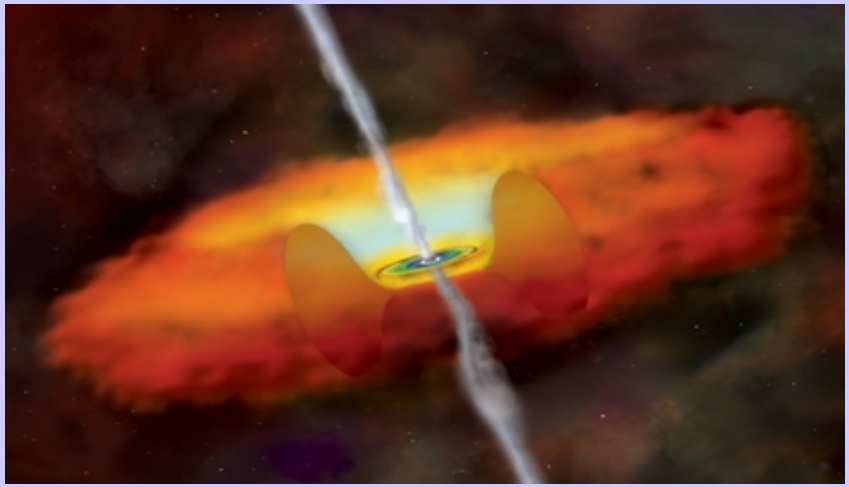
New insights on the accretion disk-winds connection in radio-loud AGNs from Suzaku



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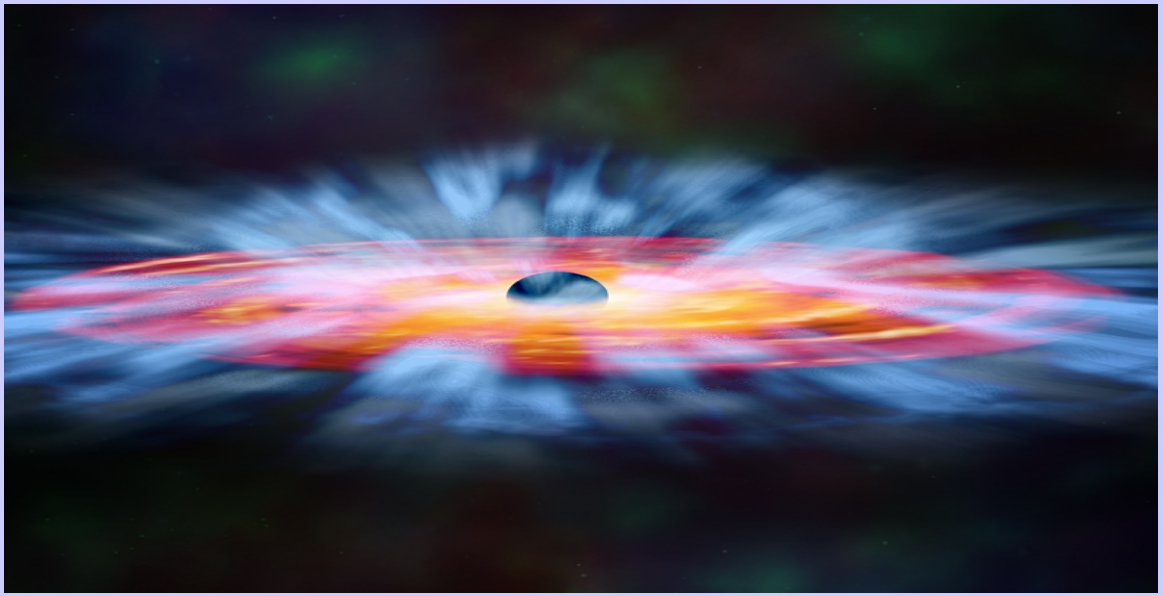
"Exploring the X-ray Universe: Suzaku and Beyond", SLAC, July 20-22 2011

X-ray evidence for ultra-fast outflows in radio-quiet AGNs



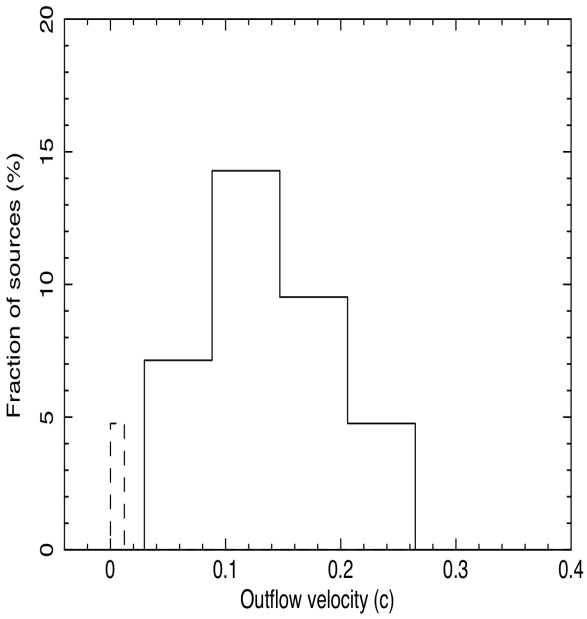
Recent evidence for blue-shifted Fe K absorption lines at E>7keV in the X-ray spectra of Seyferts/QSOs (e.g., Chartas et al. 2002, 2003; Pounds et al. 2003; Dadina et al. 2005; Markowitz et al. 2006; Braito et al. 2007; Turner et al. 2008; Cappi et al. 2009; Reeves et al. 2009)

