On AGN outflows based on their associate absorber systems

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in Coloboration with

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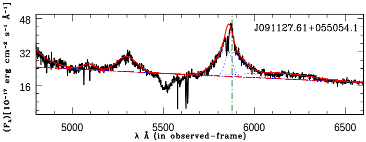
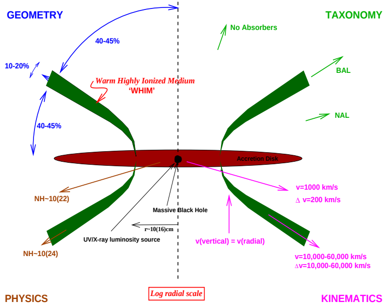
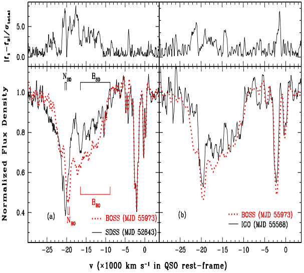
Outline of the Talk...

1. Introduction: Associated absorbers
   - Associated absorbers as Outflows
   - Associated absorption verses intervening absorption
2. Are associated absorbers density background source dependent
   - Along QSOs verses GRBs verses Blazar
3. CDQ Jets and outflow as associated absorbers
   - Large SDSS CDQs sample
   - Evidence of excess associated absorbes in CDQs as ouflows
4. Discusion and Summary
   - In context of Unification scheme

Example of C IV outflow in BALQSOs: Joshi, & Chand et al. 2014



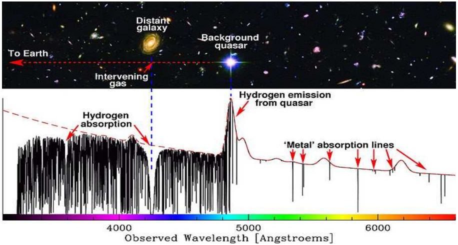




Conventionally outflow with

$v_{offset} < 5000$km/s considered as

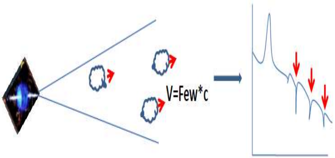
Associated line in QSOs specra outflows



$$\beta \equiv \frac{v}{c} = \frac{(1+z_{\rm em})^2 - (1+z_{\rm abs})^2}{(1+z_{\rm em})^2 + (1+z_{\rm abs})^2},$$

$$\frac{dN}{dz} = \frac{N_{obs}}{\Delta z}$$

Compare $\frac{dN}{dz}$ along QSOs verses GRBs verses Blazar



Some recent results:

Source Type	Excess factor of dN/dz over QSO	sample size used	Redshift range (median z-path)	Spectral resolution	References
GRB	$\sim$4	14	$0.366 < z_{\rm abs} < 2.27$ (1.1)	High and intermediate	Prochter et al. (2006)
GRB	$\sim$3	8(5 common with Prochter et al. 2006)	$0.4 < z_{\rm abs} < 2.4$ (1.11)	4000 (High)	Tejos et al. (2009)
GRB	2.1 $\pm$0.6	10+16(literature)	$0.366 < z_{\rm abs} < 2.27$ (1.11)	High and intermediate	Vergani et al. (2009)
Blazar	2.2 $\pm$0.7	45	$0.8 < z_{\rm abs} < 1.90$ (0.82)	$\sim$1000	Bergeron et al. (2011)
GRB	$\sim$ 1.5	95	$0.4 < z_{\rm abs} < 2.2$	High	Cuccihiara et al. (2012)
CDQs (FSRQs)	$\sim$1	115	$0.24 < z_{\rm abs} < 1.97$ (1.09)	$\sim$1000	Chand & Gopal-Krishna (2012)
CDQs & LDQs	Associated Only	3975 CDQs 1583 LDQs	$0.39 < z_{\rm abs} < 2.30$ (0.90)	$\sim$2000	Joshi et al. (2013)

Does Incidence of absorber depend on the backgroud source ?

