MHD Accretion-Disk Winds as the Unifying AGN Structure

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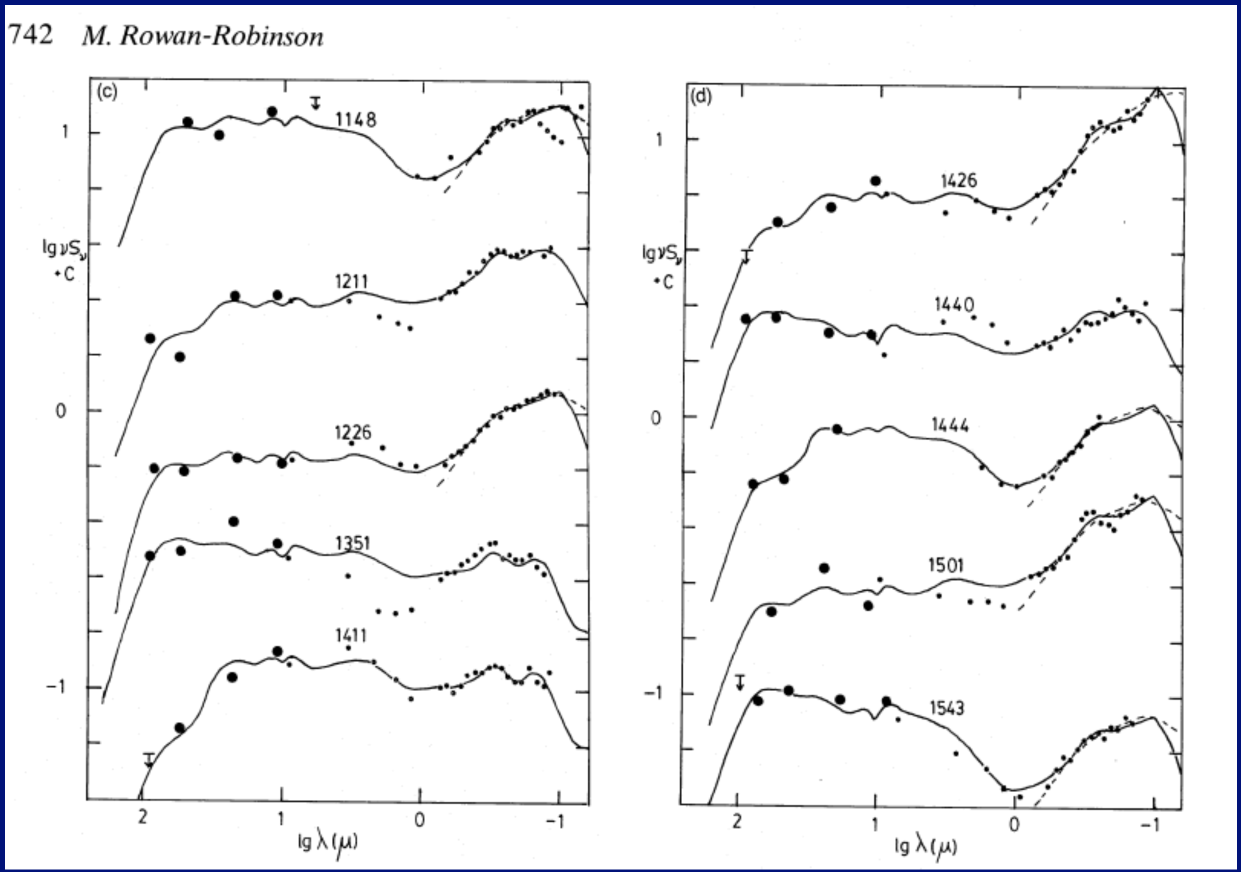
- ApJ (2010), 715, 636
- ApJ (2010), 723, L228

Credit: NASA/CXC

Dust reprocessing, n(r) ~ 1/r (Rowan-Robinson 1995)



The Scientific Method

It is a capital mistake to theorize before one has the data. Insensibly, one begins to twist facts to suit theories, instead of theories to suit facts.

Sir Arthur Conan Doyle

It is also a good rule not to put too much confidence in experimental results, until they have been confirmed by theory.

Sir Arthur Eddington

First you get your facts; then you can distort them at your leisure.

Mark Twain

Some Facts

- AGN are multiscale, multifrequency objects. Need to understand their structure over large number of decades in ***r***

- Use Unification arguments to obtain their structure from objects at high inclination angle (IR – Torii).

- Structure along LOS can be probed efficiently by X-ray spectroscopy! X-ray absorption features are ubiquitous in the spectra of AGN, GBHC (*50% of all AGN exhibit UV and X-ray absorption*). ***They span a factor of ~10^5 in ionization parameter*** indicating the presence of ions ranging from highly ionized (H-He - like Fe) to neutral, ***all in 1.5 decades in X-ray energy!***

- These "live" in very different regions of ionization parameter space and likely in different regions of real space.

- Use X-ray spectroscopy to probe the molecular torii and the intervening region.

- Molecular torii are impossible objects: They have H/R ~1 implying random velocities comparable to their Keplerian ones (300 – 500 km/s).

- However, with temperatures T ~10-100 K, V_{th} <~ 1 km/s!!

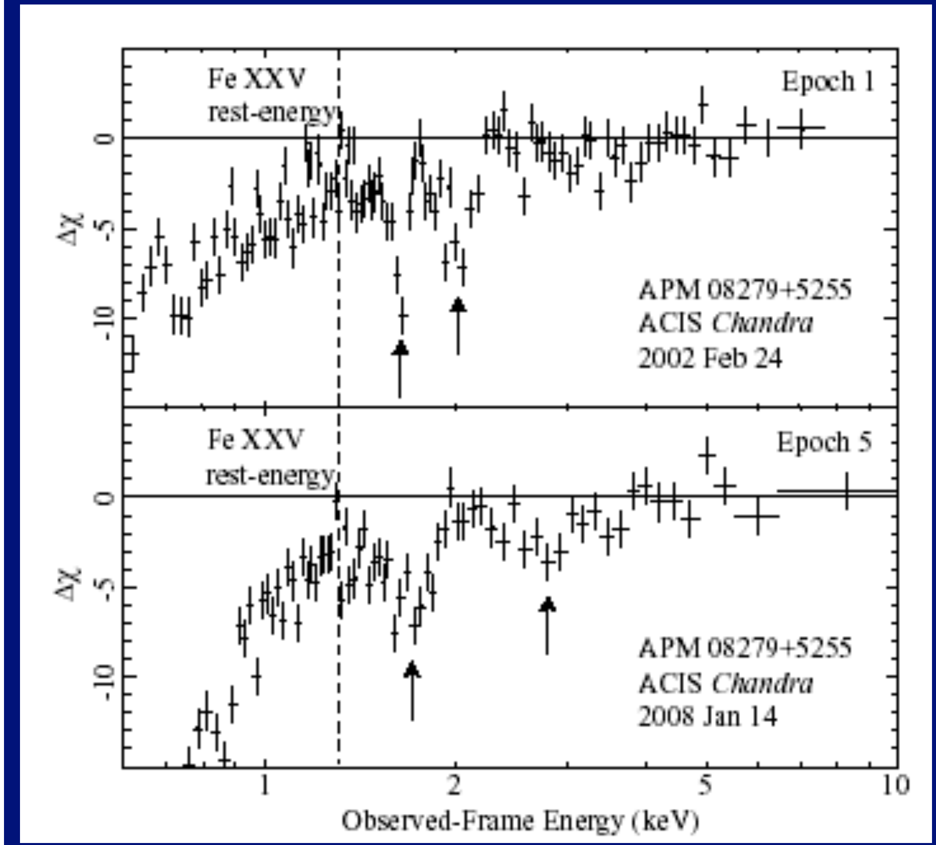
- They cannot be static objects → Winds.
- At their distances (~ pc) the radiation field has very little momentum; Therefore

- Magnetically-Driven Accretion-Disk Winds! (Konigl-Kartje 1994).

BAL QSO: X-ray Absorptions

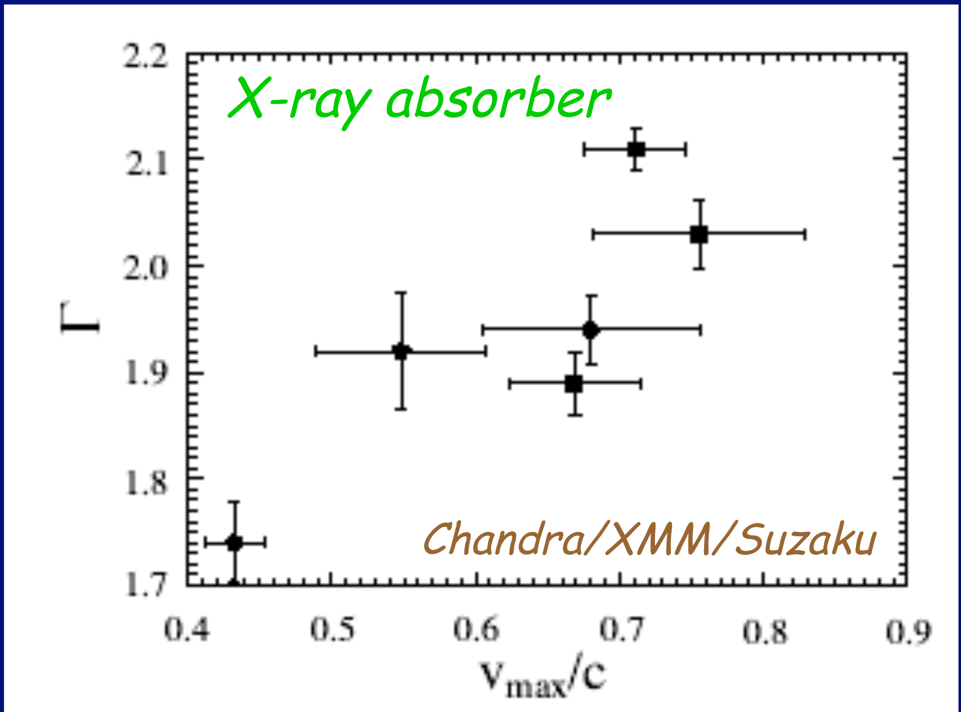
- High-velocity outflows: v/c~**0.1-0.7 in Fe XXV/XXVI**

X-ray Absorption line (Fe XXV)



Fe resonance transitions

Spectral index vs. wind velocity



Effect of ionizing spectrum(!?)

Brandt+(09); Chartas+(09)

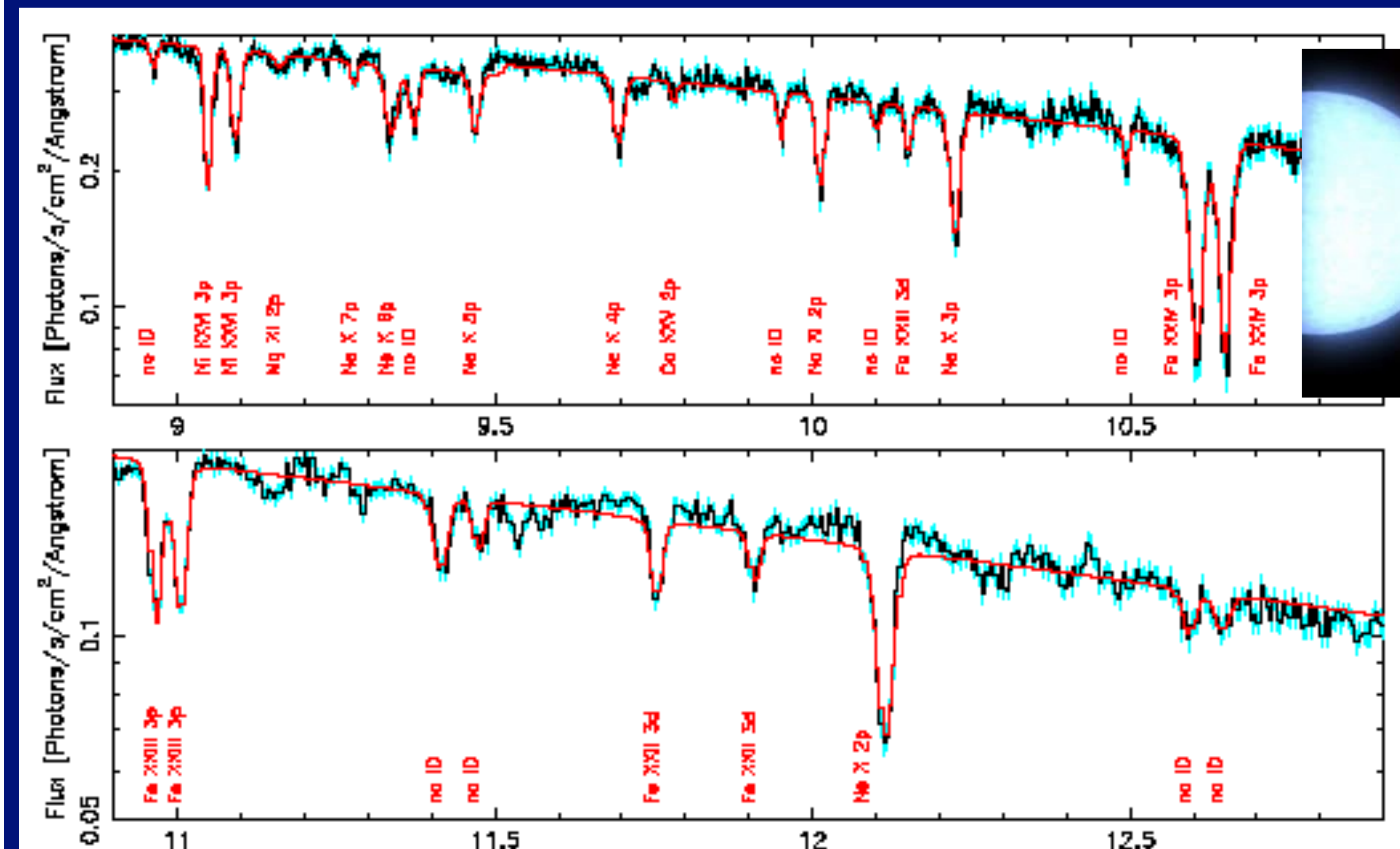
Galactic Black Hole (GBH) Binaries

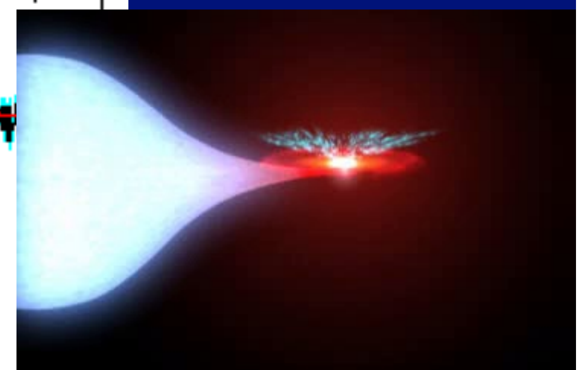
GRO J1655-40:

- M(BH)~7Msun
- M(2nd)~2.3Msun

- High ionization: log(ξ[erg cm s^{-1}]) ~ 4.5 - 5.4
- Small radii: log (r[cm]) ~ 9.0 - 9.4
- High density: log(n[cm^{-3}]) ~ 14

Miller+(06)





NASA/CXC/A.Hobart

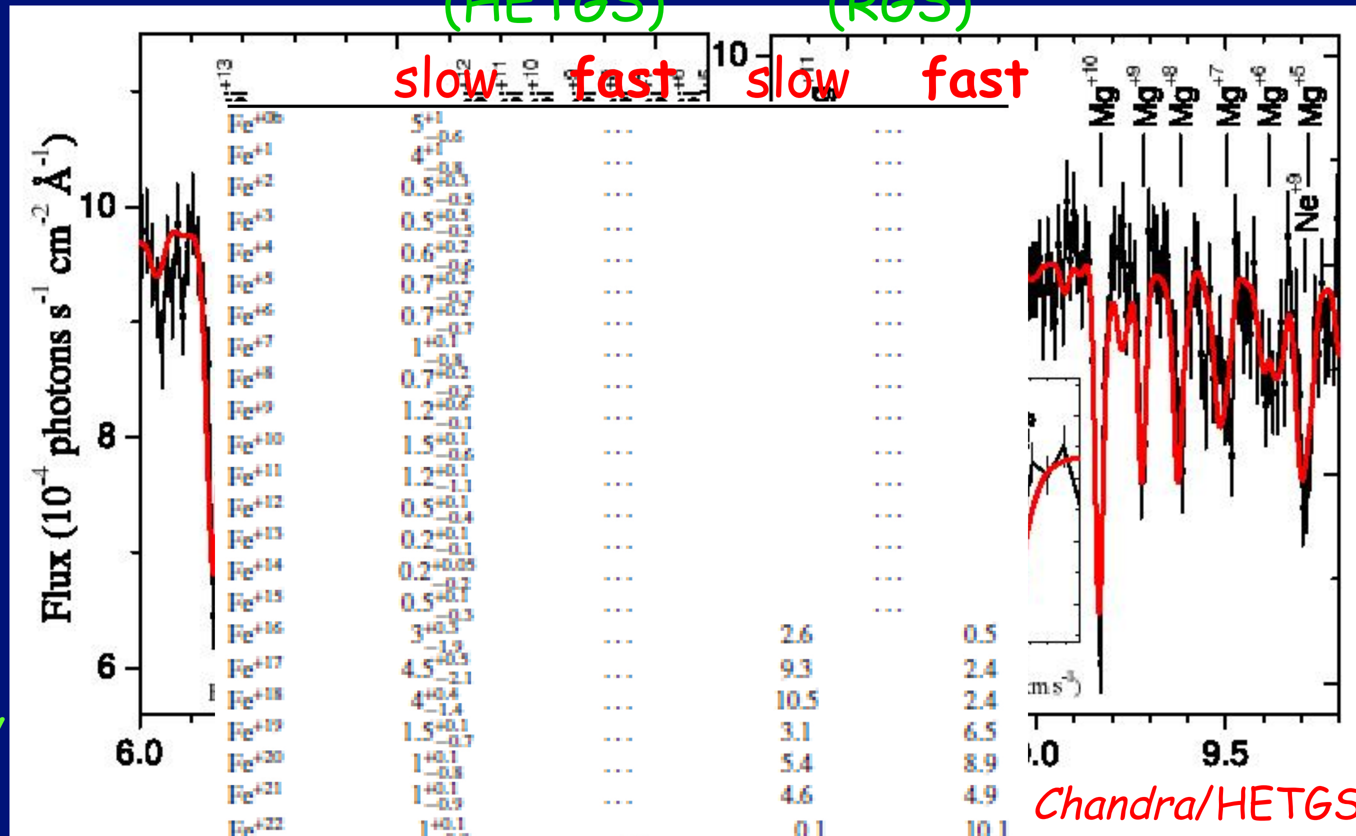
Chandra Data
Miller+(08)

Seyfert and Radio Galaxies

MCG-6-30-15:
(z = 0.007749)

Photoelectric Absorption:
- *Lines*
- *Edges*

"Warm Absorber"



