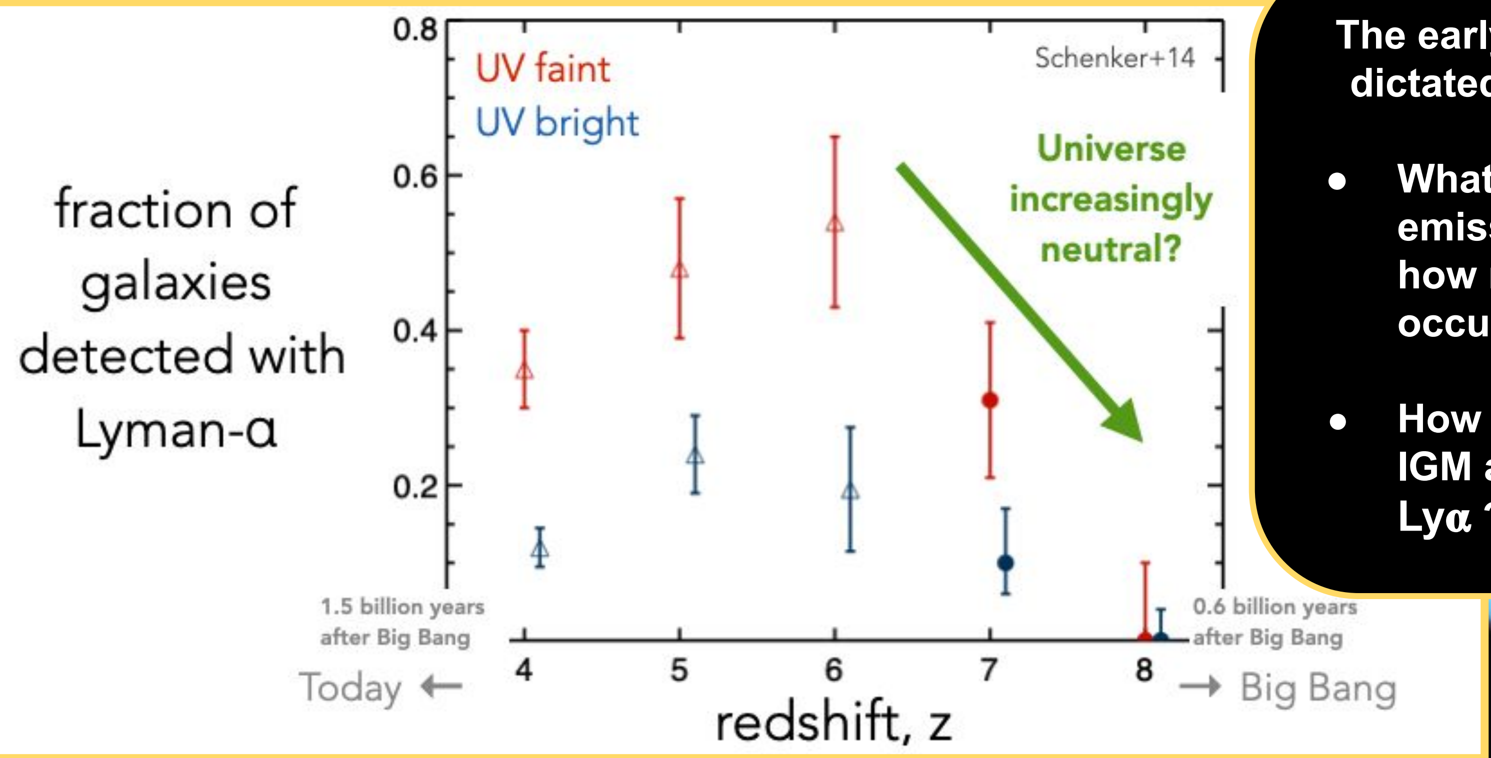
Lyman Alpha Velocity Offsets:
The transmission of Lyman-alpha from UV-faint galaxies



Gonzalo Prieto-Lyon
Charlotte Mason
+ the GLASS-ERS team

DAWN

UNIVERSITY OF COPENHAGEN



The early IGM structure is dictated by the galaxies.

- **What can Lyman Alpha emission tells about how reionization occured?**
- **How can we disentangle IGM and ISM effects on Lyα ?**

How can we disentangle IGM and ISM effects?

- Looking at the emerging line profile of galaxies not affected by reionization. Outside of the EoR.
- As of now we do not know how this looks like for the bulk of faint high-z galaxies
- JWST gives us rest-frame optical coverage :
  Systemic Redshifts !

