An Update on a Work in Progress:

Velocity Distribution of Intrinsic C IV Absorbers

DANIEL NESTOR, FRED HAMANN, & PAOLA RODRIGUEZ HIDALGO
University of Florida

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Motivation

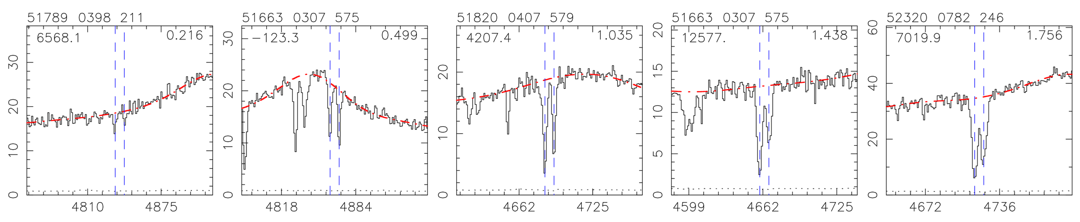
Outflows are likely the chief manner by which angular momentum is redistributed to allow accretion in AGN, making them perhaps a necessary aspect of nuclear activity. Understanding the powering mechanisms and outflow geometry are therefore key to our knowledge of AGN. Thus, we have undertaken a project to measure the velocity distribution of outflows as traced by C IV absorption in order to further constrain outflow models.

The Sample

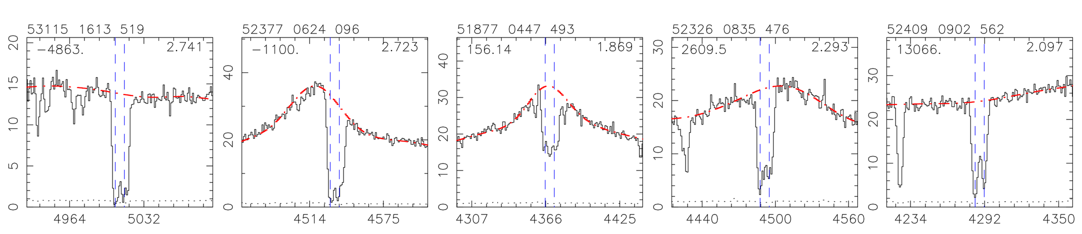
- Over 10,000 QSO spectra are available from the Sloan Digital Sky Survey (SDSS) DR4 with $1.8 \le z_{QSO} \le 2.25$.
- We sort by r'-band signal to noise ratio. After removing strong BAL QSOs, we have analyzed 650 QSO spectra thus far.
- We fit continua, flag C IV absorption candidates, and inspect and measure z_{abs} and $\lambda1548$ rest equivalent width ($W_0^{\lambda1548}$) for each confirmed system.
- Our absorption-line sample presently consists of $\approx 1{,}500$ "narrow" systems and ≈ 60 "miniBALs" (see below).
- There are several issues yet to be addressed, such as velocity-windowing (i.e., how to count systems close together in velocity) and systematic categorization of BAL QSOs and miniBAL absorbers.

C IV Absorber Examples

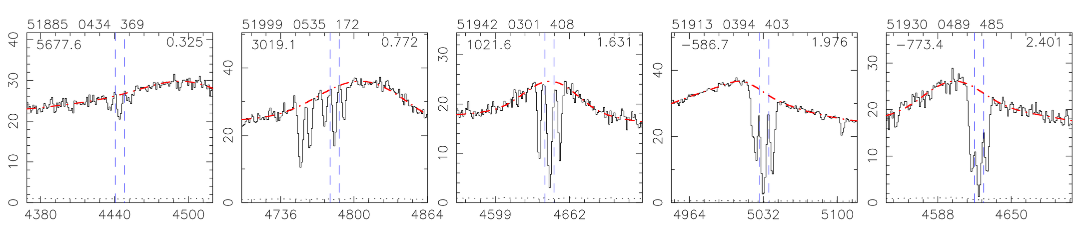
We show examples of C IV absorbers from our sample below. Above each panel are the MJD, plate number and fiber ID of the SDSS observation. The QSO-frame velocity and $W_0^{\lambda1548}$ are also displayed.



