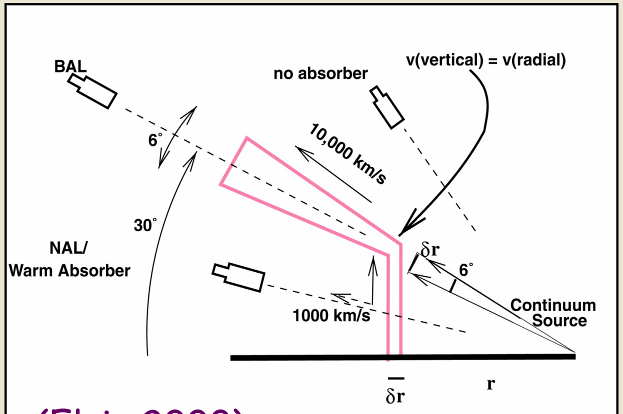
Do CIV 1549Å narrow associated absorption lines take origin in disk winds?



(Elvis 2000)

Long-standing issue: narrow associated absorbers in quasars

- origin?

- physical properties: n,T,P, covering factor, location etc?

Overview:

- **Basic statistics of quasar CIV 1549Å NALs**
- **Crude tests of disk-wind scenario possible**
- **Evidence for NAL gas being launched from disk and radiatively accelerated outward?**

PS: Work in progress

CIV NALs take origin in disk winds?

Quasar Sample

- Representative z≈2 sample: $1.5 \leq z \leq 3.6$
- 114 radio-loud and radio-quiet quasars (66, 48)

(Barthel, Tytler, & Thomson 1990, Vestergaard 2003)

- RLQs and RQQs match in M_V and redshift, z
- No selection based on absorption properties
- Range in source inclination for radio-louds (R_{5GHz}, R_V)

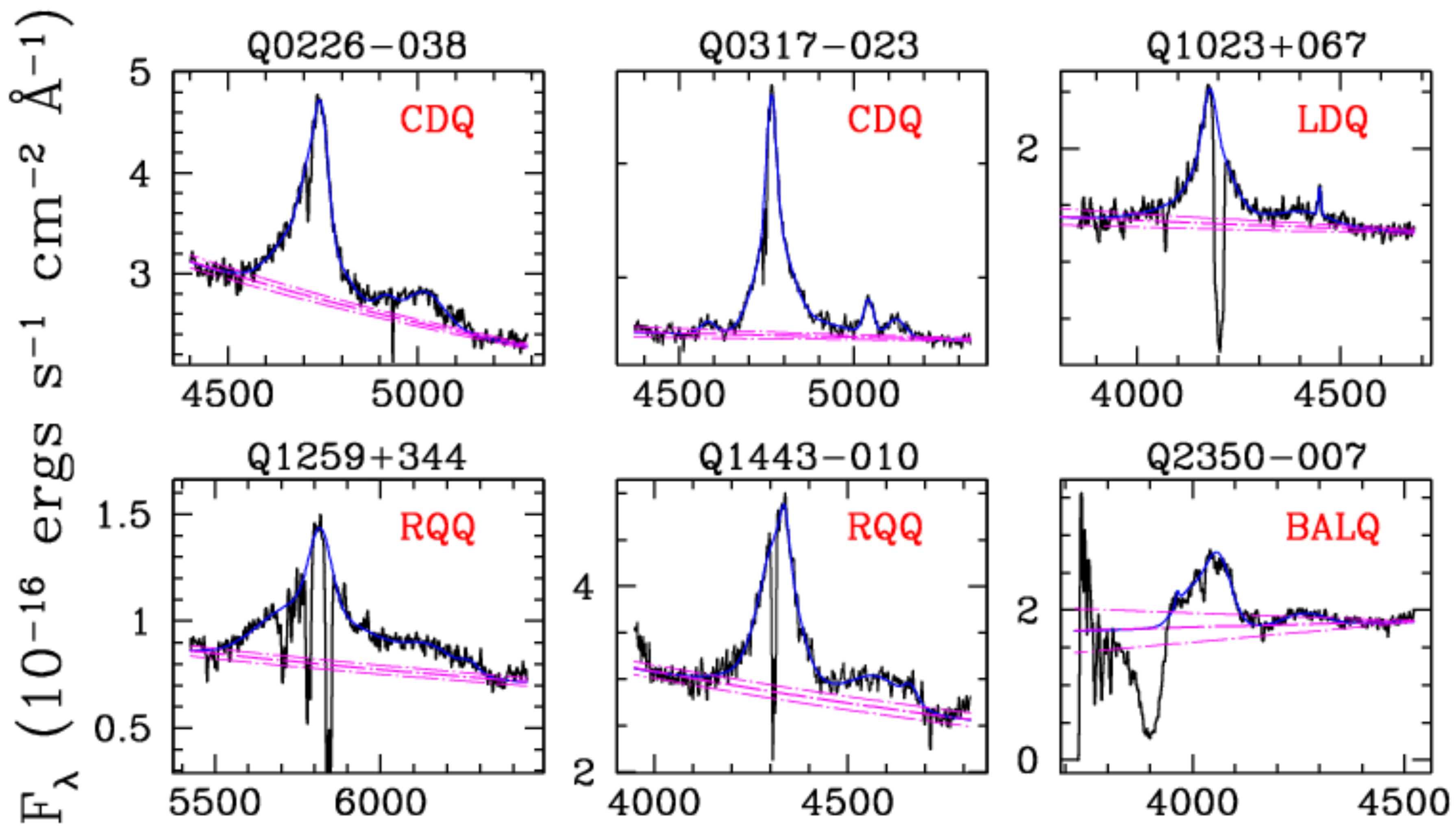
$R_{5GHz} = S_{5GHz;core} / S_{5GHz;total}$; $R_V = L_{5GHz;core} / L_V$ (Wills & Brotherton 1995)

- Narrow CIV λ1549 absorption lines measured to velocities from ~ 20,000 km/s to 25,000 km/s from $z_{emission}$

CIV NALs take origin in disk winds?

