Absorption Line Studies of Quasar Outflows & Host Galaxy Environments

UF | Astronomy

Fred Hamann (U Florida), Leah Simon (APSU), Dan Capellupo (UF)

T. Barlow, S. Ellison, V. Junkkarinen, N. Kanekar, A.L. Malec, N. Milutinovic, M.T. Murphy, M. Pettini, J.X. Prochaska, J. Shields, W. Ubachs

Abstract / Introduction:

Quasars provide unique opportunities to study the formation of massive galaxies. We are using various broad and narrow quasar absorption lines to place new constraints on 1) the nature and energetics of quasar outflows, and 2) the metallicities and physical conditions in the larger gaseous environments of quasar host galaxies.

Quasar outflows are natural byproducts of accretion onto the central SMBH. They might provide important "feedback" to the host galaxy's evolution. Broad absorption lines (BALs) in quasar spectra are obvious signatures of powerful flows with speeds reaching >0.1c and mass loss rates that *might* rival the accretion rates. A surprising number of narrow absorption lines (NALs) also form in outflows with speeds and ionizations similar to BALs. However, much less is known about their incidence, locations, and physical properties.

Some NALs also form in the galaxy-scale environments of quasars, including potentially starburst-driven winds, the gaseous remnants of recent mergers, and ambient interstellar gas in the host galaxies.

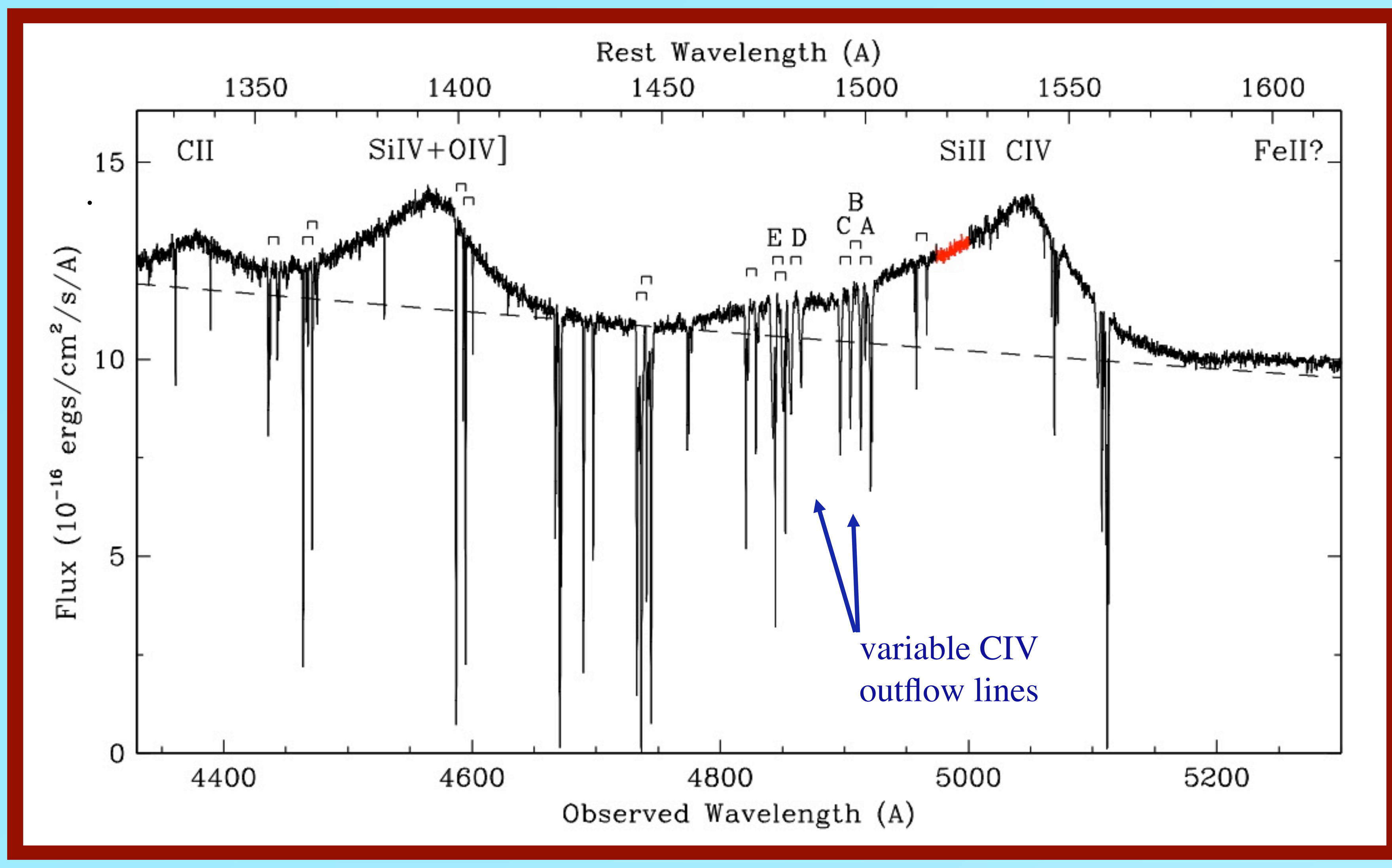
An essential step in NAL studies is to indentify "intrinsic" features that form physically near the quasars, versus the many other narrow lines with unrelated intervening origins. We use a variety of intrinsic indicators including 1) line variability, 2) partial covering of the tiny quasar emission source, 3) broad rounded (super-thermal) line profiles, and 4) excited-state lines that yield density and location constraints.