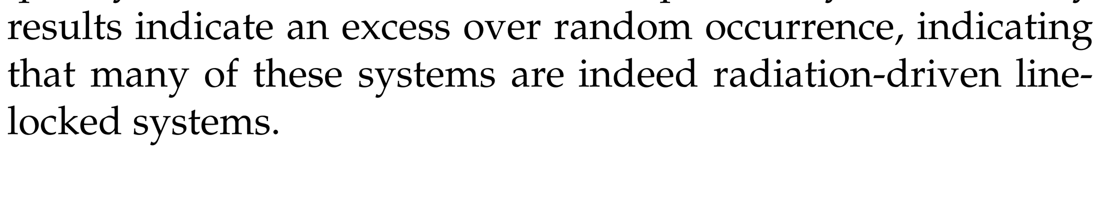
Classic Systems: The majority of absorbers in our sample exhibit the classic doublet with a line spacing of $\simeq 500$ km s^{-1}.



Strong Systems: Particularly strong absorbers exhibit a blended doublet. In these cases we approximate $W_0^{\lambda1548} = 0.6 \times W_0^{total}$, which is the average fractional $W_0^{\lambda1548}$ for strong absorbers with resolved doublets.



"Line-Locked" Systems: Many pairs of systems have velocity separations $\delta v \simeq 500$ km s^{-1}, such that the $\lambda1551$ and $\lambda1548$ lines from the two systems are coincident in wavelength. We are doing Monte Carlo simulations to test whether the frequency of such occurrences can be explained by chance. Early results indicate an excess over random occurrence, indicating that many of these systems are indeed radiation-driven line-locked systems.



"MiniBALs": Some absorbers exhibit smooth, broad profiles indicating origins intrinsic to the AGN. We have removed these from most of the following analysis.

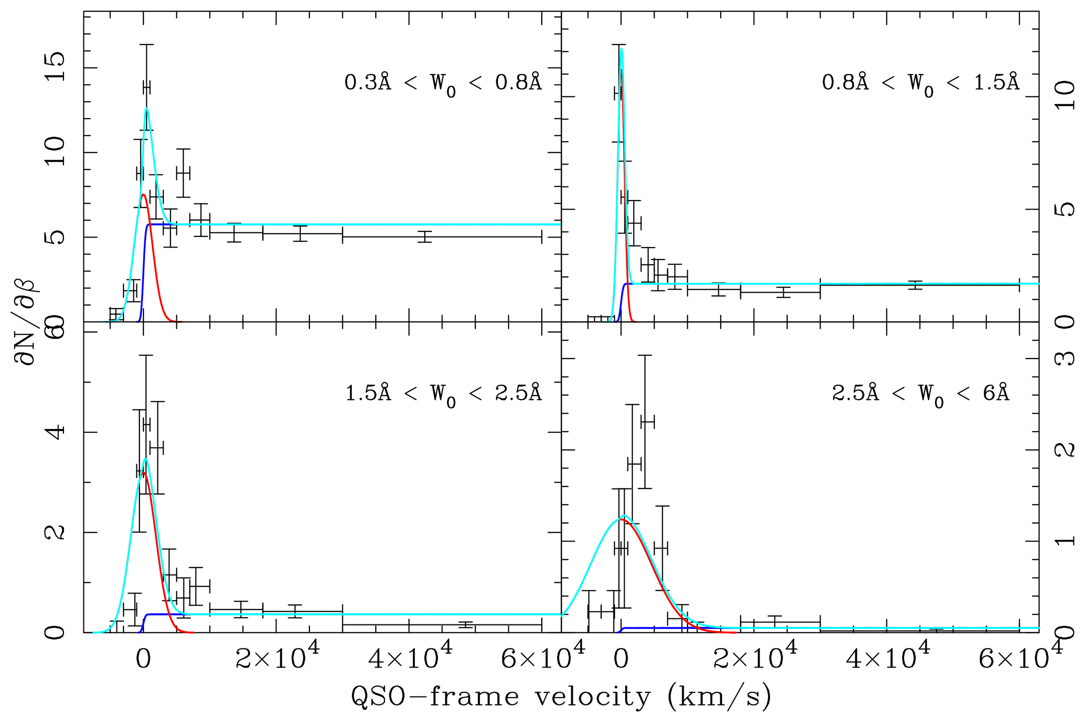
Modeling the Velocity Distributions

The seminal study by Weymann et al. (1979, ApJ, 234, 33) mapped the distribution of C IV absorbers in QSO-frame velocity space for a sample of 66 QSOs. Since then, little progress has been made in determining the velocity distribution of the material (putatively) ejected from AGN accretion disks that is seen in absorption against the background QSO source.

There are several difficulties involved in such an experiment. First, the determination of the velocity zero-point for each QSO is far from straightforward, since emission lines are known to have a range of offsets (either red- or blue-shifted w.r.t. the galactic rest frame). According to Richards et al. (2002, ApJ, 124, 1), Mg II emission has a median blueshift of 97 km s^{-1} from [O III] emission (which is believed to be close to the systemic redshift of the QSO) with a spread of 269 km s^{-1}. Thus we fit the peak of Mg II emission and assume an offset of -97 km s^{-1} to obtain the velocity zero-point.

