Probing Quasar Winds Using Intrinsic Narrow Absorption Lines

PENNSTATE

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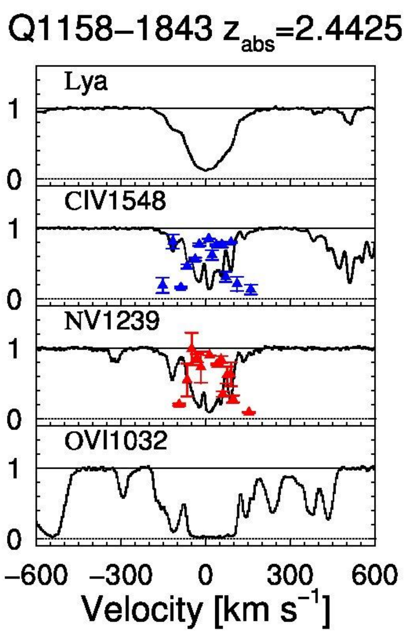
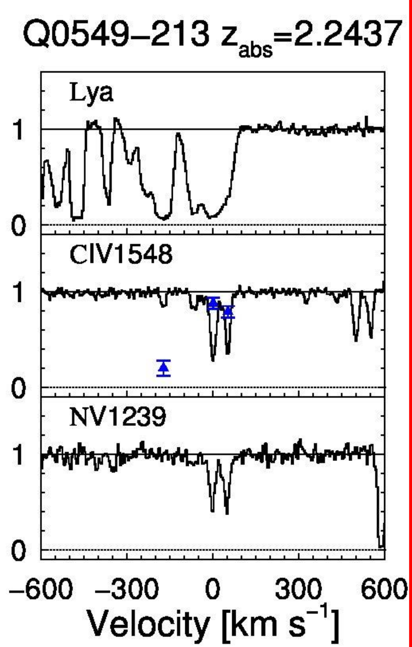
Intrinsic NAL Ionization Continuum