Results / Initiatives:

- The NALs in Figure 1 are confirmed quasar outflow lines based on their variability, partial covering, broad rounded profiles (with doppler b ~ 30-70 km/s), and high speeds of 9700-14,000 km/s. The five NAL systems require five outflow structures with characteristic sizes of only 0.01-0.02 pc (from the partial covering) located several pc from the central quasar (from the lack of acceleration and cloud survival times). The metallicity is ~2 Z_o, consistent with a near-quasar origin. The kinetic energy yield (KE ~ $2Q_{0.1}$ x 10^{52} ergs, where $Q_{0.1}$ is the global covering fraction relative to 10%) is orders of magnitude too small to be important for feedback to galaxy evolution. See Hamann et al. (2011).

- The BALs in Figure 2 were measured as part of a program to monitor 24 quasars across timescales from ~0.02 to ~8 yr rest (Capellupo et al. 2011 and in prep.). Variability occurs in >70% of CIV BALs over the longest time intervals, with decreasing probability over shorter times. We are now investigating the shortest times to place constraints on the locations, sizes and kinematics of the outflow structures. Variability occurs more often in SiIV BALs and in weaker parts of BAL troughs in general, indicating that the lines are saturated and the column densities might be very large. We are analyzing HST spectra covering higher ions (OVI) and lower abundance species (PV) to place tighter constraints on the total columns and kinetic energies in BAL and narrower "mini-BAL" outflows.

- The results in Figures 3-5 are from a large survey to identify intrinsic CIV NALs in high resolution spectra (Keck, VLT) of 24 quasars (Simon et al. 2010 and in prep., see also a similar study by Misawa et al. 2007). We divide the lines into three classes: **A** = definite partial covering or b > 80 km/s (definite intrinsic), **B** = probable partial covering or 60 < b < 80 km/s (probable intrinsic), and **C** = all others. Intrinsic lines are common: Roughly 20% of all NALs we measure at velocities +5000 > v > -40,000 km/s and REW > 0.02 A are intrinsic classes A or B, and roughly 2/3 of them form in high-speed (v < -2500 km/s) quasar-driven outflows. Similarly, ~48% of quasars in our sample have at least one intrinsic NAL, while ~35% have a quasar outflow line at v < -2500 km/s. Lower velocity lines might form in a variety of environmental or quasar outflow locations. In rare cases excited-state lines indicate low densities (n_H ~ a few to hundreds cm^{-3}) and large distances (10s to 100s of kpc) from the quasars (Hamann et al. 2001, Hamann & Simon in prep.). Overall, basic intrinsic NAL properties like REW, b, and CIV column density, N(CIV), overlap considerably with the other/non-intrinsic lines, but larger values of these parameters are clearly favored (Figure 5). We are now working to measure and compare the ionizations, total column densities, N_H, and metal abundances in these intrinsic versus non-intrinsic/other NAL samples (Simon et al. in prep).