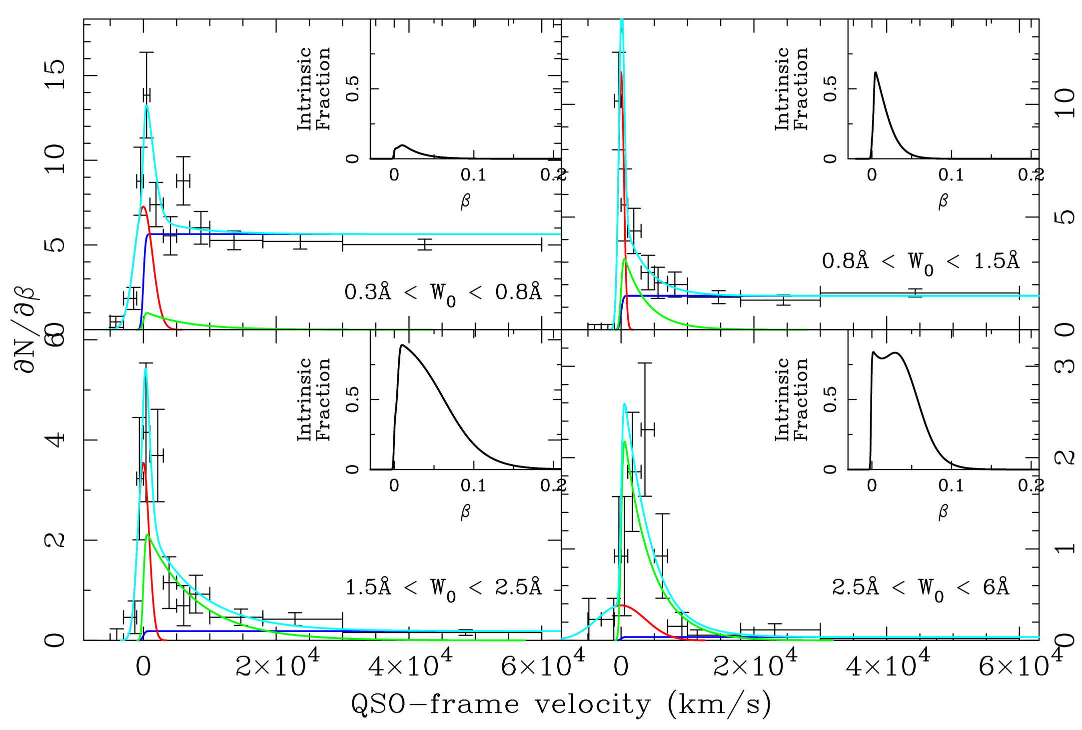
Secondly, there is expected to be a large contamination from: (a) intervening galaxy haloes whose blueshifts (w.r.t the QSO frame) are cosmological; (b) galaxies in the QSO-host environment; and (c) the QSO-host galaxy itself. We in part mollify this difficulty with large numbers. At present, we have analyzed 650 QSOs and will continue to expand our sample. With a large enough sample, we will be able to fit separate intervening, environmental, and ejected components to the velocity distribution with precision.

Fits Without Ejected Components



Shown are the incidence of absorbers, $\partial N/\partial\beta$ (where $\beta = v_{ej}/c$), as a function of QSO-frame velocity for ranges of $W_0^{\lambda1548}$. We use a maximum-likelihood analysis to fit a combination of a Gaussian centered at $v_{ej} = 0$ representing the environmental contribution (red curve), plus a constant for $v_{ej} \ge 0$ (though convolved with the velocity zero-point uncertainty) representing the intervening systems (dark-blue curve). The total is represented by the light-blue curve. The weakest systems can be reasonably well-fit without an ejected component, though the fit is increasingly poor for stronger systems.

Fits With Ejected Component



Here we use a three-component fit. The addition of an exponential representing the ejected component (green curve), greatly improves the fits. However, the strongest ejected systems seem not to peak at $v_{ej} = 0$ making the fit less-satisfactory. This may be an effect of blending, or the true distributions may indeed have a dearth of low-v_{ej} systems. We also show the "Intrinsic Fraction" (ejected component divided by total) for each subsample.