	(HETGS) slow	(HETGS) fast	(RGS) slow	(RGS) fast
Fe^{+0b}	$5^{+1}_{-0.6}$	…	…	
Fe^{+1}	$4^{+1}_{-0.8}$	…	…	
Fe^{+2}	$0.5^{+0.3}_{-0.5}$	…	…	
Fe^{+3}	$0.5^{+0.5}_{-0.5}$	…	…	
Fe^{+4}	$0.6^{+0.2}_{-0.6}$	…	…	
Fe^{+5}	$0.7^{+0.2}_{-0.7}$	…	…	
Fe^{+6}	$0.7^{+0.2}_{-0.7}$	…	…	
Fe^{+7}	$1^{+0.1}_{-0.8}$	…	…	
Fe^{+8}	$0.7^{+0.2}_{-0.2}$	…	…	
Fe^{+9}	$1.2^{+0.6}_{-0.1}$	…	…	
Fe^{+10}	$1.5^{+0.1}_{-0.6}$	…	…	
Fe^{+11}	$1.2^{+0.1}_{-1.1}$	…	…	
Fe^{+12}	$0.5^{+0.1}_{-0.4}$	…	…	
Fe^{+13}	$0.2^{+0.1}_{-0.1}$	…	…	
Fe^{+14}	$0.2^{+0.05}_{-0.2}$	…	…	
Fe^{+15}	$0.5^{+0.1}_{-0.3}$	…	…	
Fe^{+16}	$3^{+0.5}_{-1.9}$	…	2.6	0.5
Fe^{+17}	$4.5^{+0.5}_{-2.1}$	…	9.3	2.4
Fe^{+18}	$4^{+0.4}_{-1.4}$	…	10.5	2.4
Fe^{+19}	$1.5^{+0.1}_{-0.7}$	…	3.1	6.5
Fe^{+20}	$1^{+0.1}_{-0.8}$	…	5.4	8.9
Fe^{+21}	$1^{+0.1}_{-0.9}$	…	4.6	4.9
Fe^{+22}	$1^{+0.1}_{-0.9}$	…	0.1	10.1
Fe^{+23}	$0.5^{+0.4}_{-0.4}$	$3^{+0.5}_{-3}$	2.6	$\leqslant 4.1^{a}$
Fe^{+24r}	…	60^{+13}_{-36}	…	
Fe^{+25r}	…	120^{+32}_{-28}	…	

Chandra/HETGS

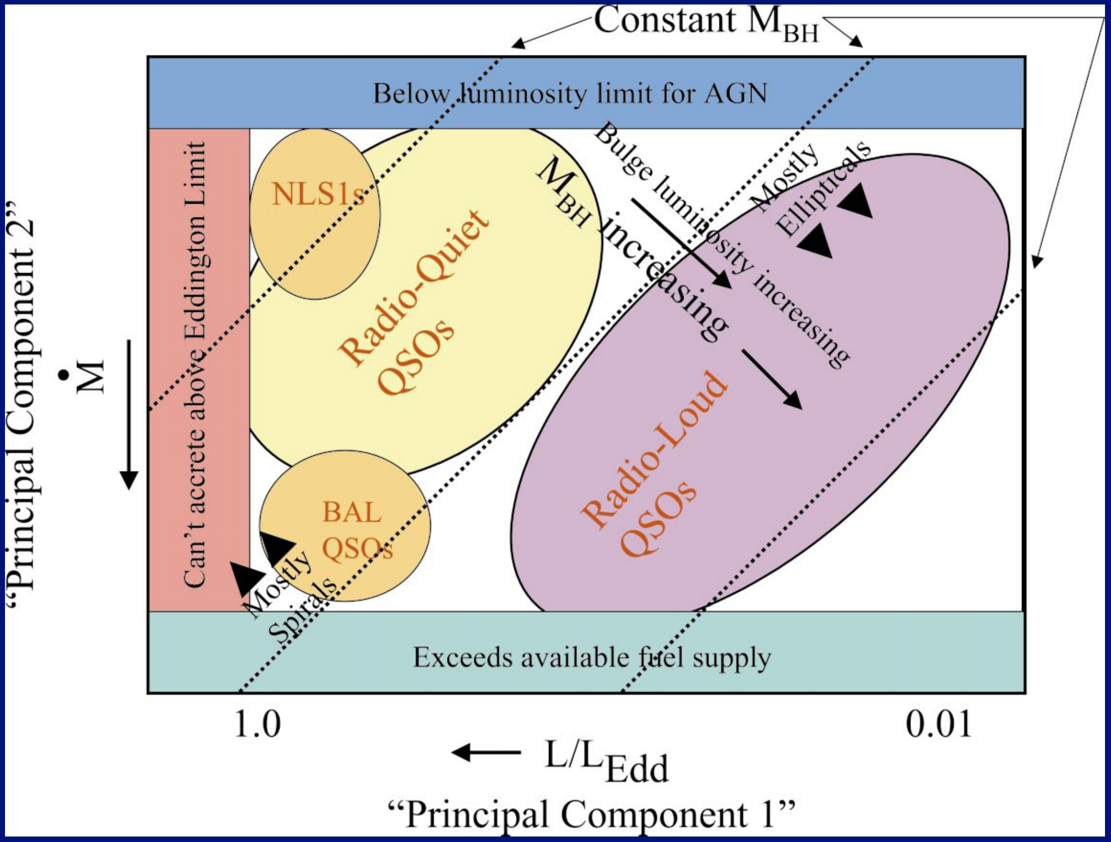
Holczer+(10)

- Slow ~ 100 km/sec @ low-ξ
- High ~ 1,900 km/sec @ high-ξ
- Integrated N_H ~ 5.3 x 10^{21} cm^{-2}

(see also Otani+96, Reynolds+97, Sako+03, Miller+08)

Our thesis (and hope) is that these diverse data (including those of galactic X-ray sources) can be systematized to include the blazar phenomenology with a small number of parameters (2)

Boroson 2002



Flows (accretion or winds) and their ionization structure are invariant (independent of the mass of gravitating object;ADAF) if:

1. Mass flux is expressed in terms of Eddington mass flux

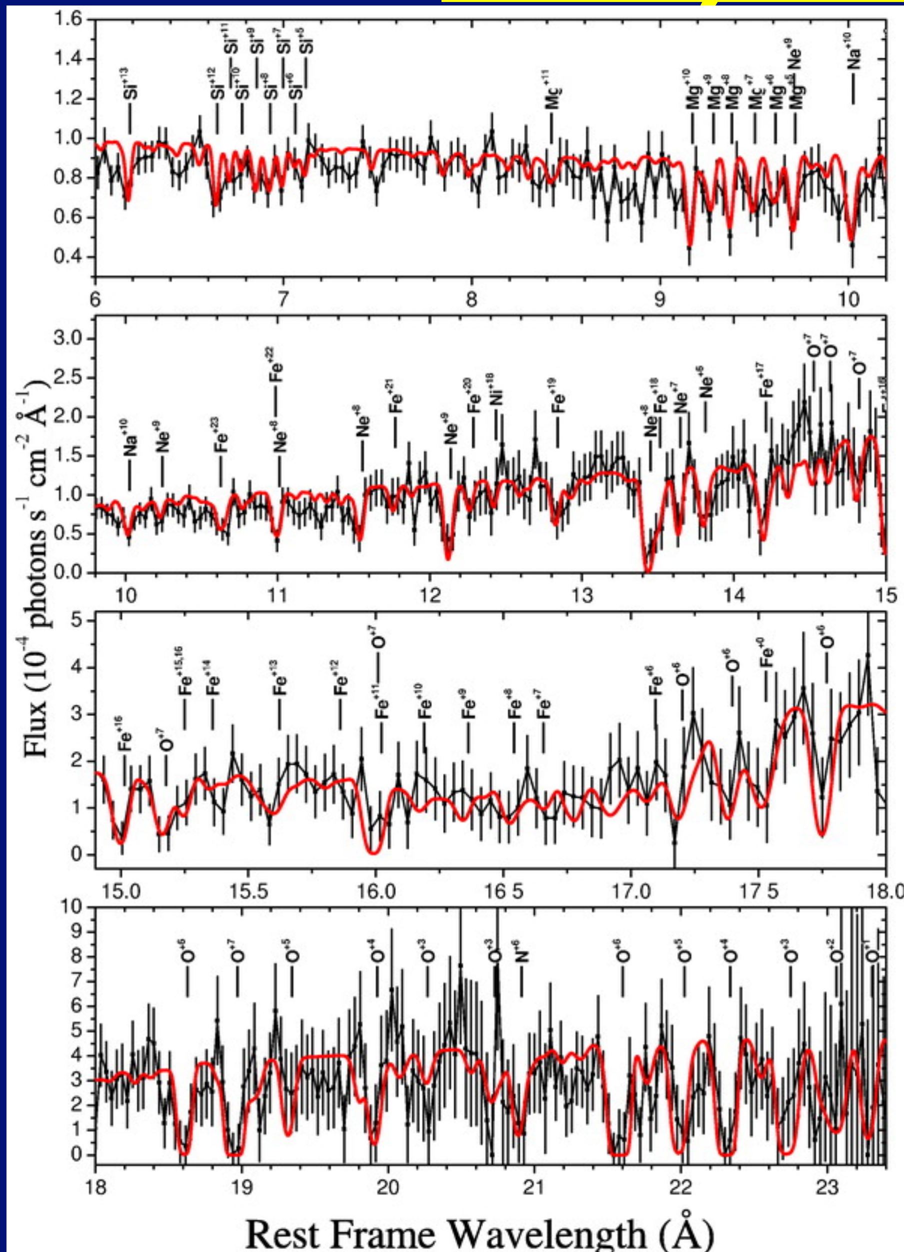
$$\dot{m} = \frac{\dot{M}}{\dot{M}_E}, \quad \dot{M}_E = \frac{L_E}{c^2}, \quad L_E \propto \frac{M}{\sigma_T/\sigma} \simeq 1.3 \times 10^{38} \left(\frac{\mathrm{M}}{\mathrm{M}_\odot}\right) \mathrm{erg/sec}$$

2. The radius in terms of the Schwarzschild radius

$$x = \frac{r}{R_S}, \quad R_S = \frac{2G\mathrm{M}}{c^2} \simeq 3 \times 10^5 M, \quad M = \left(\frac{\mathrm{M}}{\mathrm{M}_\odot}\right)$$

3. The velocities are Keplerian $v^2 \propto \frac{1}{x}$

X-ray-Bright AGNs



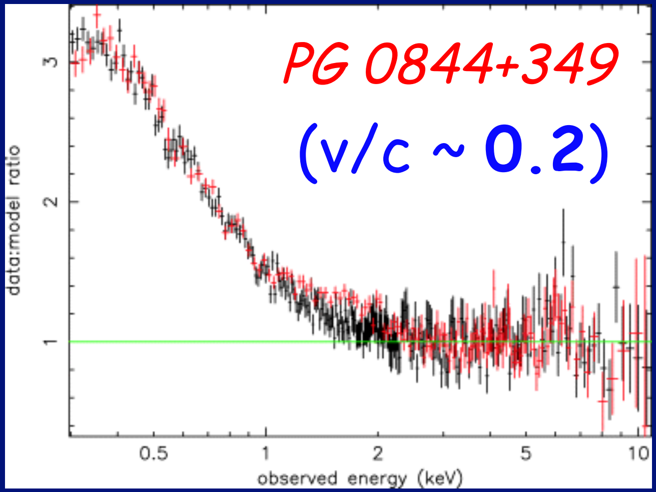
QSO: **IRAS 13349+2438:**
(z = 0.10764)

- X-ray bright, IR-loud/radio-quiet QSO
- X-ray obs. with *ROSAT*, *ASCA*, *Chandra*, *XMM-Newton*

- Ions with various charge state
- Fe XVII ~ 300 km/sec
- Potential velocity scatter
- Integrated N_H ~ 1.2×10^{22} cm^{-2}

Chandra data
Holczer+(07)

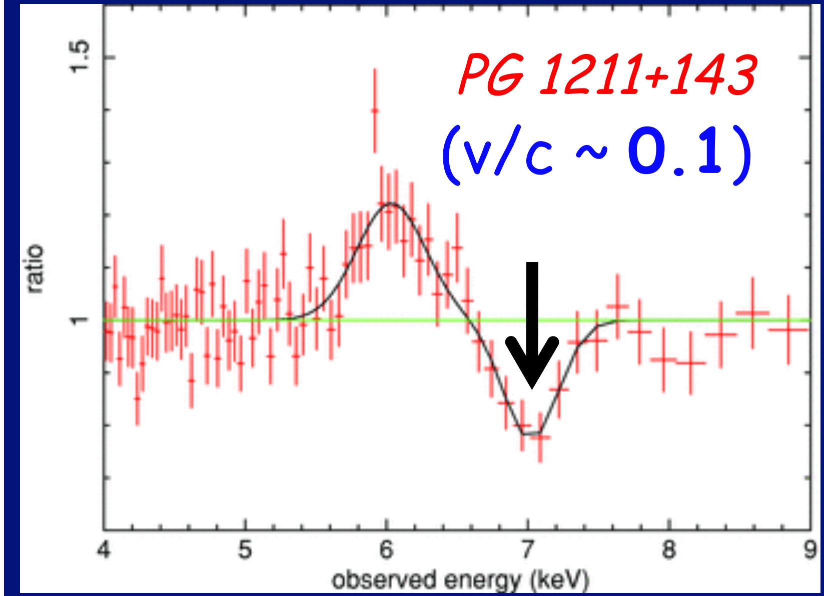
Narrow-Line Seyferts (PG QSOs)

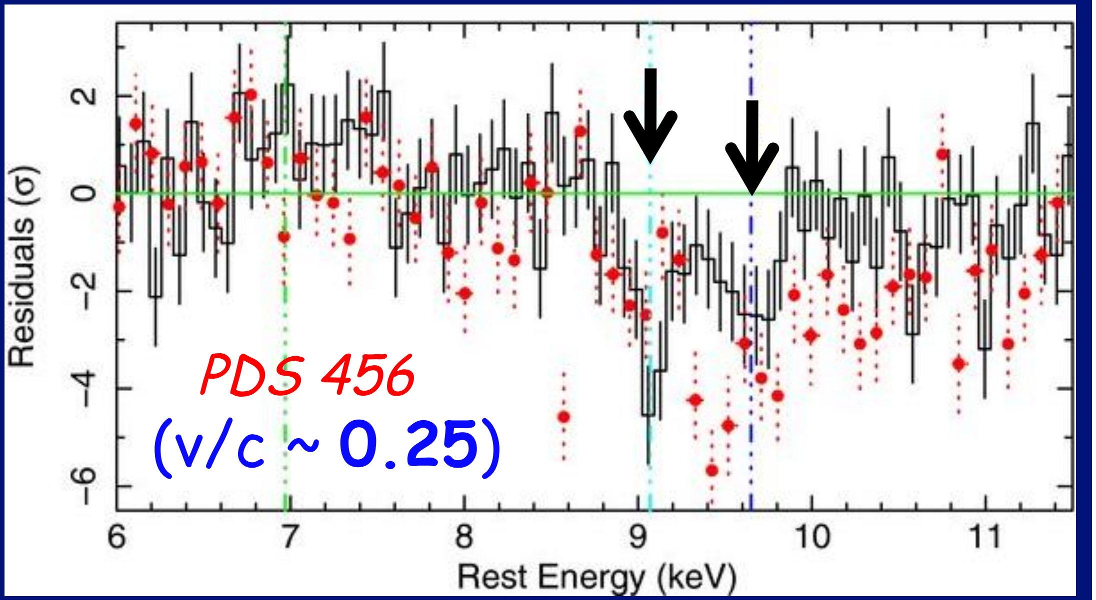


- "Narrow" Hβ line < 2,000 km/sec
- Weak O III/Hβ ratio
- Strong "Soft X-ray Excess"
- Highly-blueshifted absorption lines

Pounds+(03)

Chandra/XMM-Newton data





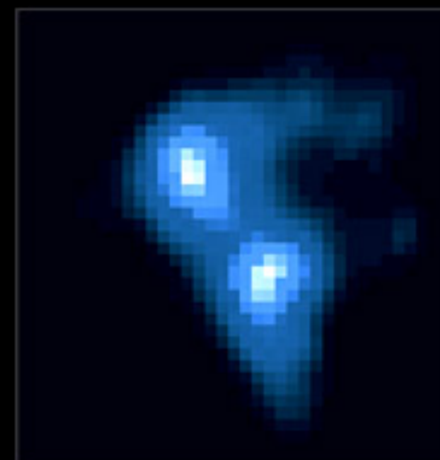
Pounds+Reeves(09)

Reeves+(09)

Broad Absorption Line (BAL) QSOs: APM 08279+5255

- ~10% of optically-selected QSOs
- Faint X-ray relative to O/(F)UV continua
- Broad C IV line ~ 2,000-30,000 km/sec
- Highly-blueshifted ~ 10,000-30,000 km/sec

ILLUSTRATION: WIND FROM ACCRETION DISK AROUND A BLACK HOLE



CHANDRA IMAGE OF APM 08279+5255

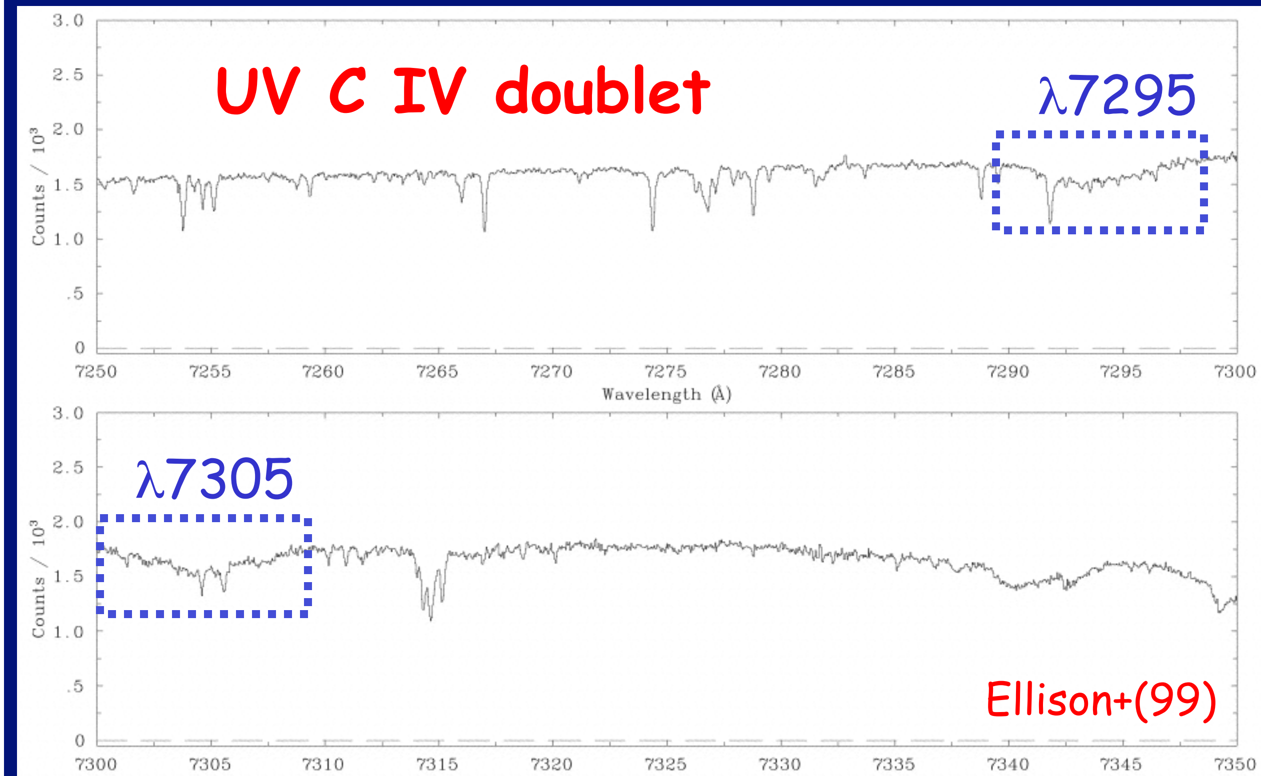
HST image of the quasar at the heart of the primeval galaxy. Two images are seen because the quasar is gravitationally lensed.

