On the evidence of massive, high velocity outflows in AGNs and QSOs

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Outline

1. Framework
   Outflows/winds
2. X-ray Observations: (some of) latest results
   Blue-shifted abs. lines…
3. Absorption lines variability
   Blue-shifted, variable, abs. lines…
4. From skepticism to finding this possibly very relevant
   Critical issues and impact…
5. Future
   XMM, and XEUS…

Collaborators: M. Dadina, M.Giustini, G. Palumbo, G. Ponti, F. Tombesi

Framework (i/ii): Fast winds/outflows/ejecta in AGNs

…known/seen in AGNs since long ago

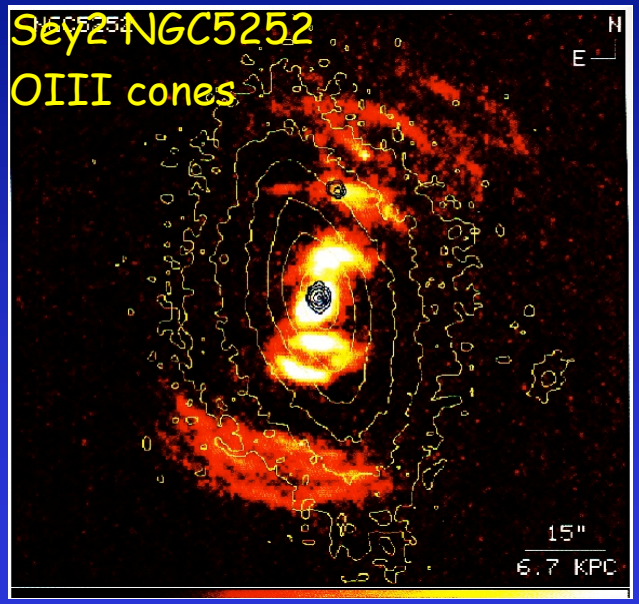
Jets in radio-loud AGNs

Fast (v up to ~ 50000 km/s) winds in BAL QSOs
(~ 20% of all QSOs)

Weymann et al., '91;
Reichards et al., '03

Wide-angle winds & jets in Seyfert galaxies

See yesterday's talks by Kriss and Gallagher

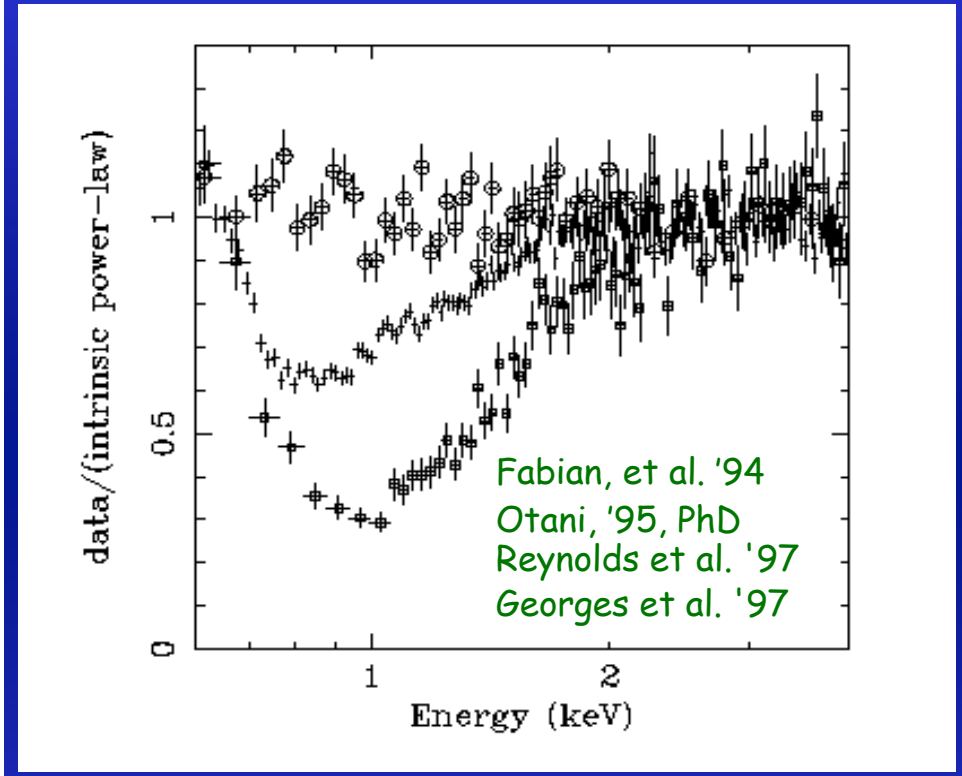


Tadhunter & Tsvetanov, Nature, 1989; Wilson & Tsvetanov, 1994
Cappi et al. 1995

Framework (ii/ii): Warm (X-ray) absorbers…probe highest-v gas

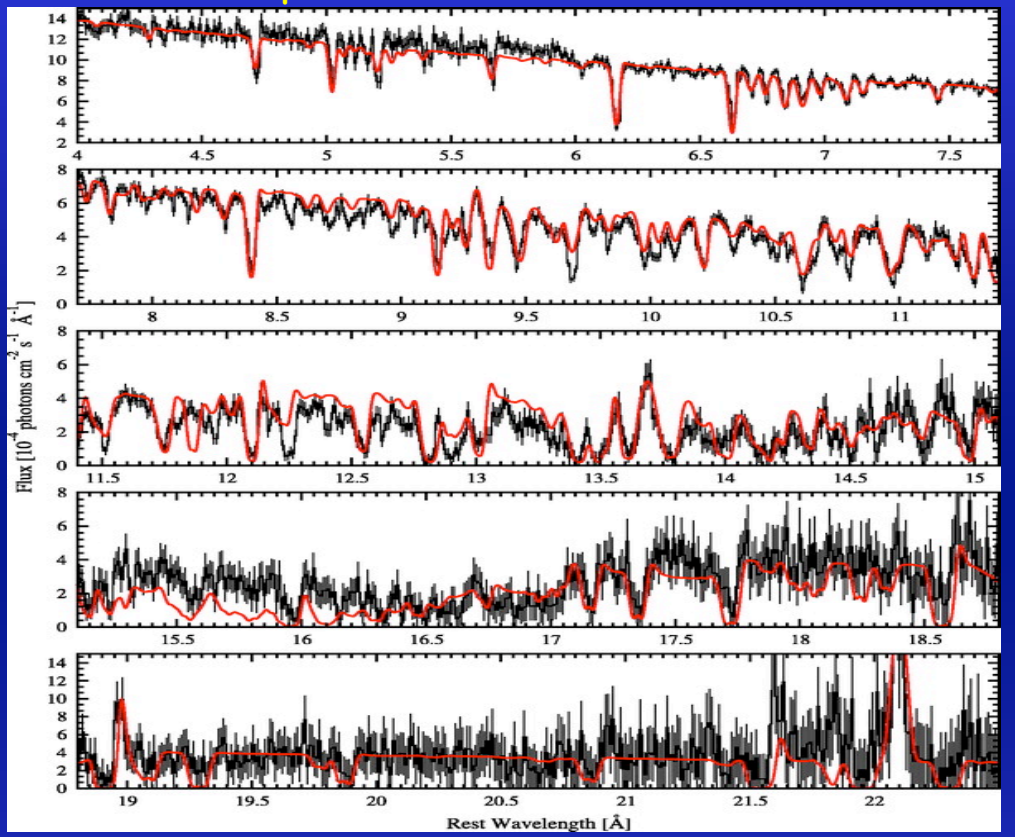
50% of all Sey 1s exhibit WAs

ASCA



Many details from Chandra/XMM gratings

NGC3783 Exp=900 ks



Kaspi et al. '01; Netzer et al. '02;
Georges et al. '03; Krongold et al. '03

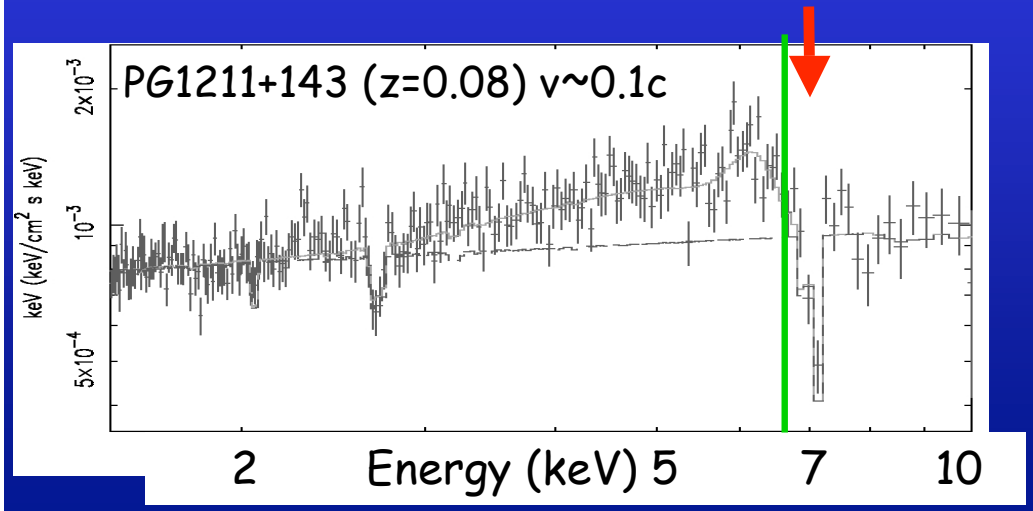
⇒ Clear now that often multiple ionization & kinetic components: outflows with v~100-1000 km/s