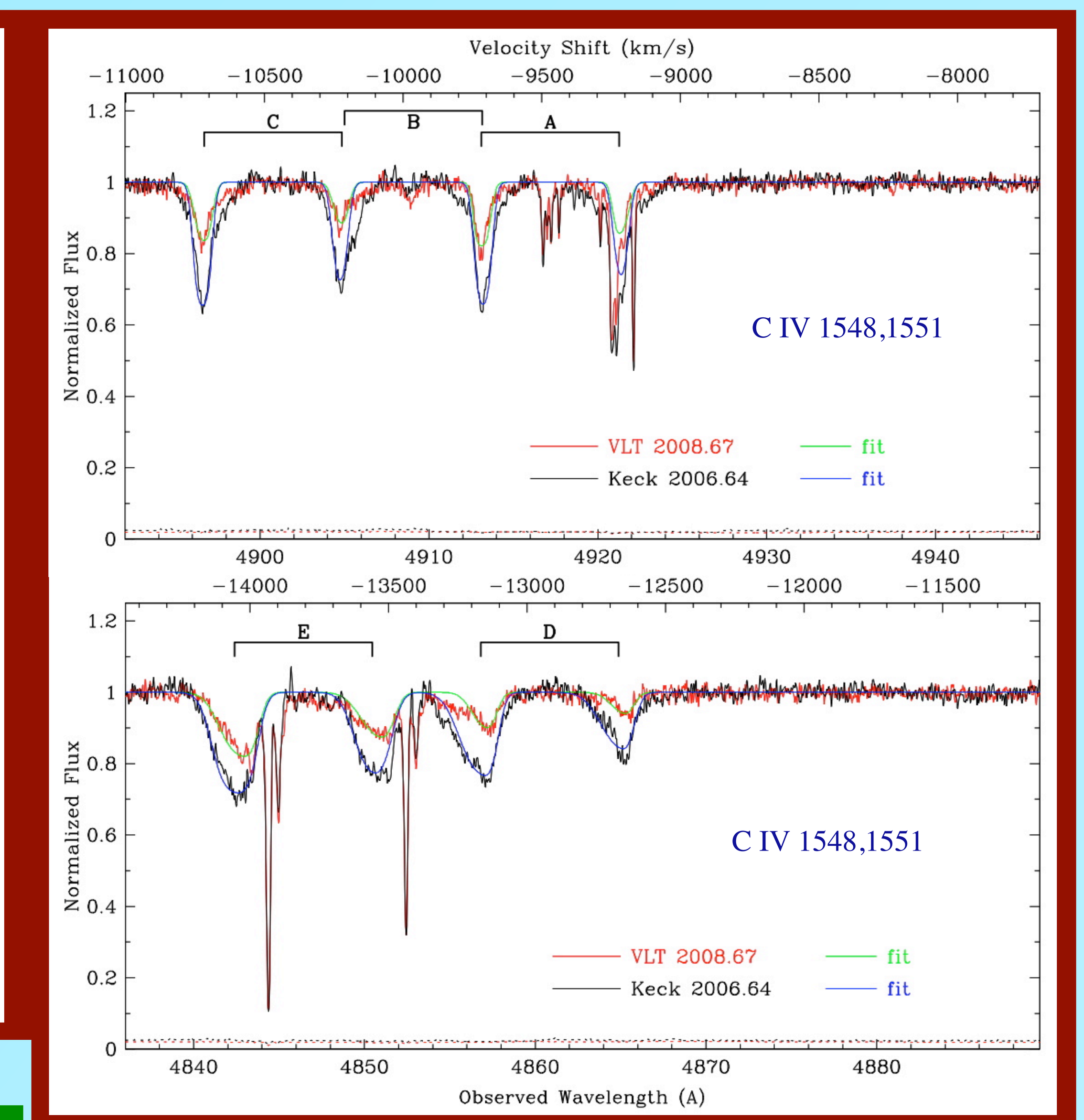


Figure 1. *Left panel*: Keck/HIRES spectrum of the quasar J2123-0050 with variable CIV NALs (labeled A-E) that form in a quasar-driven outflow. Many unrelated NALs are also present. *Right panels:* The same outflow lines on an expanded scale showing their variability, rounded profiles, and flow speeds of 9700-14,000 km/s.

