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Testing Disk-Wind Models with Quasar CIV λ1549Å Associated Absorption Lines

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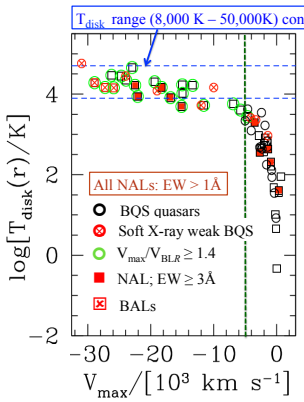
ABSTRACT – Narrow associated CIV λ1549Å absorption lines (NALs) with a rest equivalent width EW ≥ 3Å, detected in $z \approx 2$ quasars (Vestergaard 2003, ApJ 599, 116), (a) exhibit evidence of an origin in radiatively accelerated gas and (b) may be closely related to broad absorption line (BAL) outflows. These NALs and the few BALs detected in this sample of radio-loud and radio-quiet quasars obey key predictions of models of radiatively driven disk-winds in which (1) the local disk luminosity launches the wind, (2) the central UV radiation drives it outwards, and (3) the wind acceleration (i.e., terminal velocity) depends on the strength of the X-ray to UV emission ratio, i.e., α_{OX}. The latter means that radio-loud quasars, which typically have higher X-ray to UV emission ratio than radio-quiet quasars, should not have strong, high-velocity (BAL-like) outflows. The detected absorbers are entirely consistent with this prediction (Figures 3 – 5). In addition, the properties of the BALs follow the trends established by the soft X-ray weak quasars and BAL quasars from the $z \leq 0.5$ Bright Quasar Survey (Laor & Brandt 2002; Figure 5). This shows that the absorbing outflows in these more luminous and more distant quasars are radiatively driven in a manner similar to the low-z quasars. These results are of interest not only to studies of disk wind scenarios and quasar structure, but also to studies of quasar feedback: NALs that originate in powerful outflows are potential probes of quasar feedback on its environment, since NALs are more commonly occurring among quasars than BALs, irrespective of radio properties (Vestergaard 2003).

NALs and BALs: Evidence for Disk Winds launched from the accretion disk and radiatively accelerated



$V_{max}/V_{BLR} \geq 1.4$, as α(force) > 0.6

Figure 1

The NALs with $V_{max} \leq 5000$ km/s (vertical dotted line) are not consistent with a launching radius conducive for creating disk winds.

Are these NALs different or subject to severe projection effects?

A test of the launching force of the absorbing wind is to estimate the disk surface temperature at the wind launching radius, r_i. The temperature follows from the standard α-disk formalism (Shakura & Sunyaev 1973, A&A 24, 337). 'r_i' can be estimated if V_{max} is close to the terminal velocity of the flow, V_{term}. Figure 1 shows that BALs and the high-velocity NALs (v > 5000 km/s) are consistent with being launched at r_i by the disk luminosity; $V_{term} \approx 2 \times V_{max}$ is assumed. This may not be a strong test for NALs with low V_{max} due to potentially strong projection effects.

Disk launches the wind

- □ Radio-quiet quasars, $z \approx 2$
- ▲ Radio-loud quasars, $z \approx 2$
- ▼ Compact steep spectr. source
- ○ BQS quasars, $z \leq 0.5$
- ⊗ Soft X-ray weak BQS QSOs
- ⊠ BALs, mini-BALs, $z \approx 2$

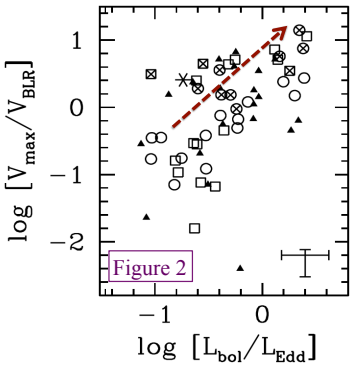
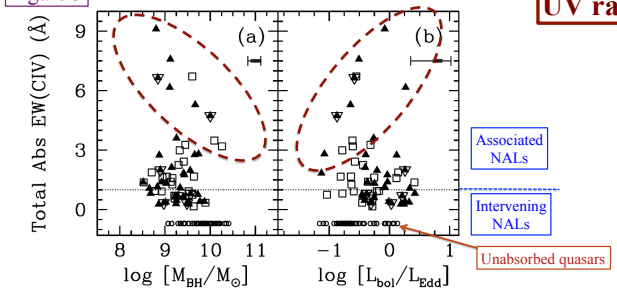


