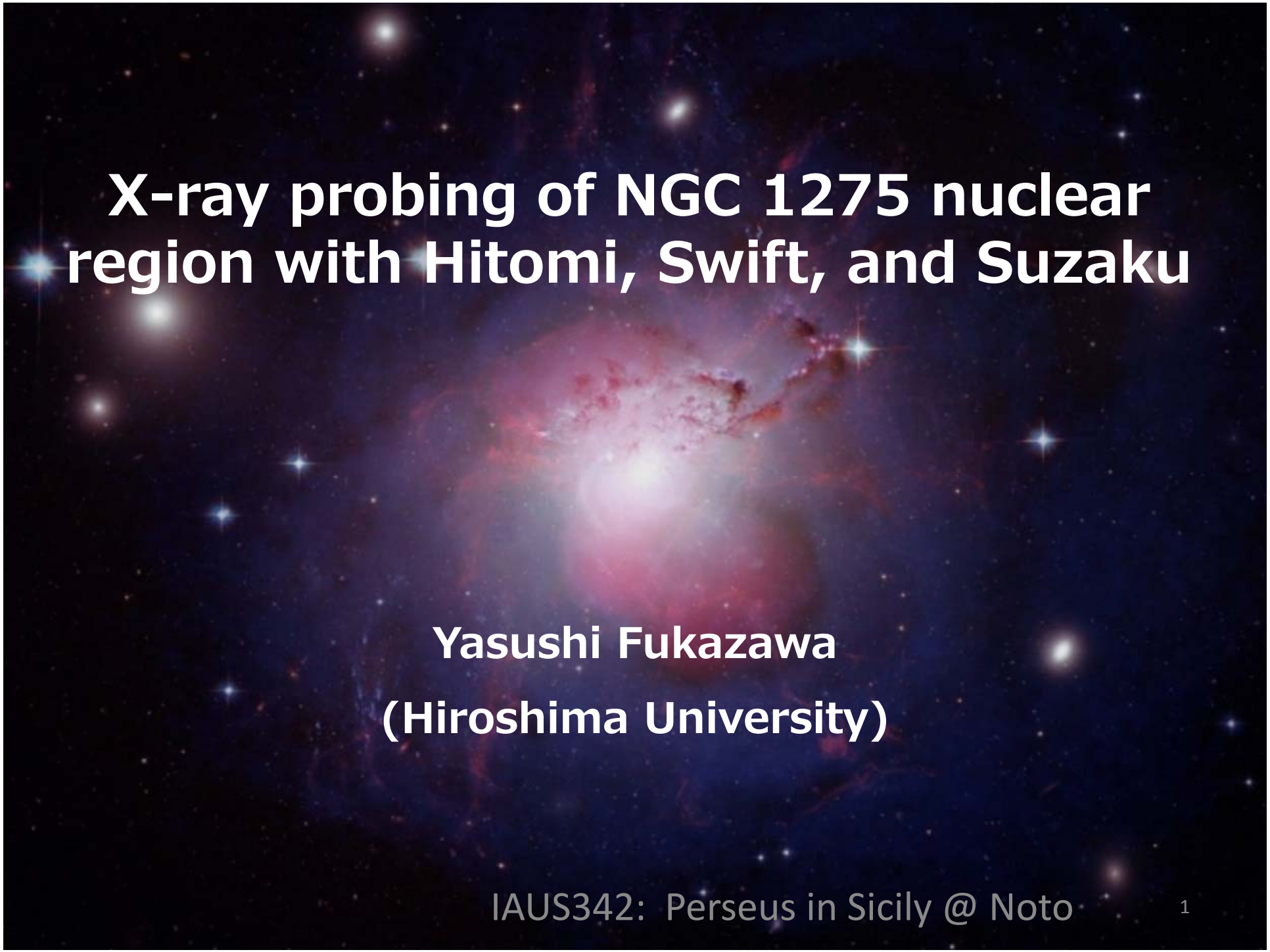
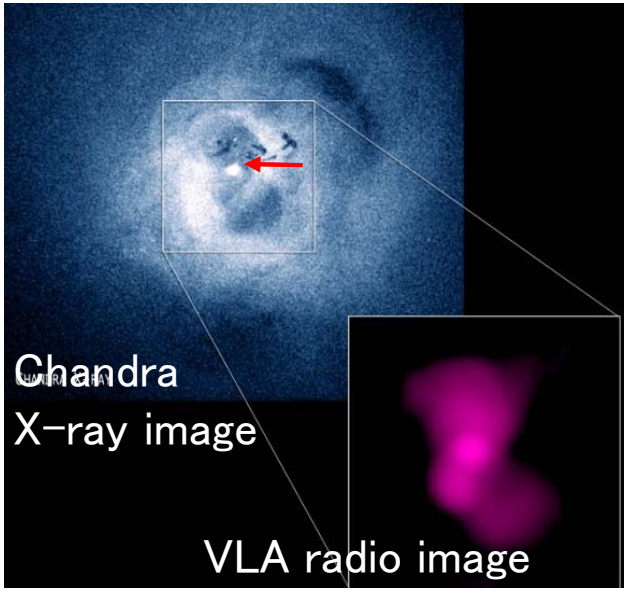


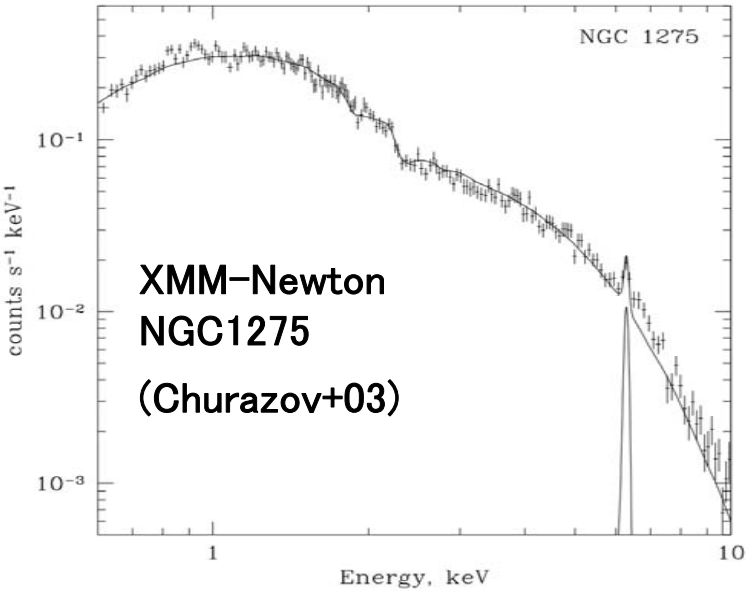
X-ray probing of NGC 1275 nuclear region with Hitomi, Swift, and Suzaku

Yasushi Fukazawa

(Hiroshima University)

X-ray from NGC 1275





☆ **Point-like source has been detected.**

Einstein/HXI, ROSAT/HXI, Chandra, XMM-Newton (e.g. Fabian+15)

☆ **XMM-Newton detected Fe-Kα (6.4keV) line. (Churazov+03, Yamazaki+13)**

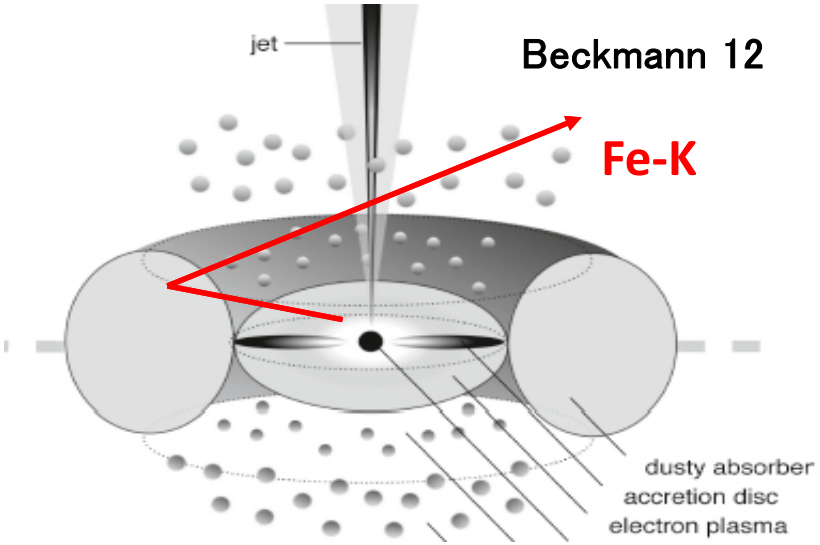
Fe-K 6.4keV is typical for Seyfert galaxies.

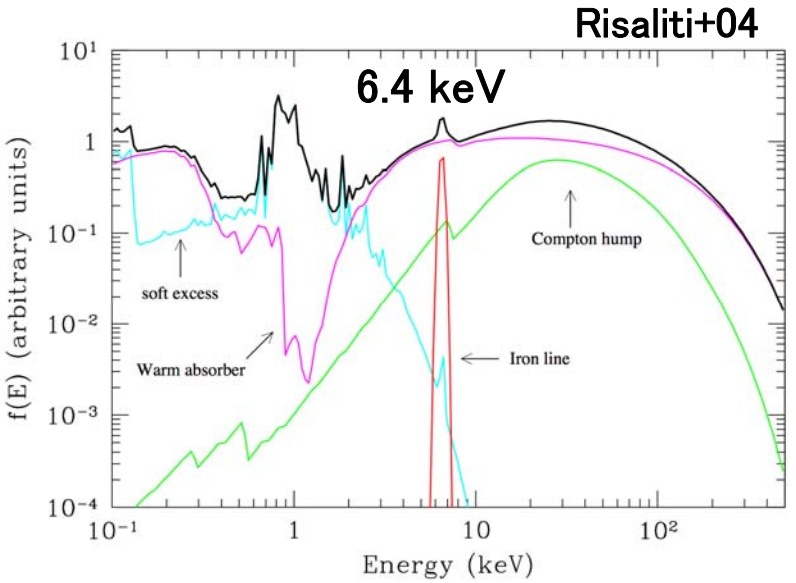
L/Ledd is low (10-^4 to 10^-3) Does normal torus exist ?

Q: What is an origin of Fe-K line ?

Torus as well as Seyfert galaxies ?