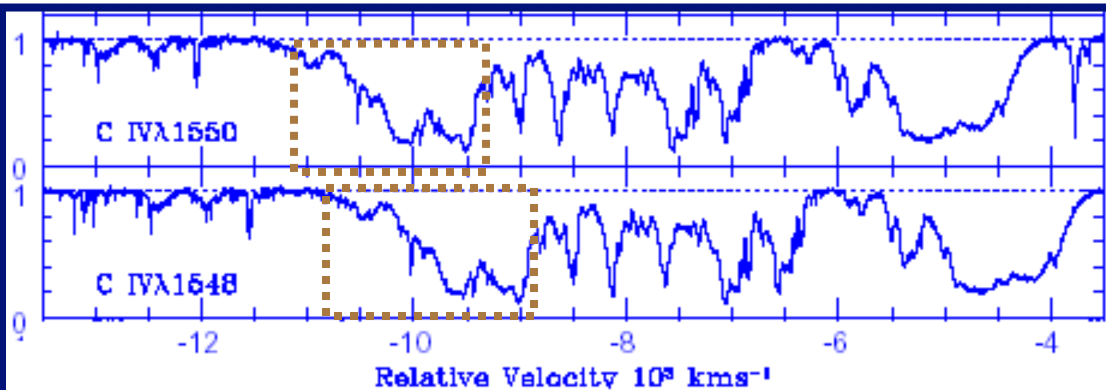
Credit: NASA/CXC/PSU/M.Weiss/G.Chartas

$z = 3.91$

NRAO/AUI/NSF,STScI

BAL QSO: UV Apsorptions





Srianand+Petitjean(00)

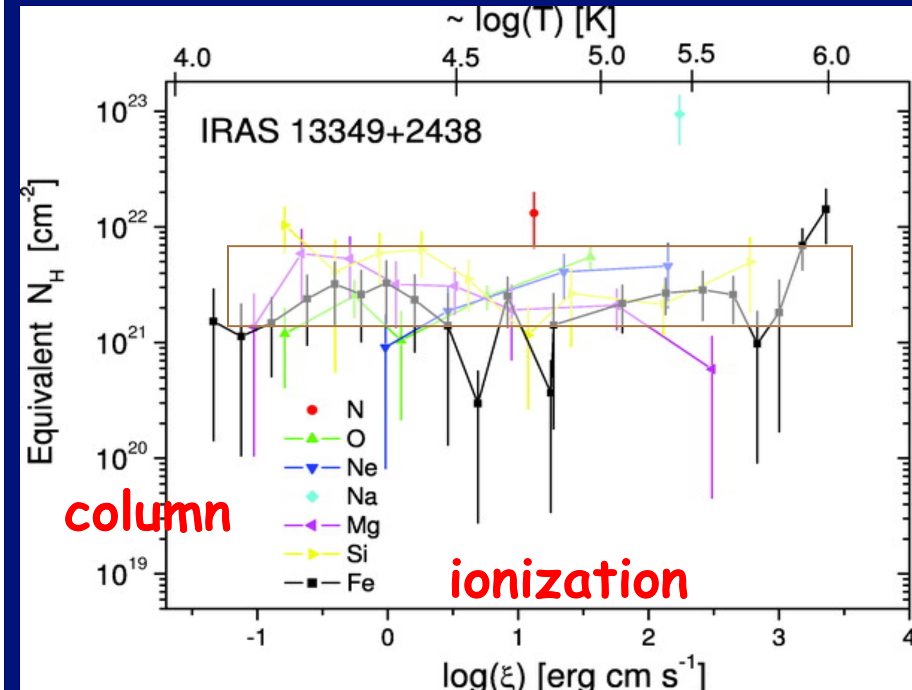
APM 08279+5255:
(z = 3.91)

- Lensed QSO (x100)
- Optically-bright
- IR-loud, radio-quiet

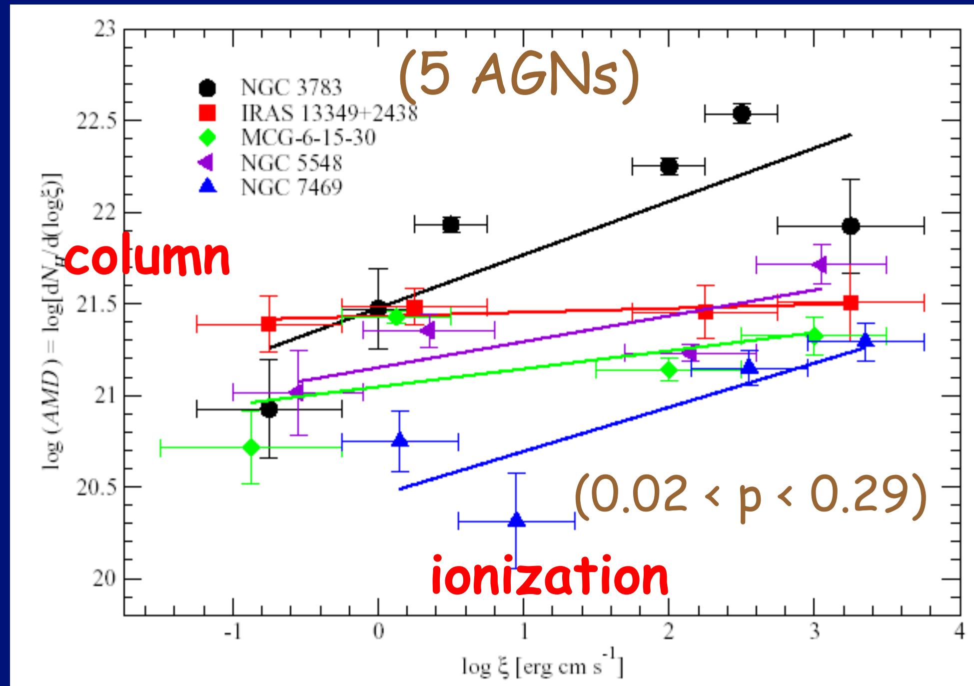
- High-velocity outflows
  v/c~**0.04-0.1 in *C IV***
  (UV: Keck/HIRES)

Absorption Measure Distribution (AMD)

$AMD(\xi) = dN_H / d\log\xi \sim (\log\xi)^p$ where $\xi = L/(n r^2)$



Holczer+(07)



Behar(09)

➔ presence of nearly equal N_H over ~4 decades in ξ ($p \sim 0.02$)

$$\xi(r) \sim \frac{L}{n(r)r^2} \sim \frac{L}{N_H r} \rightarrow N_H \sim \frac{L}{\xi(r) r}$$

$$\frac{dN_H}{d\log\xi} \sim \frac{L}{\xi(r) r} \simeq \text{const.} \rightarrow \xi(r) \sim \frac{1}{r}$$

$$n(r) \propto \frac{1}{r}$$

For radiatively driven winds $v(r) = v_\infty(1 - r_*/r)$ one obtains

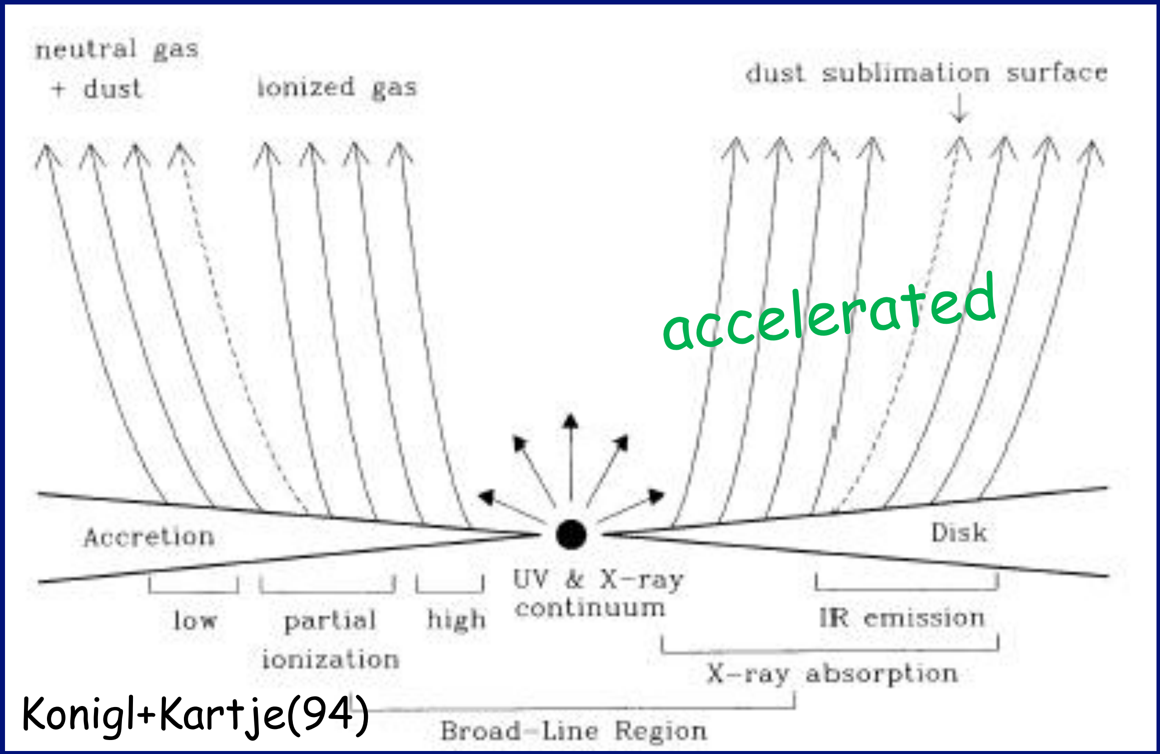
$$AMD \equiv \frac{dN_H}{d\log\xi} \propto \frac{\xi_\infty}{\xi}$$

ξ_∞ is the ionization parameter at the distance where the asymptotic wind velocity is attained

Fundamental Questions:

- Geometry?
- Spatial location?
- Properties?
- Physical origin?

To AMD through MHD Winds



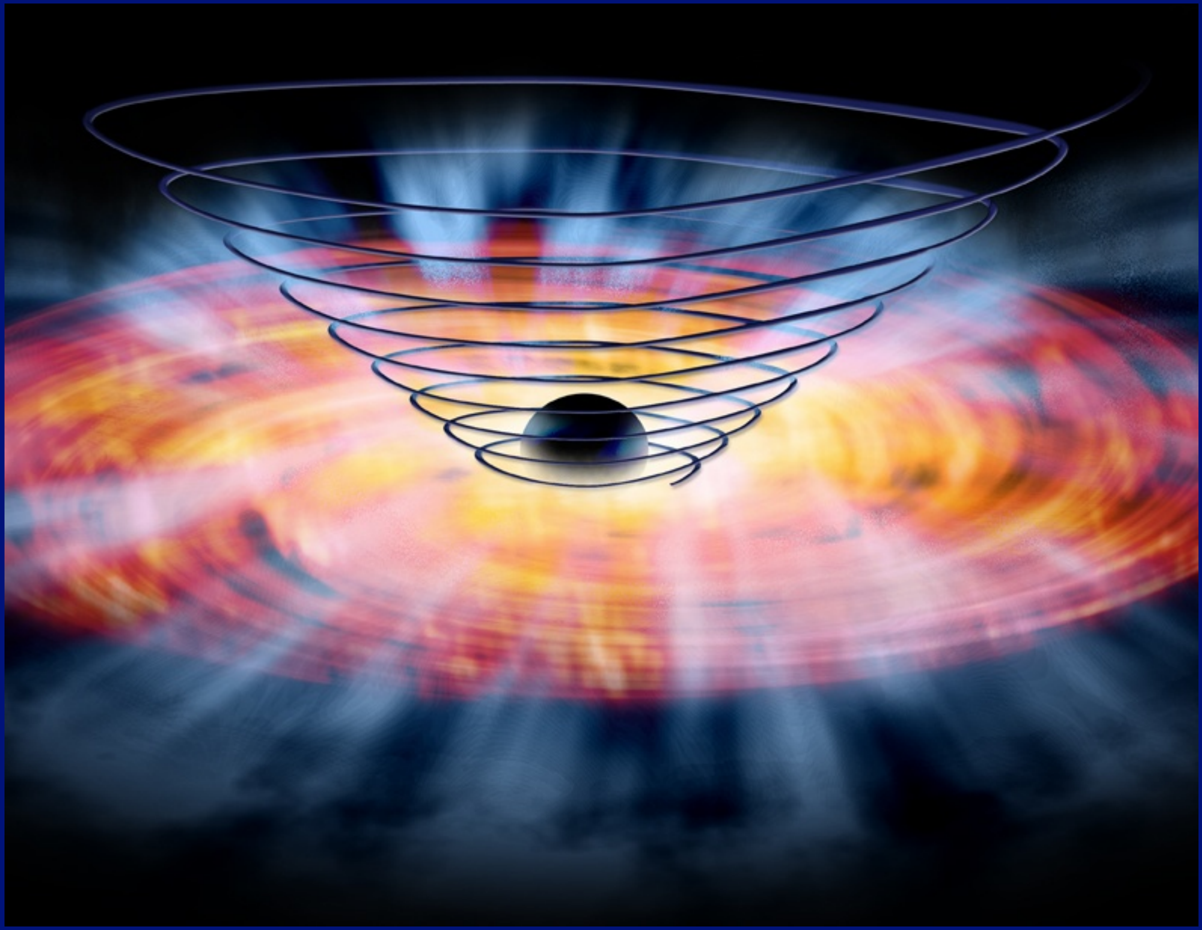
Blandford+Payne(82)
Contopoulos+Lovelace(94)
Konigl+Kartje(94)
Contopoulos(95)
Murray+(95;98)
Blandford+Begelman(99)
Proga+Kallman(04)
Everett(05)
Schurch+Done(07,08)
Sim+(08;10)
& more…

- Accretion disks necessarily produce outflows/winds (launched initially with Keplerian rotation)
- Driven by some acceleration mechanism(s)
- Local X-rays heat up and photoionize plasma along the way

➔ *Need to consider mutual interactions between ions & radiation*

Magnetically-Driven Outflows

Magnetohydrodynamics (MHD)



(At least) 2 candidates:

- GRO J1655-40
  Miller+(06,08)
- NGC 4151
  Kraemer+(05)
  Crenshaw+Kraemer(07)

MHD Disk-Wind Solutions

(Blandford+Payne82; Contopoulos+Lovelace94)

- Steady-state, axisymmetric MHD solutions (2.5D):

$$\nabla \cdot (\rho \mathbf{v}) = \mathbf{0} \qquad \text{(mass conservation)} \ , \quad (P_{rad}=0)$$

$$\nabla \times \mathbf{B} = \frac{4\pi}{\mathbf{c}} \mathbf{J} \qquad \text{(Ampere's law)} \ ,$$

$$\mathbf{E} + \frac{\mathbf{v}}{\mathbf{c}} \times \mathbf{B} = \mathbf{0} \qquad \text{(ideal MHD)} \ ,$$

$$\nabla \times \mathbf{E} = \mathbf{0} \qquad \text{(Faraday's law)} \ ,$$

$$\rho(\mathbf{v} \cdot \nabla)\mathbf{v} = -\nabla \mathbf{p} - \rho \nabla \Phi_{\mathbf{g}} + \frac{1}{\mathbf{c}}(\mathbf{J} \times \mathbf{B}) \qquad \text{(momentum conservation)} \ ,$$

→ 5 "conserved" quantities: *Energy, Ang.Mom., Flux, Ent., Rot.*

- Look for solutions that the variables separate

Assume Power Law radial dependence for all variables

$$B(r,\theta) \equiv (r/r_o)^{-(s+1)/2}\tilde{B}(\theta)B_o\ ,$$
$$v(r,\theta) \equiv (r/r_o)^{-1/2}\tilde{v}(\theta)v_o\ ,$$
$$p(r,\theta) \equiv (r/r_o)^{-(s+1)}\mathcal{P}(\theta)B_o^2\ ,$$
$$n(r,\theta) \equiv (r/r_o)^{-s}\mathcal{N}(\theta)n_o\ ,$$

$$n_o = \frac{f_W \dot{m}_o}{2\sigma_T r_s}\ ,$$

- Solve for their angular dependence using the force balance equation in the θ-direction (Grad-Safranov equation).
- This is a wind-type equation that has to pass through the appropriate critical points.
- BP82 solution: *s = 3/2* ; CL94 solution: *s =1*

- With the above scalings

$$\dot{m}(x) = \dot{m}_o x^{-s+3/2}$$

- In order that n(r)~1/r, s = 1 and $\dot{m} \propto x^{1/2}$
- The mass flux in the wind increases with distance!! Or rather, most of the accreting gas "peels-off" to allow only a small fraction to accrete onto the black hole (Blandford & Begelman 1999).
- There is mounting observational evidence that the mass flux in the wind is much higher than that needed to power the AGN/LMXRB.
- Feedback! Edot ~ mdot v^2 ~$r^{-1/2}$; Momentum input: Pdot ~ mdot v ~ logr → Equal momentum per decade of radius!

- By expressing BH luminosity in terms of dimensionless variables ($L \propto \eta \dot{m}_a M$ or $L \propto \eta \dot{m}_a^2 M$) the ionization parameter can now be expressed in the dimensionless variables

$$\xi(x) \simeq \frac{L}{n(r)r^2} \simeq \frac{\eta \dot{m}_a}{N_H(x)x} \simeq \begin{cases} 10^8 \frac{\eta}{f_W} \frac{1}{x^{-s+2}} & \text{for } \dot{m}_a > \alpha^2 \text{ (non-ADAF)} \\ 10^8 \frac{\eta}{f_W} \frac{\dot{m}_a}{x^{-s+2}} & \text{for } \dot{m}_a < \alpha^2 \text{ (ADAF)} \end{cases}$$

- For s=1, $\xi(r) \sim 1/r$; species "living" in lower ξ–space should come from larger distances.
- The radiation seen by gas at larger distances requires radiative transfer thru the wind.

