Quasar Narrow UV Absorbers: Useful Probes of Disk Winds and Outflows?

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Why are Quasar Narrow Absorption Lines of Interest?

- Intrinsic?
  - Quasar structure
- Origin: Winds/Outflows?
  - Quasar feedback on environment
  - Effect on galaxy formation & evolution?
- Frequency of Occurrence → additional probes of feedback?

Overview

- Basic statistics of quasar C IV λ1549 NALs
- Crude tests of disk-wind scenario possible
- The $z \approx 2$ BALs radiatively driven as for the low-z BQS?
- Evidence for radiative acceleration of NALs?
- NALs radiatively launched from disk?

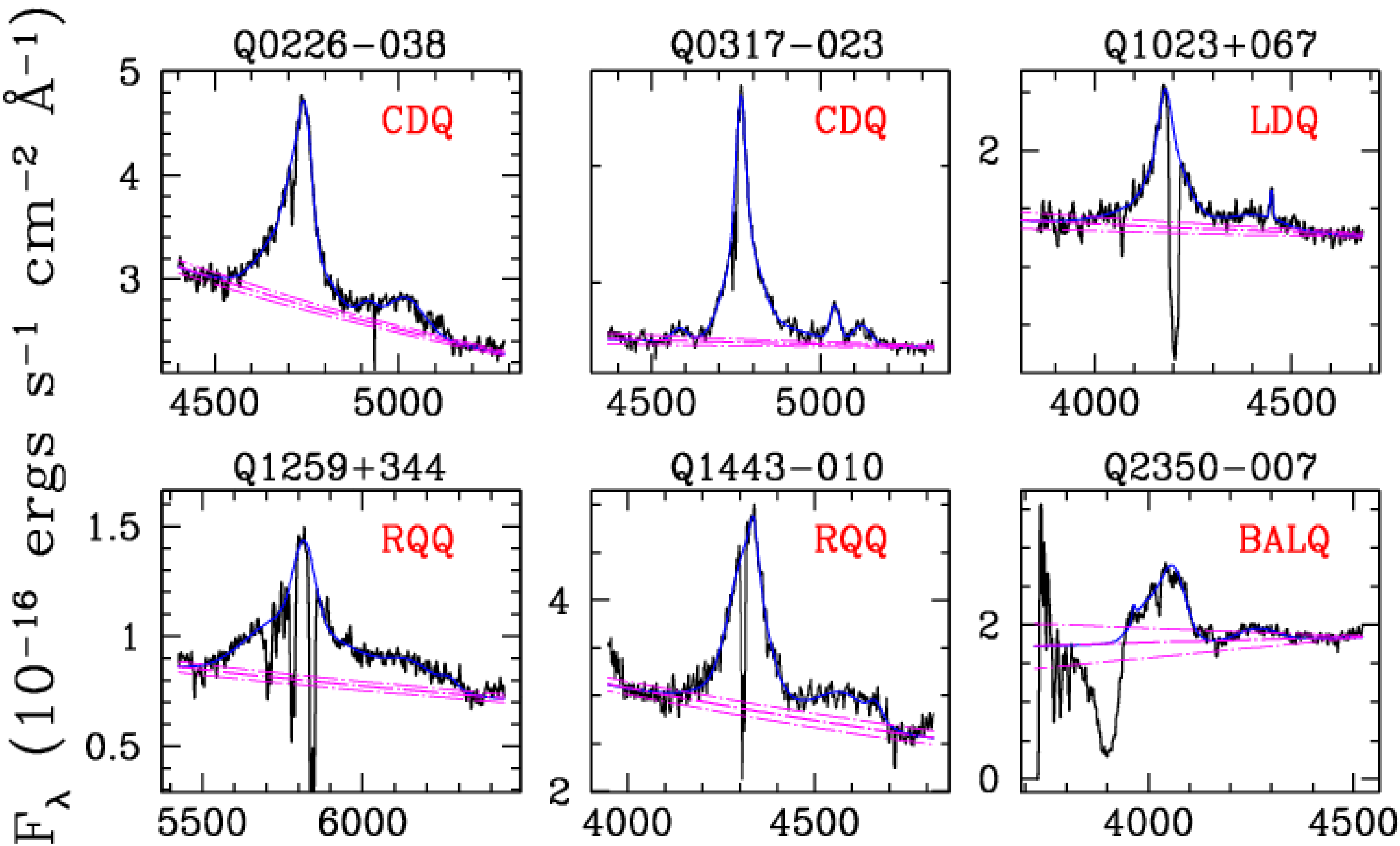
Quasar sample

- Representative $z \approx 2$ quasar sample ($1.5 \leq z \leq 3.6$)
- 114 Radio-loud and radio-quiet quasars (66; 48)

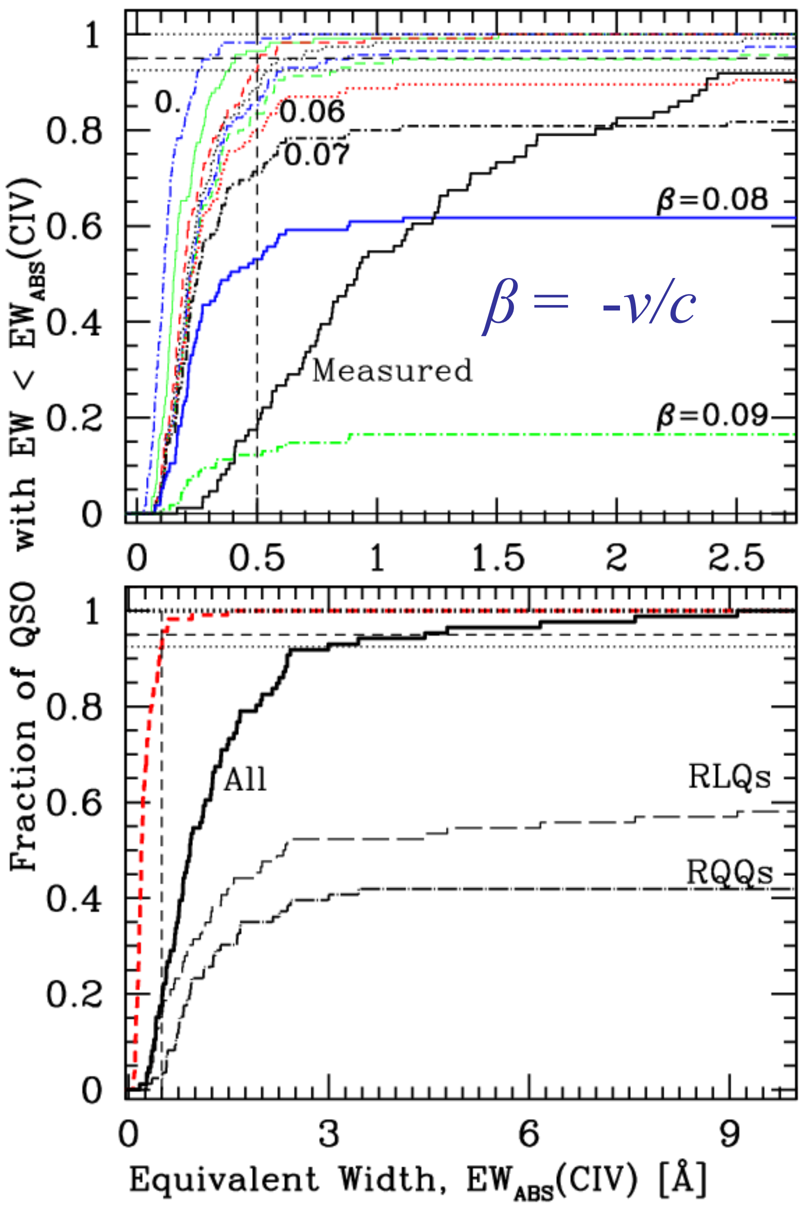
(Barthel, Tytler, & Thomson 1990; Vestergaard 2000)

