Multi-Year BAL Variability: Current Results and SDSS-III Prospects

Density Maps from BAL Quasar Wind Simulation

Launching radius is typically taken to be $\sim 10^{16-17}$ cm.

Significant dynamical evolution expected on multi-year timescales.

Characteristic timescale for disk rotation ($>10\%$) and for BAL material crossing.
Main Collaborators

Rob Gibson
Sarah Gallagher
Paul Hewett
Don Schneider

Nurten Filiz Ak

Pat Hall
SDSS-III BAL Quasars Group
(e.g., Anderson, Gibson, Hewett, Petitjean, Ross, Schneider)
Current Results
Will give a few highlights from these papers; many more findings and important technical details in these papers.
Long Rest-Frame Timescales

Timescales of Some BAL Variability Samples

Compared 1980’s LBQS/Palomar vs. 2000’s SDSS/HET for two samples (23 quasars total).
BAL Variability Commonly Seen

C IV Var. Examples

Variability seen in 70-90% of 23 objects.

LBQS 1986-1988

Palomar 1988-1989

HET 2008-2009

Gibson et al. (2010)
Multi-year variations occur over broad range of velocities; 6000-24000 km s\(^{-1}\).
Effects of Rest-Frame Timescale

C IV BAL EW Changes vs. Rest-Frame Timescale

BALs vary more strongly on long timescales.
No Preferential Strengthening / Weakening

Histogram of C IV BAL EW Changes Over 3-7 Rest-Frame Years

BALs strengthen vs. weaken comparably often (13/23 strengthen in full sample).

Asymmetry could occur, e.g., with fast formation then slow decay.

Gibson et al. (2010)
Multi-Month vs. Multi-Year EW Variations

LBQS-Palomar-SDSS-HET Variations of C IV EW

LBQS + Palomar + SDSS + HET gives 3-4 epochs spanning months-years.

In general, BALs do not strengthen or weaken monotonically.

Multi-month variations do not predict multi-year variations.
Discrete Velocity Regions of Variation

Number of Varying C IV Absorption Regions vs. Velocity Width

On multi-year timescales, BALs often vary in discrete regions of width ~ 1000-3000 km s\(^{-1}\) (not monolithically). “Quantization” of BALs?

Gibson et al. (2008)
Long-timescale constraints powerful since velocity shifts accumulate over time.

BAL acceleration is rare - only a few examples known. Three candidates from our work needing further multi-year monitoring.

Consistent with gas being in “standing pattern” outflow (azimuthally symmetric).
SDSS-III
Prospects
How to Do Better?

Many possible approaches to doing better:

• Larger sample sizes
• More epochs and timescales
• Higher spectral resolution
• Higher signal-to-noise
• Better spectral calibration

But too expensive to have it all (in one experiment).

Will talk about one approach mainly focused on giving much larger sample sizes.

See other talks and posters for other approaches.
Main BOSS Goals and Targets

5-year program (2009-2014)
Covering 10,000 deg$^2$ with spectroscopic observations
1.5 million lum. red galaxies
150,000 quasars at $z > 2.2$

Spectra from 3600-9800 Ang with resolution ~ 2000 and good calibration.
1000 objects observed simultaneously in 7 deg$^2$ field-of-view.
Also ancillary projects of smaller scale – including BAL variability.
Main Goal - Ancillary Project

Move from small-sample and single-object studies of multi-year BAL variability to rigorous, large-sample constraints.

(Also with better spectral calibration and somewhat higher spectral resolution)
Re-Targeting BAL Quasars from SDSS-I/II

Main Source of Targets: SDSS-I/II
BAL Quasars Observed from 2000-2008

Focused on Optically Bright Targets for Good Spectra

Targeting 2005 representative BAL quasars that are *bright* and have good BAL coverage.

Probe rest-frame timescales of up to \( \sim 5.2 \) yr for high-ionization BAL quasars and \( \sim 9.3 \) yr for low-ionization BAL quasars.

Sample is \( \sim 100 \) times larger than current samples probing multi-year timescales.

0.1% of BOSS fibers utilized.

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A Catalog of Broad Absorption Line Quasars in Sloan Digital Sky Survey Data Release 5

Robert R. Gibson\(^1\), Linhua Jiang\(^2\), W. N. Brandt\(^1\), Patrick B. Hall\(^3\), Yue Shen\(^1\), Jianfeng Wu\(^2\), Scott F. Anderson\(^3\), Donald P. Schneider\(^1\), Daniel Vanden Berk\(^2\), S. C. Gallagher\(^3\), Xiaohui Fan\(^2\), and Donald G. York\(^4\)

rgibson@astro.psu.edu

ABSTRACT

We present a catalog of 5039 broad absorption line (BAL) quasars (QSOs) in the Sloan Digital Sky Survey (SDSS) Data Release 5 (DR5) QSO catalog that have absorption troughs covering a continuous velocity range \( \gtrsim 2000 \) km s\(^{-1}\). We have fit ultraviolet (UV) continua and line emission in each case, enabling us to report common diagnosties of BAL strengths and velocities in the range \(-25,000\) to \(0 \) km s\(^{-1}\) for Si IV \(\lambda 1400\), C IV \(\lambda 1549\), Al III \(\lambda 1857\), and Mg II \(\lambda 2799\). We calculate these diagnostics using the spectrum listed in the DR5 QSO catalog, and also for spectra from additional SDSS observing epochs when available. In cases where BAL QSOs have been observed with *Chandra* or *XMM-Newton*, we report the X-ray monochromatic luminosities of these sources.

We confirm and extend previous findings that BAL QSOs are more strongly reddened in the rest-frame UV than non-BAL QSOs and that BAL QSOs are...
Basic Properties of Main-Sample Targets

Luminosity vs. Redshift for Main-Sample Targets

- Low-ionization BAL Quasars (13%)
- High-ionization BAL Quasars (87%)
Supplementary targets include 56 unusual BAL quasars, 25 LBQS and FBQS BAL quasars, and 23 BAL quasars with multiple SDSS observations.
Observational Progress to Date

Number of Observations vs. Time

1292 Gibson et al. objects observed
710 main-sample observations

1.1 main-sample targets coming in per night.
Now 35% done with experiment.
Timescales Being Sampled

Presently sampling 1.5-4 year timescales with very good source statistics.
Some General Findings on BAL Disappearance

20 examples of BAL disappearance detected among 686 BAL quasars.

Including some BAL quasar to non-BAL quasar events.

On 1-4 yr rest-frame timescales, 3% of BAL quasars show at least one disappearing trough, and 1.2% of troughs disappear.

Details in Filiz Ak et al., in preparation
Absorption-strength variability as a function of timescale for different transitions.

BAL strengthening vs. weakening – asymmetry?

Systematic large-sample constraints on BAL acceleration.

BAL lifetime constraints.

BAL vs. emission-line and reddening variability.

Effects of luminosity, SMBH mass, $L / L_{\text{Edd}}$, radio properties.

BAL emergence in non-BAL quasars.

Mini-BAL and NAL variability.
Future Plans and Hopes
Additional Coverage

Hobby-Eberly Telescope and Other Facilities

After SDSS-III: TDSS Could Give Another Epoch for Full BAL Sample

Also multiwavelength follow-up; e.g., X-rays.
Better Variability Simulations

Density Maps from BAL Quasar Wind Simulation

Corresponding improvements in BAL variability simulations needed to utilize the flood of new data most effectively.

Especially simulations making observationally testable predictions, so can use the time dimension to constrain quasar winds.
The End