MHD Disk-Wind Solutions

(Contopoulos+Lovelace94)

Density

$$n(r,\theta) \equiv \frac{\rho(r,\theta)}{\mu m_p} = n_o x^{2q-3} \mathcal{N}(\theta) \qquad n_o = \frac{\eta_W \dot{m}}{2\sigma_T r_S}$$

LoS column density

$$N_H(\Delta r,\theta) \equiv \int_{\Delta r} n(r,\theta) dr \qquad x = r/rs$$

Ionization parameter

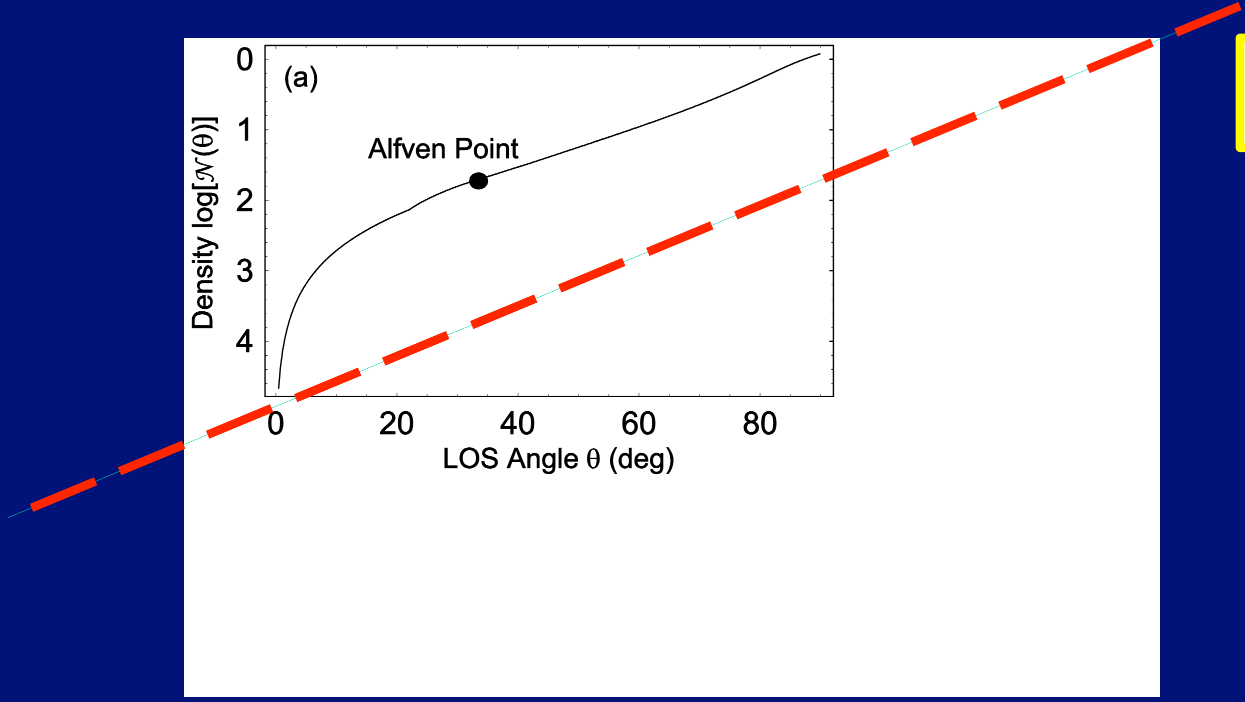
$$\xi(r,\theta) \equiv \frac{L}{n(r,\theta) r^2} \simeq \frac{\epsilon}{\mathcal{N}(\theta)\eta_W} \frac{3 \times 10^8 \dot{m}}{x^{2q-1}}$$

(c.f. Ueda+03; Tueller+08)

We seek "q=1" self-similar wind:

- $B(r,\theta) \sim B(\theta)/r$
- $n(r,\theta) \sim F(\theta)/r$ (i.e. equal column per decade in radius)
- LoS velocity ~ $1/r^{1/2}$ (Keplerian profile)
- $\xi(r,\theta) \sim G(\theta)/r$ (w/o attenuation)

MHD Wind Angular Density Profile



$e^{(\theta-\pi/2)/0.2}$

T. Fischer + (2011)

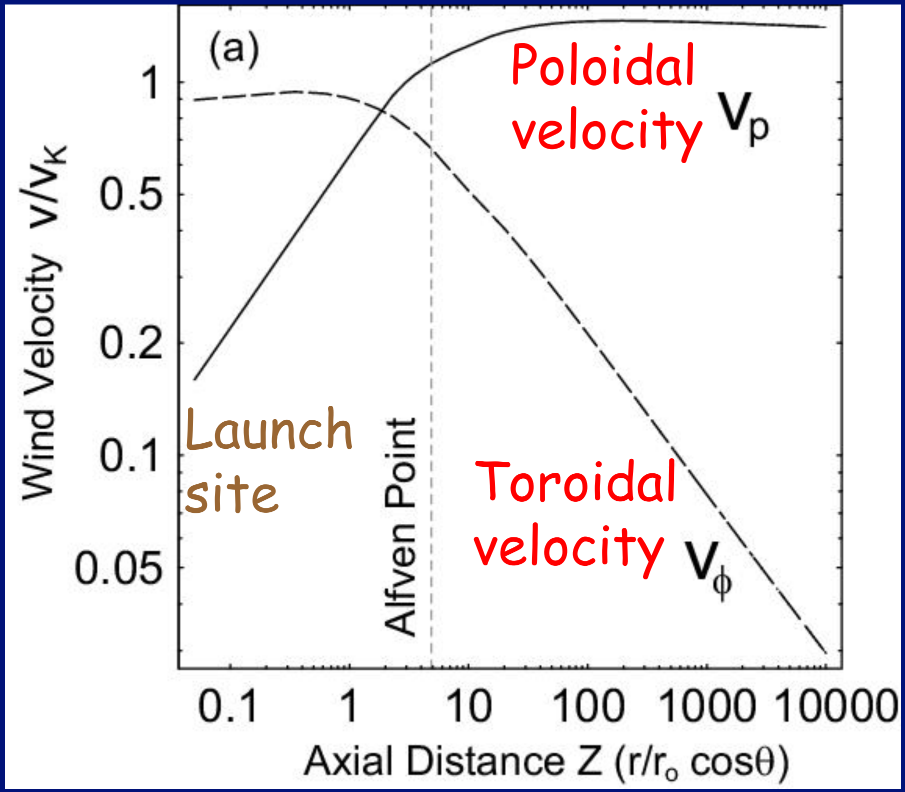
The density has a very steep θ−dependence with the polar column being 10^3 – 10^4 smaller than the equatorial. The wind IS the unification torus (Konigl & Kartje 1994).

Simple Wind Solutions with n~1/r

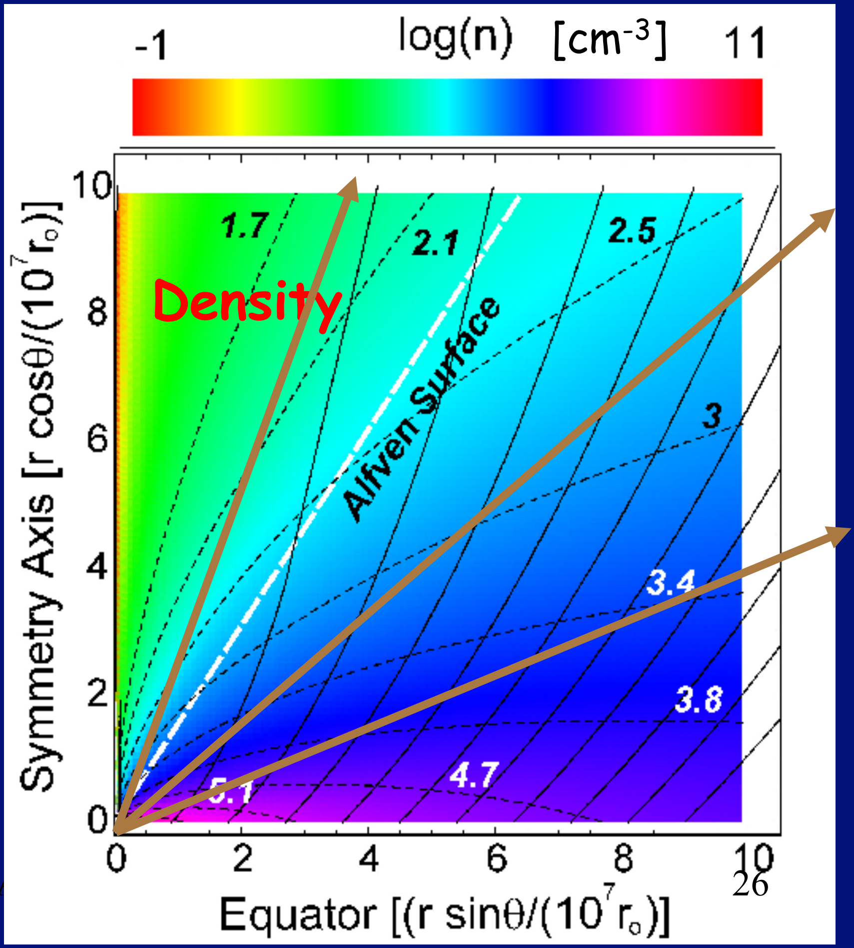
(q=1)

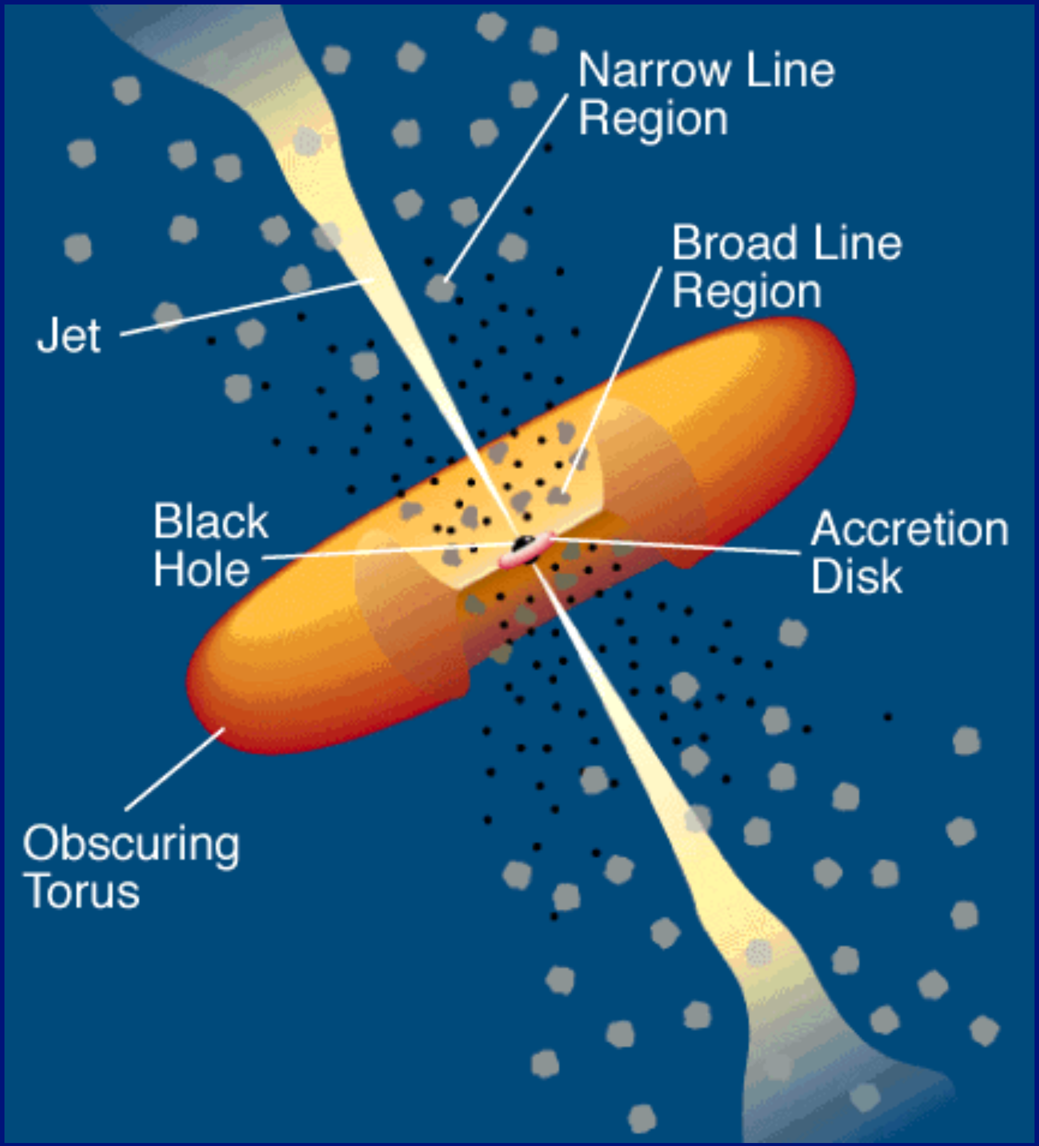
Assume:

M(BH) = 10^6 Msun, Γ ~ 2 (single power-law), L_X ~ 10^{42} erg/s,
mdot ~ 0.5, rad. eff. ~ 10%, n(in) ~ 10^{10} cm^{-3}

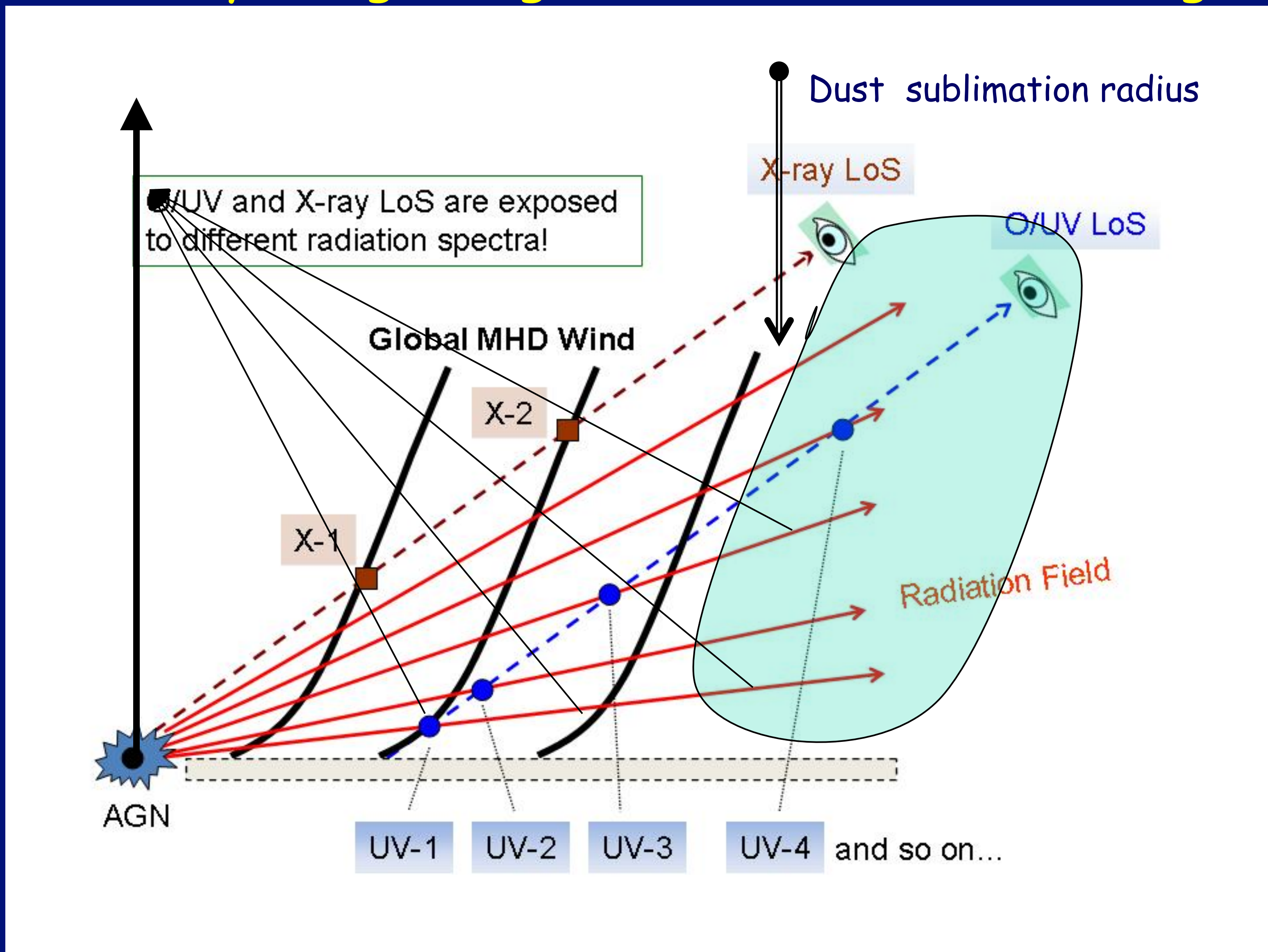


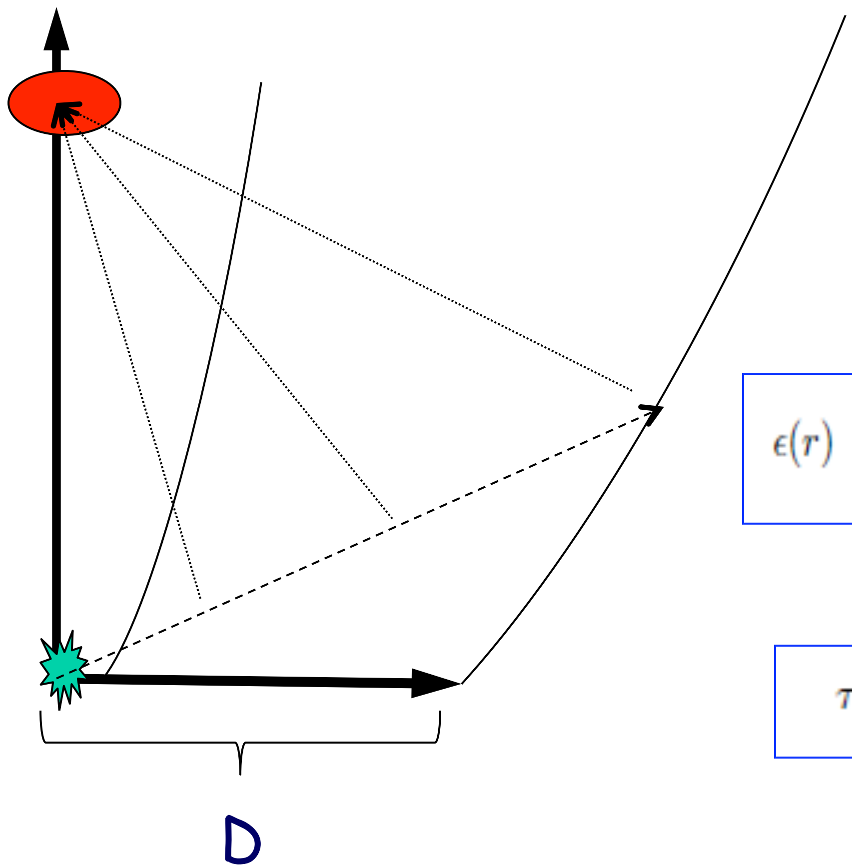
(Fukumura+10a)




Narrow Line Region
Broad Line Region
Jet
Black Hole
Accretion Disk
Obscuring Torus

The photon density at the gamma-ray blob can be calculated by integrating the source function along rays





$$r = \frac{D}{(1 - cos\theta)}$$

$$\epsilon(r) \ = \ \frac{L}{4\pi r^2} f(\theta)\tau(r), \qquad f(\theta) = e^{(\theta - \pi/2)/0.2}$$

$$\tau(r) \simeq n_0 \left(\frac{r_0}{r}\right) \sigma_T r = n_0 r_0 \sigma_T \simeq \dot{m}$$

$$\epsilon(r) \;\propto\; \frac{\dot{m}^2 sin^4(\theta/2)}{\pi D^2} f(\theta)\tau(r) \propto \frac{\dot{m}^3 sin^4(\theta/2)}{\pi D^2}$$

$$B_\phi \simeq \frac{\dot{m}^{1/2}}{r sin\theta} \rightarrow B_\phi^2 \simeq \frac{\dot{m}\, tan^4(\theta/2)}{D^2}$$

For sufficiently small values of mdot the magnetic energy dominates over the photon energy, depending on the bulk acceleration of the jet relative to the size of the disk.