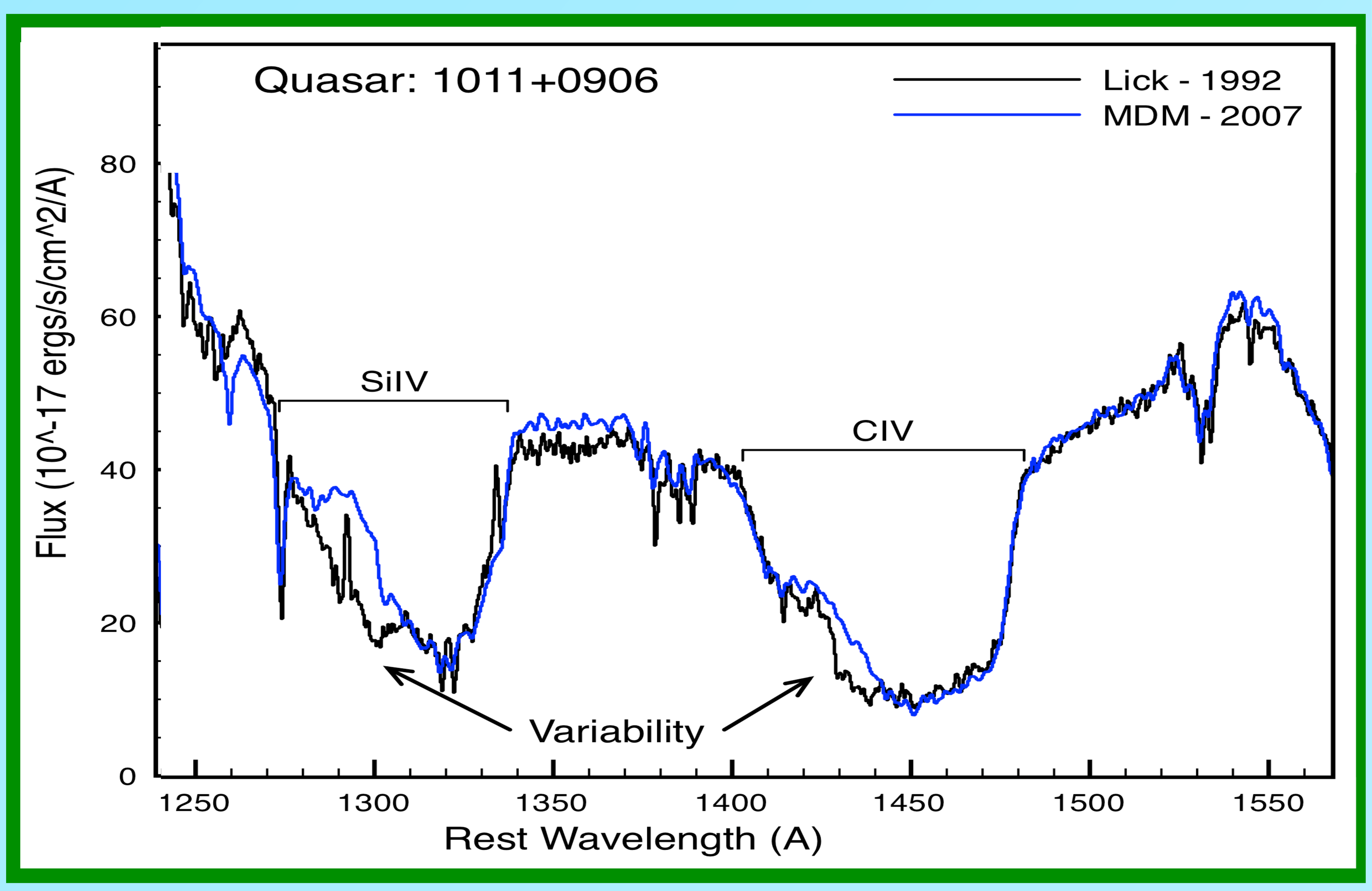


Figure 2. This BAL outflow spans velocities 12,000-30,000 km/s in SiIV and CIV. The BALs are ~100 times broader and ~100 times stronger than the NAL outflow lines shown above in Figure 1. Variability is evident in a portion of the BAL troughs, with a larger amplitude in SiIV than CIV.