Blustin et al. 2004

ARAA Creenshaw et al. 2003

X-ray Observations (i/iii): Blue-shifted absorption lines/edges - High-v

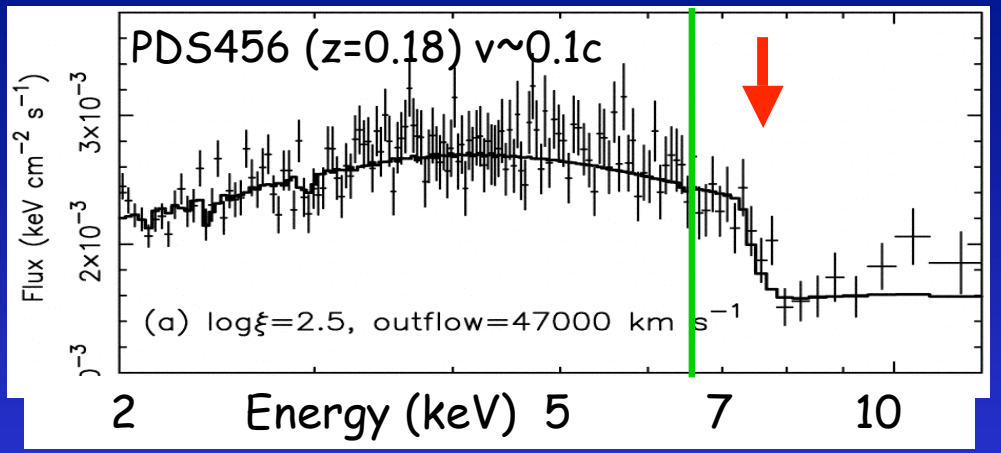
New and unexpected results from Chandra and XMM-Newton observations



See talk by Pounds

Pounds et al. 2003a,b, 2006
Reeves et al., 2008

(If) interpreted as Kα resonant absorption by Fe XXV (6.70 keV) or FeXXVI (6.96 keV)



Reeves et al. 2003

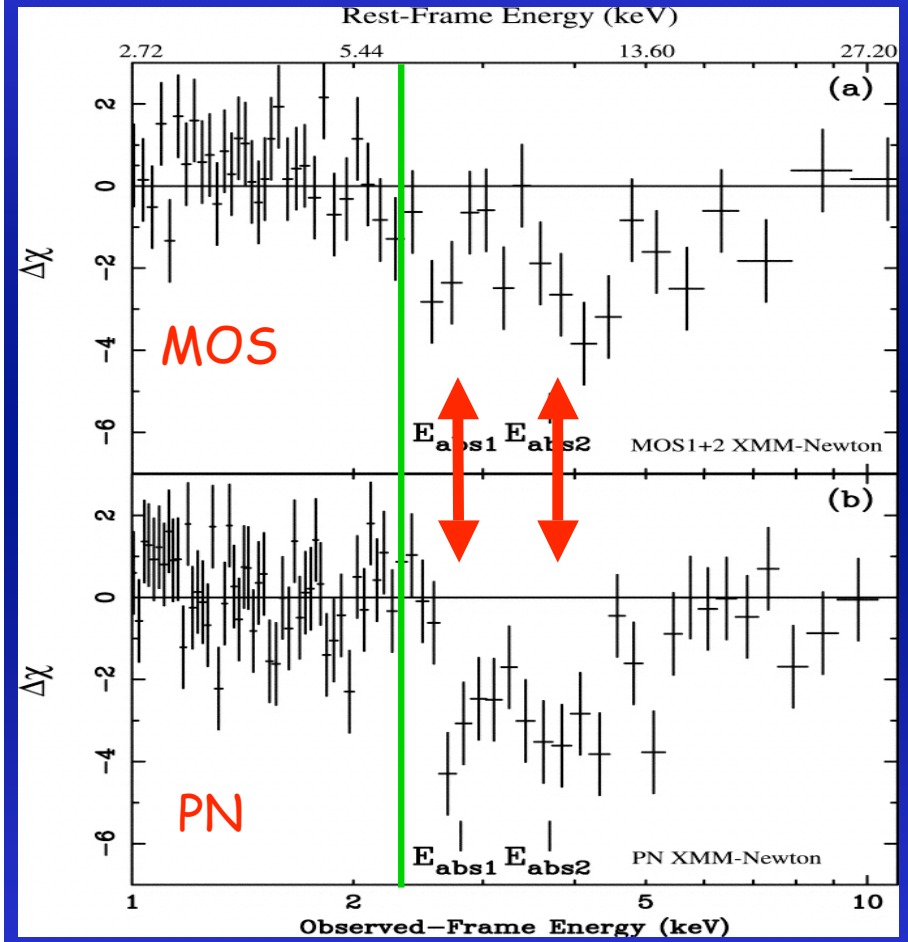
⇒ massive, high velocity and highly ionized outflows in several RQ AGNs/QSOs
Mass outflow rate: comparable to Edd. Acc. rate (~$M_\odot$/yr); velocity ~0.1-0.2 c

X-ray Observations (ii/iii): Blue-shifted absorption lines/edges - High-z

Massive outflows…also (mostly?) at high redshift

2 high-z BAL QSOs

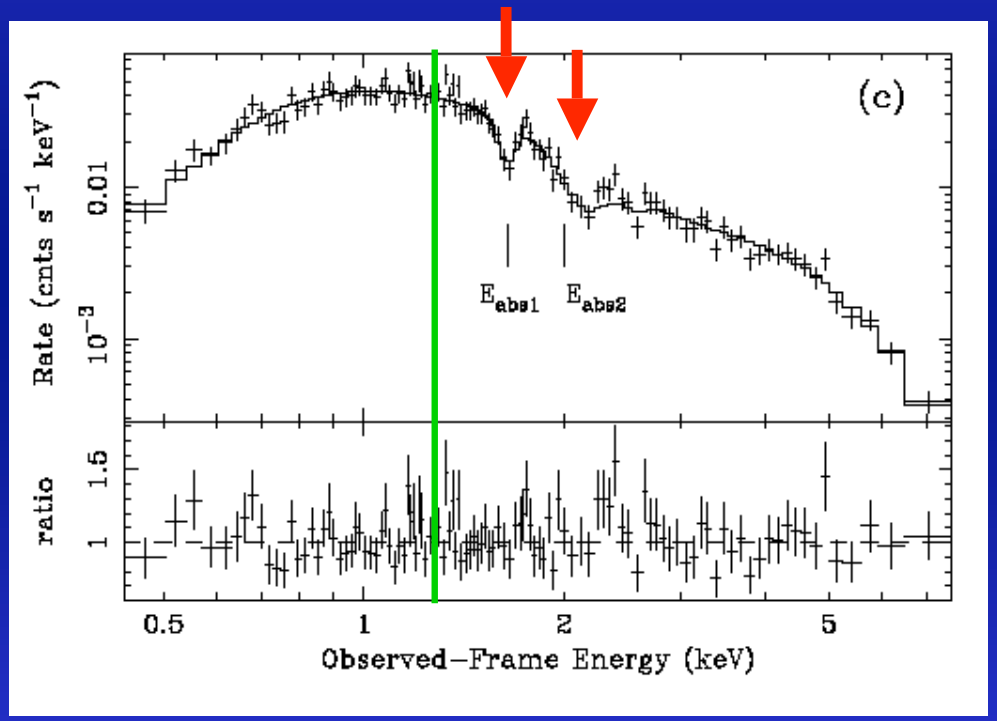
PG 1115+080 (z=1.72) v~0.1-0.3c



Chartas, Brandt & Gallagher, 2003

Chartas et al. 2002,
Hasinger, Schartel & Komossa 2002

APM 08279+5255 (z=3.91) v~0.2-0.4c



See also Wang et al. '05 (v=0.8c in qso@z=2.6)

