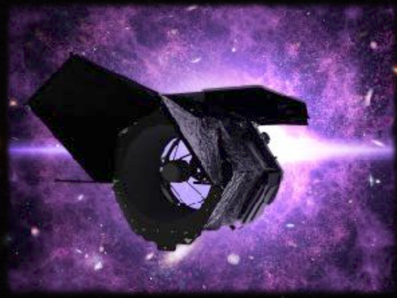
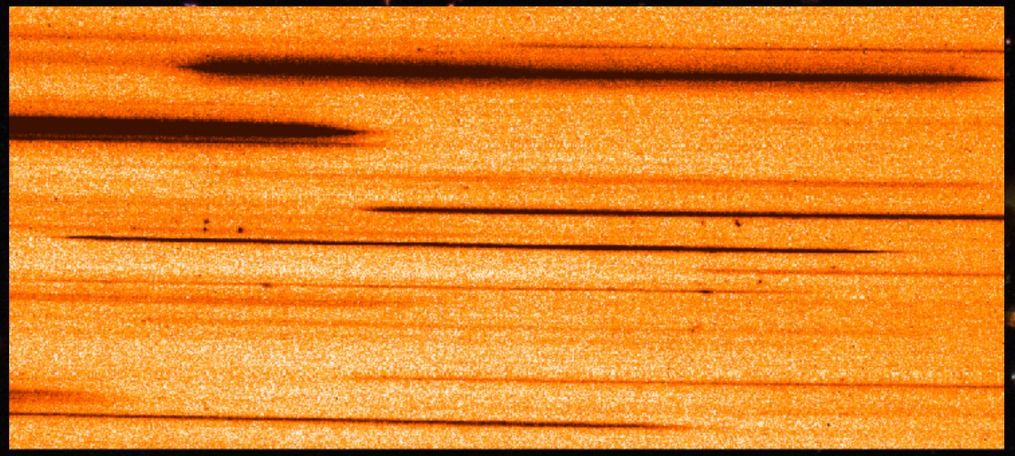
The Environment and Clustering of Distant Quasars and AGNs





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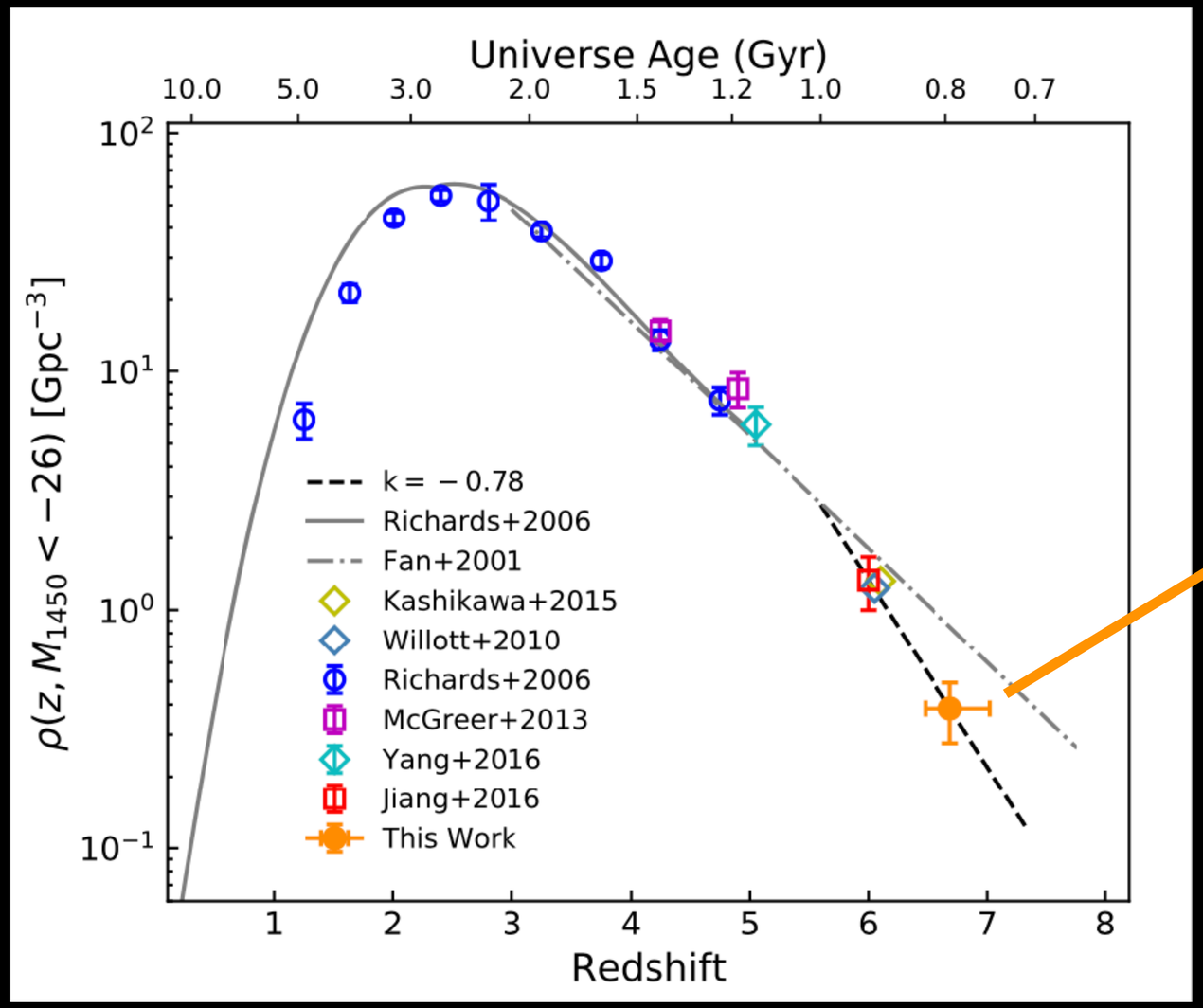
In collaboration with
HURON team at UMich
EREBUS collaboration
COSMOS-3D collaboration

Can luminous distant quasars form in the ΛCDM cosmological context?