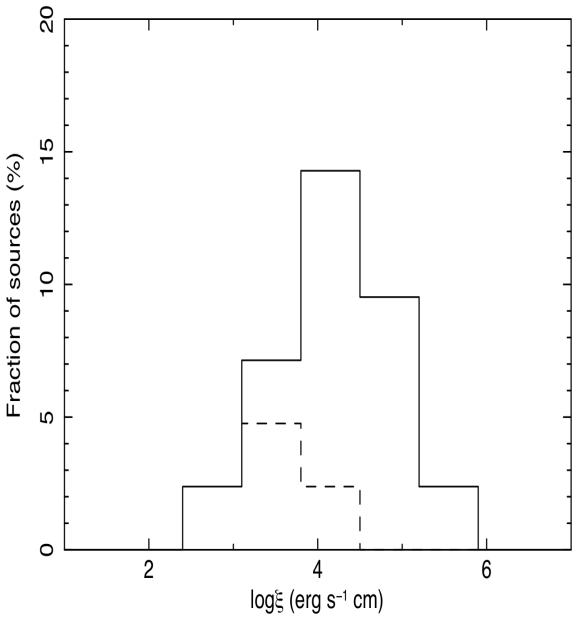
Ultra-fast Outflows (UFOs) with velocities ~0.1c, connected with accretion disk winds/outflows. Possibly important for AGN cosmological feedback (e.g., King 2010)

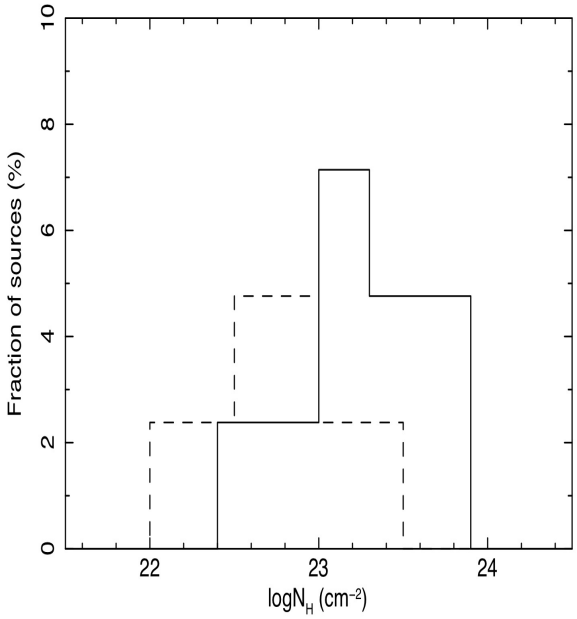
Systematic 4-10keV spectral analysis on a complete sample of 42 Seyferts, 101 XMM-Newton observations (Tombesi et al. 2010a)

- Global statistical significance lines is high (>5σ) and solved publication bias
- Detection frequency >40%, possibly large covering fraction and not collimated

X-ray evidence for ultra-fast outflows in radio-quiet AGNs







Xstar photo-ionization modeling and curve of growth analysis of UFOs, distributions of absorber parameters in Seyferts (Tombesi et al. 2011, ApJ accepted)

- Ultra-fast, outflow velocity ~0.03-0.3c, mean ~0.14c
- Highly ionized, logξ~2.5-6 erg s^{-1}cm, mean ~4.2 erg s^{-1}cm
- Large column density, N_H~10^{22}-10^{24}cm^{-2}, mean ~10^{23}cm^{-2}

