Probing Quasar Winds Using Intrinsic Narrow Absorption Lines

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Intrinsic NAL Ionization Continuum

Increasing Ionization Parameter

**N V Dominant**

Q1158–1843 $z_{\text{abs}} = 2.4425$

**C IV Dominant with non-black Lyα**

Q0549–213 $z_{\text{abs}} = 2.2437$

**C IV Dominant with Low Ionization Lines**

Q0421–2624 $z_{\text{abs}} = 2.1568$

**C IV Dominant**

Q0055–269 $z_{\text{abs}} = 3.0859$
73 Quasar Sample from VLT/UVES Archive

- Directly measured quantities:
  - Absorption redshift $z_{\text{abs}}$
  - Emission redshift $z_{\text{em}}$
  - Optical flux $f_\nu(\text{opt})$
  - Radio flux $f_\nu(5 \text{ GHz})$

- More physically meaningful quantities
  - Velocity offset $v_{\text{shift}}$
  - Velocity offset distribution of NAL systems, $dN/d\beta$ or $dN/dz$
  - Optical luminosity $L_\nu(\text{opt})$
  - Radio luminosity $L_\nu(\text{radio})$
  - Radio loudness parameter, $R = f_\nu(5 \text{ GHz})/f_\nu(4400 \text{ Å})$
Absorption Lines

- BALs; widths > 2000 km/s
- NALs; widths < 500 km/s
- Mini-Bals; 500 km/s < width < 2000 km/s
Coverage Fraction

\[ R(\lambda) = C_f(\lambda)e^{-\tau(\lambda)} + [1 - C_f(\lambda)] \]

\[ \tau \propto Nf\lambda = \begin{cases} N \times f_b \times \lambda_b \\ N \times f_r \times \lambda_r \end{cases} \]

\[ \left( \frac{R_r - 1 + C_f}{C_f} \right)^{\frac{f_b\lambda_b}{f_r\lambda_r}} = \frac{R_b - 1 + C_f}{C_f} \]

In the case of resonance doublet lines such as C IV, N V, and Si IV, \( f_b/f_r = 2 \) and \( \lambda_b \sim \lambda_r \).

\[ C_f = \frac{\left[R_r(\lambda) - 1\right]^2}{R_b(\lambda) - 2R_r(\lambda) + 1} \]
Coverage Fraction

- Determine coverage fraction by:
  - Pixel-by-pixel basis
  - Per kinematic component

- Reliability Classes
  - Class A: Intrinsic
  - Class B: Potentially intrinsic
  - Class C: Intervening

- Figure courtesy of Misawa et al. (2007)
Ratio of the BELR to the Continuum Source Flux

- Coverages fractions can’t be determined independently of each other
- Can provide interesting constraints
- \[ C_f = \left( C_c + WC_{BELR} \right) / (1 + W) \]
- \[ W = \left( F_{BELR} / F_c \right) - 1 \]
- Ratio of the Flux Contributed by the BELR and the Continuum Sources
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Absorber Transverse Size ~ $10^{-4}$ pc
Ratio of the BELR to the Continuum Source Flux

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Absorber Transverse Size ~ 10^{-4} pc

Absorber Transverse Size ~ 10^{-2} pc
Intrinsic NAL Ionization Continuum

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C IV Dominant with Low Ionization Lines
Q0421–2624 $z_{\text{abs}}=2.1568$
NAL Absorber Model
## Compositions of the Various Types of Systems

<table>
<thead>
<tr>
<th></th>
<th>Dense Core</th>
<th>Tenuous Atmosphere</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N V Dominant</strong></td>
<td>C IV, N V, O VI, some Lyα</td>
<td>O VI and High Ionization Lines</td>
</tr>
<tr>
<td><strong>C IV Dominant non-Black</strong></td>
<td>Lyα, C IV, N V</td>
<td>O VI, High Ionization Lines, possibly N V</td>
</tr>
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<td><strong>C IV Dominant</strong></td>
<td>Lyα, Si IV, possibly C IV</td>
<td>Lyα, possibly C IV and/or N V</td>
</tr>
<tr>
<td><strong>C IV Dominant w/ Low Ionization Lines</strong></td>
<td>Lyα, Low Ionization Lines</td>
<td>Lyα, Si IV, C IV</td>
</tr>
</tbody>
</table>

**Background Source**

**To Earth**
Schematic Model of the Quasar Host Galaxy

High Ionization Systems (Ne VIII, Na IX, Mg X)

N V Dominant Systems

O VI Dominant

C IV Dominant
N V Dominant

Q1158–1843 $z_{\text{abs}}=2.4425$

![Graph showing absorption features in Q1158–1843 at $z_{\text{abs}}=2.4425$. The graph includes absorption lines for Lya, CIV1548, NV1239, and OVI1032, with velocity on the x-axis and absorption strength on the y-axis.](image)
C IV Dominant with Non-Black Lyα

Q0549–213 $z_{\text{abs}}=2.2437$
C IV Dominant

Q0055–269 \( z_{\text{abs}} = 3.0859 \)

![Graph showing absorption lines at various velocities](image-url)
C IV Dominant with Low Ionization Lines

Q0421–2624 $z_{\text{abs}} = 2.1568$
Black and Non-Black Lyα

Q0011+0055 $z_{\text{abs}} = 2.2858$

![Graph showing Lyα emissions for galaxies with different redshifts.](image)
Sizes of Absorbers
Using the Definitions of Flux: \[ F = \frac{L}{4\pi r^2} \]
And Ionization Parameter: \[ U = \frac{n_\gamma}{n_H} \]
Leads to:
\[
\left( \frac{n_H}{3 \times 10^{11} \text{ cm}^{-3}} \right) = \left( \frac{\nu L_\nu (2500 \text{ Å})}{4 \times 10^{46} \text{ ergs s}^{-1}} \right) \left( \frac{U}{10^{-1.9}} \right)^{-1} \left( \frac{r}{1 \text{ pc}} \right)^{-2}
\]
Thickness:
\[
\left( \frac{\Delta r}{10^{10} \text{ cm}} \right) = \left( \frac{N_{\text{tot}}}{10^{18} \text{ cm}^{-2}} \right) \left( \frac{n_H}{10^{8} \text{ cm}^{-3}} \right)^{-1}
\]
Mass:
\[ M = m_H N_{\text{tot}} R^2 \sim 10^{27} \text{ g} \left( \frac{R}{10^{16}} \right)^2 \left( \frac{N_{\text{tot}}}{10^{18} \text{ cm}^{-2}} \right) \]
Using these values, \( M \approx 10^{-6} \text{ } M_\odot \)