Increasing Ionization Parameter

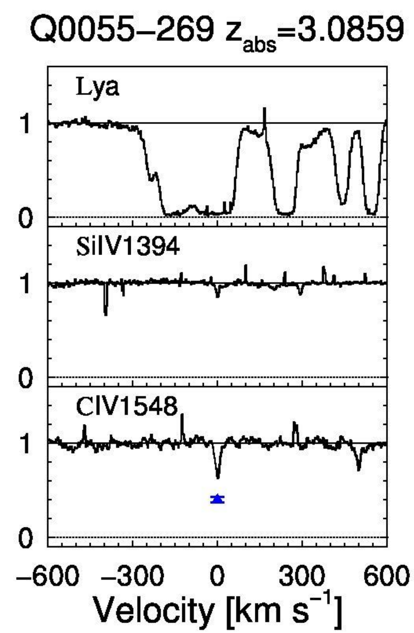
N V Dominant



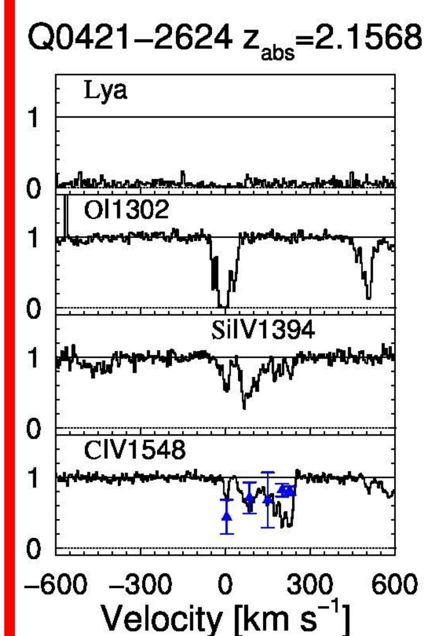
C IV Dominant with non-black Lyα



C IV Dominant

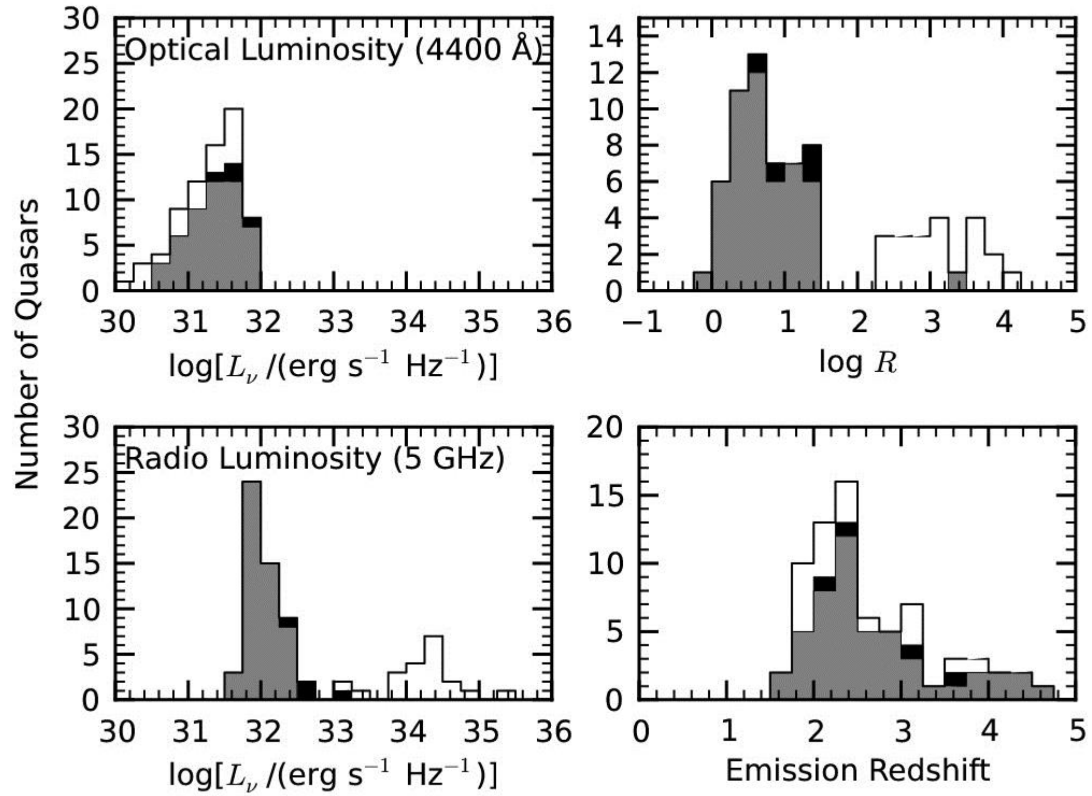


C IV Dominant with Low Ionization Lines



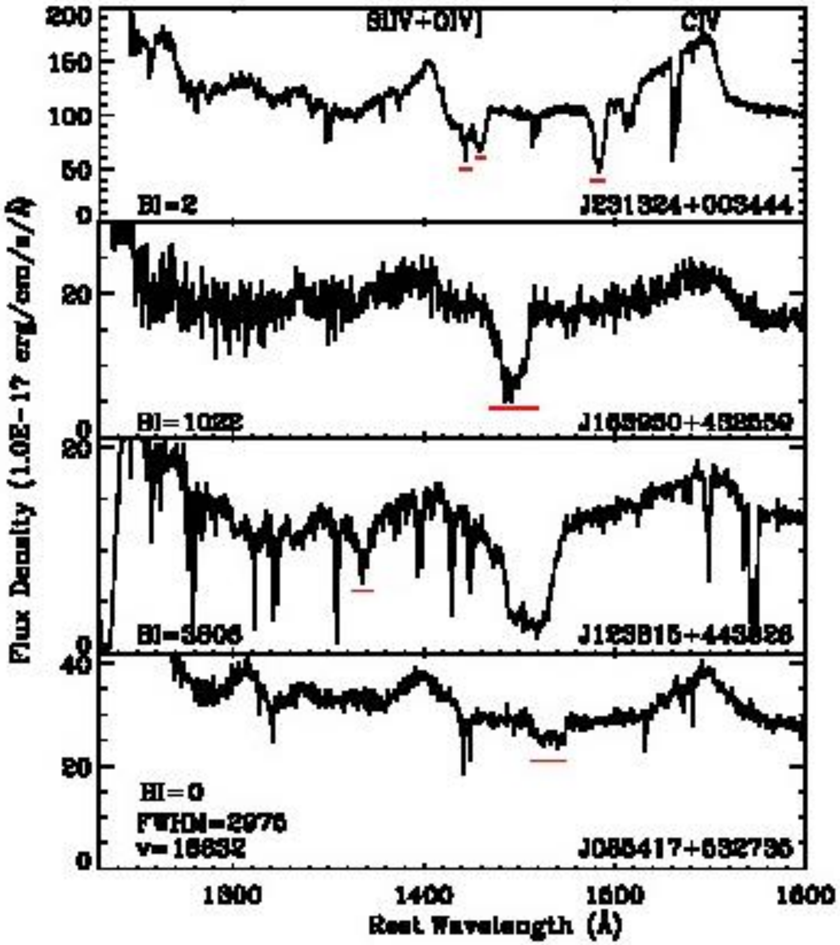
73 Quasar Sample from VLT/UVES Archive

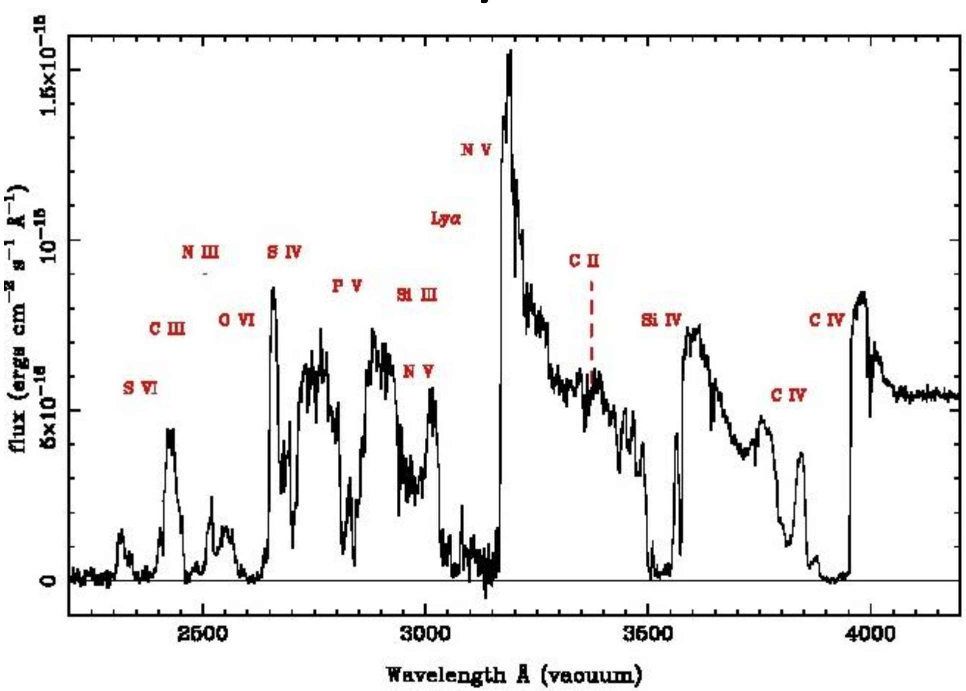
- Directly measured quantities:
  - Absorption redshift z_{abs}
  - Emission redshift z_{em}
  - Optical flux f_{ν}(opt)
  - Radio flux f_{ν}(5 GHz)
- More physically meaningful quantities
  - Velocity offset v_{shift}
  - Velocity offset distribution of NAL systems, dN/dβ or dN/dz
  - Optical luminosity L_{ν}(opt)
  - Radio luminosity L_{ν}(radio)
  - Radio loudness parameter, $R = f_{\nu}(5\ \text{GHz})/f_{\nu}(4400\ \text{Å})$



Absorption Lines

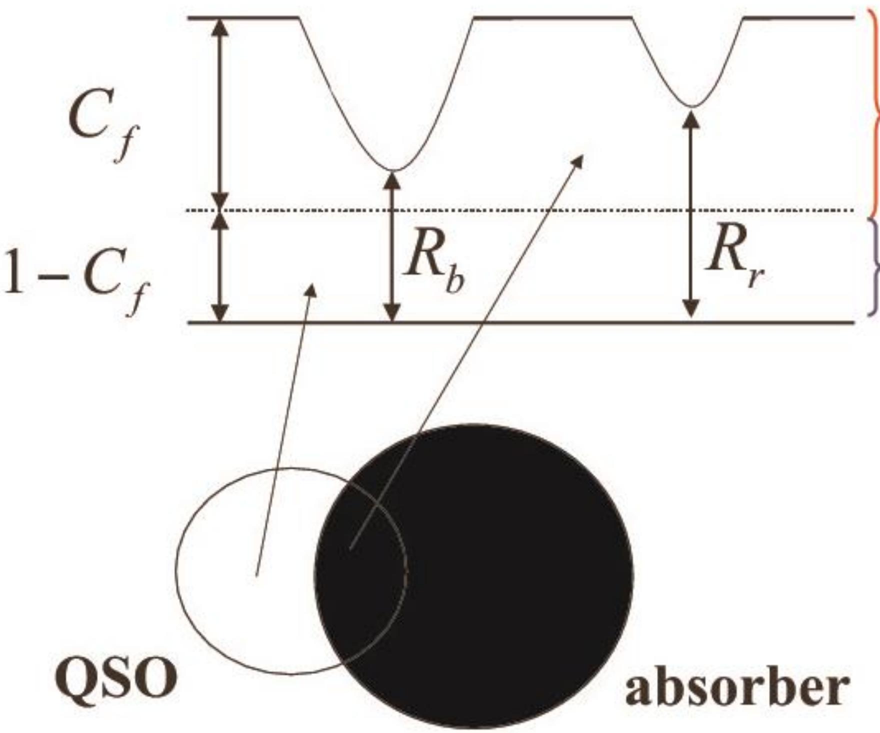
- BALs; widths > 2000 km/s
- NALs; widths < 500 km/s
- Mini-Bals;
  500 km/s < width
  < 2000 km/s





Coverage Fraction

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



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

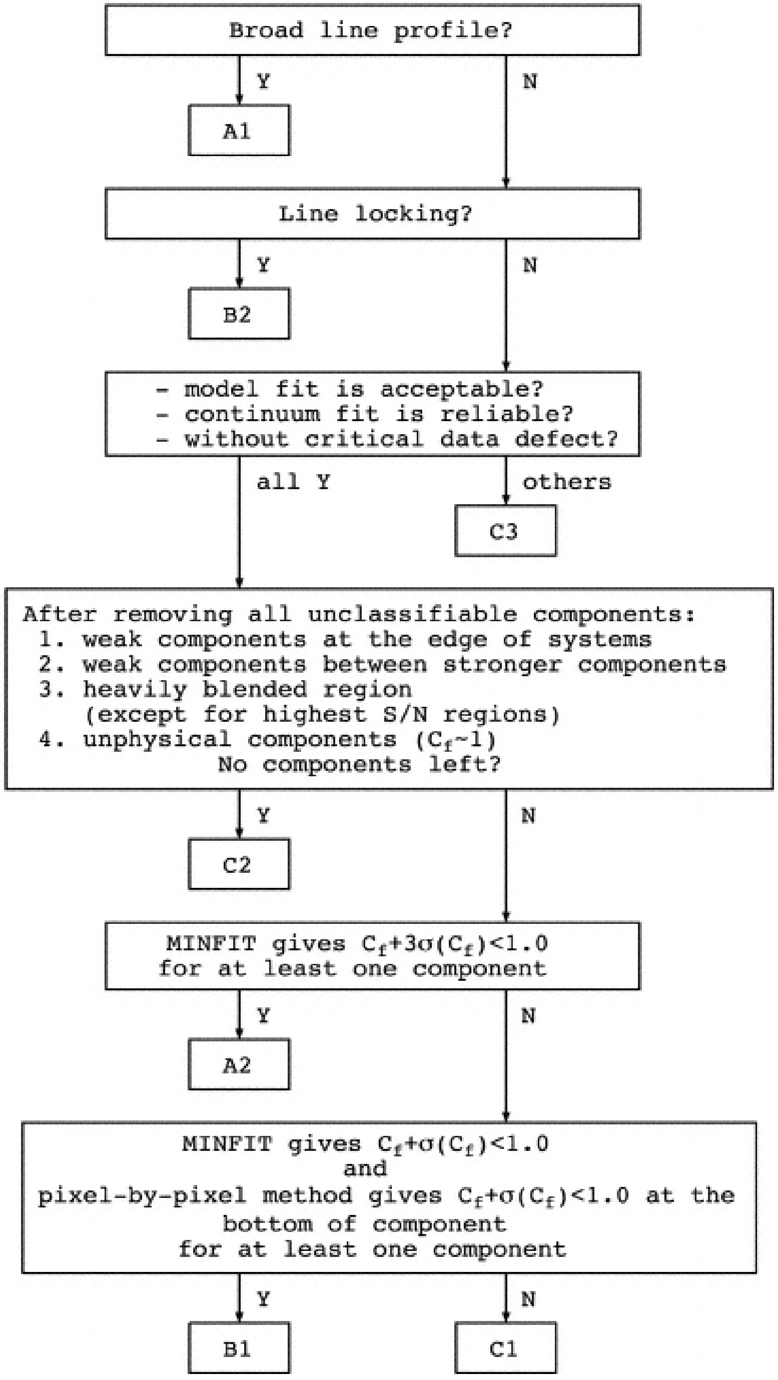
$$\left(\frac{R_r - 1 + C_f}{C_f}\right)^{f_b\lambda_b / f_r\lambda_r} = \frac{R_b - 1 + C_f}{C_f}$$