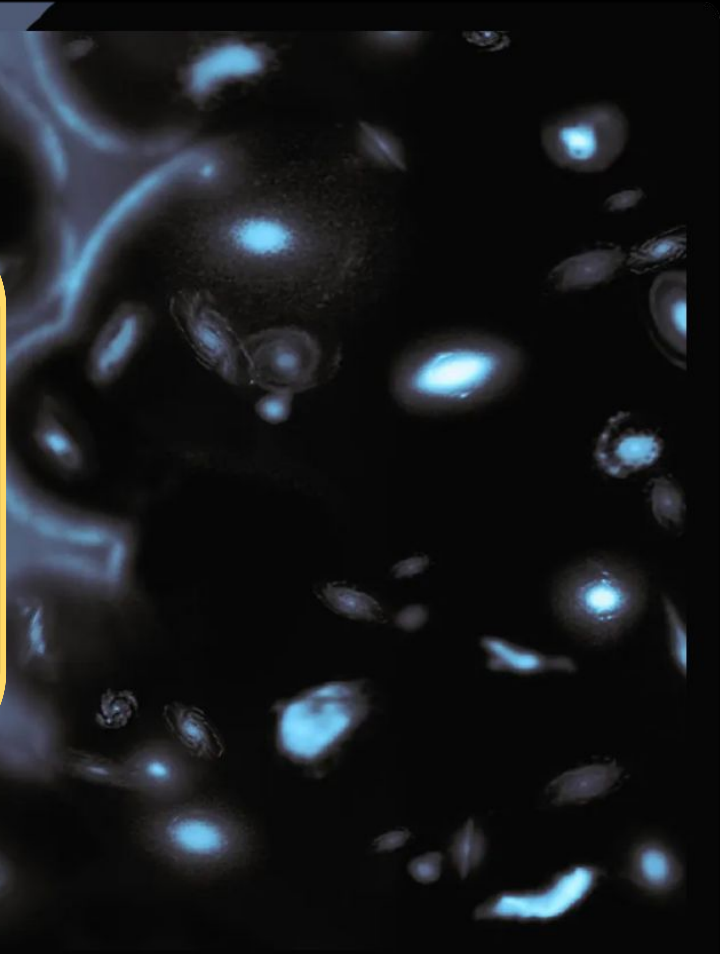
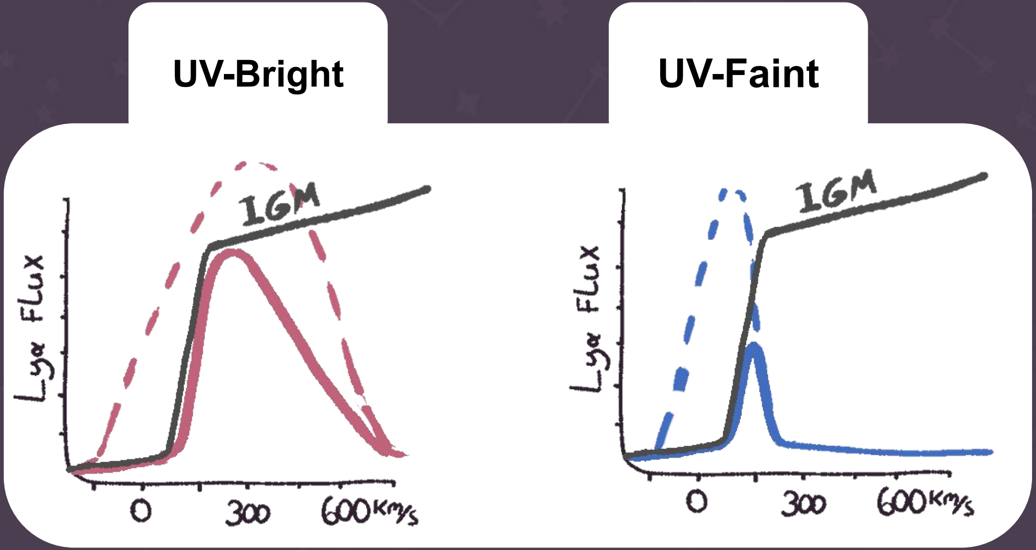


ILLUSTRATION: CHRISTOPHE CARREAU/ESA/SCIENCE SOURCE

Our best companion at the Epoch of Reionization : Lyman Alpha



- Transmission in the ISM affects transmission in the IGM.
- Lyα photons resonantly scatter in the HI ISM - emergent line profile usually shifted redward of systemic
- What does Lyα look like when it leaves a faint galaxy?

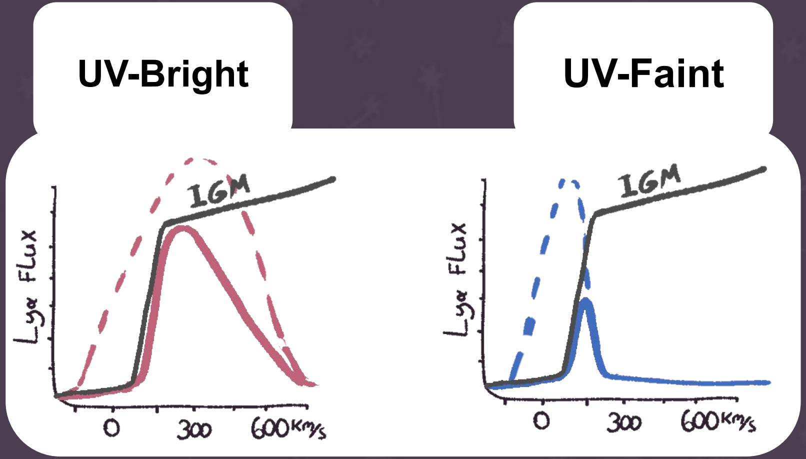
e.g. Miralda-Escude 98, Dijkstra 2014, Mesinger+15, Mason+18

Lyman-Alpha Velocity Offsets of UV-faint galaxies

First look into the emergent Lyα velocity offset of UV-faint galaxies

Galaxies outside the EoR (z ~ 3 - 6)

Prieto-Lyon+23b



What can we learn of ionizing bubbles by measuring Lyα velocity offsets ?

Spectra of z ~ 3 - 6 UV-faint galaxies, Abell 2744

- **JWST / NIRSpec [** GLASS **] :**
  - Follow up of already detected Lyα galaxies.
  - H-α and [OIII] emission lines to measure systemic redshifts and Lya velocity offset
- **VLT / MUSE**
  - Richard et al. 2021. Lyman-α detections in Abell 2744