Suzaku discovery of ultra-fast outflows in radio-loud AGNs

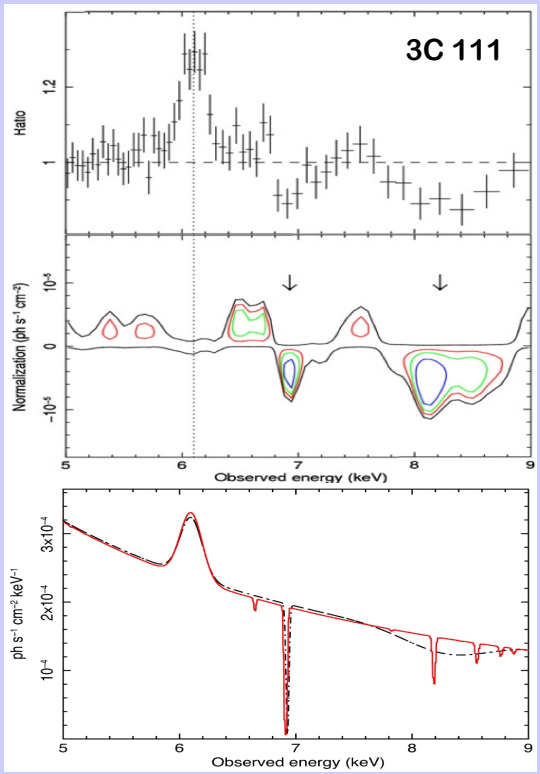
- Broad Line Radio Galaxies are the radio-loud counterpart of Seyfert 1s
- Show observable strong relativistic radio jets
- Limited observations in X-ray archives to five "classical" sources
- 3C 111, 3C 390.3, 3C 120, 3C 382, 3C 445

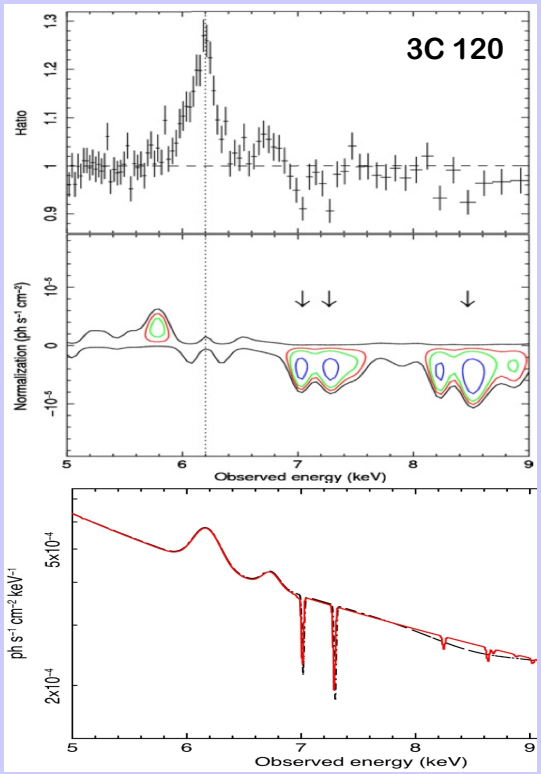
Centaurus A

Systematic spectral analysis (Tombesi et al. 2010b):

- Suzaku long (>100ks) observations
- 4-10 keV XIS spectral analysis
- Search for blue-shifted Fe K absorption lines
- Fe XXV/XXVI K-shell series lines at E>7keV in 3/5 sources
- High detection probability from F-test and Monte Carlo simulations, >99%