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

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

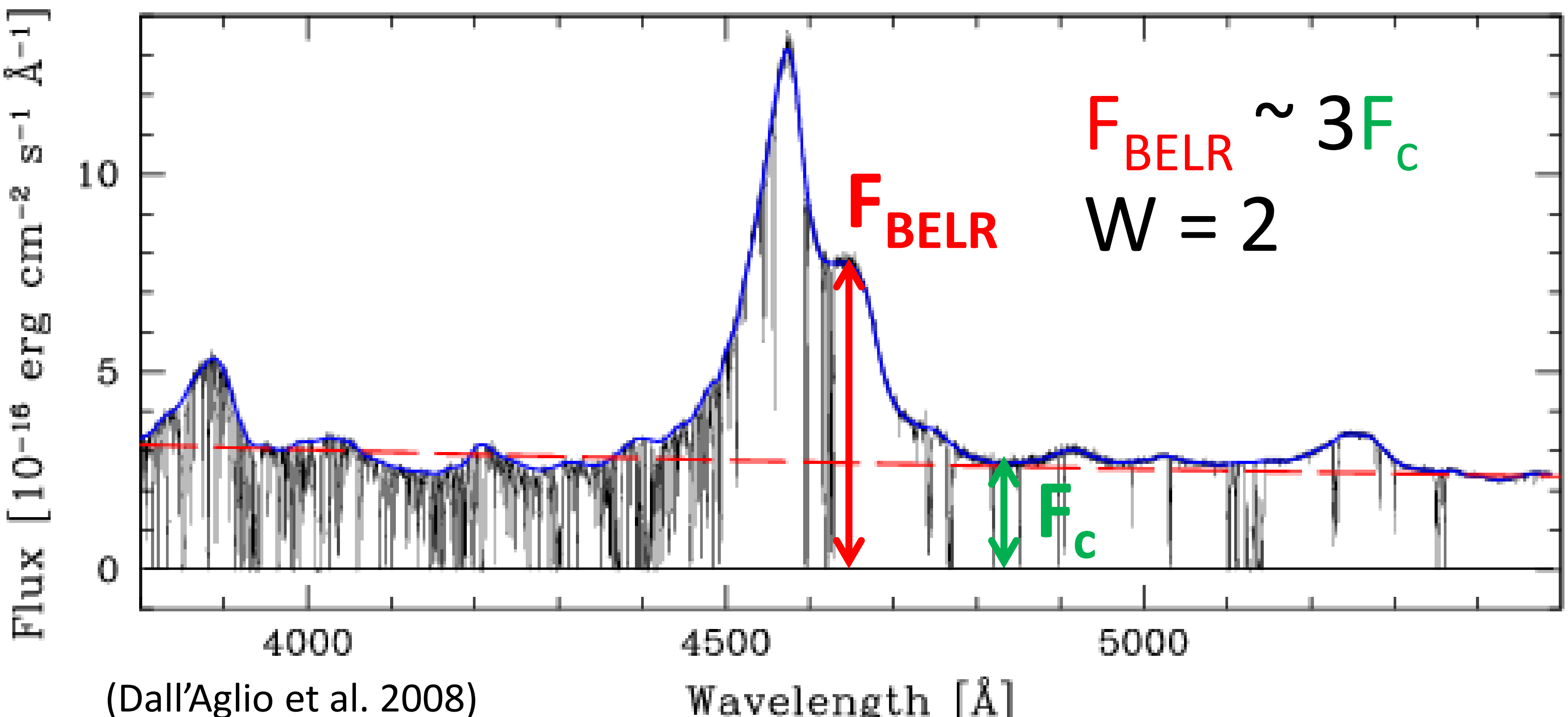
Coverage Fraction

- 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
- $C_f = (C_c + W C_{BELR}) / (1 + W)$
- $W = (F_{BELR} / F_c) - 1$
- Ratio of the Flux Contributed by the BELR and the Continuum Sources



(Dall’Aglio et al. 2008)

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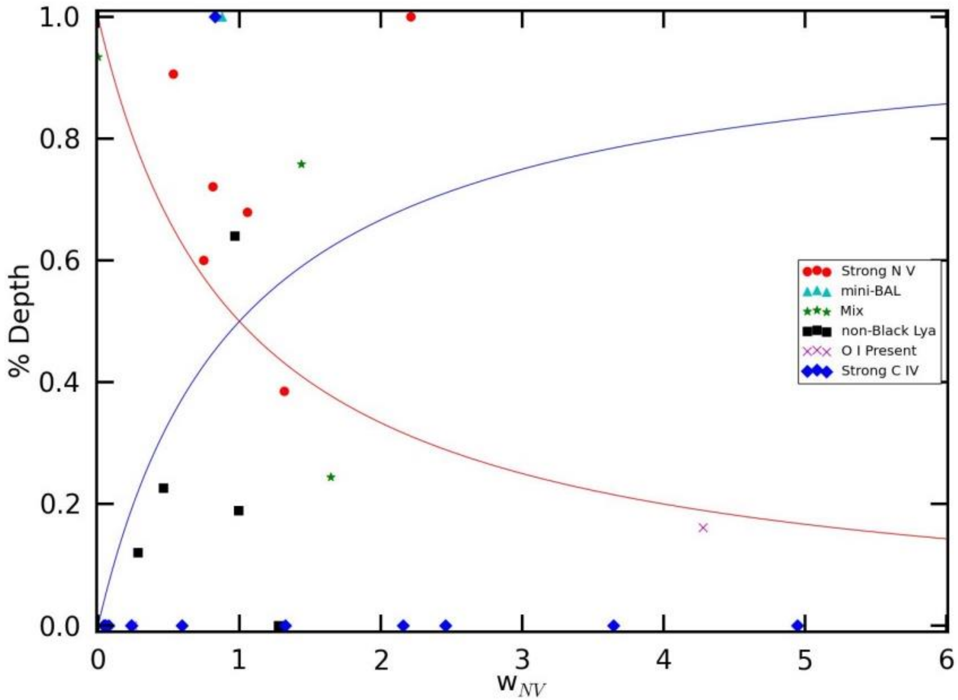

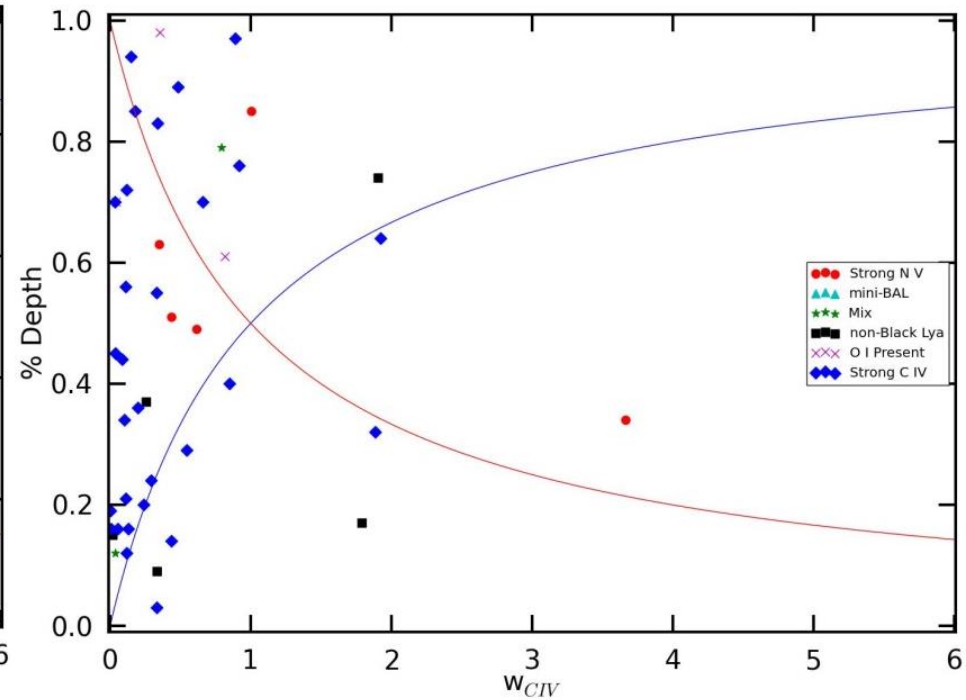

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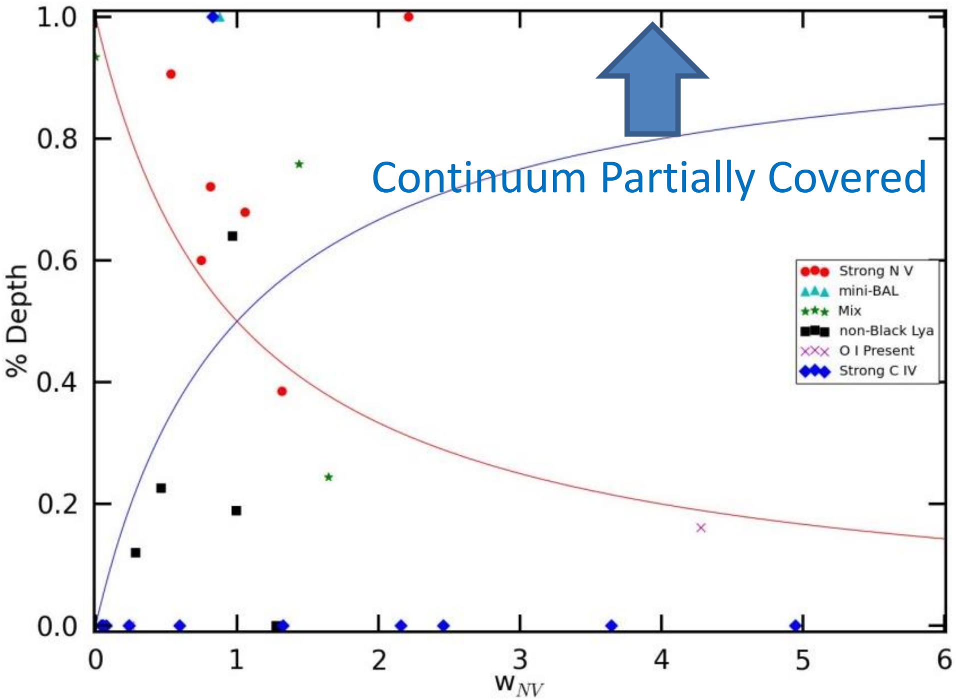