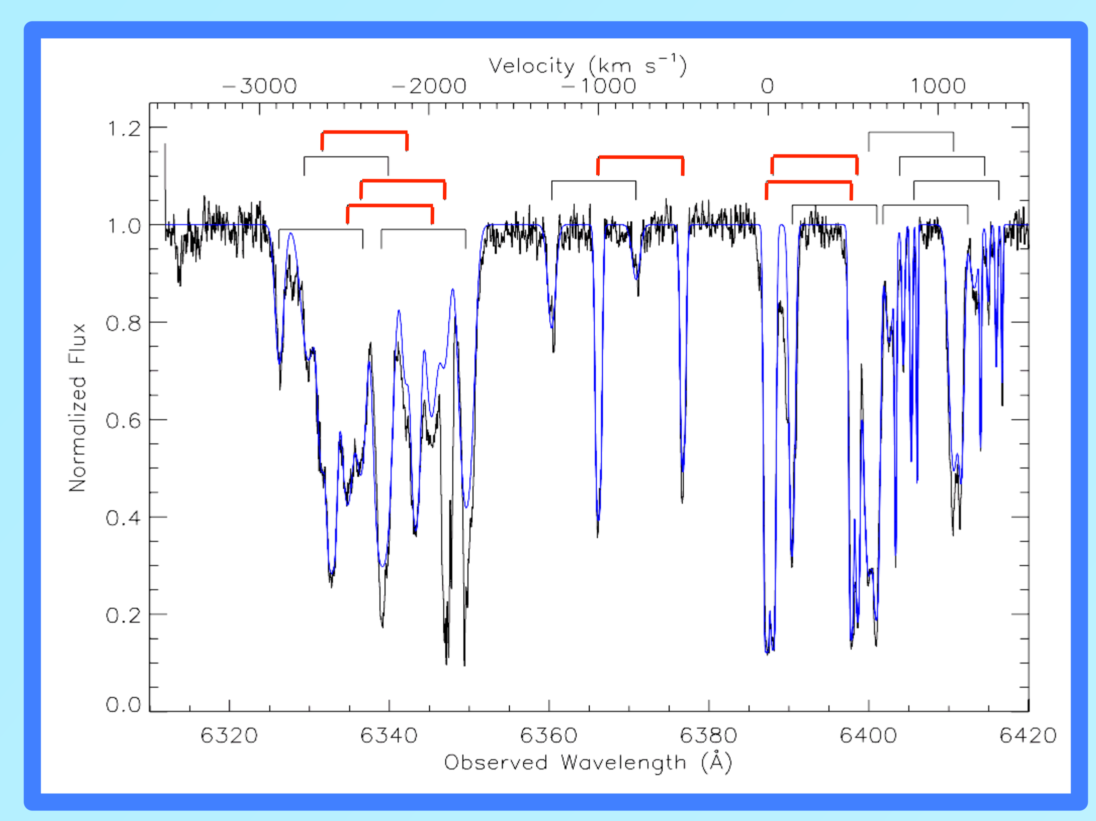


Figure 3. Keck/HIRES spectra of a rich CIV absorption complex with at least 12 components spanning 3900 km/s. Component pairs marked in red have measured partial covering. The velocity scale is uncertain by ~1000 km/s, but this and other similar rich complexes probably form in highly structured quasar-driven outflows.

