Investigating the X-Ray Enhancements of Highly Radio-Loud Quasars at $z > 4$

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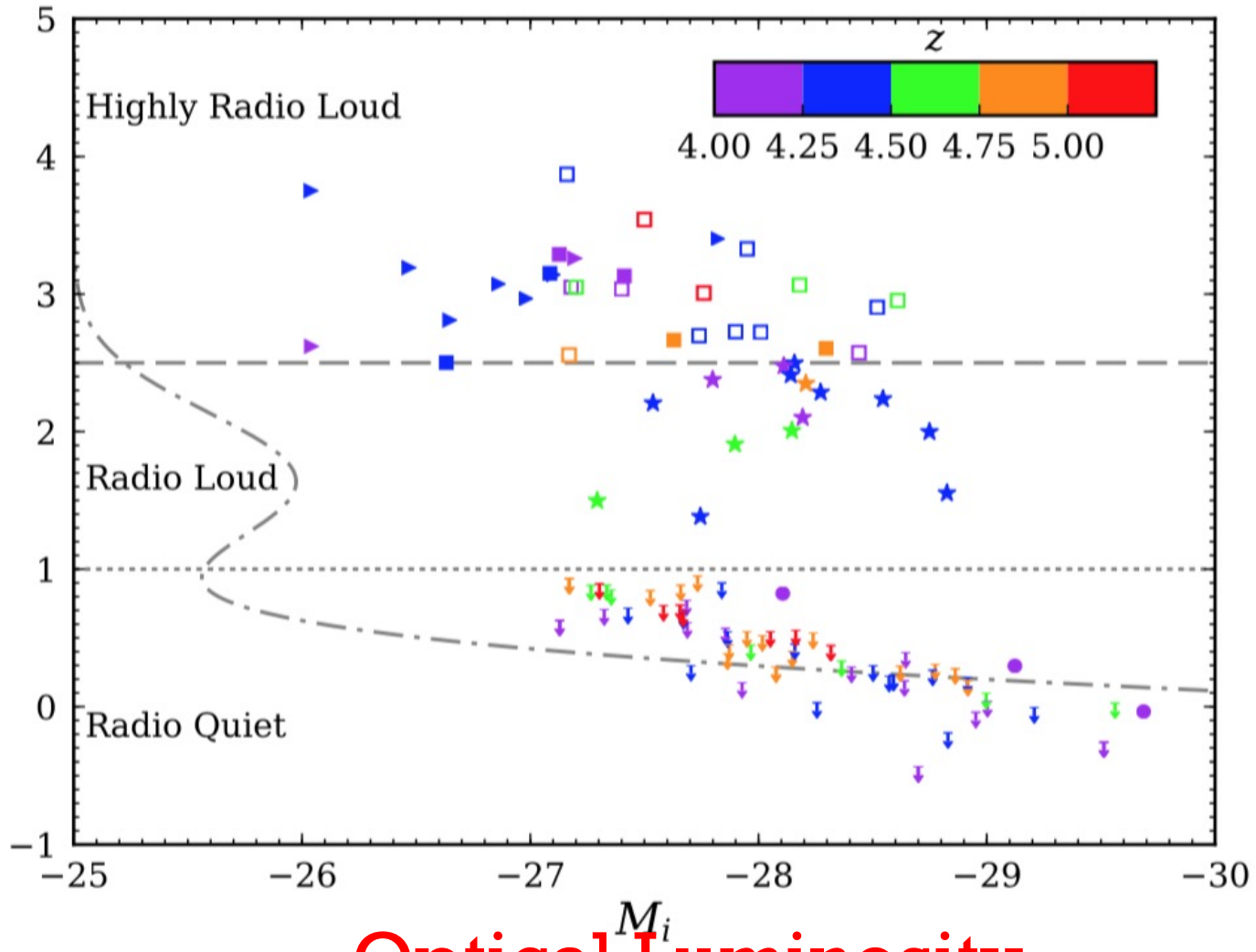
(arXiv: 1810.06572)

Highly Radio-Loud Quasars (HRLQs; $\log R > 2.5$)