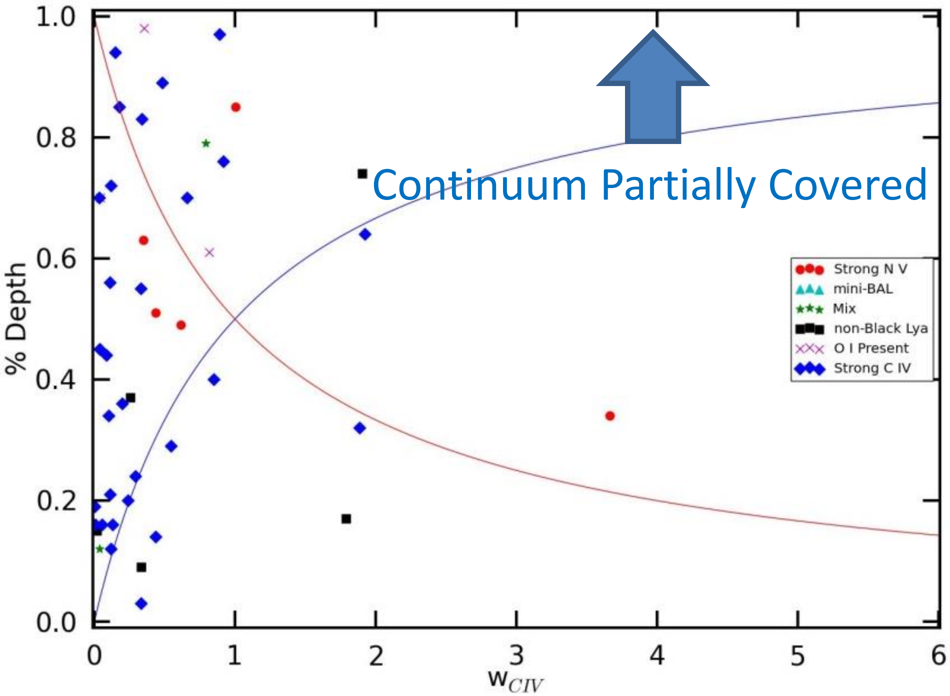

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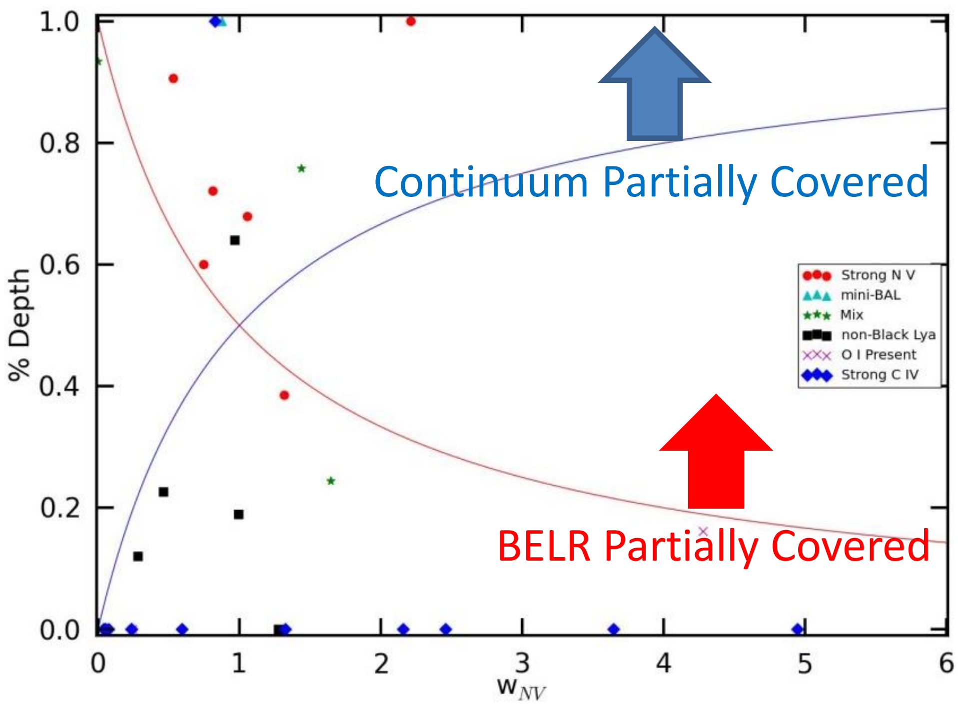

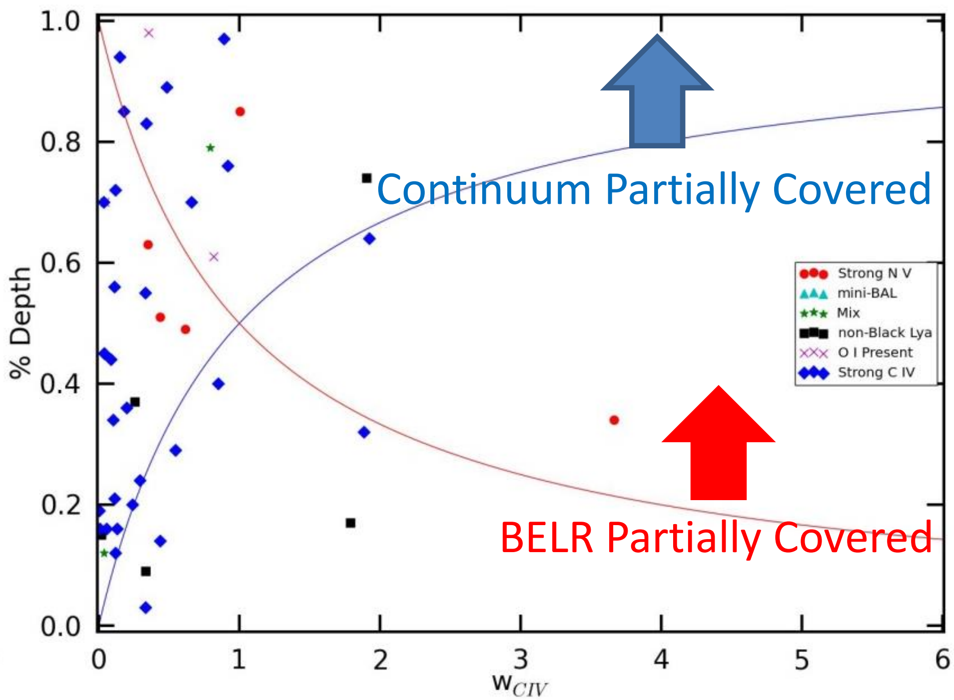

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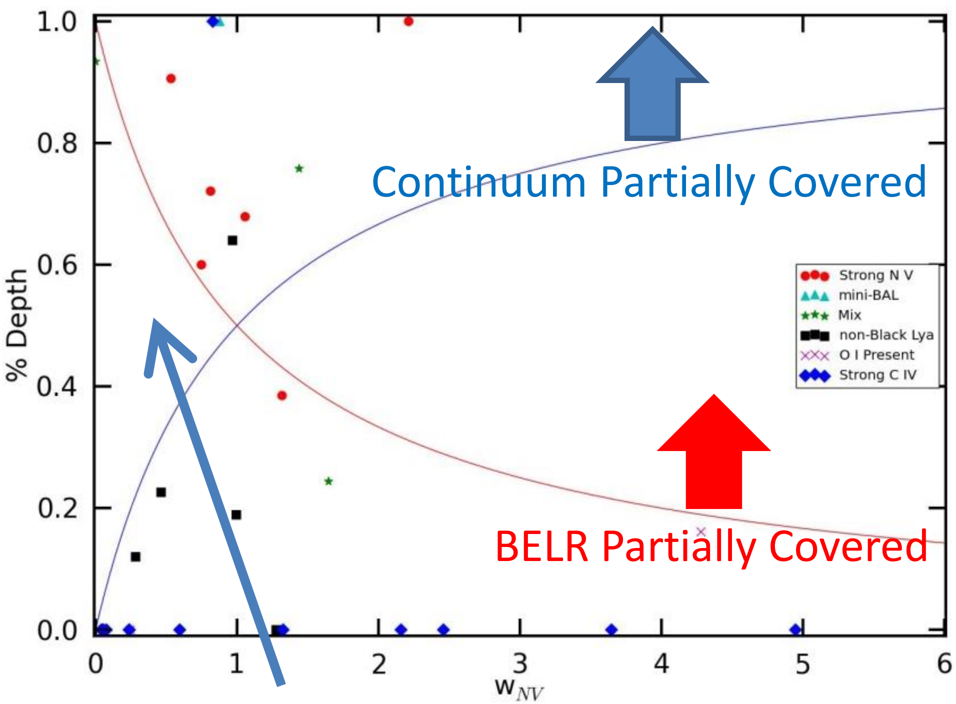