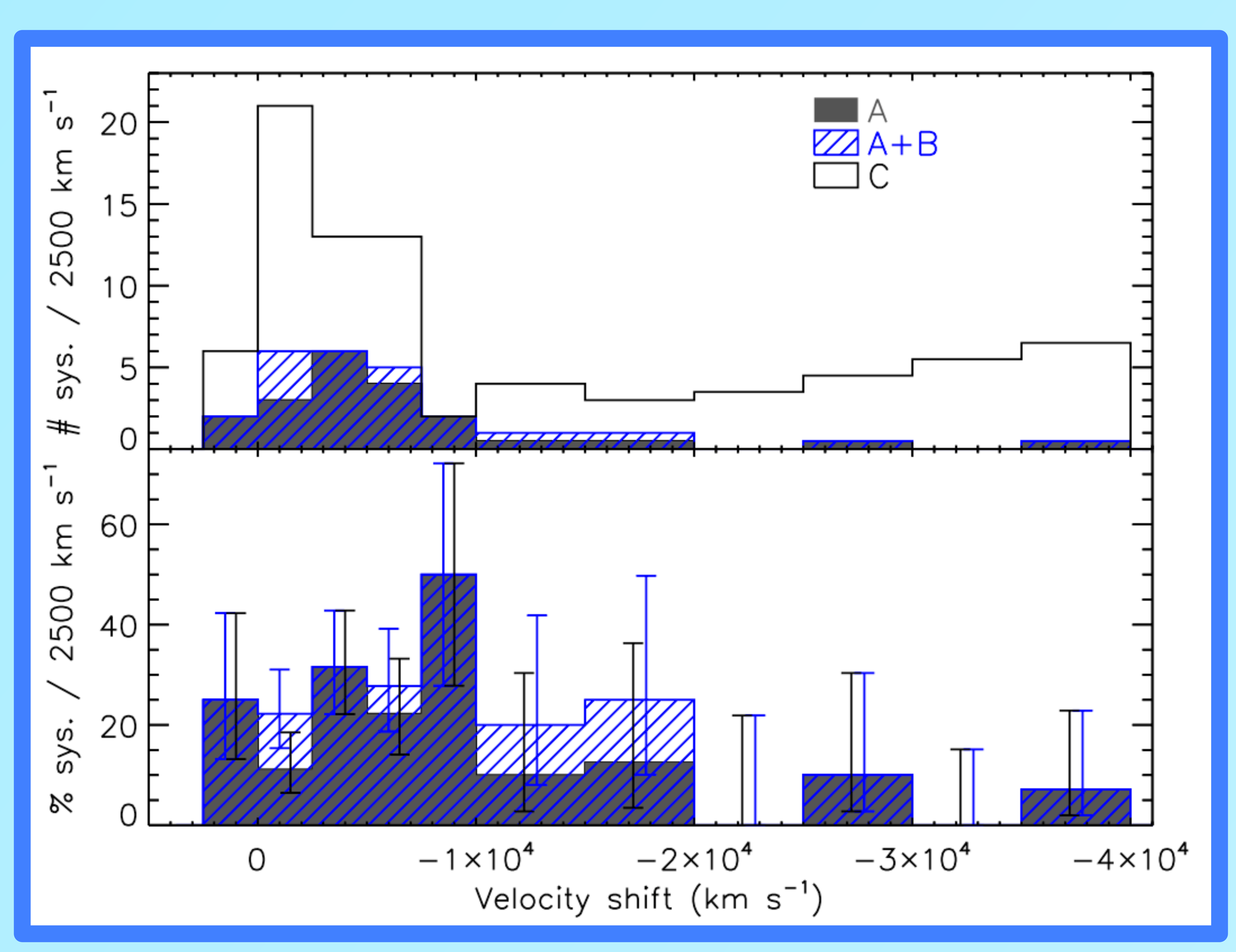


Figure 4. Velocity distributions of the numbers (top panel) and fractions (bottom) of definite intrinsic (class A), probable intrinsic (class B) and all other (class C) CIV NALs in our survey of 24 quasars. Intrinsic lines at shifts above ~2500 km/s originate in quasar outflows. The excess in class C at low shifts shows that our intrinsic identifications based on partial covering or broad profiles miss roughly half of the true intrinsic NALs.