AGN Fe-K fluorescence line





Precise line spectroscopy with X-ray calorimeter is promising to measure a Fe-K line profile (center energy, width and shape, line structure …)

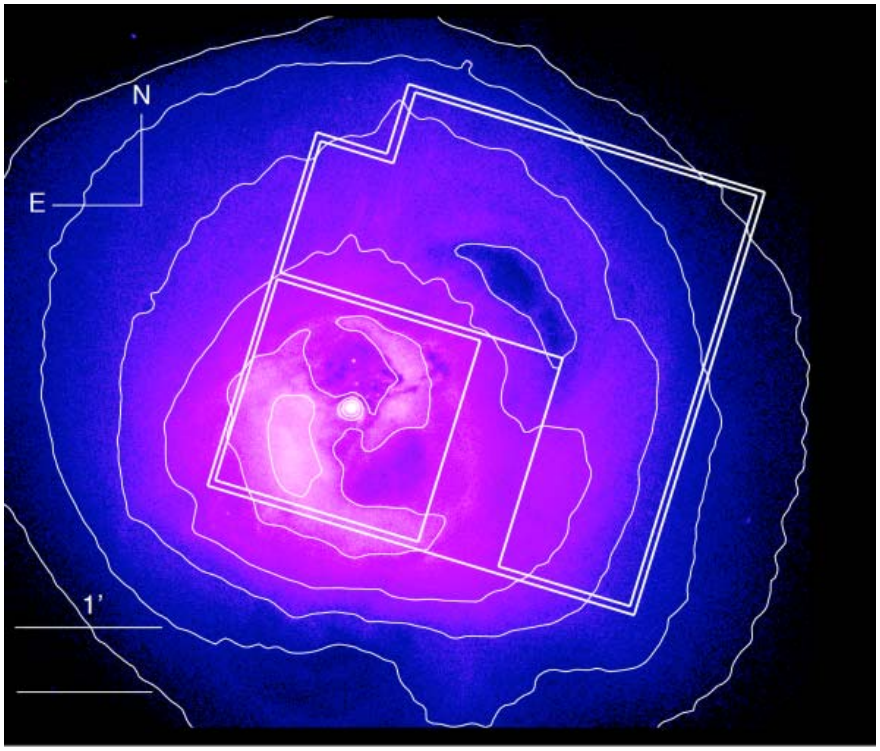
☆AGN Narrow neutral Fe-Kα line

- accretion disk? BLR ➔ width > 2000 km/s
- Torus? Molecular disk? or Outer? ➔ several 100 km/s

☆ X-ray CCD cannot distinguish between 2000 km/s and several 100 km/s

☆ Grating spectroscopy of line width → BLR? (e.g., Shu+10)

☆ Time scale (a few years) of X-ray variability of FeK → Torus? (e.g., Fukazawa+16)

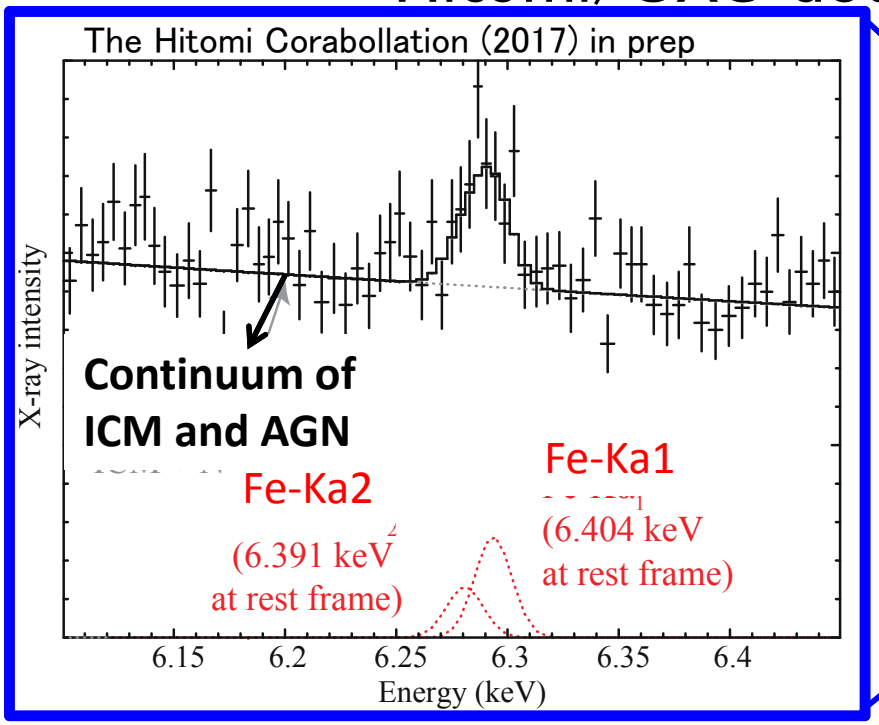


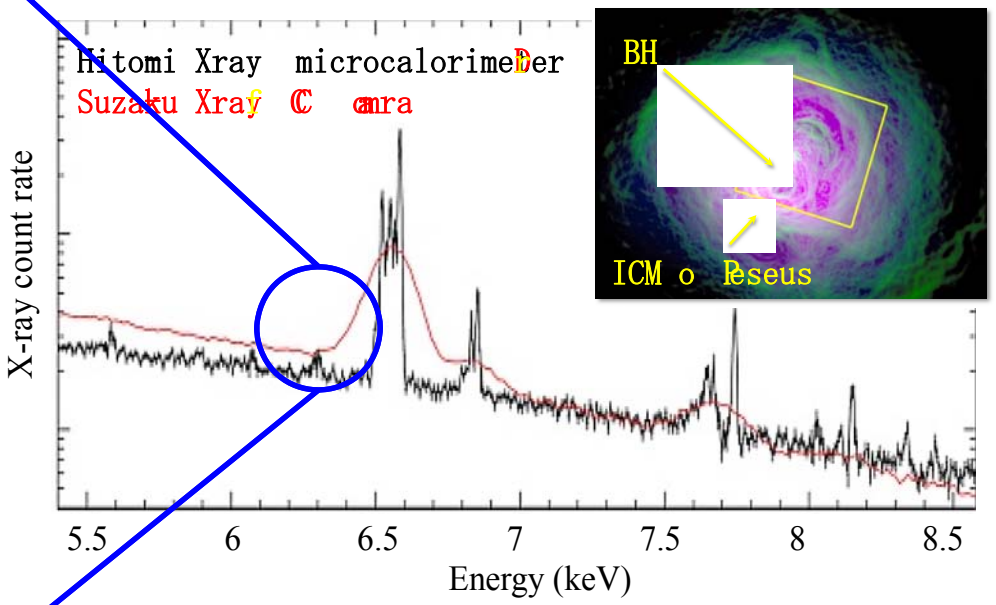
Hitomi/SXS : Feb 25-27th and March 4-6th, 2016 (~240 ks)

SXI(CCD) took only a small mount of data.
High-E X-ray instruments (HXI, SGD) was not yet operated.

Hitomi collaboration 2018, PASJ 70, 13

Hitomi/SXS detected Fe-Kα line





The Hitomi Collaboration, Nature (2016)

☆ The first fine spectroscopy ($\Delta E/E$ = 4.9 eV/6 keV) of AGN Fe-K line

☆Line is simple (Ka1 + Ka2),, no multiple lines –→ almost not ionized Fe

☆ Center energy : 0.01700 ± 0.00063 (optical 0.017284 with WHT 4.2m)

☆ Width_ 500-1600 km/s (FWHM) considering Ka1/Ka2

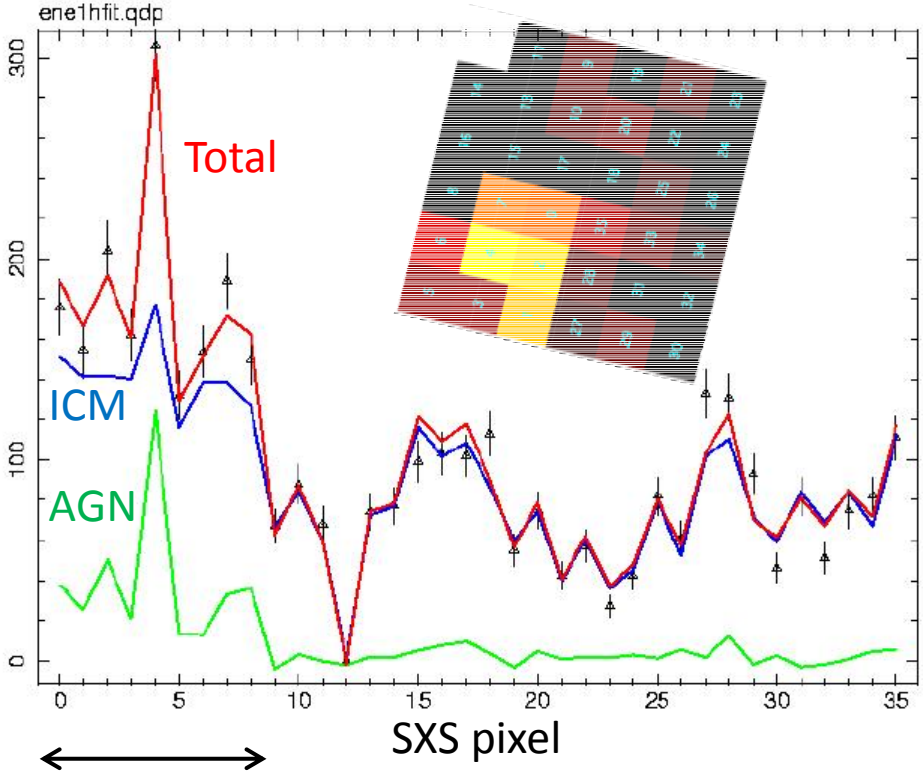
Narrower than BLR (Hα ~ 2750 km/s FWHM)