Wang et al. 2019

Luminous quasar number density:

$0.4\ \mathrm{Gpc}^{-3}$ **at** $z \sim 6.7$

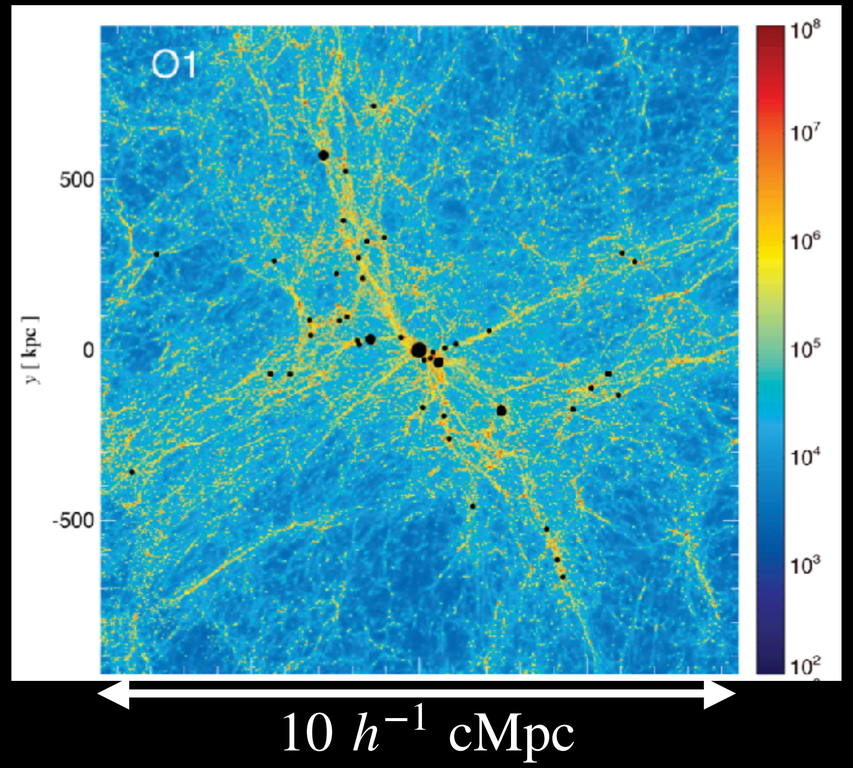
$$N_{\mathrm{Quasar}}(L > L_{\mathrm{min}}) = N_{\mathrm{halo}}(M > M_{\mathrm{min}})$$

(e.g., White et al.)

$$M_{\mathrm{Halo,min}} \sim 5 \times 10^{12}\ M_{\odot}$$

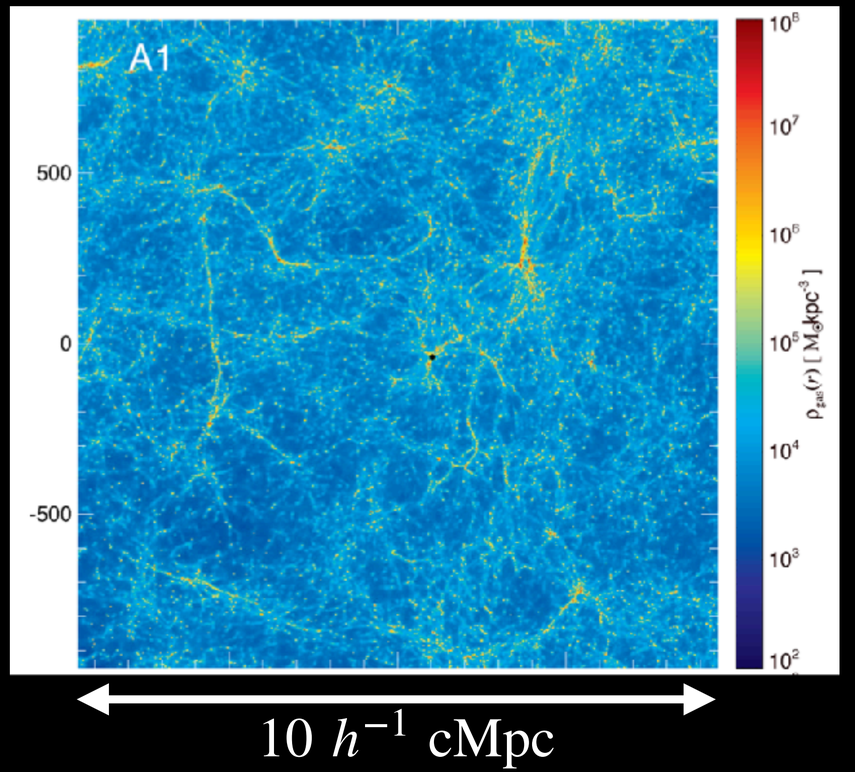
The Dark Matter Halos and Environment of Distant Quasars

Overdense region



Luminous quasar resides in massive halo and inhabits galaxy overdensity

Average region



Costa+2014,2023

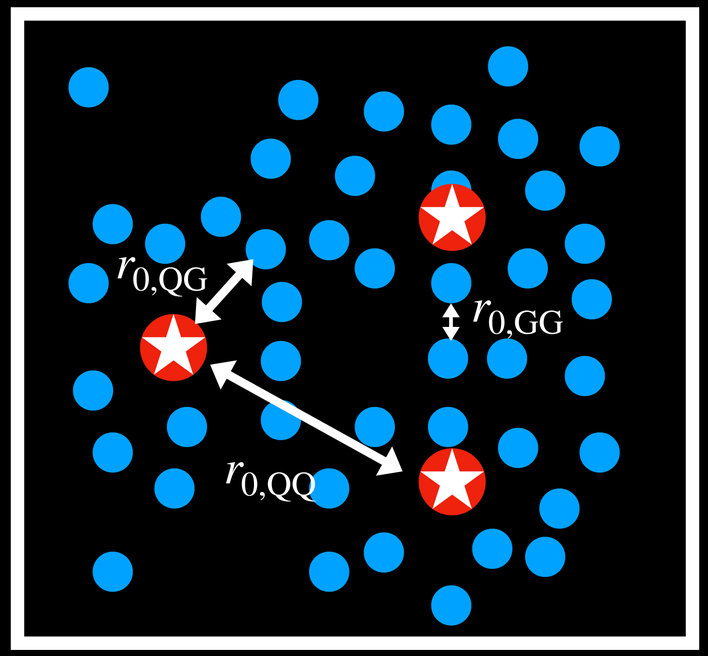
Determining dark matter halo mass with quasar-galaxy cross correlation function