- RLQs and RQQs match in M_{V} and z
- No selection based on absorption properties
- Range in RLQ source inclination ($R_{5\mathrm{GHz}}$ and R_{V})
- Narrow C IV λ1549 absorption lines measured to ~20,000 - 25,000 km/s from emission redshift (z_{em})

Sample Spectra



Basic Narrow Absorption Properties



- Completeness ≥ 95% at velocities below ± 6000 km/s
- 3σ detection limit = 0.5Å, measured to a completeness level of ~95%
- 80% of NALs have EW ≥0.5Å
- Most RQQs NALs:
  EW > 0.5Å

(Vestergaard 2003, ApJ 599, 116)

Basic Narrow Absorption Properties

- Frequency of Occurrence:
  (both RLQs and RQQs alike)
  - All NALs (velocity < 21,000 km/s): ~50% ± 7%
  - NALs with EW≥ 0.5Å : ~40% ± 5%
  - NALs with EW≥ 1Å : ~35% ± 5%
  - "Associated" NALs : ~25% ± 5%
    (EW ≥ 1Å; velocity ≤5000 km/s)

(Vestergaard 2003, ApJ 599, 116)

Inclination Dependent Absorption

- Absorbed quasars have redder UV continua

  $F \propto \lambda^{\alpha}$, $<\alpha_{UV}>$: -1.47 ±0.6 vs. -1.99±0.6 (unabsorbed)

  KS-test: α-distributions are different at 99.95% level

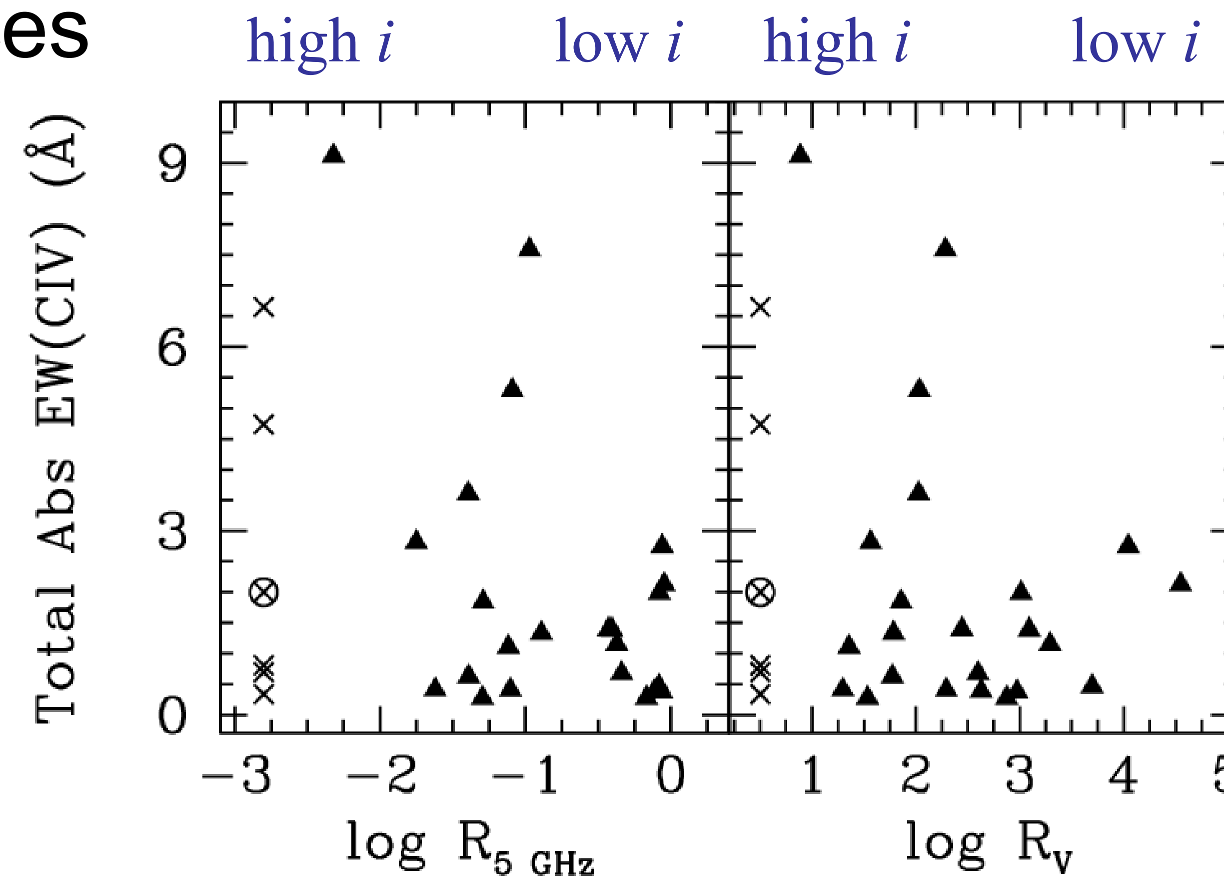
- Stronger absorption in
  - more inclined radio-loud quasars
  - redder quasars (especially radio-loud quasars)

- Luminosity dependence
  - Radio-quiets: EW $\propto$ L
  - Radio-louds: EW $\propto L^{-1}$?

(Vestergaard 2003, ApJ 599, 116)

NALs in Radio-loud Quasars

- Stronger NALs in radio sources with:
  - Larger inclination *i*
  - Largest size



(Vestergaard 2003, ApJ 599, 116)

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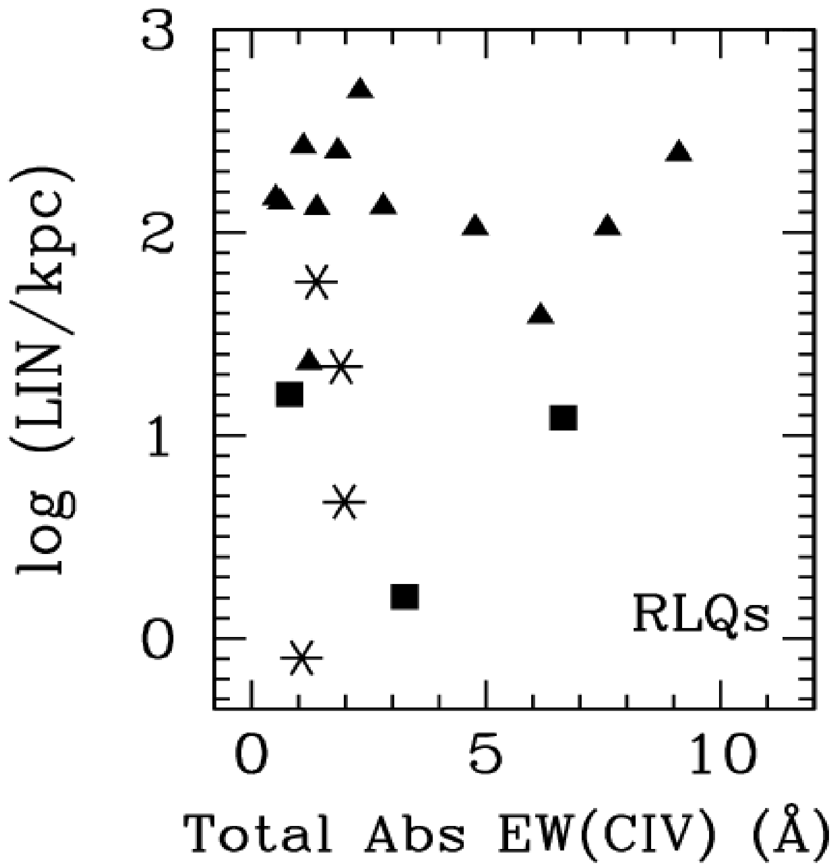