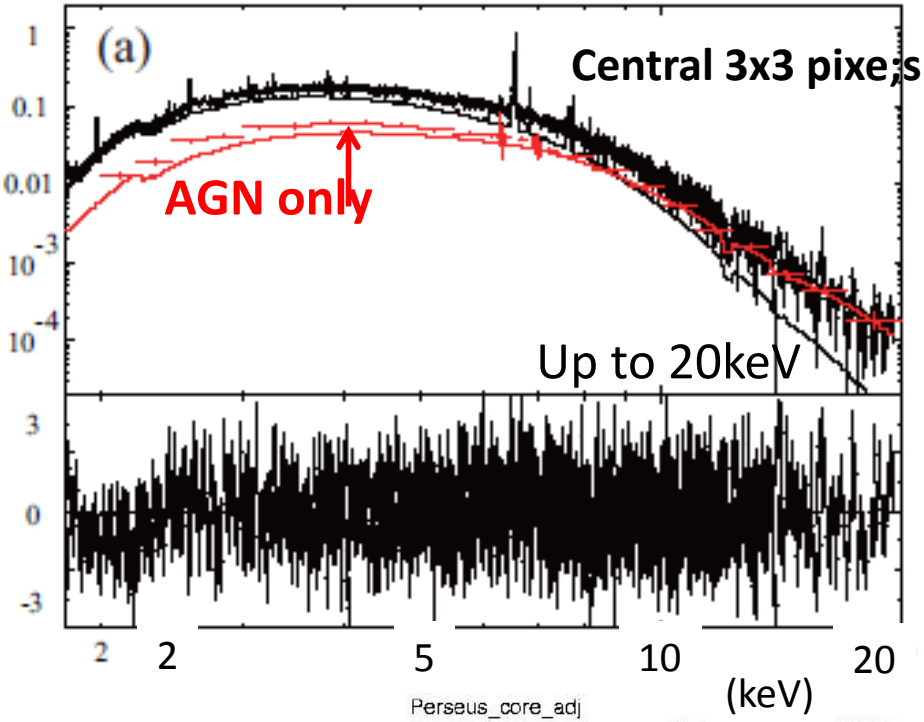
➔ Rule out an origin of accretion disk and BLR。

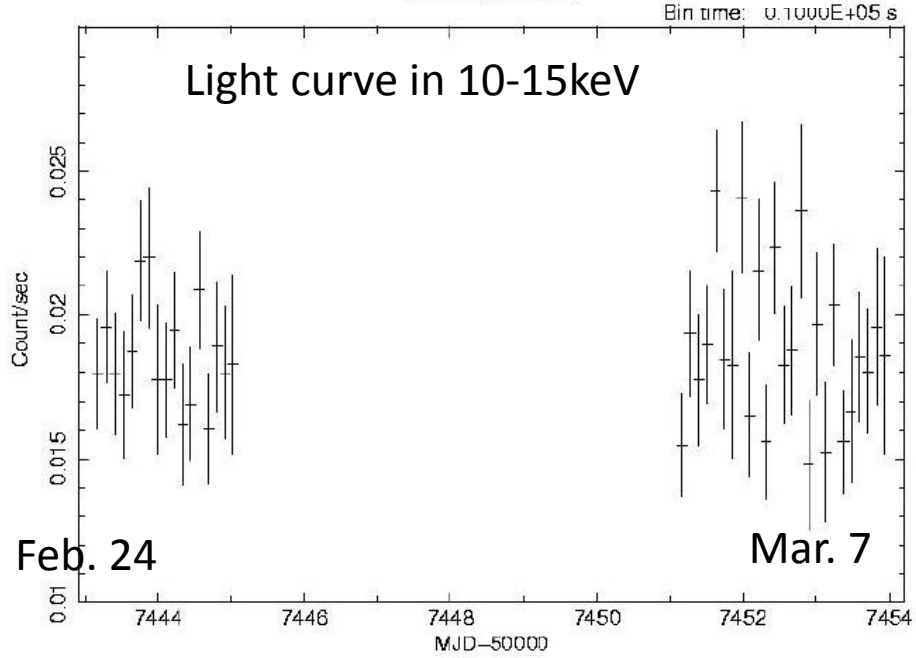
☆ EW ~ 10 eV against total continuum → ~25 eV against AGN continuum)

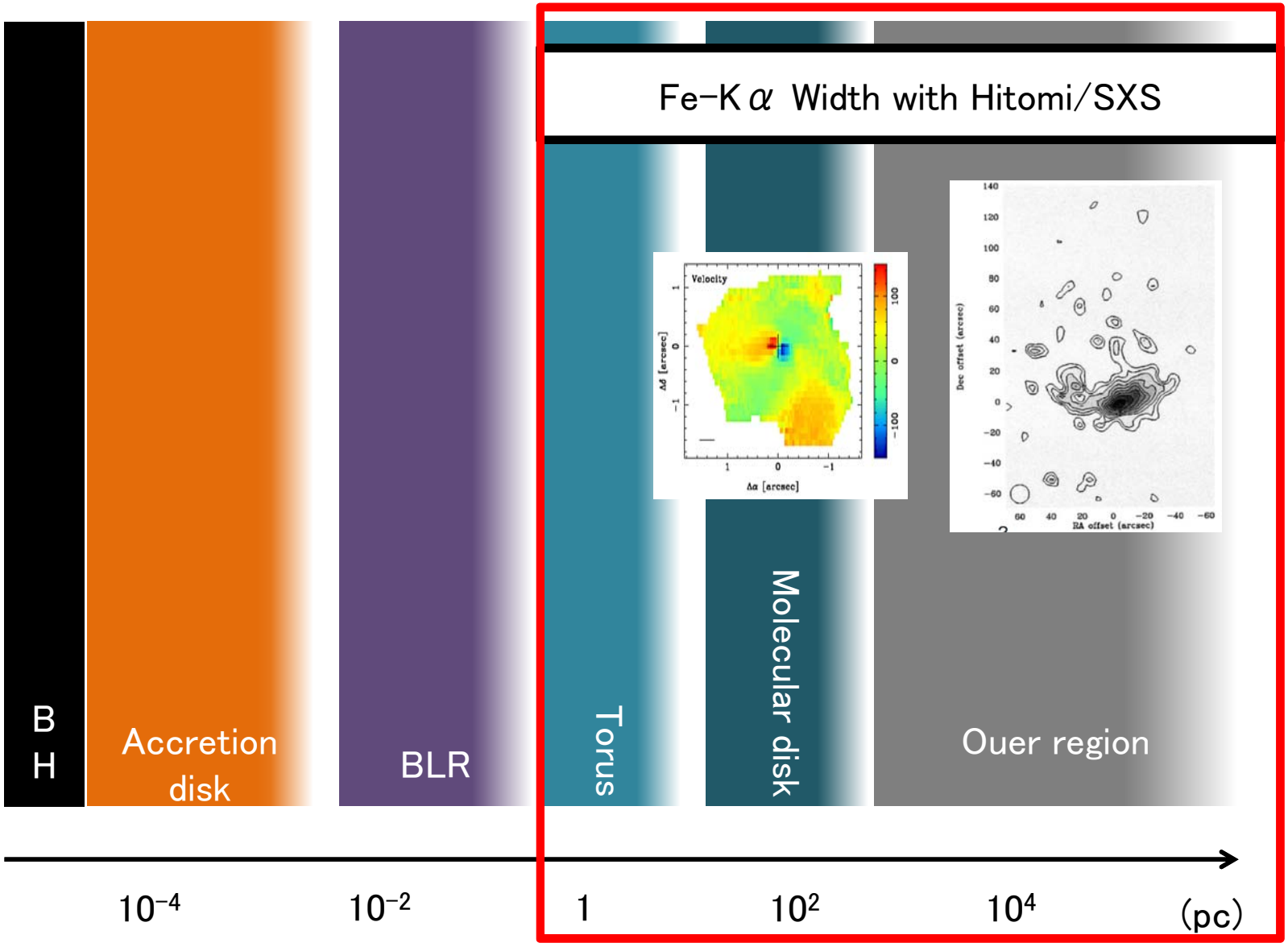
AGN continuum is estimated by PSF photometry

