A search for relativistic outflows signatures in the X-ray spectra of Radio-Quiet AGNs

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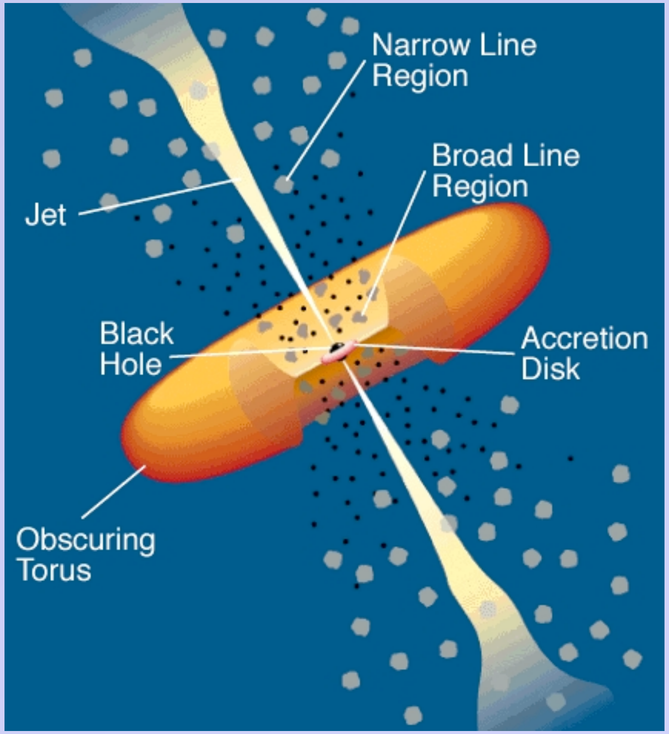
Active Galactic Nuclei



- Very luminous phenomena at center of galaxies

  $L=10^{41}$-10^{46} erg s^{-1}

- Powered by accretion onto SMBHs

  $M=10^{6}$-10^{9} $M_{\odot}$

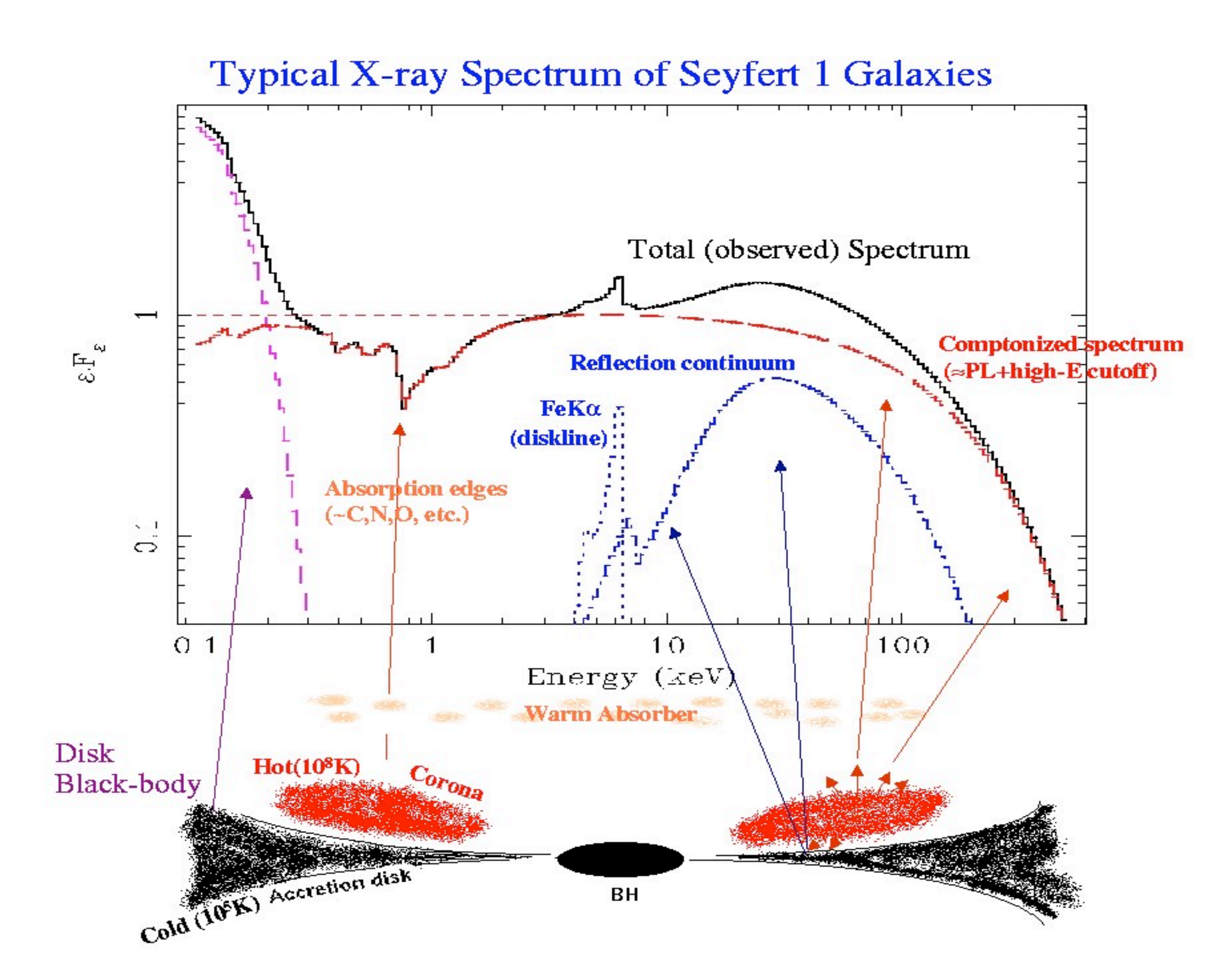
General structure:

- Central SMBH
- Accretion disk
- Obscuring Torus (Type 1 and 2 dicotomy)
- Outflows, winds
- Relativistic Jets (in Radio Loud Objects)

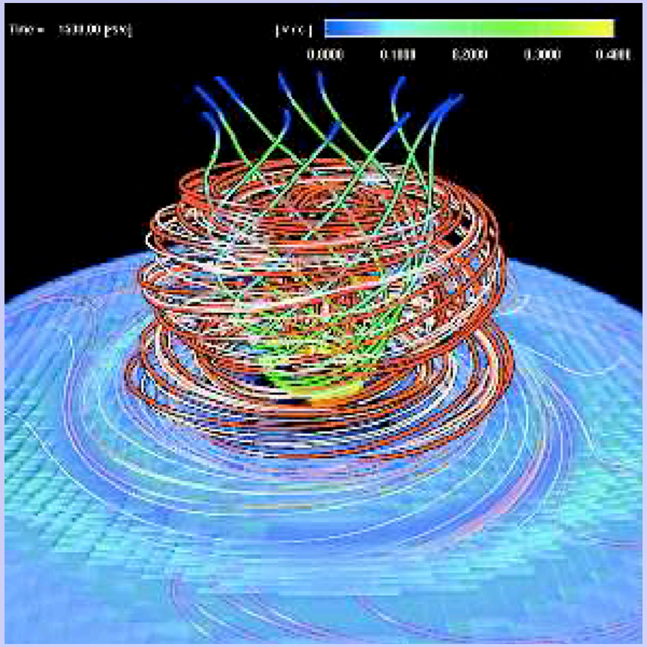
X-ray emission:

- Production region very close to SMBH
- Fundamental for the study of accretion physics (the central engine)

The complex X-ray Spectrum



X-ray outflows



Magnetically driven accretion disk wind (Kato et al. 2004)

<u>Classical AGN warm absorbers</u>:

- ~50% Seyfert Galaxies
- mainly absorption in soft X-rays (OVII/VIII, NeIX/X, Fe L)
- ionization logξ=0-3 erg s^{-1} cm
- outflow velocity v=10-1000 km/s
- column density $N_H=10^{20}-10^{23}$ cm^{-2}
- distance r=1-100pc
- possible connection optical-UV BLR or Torus Winds

(Blustin et al. 2004, McKernan et al. 2007)

<u>Evidence for a new, more extreme component</u>?

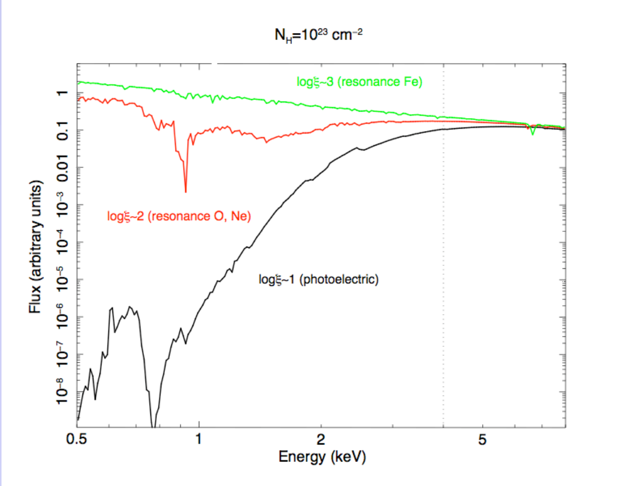
- higher ionization logξ=3-5 erg s^{-1} cm
- higher column density $N_H=10^{22}-10^{24}$ cm^{-2}
- relativistic outflow velocity v=0.01-0.3c
- variability on short time scales (~100ks)
- location closer to SMBH r<0.01pc (<$10^3 r_s$)
- <u>accretion disk winds/ejecta</u>? (see review Cappi 2006)
- <u>global statistical incidence and characteristics on population</u>?