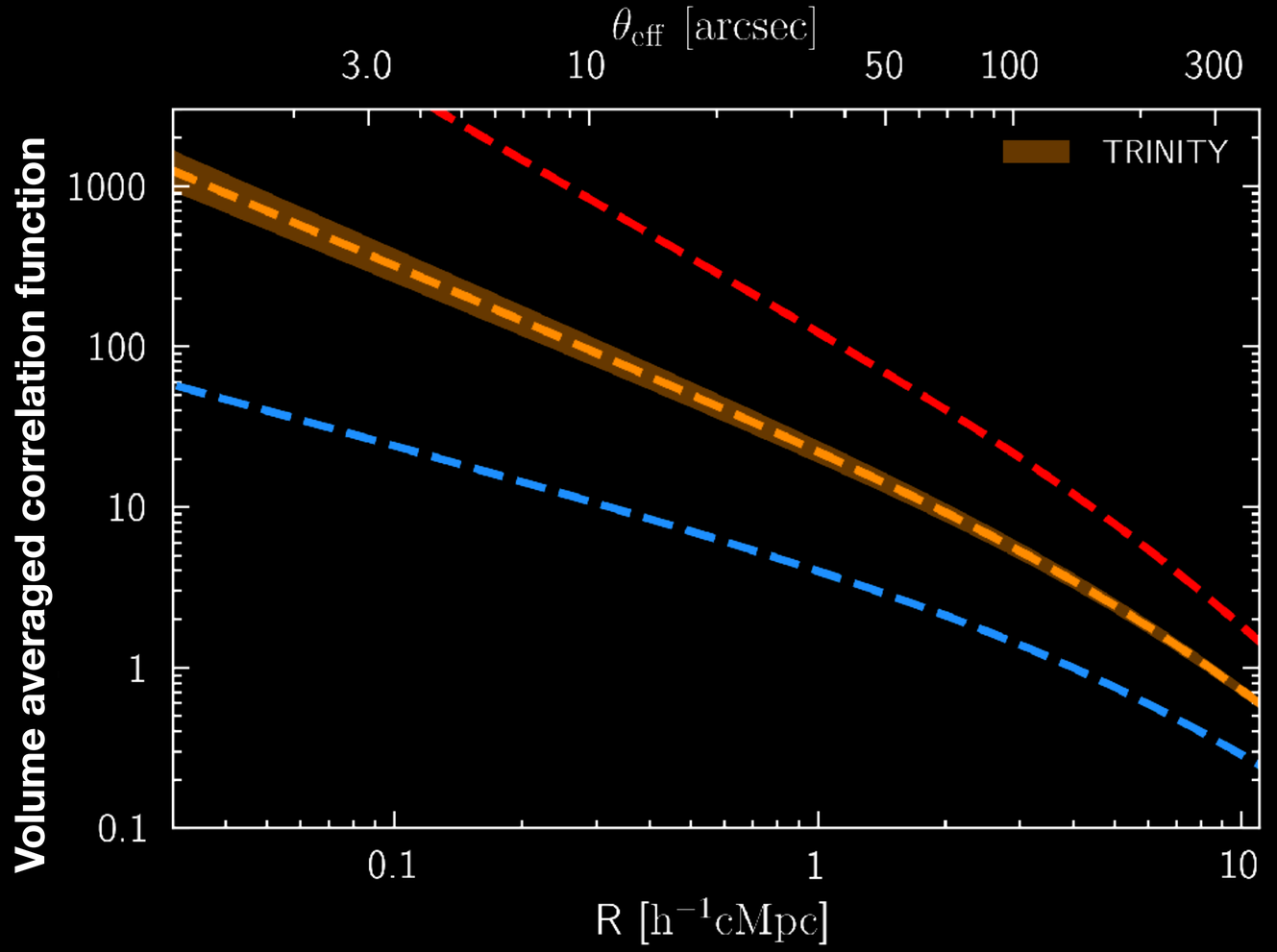
$$\delta P = n\delta V[1 + \xi(r)]$$

Correlation function: $\xi(r) = (\frac{r}{r_0})^{-\gamma}$

quasar-galaxy cross correlation:

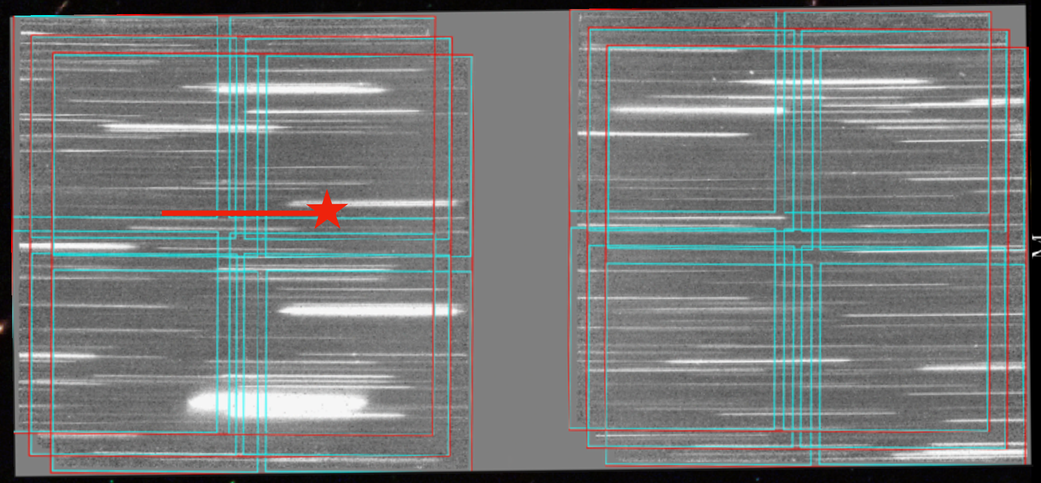
$$\xi_{QG} = \sqrt{\xi_{QQ}\xi_{GG}}$$



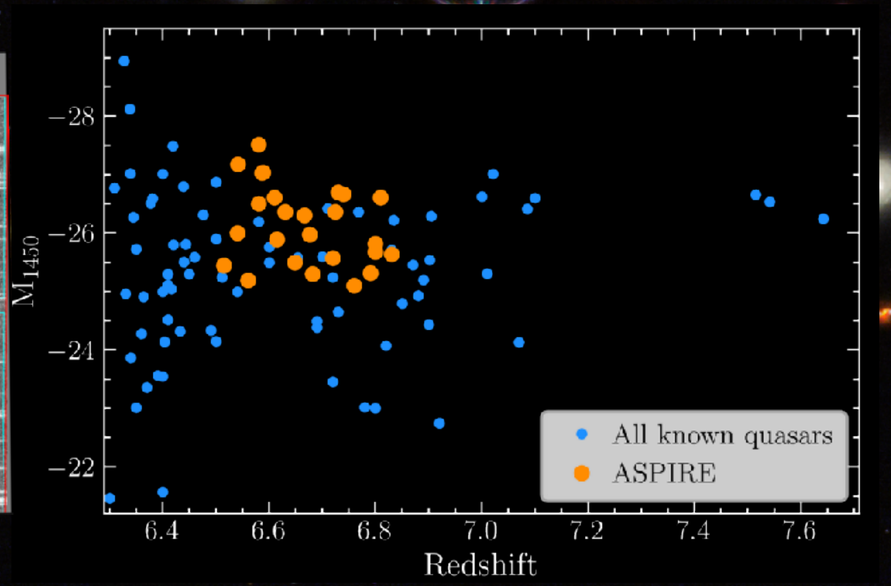


A SPectroscopic survey of Biased Halos In the Reionization Era: A Quasar Legacy Survey

