Probing Quasar Winds Using Narrow Intrinsic Absorption Lines

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Summary

We use the spectra of 73 quasars from the VLT UVES archive at z_{em} = 1.5 − 5 to expand the sample of Misawa et al. (2007, ApJS, 171, 1) in order to study the narrow absorption lines (NALs) that are intrinsic to (physically associated with) the quasars. We calculate the coverage fraction of the background source(s) by absorbing gas through multiple methods in order to determine which NALs are intrinsic to the quasar itself, as opposed to a cosmological absorber along the line of sight. Of the 414 systems identified, 377 are detected in C IV, 24 in N V, and 56 in Si IV.

Observations and Reduction

We used the spectra of 73 quasars from the VLT UVES archive. Quasars were randomly sampled, with a preference for optically bright quasars, with emission redshifts of z_{em} = 1.5−5. As described in Narayanan et al. (2007, ApJ, 660, 1093), the reduction and wavelength calibration of the echelle data were accomplished using the MIDAS pipeline provided by ESO. In order to utilize all observed photons and to enhance the S/N of the spectra, all available observations of a particular target were included in the reduction. The reduced one-dimensional spectra were vacuum-heliocentric velocity corrected, and rebinned to 0.03 Å. All exposures were re-scaled, co-added, and weighted by the S/N corresponding to each pixel. Continuum fitting was done on the reduced spectra using the IRAF SFIT procedure. The continuum fit was then used to normalize the spectra.

Sample Properties

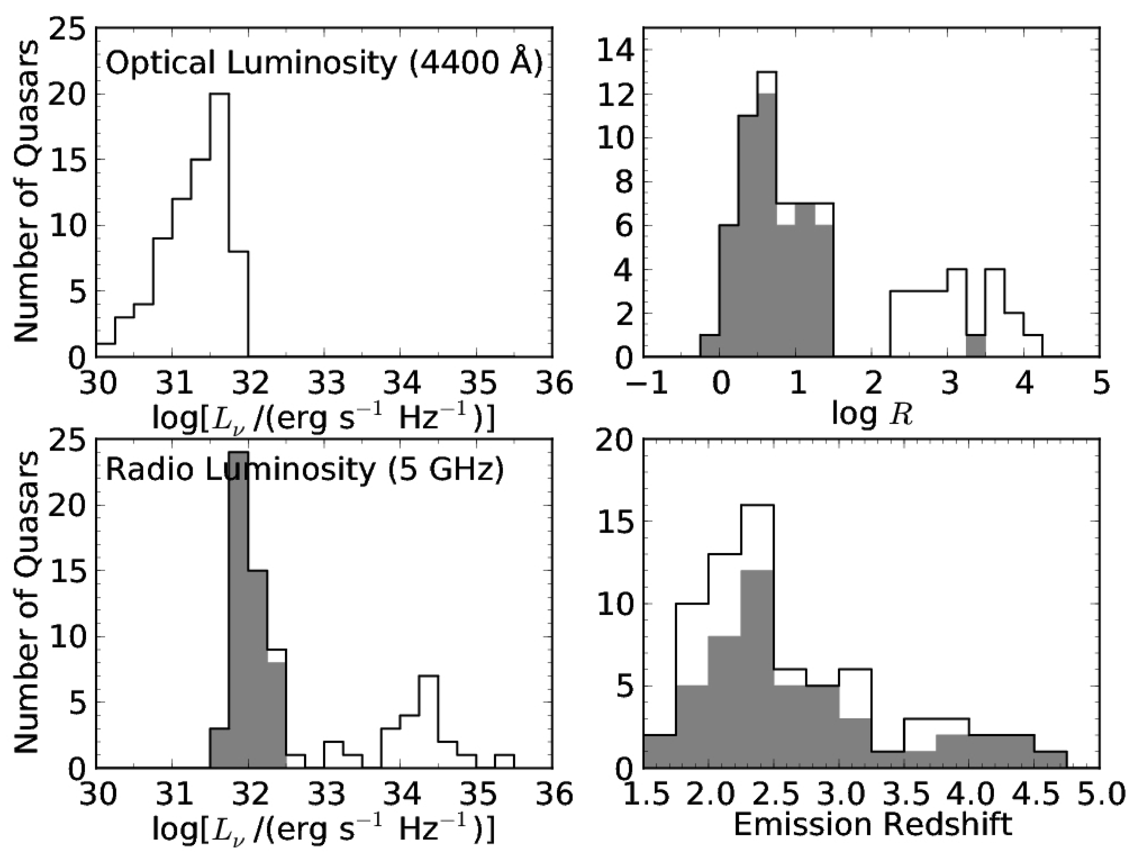

Fig. 1.— Distribution of optical (4400 Å) and radio (5 GHz) luminosities, the radio loudness parameter, and the emission redshift of the 73 quasars in our sample. The gray bins represent those quasars for which only an upper limit on the radio luminosity was determined. The radio-loud objects cluster at 5 GHz luminosities between 10^{34} and 10^{35} erg s^{-1} Hz^{-1}.