Dark Cosmology Centre

Sample Spectra



CIV NALs take origin in disk winds?

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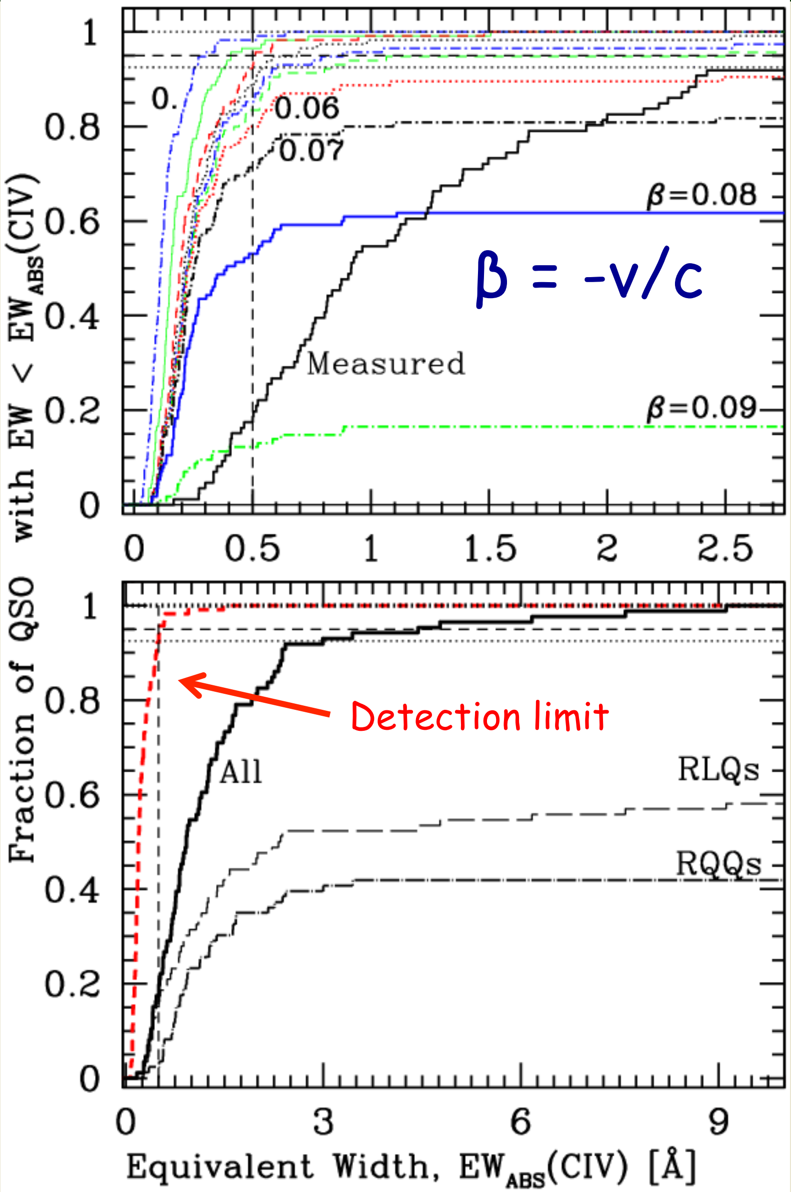


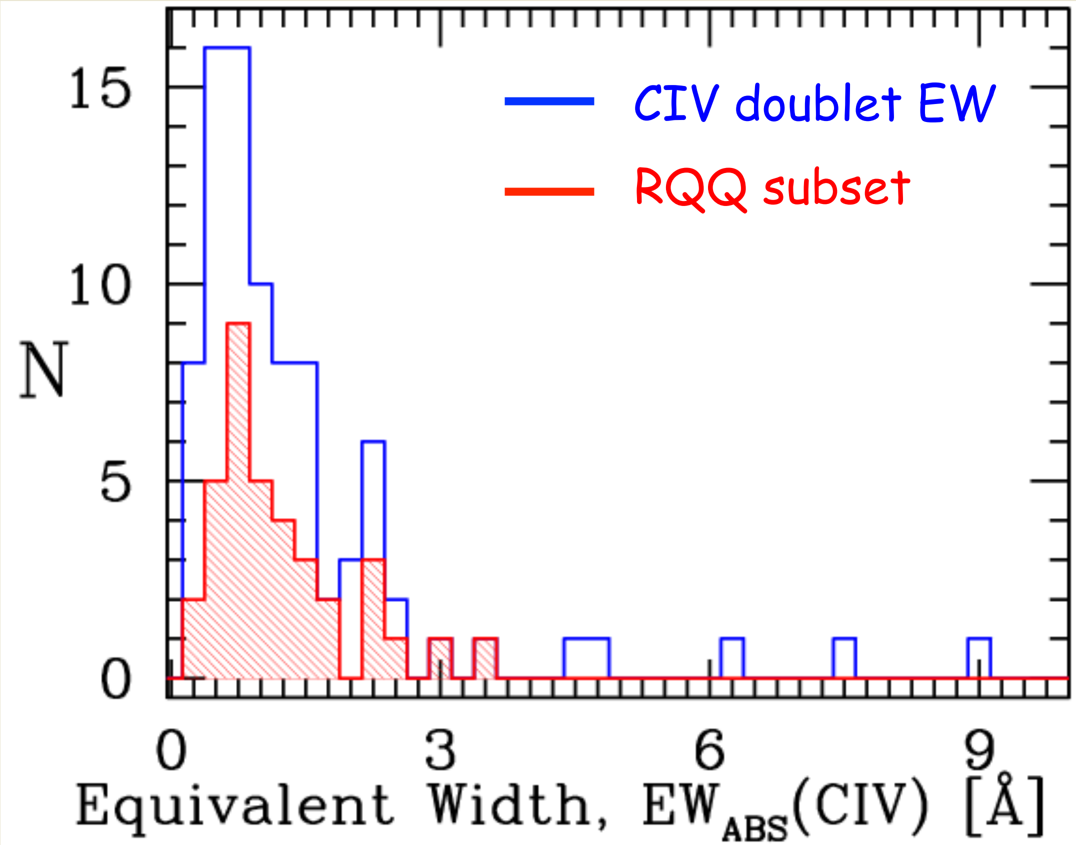
Detection Statistics

- Completeness ≥ 95% at velocities below ± 6,000 km/s (β~0.02)
- 80% of NALs have EWs ≥ 0.5Å
- 3 σ detection limit = 0.5Å, measured to a completeness level of ~95%
- Most NALs in radio-quiet quasars: EW > 0.5Å