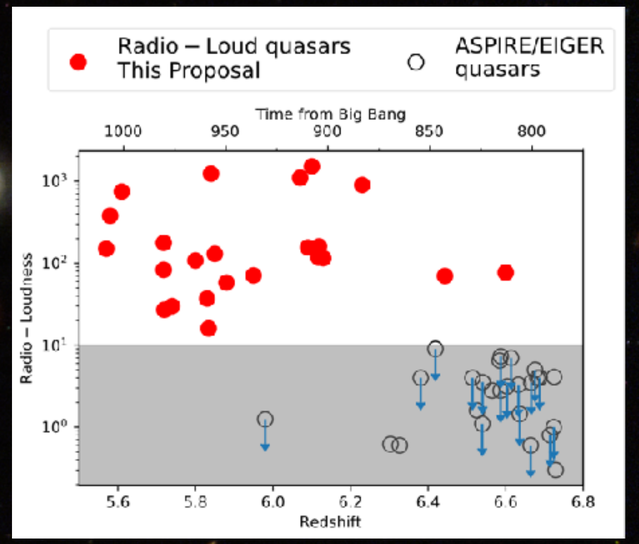
NIRCam WFSS and imaging



A legacy galaxy redshift survey with emission lines



ASPIRE for z>6.5 radio-quiet quasars (GO2078)