This simple MHD-wind based model provides a direct account of the BL Lac – FSRQ phenomenology.

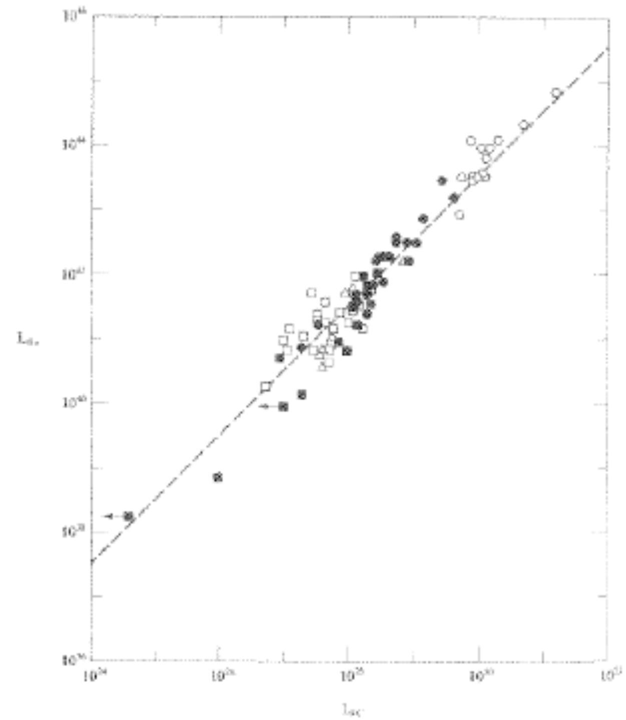
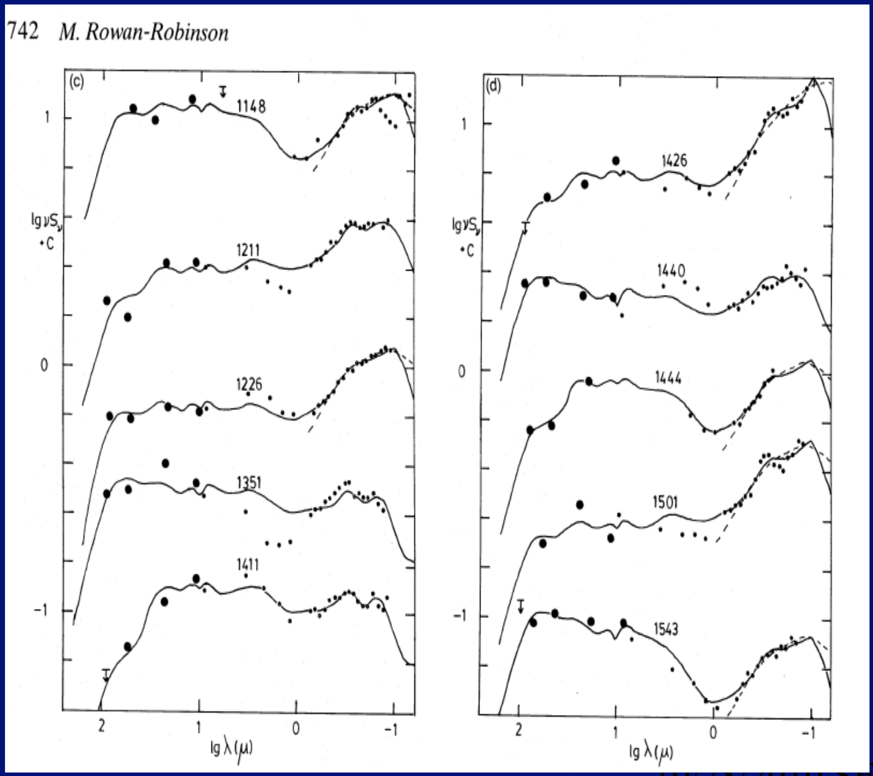


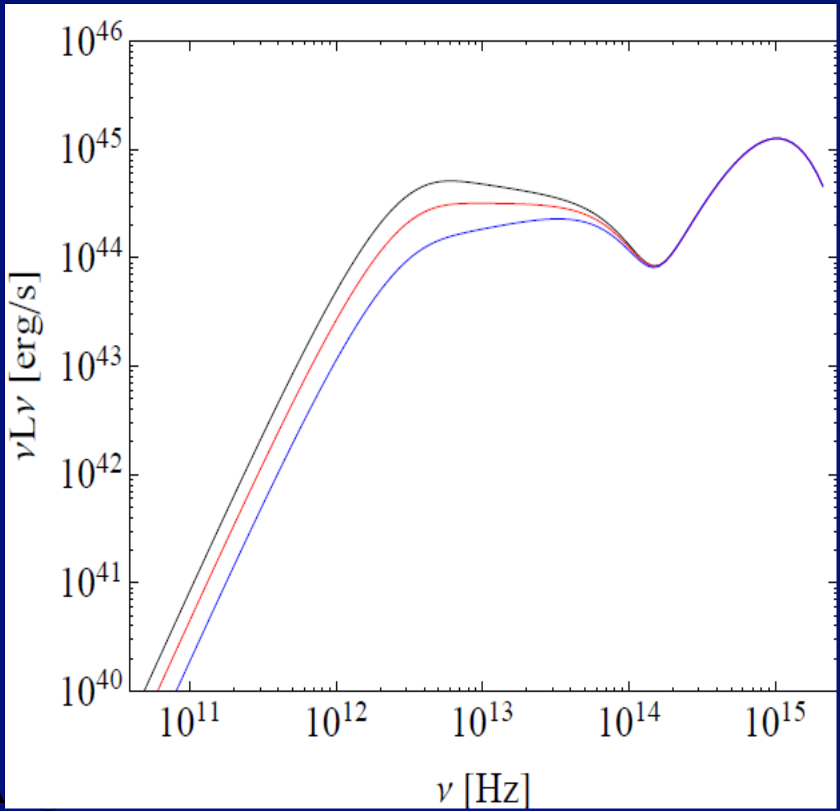
Figure 3.12 Luminosity in the Hα emission line versus mono-chromatic continuum luminosity (at $\lambda 4800$ for different AGN types: QSOs (open circles), Seyfert 1 galaxies (filled circles and Seyfert 2 galaxies (open squares). The dashed line shows the predicted relationship for a photoionization model with an input spectrum $L_\nu = C\nu^{-1.05}$ (from Osterbrock 1989).

Line emission reflects also on the accretion / wind mass flux rate and should relate to the character of the objects (P. Padovani's talk)

$$
\begin{aligned}
n(x) &\simeq 10^{10}\frac{\dot m}{M_9}\frac{1}{x} \quad \mathrm{cm}^{-3} \\
L_{H\alpha} &\simeq \alpha(T)\, n^2(r)\, V \simeq 10^{-13}\left(10^{10}\frac{\dot m}{M_9}\frac{1}{x}\right)^2 (3\times10^{14})^3\, M_9^3\, x^3 \\
&\simeq 3\times10^{38} x\, \dot m^2\, M_9 \simeq 3\times10^{44}\, \boxed{\dot m^2\, M_9} \quad (x=10^6) \quad \mathrm{erg\ s^{-1}} \\
\nu L_\nu &\simeq 10^{47}\, \eta\, \dot m^2\, M_9 \quad \simeq \quad 10^{46}\, \boxed{\dot m^2\, M_9} \quad (\eta = 0.1) \quad \mathrm{erg\ s^{-1}}
\end{aligned}
$$

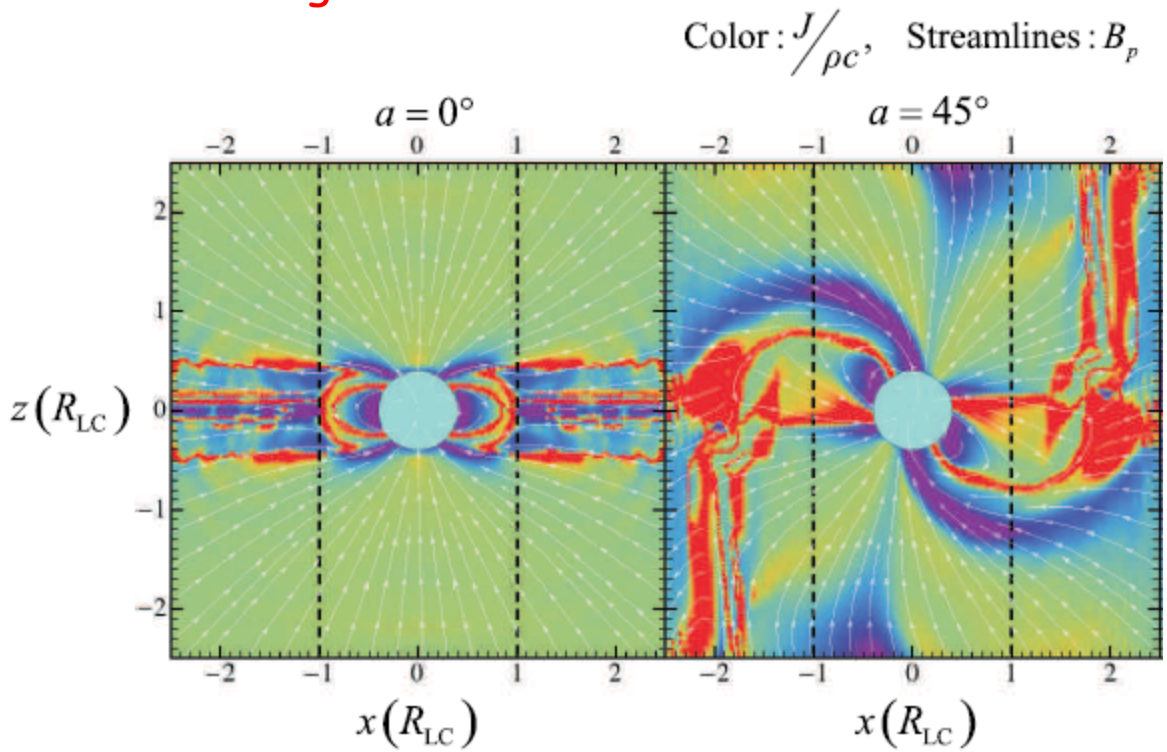
Dust reprocessing: For n(r)~1/r, equal energy per decade of radius is absorbed and emitted as dust IR emission at progressively decreasing temperature. This leads to a flat nuFnu IR spectrum





What about the particle acceleration?

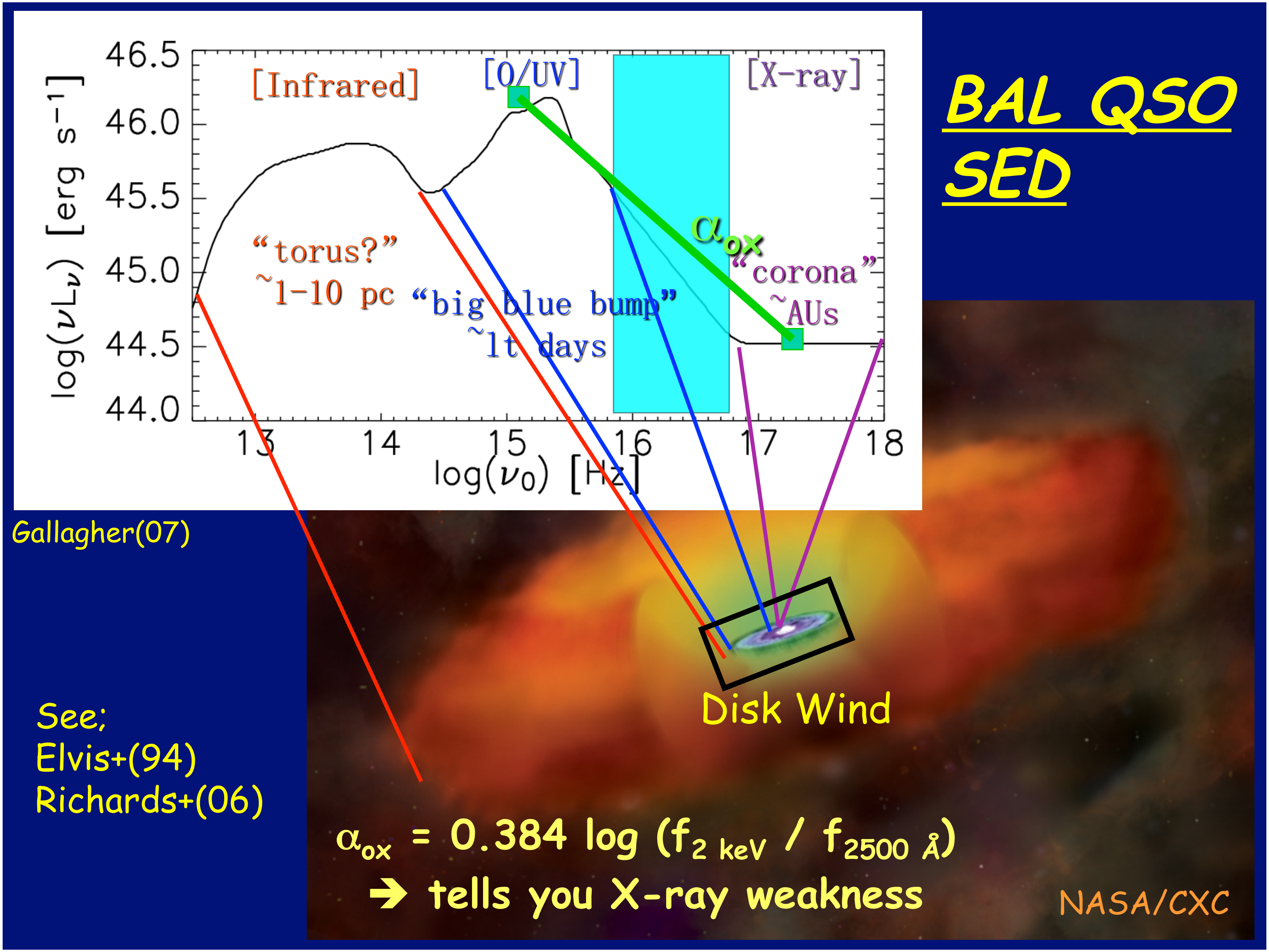
IMHD pulsar solution: BC force a parallel electric field and Creation of charges while none is assumed in the outset.



(Kalapotharakos, Kazanas, Harding, Contopoulos, 1108.2138)

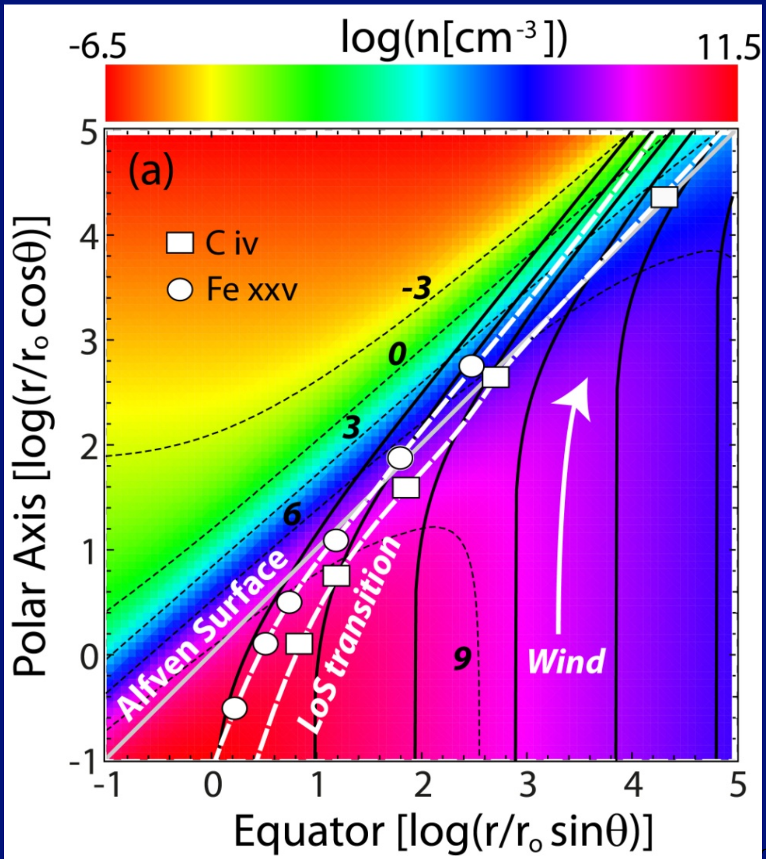
Conclusions

- AGN Unification models that can accommodate their X-ray absorber properties provide novel insights concerning the Fermi blazar observations:
- The ~1/r density profiles implied by the AMD provide the possibility of external photons along the jet axis either through scattering or reprocessing into lines. Both can be calculated once we fix on a specific MHD model.
- The model suggests that low values of mdot are associated with non-thermal emission dominated by SSC rather than EC.
- The model relates the wind characteristics (e.g. outer radius) to the IR properties of AGN, which in turn are related to the Compton dominance of the object.

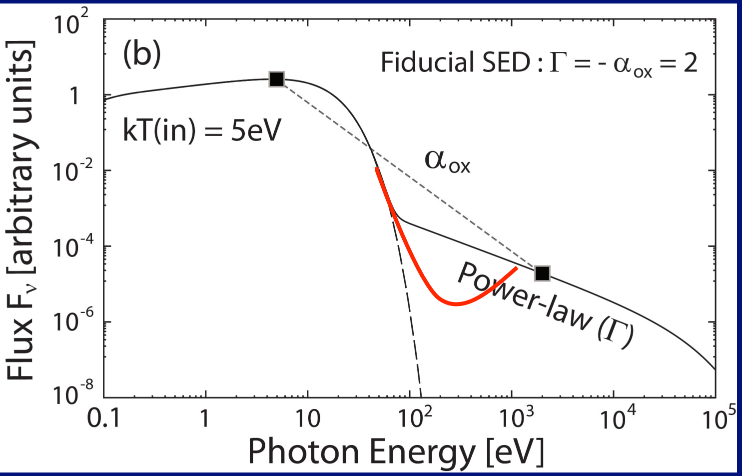

BAL QSO SED
[Infrared]
[O/UV]
[X-ray]
"torus?"
~1-10 pc
"big blue bump"
~lt days
α_{ox}
"corona"
~AUs
$\log(\nu L_\nu)$ [erg s^{-1}]
$\log(\nu_0)$ [Hz]
46.5
46.0
45.5
45.0
44.5
44.0
13
14
15
16
17
18
Gallagher(07)
Disk Wind
See;
Elvis+(94)
Richards+(06)
$\alpha_{ox} = 0.384 \log (f_{2\ keV} / f_{2500\ Å})$
➔ tells you X-ray weakness
NASA/CXC

Apply the model to BAL QSOs by changing only α_{OX} : The decrease in ionizing X-rays allow for FeXXV very close to the BH → hi FeXXV velocity, absorption of CIV forming photons → CIV forms also at small distances leading to hi CIV velocity (but smaller than that of FeXXV).