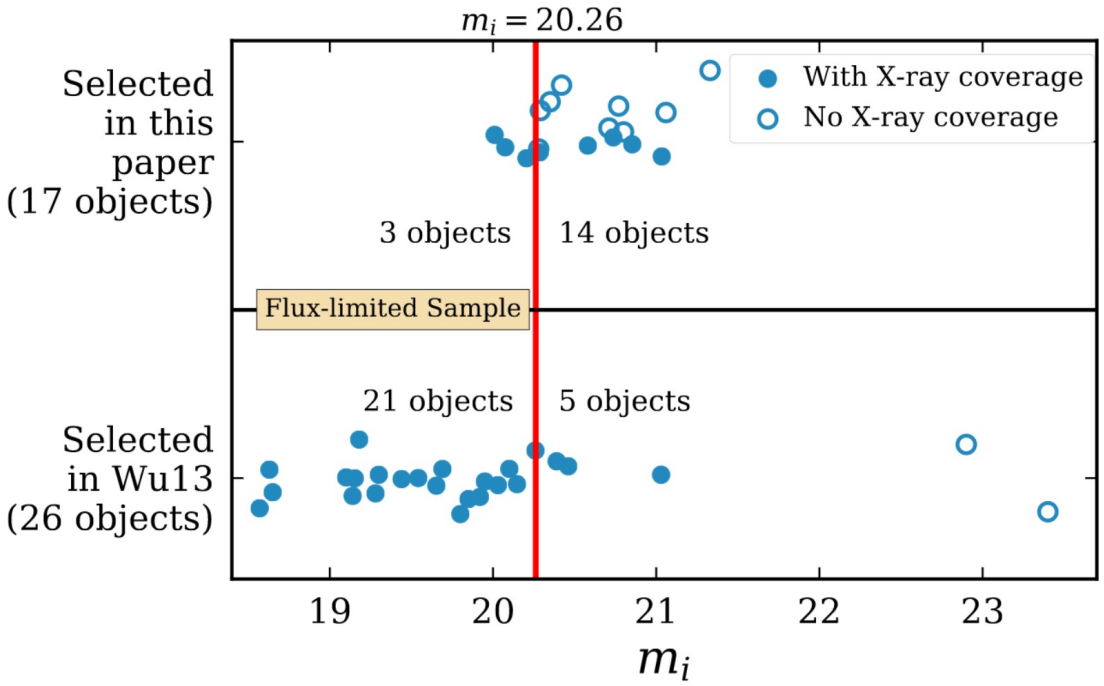
Radio Loudness

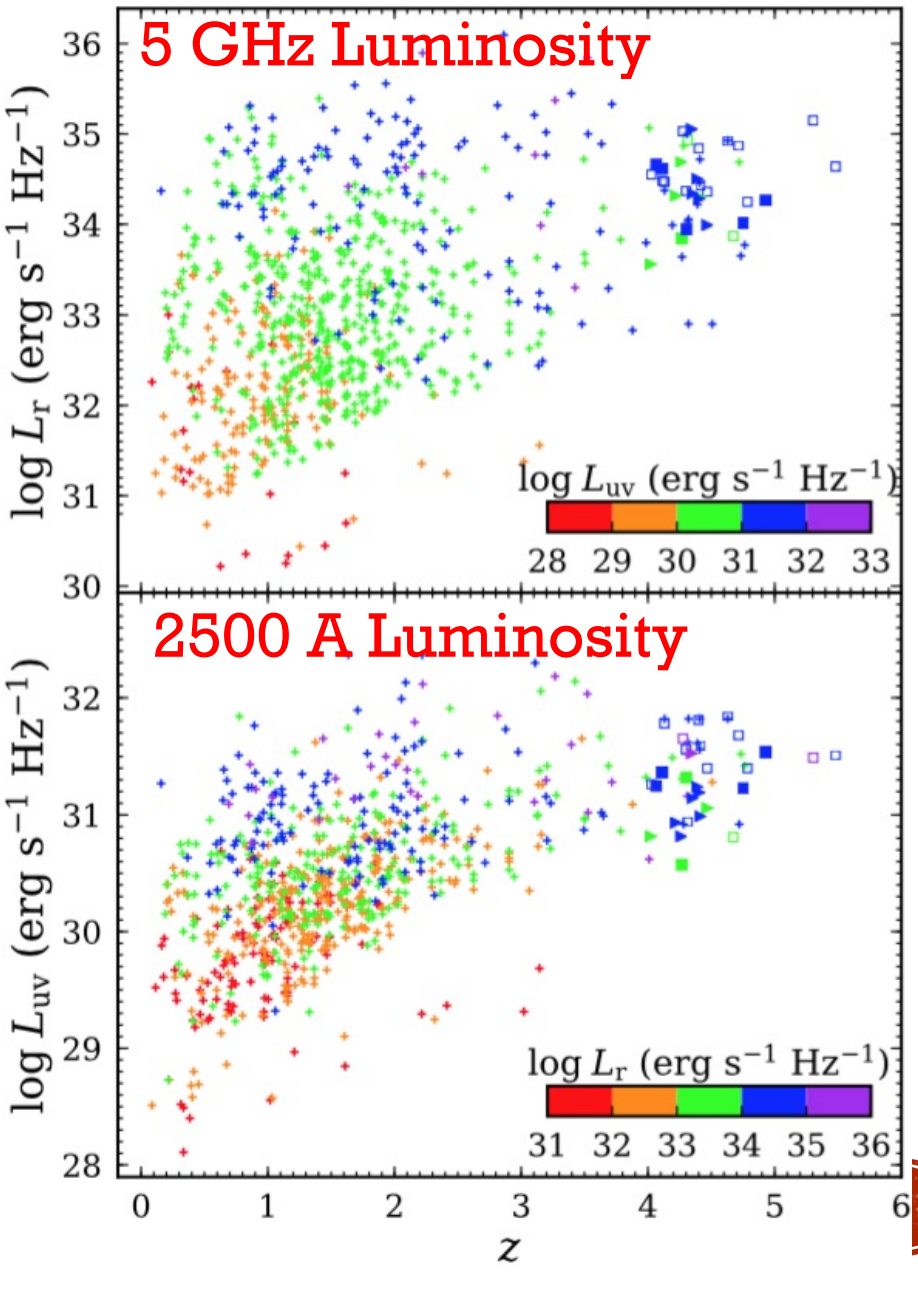
Optical Luminosity

- The SED of quasars generally does not change with redshift.
- However, HRLQs at z>4 show X-ray enhancement relative to their low-z counterparts (~3σ with 12/15 objects having sensitive X-ray coverage, Wu+ 2013).

