Probing Large Scale UV Background Inhomogeneities with Metal Absorption

Sean Morrison[1]
Mat Pieri,[1] David Syphers,[2] Debopam Som,[3] Ignasi Pérez-Ràfols,[1] & Tae-Sun Kim[4]

[1]Laboratoire d'Astrophysique de Marseille, Université d'Aix-Marseille,
[2]Eastern Washington University,
[3]Ohio State University,
[4]University of Wisconsin-Madison

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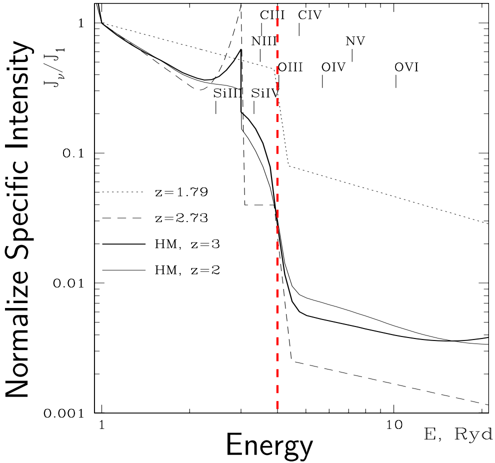
Overview

1. Inhomogeneities in the UV Background
   - Introduction: Inhomogeneities in the UV Background
   - η: The Opacity Ratio of He II to H I
   - Measuring η
   - Measuring Metals in the IGM
   - Techniques
   - Evolution of the UV Background
   - Summary
2. Inhomogeneities Associated with Observed Quasar Positions
   - Methodology
   - Preliminary Results
   - Summary

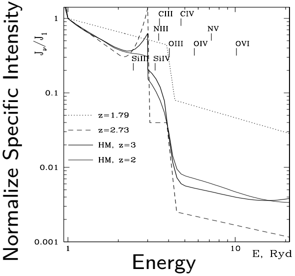
UV Background Shape & Intensity

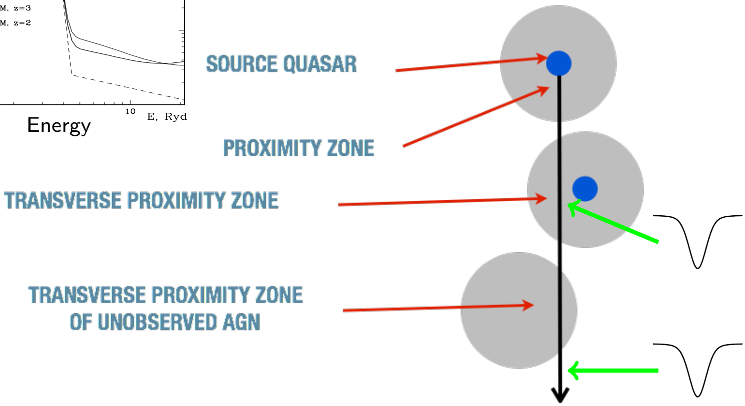
- component to an understanding:
  - star formation
  - AGN activity
  - reionization
  - Quasar population
  - galaxy population
- Impacts Ly-α forest cosmological constraints
- Traced using various ionization species
  - O VI - most sensitive metal species for a probe of these effects



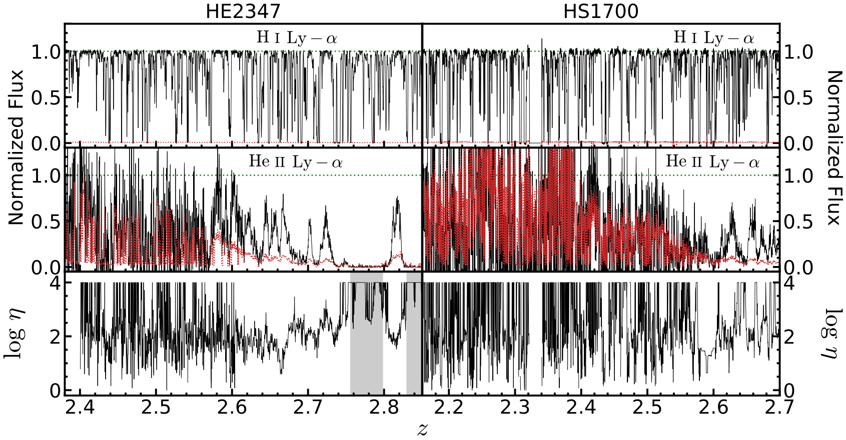
Agafonova et al. (2007)