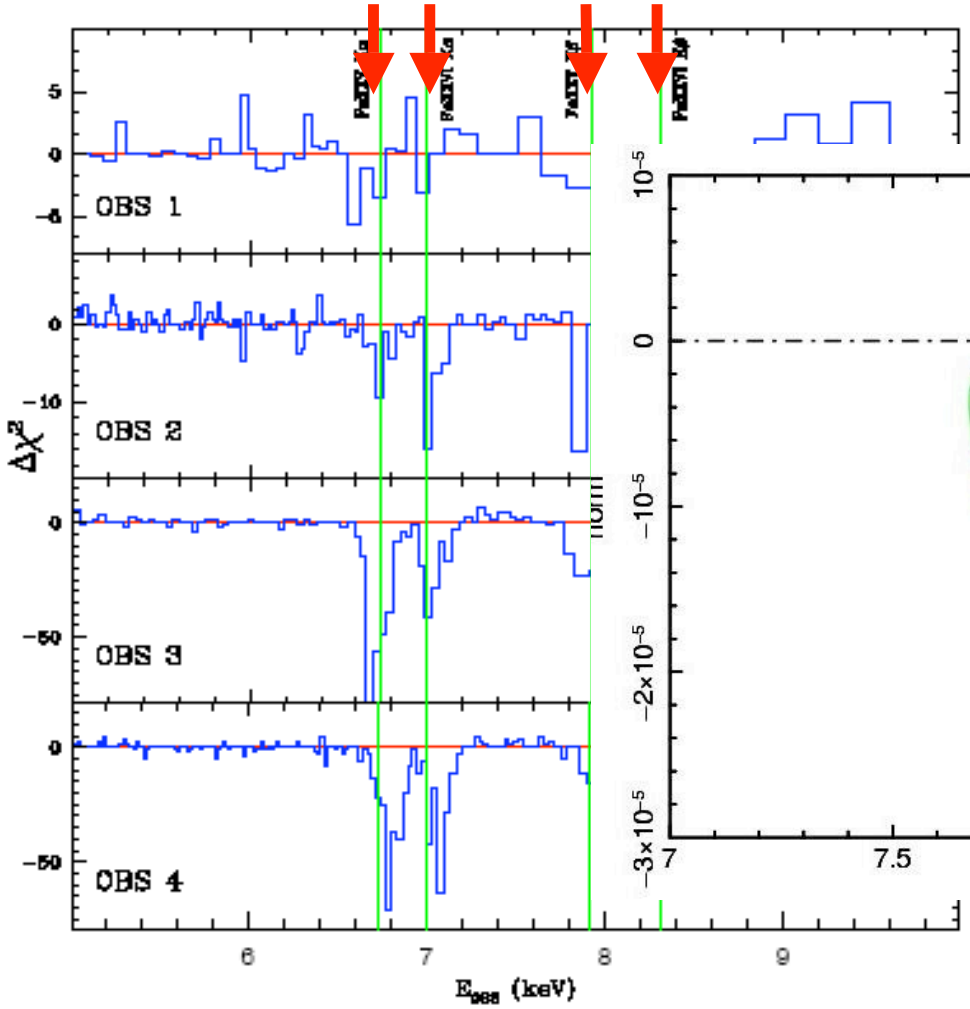
N.B.: Would have been undetected at z=0...

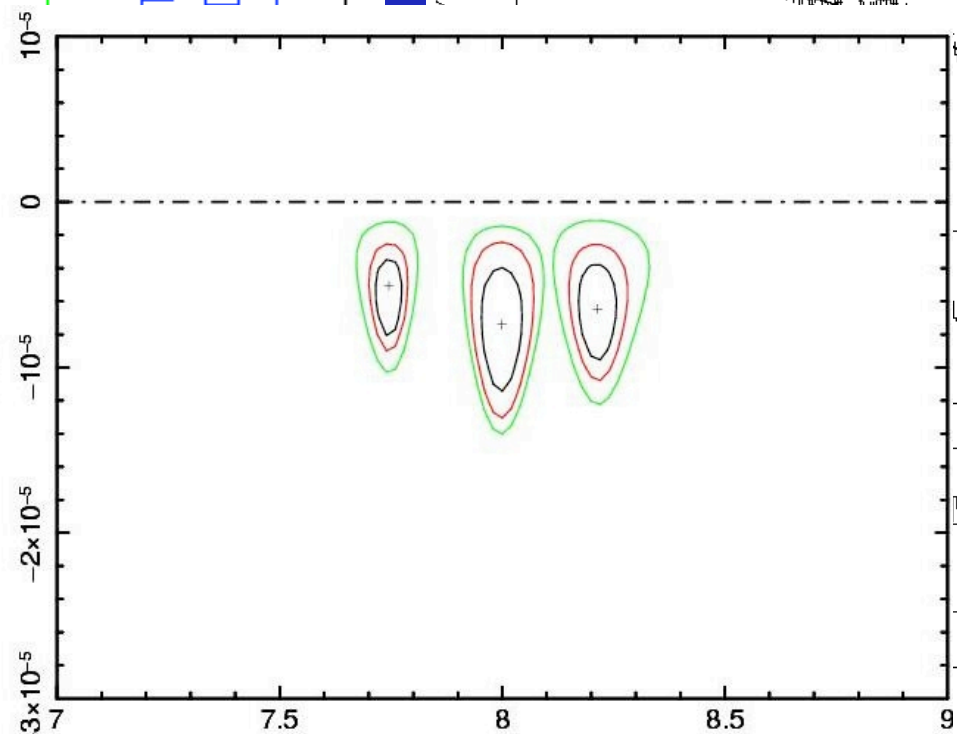
X-ray Observations (iii/iii): Blue-shifted absorption lines/edges - Variability

NGC1365

WA variability on timescales 1000-10000s

Mrk 509 (long-look, 200ks)





Risaliti et al. 2005

(See also Krongold et al. 2007)

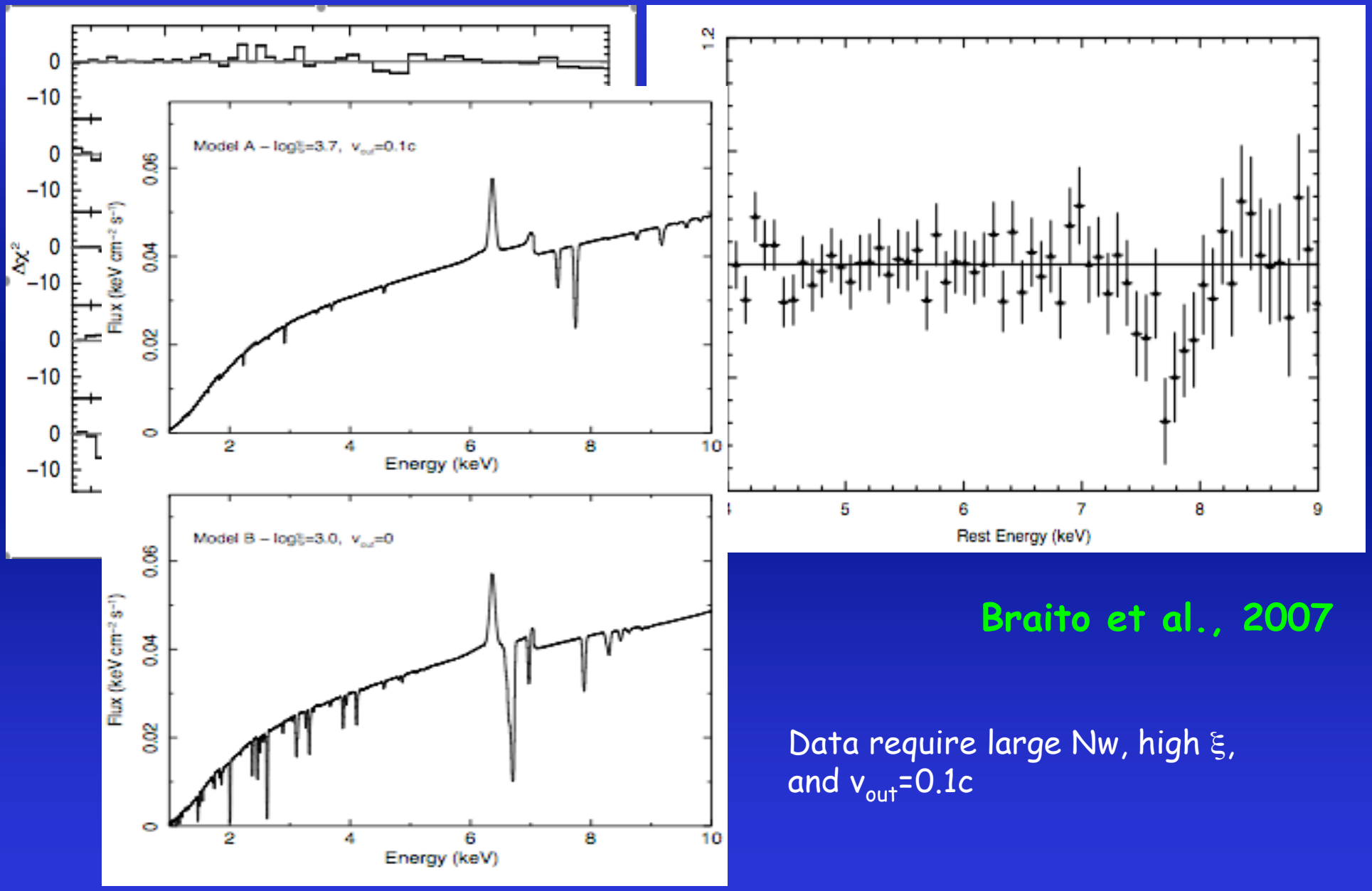
Cappi et al., in preparation; Dadina et al. '05