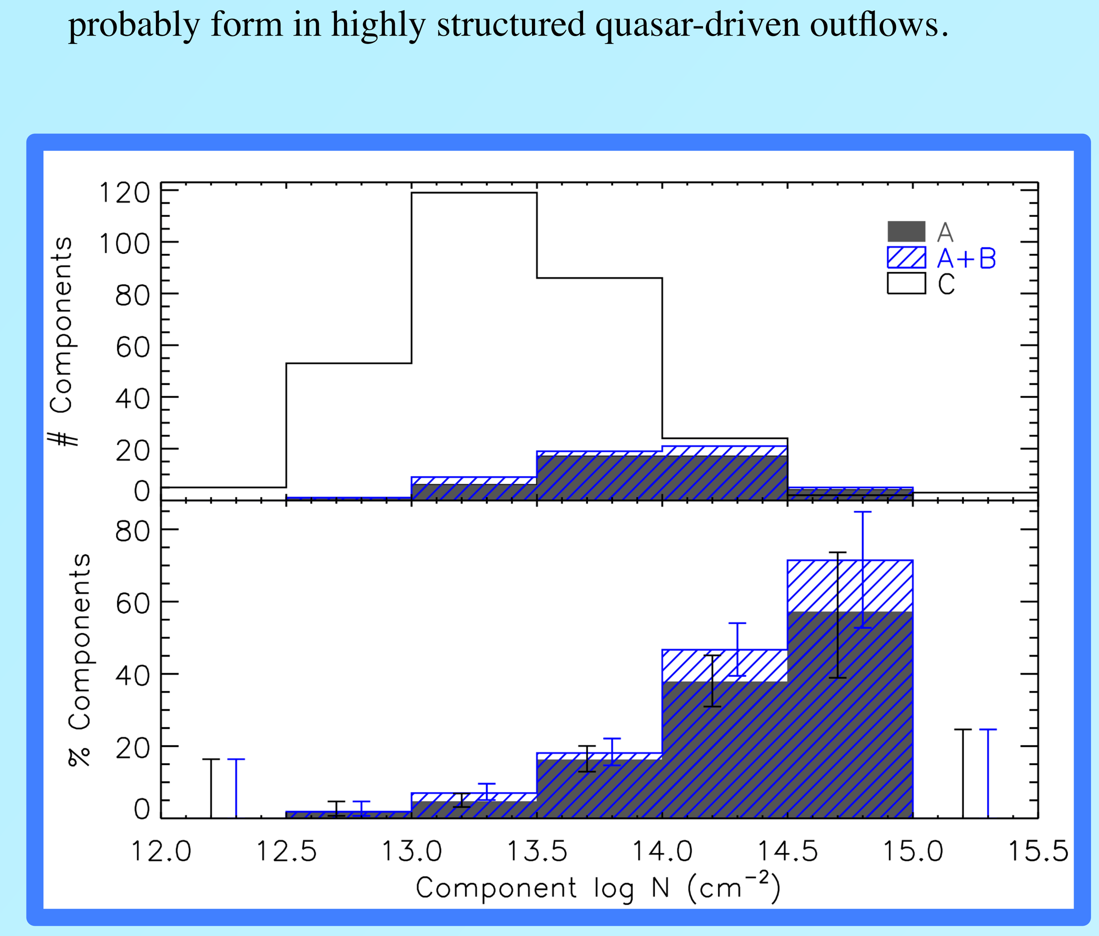


Figure 5. Intrinsic CIV NALs (classes A+B) strongly favor larger column densities (also larger REWs and larger b values, not shown) compared other/non-intrinsic NALs (class C). See Figure 4 caption.

References

Capellupo, D.M., Hamann, F., Shields, J. Rodriguez Hidalgo, P., Barlow, T. 2011, MNRAS, 413, 908

Hamann, F., et al. 2011, MNRAS, 410, 195

Hamann, F., et al. 2001, ApJ, 550, 142

Misawa, T., et al. 2007, ApJS, 171, 1

Simon, L., & Hamann, F. 2010, MNRAS, 409, 269

Acknowledgements

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