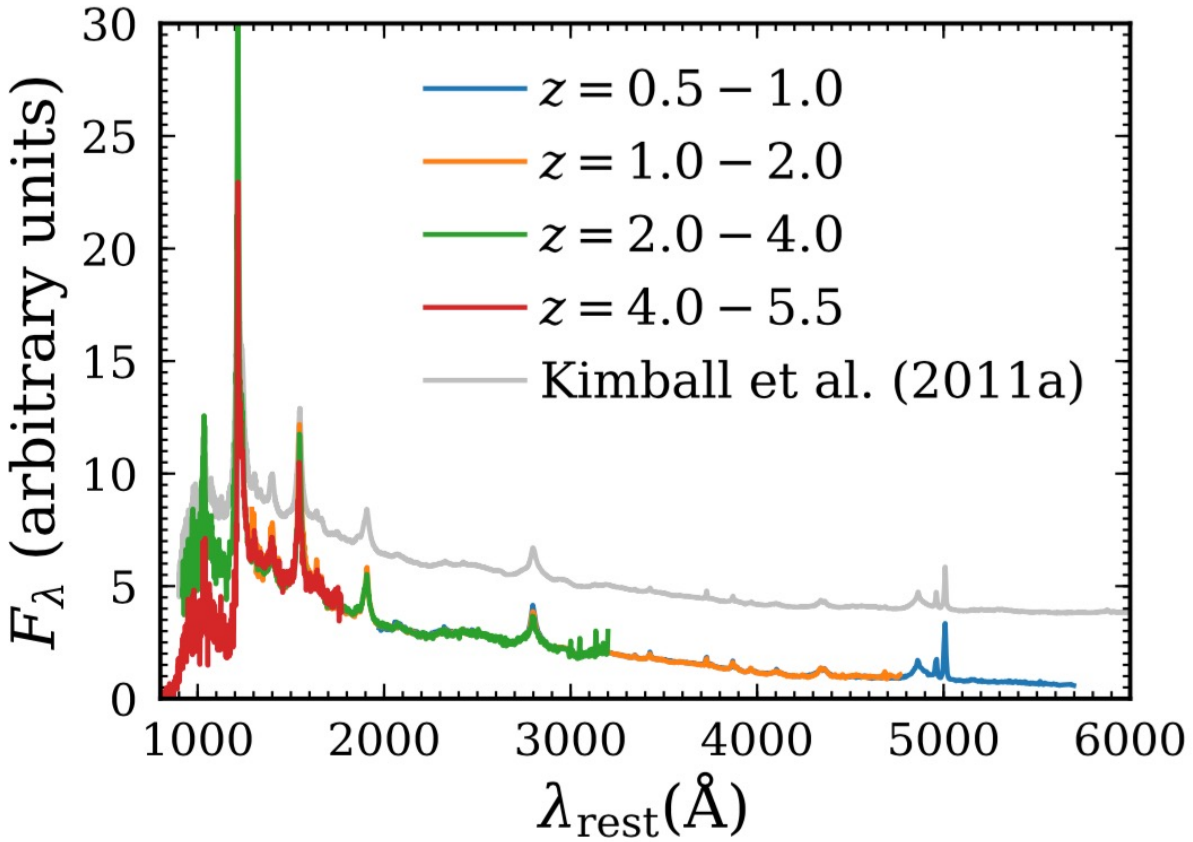
SAMPLE SELECTION

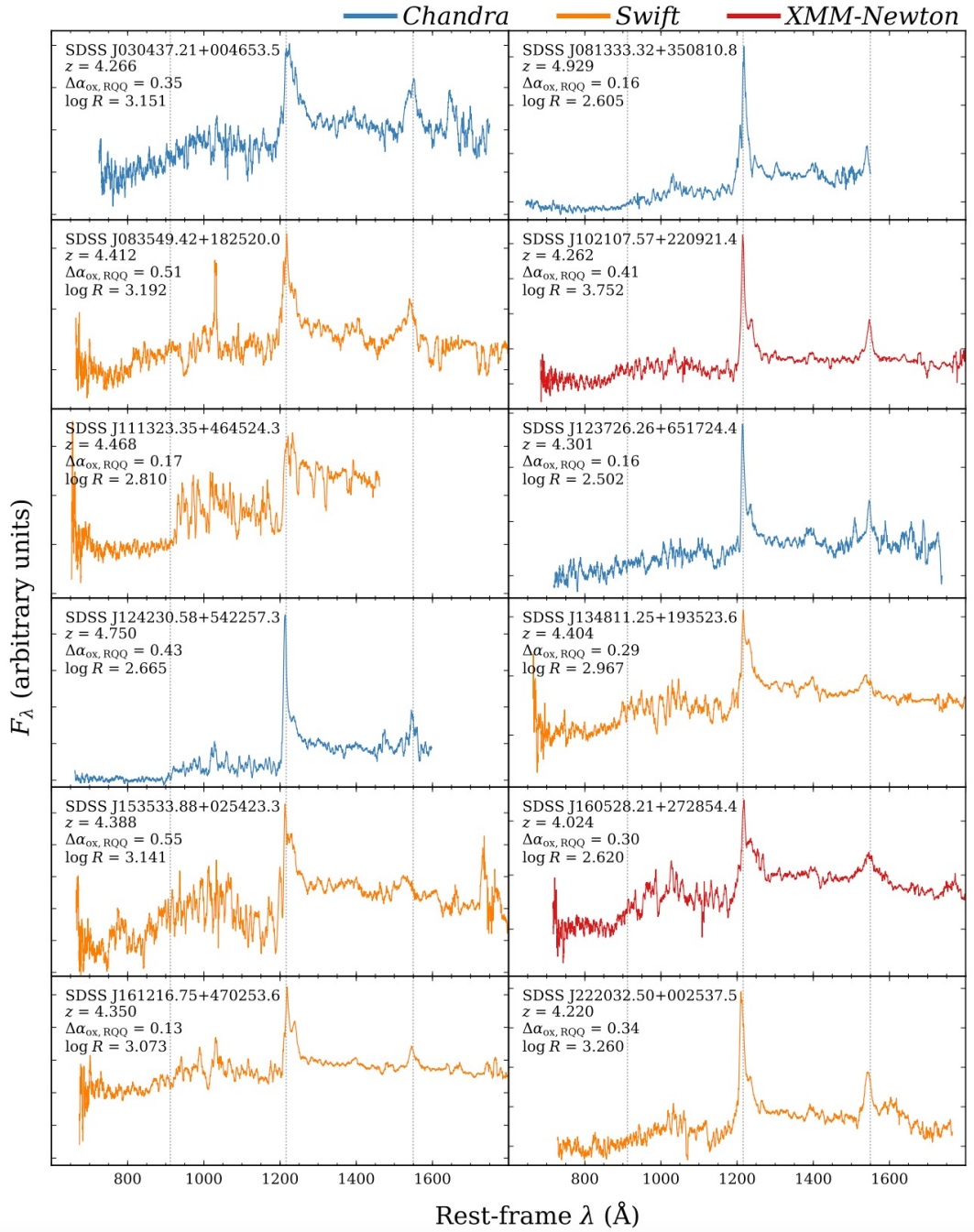
- We selected all known HRLQs (37 quasars) at z=4-5.5, $\delta > -40$ deg, and m_i<21
- FIRST+NVSS
- New and archival X-ray Observations.





