Probing Quasar Winds Using Intrinsic Narrow Absorption Lines

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Intrinsic NAL Ionization Continuum

Increasing Ionization Parameter

- **N V Dominant**
  - Q1158–1843 $z_{\text{abs}}=2.4425$
  - Lyα
  - CIV1548
  - NV1239
  - OVI1032

- **C IV Dominant with non-black Lyα**
  - Q0549–213 $z_{\text{abs}}=2.2437$
  - Lyα
  - CIV1548
  - NV1239

- **C IV Dominant**
  - Q0055–269 $z_{\text{abs}}=3.0859$
  - Lyα
  - SilV1394
  - CIV1548

- **C IV Dominant with Low Ionization Lines**
  - Q0421–2624 $z_{\text{abs}}=2.1568$
  - Lyα
  - OI1302
  - SilV1394
  - CIV1548
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 $< \text{width} < 2000$ km/s
Coverage Fraction

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

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

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

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)
Coverages fractions can’t be determined independently of each other
Can provide interesting constraints
\[ C_f = \frac{C_c + WC_{\text{BELR}}}{1 + W} \]

\[ W = \frac{F_{\text{BELR}}}{F_c} - 1 \]

Ratio of the Flux Contributed by the BELR and the Continuum Sources

\[ F_{\text{BELR}} \sim 3F_c \]

\[ W = 2 \]

Dall'Aglio et al. 2008
Ratio of the BELR to the Continuum Source Flux

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Ratio of the BELR to the Continuum Source Flux

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Ratio of the BELR to the Continuum Source Flux

- Coverages fractions can’t be determined independently of each other
- Can provide interesting constraints
- \[ C_f = \left( C_c + W C_{\text{BELR}} \right) / \left( 1 + W \right) \]
- \[ W = \left( F_{\text{BELR}} / F_c \right) - 1 \]
- Ratio of the Flux Contributed by the BELR and the Continuum Sources

Absorber Transverse Size ~ continuum source size
~ \( 5 \times 10^{-4} – 5 \times 10^{-3} \) pc
Ratio of the BELR to the Continuum Source Flux

- Coverages fractions can’t be determined independently of each other
- Can provide interesting constraints
- \( C_f = \frac{C_c + W C_{\text{BELR}}}{1 + W} \)
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- Ratio of the Flux Contributed by the BELR and the Continuum Sources

Absorber Transverse Size ~ continuum source size
\(~ 5 \times 10^{-4} – 5 \times 10^{-3} \text{ pc} \)

Absorber Transverse Size ~ size of BELR
\(~ 10^{-2} – 10^{-1} \text{ pc} \)
Intrinsic NAL Ionization Continuum

Increasing Ionization Parameter

**N V Dominant**
Q1158–1843 $z_{\text{abs}}=2.4425$

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

**C IV Dominant with non-black Lyα**
Q0055–269 $z_{\text{abs}}=3.0859$

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

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

Q1158–1843 $z_{\text{abs}} = 2.4425$

![Graph showing absorption line features with labels for Lyα, CIV1548, NV1239, and OVI1032. The x-axis represents velocity in km s$^{-1}$ with values ranging from -600 to 600.]
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 Lya, SiIV1394, and CIV1548 with velocity in km s$^{-1}$]
C IV Dominant with Low Ionization Lines

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

\[ Q0011 + 0055 \quad z_{\text{abs}} = 2.2858 \]
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, \[ M \approx 10^{-6} \text{ M}_\odot \]
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