Quasar/Transverse Proximity Effects





QSO Absorption Sightlines



η: The Ratio of He II to H I

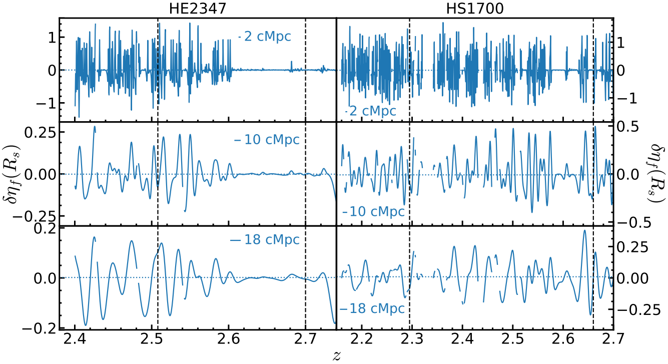
$$\eta = \frac{N_{\mathrm{He\,II}}}{N_{\mathrm{H\,I}}} \approx \frac{4\tau_{\mathrm{He\,II}}}{\tau_{\mathrm{H\,I}}}$$

- Density independent
- Large η: soft radiation
- Small η: hard radiation
- η sensitive on

Mpc scales	to the locations of transverse quasars
smaller scales	to thermal broadening, galactic outflows, and proximity to local galaxies

Measuring η on Large Scales

- Measuring He Ly-α to H Ly-α (η) ratio filtered on ≥ 2 Mpc scales.
- Data from Hubble COS (He) and UVES/HIRES (H)



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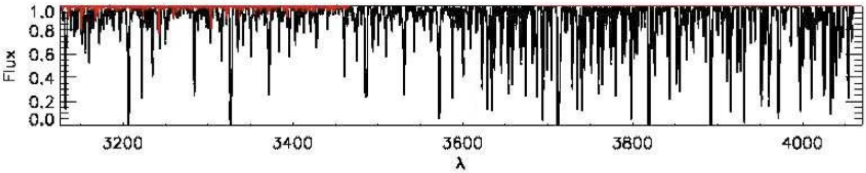
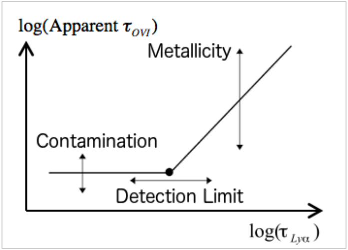
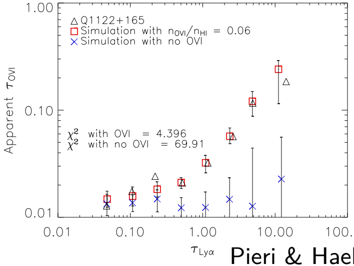
Measuring Metals in the IGM

- Pixel Optical Depth Techniques (Songaila et al. 1995; Schaye et al. 2003)
- A example (simulated) Ly-α forest in a quasar spectrum
  with an OVI forest (5 times ionized oxygen)







Pieri & Haehnelt (2004)

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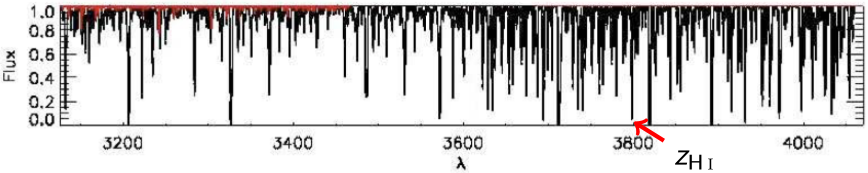

