Broad Absorption Line Quasars
from Radio to NIR band

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How many? ~20%

Broad absorption towards the blue wings of some UV emission lines, shifted up to ~ 0.2 c

- Most probably intrinsic
- Al III, Mg II, Si IV, C IV
- HiBALs, LoBALs, FeLoBALs.
Elvis (2000)

1) Orientation Scenario

2) Evolutionary Scenario: Young or recently refueled quasars
   (Briggs et al. 1984; Lipari and Terlevich 2006)
Sample selection

SDSS QSO catalogue IV + FIRST catalogue

> 30 mJy @ 1.4 GHz
1.7 < z < 4.7

536 RL QSOs

25 RL BAL QSOs (AI>100 in CIV)
34 non-BAL RL QSOs (Comparison)
Observational campaign

- Radio continuum & polarization (Effelsberg, VLA, GMRT)
- Morphology & orientation (EVN, VLBA)
- Dust detection: (IRAM 30-m, APEX)
- Infrared spectroscopy: central BH mass estimation (TNG)
I
Radio continuum & polarization
Observations

Effelsberg 100-m dish
- Polarisation and continuum at 2.6, 4.8, 8.3, 10.4 GHz
- 25 RL BAL QSOs + 34 non-BAL QSOs

Very Large Array
- Observations performed in July 2009
- Polarisation and continuum at 1.4, 4.8, 8.4, 22, 43 GHz
- 25 RL BALs + 34 non-BAL QSOs
1) Morphology

- 8 resolved source with the VLA: 4 BAL + 4 non-BAL QSOs (16% vs 12%)
- Linear sizes from 20 to 400 kpc for both
- Similar morphologies
2) Variability

- Calculation of the flux-density variability (4.8 and 8.4 GHz; Var > 20%; $\sigma_{\text{var}} > 4$)

- 1 BAL vs 3 non-BAL QSOs present variability

- Results confirmed by the variability study of the RBQ sample (20% vs 14%)
  (Salerno et al. 2012, in prep.)

- Polar orientation is not preferred
3) Fit of the spectra

- Both for non-BAL and BAL sample
- Determination of the peak frequency
  - **GPS:** 32% BAL QSOs
  - 23% non-BAL QSOs
- Evidence of low-frequency components in some cases
  - (12% BAL QSOs, 18% comparison QSOs)

Bruni et al. 2012a
Results

4) Spectral characteristics

- Spectral index: steep
  - 68% BAL QSOs
  - 50% non-BAL QSOs
- Wide range of orientations
5) Polarimetry

- Polarisation percentage: \( \sim 1-10\% \) Similar to non-BAL QSOs
- Rotation Measure: \( 800 < |RM| < 3500 \text{ rad/m}^2 \), 1 outlier

\[
RM = 8.1 \times \int (n_e \cdot B_v) dL \text{ [rad \cdot m}^2]\]

Benn et al. (2005) \((-18350 \pm 570 \text{ rad/m}^2\))

Bruni et al. 2012a

![Histogram of RM values]
II
Morphology at high angular resolution
VLBI observations

VLBA
- First 6 brightest sources of the sample
- 4.8 and 8.4 GHz observations

EVN
- Second 5 brightest sources of the sample
- 4.8 GHz observations
Results
- 4 core-jet
- 2 doubles
- 3 symmetric
- 2 unresolved (18%)
- $10 < L_S < 100$ pc

Bruni et al. 2012b
Results

- 82% of sources are resolved at pc-scale
- Different morphologies imply different possible orientations
- Missing flux in some cases, possibly due to extended components.
- Linear sizes up to 200 kpc from previous VLA observations: not all sources are young/compact.
III
Dust detection
Observations

**IRAM 30-m**
- Observations during 2010
- Continuum at 250 GHz
- 11/25 RL BAL QSOs

**APEX**
- Observations performed during 2010,
- scheduled for next fall
- Continuum at 850 GHz
- 6 equatorial sources of the sample (8/25)
- 7% with clear evidence of dust emission (1/14)
- 26% found from Omont et al. (2003) in the dust emission study of QSOs with z~2
- More statistic with new data (APEX)

Bruni et al. 2012b
IV
BH mass estimation
Why are RL BAL QSOs rare?

- BAL QSOs are 4 time less common among QSOs with $R^*>2$ (Stocke et al. 1992)
- FR II BAL QSOs found by Gregg et al. (2006) with strong anticorrelation between Radio-Loudness and BAL strength

Evolutionary track?