WA variability on time-scales 1000-10000 s ⇒ compact and inner absorber (current estimates <100 Rs)

X-ray Observations: Variability

Again, absorber **variability** on timescales ~20000s

MCG-5-23-16 (XMM+Chandra)

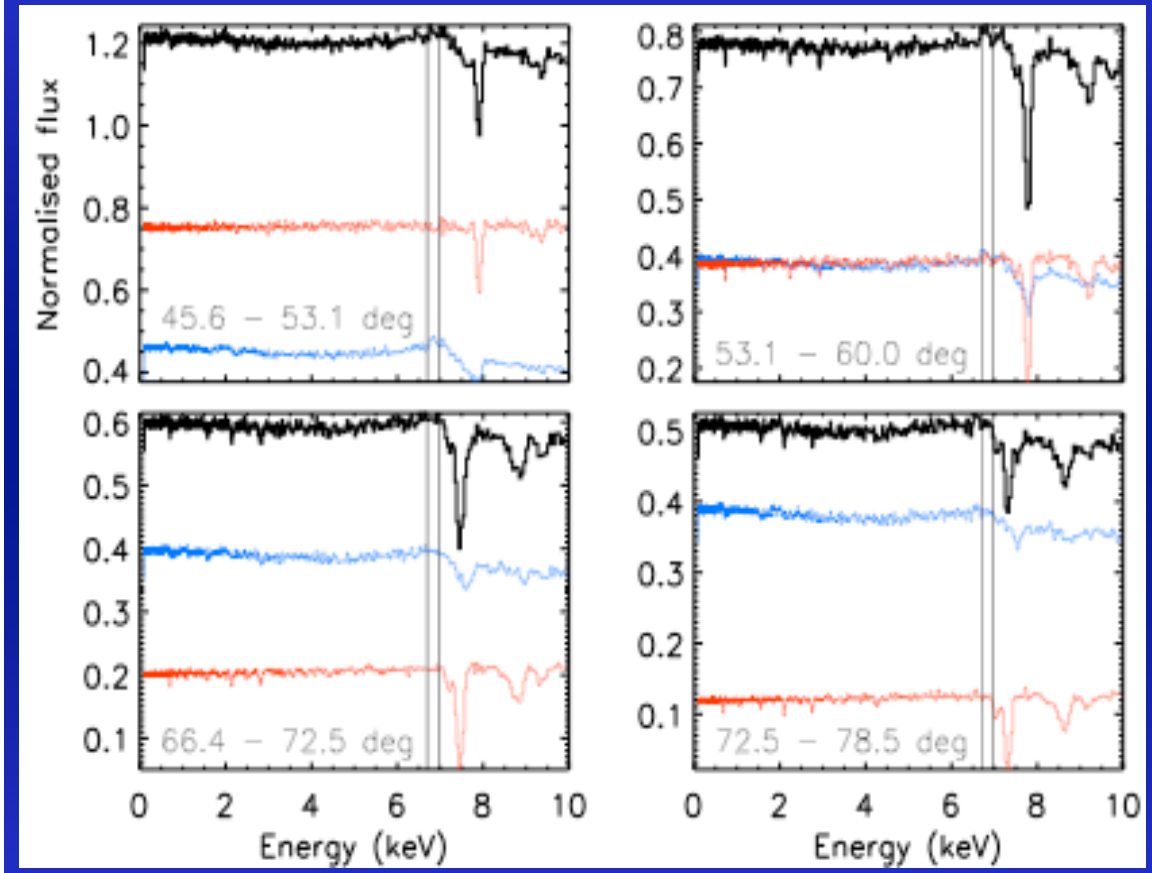


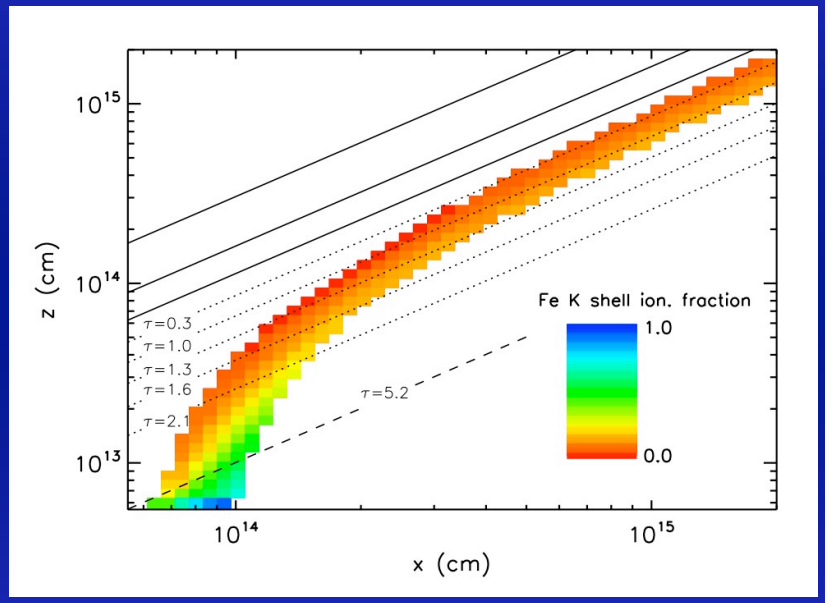
Braito et al., 2007

Data require large Nw, high ξ, and v_{out}=0.1c

Data Interpretation:

Yes indeed…one expects (mostly/only) strong Fe line absorptions when accounting for proper wind geometries and physics

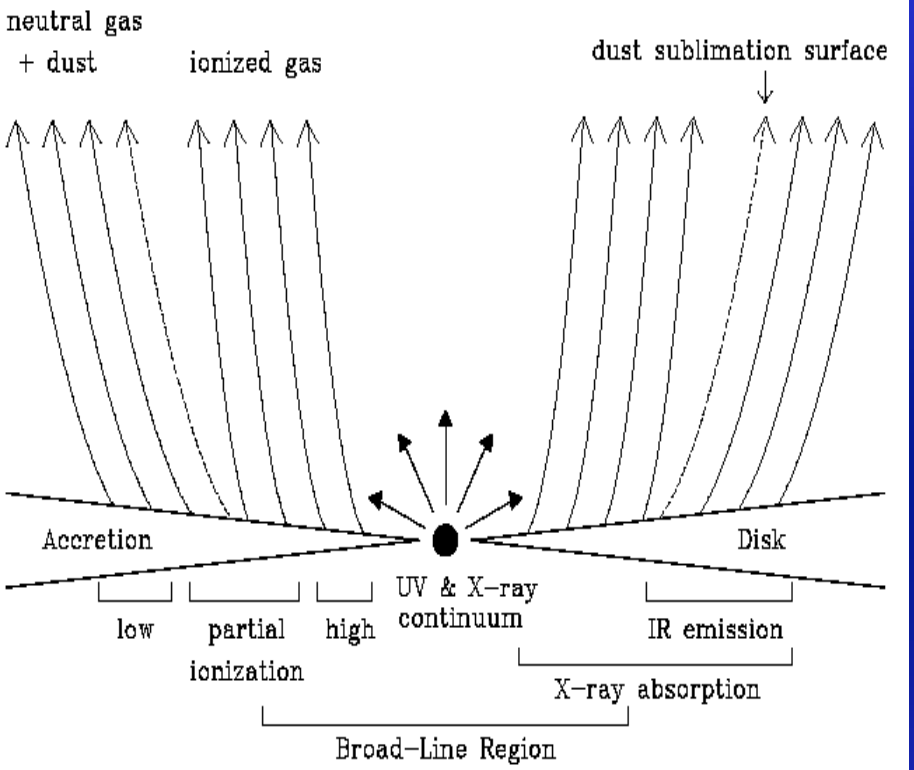




Sim et al., 2008

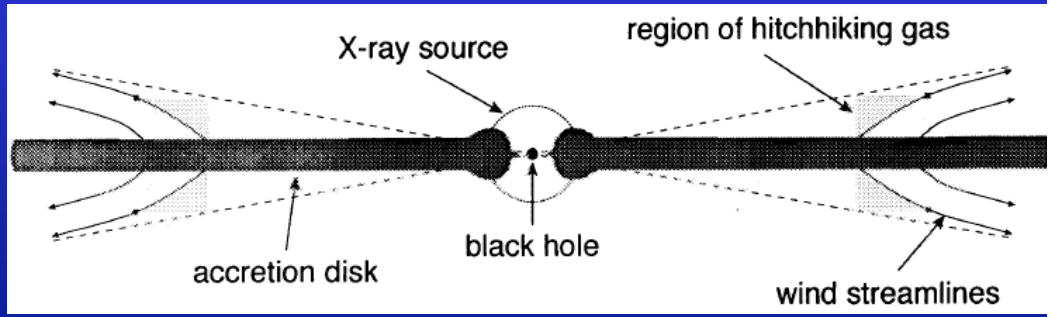
Theoretical Interpretation: (Three main) Wind dynamical models