Classification of Absorption Lines

We classify absorption line systems into three classes based on our confidence that they are truly intrinsic.

Class A:
- Smooth, broad, self-blended profile, such as a mini-BAL
- Coverage Fraction $C_f + 3\sigma(C_f) < 1$ for at least one component

Class B:
- Coverage Fraction $C_f + \sigma(C_f) < 1$ for at least one component
- Line Locked

Class C:
- Coverage Fraction $C_f + \sigma(C_f) > 1$ for all components
- Bad continuum fit or critical data defects
- Systematic errors
  - Weak components between stronger components
  - Weak components at the edge of the system
  - Components in a heavily blended region (except those with extremely high S/N)
  - Components with unphysical values of C_f

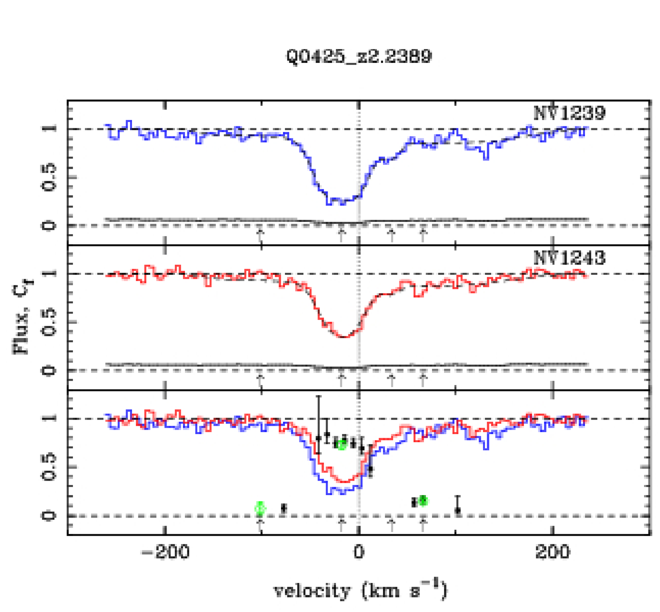

Fig. 2.— The coverage fraction as determined using the MINFIT (green) and pixel-by-pixel (black) analysis of the C IV doublet in Q0425-5214 at an absorption redshift of z=2.2389. The top panel is the 1239 Å transition, the middle panel is the 1243 Å transition, and the bottom panel is a combination of the two, as well as the coverage fraction superimposed on the two.

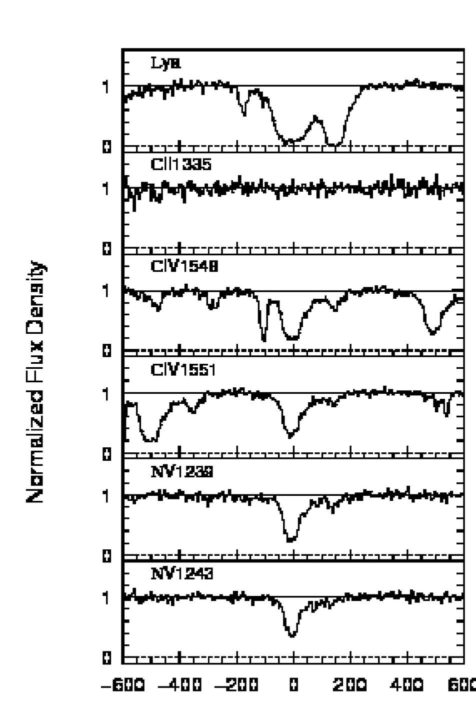

Fig. 3.— The absorption system of Q0425-5214 at redshift z=2.2389, 1026 km s^{-1} blueshifted from the quasar rest-frame. Note that only high-ionization lines are detected from this system.

Results

- 89 associated absorption systems (AALs, v_{shift} < 5000 km/s)
- 24% of the AALs reliably intrinsic
- Additional 10% of the AALs possibly intrinsic
- Minimum percentage of quasars with at least 1 intrinsic C IV NAL ≈ 33%
- Minimum percentage of quasars with at least 1 intrinsic NAL of any type ≈ 41%
- 8%− 19% of all C IV NALs reliably to potentially intrinsic
- 9%−22% of all NALs reliably to potentially intrinsic