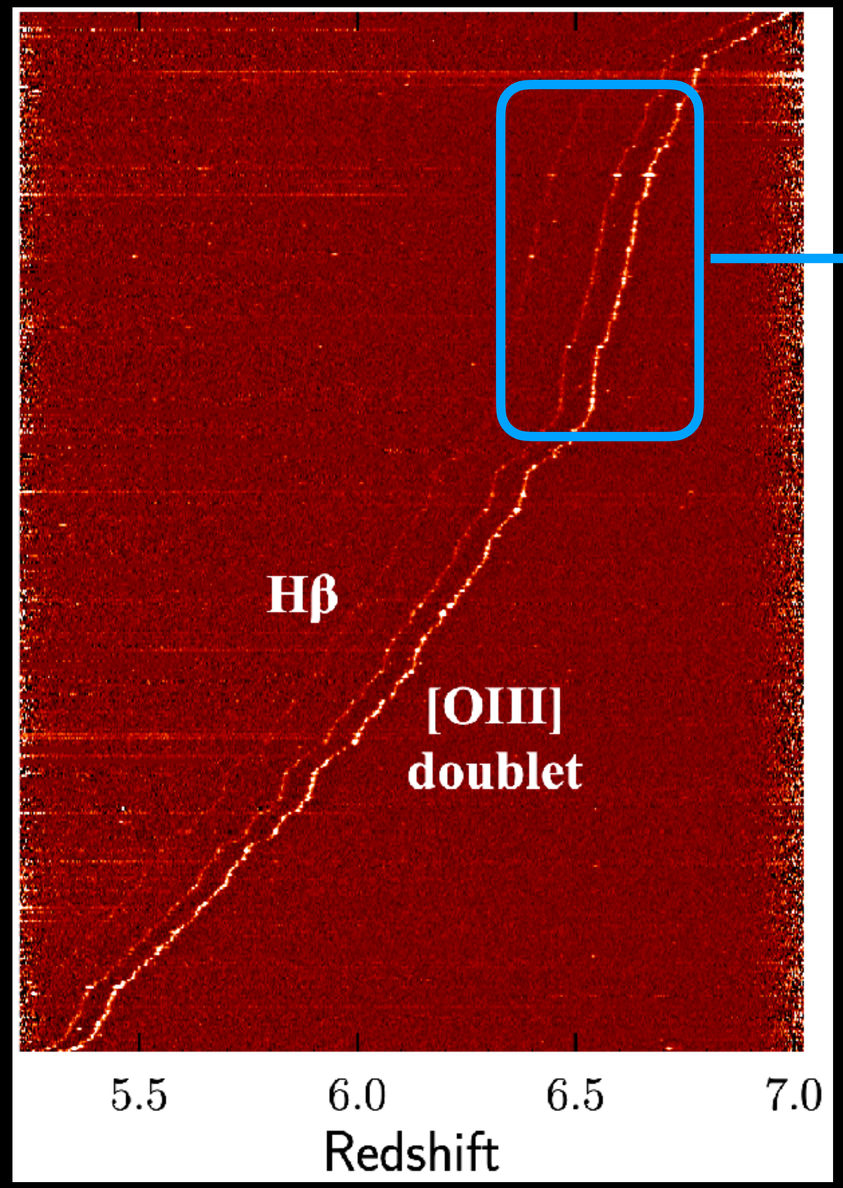


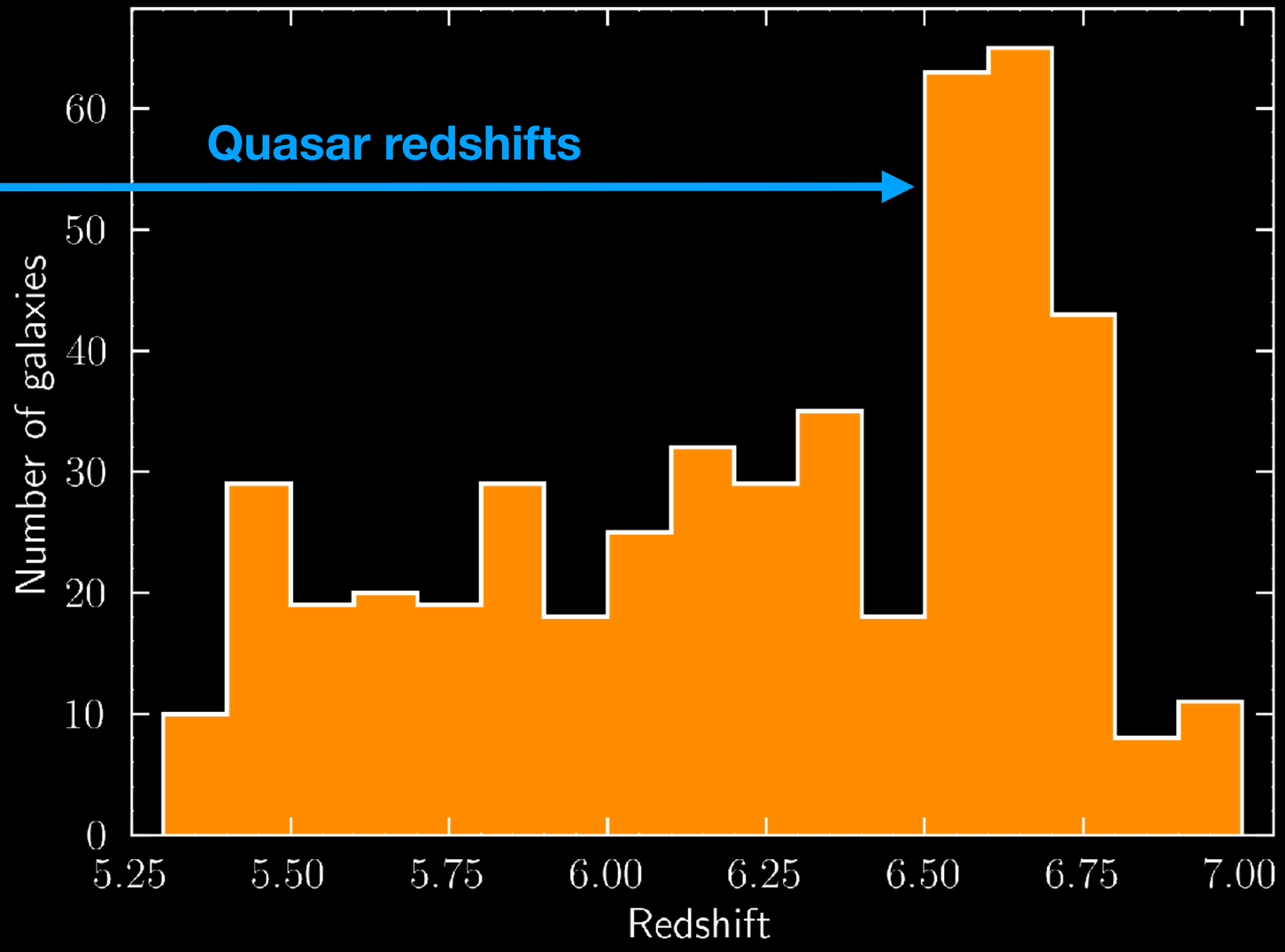
Radio-ASPIRE for z>5.5 radio-loud quasars (GO9841)

Coming soon!

https://aspire-quasar.github.io

Spectroscopically confirming ~500 galaxies at $5.3 < z < 7$





Wang et al. 2026 (arXiv:2602.04979)

Reionization-era quasars inhabit massive dark matter halos: strong quasar-galaxy correlation

quasar-galaxy cross correlation:

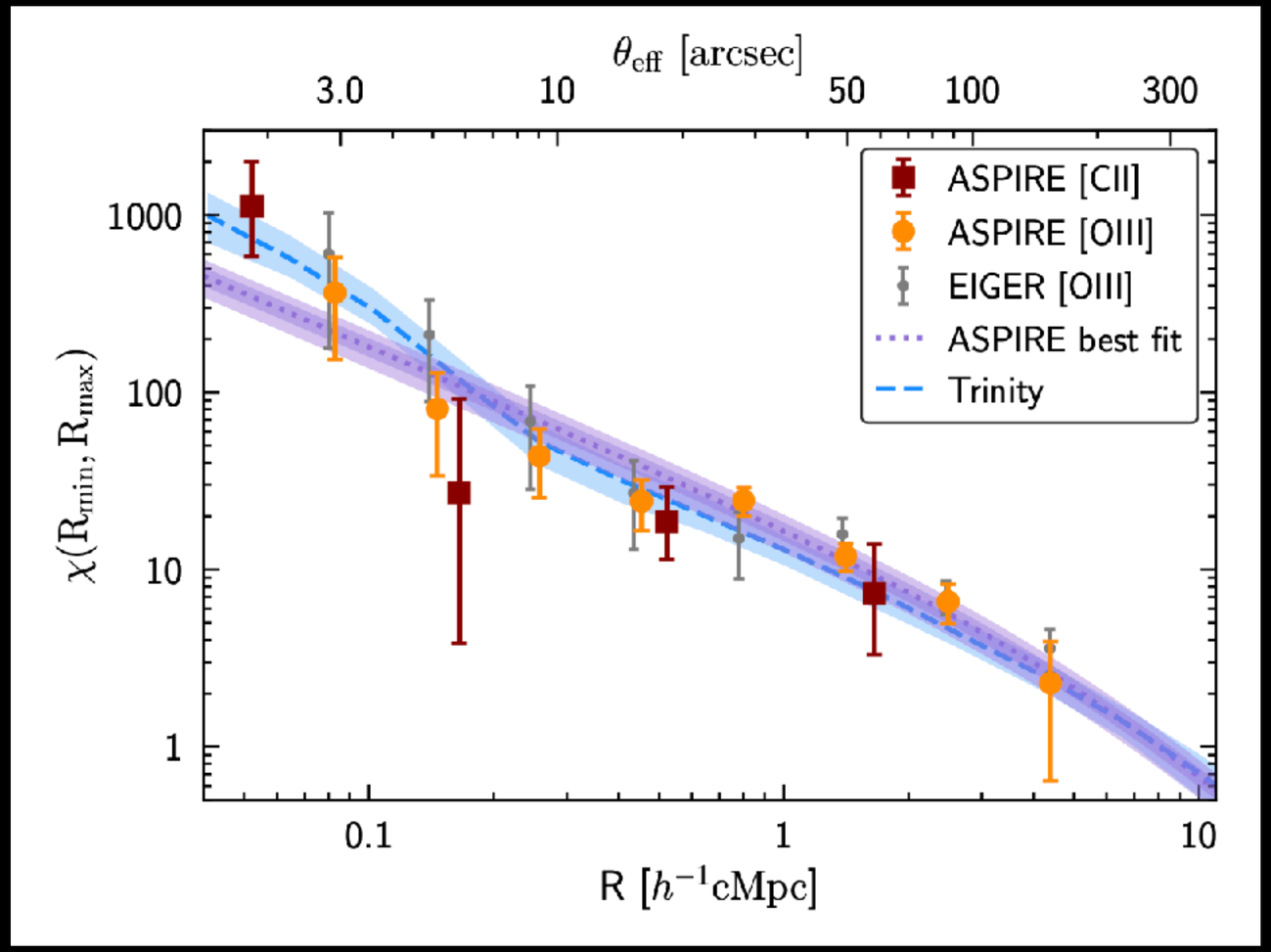
$$\xi_{QG} = \sqrt{\xi_{QQ}\xi_{GG}}$$

$$r_0^{\rm QG} = 8.68^{+0.51}_{-0.55}\ h^{-1}\ {\rm cMpc}$$

$$M_{\rm halo} = 10^{12.27^{+0.21}_{-0.26}}\ M_\odot$$

The most precise CCF we have ever measured in the early Universe!