EW = sum of CIV doublet

MV 2003, ApJ 599, 116

Rest Equivalent Width Distribution



Frequency of occurrence:

- All NALs ~50% ± 7%
  (v < 21,000 km/s)
- EW ≥ 0.5Å: ~40% ± 5%
- EW ≥ 1Å: ~35% ± 5%
- Associated NALs: ~25% ± 5%
  (EW ≥ 1Å, velocity ≤ 5,000 km/s)

EW = sum of CIV doublet

MV 2003, ApJ 599, 116

CIV NALs take origin in disk winds?

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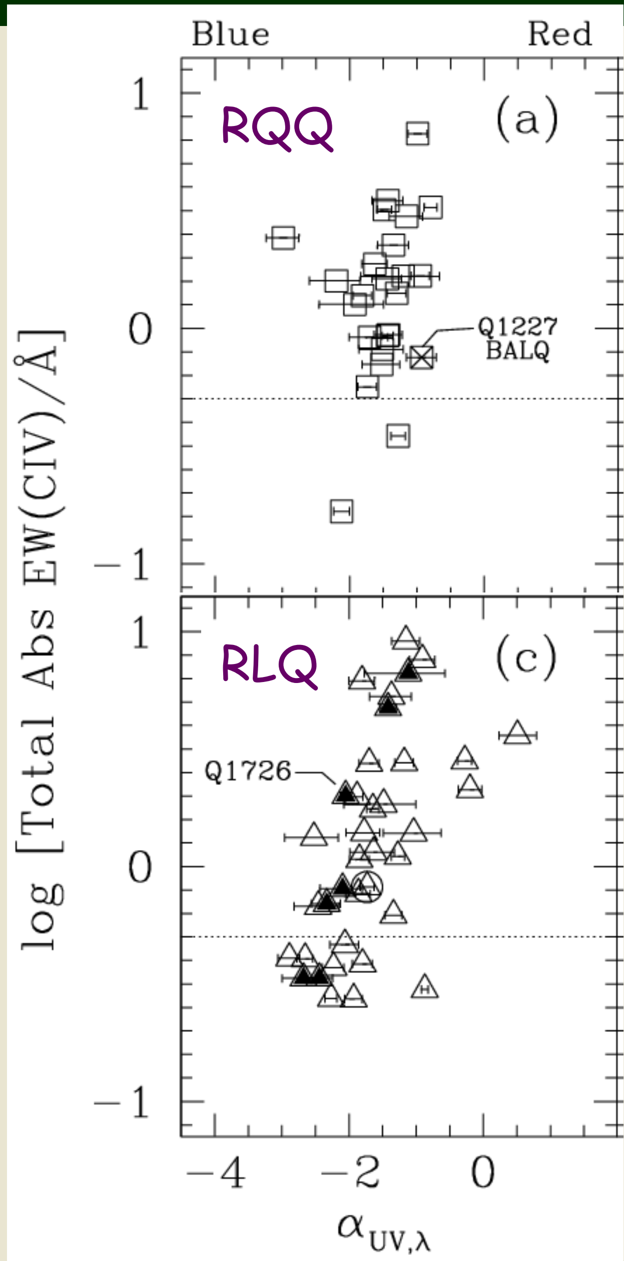
Redder UV slopes for stronger NALs



$F_\lambda \sim \lambda^\alpha$

Consistent with earlier work finding increased dust reddening in RLQs with higher EW(CIV) NALs

(e.g., Baker & Hunstead 1995)

Q1726: mini-BAL

Solid triangles: CSS
Circles: GPS

MV 2003, ApJ 599, 116

CIV NALs take origin in disk winds?

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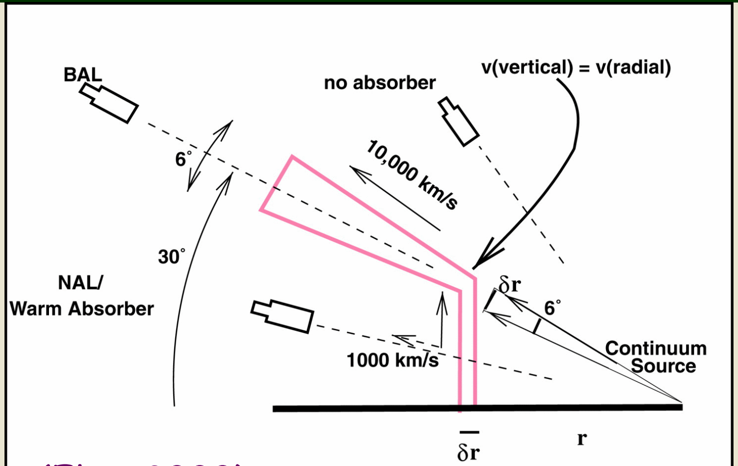