Photoionized X-ray absorbers

Ionization parameter $\xi = L/nr^2$

Line			<E>	<f>
Fe XXV Kα	$1s^2$–$1s2p$	i+r	6697 eV	7.7×10^{-1}
Fe XXV Kβ	$1s^2$–$1s3p$	i+r	7880 eV	1.55×10^{-1}
Fe XXVI Lyα	1s–2p	1 + 2	6966 eV	4.2×10^{-1}
Fe XXVI Lyβ	1s–3p	1 + 2	8250 eV	8.0×10^{-2}

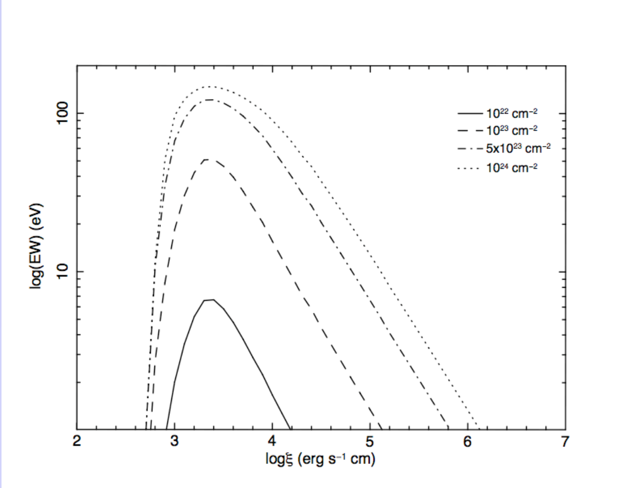
- Absorbing gas is photo-ionized by central source
- Elements lighter than Fe are fully ionized
- He/H-Fe resonant absorption lines spectroscopy (4-10keV)
- All main atomic processes modeled by XSTAR code
- Direct fit of X-ray spectral data



Curve of Growth analysis

- extensive XSTAR simulations to derive Fe ion populations
- tested different input SED shapes
- direct line Voigt profile integration
- line EW as a function of:
  - Total column density N_H
  - Ionization parameter ξ
  - Gas turbulent velocity v_{turb}

(results will be published in Tombesi et al. in prep (2))

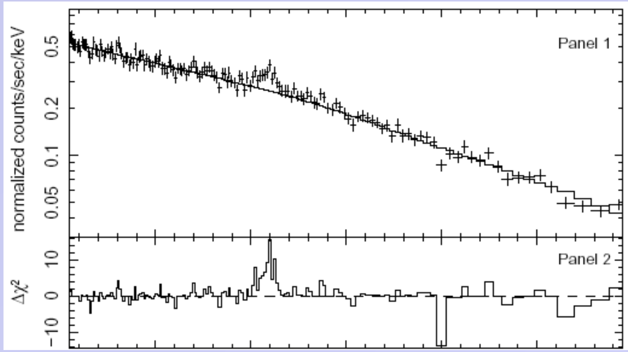


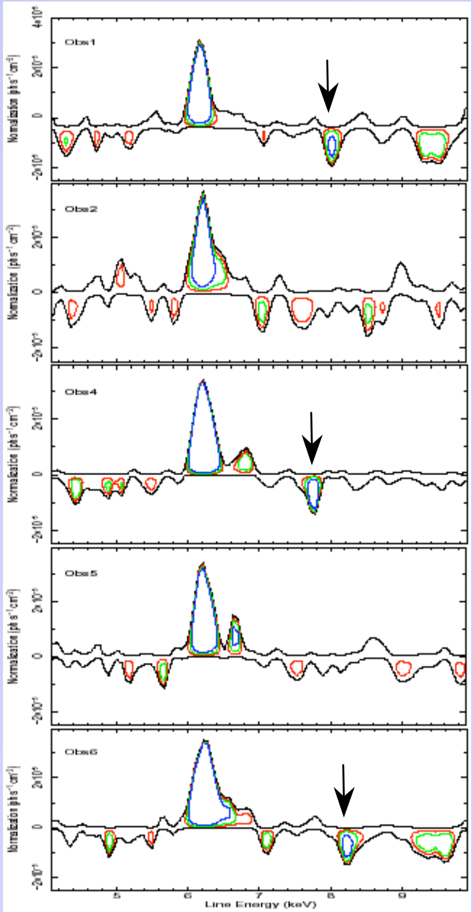
Curve of Growth FeXXVI Lyα
(Tombesi et al. in prep (2))