PI: Treu

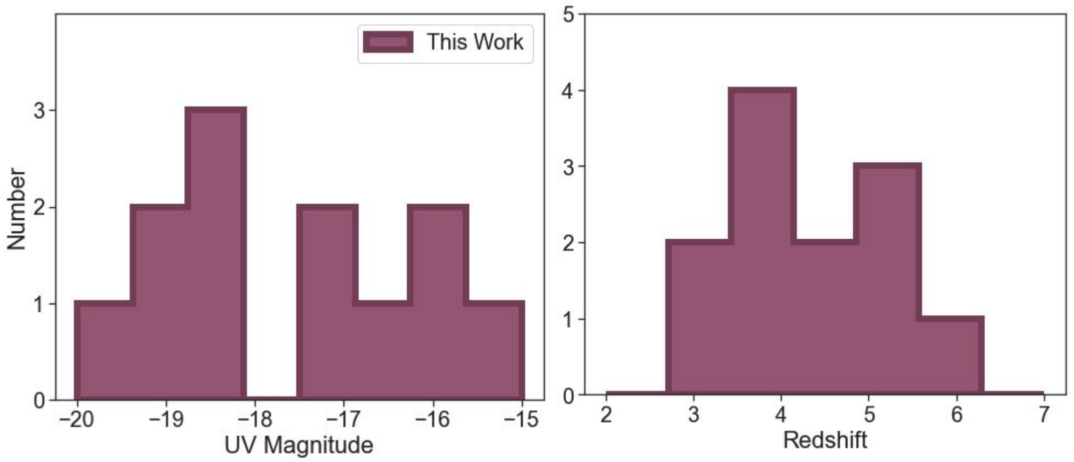
Rest-frame optical emission lines of UV-faint galaxies

- **Total sources : 12 (NIRSpec) GLASS , z = 3 - 6**

- Randomly selected from known Lyman-Alpha galaxies (MUSE).

- Offset with systemic redshift. [OIII] and / or Hα in NIRSpec R~2700

Prieto-Lyon+23b.

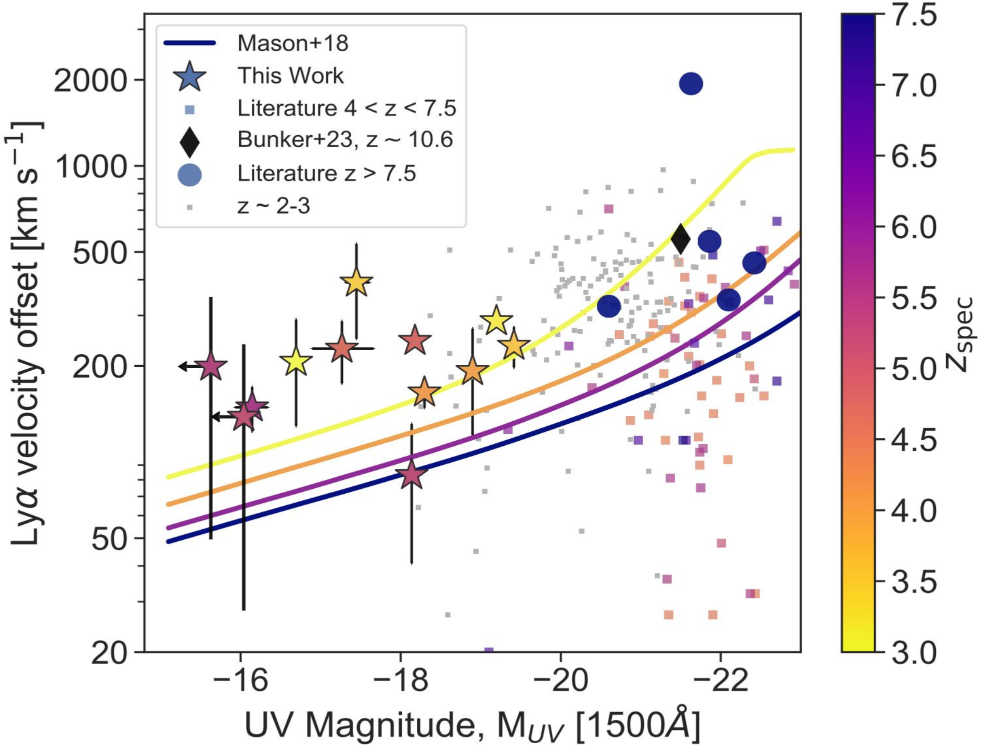


Richard+21, Treu+22

We find low velocity offsets in UV-faint galaxies at z ~ 3 - 6 !

- **Magnitudes never seen before at z>3. Muv > -18**
- **Emergent low velocity offsets ~ 200 km/s**
- **Helps explain low visibility of Lyman-Alpha in UV-faint galaxies during reionization.**

Low emergent velocity offsets = Difficult transmission through IGM at EoR

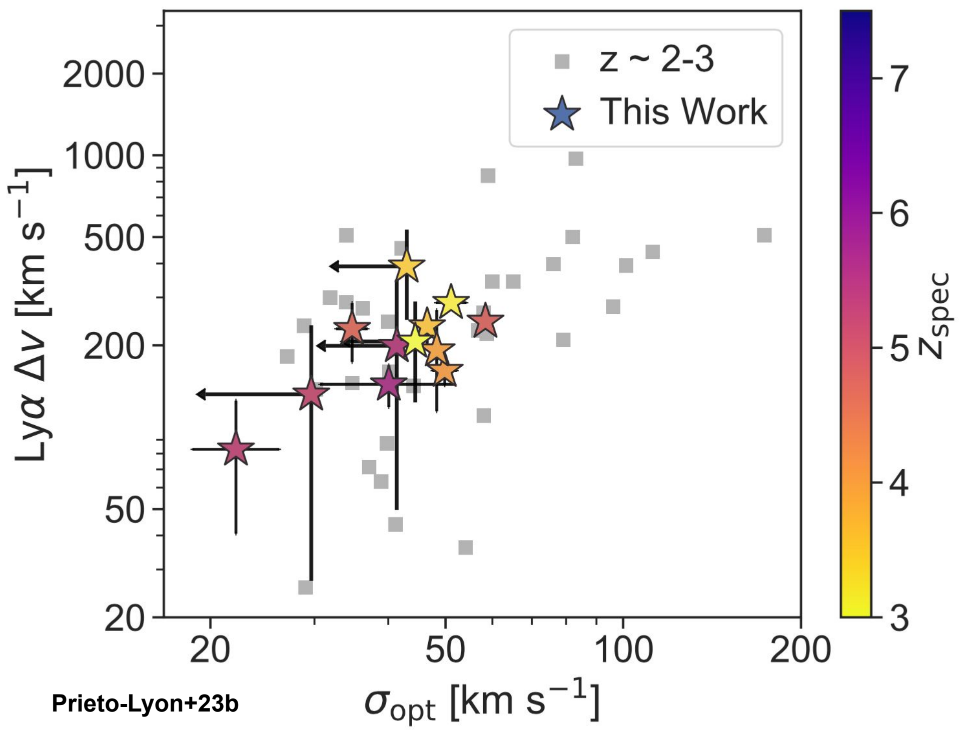


Prieto-Lyon+23b

e.g.Stark+15, Willott+15, Bradac+17, Inoue+16, Mainali+18a, Pentericci+16, Stark+17, Endsley+22, Cassata+20, Tang+23, Mason+18