2.0000-2.2115 keV

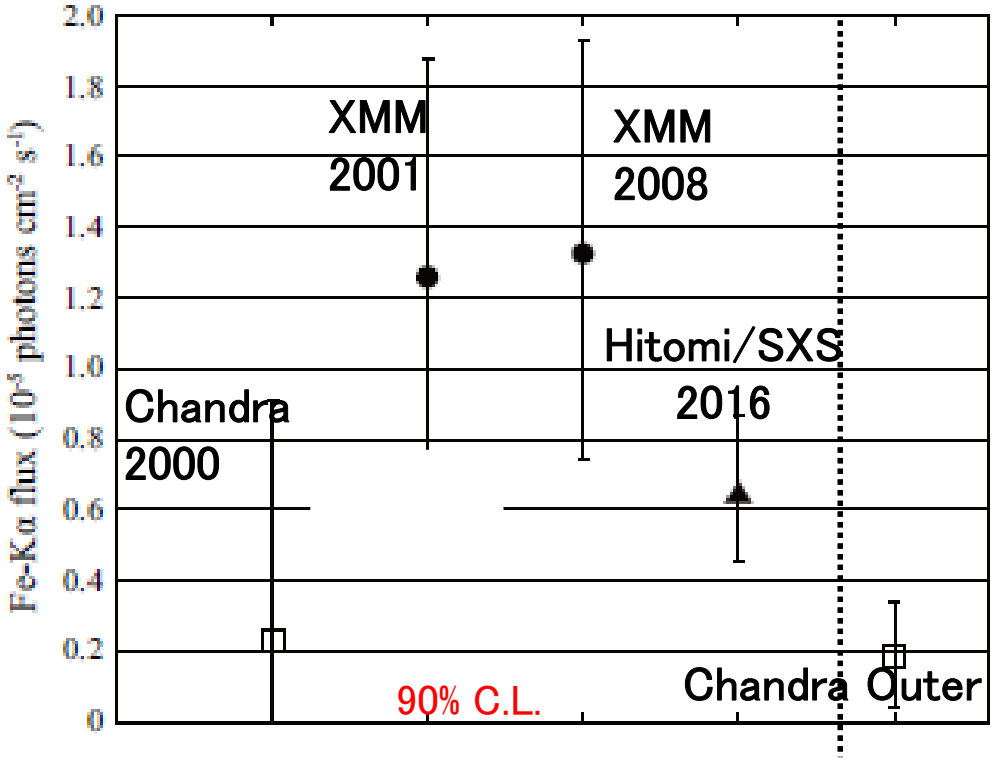


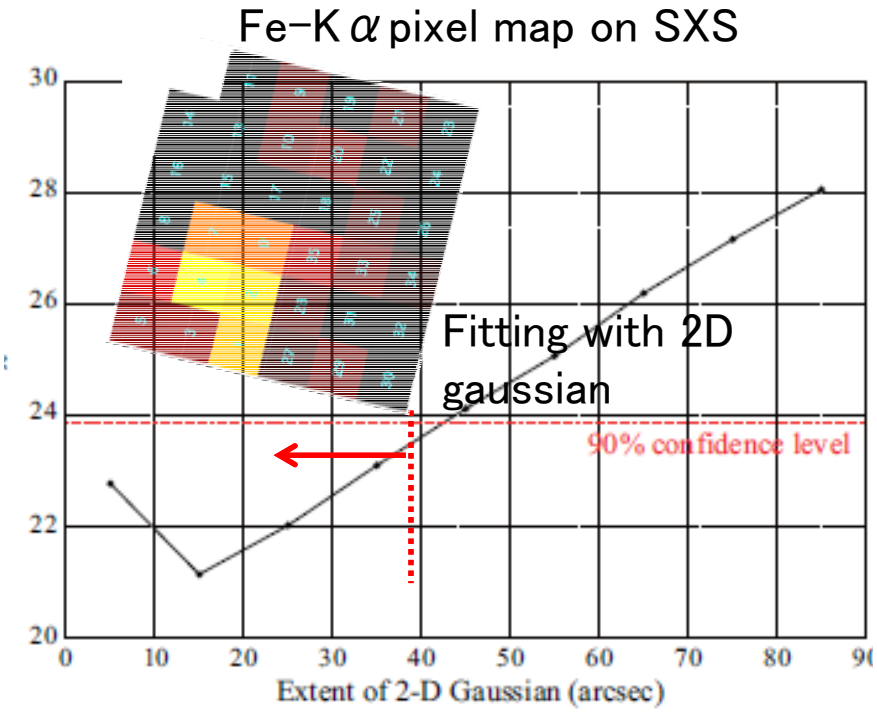





Fe-Kα Width with Hitomi/SXS
B
H
Accretion disk
BLR
Torus
Molecular disk
Ouer region
Velocity
Δδ [arcsec]
Δα [arcsec]
100
0
−100
Dec offset (arcsec)
RA offset (arcsec)
10^{-4}
10^{-2}
1
10^{2}
10^{4}
(pc)

Time variability and Emission region of Fe-Kα





☆ No variability of Fe-Kα intensity over 15 years –→ > >Several pc scale

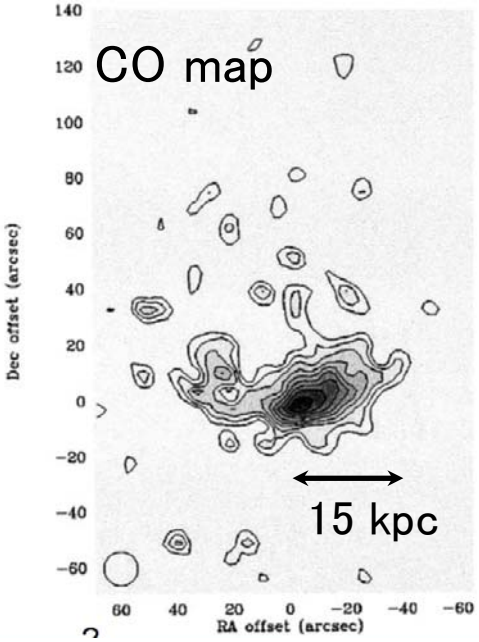
☆ Constraint of extent of Fe-K with Hitomi/SXS → <42"=17 kpc

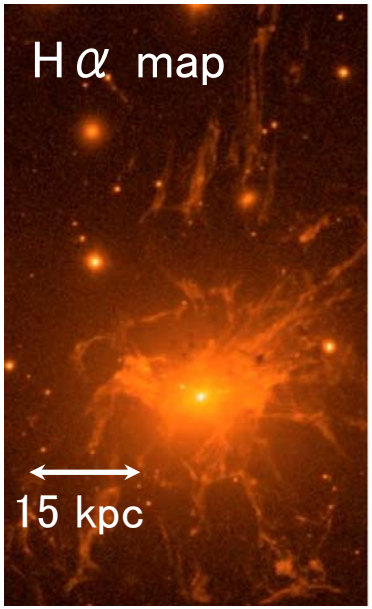
☆ Chandra U.L. at 4—30" = 1.6-12 kpc cannot explain the SXS intensity.

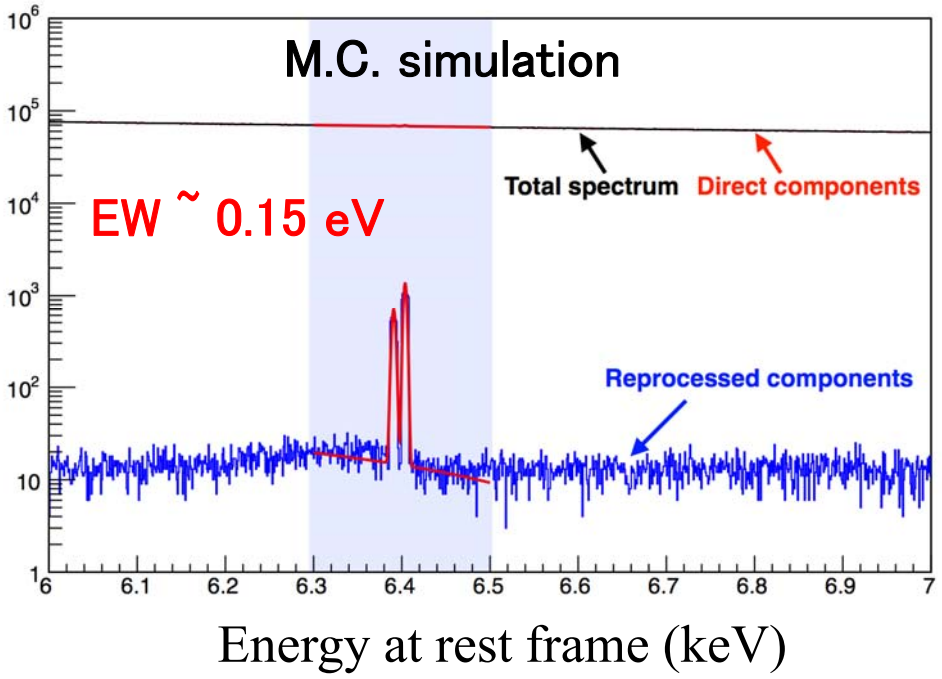
➔ Emission region : Several pc to 1.6 kpc –> Torus, Molecular disk, Outer region

Fe-K from the outer region: Molecular clouds

Salome+06







☆ Estimate fluorescence line intensity with M.C. using MONACO (Odaka+11)

☆ Assuming that molecular clouds illuminated by AGN and ICM continuum,
→ EW ~ 0.15 eV << 25 eV(SXS)

➔ Torus or Molecular disk

Torus or Molecular disk？

☆ Fe-K line width is consistent with [Fe II] line width 380—1000 km/s (FWHM) from molecular disk.

Prefer an origin of molecular disk

☆ Small EW of Fe-K (25eV) << 100-200 eV of typical Seyferts

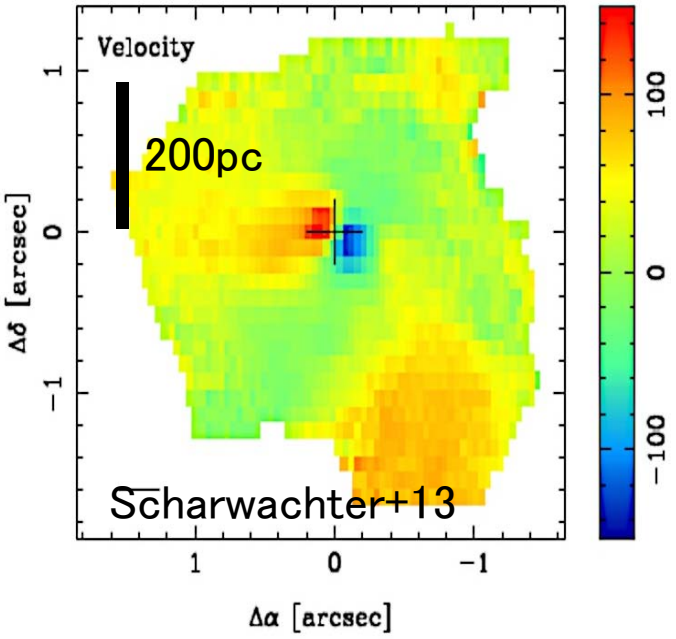
Or peculiar torus wiith a small colune density ?

$$EW \sim 65 \left(\frac{Z}{1solar}\right)\left(\frac{f \cdot NH}{10^{23} cm^{-2}}\right) \text{eV}$$

$$\text{f·NH} \sim 3 \times 10^{22} cm^{-2}$$

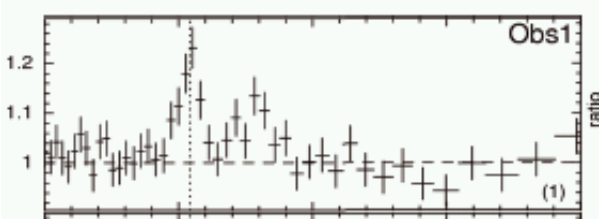
$$\text{M} \sim 4\pi r^2 f NH \mu m_p \sim 4 \times 10^7 M$$

R=100oc

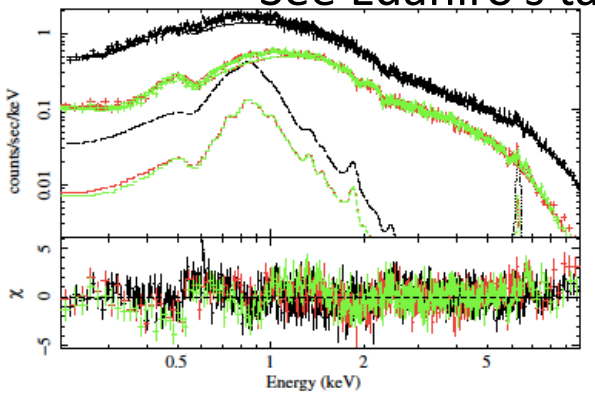


Suzaku X-ray spectra of Fermi radio galaxies

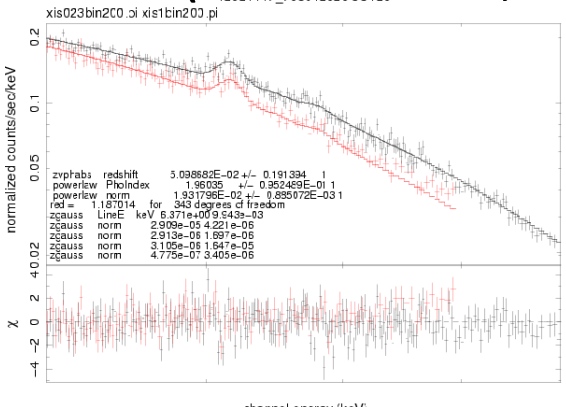
3C111(Tombesi+11)