Suzaku discovery of ultra-fast outflows in radio-loud AGNs





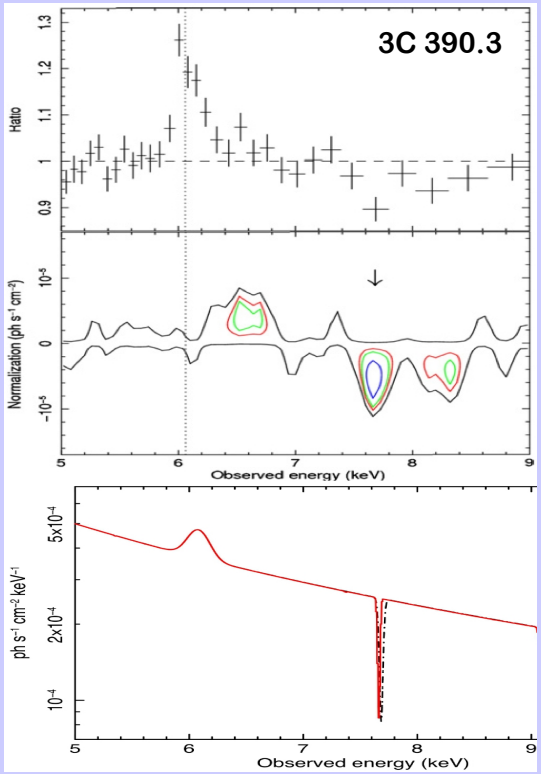


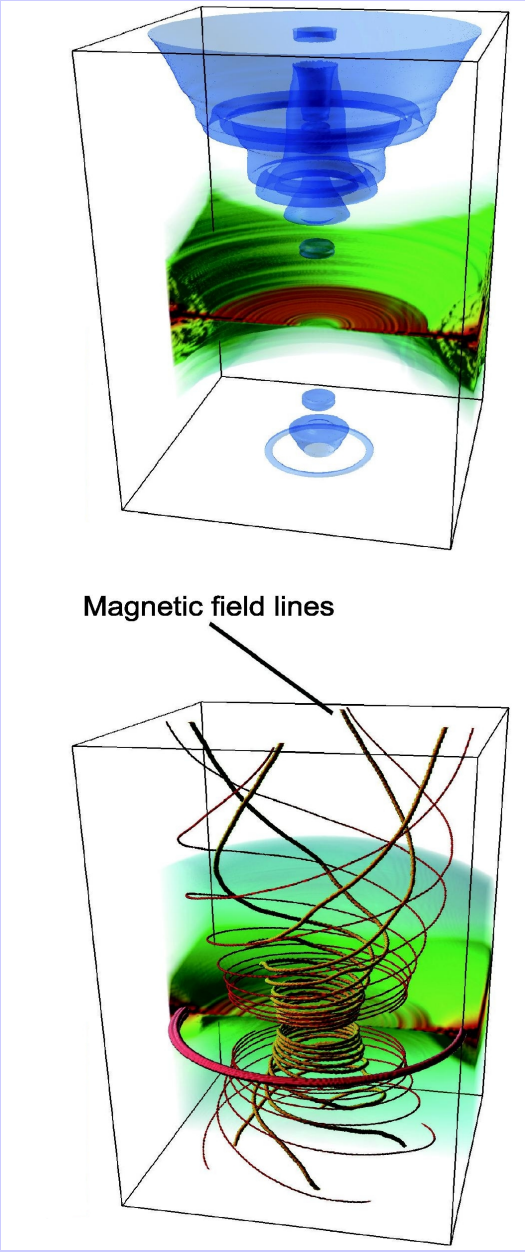
Photo-ionization modeling of Fe K absorbers

Source	$\log \xi$ (erg s^{-1} cm)	$N_{\rm H}$ (10^{22} cm^{-2})	$v_{\rm out}$ (c)
3C 111	5.0 ± 0.3	$>20^{a}$	$+0.041 \pm 0.003$
3C 390.3	$5.6^{+0.2}_{-0.8}$	$>3^{a}$	$+0.146 \pm 0.004$
3C 120b	3.8 ± 0.2	$1.1^{+0.5}_{-0.4}$	$+0.076 \pm 0.003$

Suzaku discovery of ultra-fast outflows in radio-loud AGNs

Physical characteristics of UFOs in BLRGs:

- Common, detected in 3/5 sources
- Compact and close to the BH, d<0.01-0.1pc (<100-1000r_g)
- Expected variability on ~ days, duty cycle?
- Covering fraction roughly ~0.5, similar to Seyferts
- Massive, instantaneous M_{out}~ 1$M_{Sun}yr^{-1}$ ~M_{acc}
- Powerful, E_K~10^{43}-10^{45}erg/s ~ radio jet power
- L_{bol}/L_{Edd}~0.1-0.5, force multiplier Γ ?
- wind/photon momentum, $(M_{out}v_{out})/(L_{bol}/c) \geq 1$
- Radiation pressure important, but possible additional magnetic thrust to reach higher velocities
- Role on AGN feedback? (e.g., King 2010)

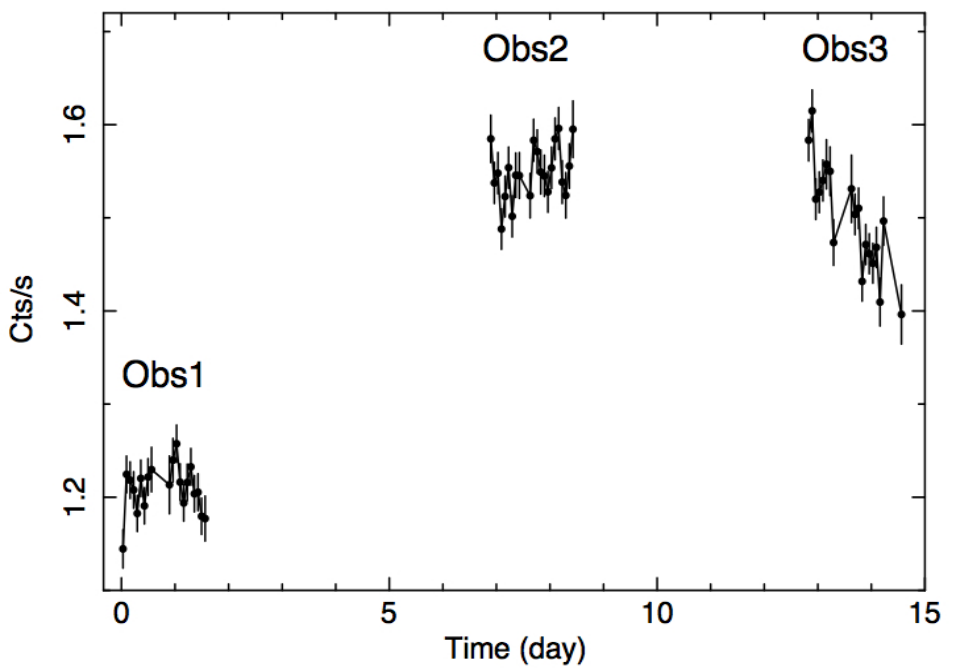


(Ohsuga et al. 2009)