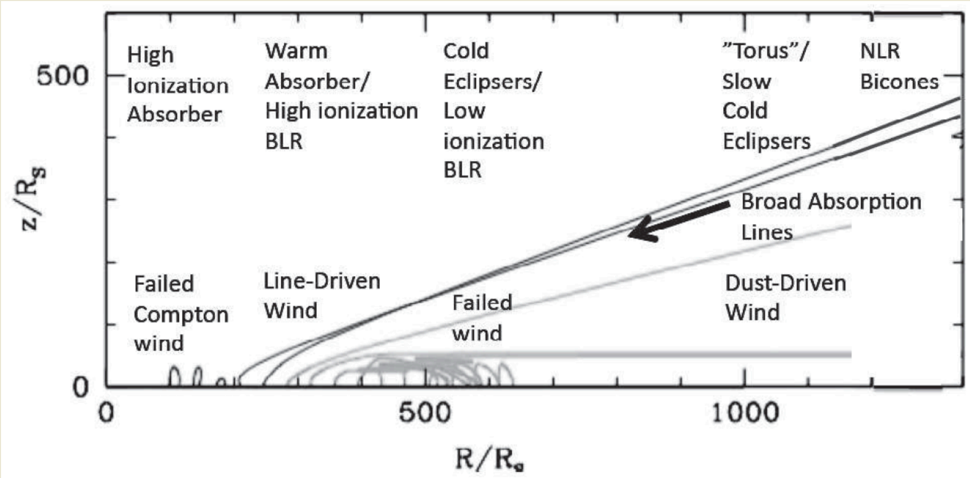
(Elvis 2000)

- Wind is launched from specific radii (disk temperatures)

BLR Outflows

Are NAL failed BALs or BALs seen at other viewing angles?

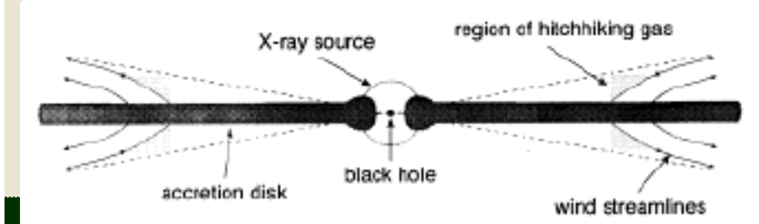
(Elvis 2012)



- Wind is launched from all disk radii but fail to escape for some radii

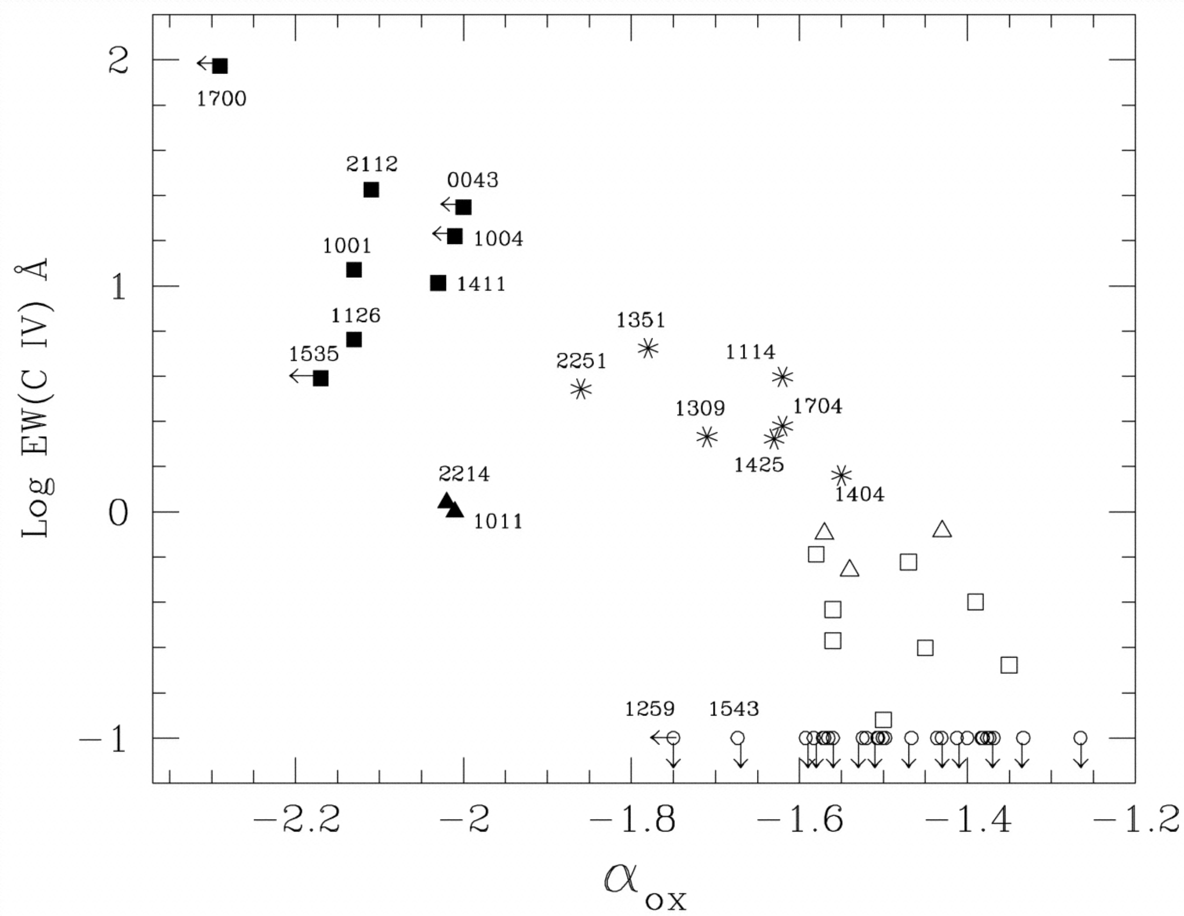
Condition for wind: T_{disk} & $L^{eff}_{disk} = L_{disk} \times FM_{max} > L_{Edd}$

(e.g., Proga 2002)



- Systems with steep α_{OX} are conducive to generating and driving winds (Murray + 1995)

CIV NALs take origin in disk winds?



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

Low z BQS and α_{OX}

- Low-z soft X-ray weak quasars have large α_{OX}
- BAL Qs: most luminous subset of soft X-ray weak Qs
- Systems with steep slopes (low α_{OX}) are conducive to generating winds (Murray + 1995)

X-ray weakness intrinsic?

