## PENNSTATE



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# Narrow Absorption Lines from Quasar Outflows

by Mike Eracleous

# The Zoo of UV Absorption Lines

#### **BALs: Broad Absorption Lines**

- smooth, deep, blue-shifted absn. troughs in UV resonance lines
- + FWHM > 2,000 km s<sup>-1</sup> (traditional definition)
- **NALs: Narrow Absorption Lines**
- UV resonance doublets must not be blended
- + FWHM < 500 km s<sup>-1</sup>, based on C IV  $\lambda\lambda$ 1548,1551

"mini-BALs": narrower than BALs (broader than NALs)

- Catch-all for everything in between
- wide variety of profiles
- are they "mini-BALs" or "super-NALs"?

#### CSO 673: Example of a BAL Quasar



from Junkkarinen et al. in prep (plot courtesy of Fred Hamann)

#### **Examples of mini-BALs and NALs**





from Rodriguez et al. in prep (plot courtesy of Paola Rodriguez)

## **Identifying Intrinsic NALs**

- Most practical criteria from Barlow & Sargent (1997, AJ, 113, 136)
- Smooth troughs (applicable to mini-BALs and super-NALs)
- Variability of equivalent width (or profile)
- Partial coverage of background source
- From variability studies so far: > 25% of all NALs are intrinsic.
- ◆ z < 1.5 Wise et al. (2004, ApJ, 613, 129)
- ★ z ~ 2 Narayanan et al. (2004, ApJ, 601, 715)

#### **Partial Coverage from Discrepancy in Doublet Ratios**



# Survey of Intrinsic NALs

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

- 37 quasars observed with Keck HIRES (R=45,000)
- + z = 2 4 from D. Tytler's private collection
- unbiased relative to NAL properties, but BALs were excluded
- Identify intrinsic C IV, Si IV and N V NALs
- use partial coverage analysis
- cover wide range in apparent outflow velocity: up to 70,000 km/s in C IV, but only up to 5,000 km/s in N V
- fit line profiles to get coverage fraction, column density, broadening parameter
- systematic and objective assessment of reliability and uncertainties

#### **Survey Results**

- Identification of ~120 C IV NALs plus more Si IV and N V NALS
- ~ 30% of all NALs are intrinsic
- Intrinsic NALs found up to  $\Delta v \sim 60,000$  km s<sup>-1</sup>; no apparent trend in velocity distribution
- 50% of all quasars have at least one intrinsic NAL
- Two distinct families based on absorber ionization state
- strong C IV intrinsic NALs
- strong NV intrinsic NALs



#### **Families of Wind Models**

- Line-Driven Murray+05; Proga+...
- Magnetocentrifugal+Line-Driven Köenigl & Kartje 94; Proga 00; Everett 05
- Thermal (X-Ray) Krolik & Kriss 95,01; Chelouche & Netzer 05











# Variability of mini-BALs



from Rodriguez et al. in prep (plot courtesy of Paola Rodriguez)

#### Variability of the CIV mini-BAL in HS 1603+3820



#### **Lessons from the Variability of HS 1603+3820**

Variability pattern cannot be explained by motion of the absorbing gas across the line of sight. It can be explained by...

Changes in the intensity of ionizing radiation seen by the absorber as long as...

★ τ<sub>C IV</sub> ~ 1 , n<sub>e</sub> > 10<sup>5</sup> cm<sup>-3</sup>, and rapid continuum fluctuations
⇒ continuum modulation by an interior porous screen

or by...

Variable scattering of continuum photons around absorber.

## X-Ray Properties of NAL Quasars

#### **Need for X-Ray Observations**

- UV intrinsic NALs trace only the "cold" phase of the wind. What about the "hot" phase? Hot phase (X-ray) may contain a great deal of mass and possibly dominate the mass outflow rate.
- Verify total column density of "cold" gas and constrain location of NAL gas relative to other parts of the flow.

#### X-Ray Survey Under Way

- Archival Survey of 4 quasars with intrinsic NALs (*Chandra, XMM*) (Misawa et al 2008, ApJ, 677, 863)
- New snapshot observations of 12 quasars with XMM and Suzaku
- Define basic X-ray properties of NAL quasars and set the stage for detailed case studies.

#### X-Ray Results: Trends (or not) with $\alpha_{ox}$



#### X-Ray Results: Comparison with BAL Quasars



## **Preliminary Conclusions**

No significant cold absorption No ionized absorption  $N_{\rm H} < \text{few x } 10^{22} \text{ cm}^{-2}$  $N_{\rm H} < 10^{23} \, {\rm cm}^{-2}$ NAL quasars follow extensions of many trends set by BAL Line of sight through NAL quasars – reminiscent of gas not same as line of sight "normal" quasars. through BAL gas. Instead... at high latitudes, above Velocities of NALs do not dense wind follow BAL trend with  $\Delta \alpha_{ox}$ samples different velocity 0 field Line of sight to UV source Presence and properties not same as line of sight to of UV NALs X-Ray source ?

# So Far, So Good. Now What?

- Larger Survey from VLT+Keck Archives 10x Sample; multiple observations — under way
- *Variability Studies at High Spectral Resolution* Both NALs & mini-BALs — under way

**X-Ray Properties** Case studies — search for warm absorber & high-*v* lines

**Spectropolarimetry of HS 1603+3820** Test of scattering hypothesis — this summer

#### **Photoionization modeling**

Physical conditions of absorbers & location in overal outflow; understand ionization families

# The End