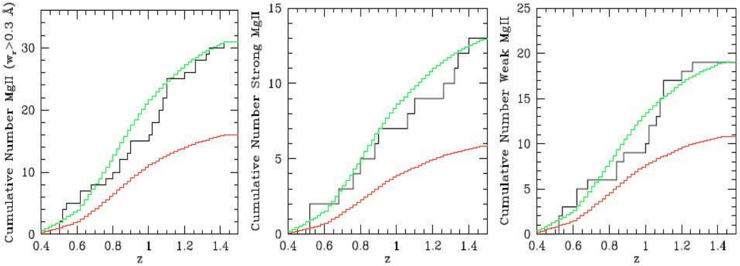
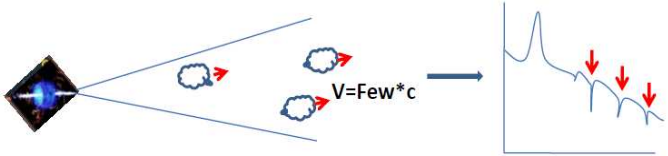


Fig. 2. *Left*: cumulative number of $w_r(2796) > 0.3$ Å intervening Mg II systems towards blazars, excluding the systems with $\Delta v < 5000$ km s^{-1} (thick, black curve). The curve of intermediate thickness (red) shows the cumulative number of such Mg II systems towards QSOs, adopting the incidence of these systems given by Nestor (see text), and the thinner (green) one is obtained by normalizing the latter to the total number of Mg II systems towards blazars. *Center*: incidence of strong ($w_r(2796) > 1.0$ Å) Mg II systems adopting the incidence of these systems given by Prochter et al. (2006a). *Right*: incidence of weak ($0.3 < w_r(2796) < 1.0$ Å) Mg II systems.

Bergeron et al. (2011), using **45 blazar** observed with FORS/VLT, at resolution of $R \sim 1000 - 1500$, at SNR 100.

What about origin of the Excess?

Intrinsic Origin: for excess towards blazar



- **Appealing scenario**, specially in case of **blazars**, if **material is** present(either in interstellar medium or in halo) and **swept up by the jet to high velocities**.
- Bergeron et. al 2011 proposed that for reasonable jet power can swept-up **column density as large as** 10^{20},can attain an **expulsion velocity as large as 0.1c.**, e.g

$$N_e(cm^{-2}) \simeq 2 \times 10^{19} \left(\frac{P}{10^{45}\, ergs^{-1}}\right)^{0.5} \left(\frac{n_e}{0.1 cm^{-3}}\right)^{0.5} \left(\frac{V}{0.1c}\right)^{-1.5}$$

Our motivation: using FSRQs, high resolution spectra

- Core-dominated radio quasars (CDQs) which are also called flat-spectrum radio quasars (FSRQs), also possess jets similar to blazars.
- So, do they also show enhanced dN/dz for MgII absorbers, compare to QSOs?

Table: Finally we selected 115 non-blazar type FSRQs.

Selection Criteria	Source remain
Total number of radio quasar	301
Selecting only flat spectrum	
i.e CDQ $\alpha > -0.5$ F(4.8Ghz)$> 65mJy$	
After excluding HP and uncertain type	163
After possible archival search VLT/Keck	
(SNR > 20 R$\sim$ 40000)	115CDQs (final sample)

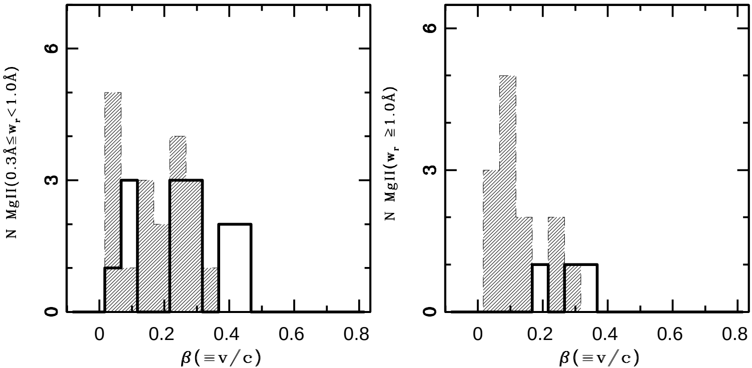
Our result: Does dN/dz for CDQs differ from Blazars / QSOs?

Table: Finally using 115 non-blazar type FSRQs.