See also Eilers et al. from EIGER survey

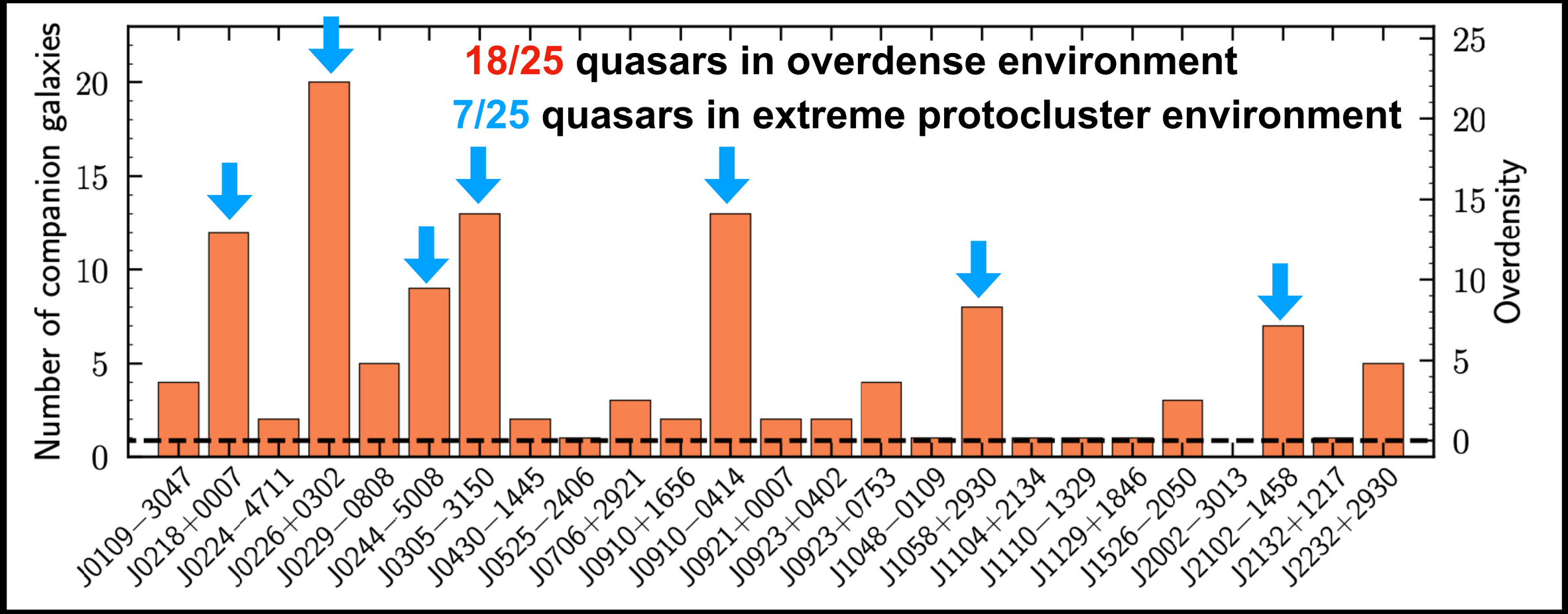


Wang et al. 2026 (arXiv:2602.04979)
Huang et al. 2026 (arXiv:2602.04974)