Accretion disk-outflow connection in 3C 111 with Suzaku

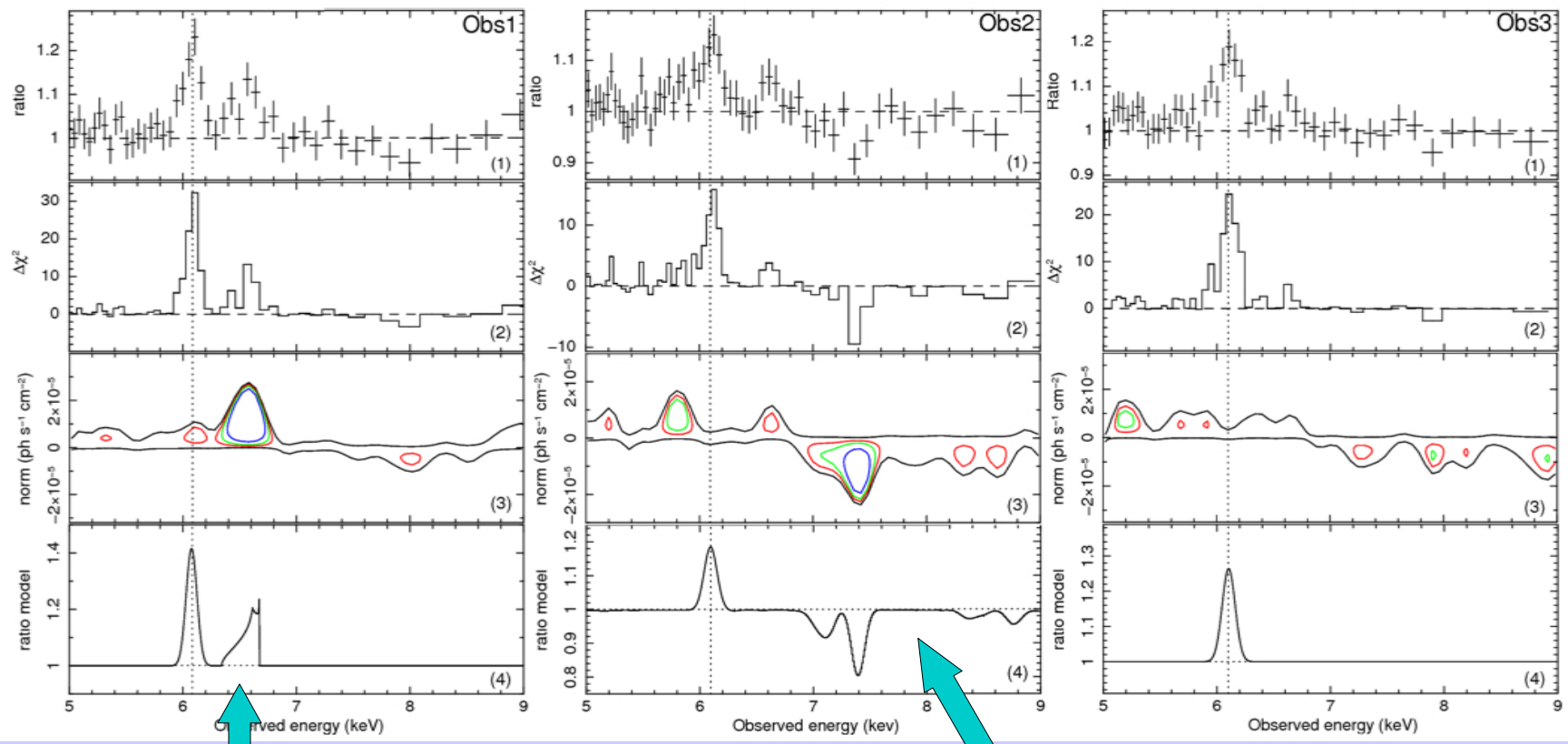
Follow-up 3C 111: Suzaku proposal GO5 to monitor predicted UFO variability on ~7 days time-scales

Tombesi et al. (2011, in prep.)