$w_r(2796)$-range	$\langle z\rangle$	$\frac{dN}{dz}$	$\left(\frac{dN/dz}{(dN/dz)_{qso}}\right)$	$\eta(\langle z\rangle)$	$\left(\frac{\eta(\langle z\rangle)(dN/dz)}{(dN/dz)_{Blz}}\right)$
0.3 Å$\leq w_r(2796) < 1.0$	1.12 ± 0.42	$0.66^{0.10}_{0.09}$	$1.40^{0.22}_{0.19}$	0.91	$0.79^{0.27}_{0.19}$
1.0 Å$\leq w_r(2796)$	1.09 ± 0.42	$0.21^{0.05}_{0.04}$	$0.85^{0.22}_{0.18}$	0.81	$0.39^{0.19}_{0.12}$

- dN/dz (for strong MgII systems) for CDQs is ~ 0.5 compared to blazars.
- Which means it is very similar to that seen towards normal QSOs.
- The excess absorbers seen towards blazars could be clouds ejected by their jets which are known to point along the line-of-sight (unlike CDQ jets).
- What about, distribution of offset velocities of absorbers: Blazars v/s CDQs

Velocity offset comparison: Chand, & Gopal-Krishna et al. 2012



$$\beta \equiv \frac{v}{\mathrm{c}} = \frac{(1+z_{\mathrm{em}})^2 - (1+z_{\mathrm{abs}})^2}{(1+z_{\mathrm{em}})^2 + (1+z_{\mathrm{abs}})^2},$$

Only 15 out of 115 FSRQ was in matching blazar redshift range.

Testing the results with large sample derived from SDSS DR-7 (Shen et al. (2011) catalog)

SELECTION CRITERIA	CDQs (remained)	LDQs (remained)
(1) Total number of radio loud quasar with $f(5GHz)/f(2500\AA) > 10$	6152	2105
(2) After excluding the quasar with $z_{qso} < 0.389$ **having Mg II out of SDSS spectral coverage**	5824	2014
(3) After excluding BAL QSOs	5447	1971
(4) After excluding High-Polarization quasars (HP) and BL Lac and Seyfert (Veron et al. 2010)	5333(final sample)	1925(final sample)

❶ ANALYSIS: Continuum Fitting

- An **automated routine** is **developed** in interactive data language **(IDL)** to get the Mg II absorber.

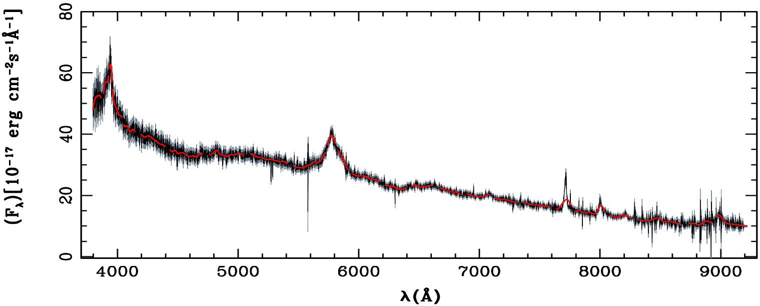


Figure: SDSS quasar spectra of J002745.23−094603.3(black), corresponding 1σ error bar range (gray) and continuum fit (red).

❶ Line Identification

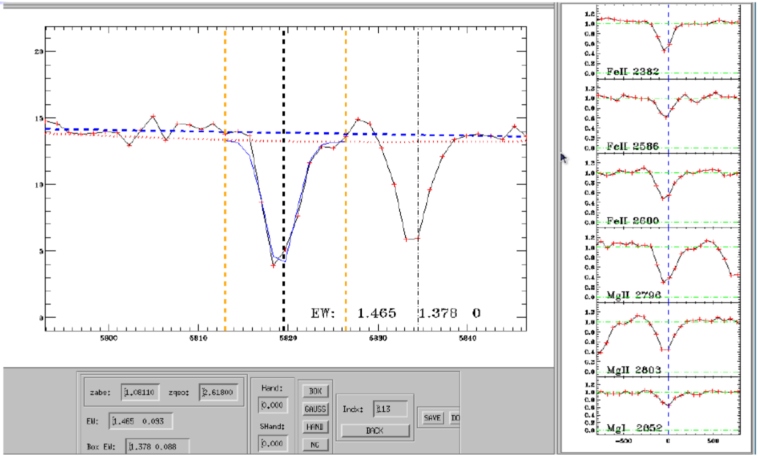


Figure: Mg II doublet identification through automated search.