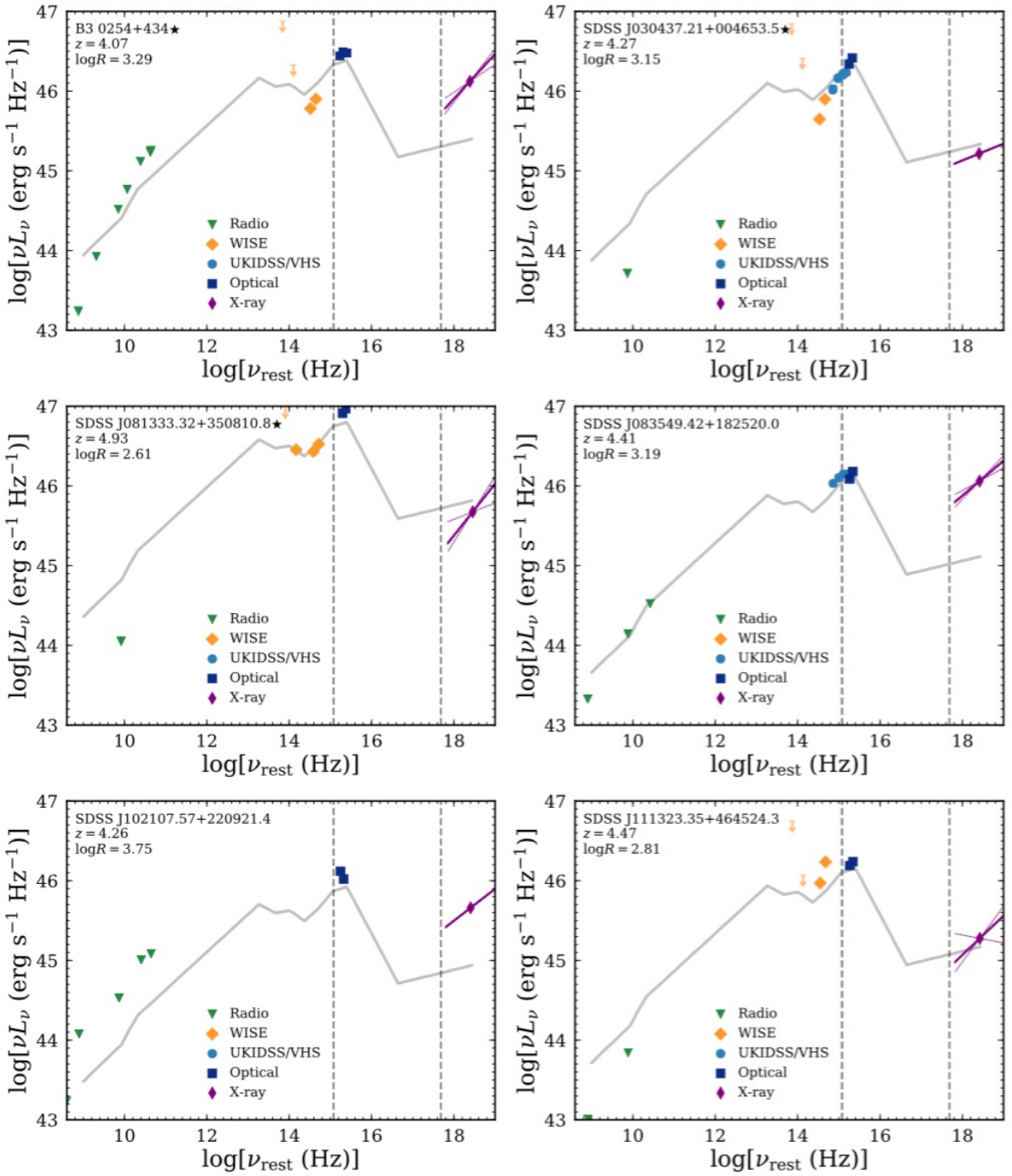
- Our HRLQs show strong broad emission lines in SDSS or other observations.
- Beamed jet emission contributes little optical/UV; accretion-disk continua are well measured.