- 3 x 60ks Suzaku observations, september 2010
- 30% flux variability between Obs1 and Obs2
- 4-10 keV XIS spectral analysis, power-law continuum Γ ~1.7 and 6.4keV Fe K
- Detection emission line E=6.88keV in Obs1, absorption line E=7.75keV in Obs2
- High significance, >99.9% from F-test and Monte Carlo simulations
- Constancy emission/absorption lines excluded at 99.7% and 99.9%

Accretion disk-outflow connection in 3C 111 with Suzaku



Obs1

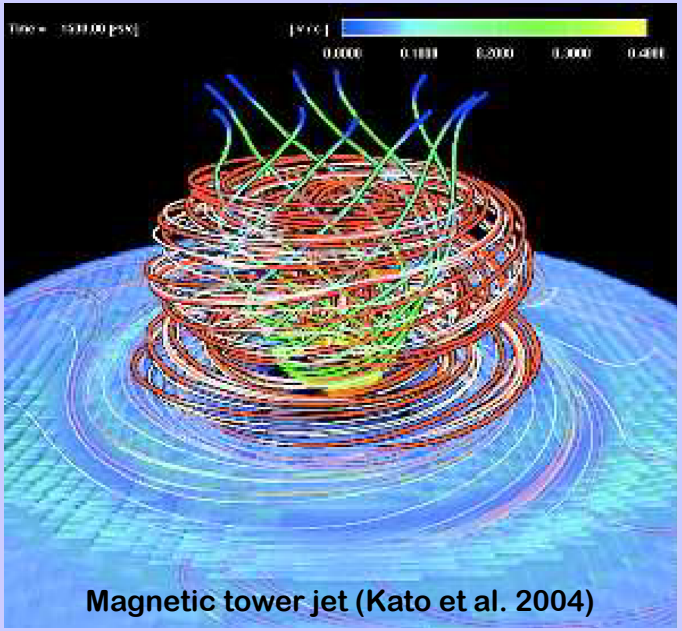
- Ionized relativistic line (relline profile)
- Bulk emission possibly from Fe XXV/XXVI
- Reflection from accretion disk ~20-100r_g, inclination ~18°

Obs2

- Ultra-fast Outflow (Xstar modeling)
- Velocity v_{out}=0.106±0.006c
- logξ=4.32±0.12 erg s^{-1}cm, Fe XXVI
- N_H=(7.7±2.9)x10^{22} cm^{-2}

Accretion disk-outflow connection in 3C 111 with Suzaku

- Variability ~7days, d<0.006pc (<50-500 r_g, M_{BH}~3x10^9 or 2x10^8 M_{sun})
- Ionized reflector, n>$10^9$$cm^{-3}$, N_H>$10^{25}$$cm^{-2}$
- Ultra-fast Outflow ~0.1c, for C~0.5, M_{out} ~ 1M_{Sun} yr^{-1} ~M_{acc}
- E_K~5x10^{44}erg/s, comparable radio jet power
- L_{bol}/L_{Edd}<0.3, E_K/L_{bol}~0.06
- Wind/photon momentum, $(M_{out}v_{out})/(L_{bol}/c)$ ~ 1
- Photospheric radius for τ~1, momentum deposition ~100r_g



Magnetic tower jet (Kato et al. 2004)

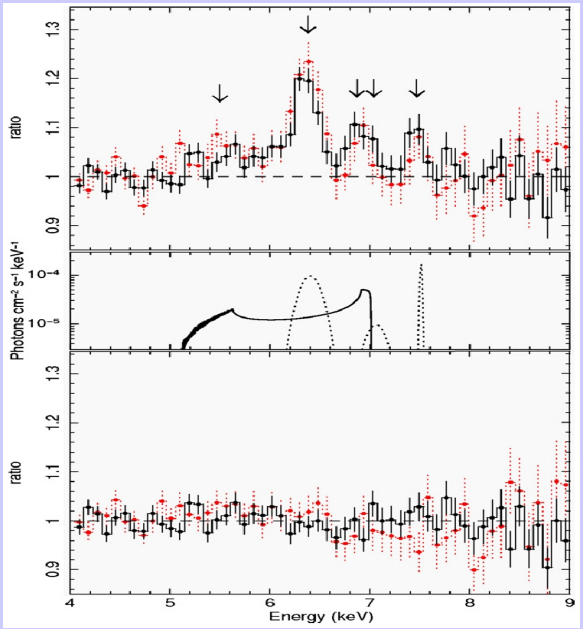
First direct evidence for accretion disk-outflow connection in an AGN

- Increased illumination inner part accretion disk due to rise in accretion rate Obs1-Obs2
- Outflow lifted from disk at ~100r_g, acceleration to ~0.1c by radiation pressure Obs1-Obs2
- Superluminal source and inclination ~18°, possible plasma additional magnetic acceleration