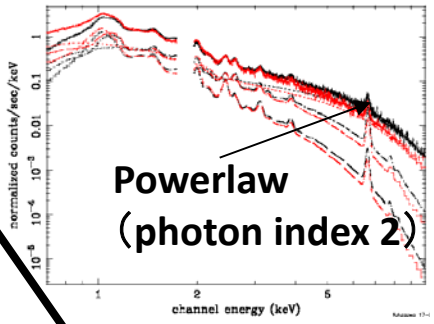
NGC1275 (Yamazaki+13;
See Edahiro's talk)



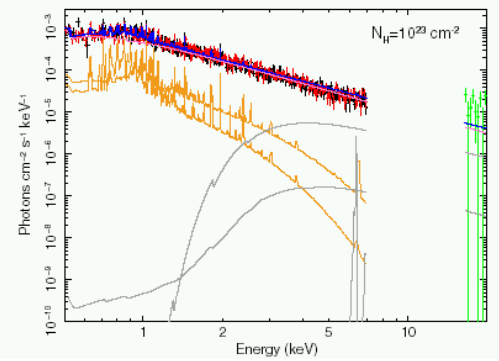
3C120(Kataoka+07,11)



M87 HST-1 knot
(Fukazawa+14)

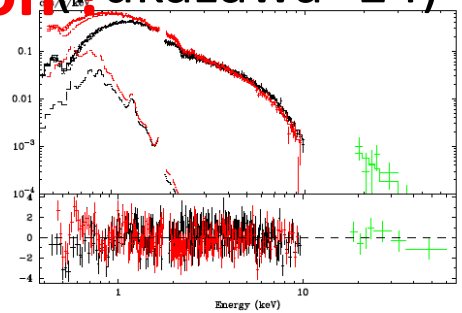


NGC6251(Evans+11)



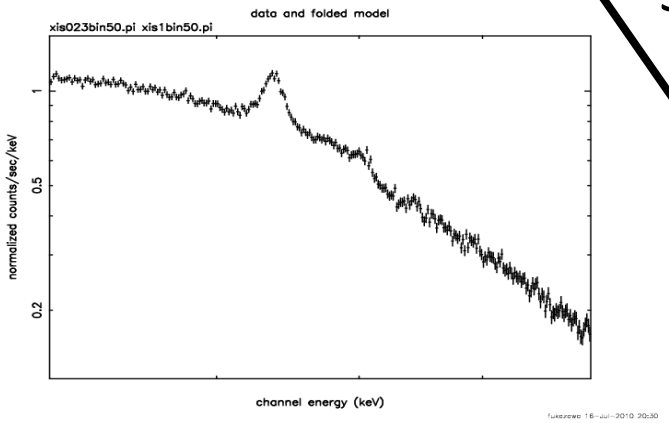
No Fe-K
Jet emission?

PKS0625-354
(Fukazawa+14)

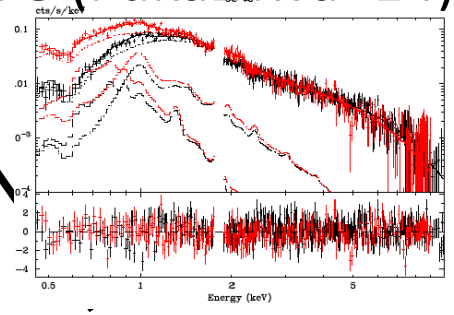


Fe-K

Cen A (Fukazawa+11)

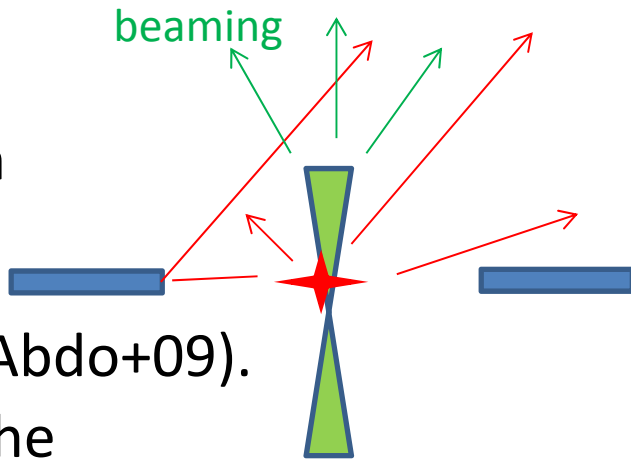


3C78 (Fukazawa+14)



How about NGC 1275 ?

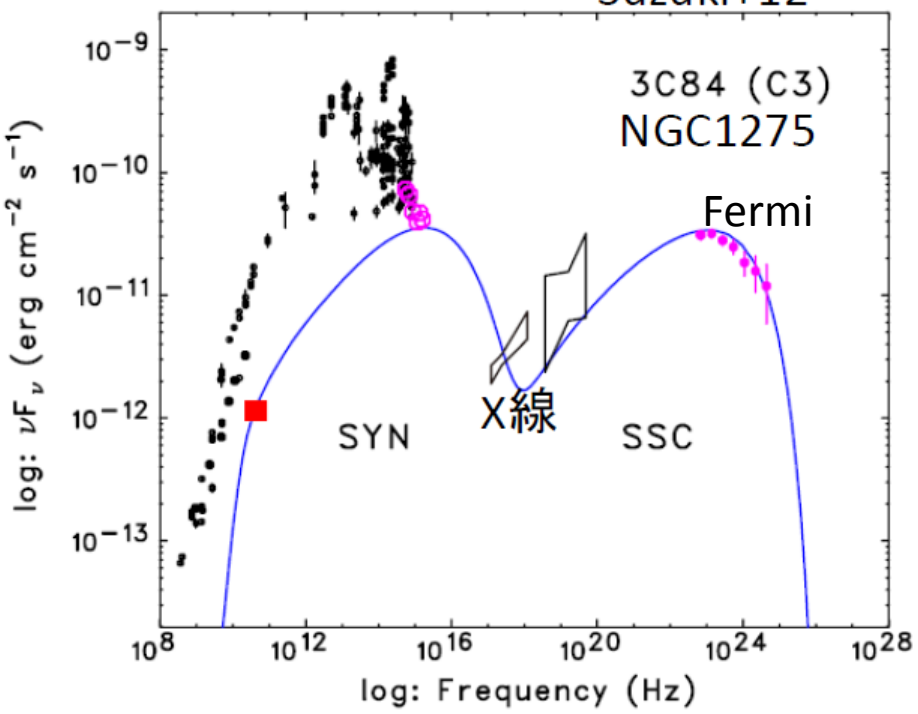
Fe-K line suggests a non-beaming X-ray continuum from the central engine. → accretion disk/corona ?



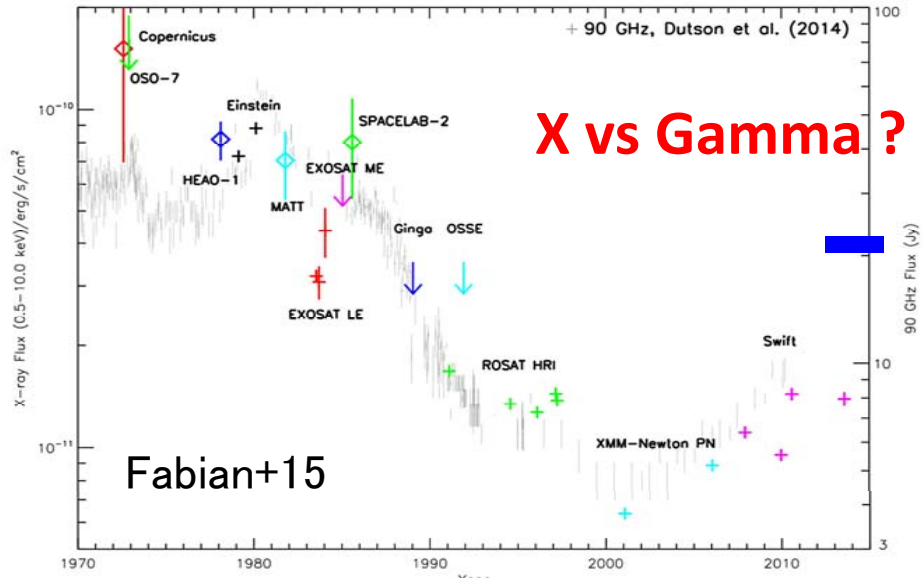
GeV emission has been detected by Fermi/LAT (Abdo+09). SED. Is almost expressed by SSC model, also in the X-ray band.

Q: X-ray continuum from disk/corona or jet ?