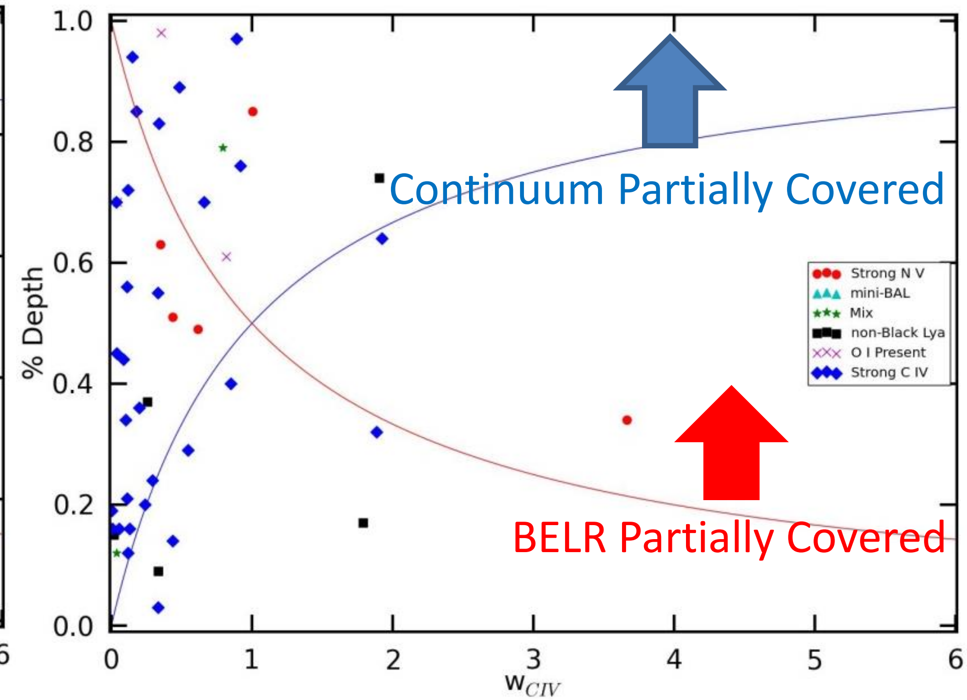

Absorber Transverse Size ~ continuum source size

~ $5 \times 10^{-4} - 5 \times 10^{-3}$ pc

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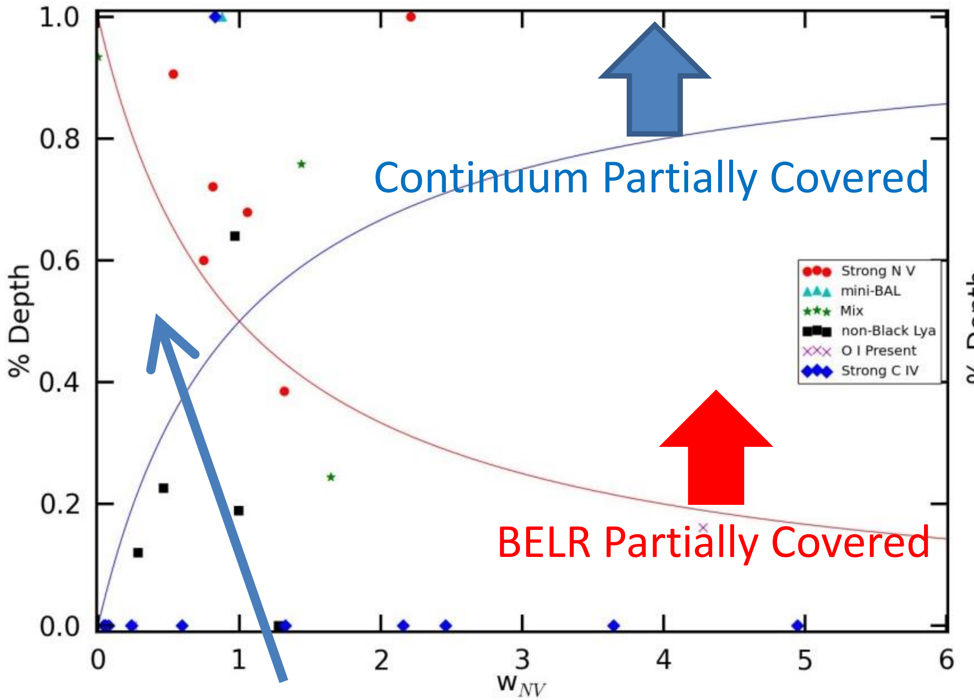
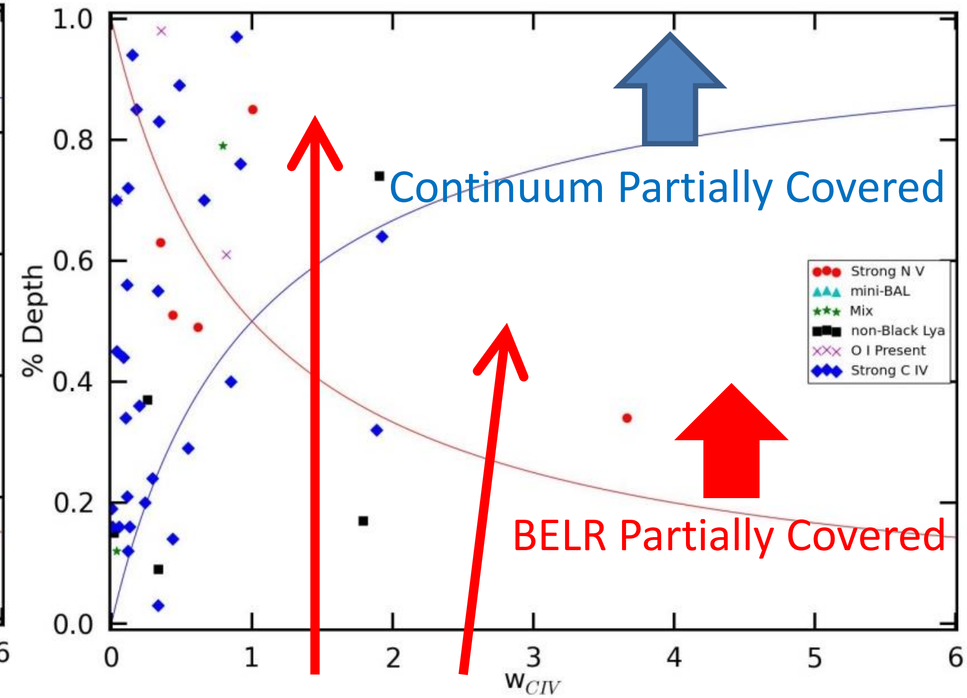