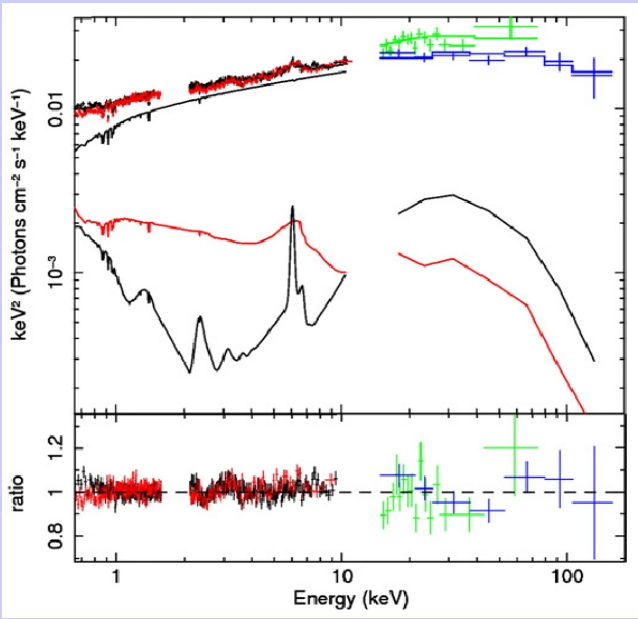
Under investigation

- Connection with radio jet? External layers, collimation, shocks? (e.g., Chattergee et al. 2011)
- Coupling between accretion disk, outflows and jets? (e.g., GRS 1915+105 Neilsen & Lee 2009)
- Role on AGN cosmological feedback? (e.g., King 2010) **Additional monitoring required!**