❶ Analysis: **Visual Inspection**

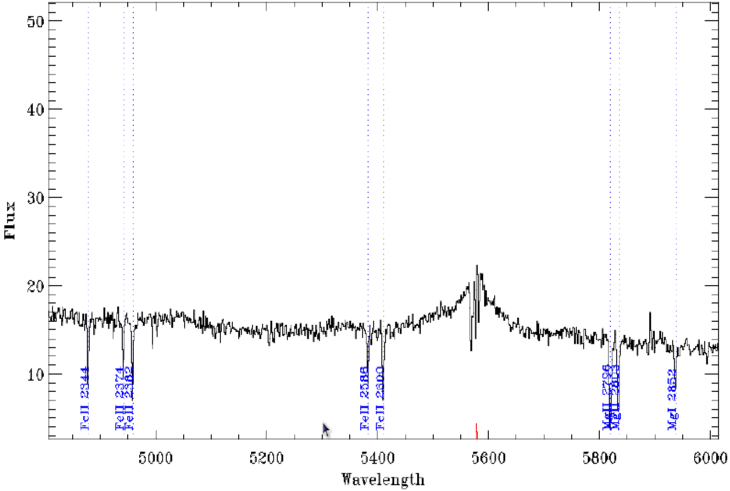


Figure: visual identification/confirmation Mg II doublet

❶ dN/dz of Mg II towards CDQs and LDQs versus normal QSOs

1. along the **3975 core dominated quasars as:**

$$\frac{dN}{dz}(w_{\rm r}(2796) > 1.0\ \AA) = \frac{N_{obs}}{\Delta z} = \frac{640.00}{2333.01} = \mathbf{0.27^{+0.01}_{-0.01}} \tag{1}$$

at $\langle z \rangle \simeq 1.01$.

2. For **1583 Lobe dominated quasars(LDQs)** sightline as:

$$\frac{dN}{dz}(w_{\rm r}(2796) > 1.0\ \AA) = \frac{N_{obs}}{\Delta z} = \frac{224.00}{922.11} = \mathbf{0.24^{+0.02}_{-0.02}} \tag{2}$$

at $\langle z \rangle \simeq 0.93$.

- **CDQs vs QSO Excess:**

$$Ex = \left(\frac{dN}{dz}\right)_{\rm CDQs} / \left(\frac{dN}{dz}\right)_{\rm QSO} = \mathbf{1.09 \pm^{0.06}_{0.06}}, \tag{3}$$

at around $\sim 1.5\sigma$.

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1. COSMOLOGICAL EVOLUTION OF dN/dz TOWARDS CDQS/LDQS VS QSOS

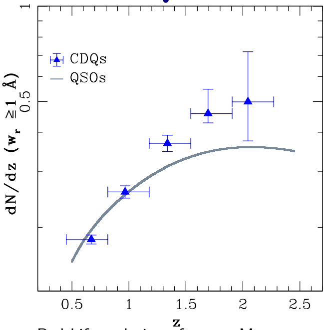


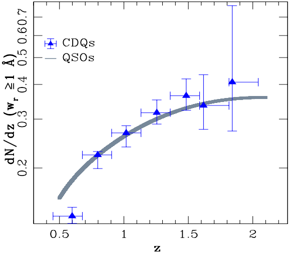
Figure: Redshift evolution of strong Mg II systems along CDQ versus normal quasar sightline, (here quasar evolution in taken from Zhu & Menard (2012))

- **CDQs vs QSO Excess: using ∼4000 CDQs**

$$Ex = \left(\frac{dN}{dz}\right)_{\rm CDQs} / \left(\frac{dN}{dz}\right)_{\rm QSO} = \mathbf{1.09}\pm^{\mathbf{0.06}}_{\mathbf{0.06}}, \quad (4)$$

The χ^2 -test shows distinguish-ability at 1.6 σ.

1 z−evolution for $v/c > 0.2$ Mg II strong absorbers: CDQs versus QSOs



$$\beta \equiv \frac{v}{c} = \frac{(1+z_{em})^2 - (1+z_{abs})^2}{(1+z_{em})^2 + (1+z_{abs})^2}, \qquad (5)$$

Only using spectra with $v/c > 0.2$

(i.e unambiguously intervening systems)

- χ^2 -test shows that dN/dz evolution for CDQs versus QSOs is distinguishable only at 1.03σ (i.e., insignificant, as indeed expected for truly intervening absorbers). Earlier the two distribution computed for full range of v/c were found to differ at 2.3σ.

  For these redefined and z-matched samples of CDQs and QSOs:

$$Ex = \left(\frac{dN}{dz}\right)_{\rm CDQs} / \left(\frac{dN}{dz}\right)_{\rm QSO} = 1.06\pm^{0.07}_{0.07}, \qquad (6)$$

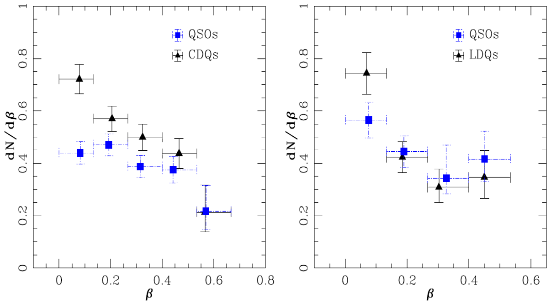
  i.e., the same z - evolution for CDQs and QSOs (for $v/c > 0.1$), as indeed expected for bona-fide intervening absorbers.