Evidence of Lyα velocity offsets relation to Galaxy Mass

- Dispersion of optical lines, probe of dynamical mass.
- In low mass galaxies:
  Lyα is likely to emerge with low velocity offsets.
- Low mass galaxies, likely to have lower NHI.

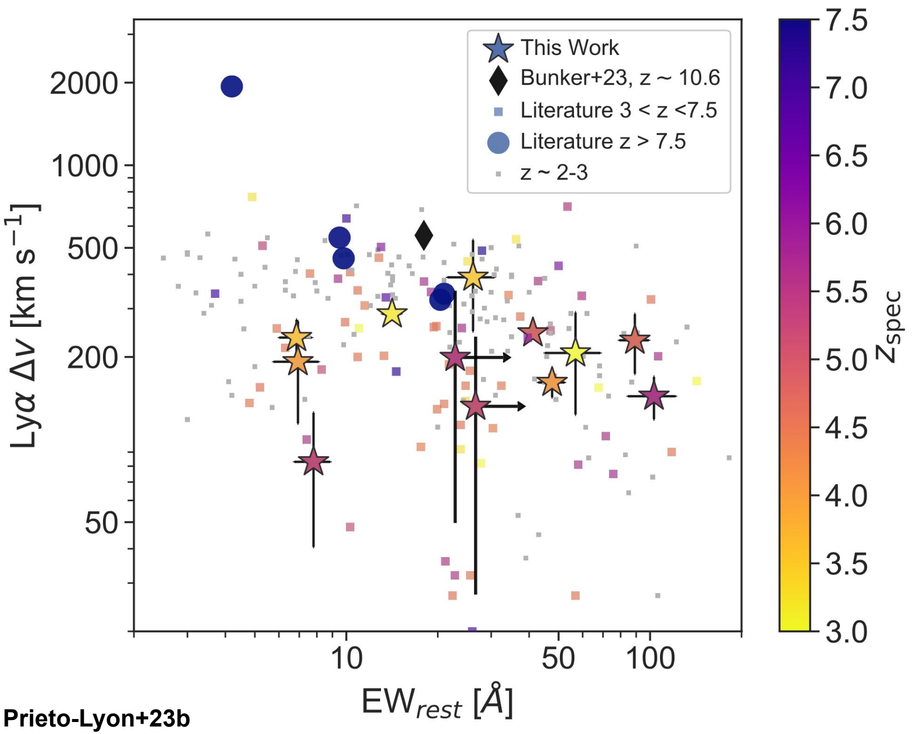


Prieto-Lyon+23b

Erb+14, see also e.g., Henry+15, Hayes+23

Velocity offsets usually anti-correlated with Lyα EW

- As line shifts from systemic due to scatter, it broadens.
- Less broadening in low mass, low velocity offsets.
- Particular outlier : Clumpy, low velocity offset, but low EW !

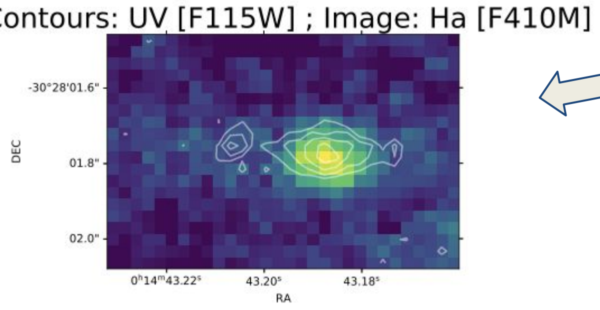


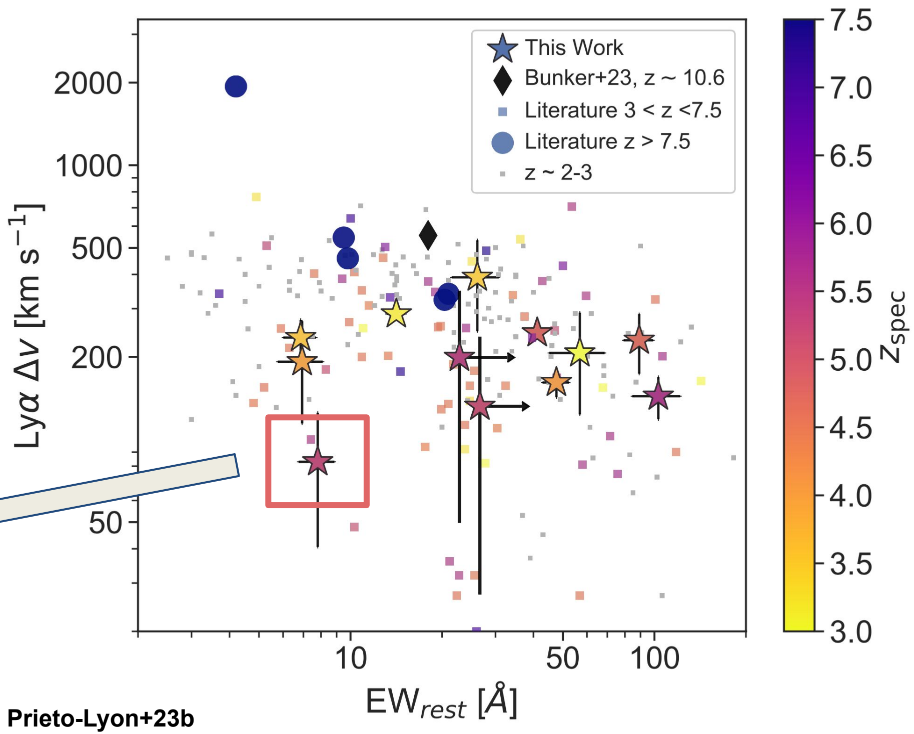
Prieto-Lyon+23b

e.g.Stark+15, Willott+15, Bradac+17, Inoue+16, Mainali+18a, Pentericci+16, Stark+17, Endsley+22, Cassata+20, Tang+23, Mason+18, Bunker+23