BAL QSOs → RL QSOs
Infrared observations

- TNG spectroscopic observations of 21 RL + 23 RQ BAL QSOs optically bright (r<19)
- Low resolution (R~50)
Mass of the BH from FWHM of MgII and H$_\beta$

\[ M_{\text{BH}} [M_\odot] = 10^{6.86} \left( \frac{\text{FWHM(MgII)}}{1000 \text{ km s}^{-1}} \right)^2 \left( \frac{\lambda L_\lambda(3000 \text{ Å})}{10^{44} \text{ erg s}^{-1}} \right)^{0.50} \]

Vestergaard et al. 2006

\[ M_{\text{BH}} [M_\odot] = 10^{6.91} \left( \frac{\text{FWHM(H}\beta)}{1000 \text{ km s}^{-1}} \right)^2 \left( \frac{\lambda L_\lambda(5100 \text{ Å})}{10^{44} \text{ erg s}^{-1}} \right)^{0.50} \]

Vestergaard & Osmer 2009

![Graphs showing distribution of BH masses](image-url)
Eddington ratio and BLR radius

\[ \frac{L_{bol}}{L_{Edd}} \approx 0.13 \left( \frac{\lambda L_\lambda(5100 \, \text{Å})}{10^{44} \, \text{ergs s}^{-1}} \right)^{0.5} \]

Kaspi et al. 2000

\[ R_{BLR} = A \cdot \left[ \frac{\lambda L_\lambda(5100)}{10^{44} \, \text{erg s}^{-1}} \right]^{0.5} \, \text{lt} - \text{days} \]

Kaspi et al. 2000, 2005
Bentz et al. 2006

- Similar values for Eddington ratios:
  1. all super-Eddington (selection effect)
  2. mean values of 2.52 vs 2.80

- Similar values for BLR: 481±142 vs 433±198 light-days
Results from the SDSS DR7 QSO catalogue

- 69 RL vs 3369 RQ BAL QSOs
- 3650 BAL vs 79650 non-BAL QSOs
- means within ±1 sigma for RL vs RQ BAL QSOs
Results from the SDSS DR7 QSO catalogue

Excess of super-Eddington objects among BAL QSOs:

- 13% vs 2% for BALs vs non-BALs
- 26% vs 13% for RL BALs vs RQ BALs

- High accretion rates required to trigger the BAL phenomenon?
- BH mass is not responsible for the rarity of RL BAL QSOs
Conclusions

- No particular orientation, only steep-spectrum majority
- Both GPS and low frequency peaked, old components in some cases
- Some resolved, different morphologies, sizes from $\sim 10$ pc to $\sim 200$ kpc
- No more dust-abundant than the QSO population (not so young)
- No higher BH masses than normal QSOs
- Tentative evidences of an excess of super-Eddington objects
The BALs are most probably produced by outflows, but:

① with different possible orientations (recollimated outflows?)

② Present in different evolutionary stages of the QSO

③ Probably as an intermittent phenomenon
BROAD ABSORPTION LINE DISAPPEARANCE ON MULTI-YEAR TIMESCALES IN A LARGE QUASAR SAMPLE

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\textbf{ABSTRACT}

We present 21 examples of $\text{C}\,\text{IV}$ Broad Absorption Line (BAL) trough disappearance in 19 quasars selected from systematic multi-epoch observations of 582 bright BAL quasars ($1.9 < z < 4.5$) by the Sloan Digital Sky Survey-I/II (SDSS-I/II) and SDSS-III. The observations span 1.1–3.9 yr rest-frame timescales, longer than have been sampled in many previous BAL variability studies. On these timescales, $\approx 2.3\%$ of $\text{C}\,\text{IV}$ BAL troughs disappear and $\approx 3.3\%$ of BAL quasars show a disappearing trough. These observed frequencies suggest that many $\text{C}\,\text{IV}$ BAL absorbers spend on average at most a century along our line of sight to their quasar. Ten of the 19 BAL quasars showing $\text{C}\,\text{IV}$ BAL disappearance have apparently transformed from BAL to non-BAL quasars; these are the first reported examples of such transformations. The BAL troughs that disappear tend to be those with small-to-moderate equivalent widths, relatively shallow depths, and high outflow velocities. Other non-disappearing $\text{C}\,\text{IV}$ BALs in those nine objects having multiple troughs tend to weaken when one of them disappears, indicating a connection between the disappearing and non-disappearing troughs, even for velocity separations as large as 10000–15000 km s$^{-1}$. We discuss possible origins of this connection including disk-wind rotation and changes in shielding gas.

\textit{Subject headings:} galaxies: quasars: absorption lines
Thank you!