The extent of O VI & H I absorption around $z \approx 0.2$ galaxies

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Table of contents

IGM/Galaxy connection at $z < 0.5$: galaxy surveys in COS fields

The extent of O VI and H I around $z \approx 0.2$ galaxies
  Motivation: low-to-moderate ions
  High ionization-state gas: upcoming result

Galaxy interactions and the CGM
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$z_{\text{em}} \gtrsim 0.5$ QSOs w/ COS S/N $\gtrsim 15$: e.g PKS 0405-123
Galaxy redshift surveys in the field with IMACS on Magellan

- $\Delta \theta < 10'$ ($d = 2.7\,\text{Mpc}$ at $z = 0.3$)
- $r < 23$ ($L_r = 0.05\, L_\ast$ at $z = 0.3$)
- $\Delta v = 30 - 60\, \text{km s}^{-1}$
r < 23 galaxies close to the sightline: PKS 0405-123

Figure 2: HST ACS + WFC image of the field of the UV-bright quasar PKS 0405−12 from our Snapshot survey. The image reveals the detailed morphology of galaxies probed by the quasar sightline. Foreground galaxies with redshifts from our Magellan survey are labelled in yellow while background galaxies are labelled in grey. Galaxies associated with O VI (Ly\(\alpha\)) absorption systems are shown by solid (dotted) yellow outline. The orientation of the image is shown in white and an unotted dot circled with a radius of 1′ centered on the quasar is shown to provide scale. For reference, 1′ at z ≈ 0.3 corresponds to a physical separation of ≈ 300 kpc.
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Brighter galaxies further from the sightline: PKS 0405-123

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Completeness: PKS 0405-123

$L > 0.1 L_*$

- $\rho_0 = 100$ kpc
- $\rho_0 = 200$ kpc
- $\rho_0 = 300$ kpc
- $\rho_0 = 400$ kpc
- $\rho_0 = 500$ kpc

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PKS 0405-123 published, others coming soon

- PKS 0405-123 redshift catalog published in Johnson, et al., 2013 (arxiv:1308.2681)
- A few sightlines now nearing completion and starting on others
- Results...
Table of contents

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**Figure 8.** Comparison of the corresponding parameter and B-band luminosity.

- **Motivation:** Low-to-moderate ions
- **High ionization-state gas:** Upcoming result

**Chen et al. 2010**

- **Graph:** Shows a scatter plot with data points indicating a power-law relationship between the logarithm of some parameter and another parameter.

**Werk et al. 2013**

- **Graph:** Similar scatter plot with data points and a best-fit power-law model.

**Log $W_{\lambda}$ (2796) versus log $\rho$ ($h^{-1}$ kpc) + 0.14 ($M_B - M_{B*}$)**

- The error bar in the lower left corner indicates the intrinsic scatter estimated.

**Equation:**

$$\log W_{\lambda} = -1.93 \pm 0.11 \log \rho - 0.27 \pm 0.02 \times (M_B - M_{B*}) + 2.51 \pm 0.16$$

**Note:**

- The presence of non-detections and the observed scatter between the two radial cuts, aside from HI 1215, suggest that this is driven by small sample size of this sub-population.

**Future work:** Will combine the two datasets and use ionization modeling to estimate the gas metallicity in this component of the galaxy.
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**Liang & Chen**

**Figure 7.** Similar to Figure 6 but for the observed spatial distribution of rest-frame absorption equivalent widths of Si II (top), Si III (middle), and Si IV (bottom) in the circumgalactic space. Note that the constraints for non-detections in the COS-Halos sample appear to be worse than our typical upper limits, because the COS-Halos team adopted a much larger velocity window for measuring their detections.

**Figure 6.** The extent of O VI and H I around $z \approx 0.2$ galaxies: galaxy surveys in COS fields.

**Figure 5.** The extent of O VI and H I around $z \approx 0.2$ galaxies: galaxy surveys in COS fields.

**Panels (a) and (b) show the low-ion column density against the SFR.** In each case, we have restricted the analysis to the positive detections and have taken lower limits at their detected values match or even exceed the typical values adopted in our study. The velocity window adopted for the COS-Halos galaxies versus $R$.