High HI column density can difficult transmission

- As line shifts from systemic due to scatter, it broadens.
- More likely in high mass, high velocity offset galaxies.
- Particular outlier : Clumpy, low velocity offset, but low EW !





Prieto-Lyon+23b

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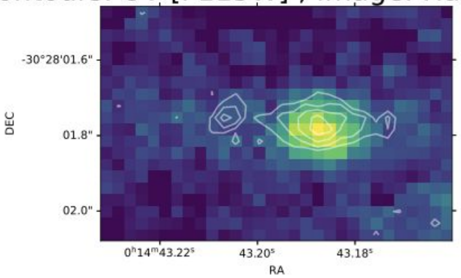
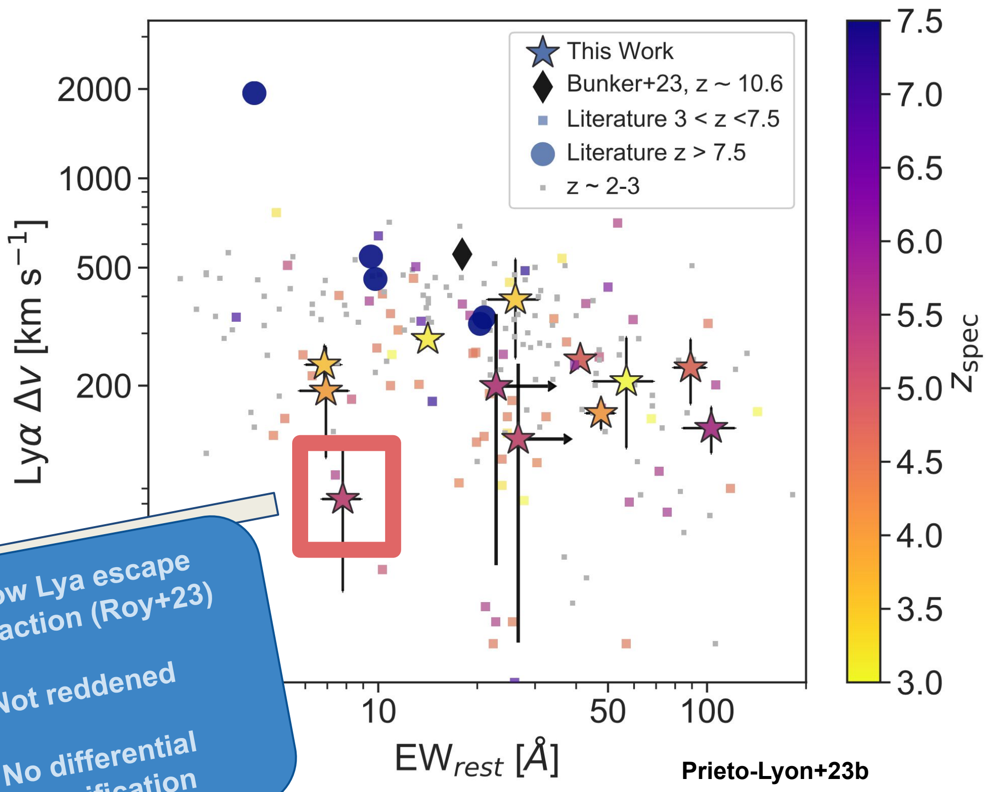
Contours: UV [F115W] ; Image: Ha [F410M]



- Low Lya escape fraction (Roy+23)
- Not reddened
- No differential magnification