i) Thermally driven winds from BLR or torus



Balsara & Krolik, 93; Woods et al. '96

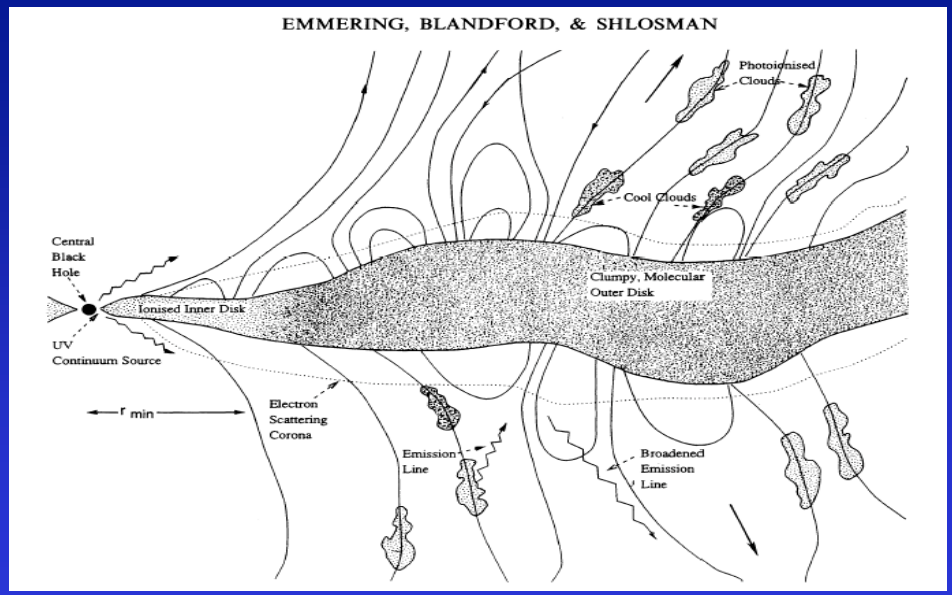
ii) Radiative-driven wind from accretion disk



Murray et al. '95, Proga et al. '00

...and/or...

iii) Magnetically driven winds from accretion disk

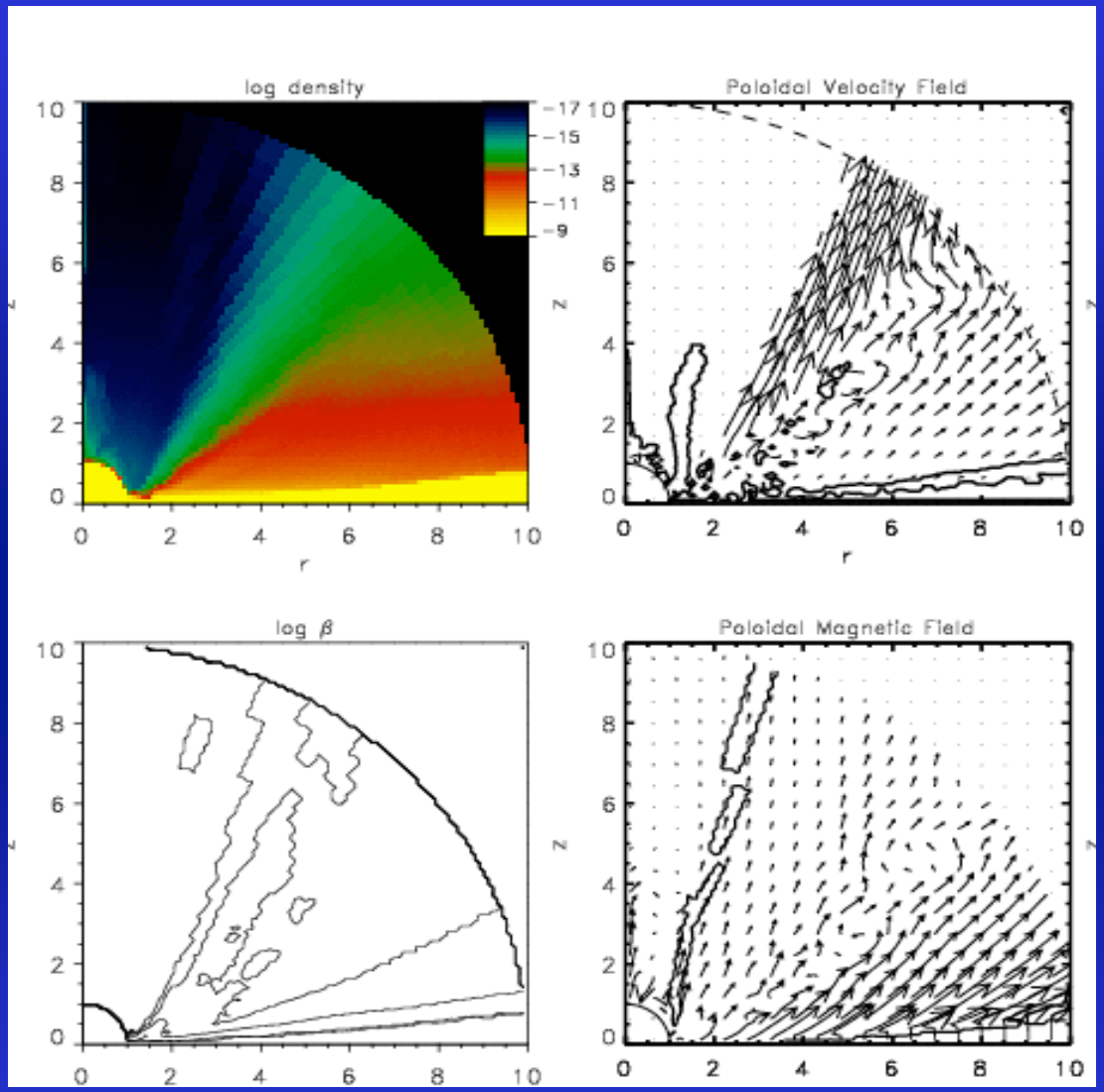


Emmering, Blandford & Shlosman, '92; Kato et al. '03

i) ⇒ Large R, low v

ii) and iii) ⇒ Low R and large v

Theoretical Interpretation: (Three main) Wind dynamical models



MHD+LD model by
Proga et al. '00, '03

Overall numbers (Nh, ξ, vout, etc.) are consistent with observations…

Most important open issue:

- ✓ Nw (cm^{-2})
- ✓ Location (R, DeltaR)
- ✓ Ionization state (ξ)
- ✓ Velocity
- ✓ Covering factor
- ✓ Frequency in AGNs

Fundamental to:

i) PHYSICS of accelerated and accreted flows (winds?, blobs?, etc.), i.e. understand how BHs accelerate earth-like quantities of gas to relativistic velocities

ii) COSMOLOGY: i.e. estimate the mass outflow rate, thus the impact of AGN outflows on ISM and IGM enrichment and heating!

Blustin et al., Creenshaw et al., King et al., Yaqoob et al., Chartas et al., Elvis et al.

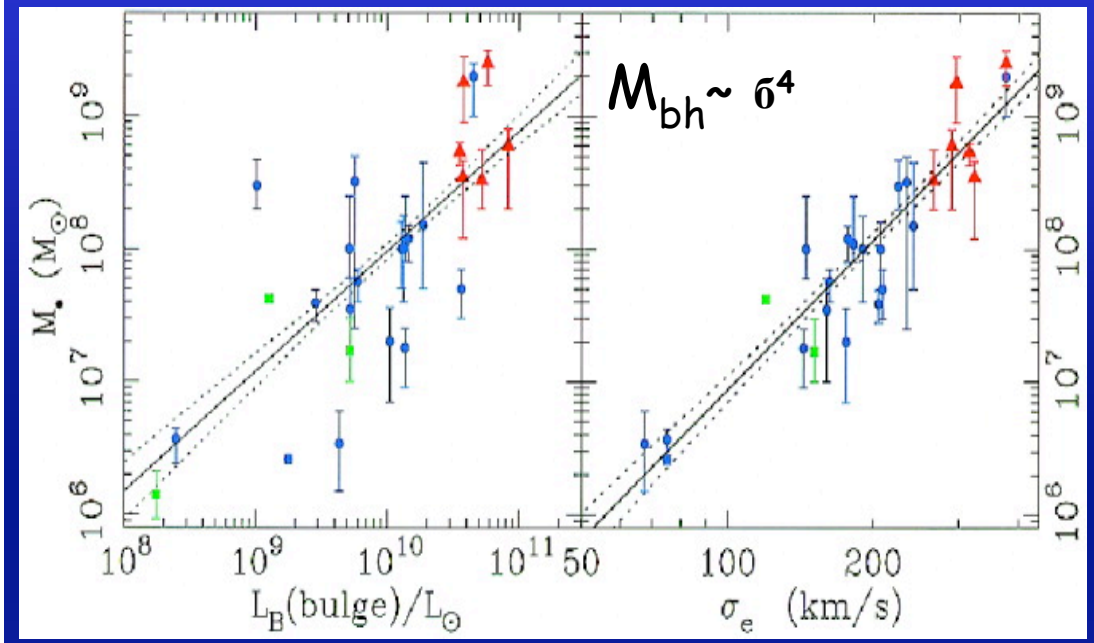
Current estimates have order of magnitude uncertainties, they go from:

dM/dt ($\propto L_{kin}$) few % to several times dM_{acc}/dt ($\propto L_{edd}$)