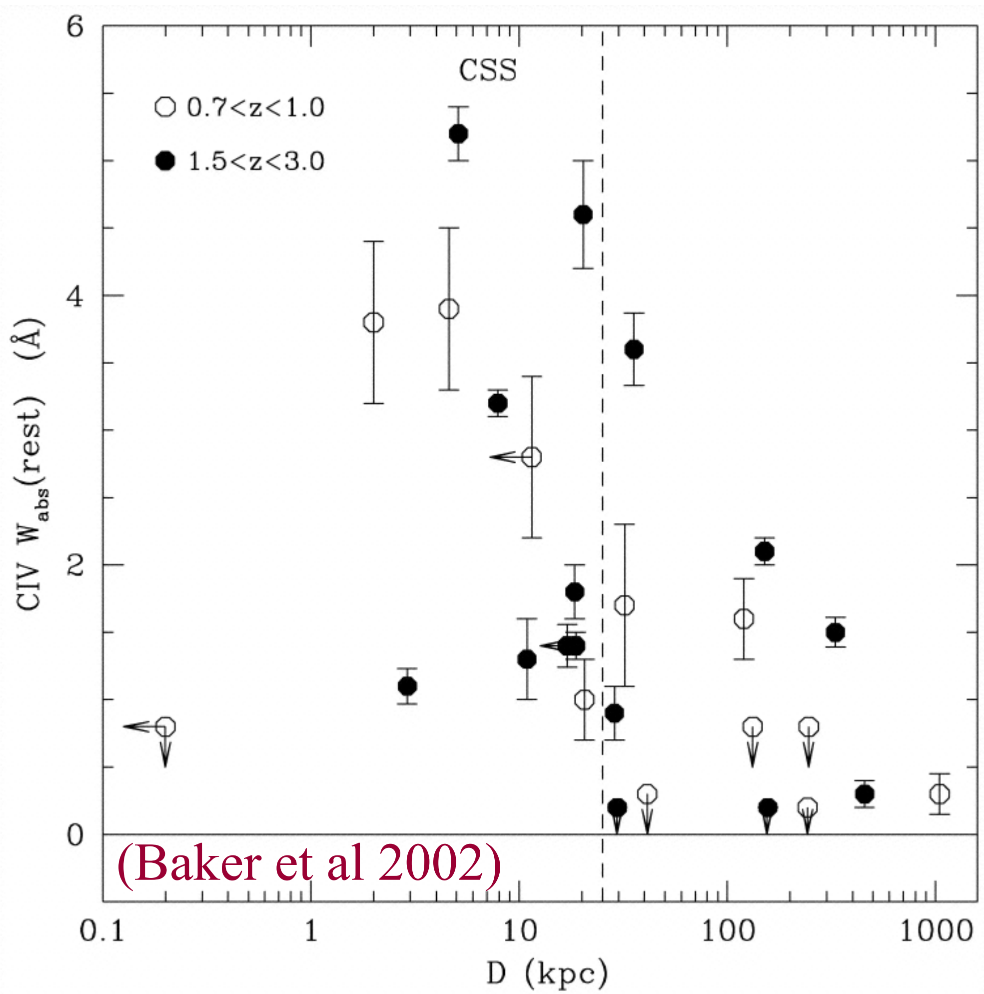
Squares: CSS
Triangles: Lobe-dom. Q
Asterisks: Core-dom. Q

(Vestergaard 2003, ApJ 599, 116)

(H_0=50 km/s/Mpc; Ω_Λ = 0.0)

NALs in Radio-loud Quasars

- Stronger NALs in radio sources with:
  - Largest size
  - Larger inclination
- Molonglo radio sources: stronger NALs in most compact quasars
  - Relatively weaker quasars
  - Younger sources?
  - => larger samples needed



(H_0=50 km/s/Mpc; $\Omega_\Lambda = 0.0$)

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- Luminosity dependence
  - Radio-quiets: EW $\propto$ L
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(Vestergaard 2003, ApJ 599, 116)

(H_0=50 km/s/Mpc; Ω_Λ = 0.0)

Luminosity Dependent Absorption

NALs only

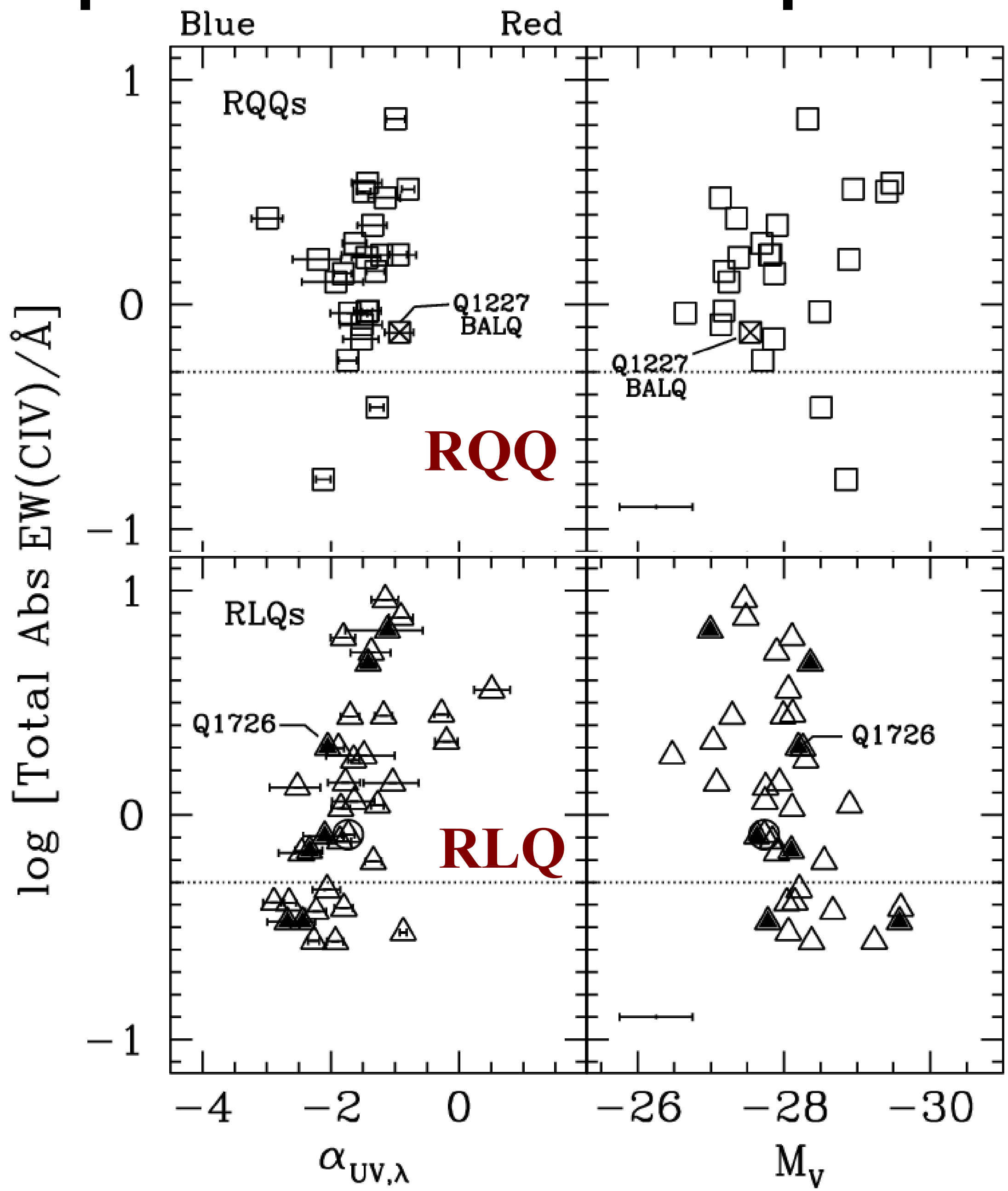
- Radio-quiets:

  EW $\propto$ L

- Radio-louds:

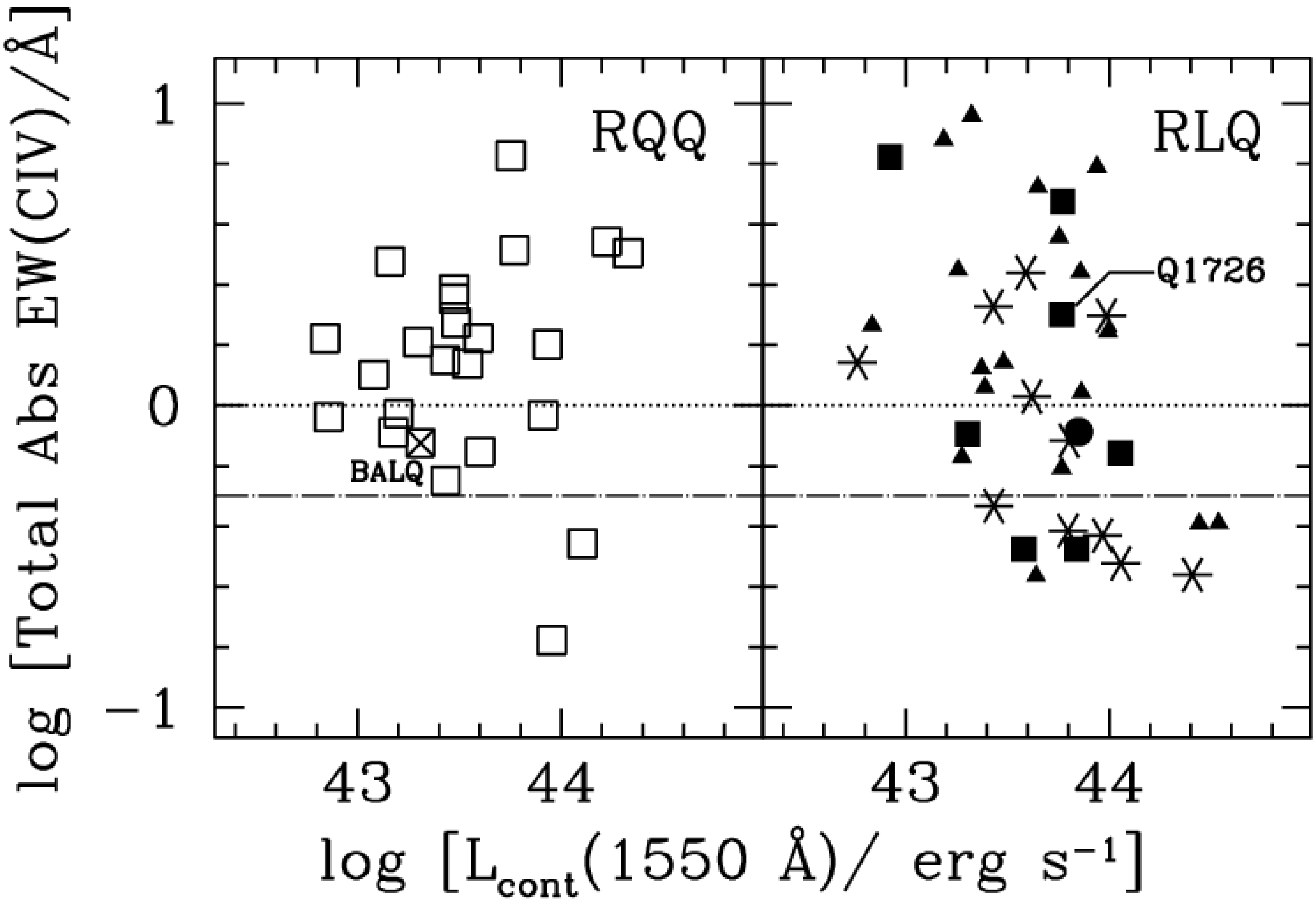
  EW $\propto$ L^{-1} ?

Solid Triangles: CSS
Circles: GPS



(Vestergaard 2003, ApJ 599, 116)