**Figure 4.** The extent of O VI and H I around $z \approx 0.2$ galaxies: galaxy surveys in COS fields.

**Figure 3.** The extent of O VI and H I around $z \approx 0.2$ galaxies: galaxy surveys in COS fields.

**Figure 2.** The extent of O VI and H I around $z \approx 0.2$ galaxies: galaxy surveys in COS fields.

**Figure 1.** The extent of O VI and H I around $z \approx 0.2$ galaxies: galaxy surveys in COS fields.

**Si III**

**Liang & Chen et al. 2014**

**Werk et al. 2013**

<table>
<thead>
<tr>
<th>$R$ [kpc]</th>
<th>$W_{\text{Si III} 1206}$ [Å]</th>
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<tr>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td>50</td>
<td>0.5</td>
</tr>
<tr>
<td>100</td>
<td>0.1</td>
</tr>
<tr>
<td>150</td>
<td>0.01</td>
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</tbody>
</table>

**Si III $\lambda 1206$**

$W_\alpha (1206)$ (Å) vs. $d/R_h$

**$R$ [kpc] $W_{\text{Si III} 1206}$ [Å]**

$W_{\text{Si III} 1206} = \log N_{\text{Si III}}$
winds with outflow velocity $v_{\text{out}}$ drive enriched gas only out to $r < R_{\text{turn}}$? or ionization state effects?
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O VI: a bit more extended

Prochaska et al. 2011

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O VI: around star-forming galaxies

Chen & Mulchaey 2009

Tumlinson et al. 2011

Figure 2: O VI association with galaxies. (A) O VI column density, $N_{\text{OVI}}$ in cm$^{-2}$, vs. $R$ in kiloparsec for the star-forming (blue) and passive (red) subsamples. Filled and open symbols mark O VI detections and 3$\sigma$ upper limits, respectively. The detections in the star-forming galaxies maintain log $N_{\text{OVI}} \approx$ 14.5 to $R$ $\approx$ 150 kpc, the outer limit of our survey. (B) Component centroid velocities with respect to galaxy systemic redshift for O VI detections, versus inferred dark-matter halo mass. The range bars mark the full range of O VI absorption for each system. The inset shows a histogram of the component velocities. The dashed lines mark the mass-dependent escape velocity at $R$ = 50, 100, and 150 kpc from outside to inside.

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Pushing beyond 150 kpc: 4 fields + Sloan

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O VI

\[
\log N(\text{O VI})/\text{cm}^{-2} = \begin{cases} 
15 & \text{late-type} \\
14 & \text{early-type} 
\end{cases} 
\]

\[
\log <M_*/M_\odot> = \begin{cases} 
10.3 & \text{late-type} \\
11.0 & \text{early-type} 
\end{cases} 
\]
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IGM/Galaxy connection at $z < 0.5$: galaxy surveys in COS fields
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Covering Fractions

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Difference between late and early-type:

\[ d/R_n = 0.75 - 2.0 \]

$P(<N)$ vs. $\log N/\text{cm}^{-2}$

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$R_{h}$

![Plot](image)

$\log \langle M_*/M_\odot \rangle = 10.7$

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Conclusions

- O VI systems around late-type galaxies
  - Strong systems out to 1 virial radius
  - Weaker systems out to 2 virial radii
  - Low incidence at larger projected distances

- Similar trend in H I

- Early-type galaxies
  - Early-type galaxies show suppressed O VI out to 2 virial radii
  - Also show suppressed H I at 0.65 – 2 virial radii

- Highly ionized, enriched gas well beyond “metal-boundary” at $\approx 0.5$ virial radii seen in lower ionization state gas, though metallicity could be quite low
An interacting galaxy pair

Johnson et al. 2014 (arxiv:1312.3944)

- G1 @ z = 0.1202 and ρ = 11.5 kpc
- G2 @ z = 0.1203 and ρ = 20.4 kpc

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