Suzuki+12

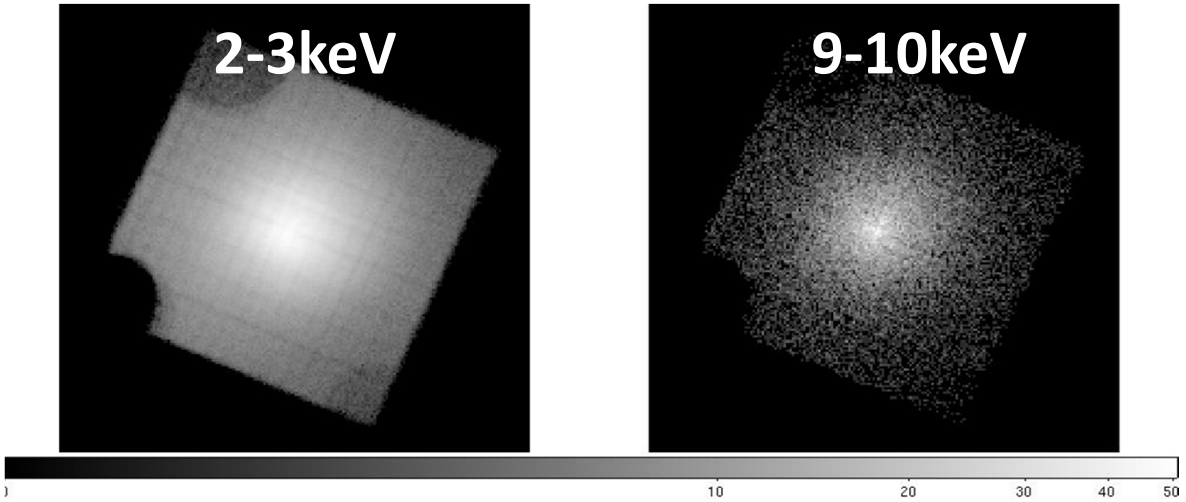


AGN intensity

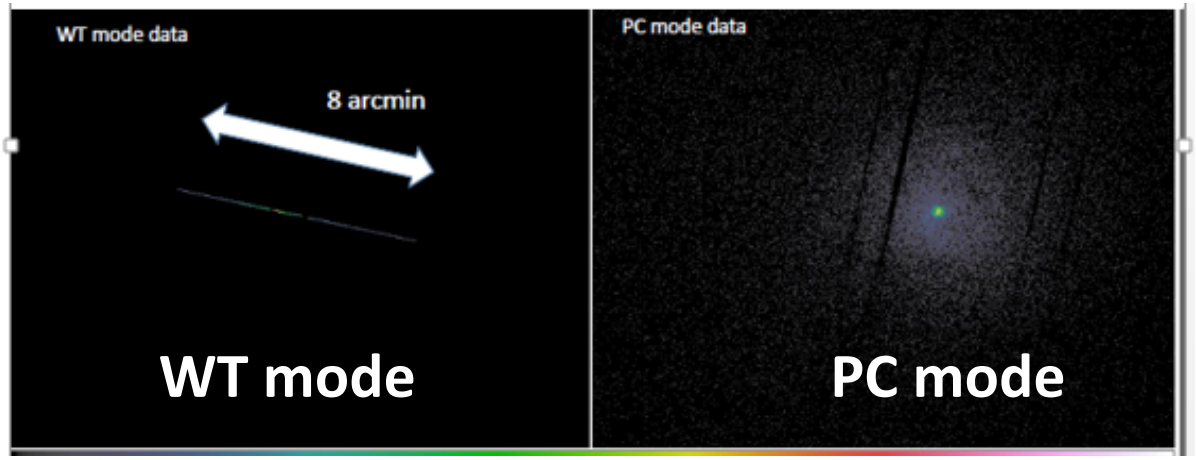


Derive a long-term X-ray light curve

Suzaku/XIS every 0.5 yr in 2006-2015



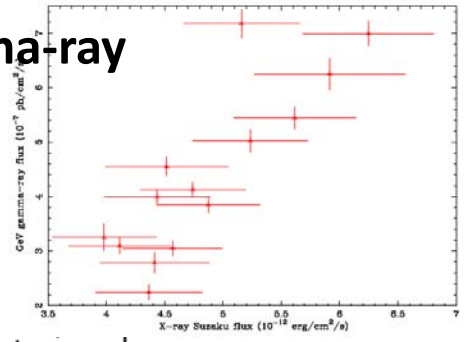
Swift/XRT/UVOT 25 obs. In 2006-2015

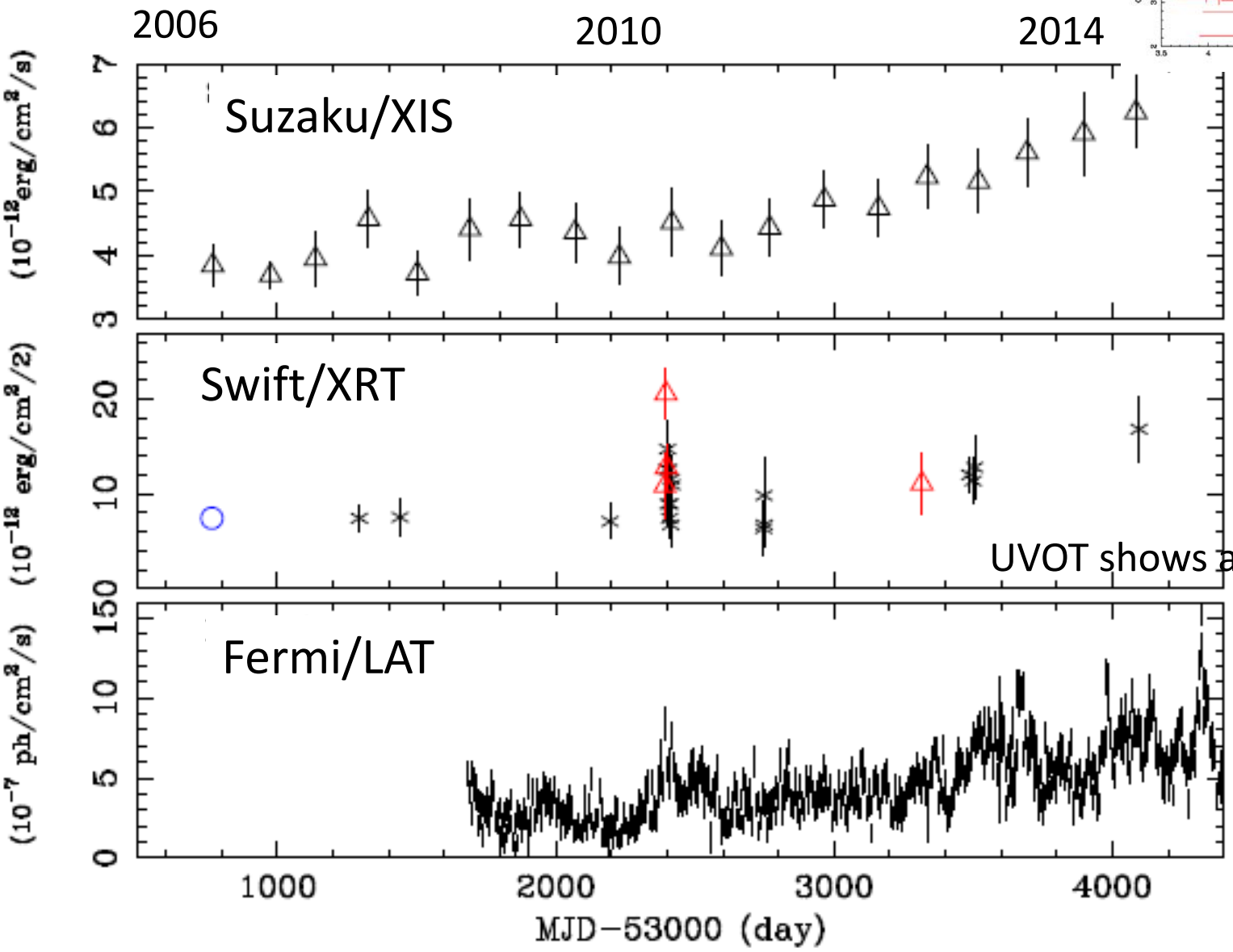


Femi/LAT GeV gamma-ray

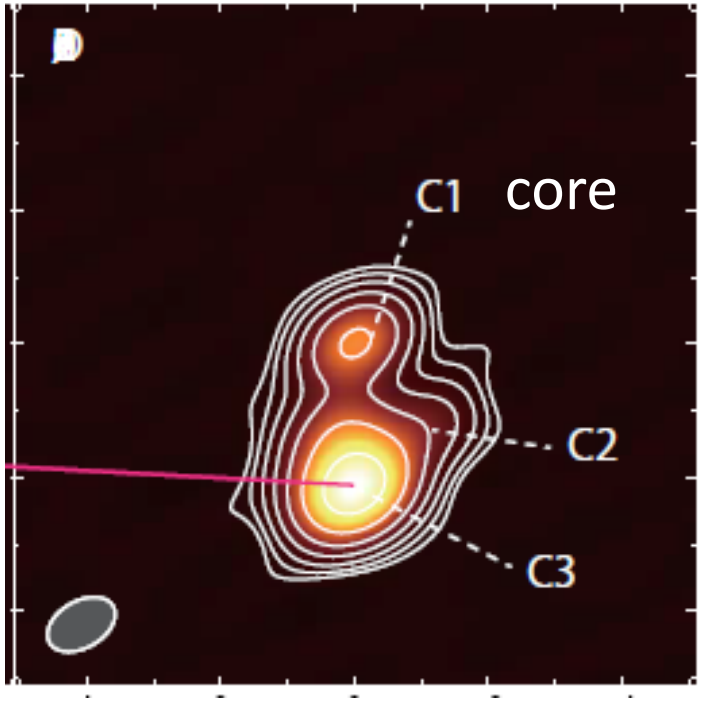
Fukazawa et al. 2018, ApJ 855, 93

Long-term variability

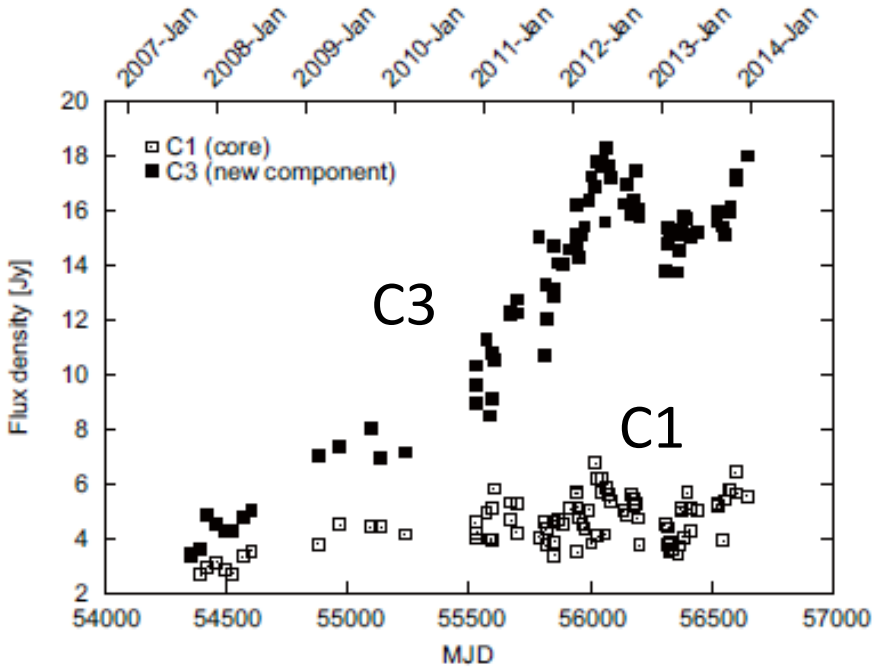


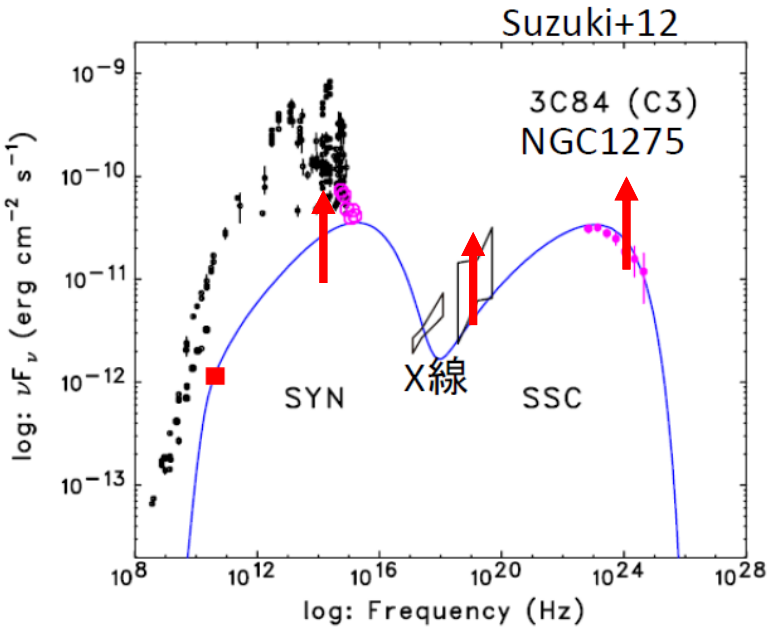


UVOT shows a similar trend.