CIV NALs take origin in disk winds?

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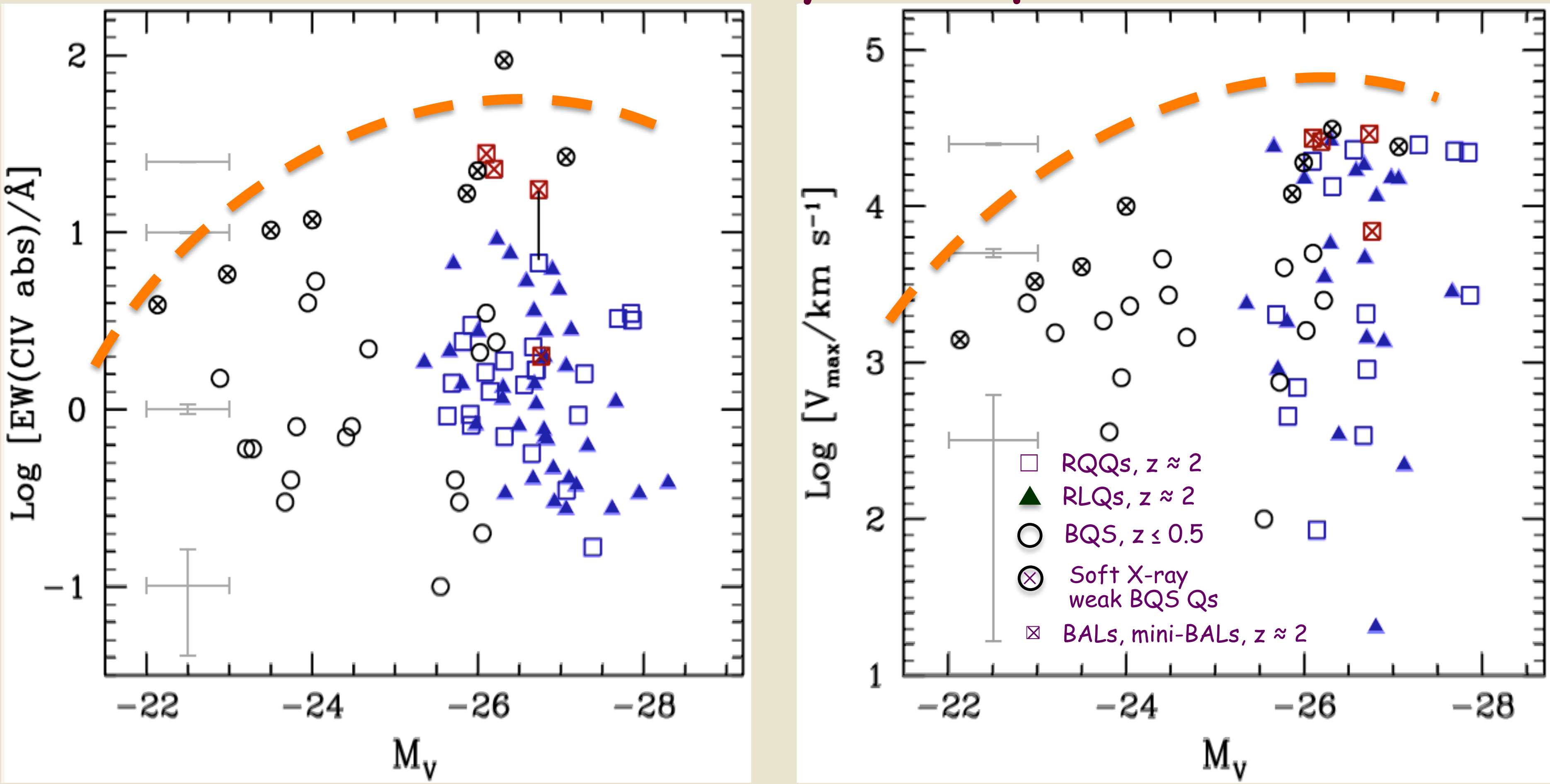
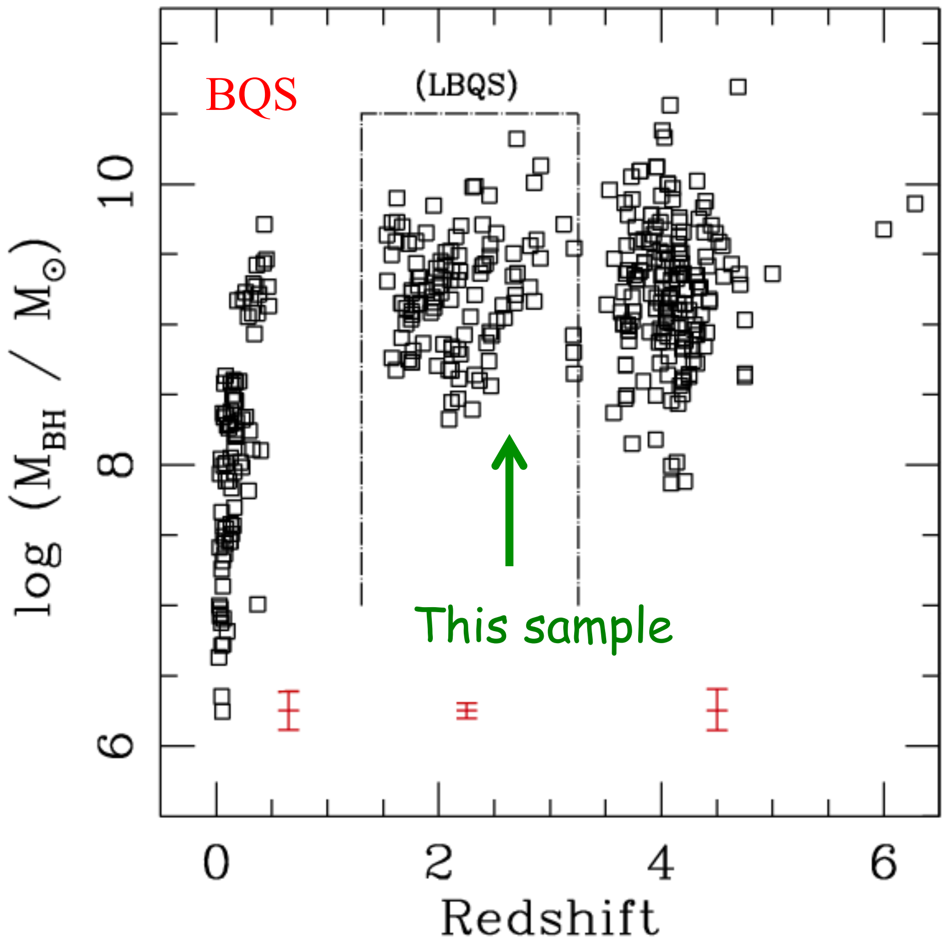
Absorbers in z~2 quasars follow extension of low-z soft-X-ray weak quasars