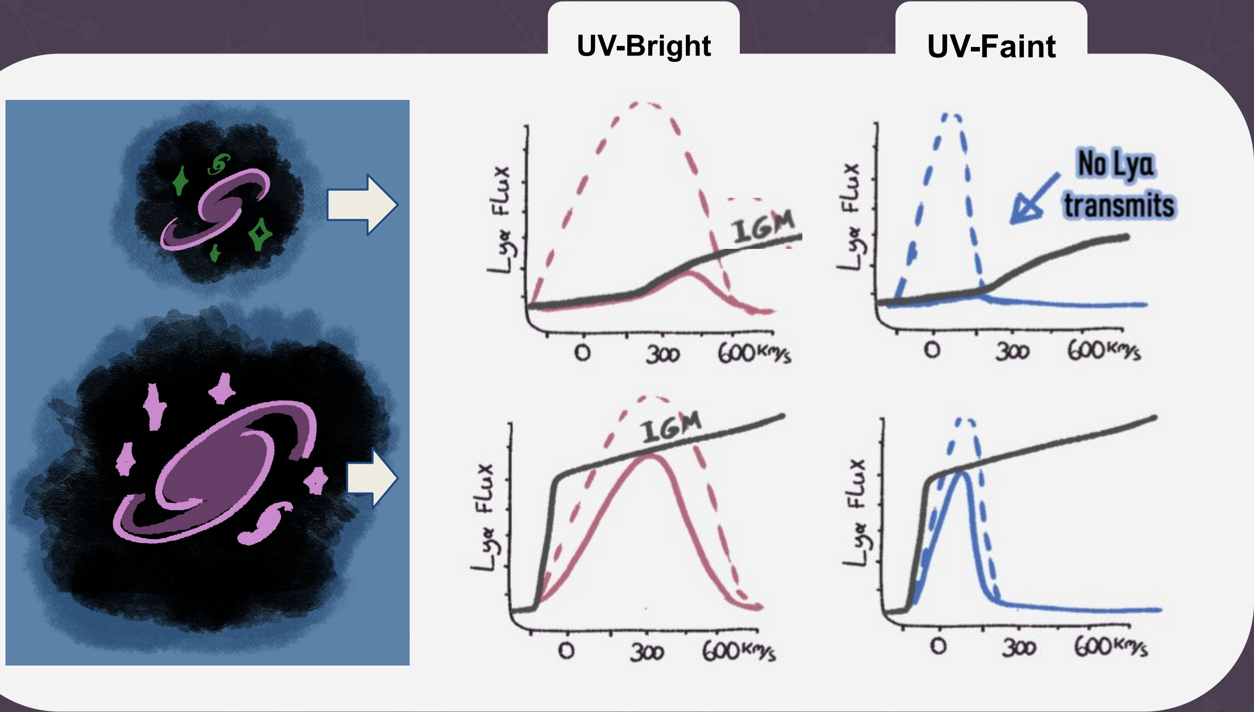


Prieto-Lyon+23b

e.g.Stark+15, Willott+15, Bradac+17, Inoue+16, Mainali+18a, Pentericci+16, Stark+17, Endsley+22, Cassata+20, Tang+23, Mason+18, Bunker+23

Lyα with low velocity offsets should more easily transmit in large ionized bubbles:

- Small ionized Bubble :
  - Ly-α only escapes if velocity offset is high.
  - Can't detect Ly-α from fainter galaxies.
- Large ionized Bubble :
  - Ly-α escapes with a lower velocity offset.
  - Detect Ly-α from fainter galaxies



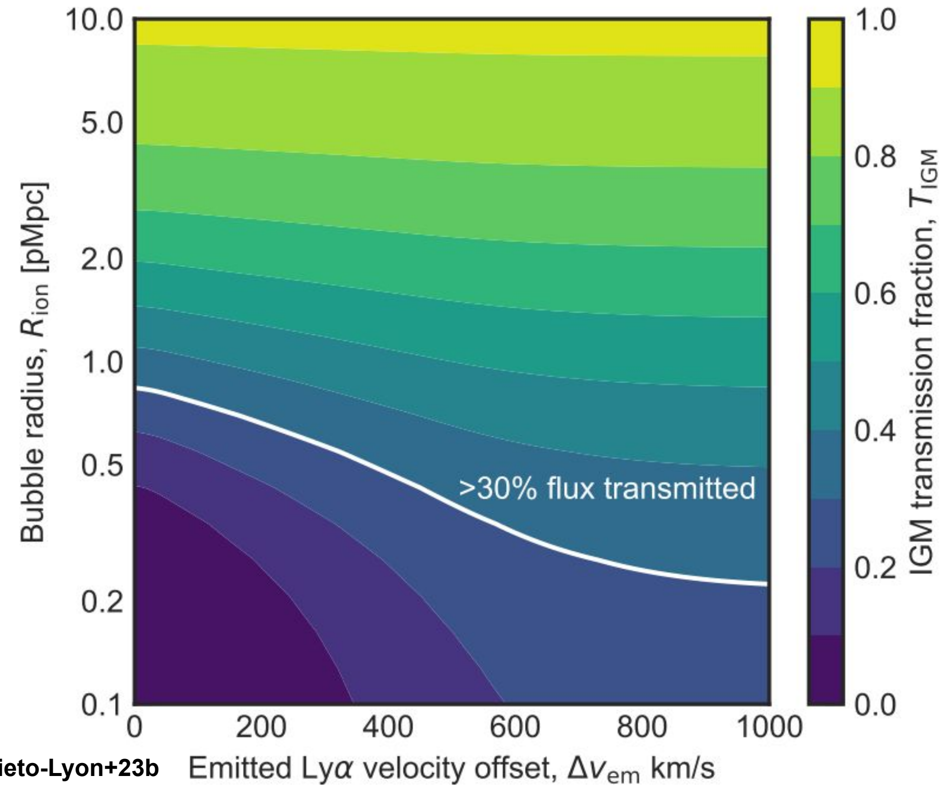
We can study reionization bubbles with Ly-α observations !

e.g. Saxena+23

IGM Transmission goes down to <10% for UV-faint galaxies

- Less massive galaxies have a harder time transmitting Lya.
- Radius needed for 30% transmission => 1pMpc.
- Massive galaxies do not drop below 10% transmission.

Biased towards observing Lya from massive galaxies at EoR !