Nagai+16





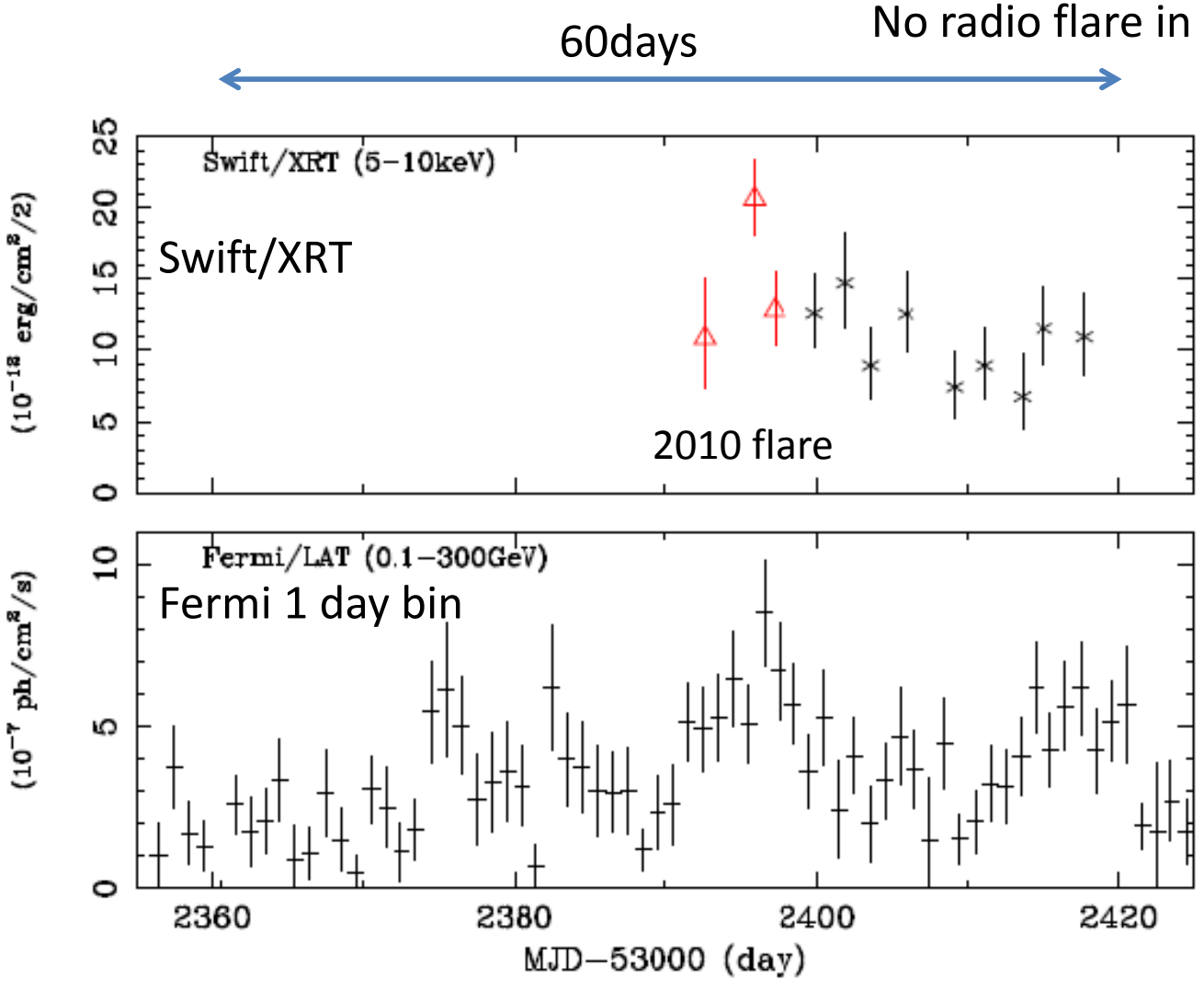
The flux of NGC1275 has been increasing from radio, optical/UV, X-ray, and GeV gamma-ray, without any large change of SED shape.

C3 is likely an origin of the long-term flux increase.

Short-term variability

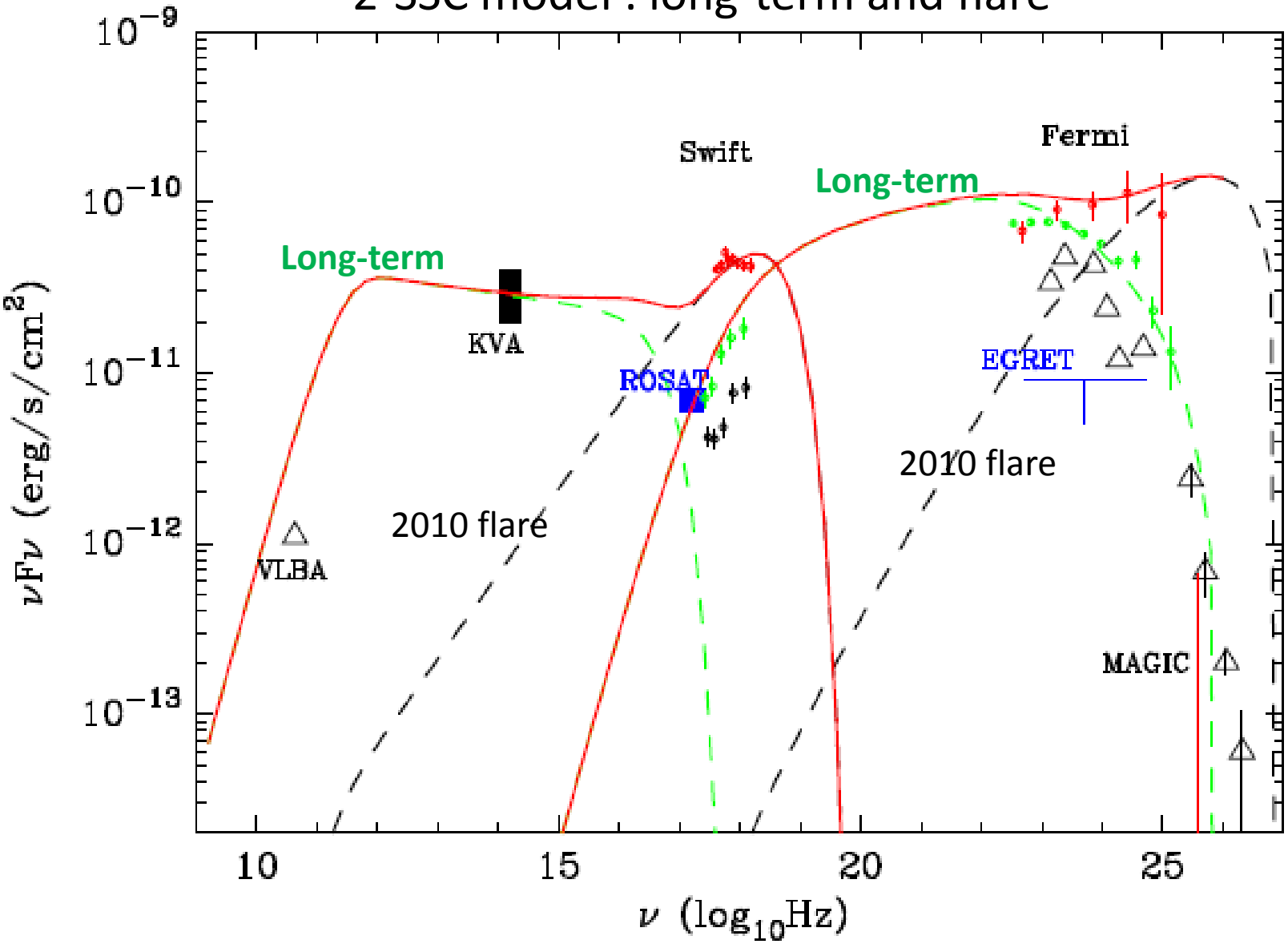
Cf:, Brown and Adams 2011

No radio flare in 2010 (Nagai+12)



Freshly accelerated electrons in the inner jet region (shock-in-jet)

2-SSC model : long-term and flare



Origin of X-ray Emission of GeV radio galaxies

Fukazawa+14

Source	Fe-K line	X-ray spectral index	X-ray variability	[O III] line	Type [ref.]
3C 78	jet	jet	inconclusive	jet	LERG [B10]
NGC1275	disk/corona	inconclusive	inconclusive	disk/corona	HERG/LERG†
3C 111	disk/corona	inconclusive	inconclusive	disk/corona	HERG‡ [E00]
3C 120	disk/corona	inconclusive	inconclusive	disk/corona	HERG‡ [E00]
PKS 0625−354	jet	jet	inconclusive	jet	LERG [M14]
M 87	jet	jet	jet	jet	LERG [G13]
Cen A	disk/corona	inconclusive	jet	inconclusive	HERG [E04]
NGC 6251	jet	inconclusive	inconclusive	jet	LERG [E11]

For low excitation radio galaxies (LERG) ,

X-ray emission is likely to be a jet origin.