Absorber Transverse Size ~ continuum source size

~ $5 \times 10^{-4} - 5 \times 10^{-3}$ pc

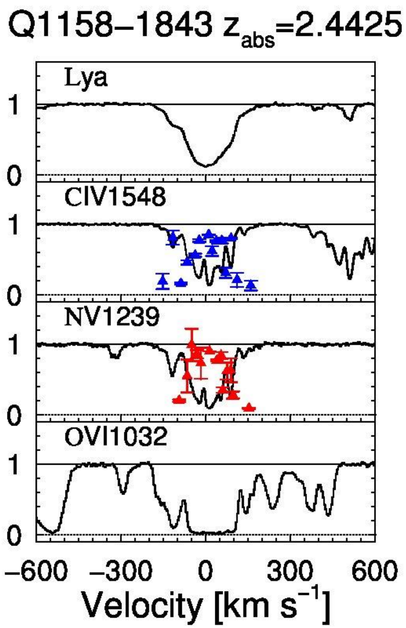
Absorber Transverse Size ~ size of BELR

~ $10^{-2} - 10^{-1}$ pc

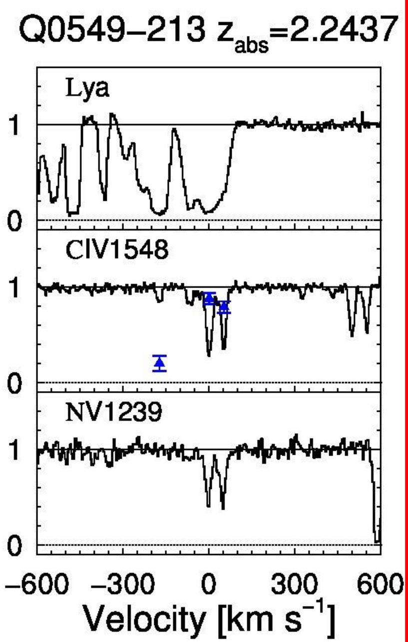
Intrinsic NAL Ionization Continuum

Increasing Ionization Parameter

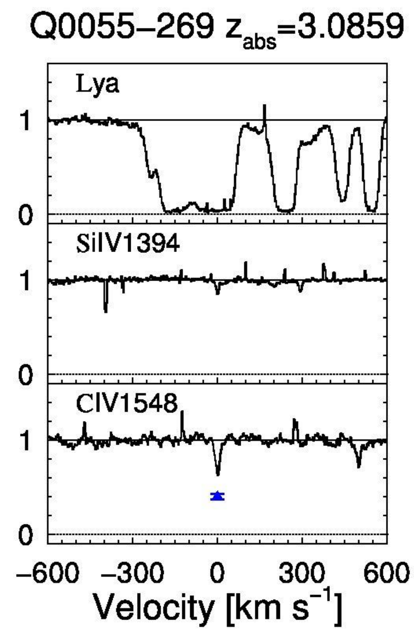
N V Dominant



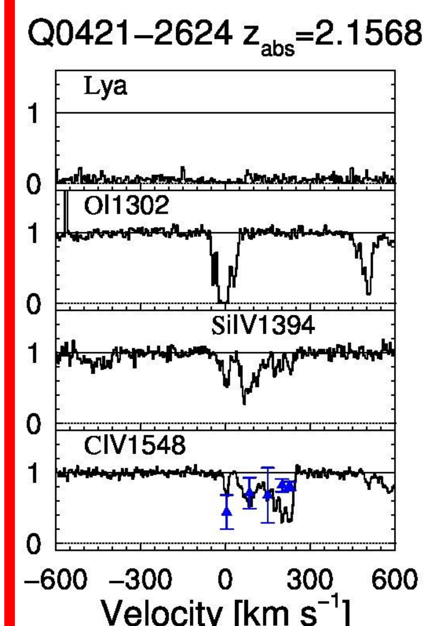
C IV Dominant with non-black Lyα



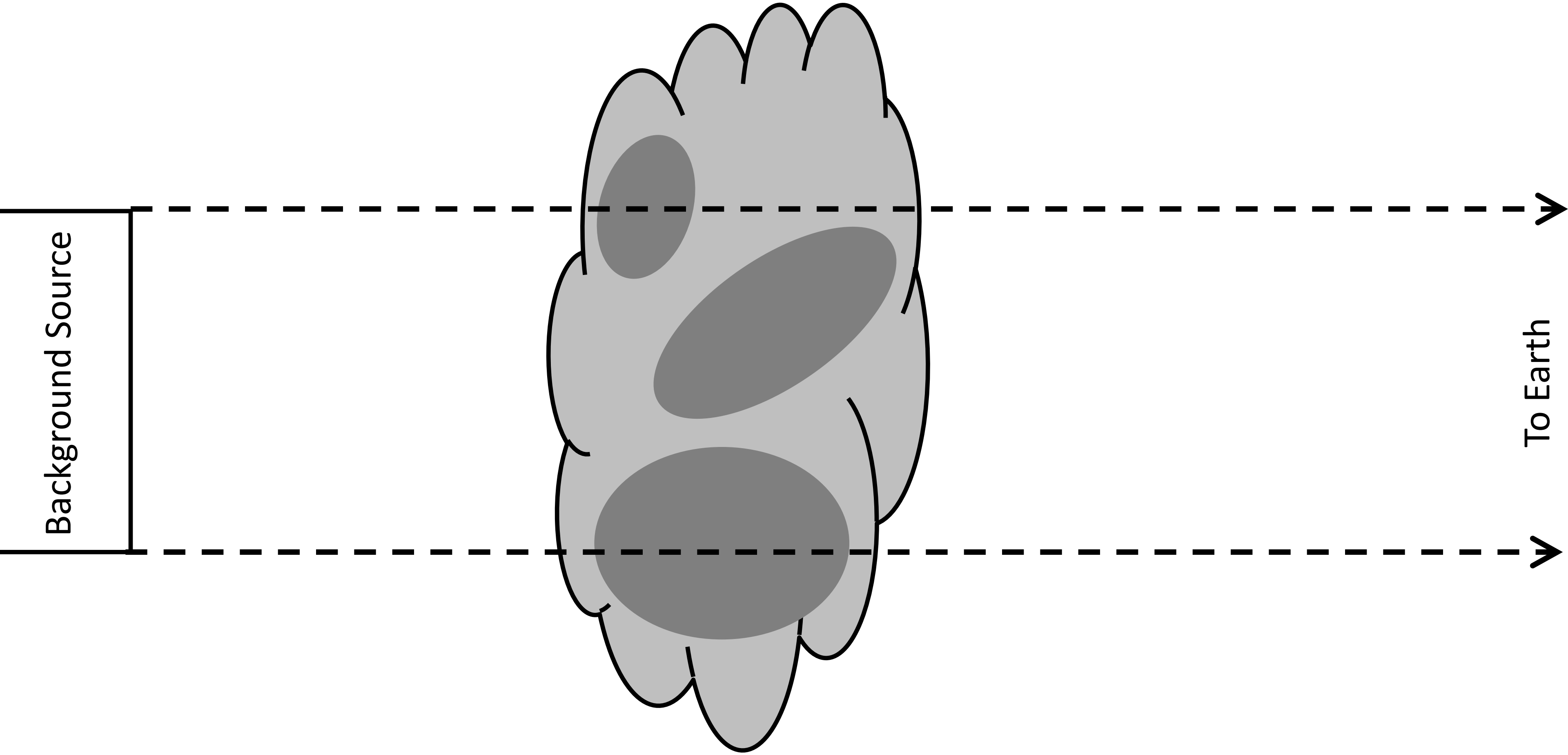
C IV Dominant



C IV Dominant with Low Ionization Lines



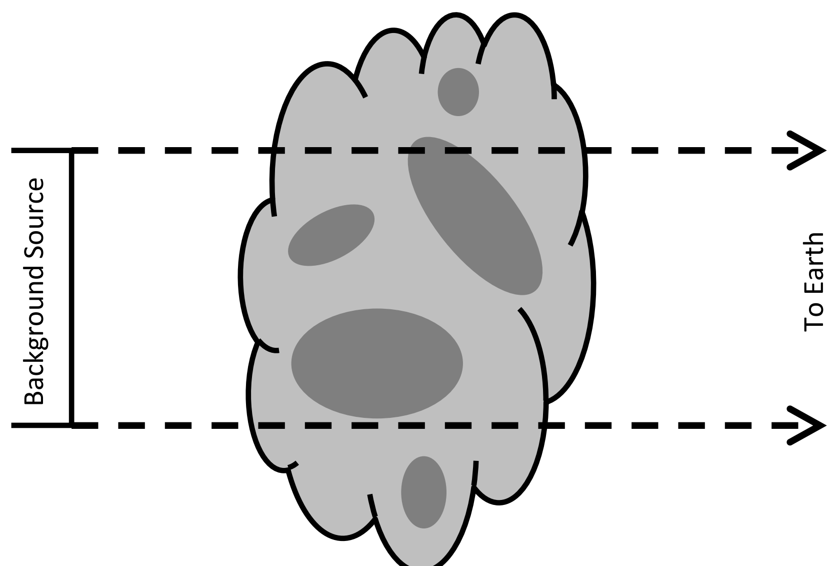
NAL Absorber Model



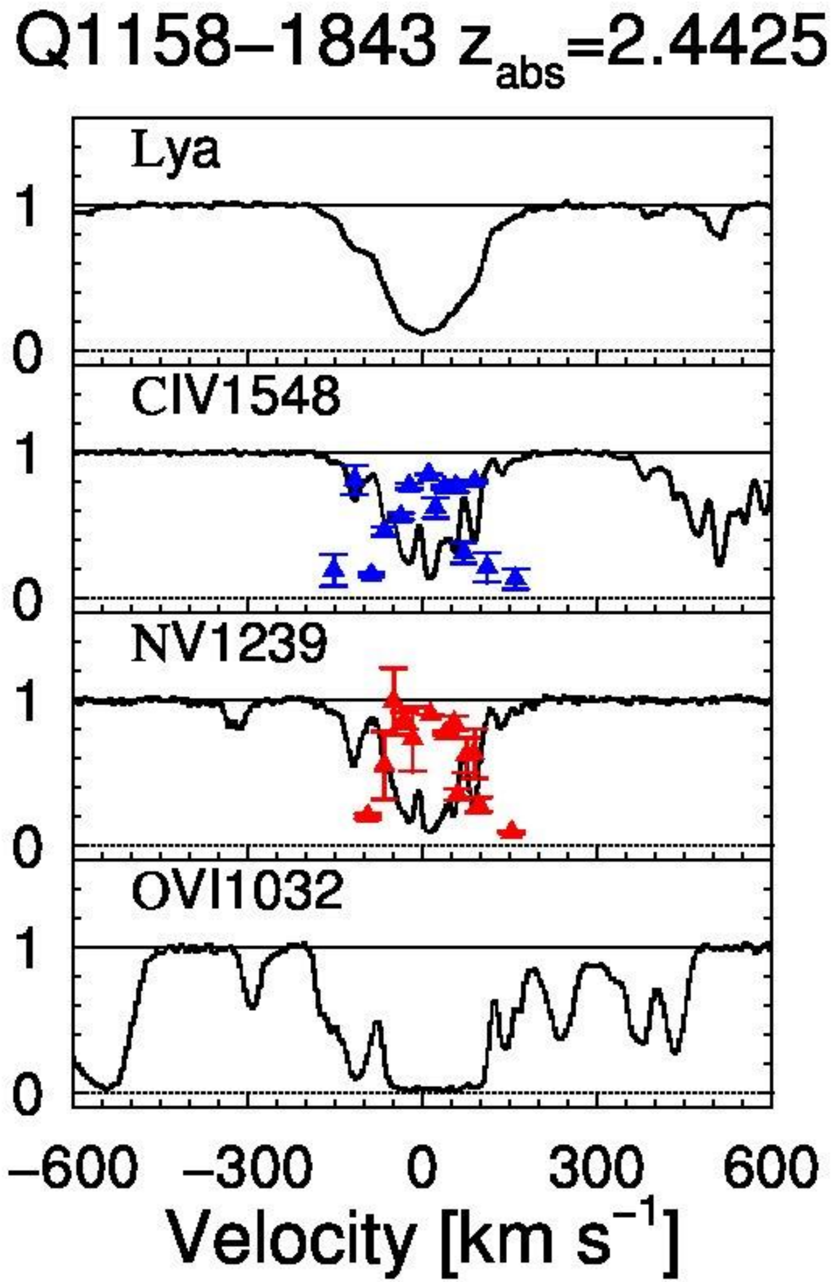
Compositions of the Various Types of Systems