Luminosity Dependent Absorption



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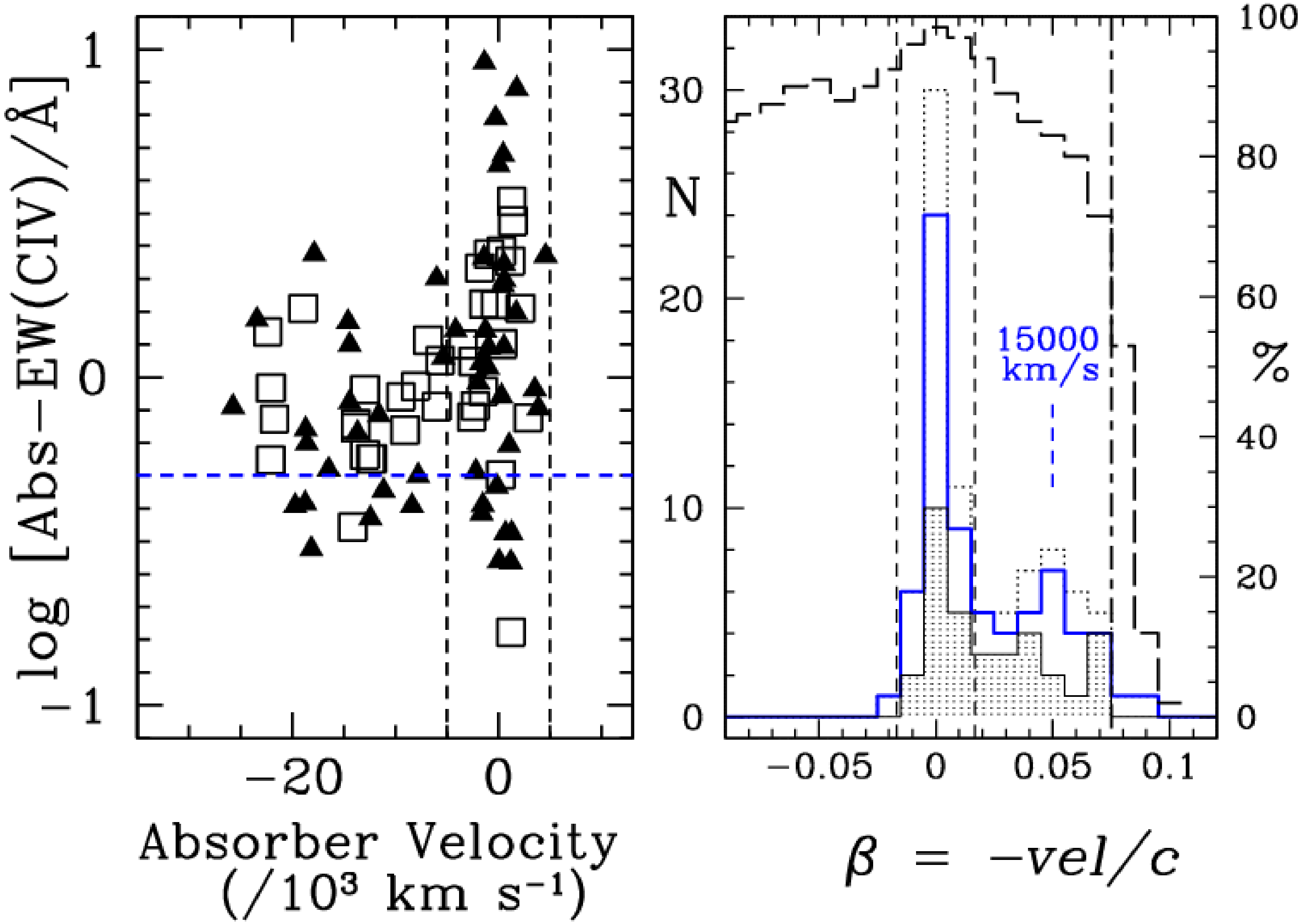
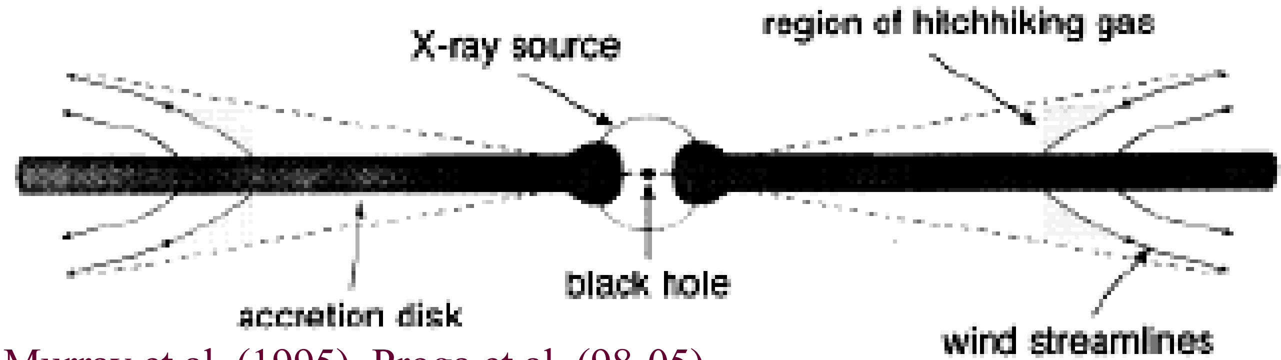
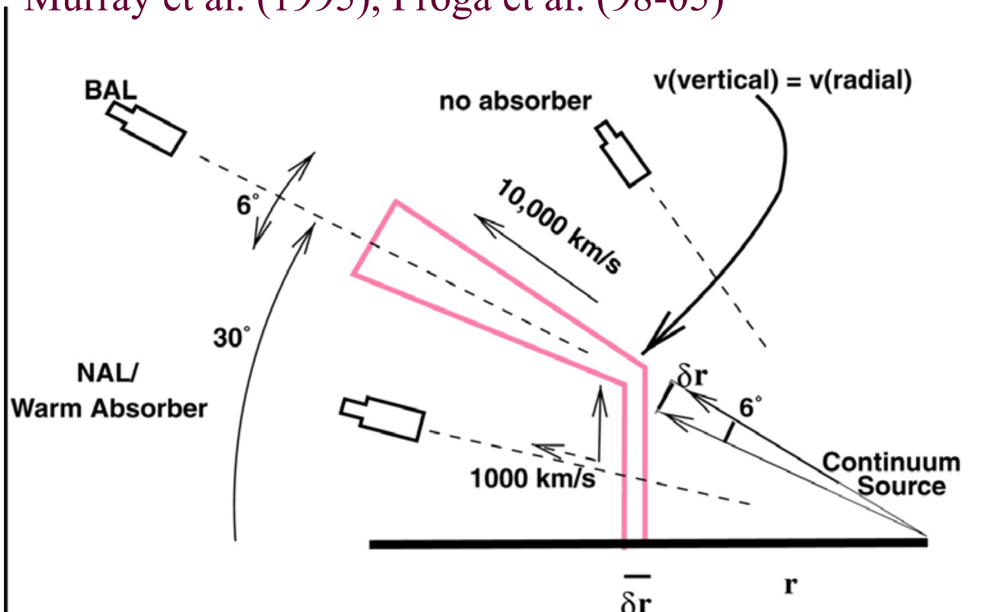


$$\beta = (r^2 - 1)/(r^2 + 1) \quad ; \quad r = (1 + z_{em})/(1 + z_{abs})$$

Disk-Wind Scenarios



Murray et al. (1995), Proga et al. (98-05)



Elvis (2000)

wind-producing conditions:

T_{disk} and $L_D^{eff} = L_D\, F_{max} > L_{Edd}$

(e.g., Proga 2002)

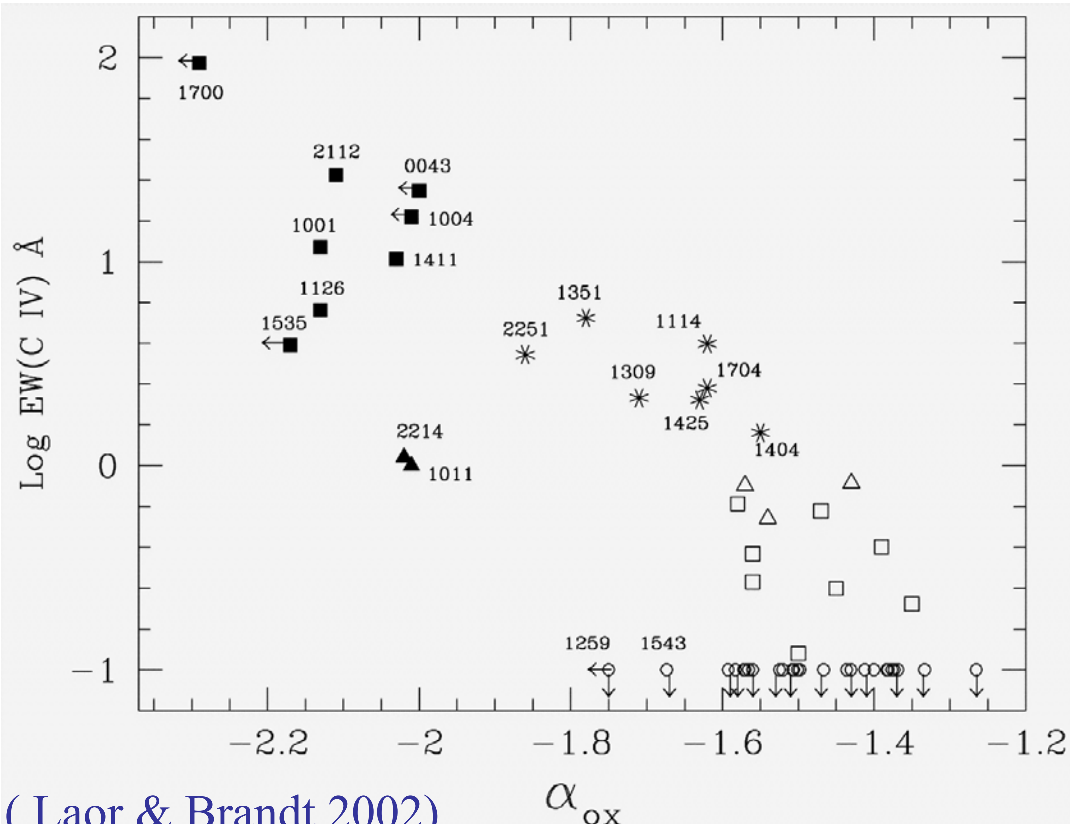
Can Qualitatively Explain:

- Existence BALs, NALs, WAs, and BELs
- BAL non-variability
- The AL frequencies, EW, velocities, incl. scarcity of BALs in RLQs and Seyfert 1s

- NAL are failed BALs?