This is a fundamental (open) issue which should be core science in the future

Cosmological Importance of massive outflows:

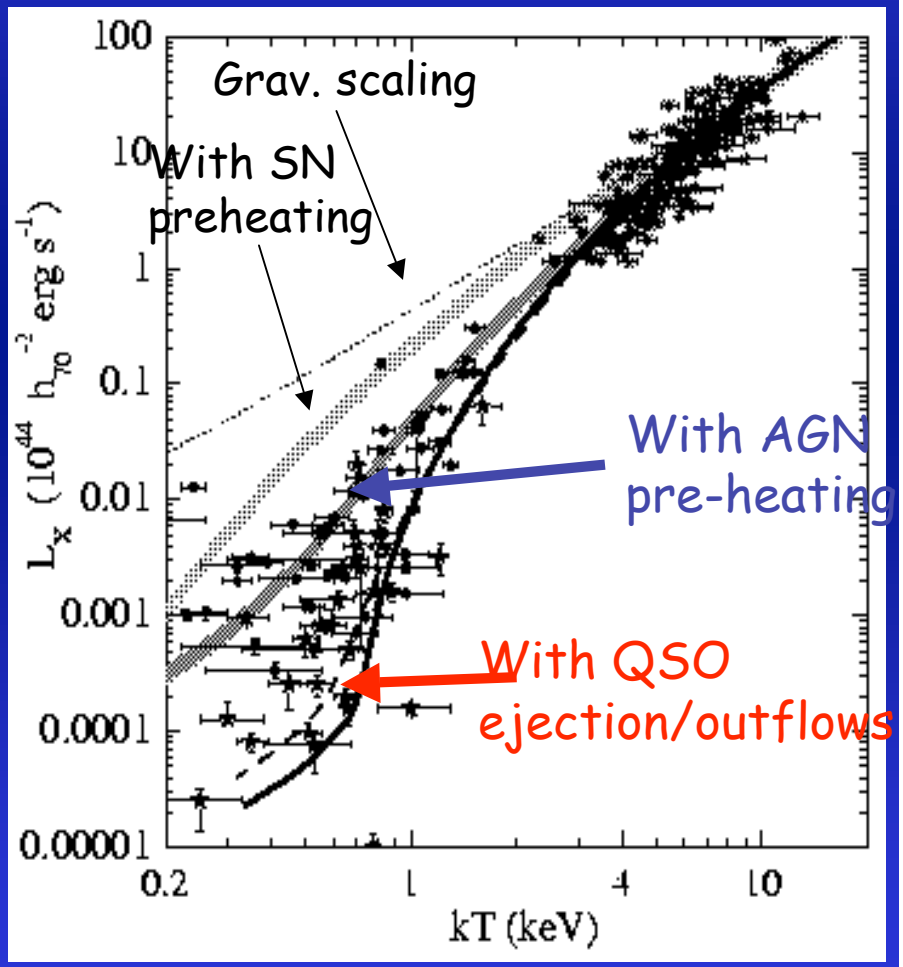
Role in feedback in the (co?)evolution of galaxies?



Magorrian et al. '98
Tremaine '02; Gebhardt '02...etc

(see e.g. King and Pounds '03, Crenshaw, Kraemer & George '03, ARA&A)

Role in heating groups and custers?



Lapi, Cavaliere & Menci, '05

Future (i/vii): In my opinion…

The tip of the Iceberg?

Maybe, BECAUSE

- "Detection bias" against transient features
- "Observational bias" against highest-v blueshifted abs. features (poor high-E sensitivity…cut-off at ~7 keV)

WHILE

X-ray absorption lines are naturally expected in models involving blobby/winds ejecta/outflows, such as those predicted by MHD simulations of accretion disks

Future (ii/vii): Directions

1) Better sample numbers/statistics from XMM-Newton

- <Nw> (cm^{-2})
- <Ionization state> (ξ)
- <Velocity>

- Typical Location (R, DeltaR)
- <Covering factor>
- Frequency in AGNs

2) Need a mission with high enough throughput between 2-15 keV…to start "following" the wind

"The answer, my friend, is blowin' in the wind" (Bob Dylan 1963)

Future (iii/vii): Better statistics on X-ray (bright) selected samples

Tombesi et al., in prep.

Source	Counts ($\times 10^6$)	FeXXV Kα	FeXXV Kβ	FeXXVI Lyα	FeXXVI Lyβ	Blue-shift	Obs.	Detection
NGC4151	1.3						0/3	
IC4329A	7.5			X		**~0.1c**	1/1	>99%
NGC3783	2.6	X				<0.01c	3/4	>99%
NGC5548	1.3						0/3	
NGC3516	1.7	X	X	X	X	**~0.01c**	4/5	>99.9%
MRK509	1.5			X		**~0.1-0.2c**	3/5	**~99%**
MCG-6-30-15	2.6	X		X		<0.01c	0/5	~99% *
MCG+8-11-11	1.3						0/1	
MRK279	0.8	X	X			<0.01c	1/3	**~99%**
AKN120	2.9						0/1	
NGC3227	1.8						0/2	
MRK590	0.3						0/1	
NGC7469	1.9						0/2	
MRK79	0.3			X		**~0.1c**	1/3	>99%
FAIRALL 9	0.3						0/1	
ESO198-G24	0.9						0/1	
NGC7213	0.7						0/1	

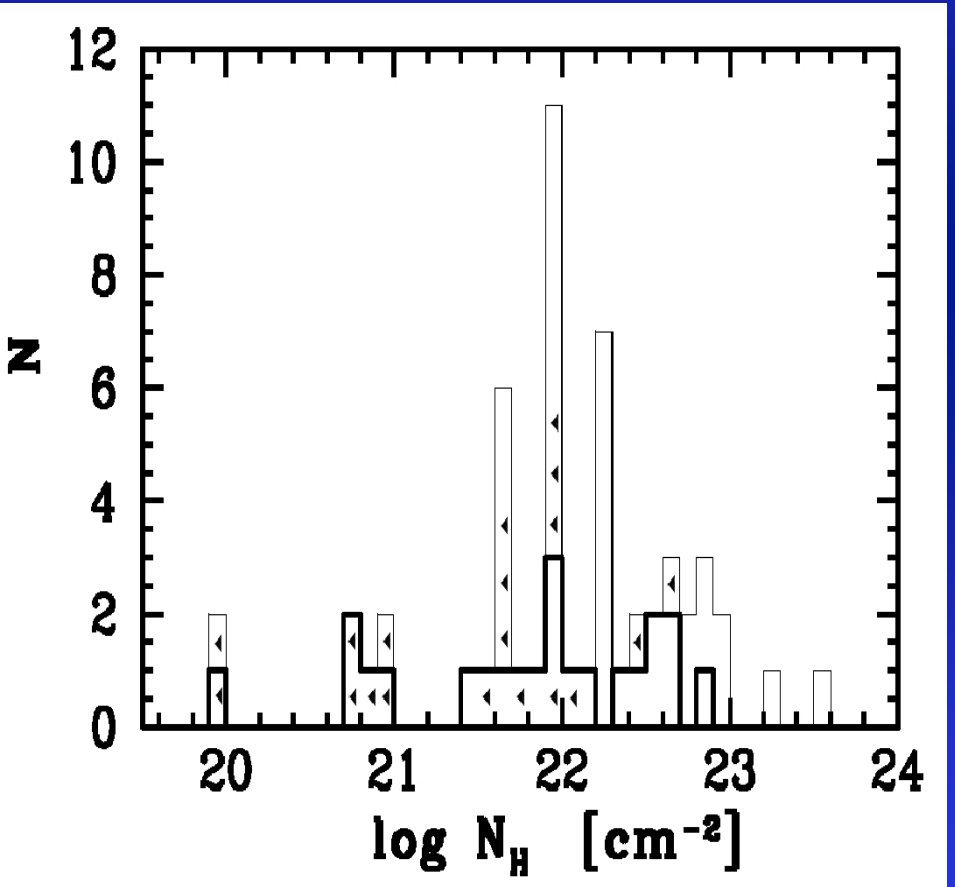
See poster by Tombesi et al.