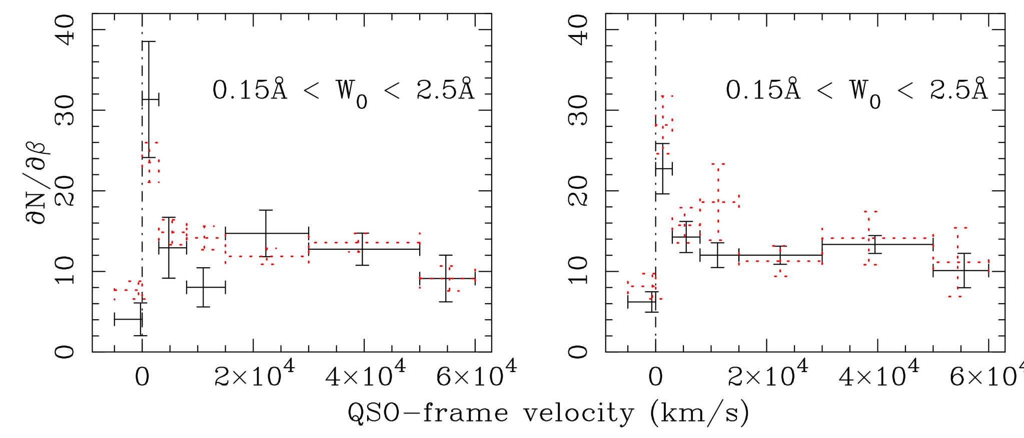
Correlations with QSO Properties

In unified AGN models, it is expected that the incidence of narrow intrinsic absorbers should depend on geometry and therefore correlate with other orientation measures. Also, correlations between AGN properties and the incidence of high-ejection velocity systems would be strong evidence for a significant intrinsic fraction even at high velocities.

Orientation Measures & High-v_{ej} Intrinsic Systems

Richards (2001, ApJ, 133, 53) reported a strong correlation between $\partial N/\partial v$ at large velocities and radio spectral index, while the corelation with radio brightness (which is also thought to be a good orientation measure) is weak. Based on the correlations, he claims that as many as 36% of high-velocity narrow C IV absorbers may be intrinsic. While we do not have radio spectral-index information, $\approx 75\%$ of our sample has been observed by the FIRST survey, of which $\approx 15\%$ were detected. Therefore, we search for correlations with properties such as radio luminosity and optical luminosity. We are also working on comparisons with other properties such as optical spectral index and black hole mass.

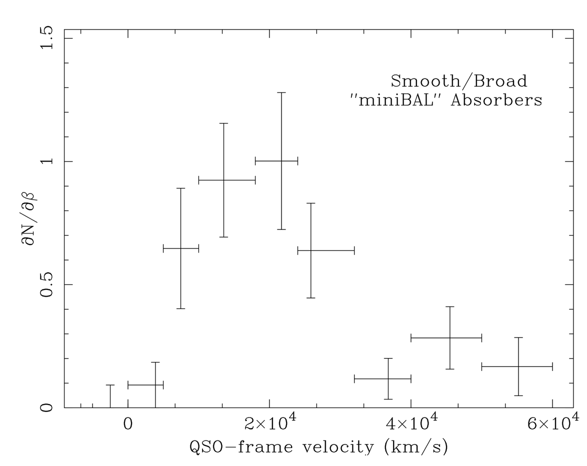
Correlation with Radio/Optical Luminosity?



Left: We find no significant difference in $\partial N/\partial\beta$ for QSOs detected in the FIRST survey (black solid bars) and those targeted but not detected (red dashed bars), as might be expected if radio flux and narrow C IV absorption traced similar aspects of AGN orientation and/or outflow powering mechanisms. *Right:* We find no significant difference in $\partial N/\partial\beta$ for QSOs with $-27.65 \le M_i \le -26.68$ (red dashed bars) and those with $-30.19 \le M_i \le -27.75$ (black solid bars), as might be expected for a simple relationship between outflows and AGN optical luminosity.

More work is needed to test for absorption/AGN property correlations. Lacking radio spectral index information, we will explore other possible measures such as optical spectral index. Black hole mass might be expected to correlate with high-v_{ej} absorbers better than optical luminosity, since terminal velocity is a function of M_{BH}.

Mini-BALs



The velocity distribution of the 57 "miniBALs" (which have been excluded from the other plots) shows that there are indeed "intrinsic-looking" systems at high-velocity. The dearth of systems at lower-v_{ej} is probably due to a blending bias.

Also see the poster by Paola Rodriguez Hidalgo.

Summary/Future

By determining $\partial N/\partial\beta$ for ranges of $W_0^{\lambda1548}$ we have begun mapping the velocity/strength distribution of C IV absorbers *intrinsic* to the AGN. We are also constraining wind models by studying line-locked and high velocity systems. In the near future, our sample will be large enough to make these measurements with unprecedented precision.

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