Importance of α_{OX} (τ_X/τ_{UV})

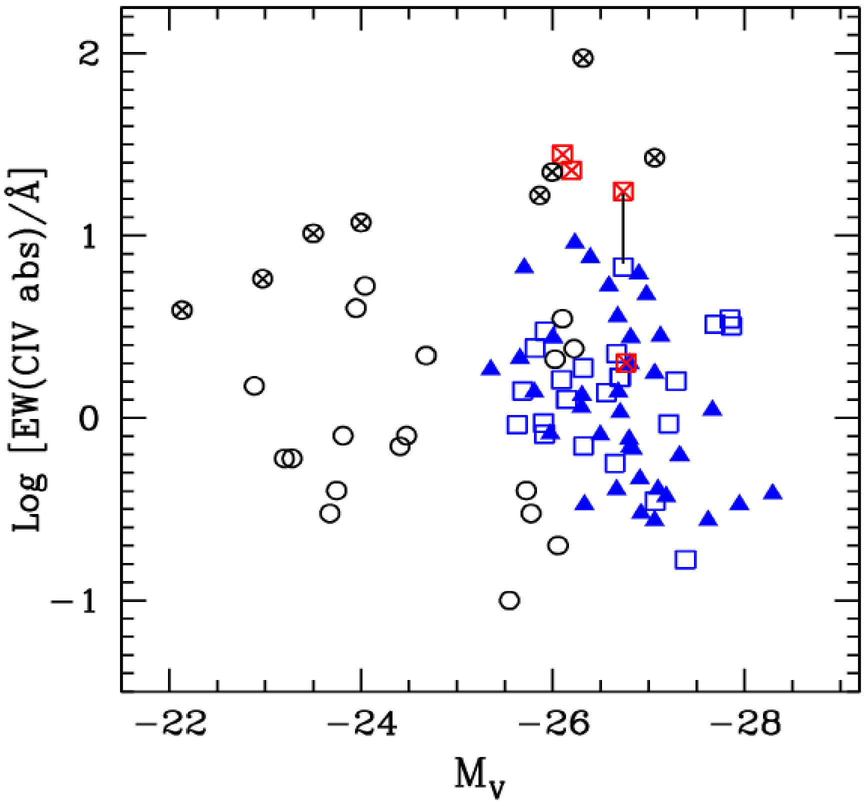
Low-z BQS and α_{OX}

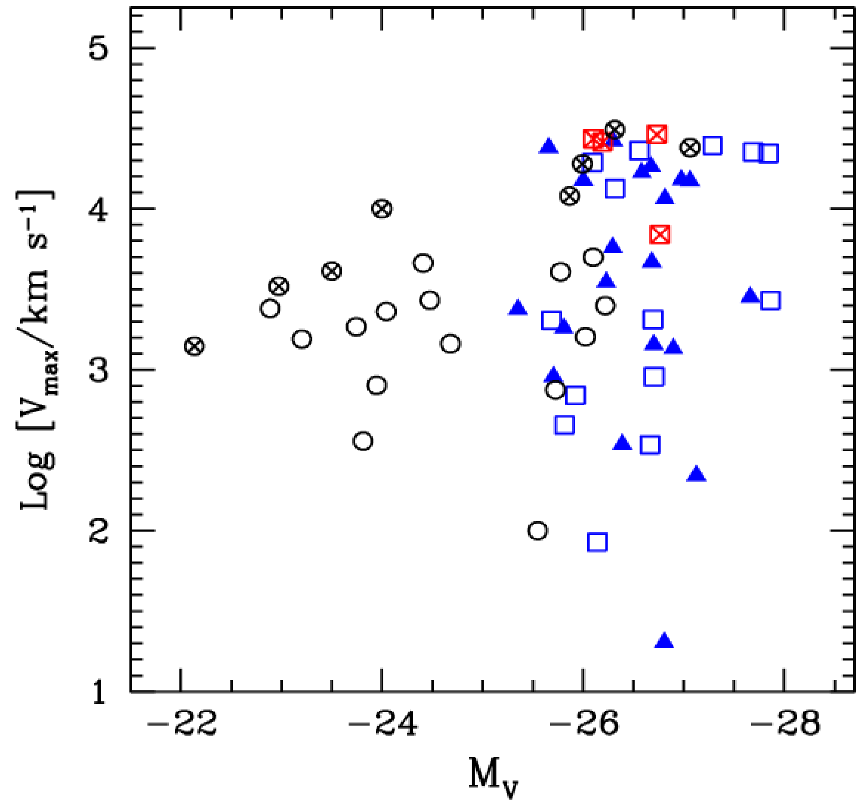


(Laor & Brandt 2002)
(Brandt, Laor, Wills 2000)

- Low-z soft X-ray weak quasars have large α_{OX}
- BAL quasars are the most luminous subset of soft X-ray weak quasars
- Intrinsic α_{OX} is steep?