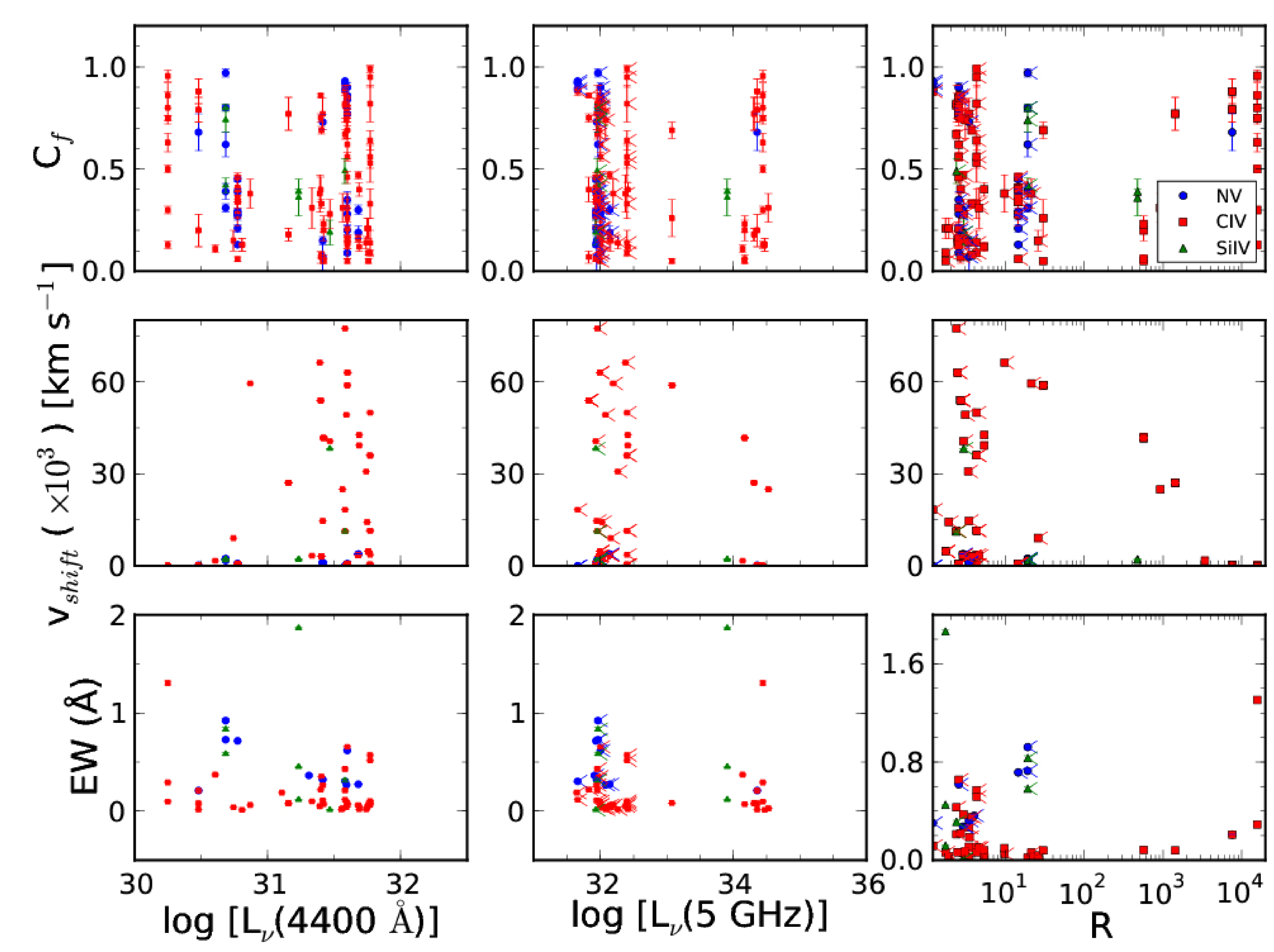

Fig. 4.— Coverage fractions (C_f, top), the velocity offset (v_{shift}, middle), and the rest equivalent width (EW_{rest}, bottom) plotted against quasar properties [i.e., L(4400 Å), L(5 GHz), and R]. Only intrinsic NAL components (class A+B) whose coverage fractions are physical (i.e., 0 < C_f ≤ 1) and evaluated with small uncertainty [i.e. $\sigma(C_f)$ < 0.1] are plotted. The blue circles denote N V NALs, the red squares represent C IV NALs, while the green triangles Si IV NALs.