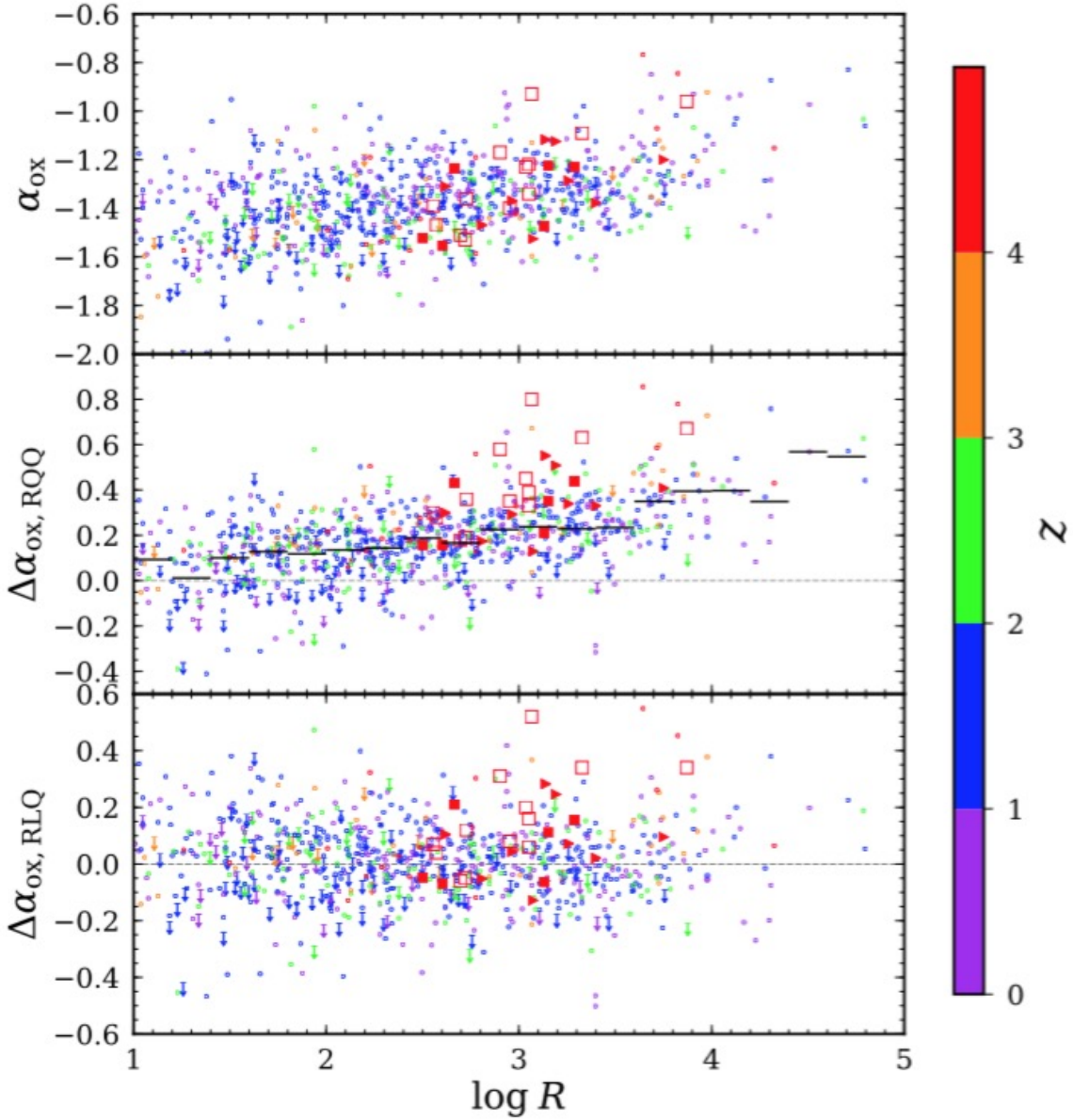
X-Ray Enhancements in SEDs

- SEDs show nominal IR-to-UV behavior
- X-ray enhancements common
- Grey curve is the matched comparison SED for HRLQs at z < 1.5 from Shang et al. (2011)