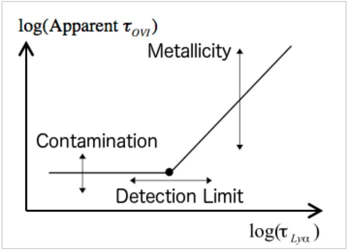

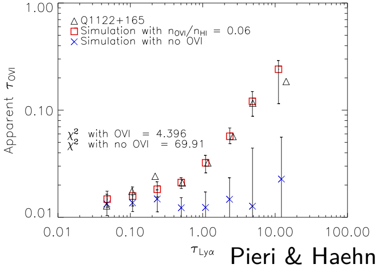

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Measuring Metals in the IGM

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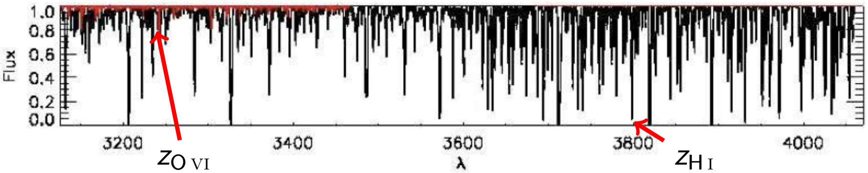

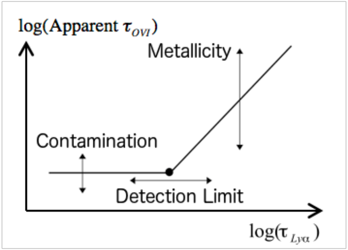

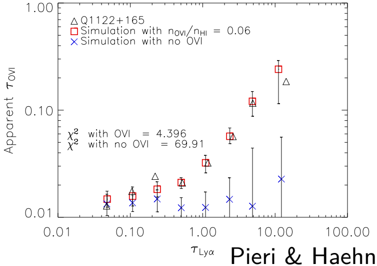

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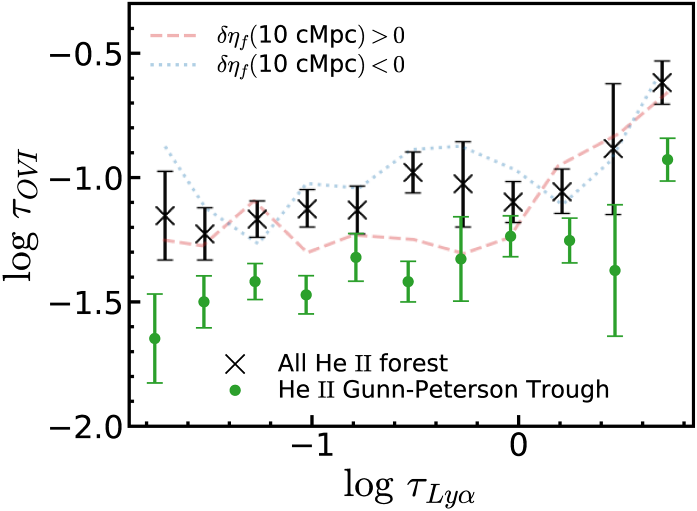
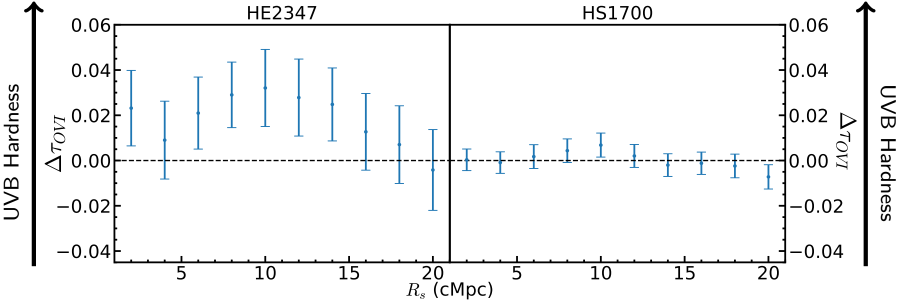
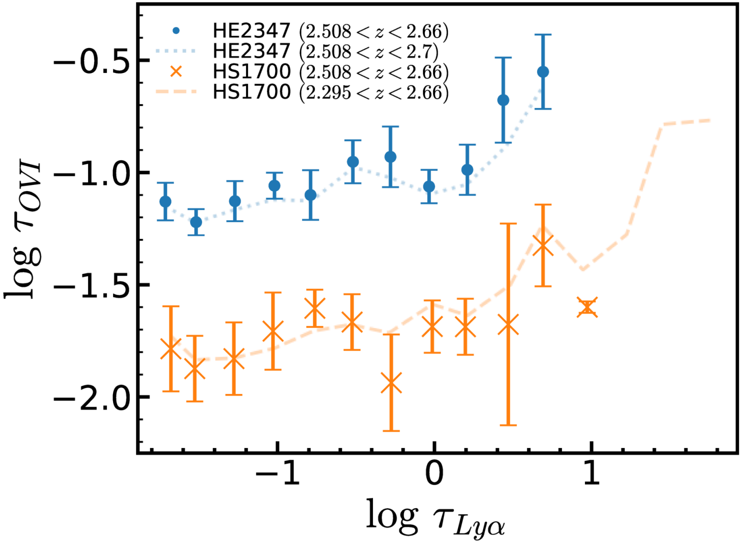
POD in the Gunn-Peterson Trough: HE2347-4342 O VI