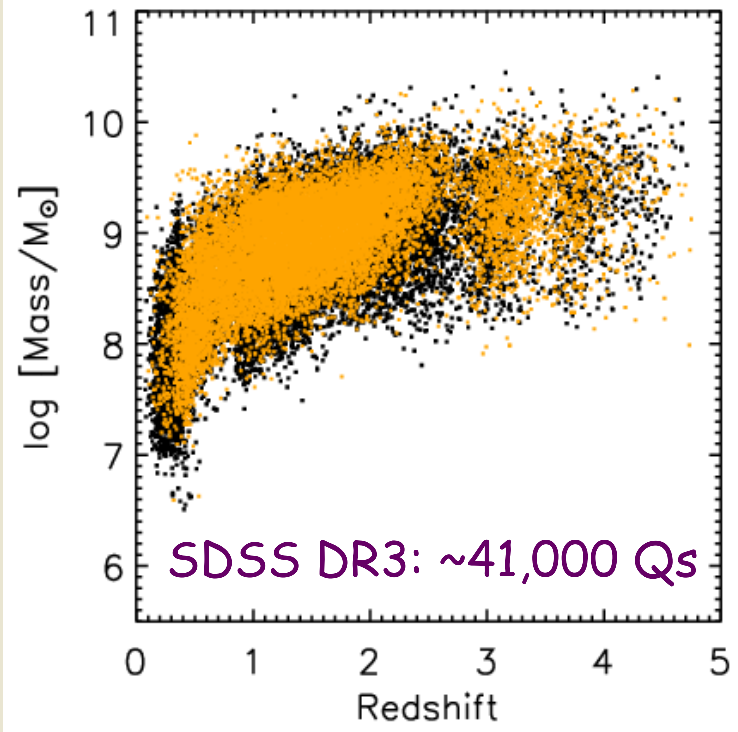


(based on data from Laor & Brandt 2002: o)

Black Hole Mass is representative of distant quasars

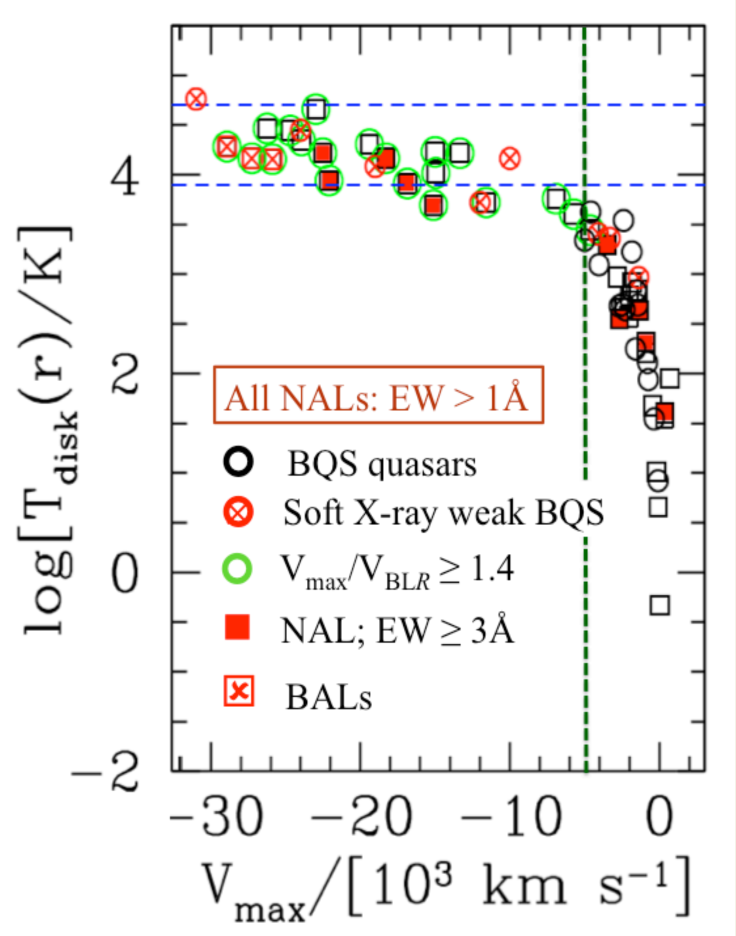


- $M_{BH} \sim FWHM^2(CIV)\ L^{0.5}(1350Å)$
- *Average* $M_{BH} \sim 10^9\ M_{\odot}$



Vestergaard 2004, ApJ 601, 676

Disk launches the wind?