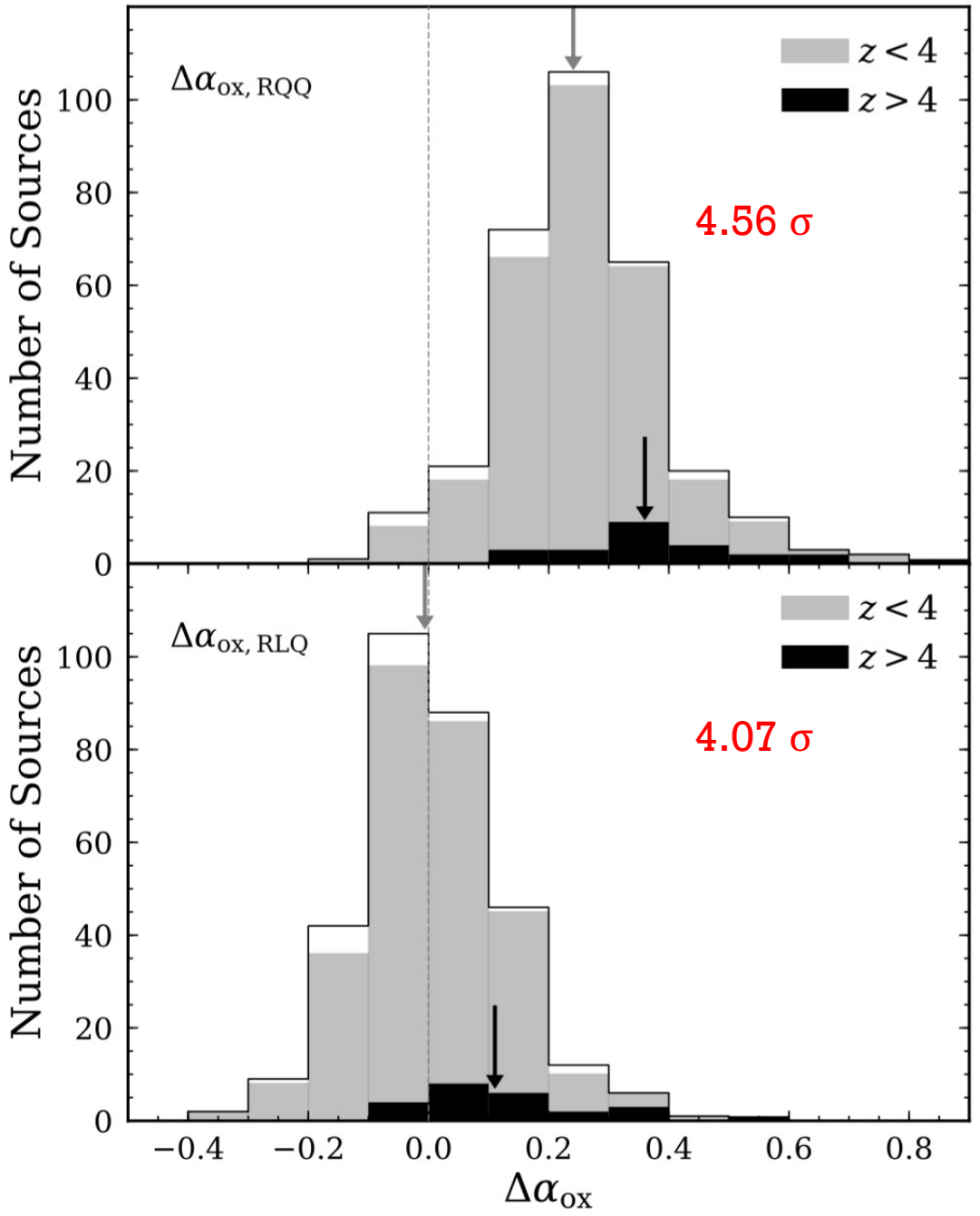
X-Ray Enhancements in α_{ox}

- α_{ox} is the power-law index between rest-frame 2500 A and 2 keV ($f_\nu \propto \upsilon^\alpha$).
- $\Delta\alpha_{ox,\,RQQ} = \alpha_{ox} - \alpha_{ox,\,RQQ}$ (expected), "excess" X-ray emission relative to RQQs, where $\alpha_{ox,\,RQQ}$ is from the L_{2keV}-L_{2500A} correlation (Just et al. 2007).
- $\Delta\alpha_{ox,RLQ} = \alpha_{ox} - \alpha_{ox,\,RLQ}$ (expected), measures if an object is exceptional compared to general RLQs, where $\alpha_{ox,\,RLQ}$ is from L_{2keV}-L_{2500A}-L_{5GHz} correlation for RLQs at z = 0.3-2.5 (Miller et al. 2011)