Soft/Hard Split as a Function of Scale: O VI



Comparison of Lines-of-Sight (Matched z)



Evolution of the UV Background

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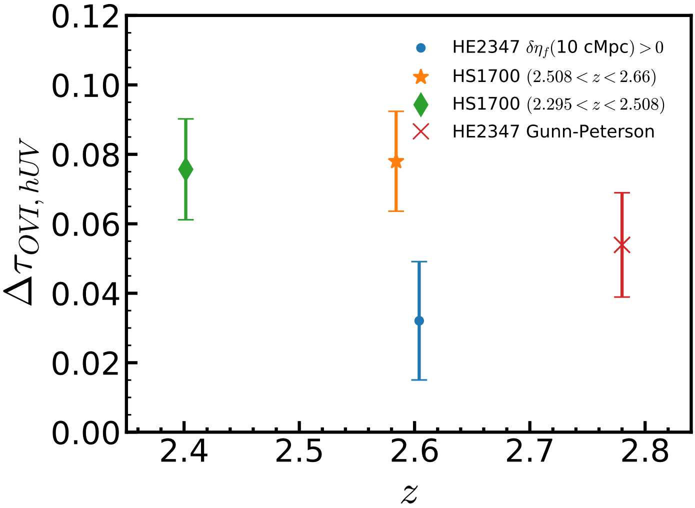
$$\Delta\tau_{\mathrm{O\,VI},hUV} \equiv med(\tau_{\mathrm{O\,VI},HE,\eta_{low}}) - med(\tau_{\mathrm{O\,VI},other}) \quad (1)$$



Summary of Inhomogeneities in the UV Background

- UV background inhomogeneities on $\gtrsim 200$ cMpc scales with
  - hard UV regions with internal ionization structure on ~ 10 cMpc
  - soft UV regions showing no such structure
- HE 2347-4342 He II Gunn-Peterson trough is consistent with post-He II-reionization conditions

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Inhomogeneities Associated with Quasar Positions