Log(density)



Injected SED (F_ν)



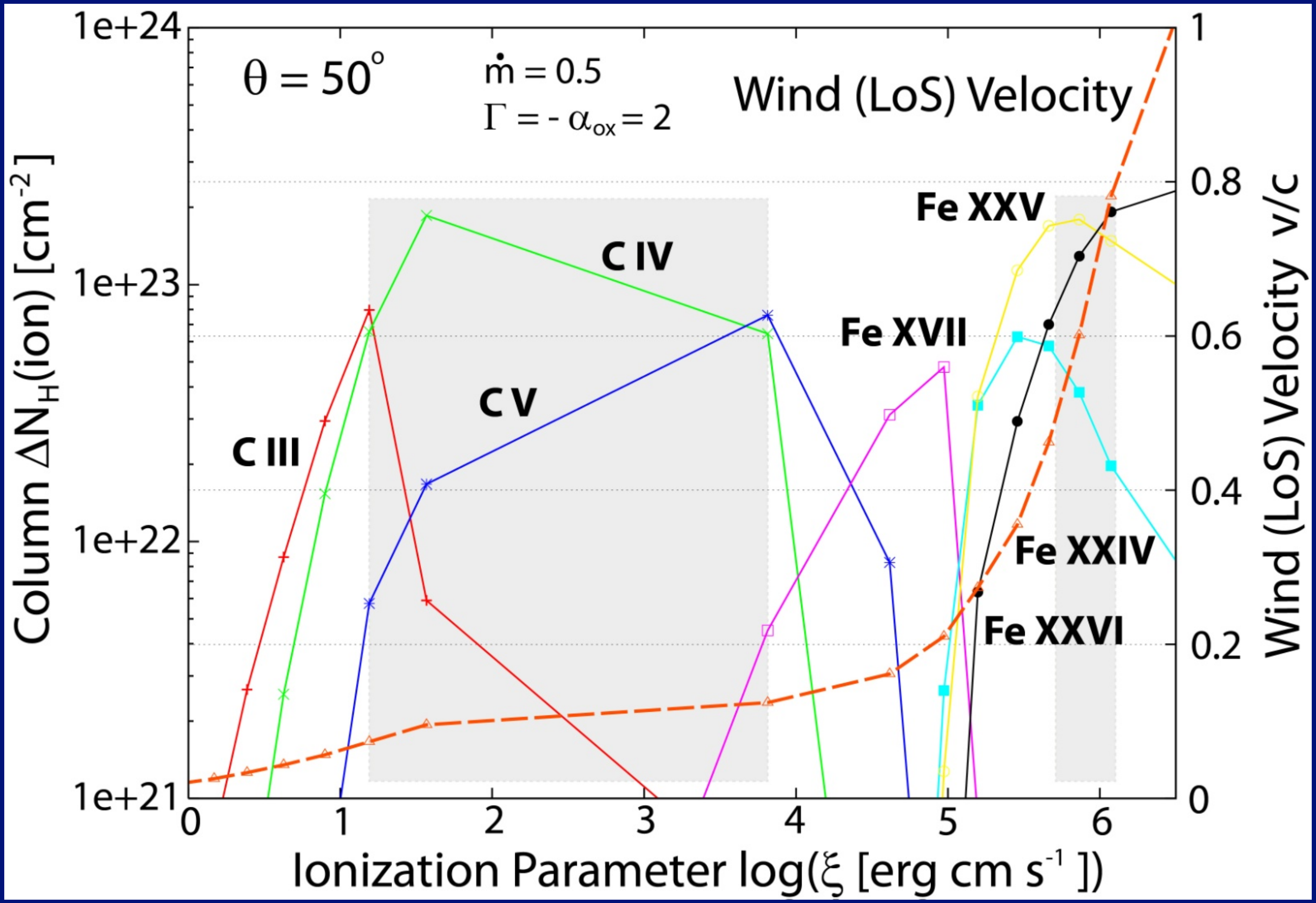
- mdot = 0.5
- kT(in) = 5eV
- $\Gamma_X = 2$
- $\alpha_{OX} = -2$

Fukumura+(10b)

AMD

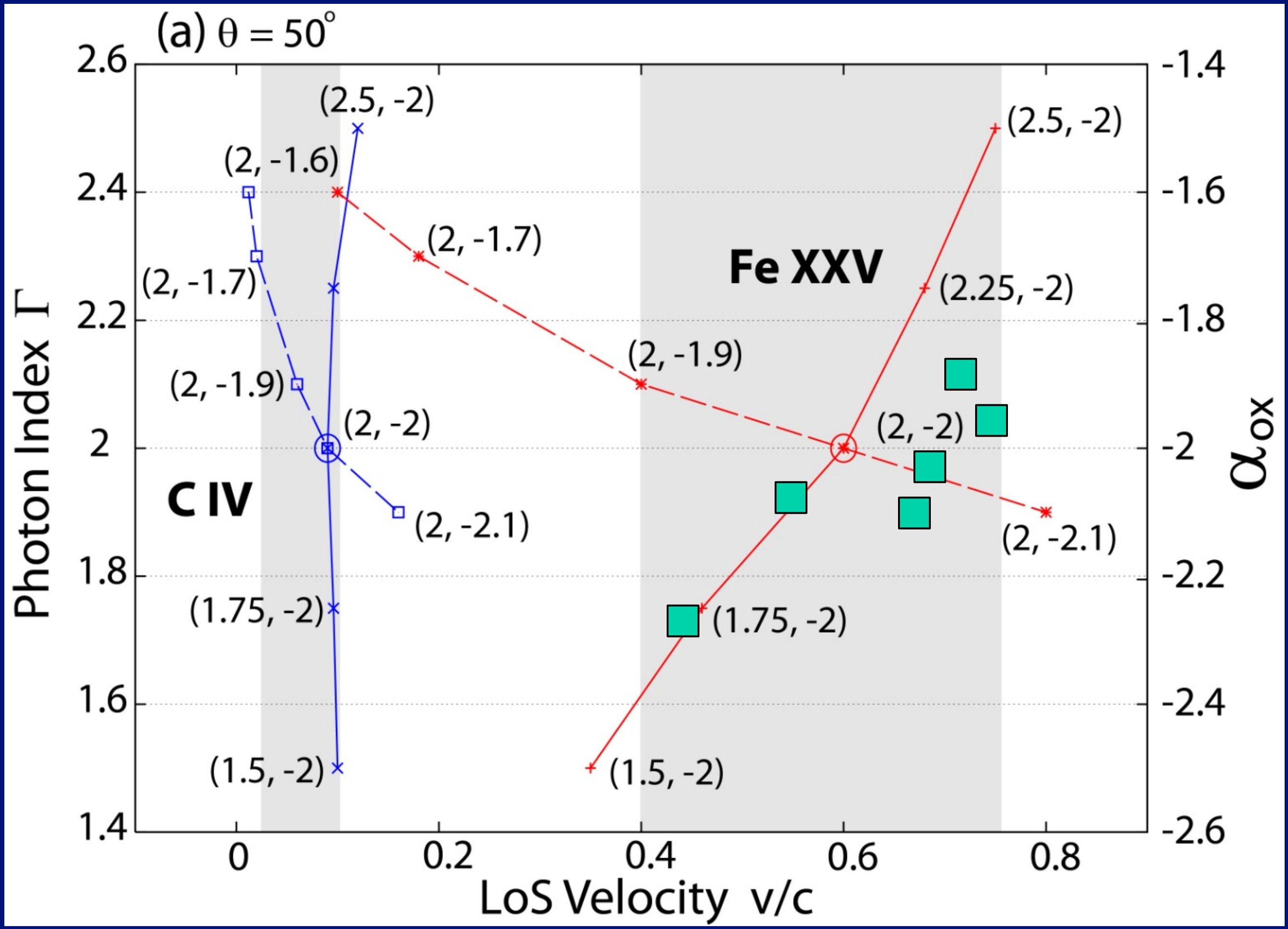
Production of CIV and FeXXV/XXVI

- mdot = 0.5
- kT(in) = 5eV
- $\Gamma_X = 2$
- $\alpha_{OX} = -2$



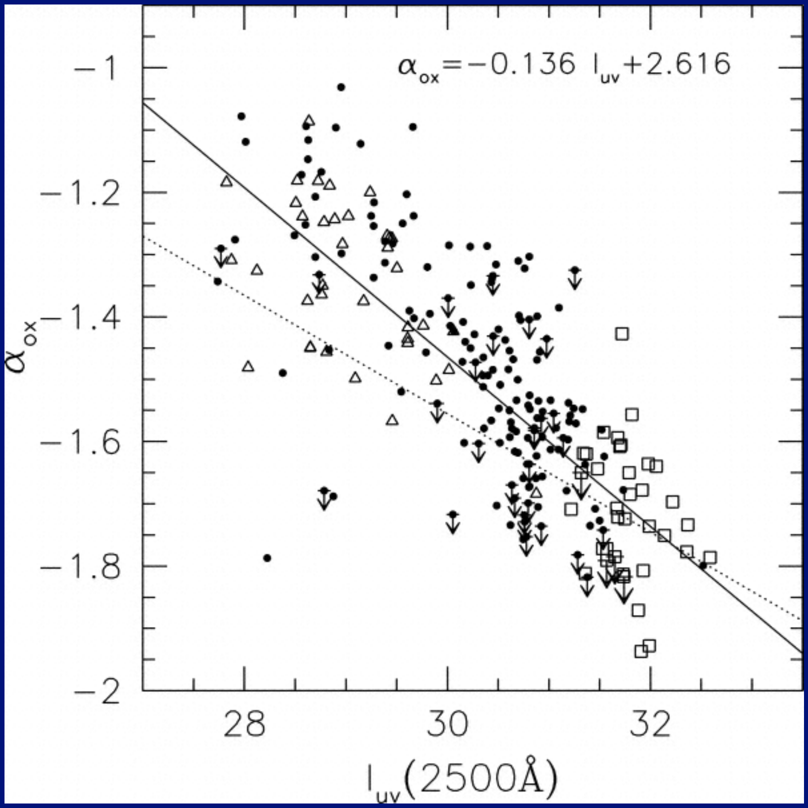
Correlations with Outflow Velocity

Velocity Dependence on SED (X-ray)



- X-ray data of APM 08279+5255 from Chartas+(09)
- Model from Fukumura+(10b)

END



Issues (Future Work)

Wind Solutions (Plasma Field):

- ✓ (Special) Relativistic wind
- ✓ Radiative pressure (e.g. Proga+00;Everett05;Proga+Kallman04)

Radiation (Photon Field):

- ✓ Realistic SED (particularly for BAL quasars)
- ✓ Different LoS between UV and X-ray (i.e. $R_{UV} > R_X$ by x10...)
- ✓ Including scattering/reflection (need 2D radiative transfer)

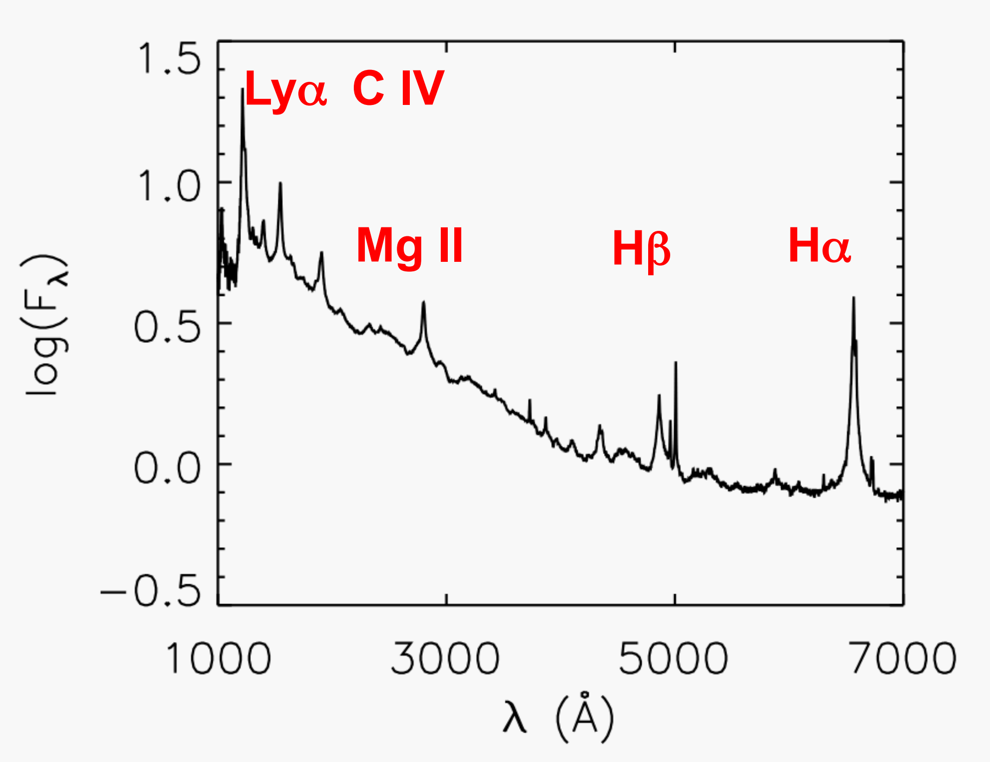
(Ultimate) Goals:

- ✓ Comprehensive understanding of ionized absorbers within a single framework (i.e. disk-wind)
- ➔ AGNs/Seyferts/BAL/non-BAL QSO with high-velocity outflows (e.g. PG 1115+080, H 1413+117, PDS 456 and more...)
- ➔ Energy budget between radiation and kinetic energy...

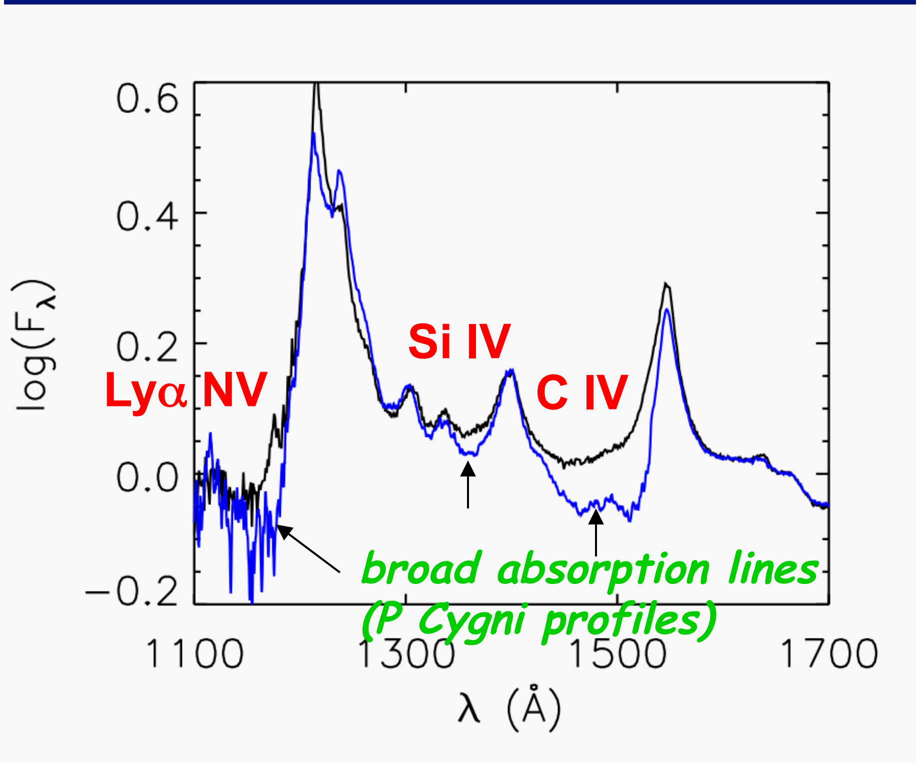
Broad Absorption Line (BAL) QSOs

- Became known with *ROSAT/ASCA* survey
- Large C IV EW(absorb) ~ 20-50 A ~ 30,000 km/sec
- ~10% of optically-selected QSOs
- Faint (soft) X-ray relative to O/UV continua
- High-velocity/near-relativistic outflows:
  v/c ~ 0.04 - 0.1 (e.g. UV C IV)
  v/c ~ 0.1 - 0.8 (e.g. X-ray Fe XXV)
- High intrinsic column of ~ 10^{22} cm^{-2} (UV)
  >~ 10^{23} cm^{-2} (X-ray)