Comparison with low-z BQS





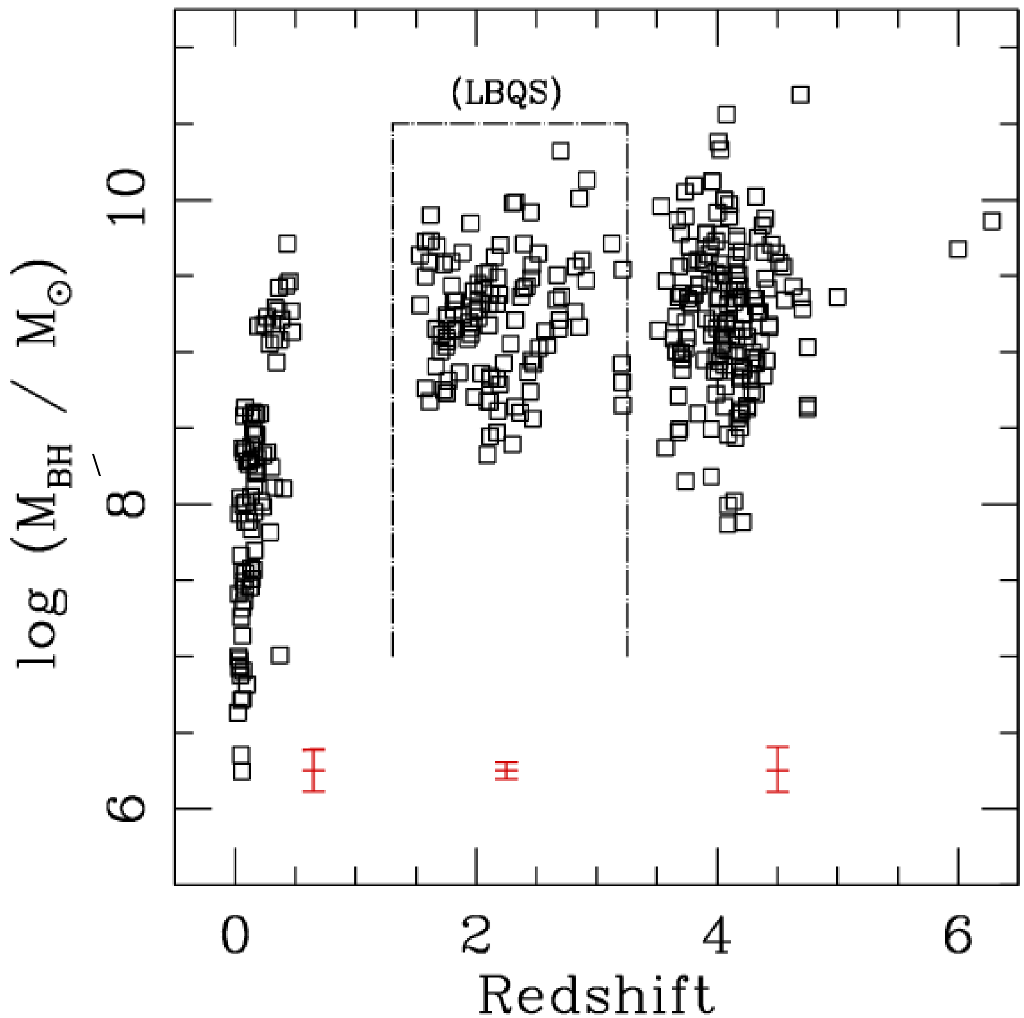
z ≈ 2 BAL quasars fall on extension of low-z soft X-ray weak quasars (including BAL quasars; Laor & Brandt (2002))

(Vestergaard 2005, ApJ, submitted)

(H_0=50 km/s/Mpc; Ω_Λ = 0.0)

Masses of Distant Quasars

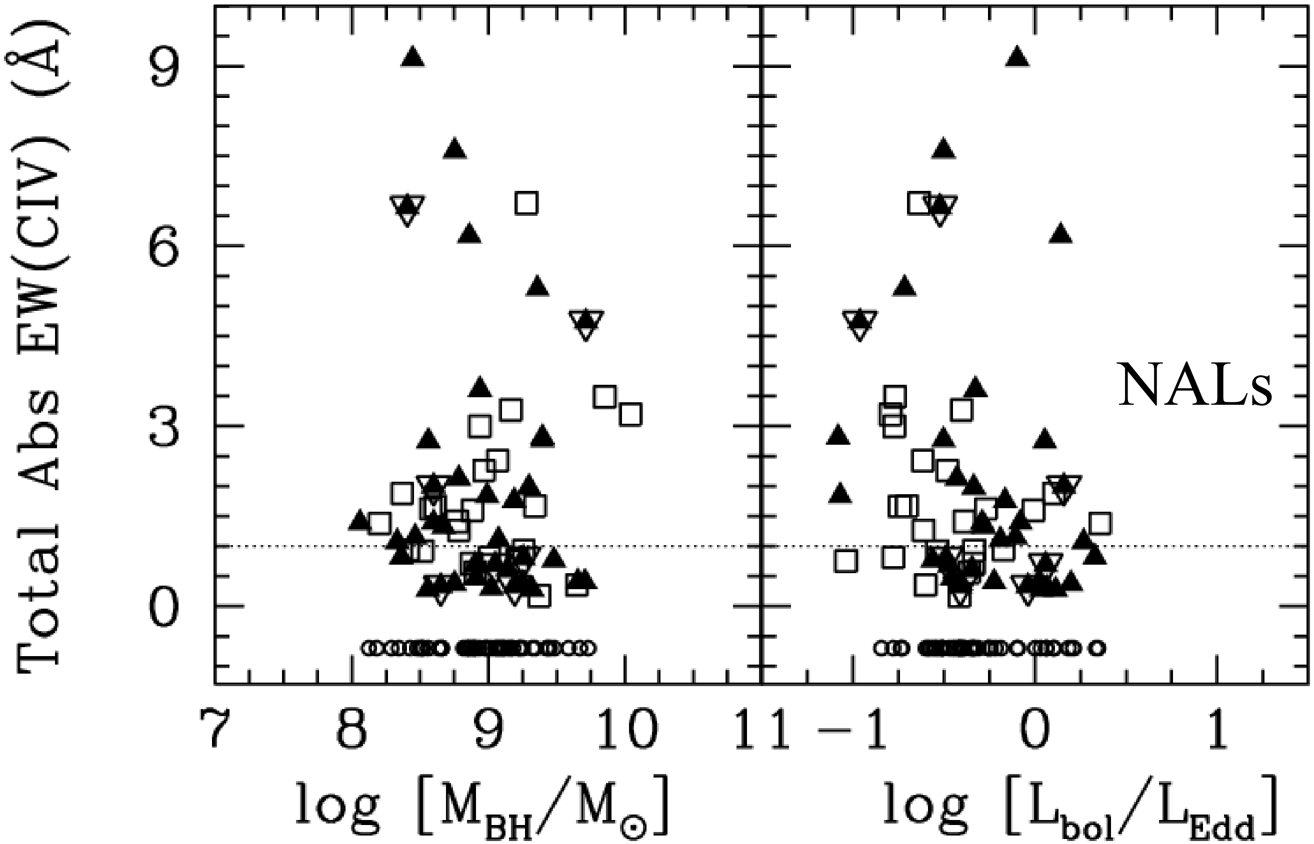
- $M_{BH} \propto FWHM^2(CIV)\ L^{0.7}$
  (Vestergaard 2002, ApJ 571, 733)
- Masses representative of distant quasars
- $M_{BH} \approx 10^9\ M_\odot$ on average



(Vestergaard 2004, ApJ 601, 676)

Testing Basic Disk-Wind Predictions

- L_{BOL}/L_{Edd} – EW| L(1550Å): partial-τ = 0.55, P=0.0035% (EW≥3Å)
  partial-τ = -0.38, P=0.010% (1Å≤EW≤3Å)



L_{BOL} = BC $\cdot L_\lambda$ (1550Å)

Wind-launching condition:

$$L_D^{eff} = L_D \cdot F_{max} > L_{Edd}$$

Mass loss rate to wind:

$$\dot{M}_W \propto L_{UV}/L_{Edd}$$

(Vestergaard 2005, ApJ, submitted)

(H_0=50 km/s/Mpc; Ω_Λ = 0.0)