	Dense Core	Tenuous Atmosphere
N V Dominant	C IV, N V, O VI, some Lyα	O VI and High Ionization Lines
C IV Dominant non-Black Lyα	Lyα, C IV, N V	O VI, High Ionization Lines, possibly N V
C IV Dominant	Lyα, Si IV, possibly C IV	Lyα, possibly C IV and/or N V
C IV Dominant w/ Low Ionization Lines	Lyα, Low Ionization Lines	Lyα, Si IV, C IV

log U

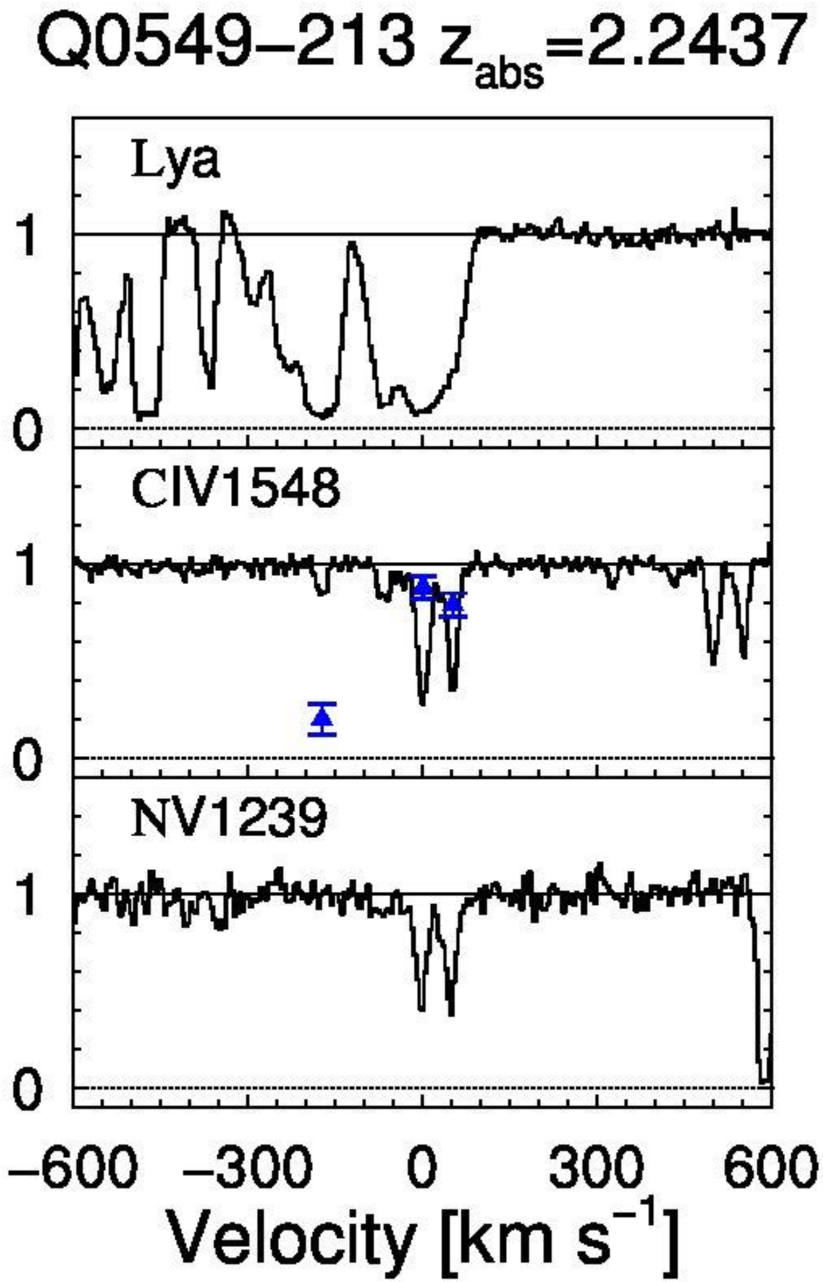


N V Dominant

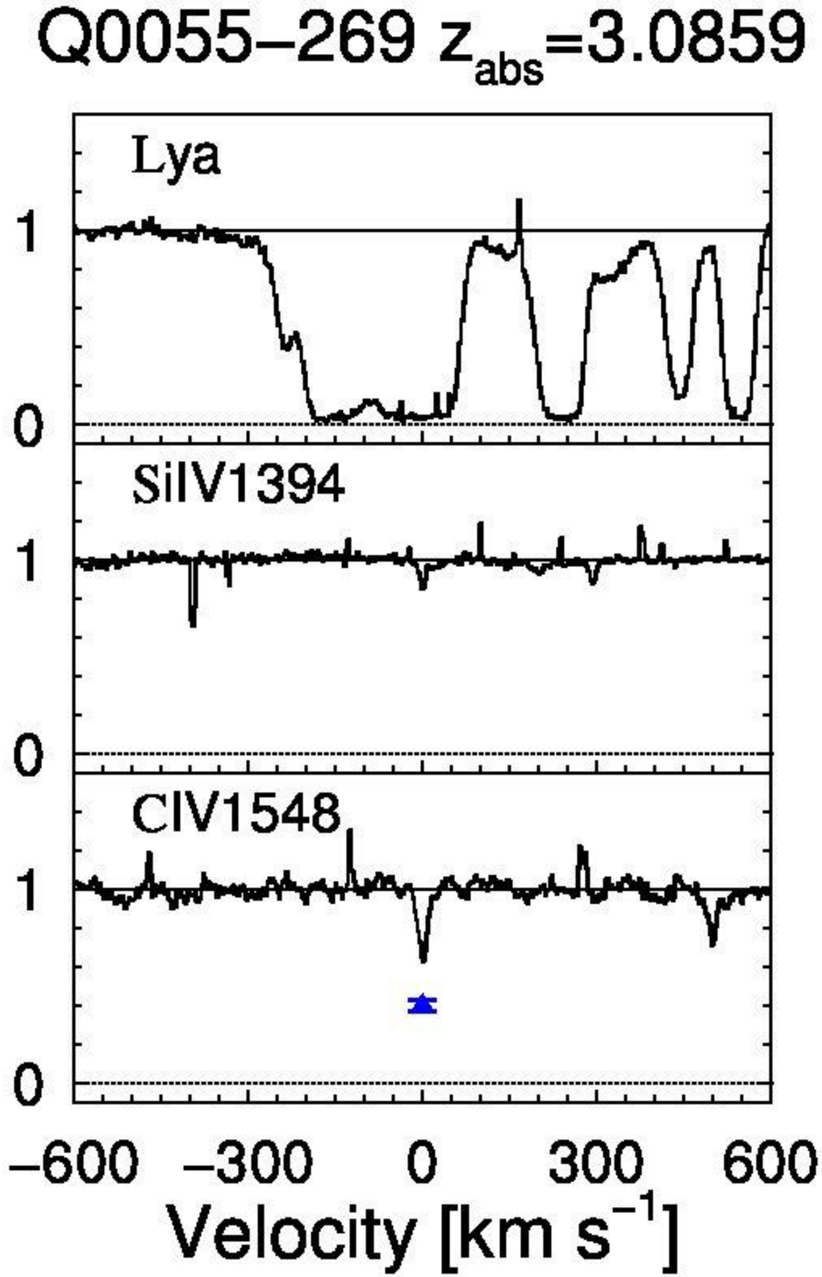


Q1158–1843 z_{abs}=2.4425
Lya
CIV1548
NV1239
OVI1032
1
0
–600
–300
0
300
600
Velocity [km s^{-1}]