  The relative velocity distribution of absorbers?

- This again supports that associated Mg II systems may well occur at velocity offsets that are an order of magnitude higher than the commonly adopted limit of 5000km s^{-1}.

❶ Distribution of Offset velocity (v/c) for 'intervening+associated' strong MgII absorbers

Joshi et al. 2013 arXiv:1307.3904v1



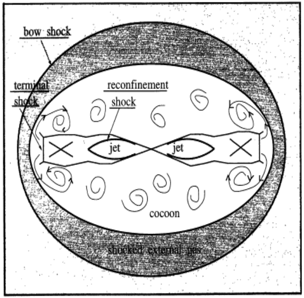
$$\beta \equiv \frac{v}{c} = \frac{(1+z_{\rm em})^2 - (1+z_{\rm abs})^2}{(1+z_{\rm em})^2 + (1+z_{\rm abs})^2}$$

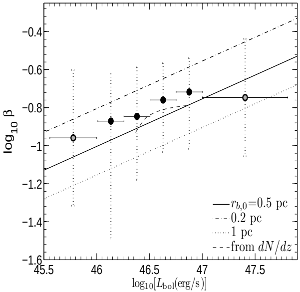
For CDQs an excess is seen at 3.75σ level

For unbiased comparison:

- To avoid bias due to fixed wavelength coverage, we limited our CDQ and QSO samples to the z-range $0.62 < z_{\rm em} < 2.2$, so that Mg II lines could be searched for offset velocities of up to 40000 km s^{-1} for each source.
- For each CDQ, a QSO was selected from SDSS DR-7, matching within a redshift tolerance of 0.003; and also for Luminosity; resulting in 2919 CDQs having 473 strong Mg II absorbers.

❶ Sweep aside the diffuse component & then accelaration by radiation





High power jets can simply sweep aside the diffuse component of the interstellar gas (Komissarov et al 1998)

Radion driven: $\beta_{med} \propto L^{1/4}$, in mixed AGN sample (Sharma,Nath, Chand et al 2013)

Discussion and Summary cnt..

Are associated absorber tracer of outflows in **FSRQs/CDQs:**

- May be as implied by 3.5σ excess in$v_{offset} < 0.1c$, with fractional excess of 0.30+/-0.08 relative to normal QSOs.
- Considering only 5% sightline actually contribute among all, implies that actual outflow was from 1.5% sighline.
- Assuming unification, 1.5% translate to $\sim 25^{\circ}$ outflow cone, and as axes of CDQ/FSRQ w.r.t. line of sight of is not random but about $\sim 30^{\circ}$, implies the opening angle $\sim 7^{\circ}$.
- Wish list: Detail modeling of such cool gas outflows).

What about in **Bl-lac:**

- Existing dN/dz w.r.t QSO excess still factor 2. BUT sample size too small (just 45). Large sample size analysis in progress (Mishra, S et al. in prep..)

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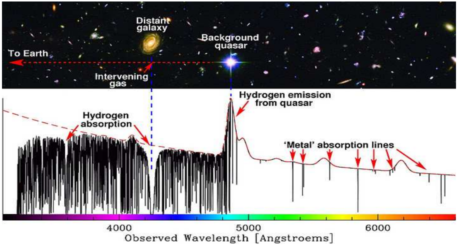
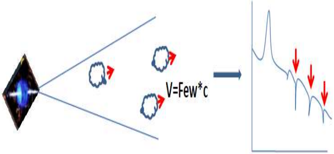
Thanks for your Attention



Bl-lac/FSRQ jet
may give rise to
outflow upto $\sim$ 0.1c!



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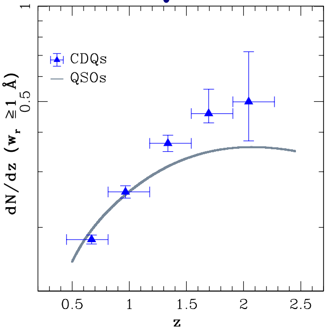

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The χ^2 -test shows distinguish-ability at 1.6 σ.