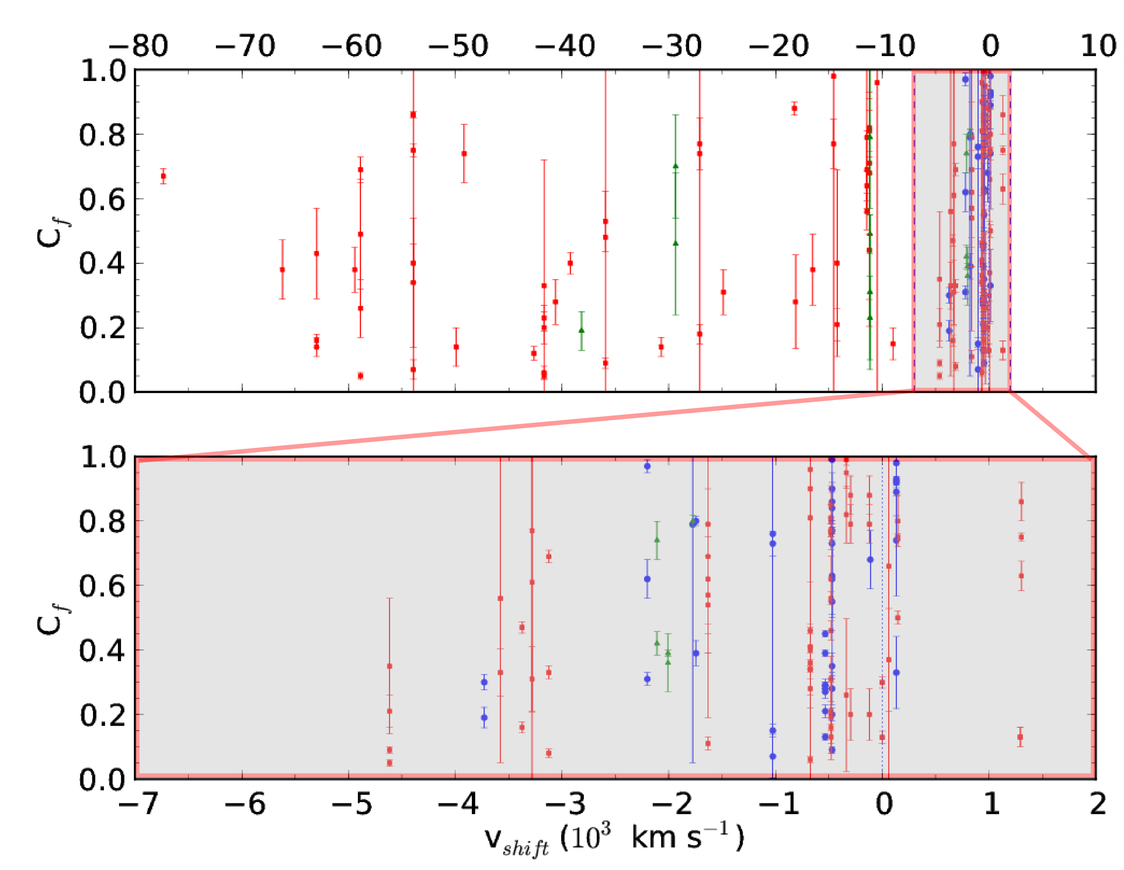

Fig. 5.— The coverage fraction (C_f) plotted against the velocity offset (v_{shift}). The only coverage fractions plotted are those with physical values (i.e., 0 < C_f ≤ 1) and evaluated with high reliability [i.e. $\sigma(C_f)$ < 0.1]. The upper panel displays a velocity offset range from −80,000 km s^{-1} to 10,000 km s^{-1}, while the lower panel focuses on the narrow range between −7000 km s^{-1} and 2000 km s^{-1}. The blue circles denote N V NALs, the red squares represent C IV NALs, while the green triangles signify Si IV. No trends were observed correlating coverage fraction to velocity offset, and no ion has a higher frequency of high or low coverage fraction than any other.

Discussion

Misawa et al. (2007) found two different families of intrinsic NALs were discovered: C IV strong systems and N V strong systems. A NAL is considered a strong C IV NAL if Lyα in the system is saturated and black, or if the total equivalent width of Lyα is larger than twice the equivalent width of N V. Otherwise, the system is considered a strong N V system, even if the equivalent width of the N V doublet is less than the equivalent width of the C IV doublet. These families are observed in our larger sample, as well, with a majority of systems being described as C IV strong. The range of ionization parameters that create these two families are possibly caused by the range of distances from the continuum source or by regions of anomalous densities.

Two popular models of the formation of NALs are the disk wind model and the galaxy model. In the disk wind model, dense filaments are embedded in an accretion disk wind while in the galaxy model, gas from the host galaxy is swept up as the wind propagates away from the central engine, creating intrinsic NALs. Observationally, it would be difficult to differentiate between the two models without knowing the distances of the NALs from the quasar. Further complicating this scenario is that a combination of these two models is possible, if not likely. Further progress can be made by determining the total column density (neutral+ionized) of the absorbing gas through X-ray observations and by deriving constraints on the distance of the absorbers from the quasar central engine through photoionization modeling.

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