Testing Basic Disk-Wind Predictions

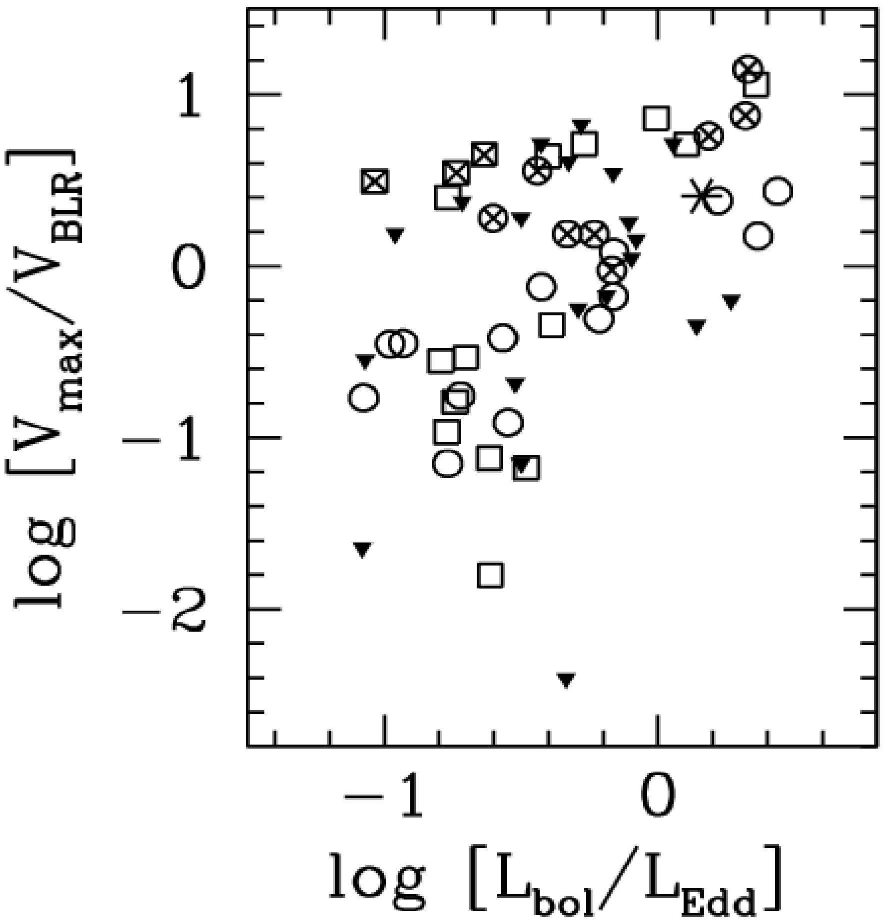
$$v^2_{\mathrm{terminal}} = \frac{\alpha}{1-\alpha} 2\left(1 - \frac{L_{\mathrm{BOL}}}{\mathrm{L_{Edd}}}\right) \frac{GM_{\mathrm{BH}}}{r_{\mathrm{i}}} = C(\alpha, L/L_{\mathrm{Edd}})\, v^2_{\mathrm{BLR}}$$

(e.g., Castor et al. 1975)

$$\frac{v_{\mathrm{term}}}{v_{\mathrm{BLR}}} = \sqrt{C} = \frac{\alpha}{1-\alpha} 2\left(1 - \frac{L_{\mathrm{BOL}}}{\mathrm{L_{Edd}}}\right)$$

Testing Basic Disk-Wind Predictions

- $L_{BOL}/L_{Edd} - V_{max}/V_{BLR}|V_{BLR}$: partial-τ =0.24, P=0.0038%
  $| M_{BH}$: partial-τ =0.33, P=0.0006%



BALs+NALs (EW≥1Å):
BQS and z≈2 Qs

$$\frac{v_{term}}{v_{BLR}} = \frac{\alpha}{1-\alpha} 2\left(1 - \frac{L_{BOL}}{L_{Edd}}\right)$$

(Vestergaard 2005, ApJ, submitted)

(H_0=50 km/s/Mpc; Ω_Λ = 0.0)

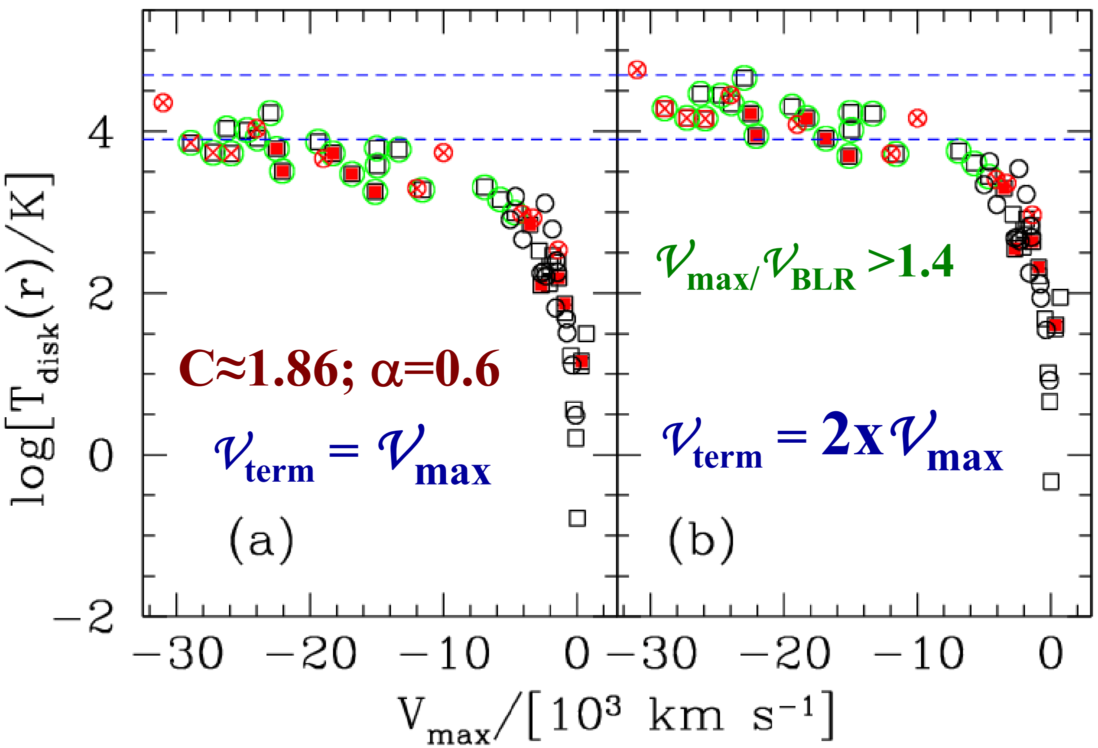
Disk Temperature at Launching Radius

$$T_{disk}(r) = 3\times10^{7}\, m^{-1/4}\,\dot{m}^{1/4}\, r^{-3/4}\,(1-r^{-1/2})^{1/4}\,\mathrm{K}\,;\quad r = R/9m$$ (SS74)

$$v_{\text{terminal}}^{2} = \frac{\alpha}{1-\alpha}\,2\left(1-\frac{L_{\text{BOL}}}{L_{\text{Edd}}}\right)\frac{GM_{\text{BH}}}{r_{\text{i}}} = C(\alpha, L/L_{\text{Edd}})\frac{GM_{\text{BH}}}{r_{\text{i}}}$$

$$\alpha \approx 0.6 - 0.9$$

(Murray & Chiang 1995; Proga et al. 2000)



Favorable disk temperature for wind launching:

$T_{\text{disk}} \approx$ 8,000 – 50,000 K

(Proga etal. 2000; Proga & Kallman 2004)

Value of C ?

- L/L_{Edd} dependence OK?

Complex velocity structure?

Main Results And Future

- Frequency of C IV λ1549 NALs is 25-40% across quasar radio type
- Crude tests of disk-wind scenario possible
- $z \approx 2$ BAL outflows likely radiatively driven in similar manner as for the low-z BQS
- Suggestive evidence for radiative acceleration of some C IV λ1549 NALs (EW >~ 3Å)
- Estimated T_{DISK} at launching radii promising, given uncertainties – Can we do better?

Future:

- XMM-Newton Cycle 5 proposal: α_{OX} measurements
- Test on larger size samples
- More theoretical work needed