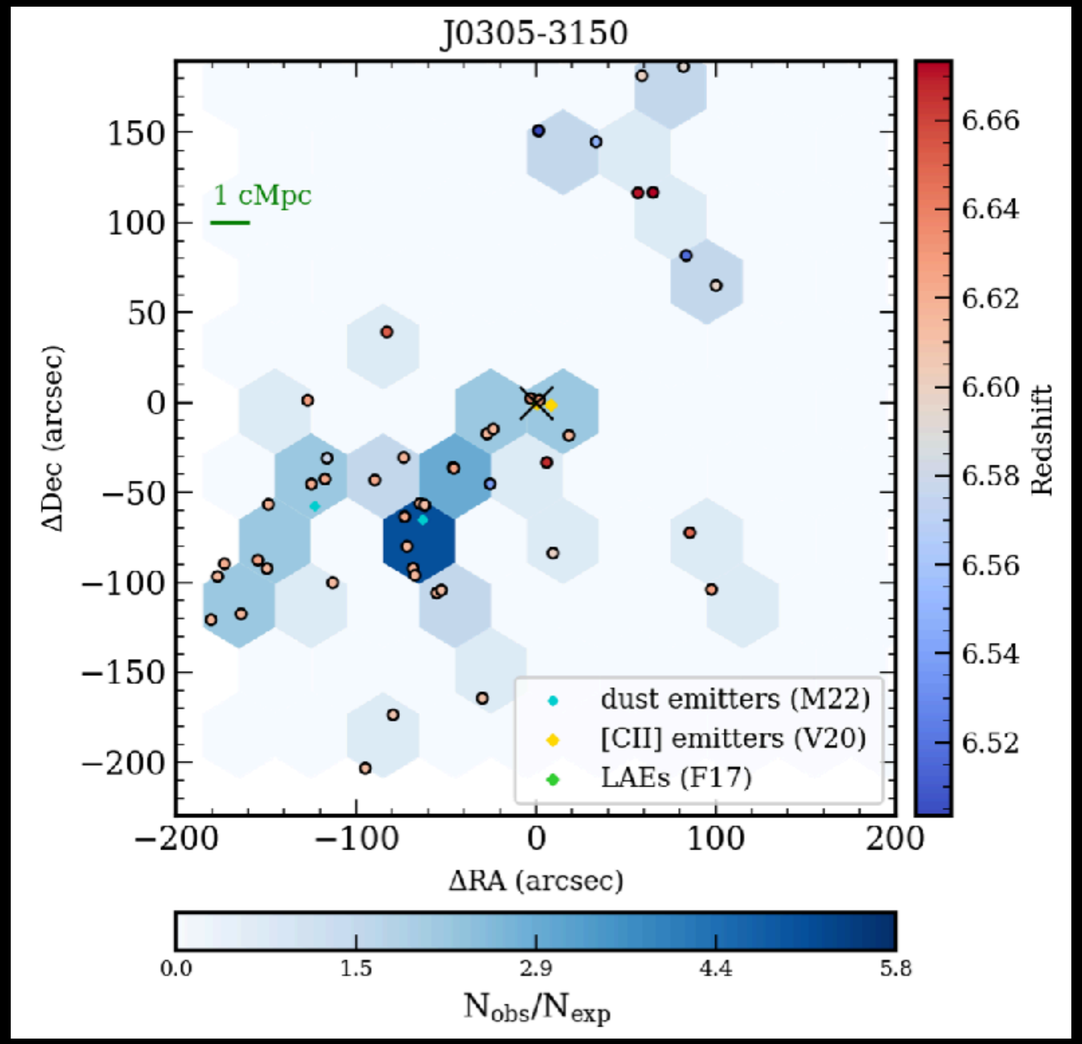
Large variety of quasar environments

25 ASPIRE quasars at $6.5 < z < 7$

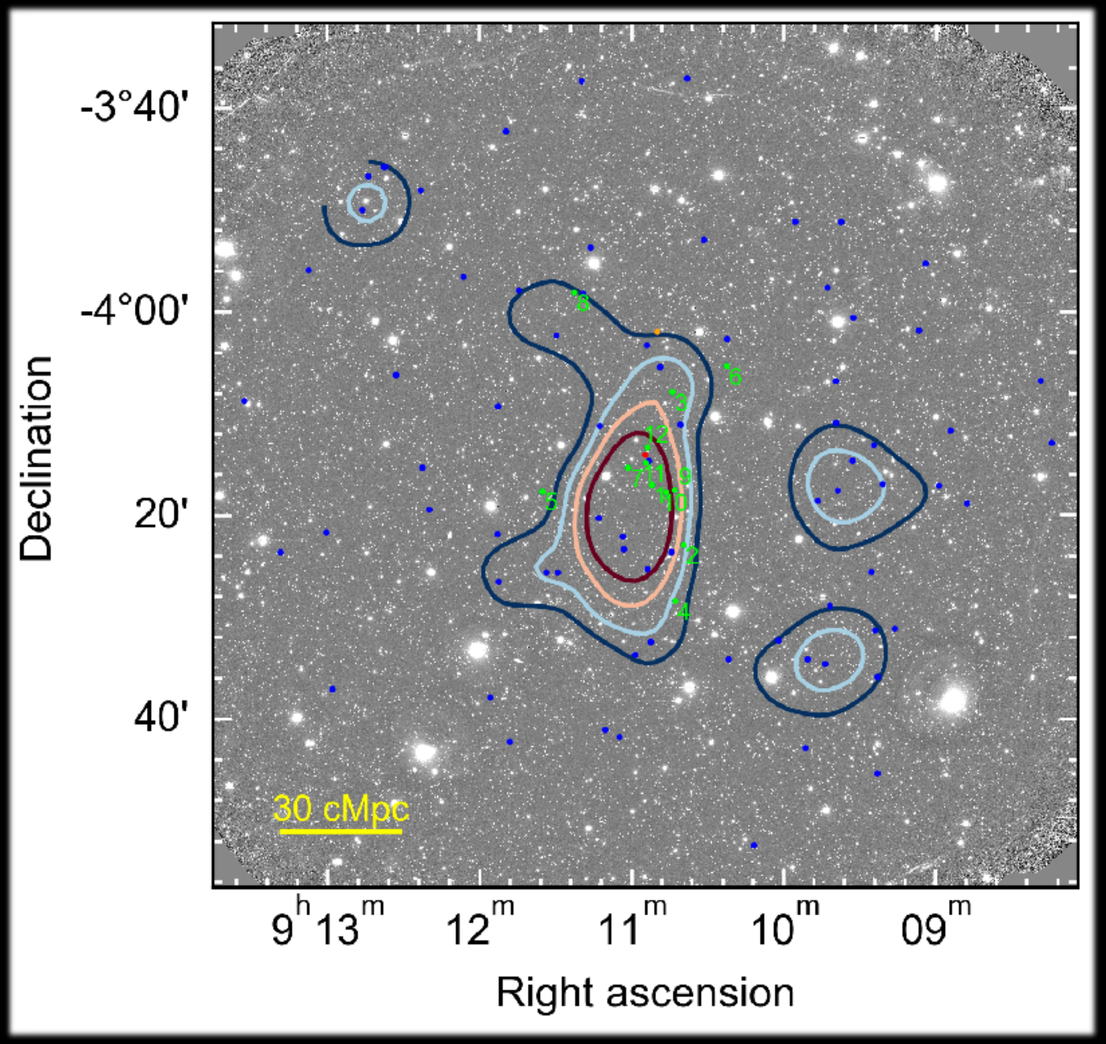
Wang et al. 2026 (arXiv:2602.04979)