50,000K

8,000K

Finding r_{launch} : $v_{term} \approx few \times v_{escape}$

$$v_{term} \leq\sim 2 \times v_{max} \Rightarrow r_{launch} \sim few \times \frac{GM}{v_{max}^2}$$

Favorable disk launching temperatures: 8,000 K – 50,000 K

(Shlosman+ 1985, Proga + 2000; Proga & Kallman 2004)

□ NALs, EW≥1Å, z ≈ 2

⊠ BALs, mini-BALs, z ≈ 2

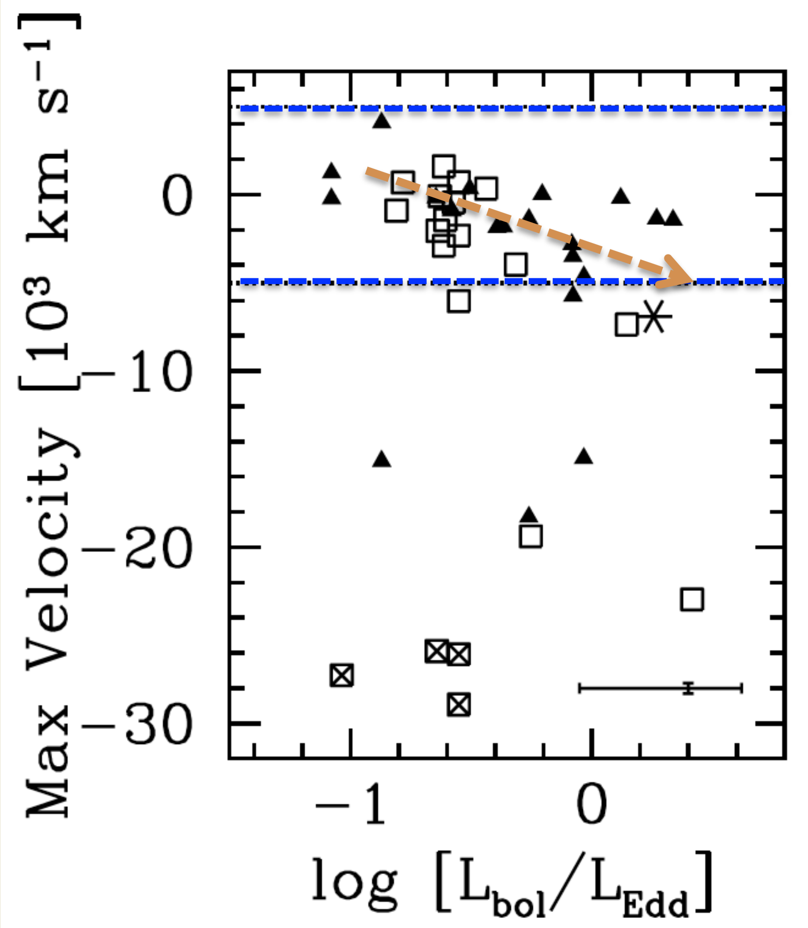
○ BQS, z ≲ 0.5

Low-v NALs:

- ✓ projection effects?
- ✓ failed winds?
- ✓ complex velocity structure?
- ✓ low-T launching radius?
- ✓ Diff force-multiplier?
- ✓ All of above?

$$T_{disk}(r) = 3 \times 10^7 m^{-1/4} \dot{m}^{1/4} r^{-3/4} (1 - r^{-1/2})^{1/4} \text{K}; \quad r = R/9m$$ (SS74)

UV radiation drives wind outward?



L(BOL) = BC L(1350Å)

$$v_{max} \propto \sqrt{\Gamma \frac{L(UV)}{L(Edd)}}$$

Γ = force multiplier (e.g., Laor & Brandt 2002)

⋆ : Mini-BAL in radio-loud quasar

All BALs and NALs in z~2 Qs, including weak NALs

CIV NALs take origin in disk winds?

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Disk launches wind and UV radiation drives it outward?

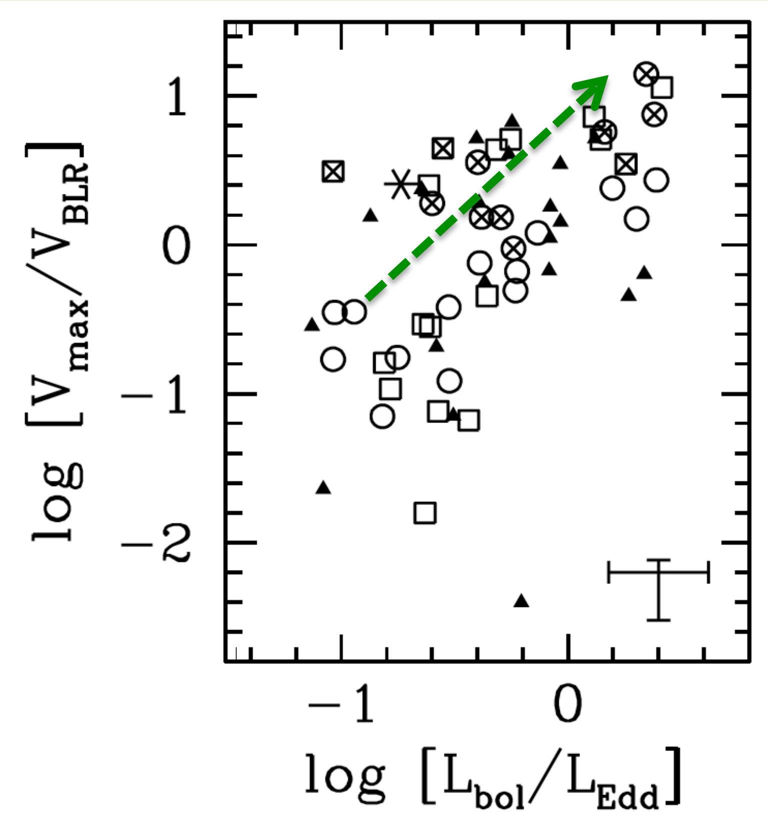
- L_{BOL}/L_{Edd} – V_{max}/V_{BLR} | V_{BLR} : Partial-τ = 0.24, P = 0.0038%
  | M_{BH} : Partial-τ = 0.33, P = 0.0006%

$$\frac{v(term)}{v(kepler)} \approx \frac{v(term)}{v(BLR)} \cong \sqrt{\Gamma \frac{L(UV)}{L(Edd)}}$$