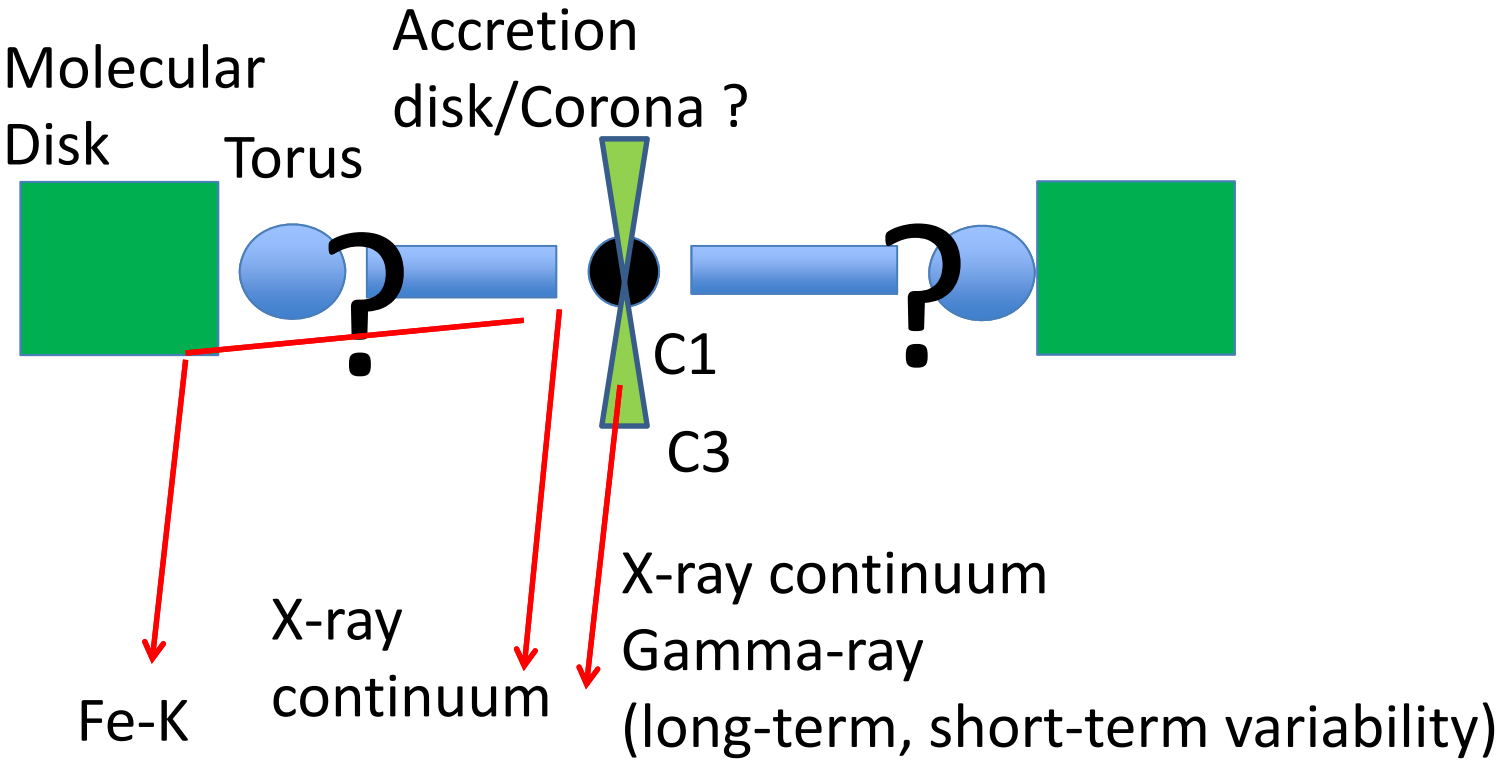
For high excitation radio galaxies (HERG) ,

X-ray emission is likely to be a disl/corona origin.

Summary

Hitomi/SXS obs of NGC1275 for the first time performed a fine spectroscopy of AGN Fe-K.
X-ray flux well correlates with GeV gamma-ray.

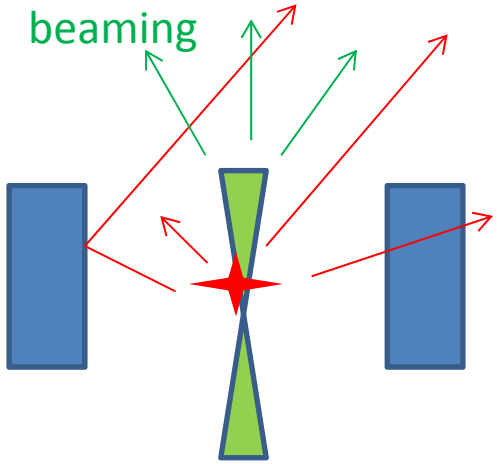
XARM … variability of Fe-K and 10-20keV continuum
Athena … More on Fe-K spectroscopy (S/N, large EW) and continuum



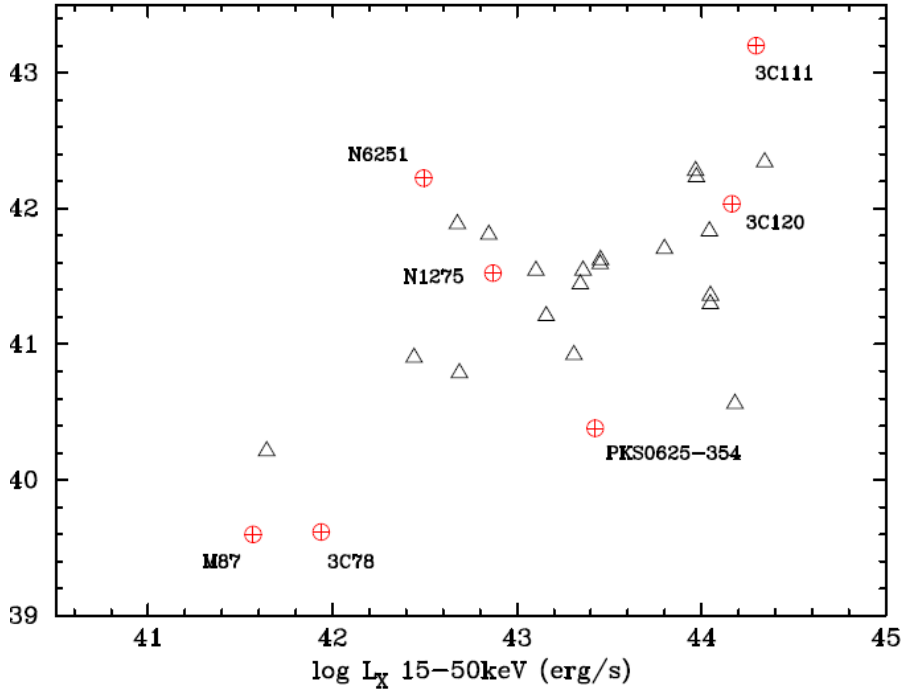
Origin of X-ray Emission

Fe-K line EWs of PKS0625-354, 3C78, M87, NGC6251 are smaller than those of typical Seyfert galaxies.

X-ray luminosity of PKS0625-354 is higher than that of typical Seyfert galaxies with a similar [O III] luminosity.

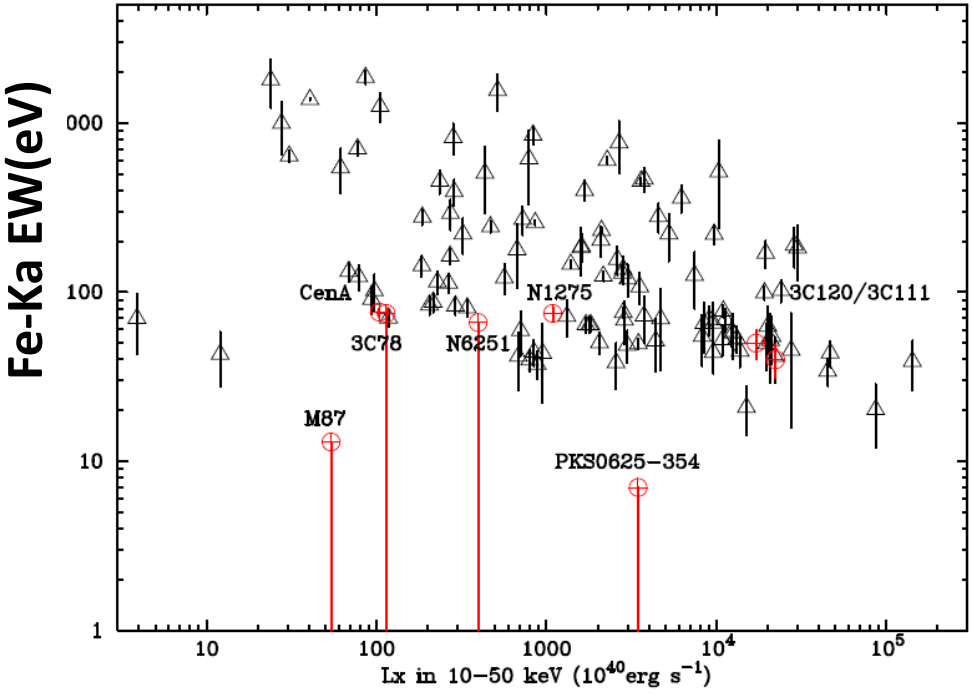


Log L O[III] **with Mulchaey+94, Winter+10**



Log L x

with Fukazawa+11



Log L x

Baseline SED Model Parameters of NGC 1275 Nucleus

	Baseline	Change	Steady	Flare
Γ	2.3	$\times 2$	same	same
B [G]	0.035	$\times 2$	same	same
t_v [Ms]	13.4	$\times 3.3$	8.94	0.50
p_1	2.1		same	2.0
p_2	3.1	-0.2	same	2.0
$\gamma_{\rm min}$	8×10^2		same	same
$\gamma_{\rm max}$	4×10^5	$\times 10$	same	4×10^6
$\gamma_{\rm brk}$	9.6×10^2		same	same
$P_{j,B}$ [10^{40} erg s^{-1}]	0.24×10^4		0.11×10^4	3.4
$P_{j,\,e}$ [10^{40} erg s^{-1}]	2.0×10^4		3.0×10^4	2.8×10^3

X-ray probing of structure of material around supermassive black hole

Fuel of central engine
Feedback to parent galaxy