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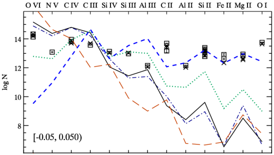
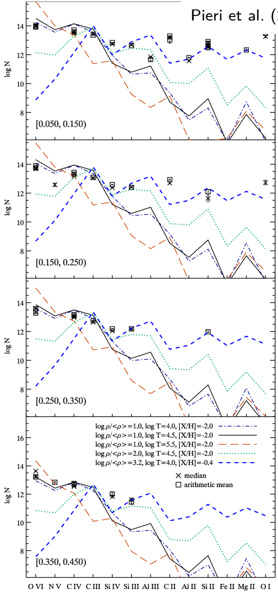
- Take advantage of the statistics and increasing completeness of Quasar samples
- Utilize the absorber frame stacking method,[1] splitting on QSO Proximity
- Utilize all 5 bins: $-0.05 \leq F(\text{Ly-}\alpha) \leq 0.45$
  - Not just interested in CGM
- Utilizing SDSS DR12 Ly-α absorbers[2], with DR14 QSO locations
- Using high-ionization lines detected in all 5 bins
  - O VI, C IV, Si IV, & Si III



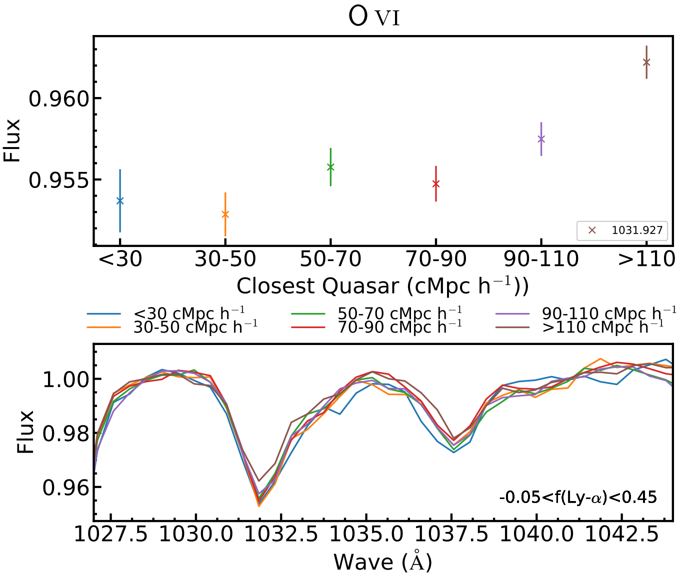
Pieri et al. (2014)



[1] See Mat Pieri's Talk for details on this method

[2] As in Pieri et al. (2014)

Preliminary Results: Closest QSO Proximity



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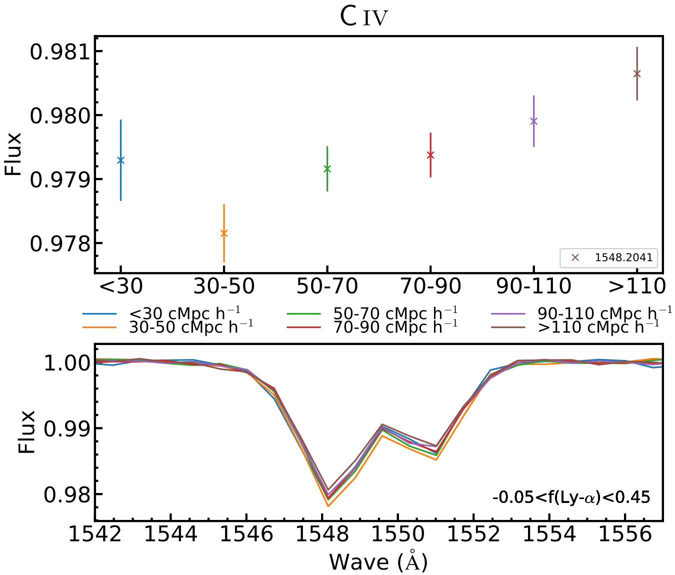