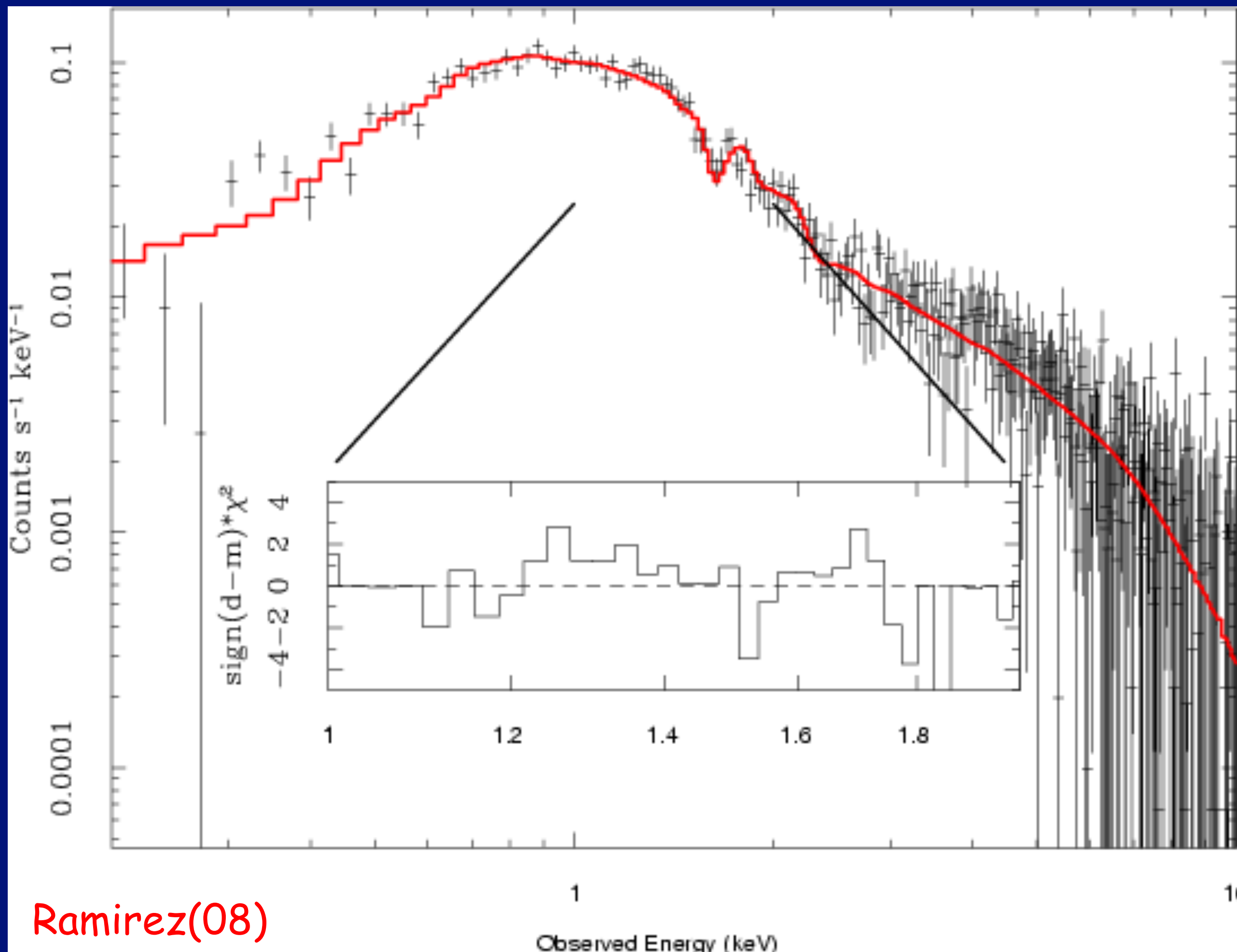
10. Normal galaxies vs. BAL quasars



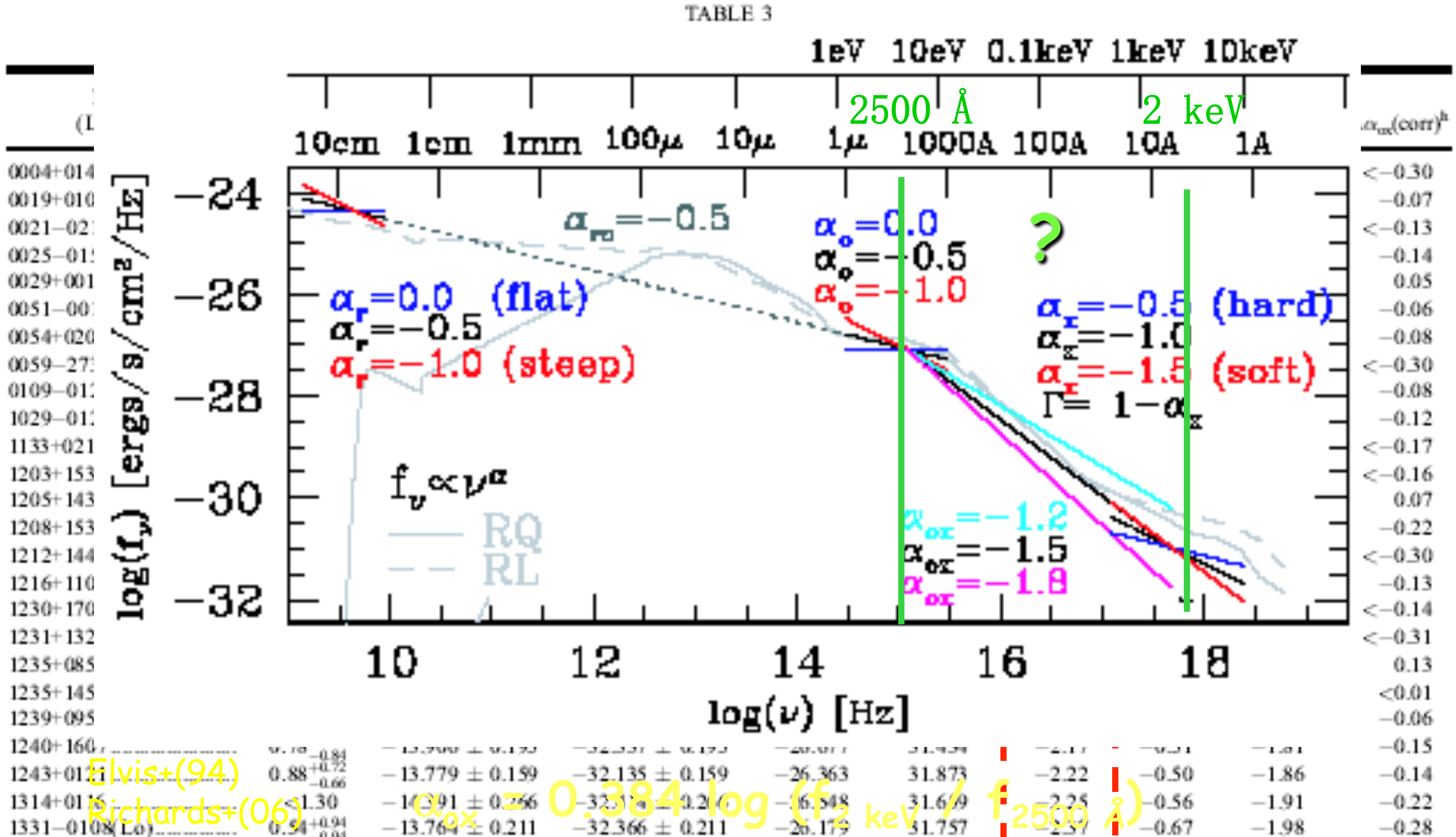
normal



BAL


Counts s⁻¹ keV⁻¹
0.1
0.01
0.001
0.0001
1
10
Observed Energy (keV)
sign(d−m)*χ^2
−4 −2 0 2 4
1
1.2
1.4
1.6
1.8
Ramirez(08)

12. Quasars – SED (UV/X-ray property)



Elvis+(94)

Richards+(06)

$\alpha_{ox} = 0.384 \log (f_{2\ keV} / f_{2500\ Å})$

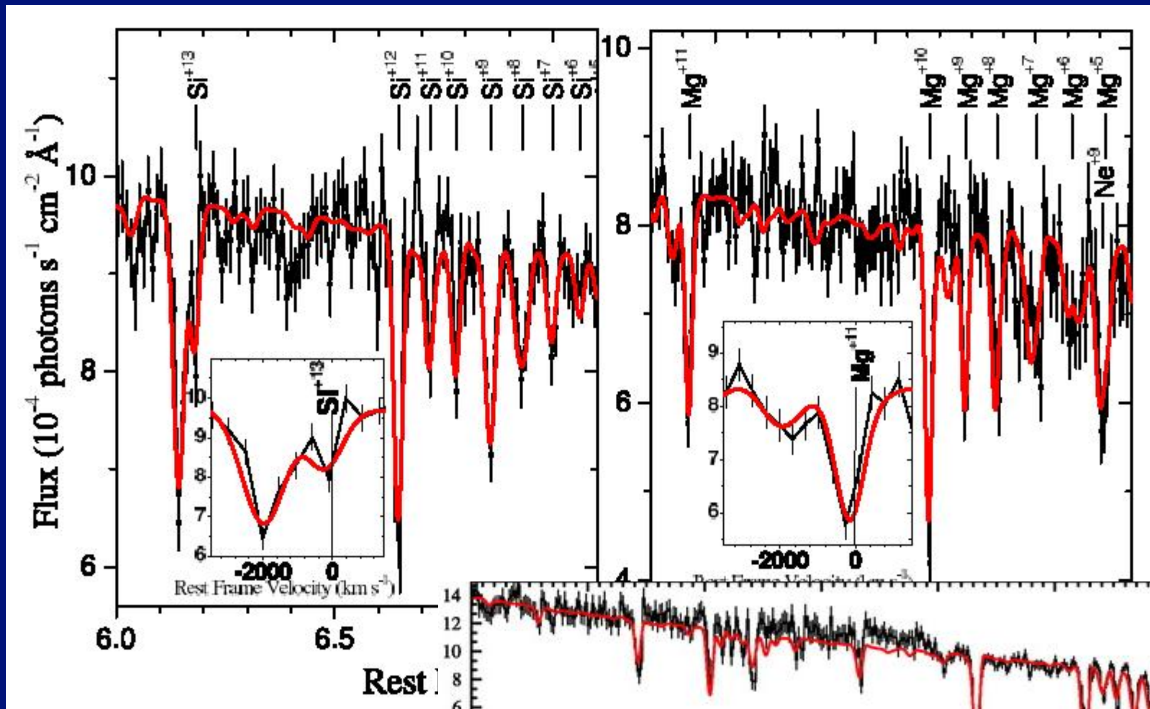
→ tells you X-ray weakness

UV bright, X-ray faint!

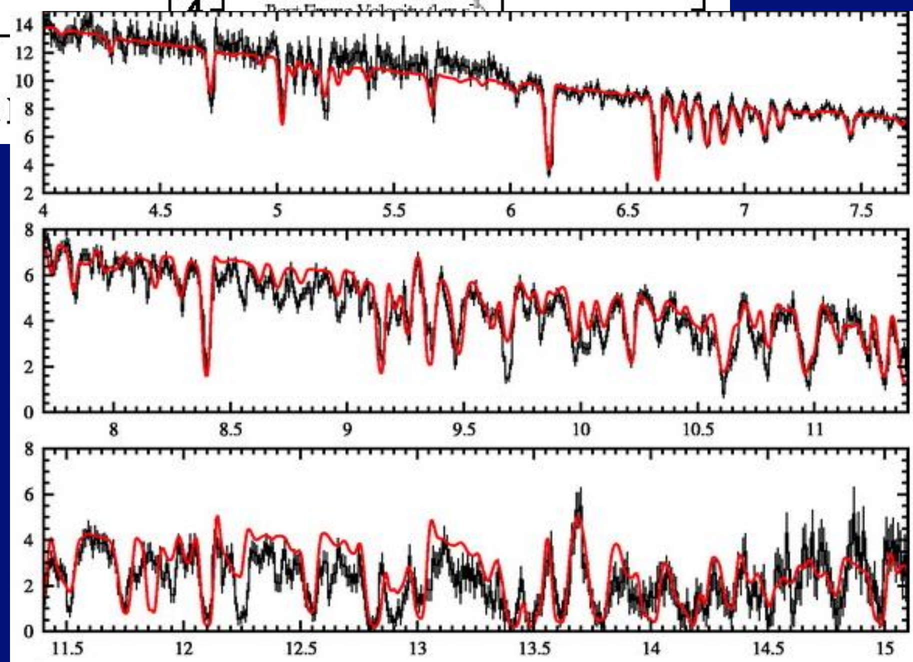
Chandra BAL QSO survey
Gallagher+(06)

Side Notes

MCG 6-30-15

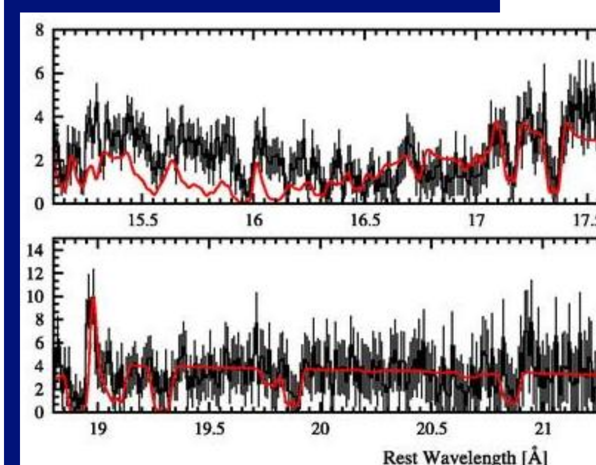


Holczer+10



X-ray spectrum of N

Netzer+(03)



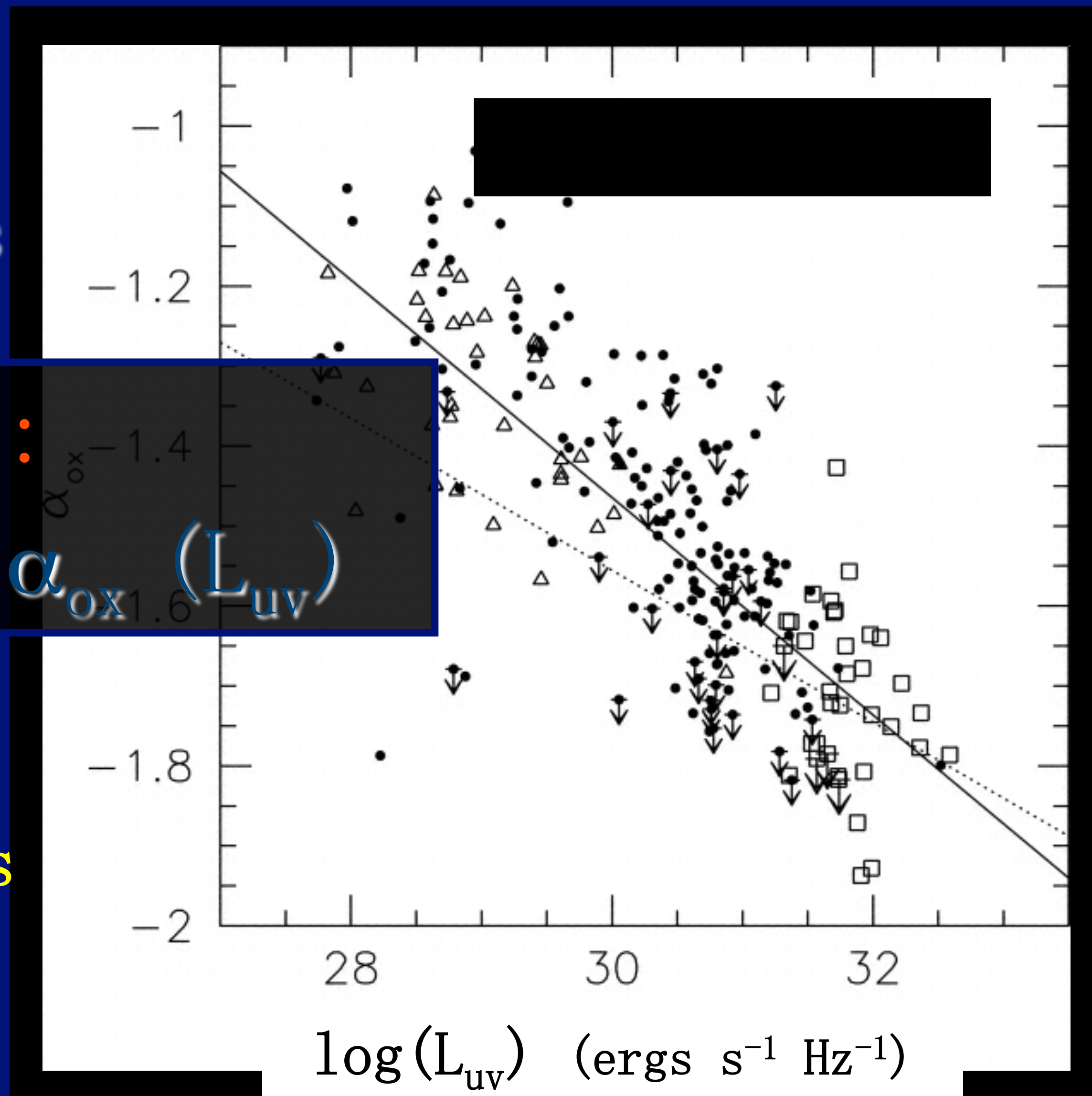
UV Luminosity vs. α_{ox}

brighter in X-rays

Define:

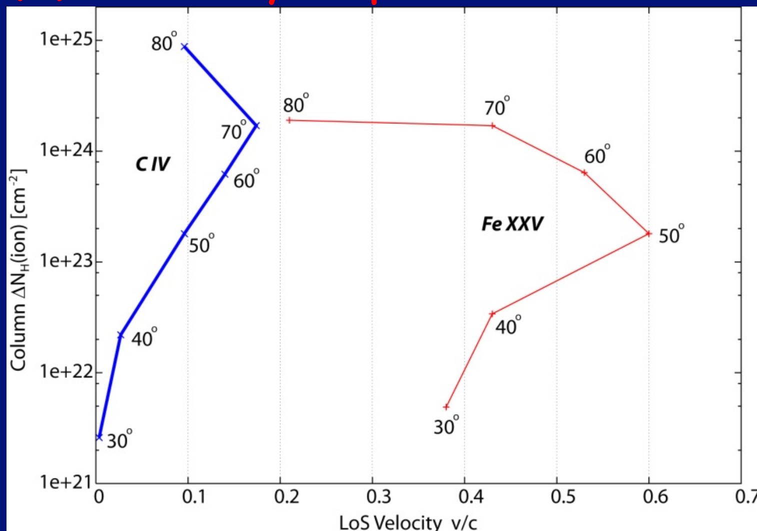
$$\Delta\alpha_{ox} = \alpha_{ox} - \alpha_{ox}(L_{uv})$$