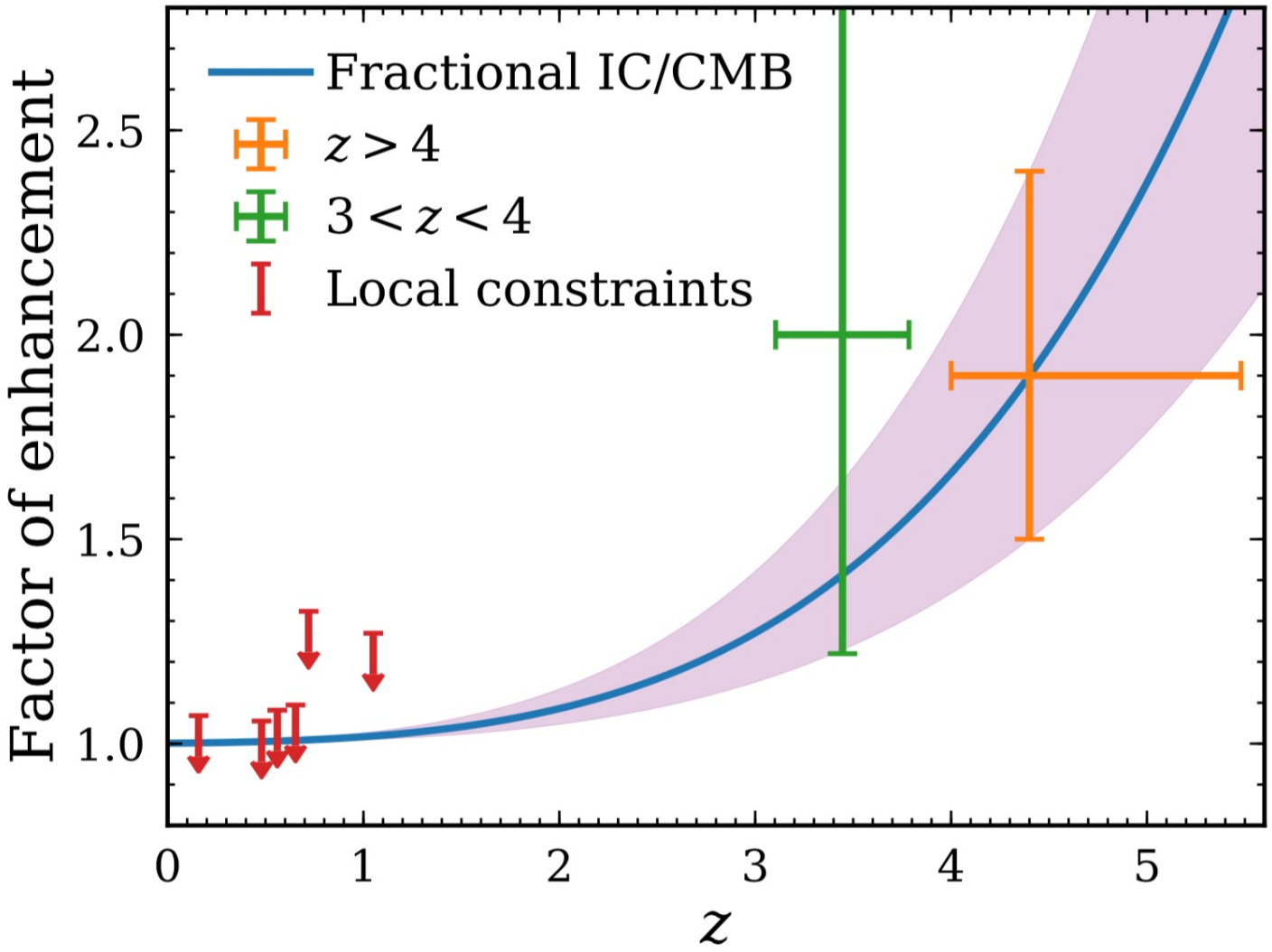
Statistical Tests

- High-redshift (z>4) sample
  - 24 quasars
  - Median z=4.4
  - All detected in X-rays.
- Low-redshift (z<4) sample
  - m_i<20.26
  - 311 quasars
  - Median z=1.3
  - 94% X-ray detection fraction.



Fractional IC/CMB model

- $U_{\mathrm{CMB}} \propto (1+z)^4$
- HRLQs at z=4-5.5 are ≈ 2 times X-ray brighter than matched HRLQs at lower redshifts.
- A *fractional* inverse-Compton/cosmic microwave background (IC/CMB) model can explain our results at high redshift.
- The X-ray contribution from IC/CMB at z<2 is small.



THE END

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