Figure 2: For a disk-wind the ratio of the terminal velocity, $\approx V_{max}$, to the velocity at the launching point in the accretion disk, V_{BLR}, should correlate with L_{BOL}/L_{Edd}. The correlation seen here is highly significant even when accounting for M_{BH} and V_{BLR} (P<0.004%). The soft X-ray weak BQS quasars have some of the highest values of V_{max}/V_{BLR} for a given L_{BOL}/L_{Edd} and display a general increase in V_{max}/V_{BLR} with L_{BOL}/L_{Edd}.

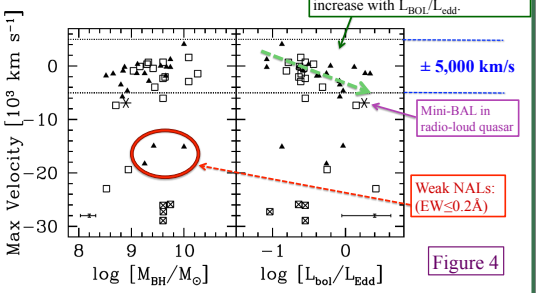
Figure 3



If the absorbing material takes origin in a radiatively accelerated outflowing disk-wind, the mass outflow rate (proportional to EW of NAL) should correlate with Eddington ratio, L_{BOL}/L_{edd} and anti-correlate with black hole mass M_{BH}. Figure 3 confirms that absorbers stronger than 3Å are consistent with an origin in a radiatively driven absorbing outflow.

UV radiation drives wind outward

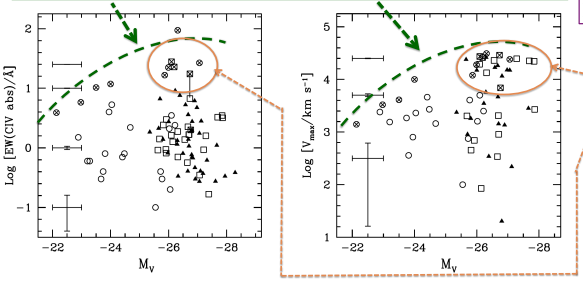
For the 'associated' absorbers (i.e., velocities within 5,000 km/s of systemic) V_{max} appear to increase with L_{BOL}/L_{edd}.



In the Disk-Wind model of Murray et al. (1995, ApJ, 451, 498) the radio-loud quasars are predicted to have no high-velocity winds due to their strong X-ray emission (flat α_{OX}) causing inefficient radiative acceleration. Radio-loud quasars have no BALs but some of the strongest NALs (Figure 3) with typically low velocities ($V_{max} \leq 5000$ km/s; Figure 4). This is consistent with radio-loud quasars having 'failed' high-velocity outflows.

The absorbers in soft X-ray weak quasars define an upper envelope

Figure 5



$z \approx 2$ absorbers fall on high M_V extension of soft X-ray weak BQS quasars ($z \leq 0.5$)

Sanity checks: The BAL gas in $z \approx 2$ quasars is radiatively accelerated similar to $z \leq 0.5$ quasars

Systems with steep α_{OX} are more condusive to generating high-velocity winds (Murray et al. 1995). Laor & Brandt (2002, ApJ, 569, 641) find the soft X-ray weak BQS quasars (i.e., steep α_{OX} ;⊗) to have the strongest UV absorption at a given optical luminosity M_V – defining an upper envelope in EW and V_{max} – and the BALs to be the most luminous subset. The BALs (⊠) detected in the $z \approx 2$ quasars, studied here, fall on the high-M_V end of the trends defined by the BQS quasars (O). Laor & Brandt argue that these trends show that the absorbers in the soft X-ray weak quasars are due to gas being radiatively accelerated. If so, the $z \approx 2$ BALs are also radiatively accelerated.

Black hole masses M_{BH} and bolometric corrections are based on Vestergaard & Peterson (2006, ApJ, 641, 689) and Vestergaard (2004, ApJ, 601, 676)