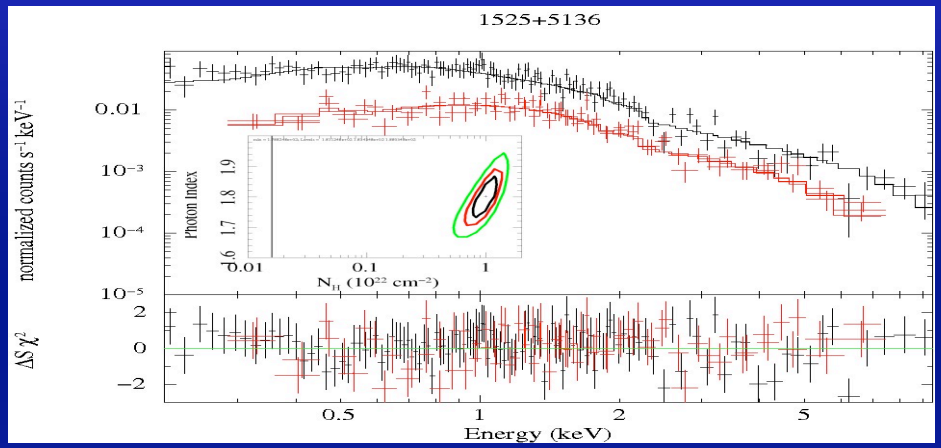
Total: 13/41 obs.
7/22 sources

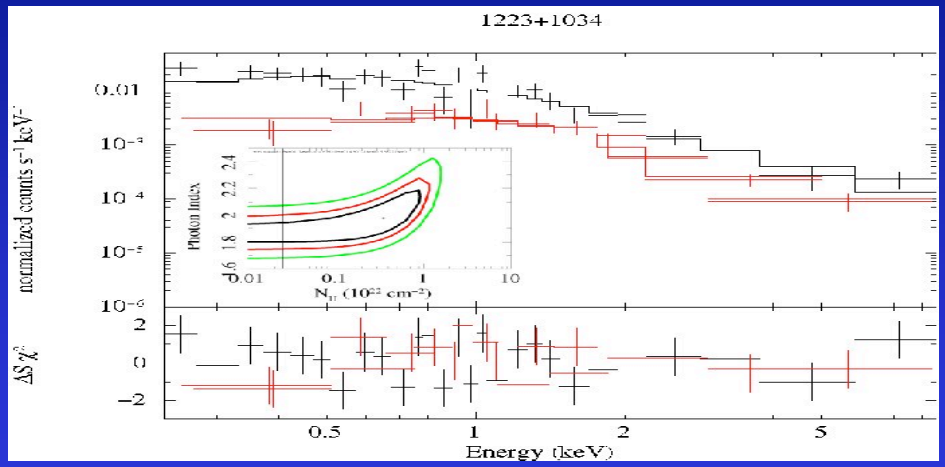
Future (iv/vii): Better statistics on optically-classified samples:

SDSS's BALQSOs cross-correlated with 2XMM
⇒ 22 spectra and 23 HRs to estimate Nh, Γ, Lx, etc.

Giustini et al., submitted



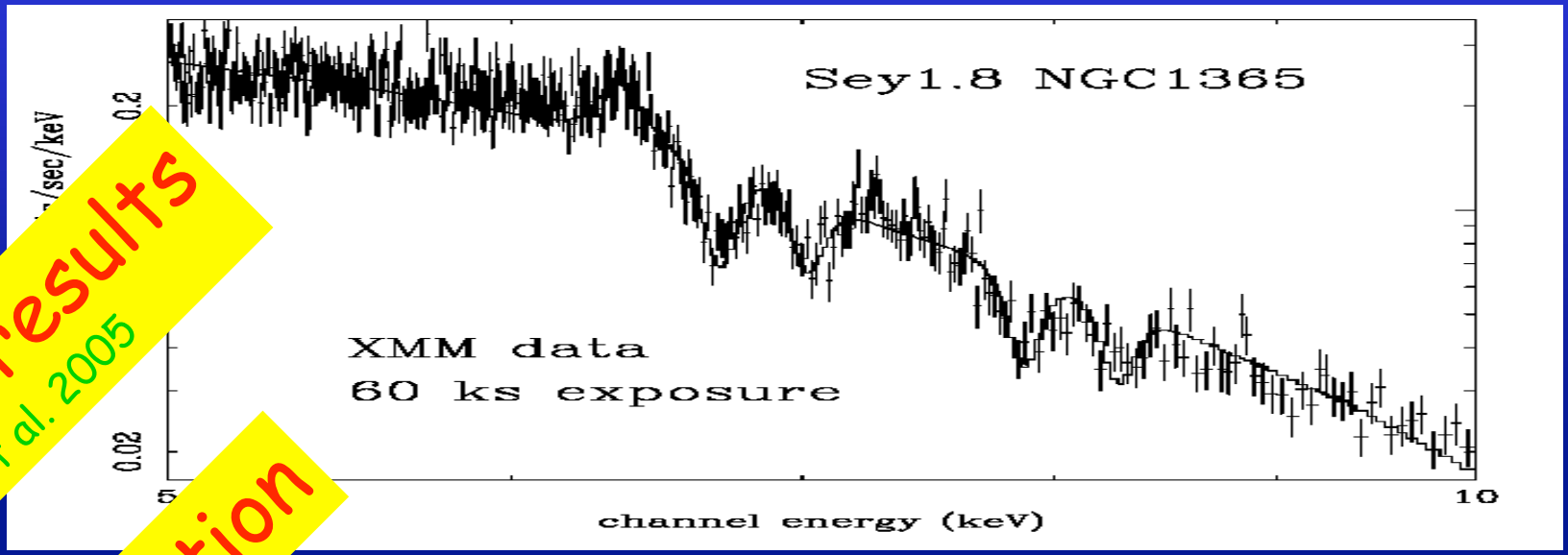




See poster E17-0049-08 by Giustini et al.