The case of Mrk509

- Bright Seyfert 1 in 2-10keV

  ($F=2\text{-}5\times10^{-11}$ erg s^{-1} cm^{-2}, $L=1\text{-}3\times10^{44}$ erg s^{-1})
- Local (z=0.034)
- $M_{SMBH} \cong 10^8 M_\odot$ (Peterson et al. 2004)
- 5 XMM-Newton observations (fom 2000 to 2006)





(Cappi, Tombesi et al. 2009 A&A accepted)

EPIC pn data analysis:

- Fe K band spectral analysis (4-10keV)
- Galactic absorbed power-law continuum
- neutral Fe Kα emission line @ 6.4 keV
- blind search for absorption lines
- visualization in contour plots

  (68%, 90%, 99% F-test confidence contours)

Detection probability:

- extensive Monte Carlo simulations
- null hypothesis without absorption lines
- 10^4 simulated spectra for each observation
- simulated $\Delta\chi^2$ distribution

The case of Mrk509

Results from data analysis:

- Narrow Fe resonant absorption lines in 3 obs
- Detection probability >99% F-test, >95% MC (global >99.9%)
- confirmed by MOS1-2 detectors
- variability on ~100ks time scales

Direct XSTAR photoionization modelling:

- $\log\xi = 5 \pm 0.4$ erg s^{-1} cm
- $N_H = 2\text{-}4$ ($\times 10^{23}$) cm^{-2}
- relativistic outflow $v_{out} = 0.14\text{-}0.20c$
- $v_{turb} \sim 1000$ km/s

Other outflow characteristics:

- Close to the SMBH: $r < L/(\xi N_H) = 0.007$pc ($<500\ r_s$)
- Faster than escape velocity: $v_{out} >> v_{exc} = (r_s/r)^{1/2}c$ at $500 r_s$
- High mass loss rate with injection in ISM: $M_{out} \leq 4\ (\Omega/4\pi)\ M_\odot yr^{-1}$
- Low covering factor (Ω) or intermittent outflow for BH growth: $M_{out}/M_{acc} \sim 10\ (\Omega/4\pi)$

Evidence of massive and relativistic outflows near SMBH!

- Outflow/ejecta from accretion disk or part of a disk wind?
- Radiatively/magnetically driven outflows?
- Stratified X-ray warm absorbers?

(eg. Proga 2003, King & Pounds 2003, Proga & Kallman 2004)

Sample of radio-quiet AGNs

Statistically quantify the incidence and characteristics of highly ionized warm absorbers in a complete sample of sources.

- Selection all Seyfert 1, Seyfert 2 and NLS1 in RXTE All-Sky Slew Survey Catalog
- Cross-correlation with XMM-Newton Accepted Targets Catalog (pointed observations)
- 44 objects for 104 XMM observations
- Local ($z \leq 0.1$)
- X-ray bright ($F_{4\text{-}10keV}=10^{-12}$-$10^{-10}$ erg s^{-1} cm^{-2})

Uniform data Analysis:

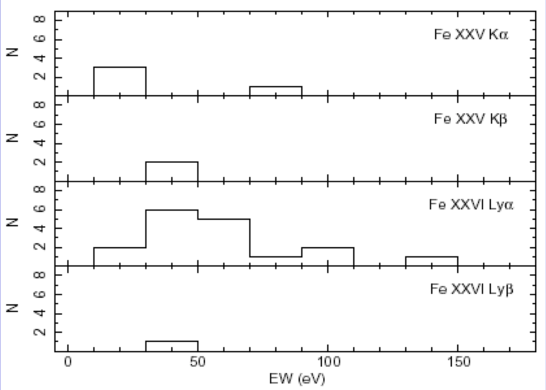
- reduction and analysis of all EPIC pn spectra 4-10keV
- baseline model: Absorbed power-law + Gaussian Fe emission lines
- blind search for blue-shifted Fe absorption lines
- detailed check of instrumental background and calibration
- detection confidence level by F-test and extensive Monte Carlo simulations