Prieto-Lyon+23b

Mason+18

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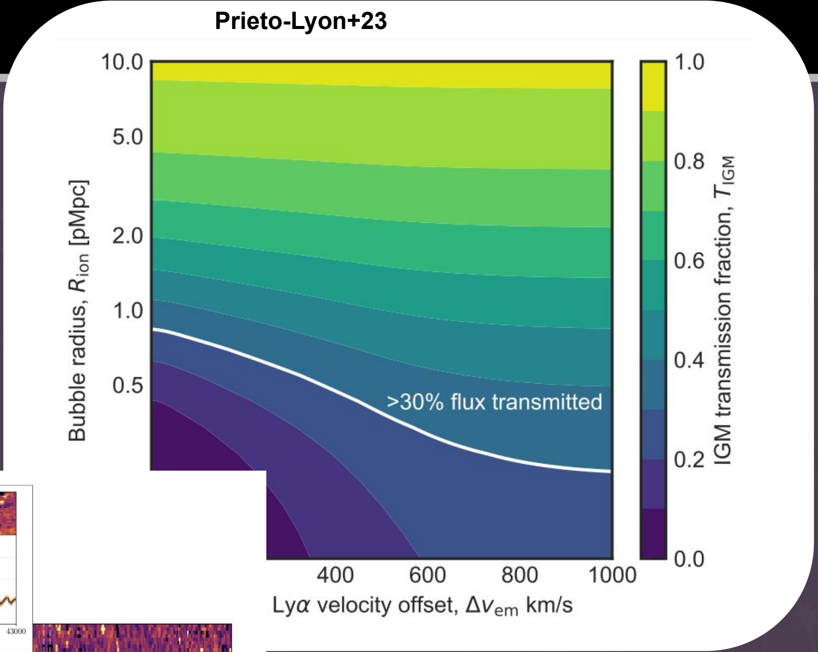
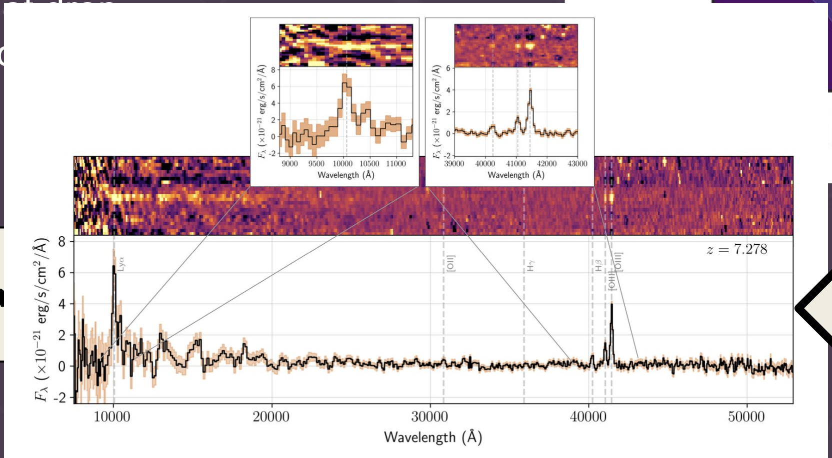




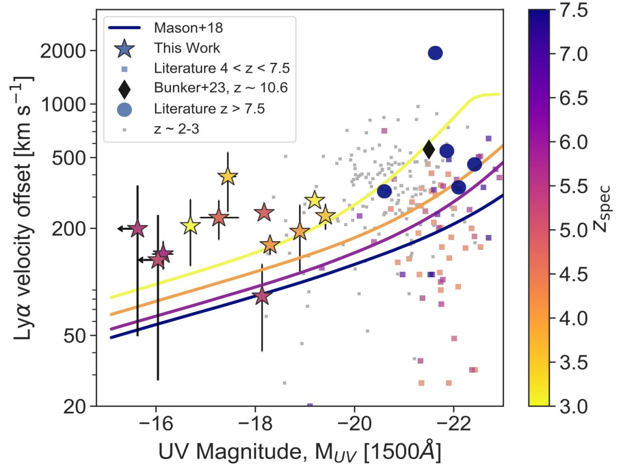
- Low velocity offset of a faint galaxy found at redshift 7.3
- Implies a large ionizing bubble of 3pMpc

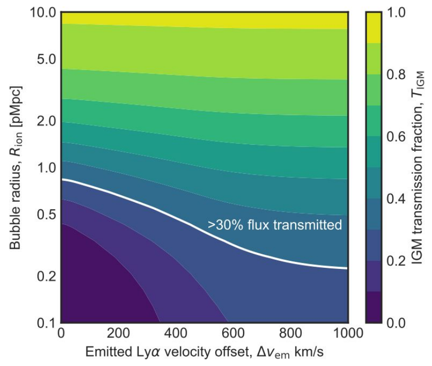
Mason+18, Saxena+23

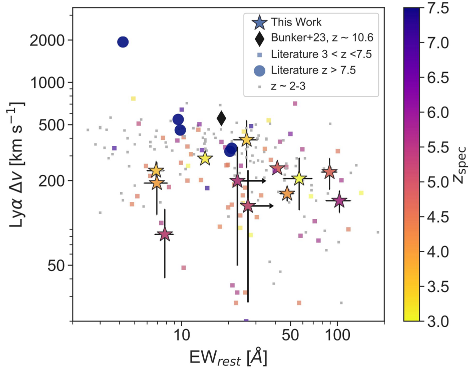
UV-faint galaxies as tracers of large ionized bubbles

- Low emergent velocity offsets easily transmit in big ionized bubbles
- Overall high equivalent widths.
- Numerous in the early universe

Great tracers of large ionized bubbles

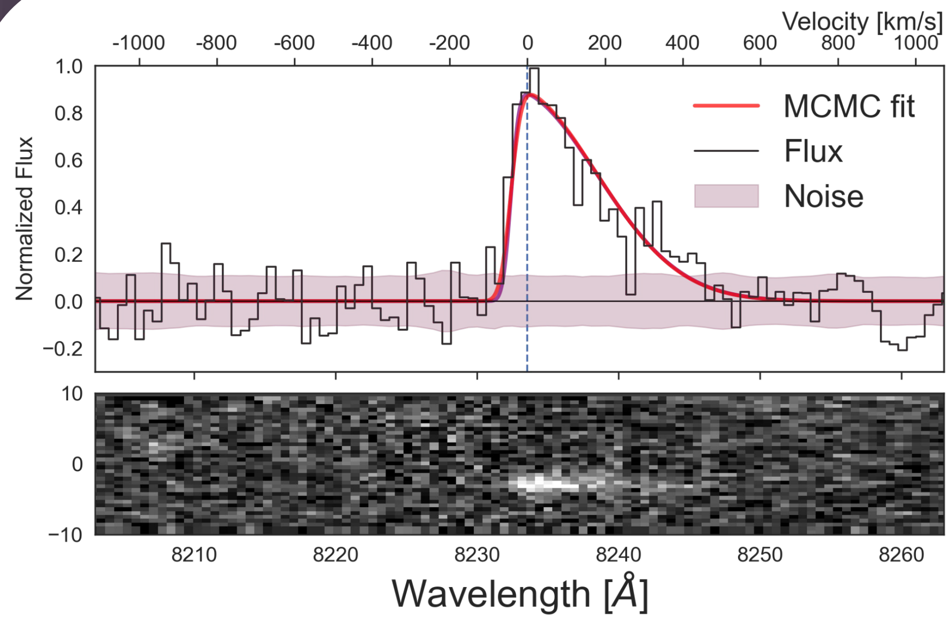






New high spectral resolution Lyα survey at z ~ 5-7, with JWST rest-frame optical follow-up