The Suzaku view of 3C 382



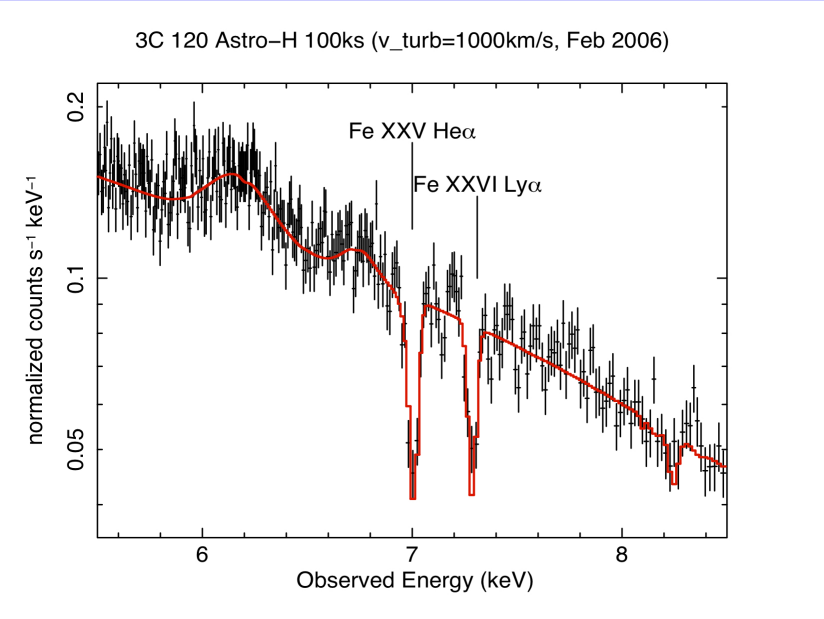
Fe K band XIS

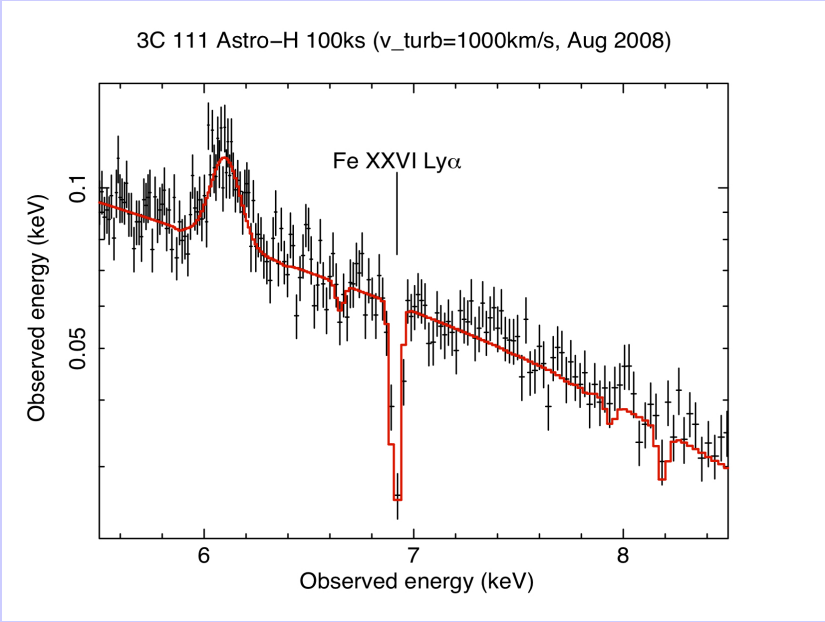


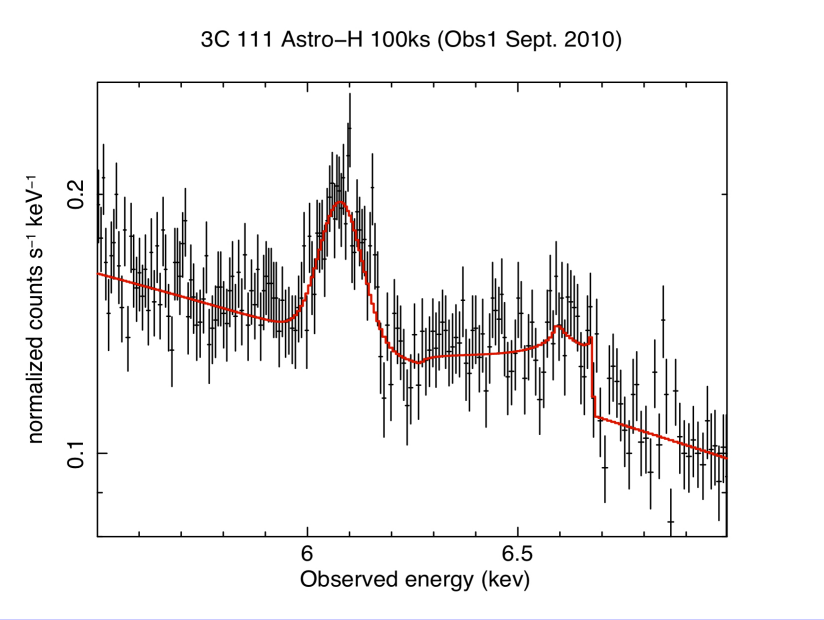
Broad-band Suzaku + Swift BAT

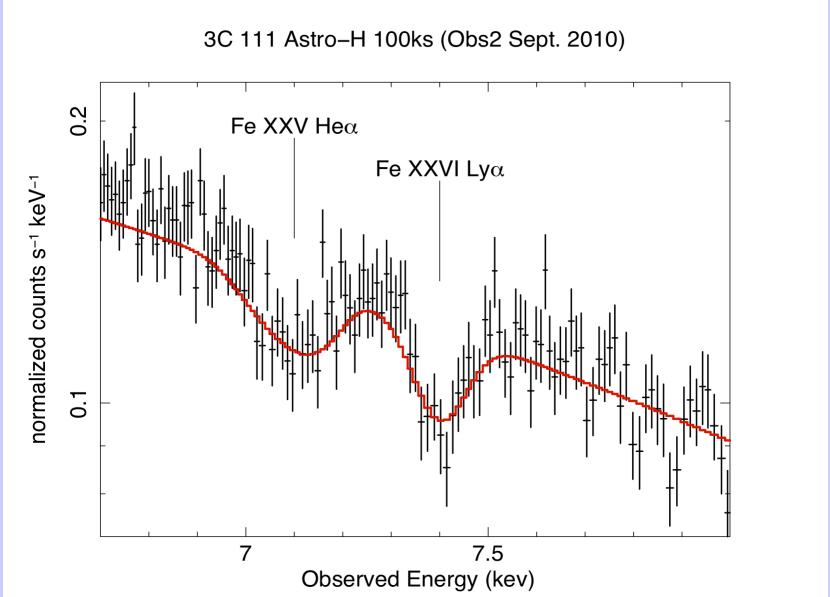
- Broad-band Suzaku (116ks) + Swift BAT 58-month, E=0.6-200keV (Sambruna et al. 2011)
- Continuum similar to Seyferts, Γ ~1.8 and cut-off E~200keV, Comptonization in corona
- Emission lines Fe K band: Fe Kα ~6.41keV, Fe Kβ ~7.06keV, Ni Kα ~7.5keV (P_F>99.99%)
- Ionized relativistic Fe K emission line profile: $r_{in}=12\pm2r_g$, $r_{out}=23\pm3r_g$, $i=30^o\pm1^o$ (P_F>99.99%)
- (1) Mildly ionized logξ=1.54±0.03, R_F~0.1, n~5x10^{7}cm^{-3}, d~0.3pc (BLR or inner torus)
- (2) Highly ionized logξ=2.93±0.04, R_F~0.1, n~10^{11}cm^{-3}, d~10-20 r_g (inner accretion disk)

Astro-H micro-calorimeter simulations









Thank you