C IV Dominant with Non-Black Lyα



C IV Dominant



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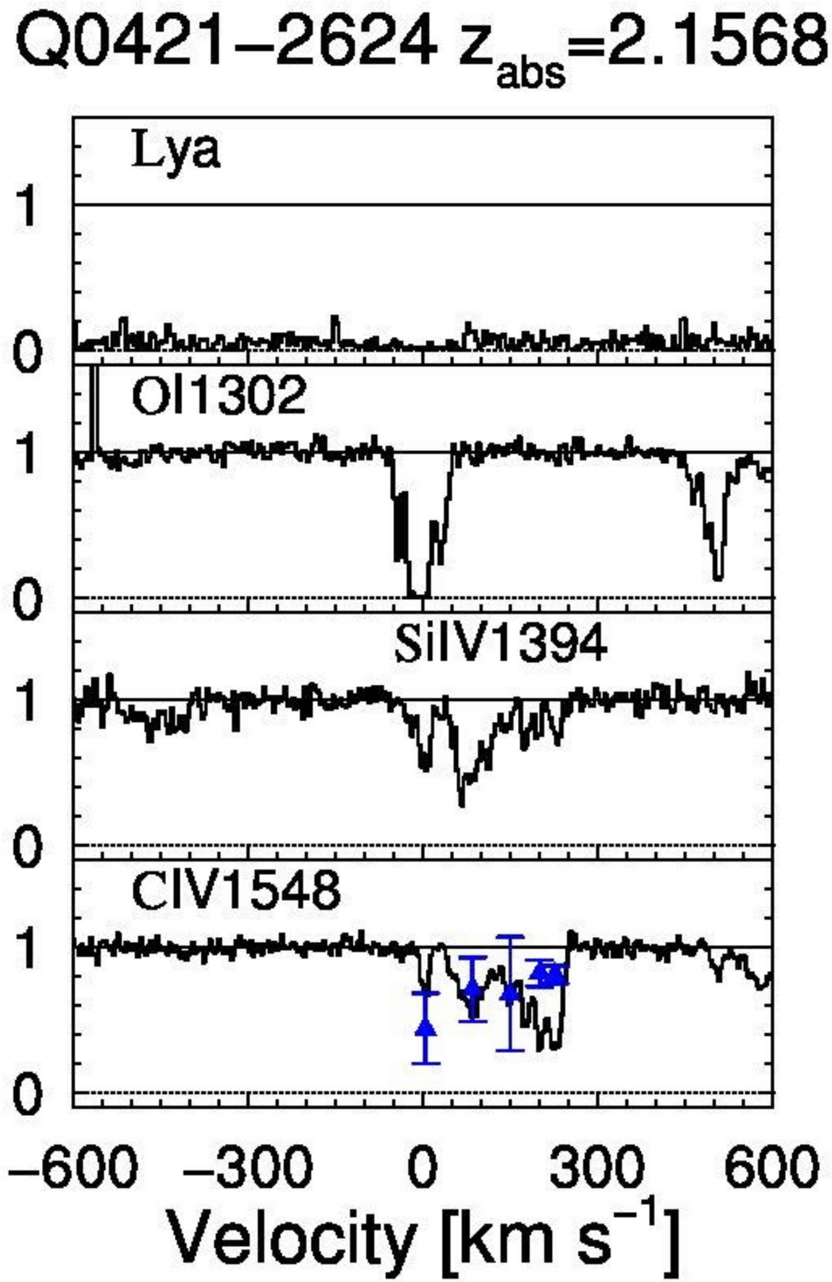
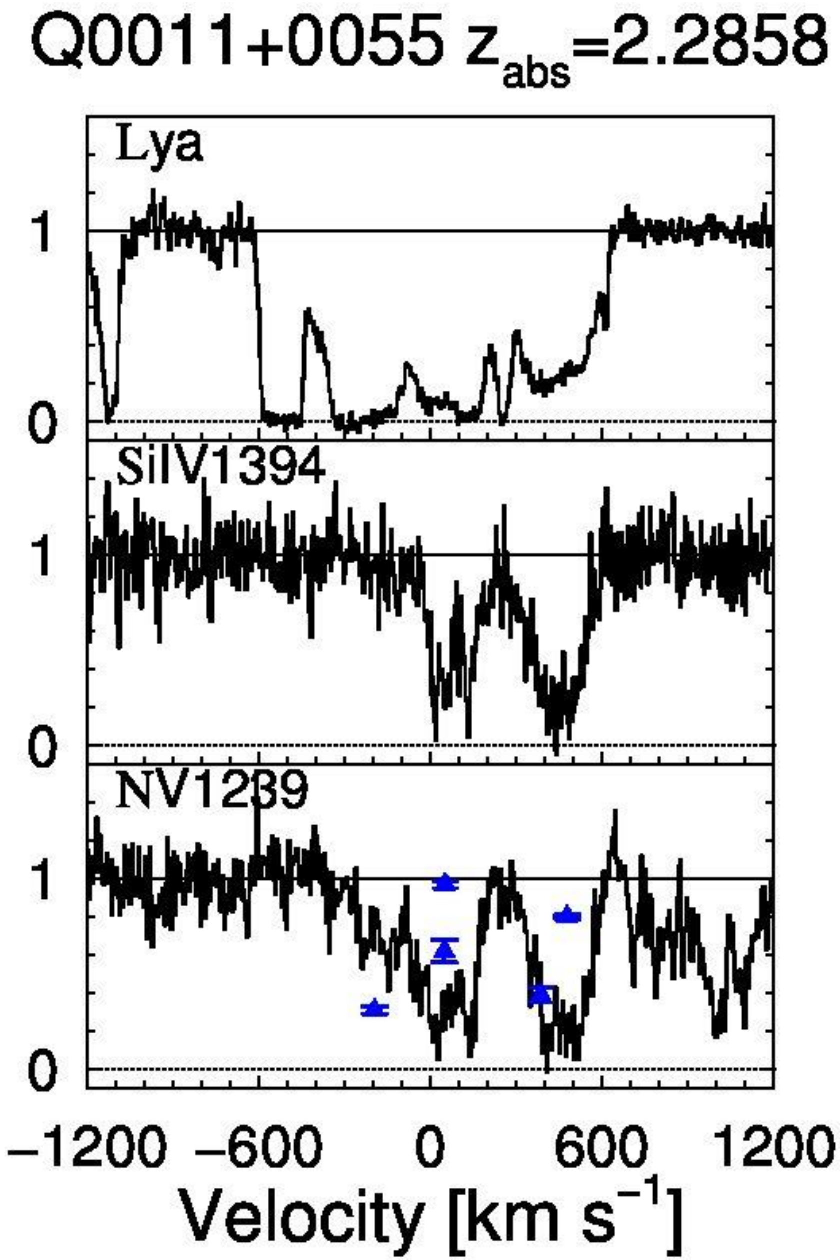


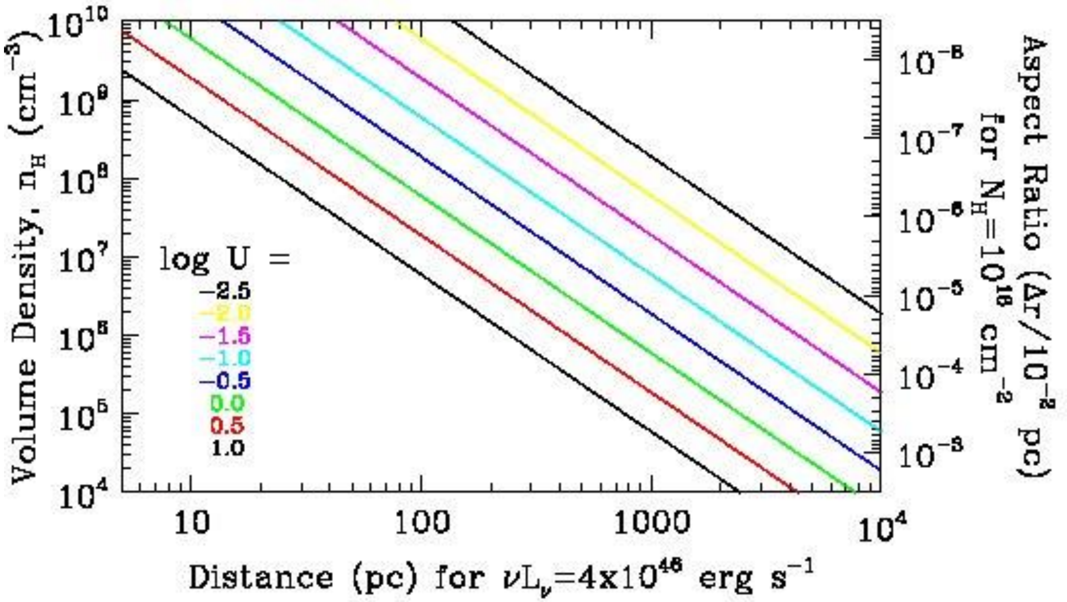
Black and Non-Black Lyα



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:

$$\left(\frac{n_H}{3\times10^{11}\ \mathrm{cm^{-3}}}\right) = \left(\frac{\nu L_\nu(2500\ \text{Å})}{4\times10^{46}\ \mathrm{ergs\ s^{-1}}}\right)\left(\frac{U}{10^{-1.9}}\right)^{-1}\left(\frac{r}{1\ \mathrm{pc}}\right)^{-2}$$

Thickness: $$\left(\frac{\Delta r}{10^{10}\ \mathrm{cm}}\right) = \left(\frac{N_{tot}}{10^{18}\ \mathrm{cm^{-2}}}\right)\left(\frac{n_H}{10^8\ \mathrm{cm^{-3}}}\right)^{-1}$$

Mass: $$M = m_H N_{tot} R^2 \sim 10^{27}\ \mathrm{g}\left(\frac{R}{10^{16}}\right)^2\left(\frac{N_{tot}}{10^{18}\ \mathrm{cm^{-2}}}\right)$$

Using these values, $M \approx 10^{-6}\ M_\odot$

Schematic Model of the Quasar Host Galaxy