Future (v/vii): Shorter time-scales and better sensitivity…with XEUS

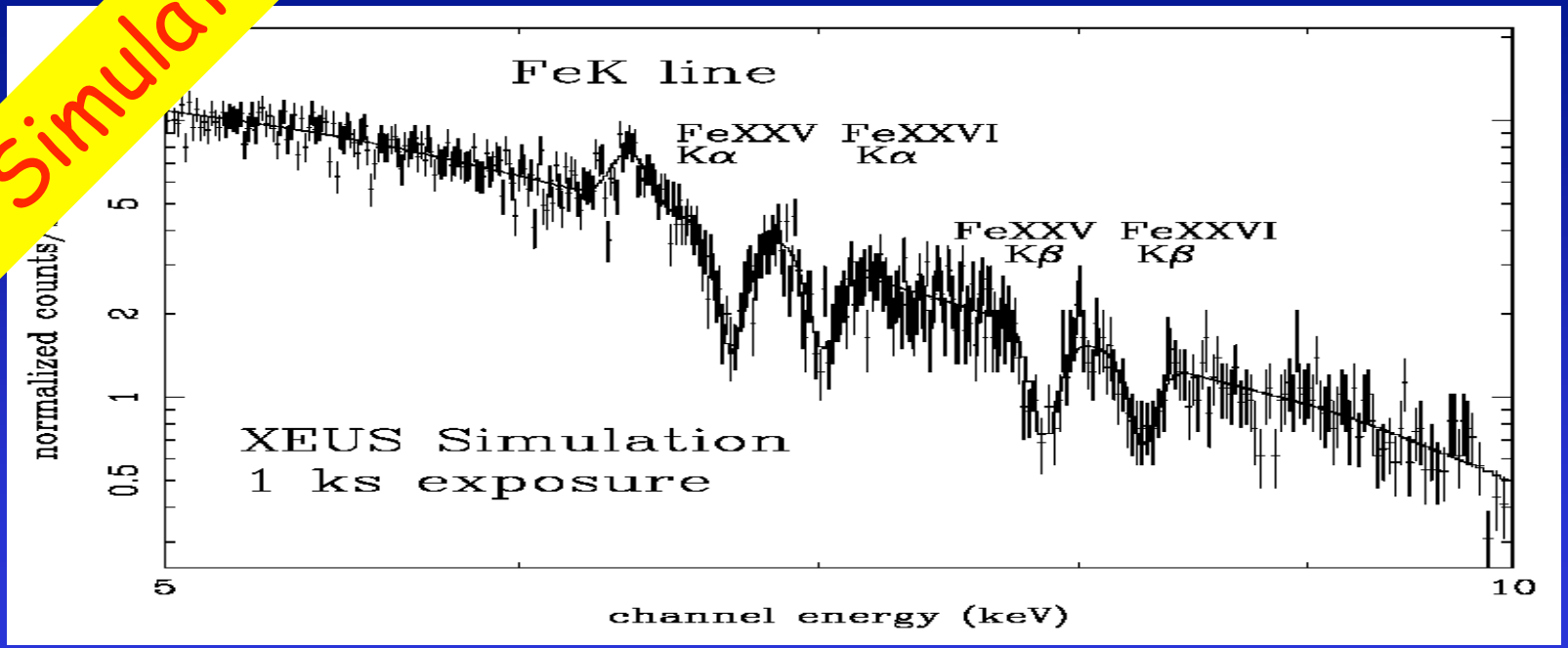
NGC1365 F(2-10)=10^{-11}cgs S/N>3



XMM results

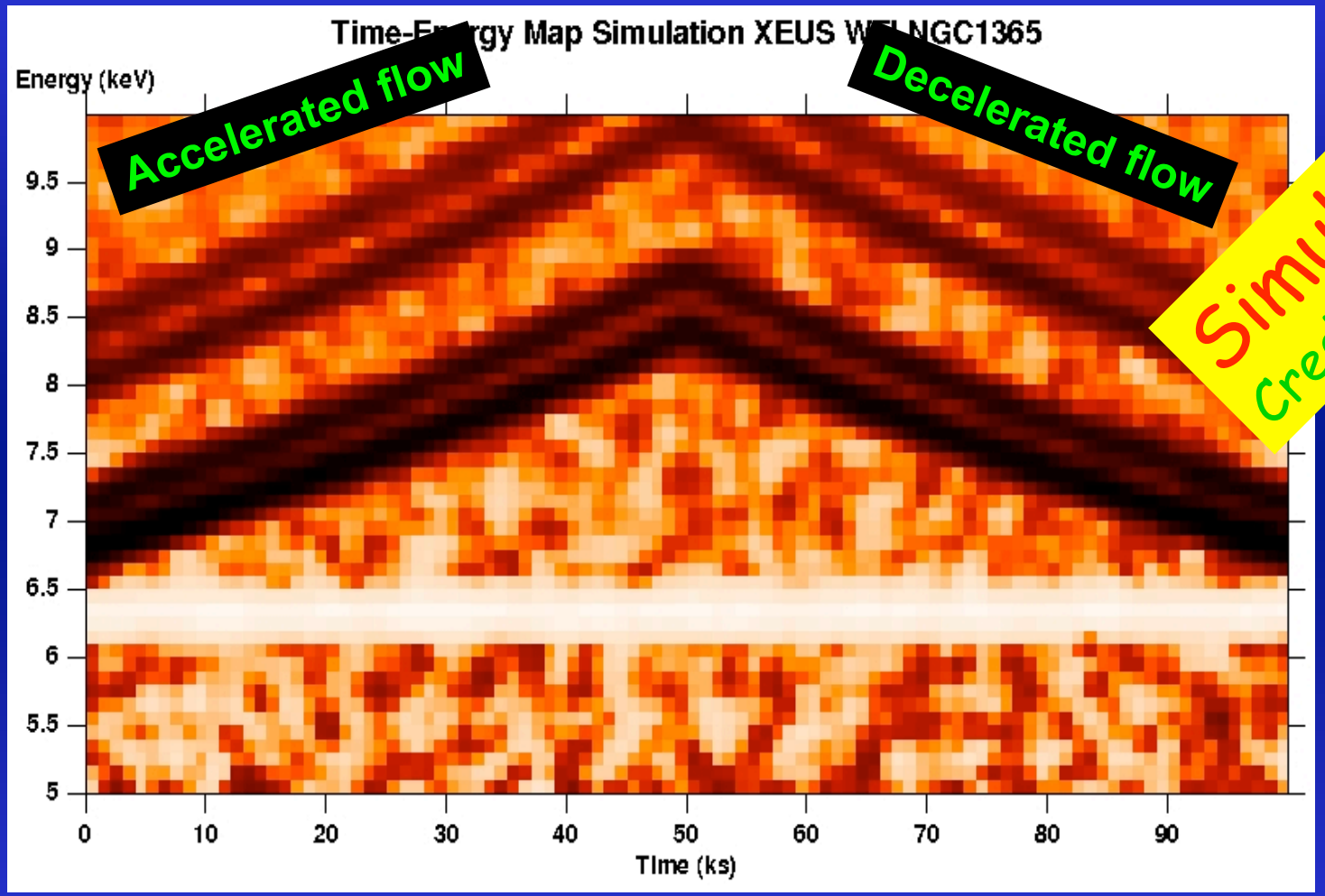
Risaliti et al. 2005

XEUS Simulation



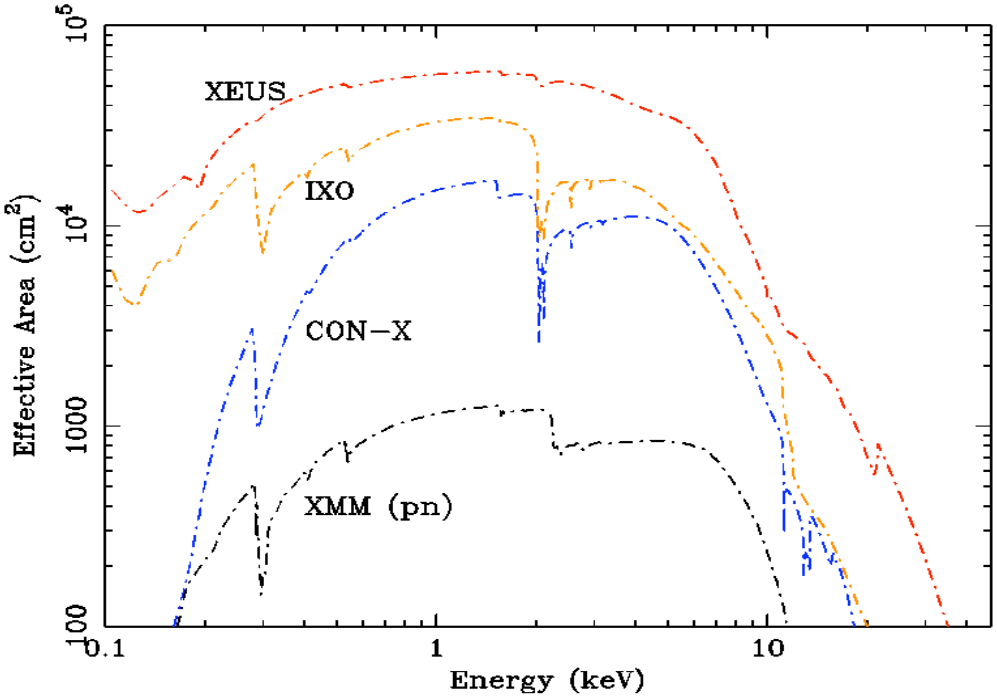
Future (vii/vii): Time vs. energy maps

NGC1365 F(2-10)=10^{-11}cgs S/N>3

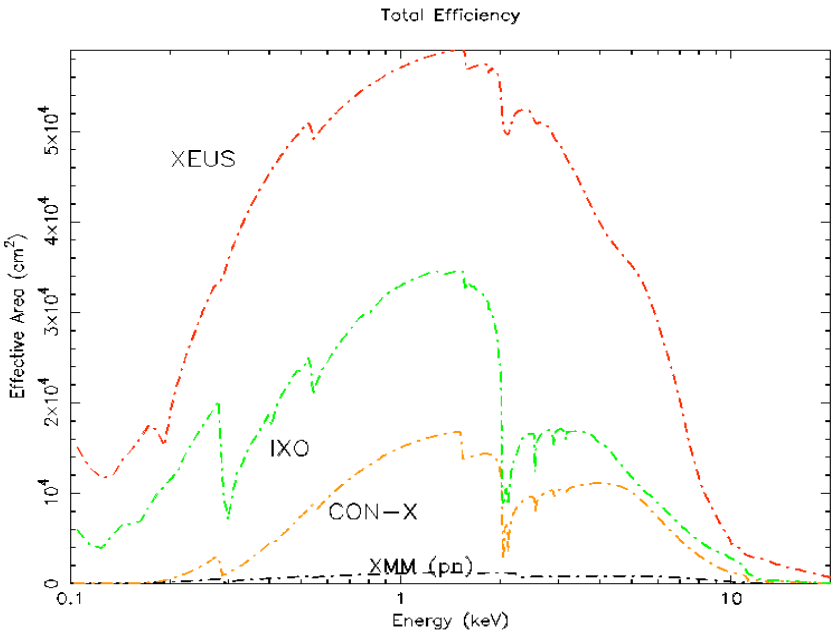


Highest throughput for time-resolved detections of abs. lines
⇒ real-time, extreme dynamics, i.e. inward and outward accelerations!?
(line $\Delta v/\Delta t$) ....blob=test particle to test Kerr vs. Schwarzschild GR

Future (vi/vii): Con-X, XEUS or IXO?



Area (cm2)	@1 keV	@4 keV	@6 keV	@7 keV
XEUS	58000	40000	30000	20000
IXO	30000	15000	9000	6000
CON-X	15000	11000	7500	5000
XMM(PN)	1150	820	800	650



$A_{eff} \approx F_{length}^2 \times \theta_{crit}^2 \times R_{efl}^2$, where $\theta_c \propto \rho^{0.5}/E$

Summary

I briefly reviewed the current evidence for blue-shifted absorption lines from highly ionized Fe in AGNs (in both Sey and QSOs)

These indicate the existence of highly-ionized, high velocity, massive outflows in AGNs, BUT STILL ORDER OF MAGNITUDES UNCERTAINTIES on energy/momentum and mass involved.

This topic still requires better measurements of intensity, energy and frequency/recurrency but has a great potential for the study of: launching mechanisms/characteristics of outflows/jets (mechanical energy emerging from BH), important not only for (relativistic) physics but also for link with cosmology

Prospects for future progress are to:

i) Confirm/secure these findings with longer XMM/Chandra observations

ii) Probe lower time-scales (with > 2m**2 @6 keV, i.e. XEUS-like mission)

iii) Probe high-velocity gas with high-energies (with Simbol-X and/or XEUS hxd)