fainter in X-rays



228 SDSS Quasars with ROSAT (Strateva et al. 2005)

(ii) Velocity dependence on LoS

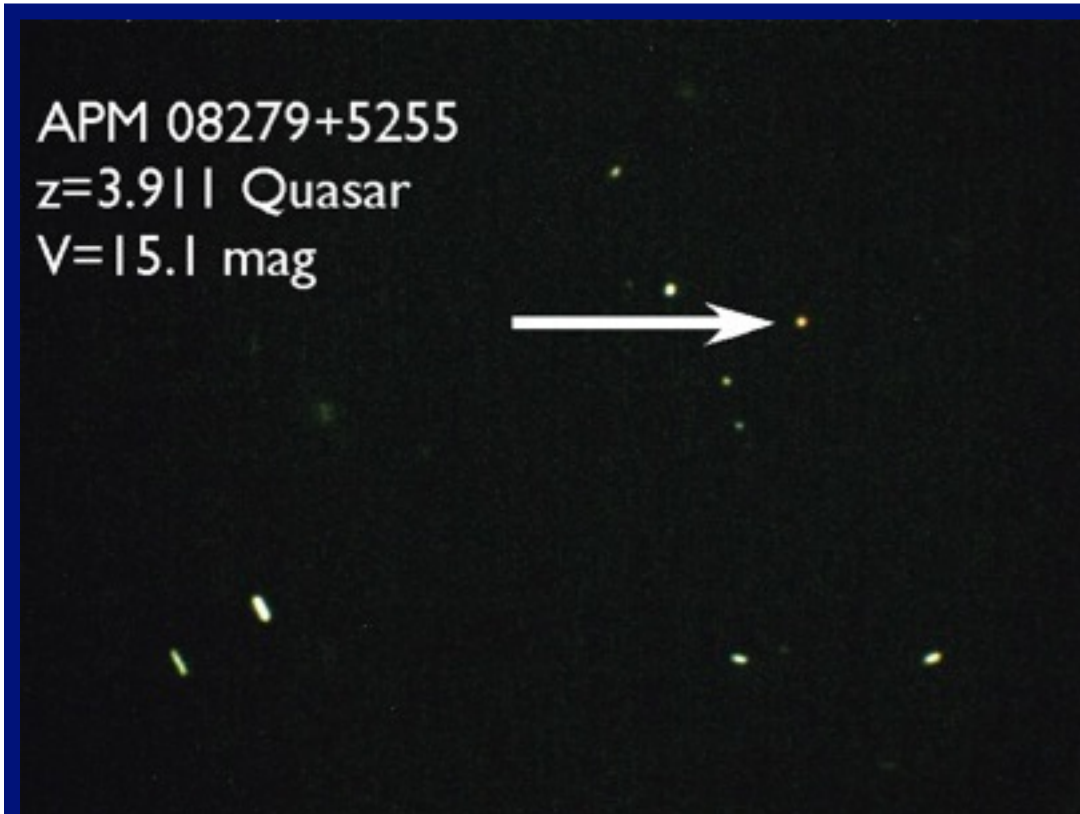


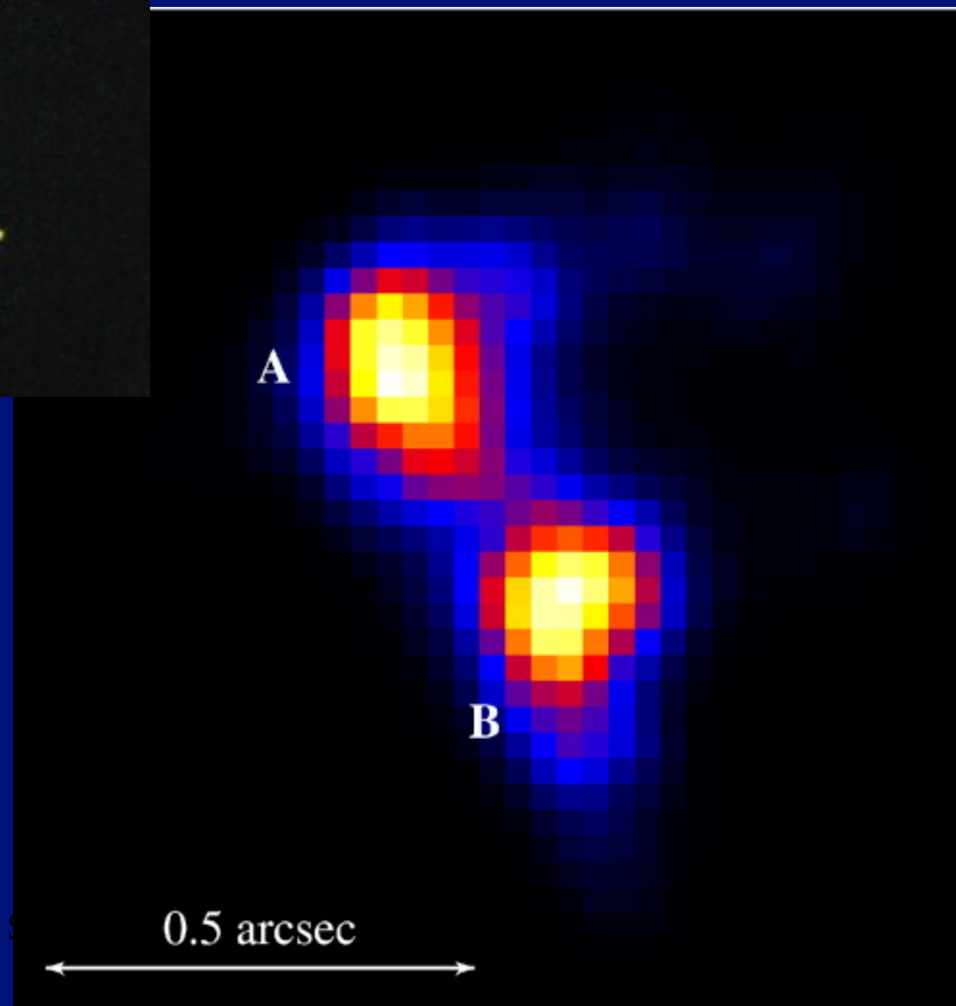
Face-down view (e.g. ~30deg)
➔ low N_H, low v/c

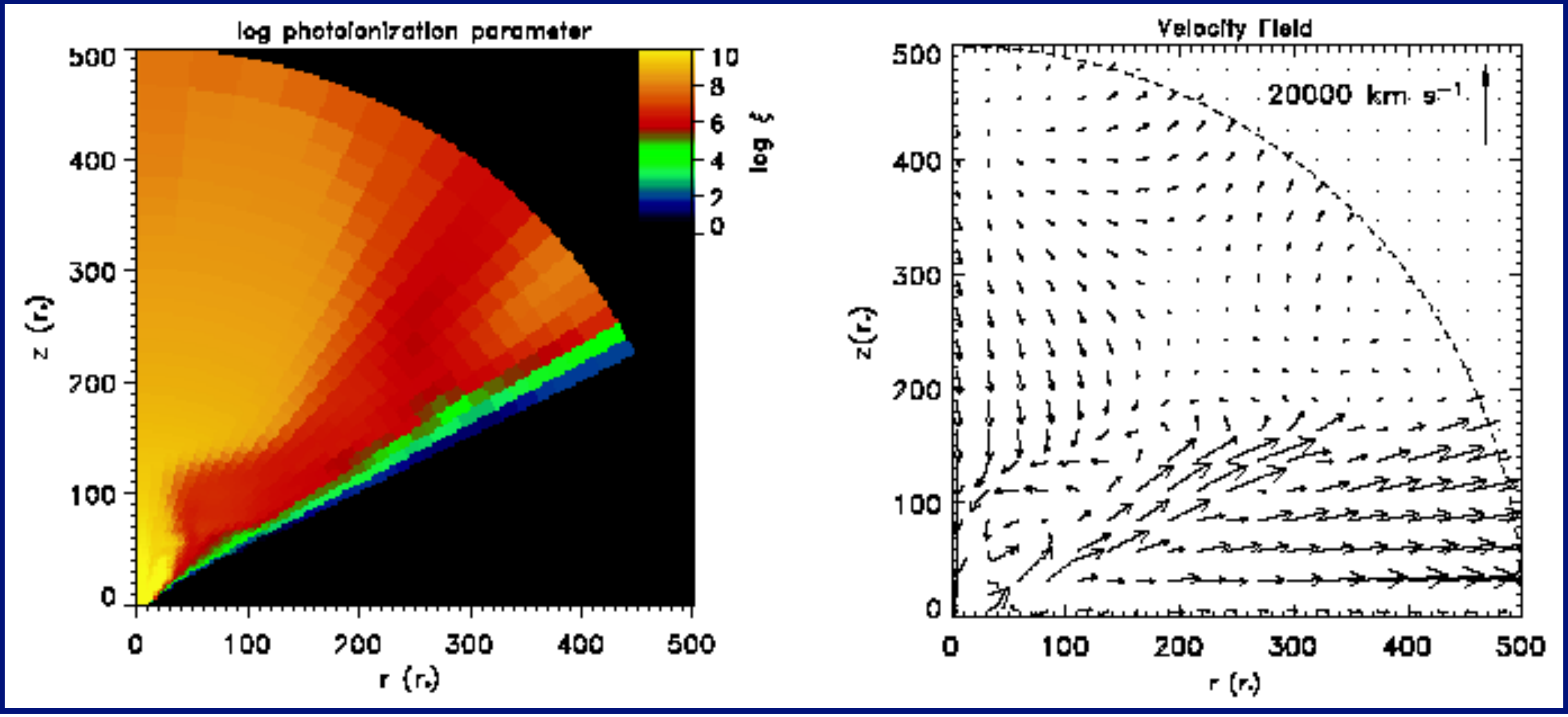
Optimal view (e.g. ~50deg)
➔ high N_H, high v/c

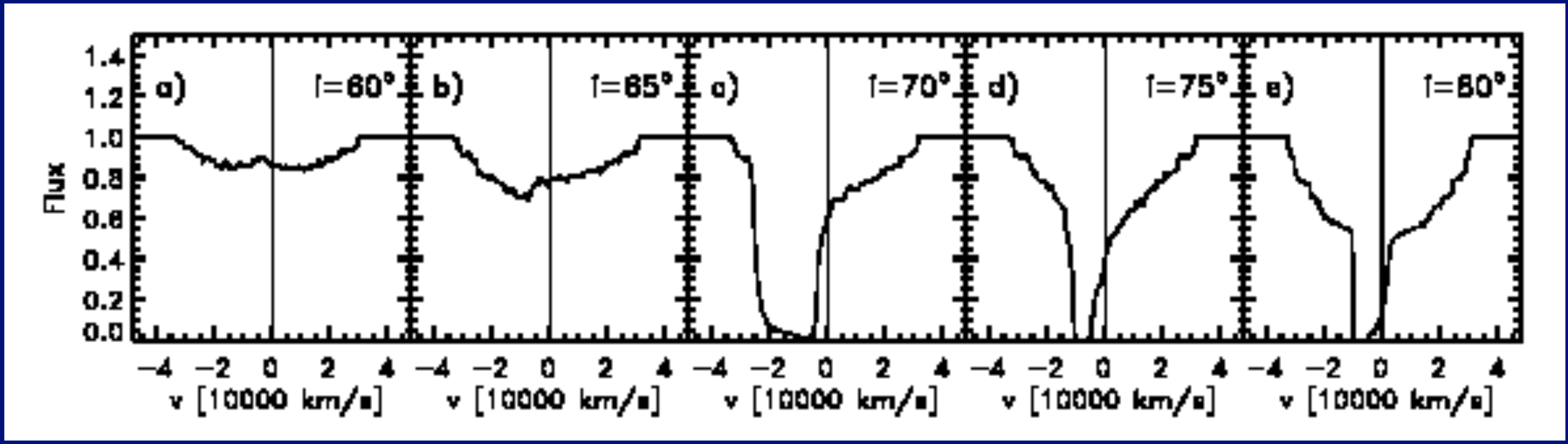
TABLE 1
Observed Targets

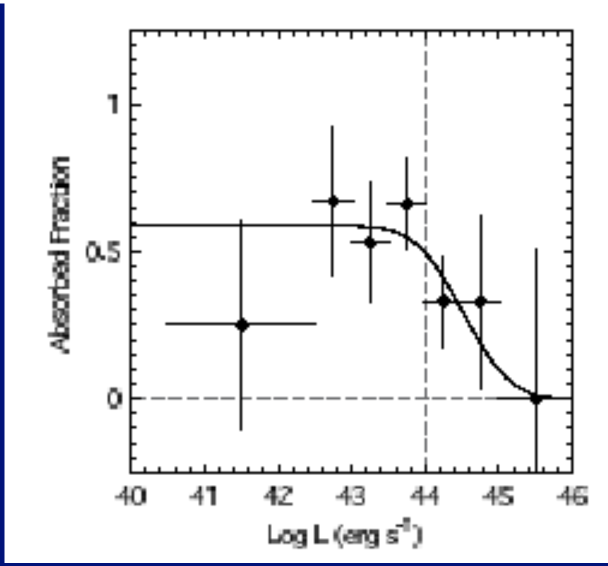
Name (LBQS B)	z[a]	B_J[a]	f_{2500}[b] ($10^{-17} f_\lambda$)	α_{UV}[c]	N_H[d] (10^{20} cm^{-2})	BI[e] (km s^{-1})	C IV EW$_a$ (Å)	v_{max}[f] (km s^{-1})	f_{deep}[g]	BAL Type[h]	R^*/R_i[i]	Notes[j]
0004+0147	1.710	18.13	24.7	−1.06	3.01	255	16.2	>25000	0.13	Lo	<−0.06/...	K, S, LH
0019+0107	2.130	18.09	19.2	−1.07	3.22	2305	23.9	13849	0.44	Hi	<−0.16/...	K, W, S, LH, H
0021−0213	2.293	18.68	10.3	−1.64	2.95	5179	40.2	20138	0.51	Hi	<0.11/...	K, W, S, LH, H
0025−0151	2.076	18.06	19.3	−1.34	2.85	2878	32.0	21765	0.15	Hi	<−0.02/...	K, W, S, LH, H
0029+0017	2.253	18.64	8.7	−1.72	2.40	5263	33.6	12267	0.53	Hi	<0.15/<0.80	K, W, SDSS, S, LH, H
0051−0019	1.713	18.67	15.1	−1.25	3.22	3244	46.3	22113	0.53	Hi	.../<0.61	K, SDSS(sp), LH
0054+0200	1.872	18.41	16.6	−1.39	3.11	498	22.7	10970	0.23	Hi	.../<0.97[k]	K, LH
0059−2735	1.593	18.13	35.9	−1.34	1.99	11053	77.5	20427	0.81	Lo	<−0.15/...	K, W, S, LH, H, G
0109−0128	1.758	18.32	17.1	−1.20	4.07	399	35.3	18794	0.25	Hi	.../<0.53	SDSS(sp), LH
1029−0125	2.029	18.43	17.9	−1.27	4.80	1848	26.8	17685	0.43	Hi	<−0.10/...	K, W, S, LH, H
1133+0214	1.468	18.38	22.6	−2.23	2.61	1950	22.5	21547	0.00	Hi	.../<0.47	SDSS(sp), LBQS
1203+1530	1.628	18.70	11.7	−2.11	2.80	1517	25.4	11702	0.04	Hi	.../<0.67	SDSS, LH, LBQS
1205+1436	1.643	18.38	17.0	−1.60	2.59	788	20.6	7947	0.18	Hi	.../<0.57	K, W, SDSS, S, LH, H
1208+1535	1.961	17.93	13.5	−1.76	2.67	4545	29.9	20325	0.20	Hi	<0.13/<0.61	K, W, SDSS, S, LH, H
1212+1445	1.627	17.87	31.0	−1.13	2.69	3618	38.8	19368	0.20	Hi	0.01/<0.34	K, W, SDSS, S, LH, H
1216+1103	1.620	18.28	22.9	−2.08	2.15	4791	33.3	12076	0.67	Hi	<0.04/<0.43	K, W, SDSS(sp), S, LH, H
1230+1705	1.420	18.44	15.7	−2.63	2.26	2945	34.9	21617	0.18	Hi	0.12/...	S, LH, LBQS
1231+1320	2.380	18.84	26.1	−0.26	1.86	3473	22.1	>25000	0.09	Lo	<−0.41/<0.35	K, W, SDSS, S, LH, H
1235+0857	2.898	18.17	21.0	−1.47	1.68	815	23.3	5339	0.69	?	−0.12/...	K, W, SDSS, S, LH, H
1235+1453	2.699	18.56	5.2	−1.33	2.37	2657	19.3	14414	0.45	?	<0.42/<0.27	K, W, SDSS, S, LH, H
1239+0955	2.013	18.38	18.6	−1.75	1.66	708	13.9	12355	0.38	Hi	.../<0.46	K, SDSS, S, LH, H
1240+1607	2.360	18.84	8.9	−0.75	2.16	2867	32.9	12568	0.32	Hi	<0.15/<0.81	K, W, SDSS, S, LH, H
1243+0121	2.796	18.50	14.4	−0.66	1.76	5953	42.1	20718	0.47	?	<−0.16/<0.58	K, W, SDSS(sp), S, LH, H
1314+0116	2.686	18.65	10.0	−1.70	1.98	2626	23.3	14210	0.23	?	<−0.02/<0.66	K, W, SDSS(sp), S, LH, H
1331−0108	1.881	17.87	38.2	0.59	2.22	7911	50.3	18811	0.45	Lo	0.37/0.64	K, W, SDSS(sp), S, LH, H

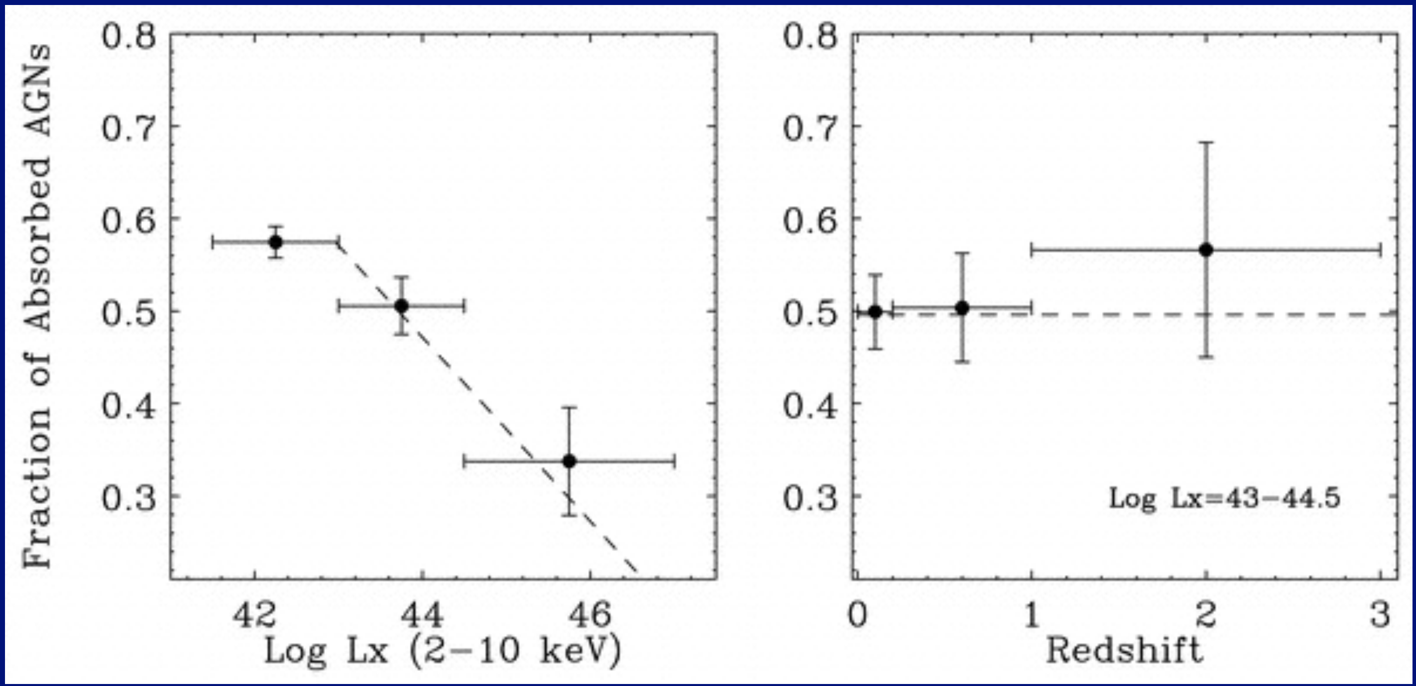

APM 08279+5255
z=3.911 Quasar
V=15.1 mag


A
B
0.5 arcsec


log photoionization parameter
log ξ
z (r*)
r (r*)
Velocity Field
20000 km s⁻¹
z(r*)
r (r*)


a) i=60°
b) i=65°
c) i=70°
d) i=75°
e) i=80°
Flux
v [10000 km/s]


Absorbed Fraction
1
0.5
0
40
41
42
43
44
45
46
Log L (erg s^{-1})


Fraction of Absorbed AGNs
0.8
0.7
0.6
0.5
0.4
0.3
42
44
46
Log Lx (2−10 keV)
0
1
2
3
Redshift
Log Lx=43−44.5