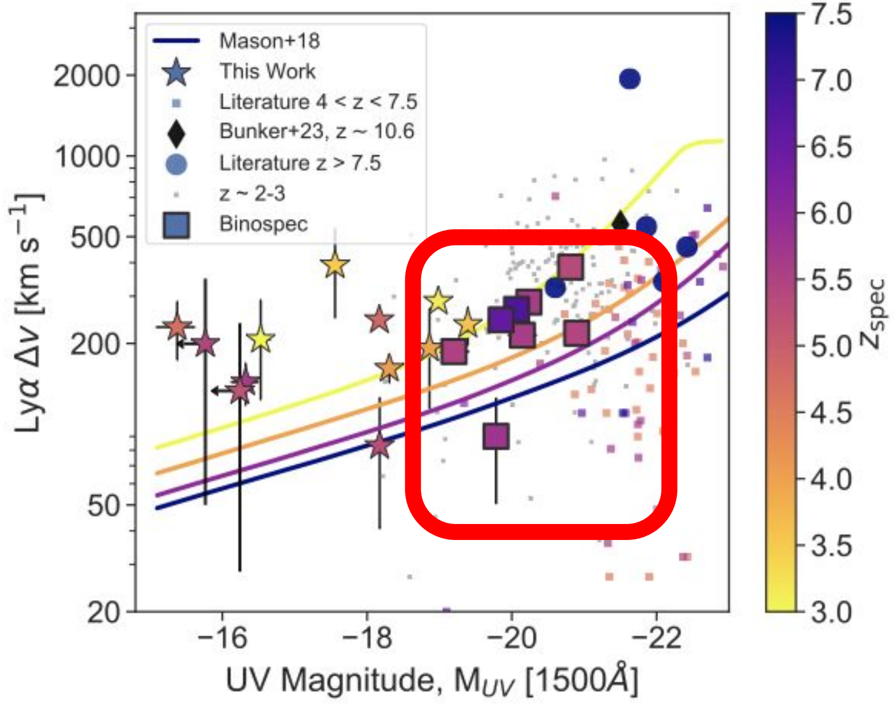
- ~ 70, z = 5 - 7, Lyman Alpha galaxies observed with high resolution spectra [MMT / Binospec]
- Slitless spectra coverage from JWST Fresco.



PI: Pascal Oesch

PRELIMINARY RESULTS

- ~ 70, z = 5 - 7, Lyman Alpha galaxies observed with high resolution spectra [MMT / Binospec]
- Slitless spectra coverage from JWST Fresco.
- 8 / 70 sources for now



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Summary

- JWST rest-frame optical spectroscopy makes Lyα velocity offset measurements feasible in UV-faint galaxies for the first time.

- We measured low velocity offsets (~200km/s) in UV-faint galaxies.

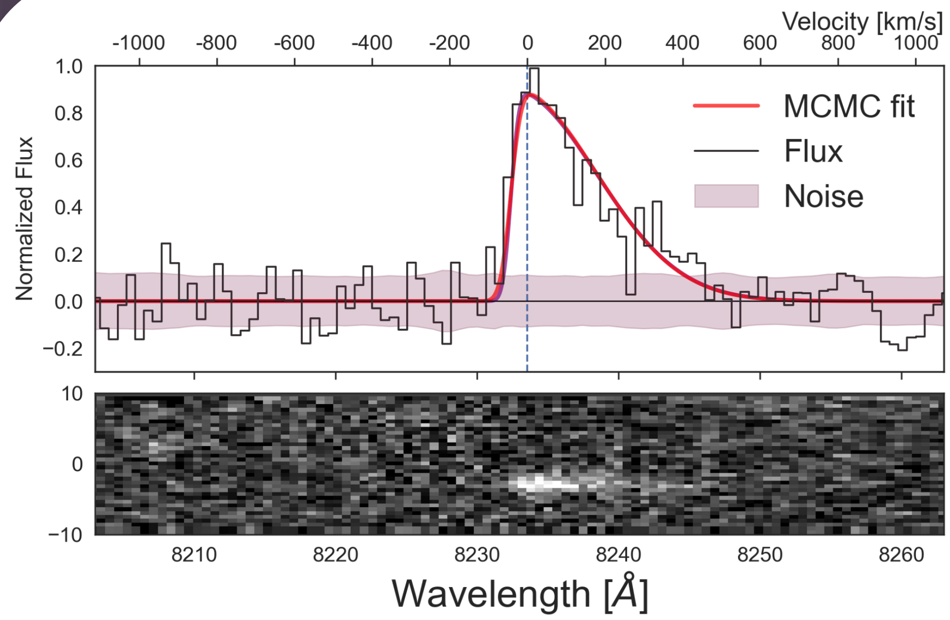
    - Low velocity offsets measured in galaxies with lowest MUV and lowest dispersion of rest-frame optical lines.

    - Consistent with scattering of Lyα being connected to galaxy mass through NHI

- Observations of UV-faint galaxies with low velocity offsets and high escape fractions at EoR, should indicate presence of large ionized bubbles.

Asymmetries, EWs, Non-detections -> Future work

- ~ 70, z = 5 - 7 ,Lyman Alpha galaxies observed with high resolution spectra [MMT / Binospec]
- Slitless spectra coverage from JWST Fresco.
- Larger sample of velocity offsets near the EoR. Asymmetries.
- + 300 Non-detections. Emergent EWLya distribution.



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