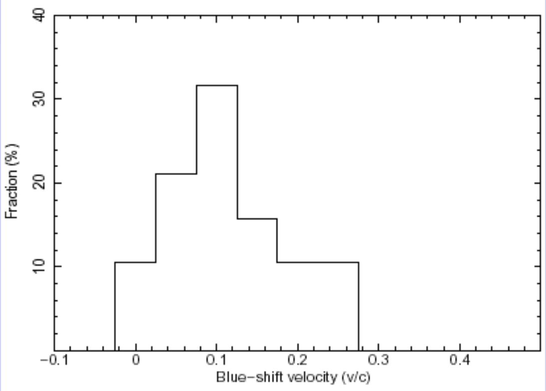
Sample of radio-quiet AGNs

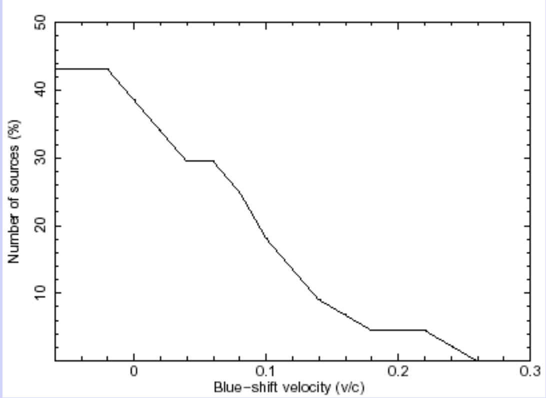
<u>Preliminary results</u>:

- 36 He/H-like Fe absorption lines detected
  (global confidence ≥99.999997% !)
- 17/44 objects with blue-shifted absorption (≥40%)
- 11/44 objects with v_{out}≥0.1c (≥25%)
- blue-shift velocity distribution ~0-0.3c, peak @ ~0.1c
- mean outflow velocity $<v_{out}>=0.103\pm0.004c$
- FeXXVI Lyα mean EW=50±10eV (other lines ~30eV)

(Tombesi et al. in prep (1))







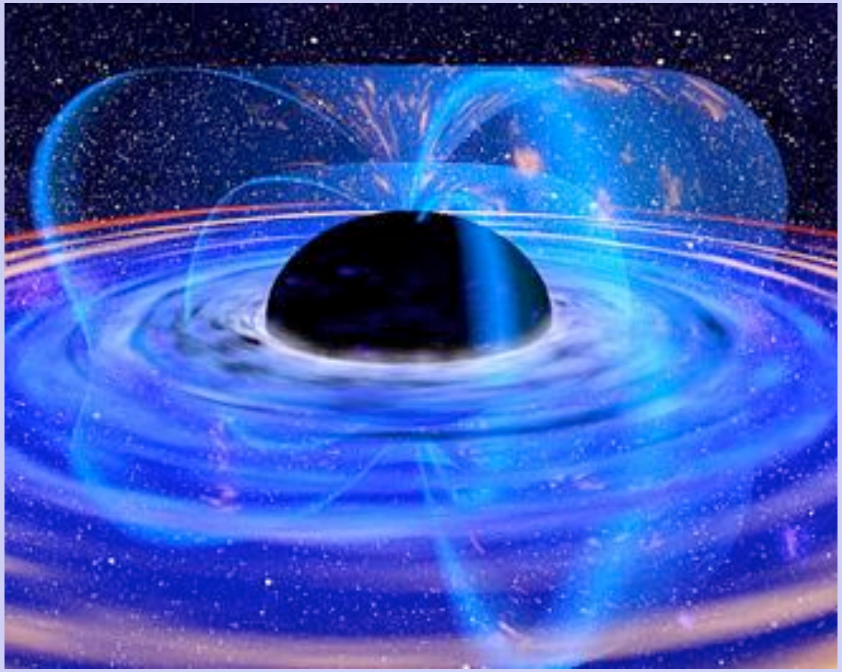
(Tombesi et al. in prep (1))

<u>Detiled modelling and fitting</u>:

- spectral fitting with XSTAR code
- Fe lines curve of growth analysis
- absorber parameters: N_H, ξ, r, v_{out}
- estimate of global mass loss rate, acc/ejection, …

(in companion paper Tombesi et al. in prep (2))

Conclusion



- Evidence for unknown relativistc and massive outflows close to SMBH
- Common from X-ray observations
- Radiatively/magnetically driven accretion disk winds/ejecta?
- Connection with radio jets (in Radio Loud objects)?
- Important for AGN and accretion physics
- Indications for X-ray emission/location
- Influence on SMBH growth?
- Contribution to feedback SMBH and host galaxy (e.g. M_{BH}-σ relation)

Future developments: study of variability; observations from other X-ray satellites (Chandra, Suzaku); connection with soft X-ray warm absorbers; ...

Thank you