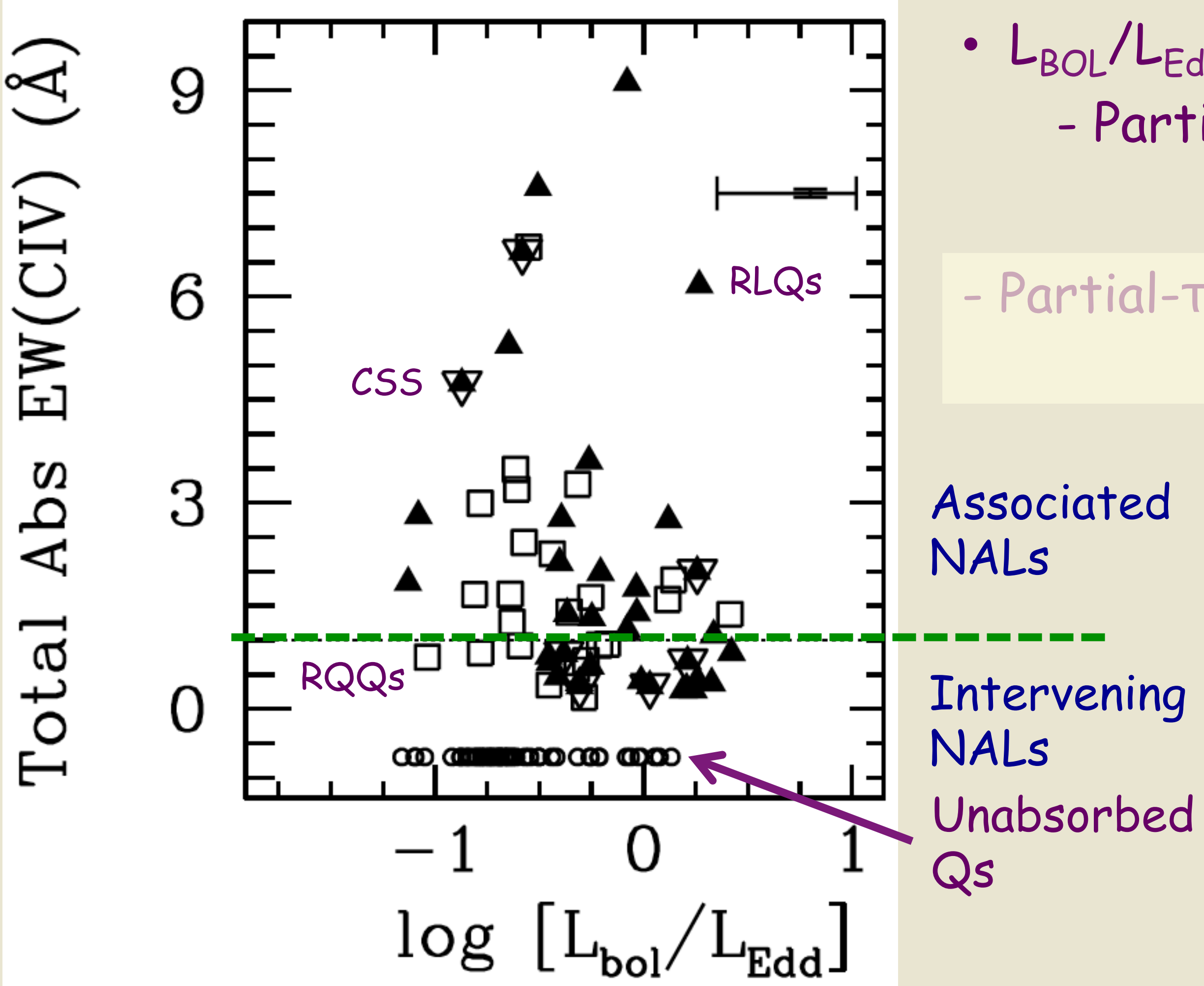
Γ = force multiplier (Laor & Brandt 2002)

BALs and NALs (EW ≥ 1Å):
BQS and z~2 Qs

L(BOL) = BC L(1350Å)



Wind driving and mass loss rate



- L_{BOL}/L_{Edd} – EW| $L_{1550Å}$:
  - Partial-τ = 0.55, P = 0.0035% (EW ≥ 3Å)
  - Partial-τ = -0.38, P = 0.01% (1Å≤ EW ≤ 3Å)

Wind-launching condition:
$L^{eff}_{disk} > L_{edd}$

Mass loss rate to wind:
$\dot{M}_W \sim L_{UV}/ L_{edd}$

(e.g., Castor+ '75, Proga + '00, Proga '02)

L(BOL) = BC L(1350Å)

Summary

Suggestive evidence for radiatively acceleration of BALs and some NALs in z~2 quasars:

- BALs behave like low-z soft X-ray weak quasars wrt V_{max} and EW vs M_V
- Estimated T_{disk} at launching radii promising for disk-wind origin of NALs with V > 5,000 km/s : T_{disk} ~ few $\times 10^4$K
- Low-velocity NALs may be failed winds, have large projections, low T_{disk} launching radii, and/or more complex velocity structures. This simple test cannot discern. (Crenshaw: Gas is farther from disk & BLR?)
- The v(max) of the NALs (and BALs) for a given black hole mass increases with L_{UV}/L_{Edd} as expected for a radiatively accelerated wind.
- The mass loss rate to the wind should correlate with L_{UV}/L_{Edd}. The strongest NALs with EW > 3Å comply.
- More rigorous tests possible? Can we infer parameters of Γ? E(Kin)?
- Given high occurrence rate, NALs may be good probes of feedback/BLR…

Low-v NALs:

- ✓ projection effects?
- ✓ failed winds?
- ✓ complex velocity structure?
- ✓ low-T launching radius?
- ✓ Diff force-multiplier?
- ✓ All of above?