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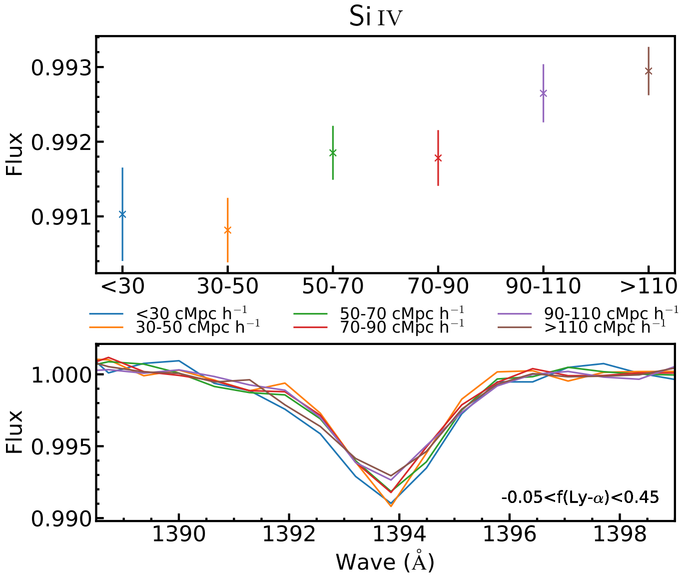

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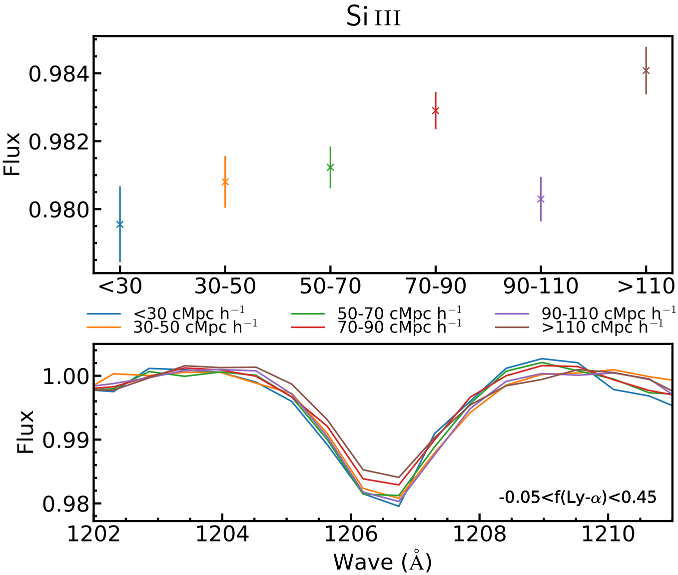


Summary of Inhomogeneities Associated with QSO Position

Motivation:

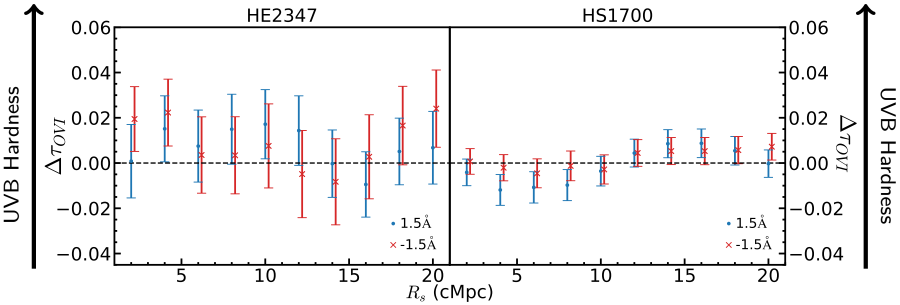
- UV Background inhomogeneities effect:
  - the Ly-α Forest (BAO and small scale)
  - the contaminating metals

Status:

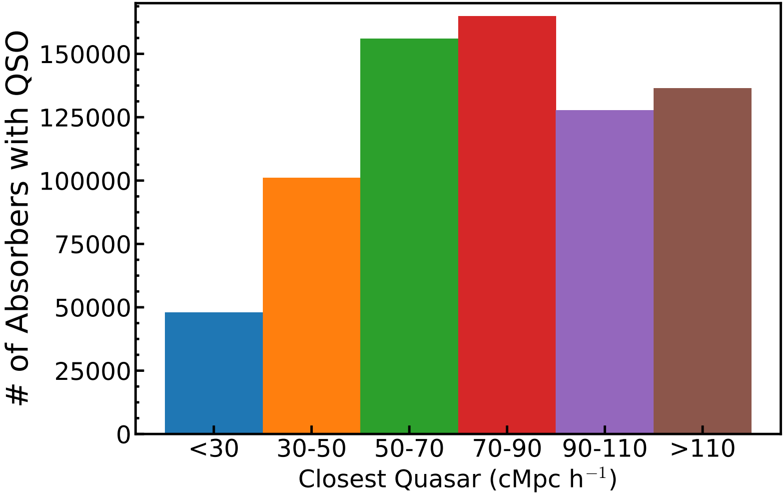
- Begun measuring the large-scale inhomogeneity of metals
- Tentative detection of the large scale sensitivity to quasar proximity

Extra Slides

Null Soft/Hard Splits: O VI



Number of Absorbers with QSO



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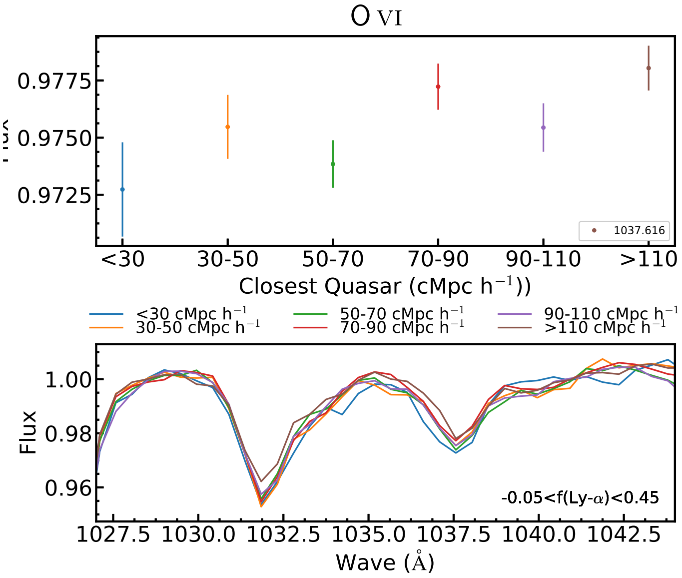

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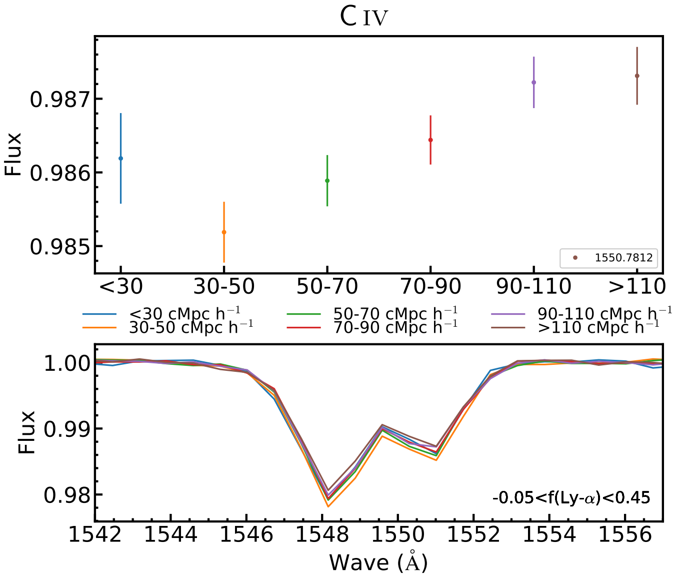

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Schaye J., Aguirre A., Kim T.-S., Theuns T., Rauch M., Sargent W. L. W., 2003, ApJ, 596, 768

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