Filamentary structures extend well beyond 10 cMpc

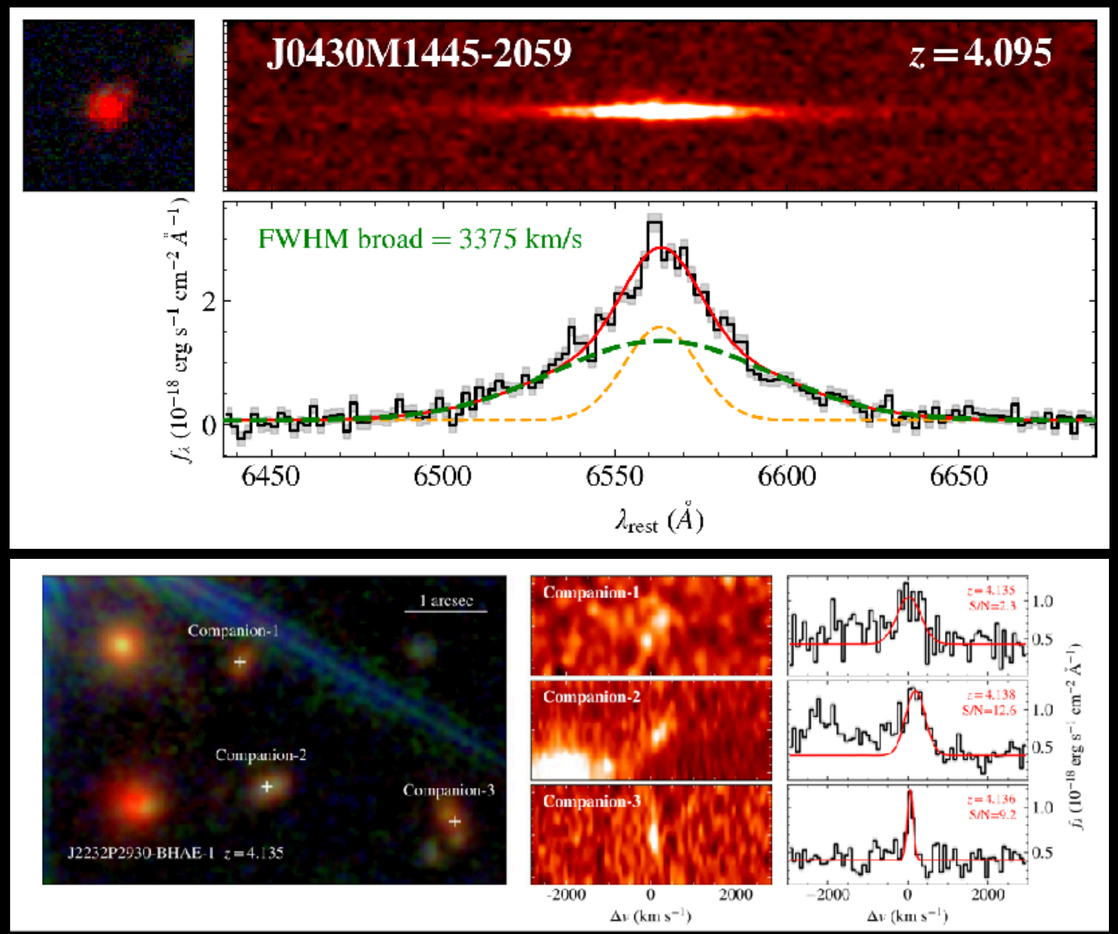


Champagne, **Wang** et al. 2025a

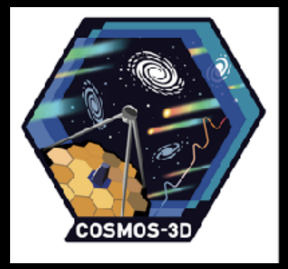


Wang et al. 2024a

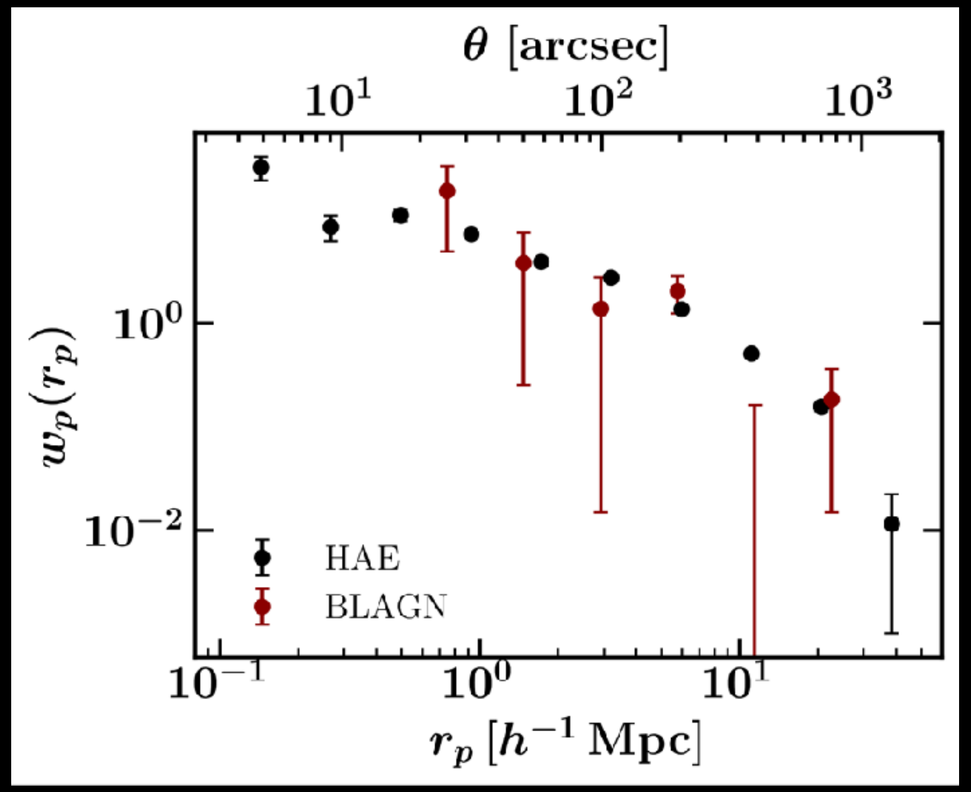
How about broad line AGNs discovered by JWST?



Lin, Wang et al. 2024
Also Dale Kocevski's review talk



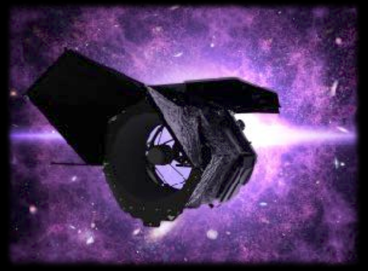
GO 5893: A cycle 3 large program
PIs: Koki Kakiichi, Eiichi Egami, Xiaohui Fan, Jianwei Lyu, Feige Wang, Jinyi Yang



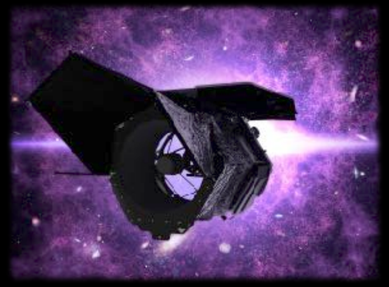
Wang et al. in prep

JWST study suggests:

- Quasars inhabit massive halos but the environment is very diverse
  - What's the physical reason behind this?
    - Different quasar trigger mechanisms? Different initial halos? Different seeds?
  - What's the role of AGN feedback?
- The structures traced by quasars could extend well beyond 10 Mpc
  - How large of the structures traced by quasars?
  - Are they progenitors of galaxy clusters?
- JWST LRDs have a different clustering/halo mass from quasars
  - Are LRDs the progenitors of quasars?



Roman will answer all of these questions!



- **What's the physical reason behind this?**
- **What's the role of AGN feedback?**
- **Are LRDs the progenitors of quasars?**

- **How large of the structures traced by quasars?**
- **Are they progenitors of galaxy clusters?**

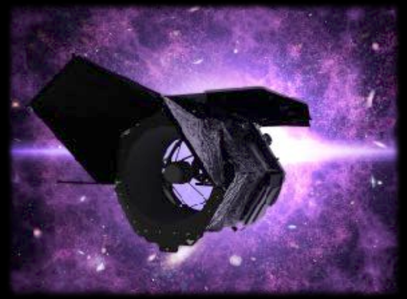
✦ Identifying [OIII] emitters around z~2-3 quasars, faint AGNs and LRDs using Roman Grism

✦ Searching for LBGs around z>5 quasars/AGNs by combining LSST and Roman

✦ New Roman Grism observation to search for LAEs around z>7 quasars

Summary

- Distant quasars (on average) inhabit massive dark matter halos.
- Distant quasars are signposts of galaxy overdensities, but with a large variance.
- LRDs have a different clustering and halo mass from quasars.
- Roman will revolutionize our understanding of quasar, AGN, and LRD host dark matter halos and environments



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