



Spectral transition of ultraluminous X-ray source, NGC 2403 SRC3

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and

Suzaku SWG team of NGC 2403

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Ultraluminous X-ray Sources (ULXs)

- X-ray point sources with a luminosity of $L \gg 10^{39} \text{ ergs s}^{-1}$, frequently found in nearby normal galaxies (Fabbiano et al. 1989)
- Promising candidate of **intermediate mass black holes** with a mass of $M \gg 10 M_{\odot}$, (M_{\odot} is the solar mass). (e.g. Makishima et al. 2000)
- Two spectral states (e.g., Kubota et al. 2001)
 - Multi-color disk (**MCD**) and Power Law (**PL**)
- Important sources to study black holes at **high accretion rate.**

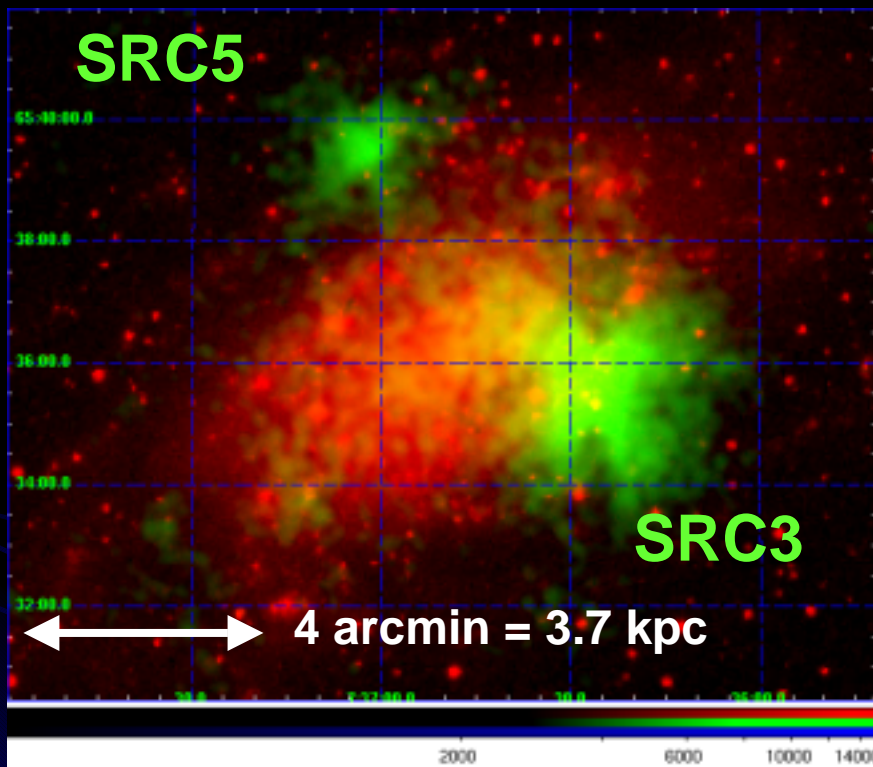
Suzaku



- 5th Japanese X-ray observatory, launched in June 2005 (Mitsuda et al. 2007)
- Two instruments
 - X-ray Imaging Spectrometer (XIS)
 - 3 FI and 1 BI CCDs
 - 0.2 – 12 keV
 - Hard X-ray Detector (HXD)
 - PIN : 10 – 70 keV
 - GSO : 40 – 600 keV
- Advantages
 - Low and stable background
 - Good energy resolution
 - High sensitivity
 - Wide energy band
- Results on ULXs
 - NGC 1313 (Mizuno et al, 2007)
 - *Suzaku* J1305-4931 (Isobe et al. 2008)



NGC 2403

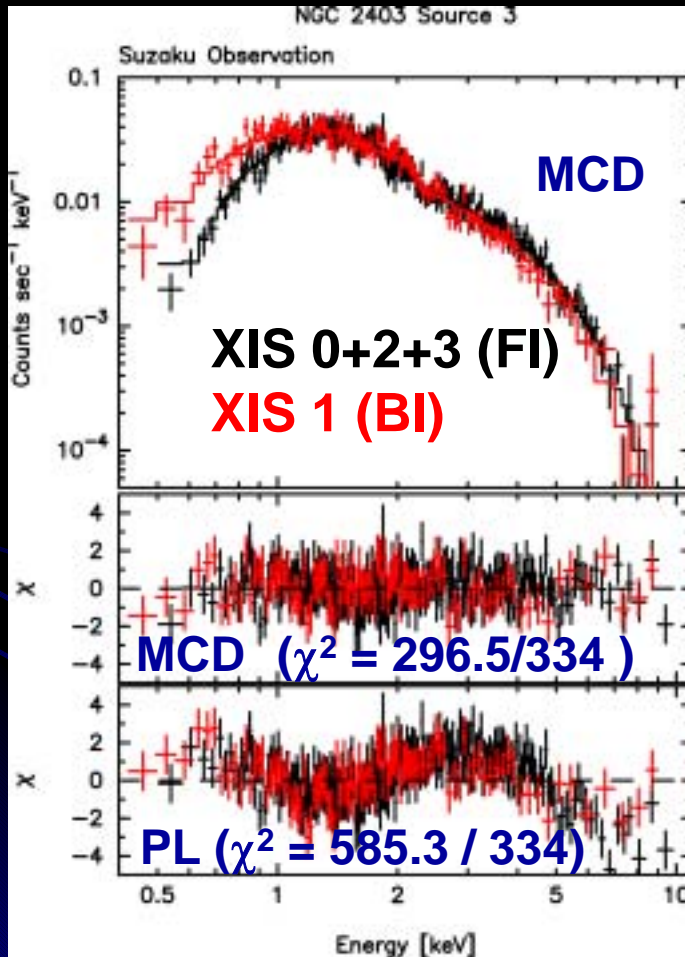


Optical
image (DSS)

Suzaku XIS image
(0.5 – 10 keV)

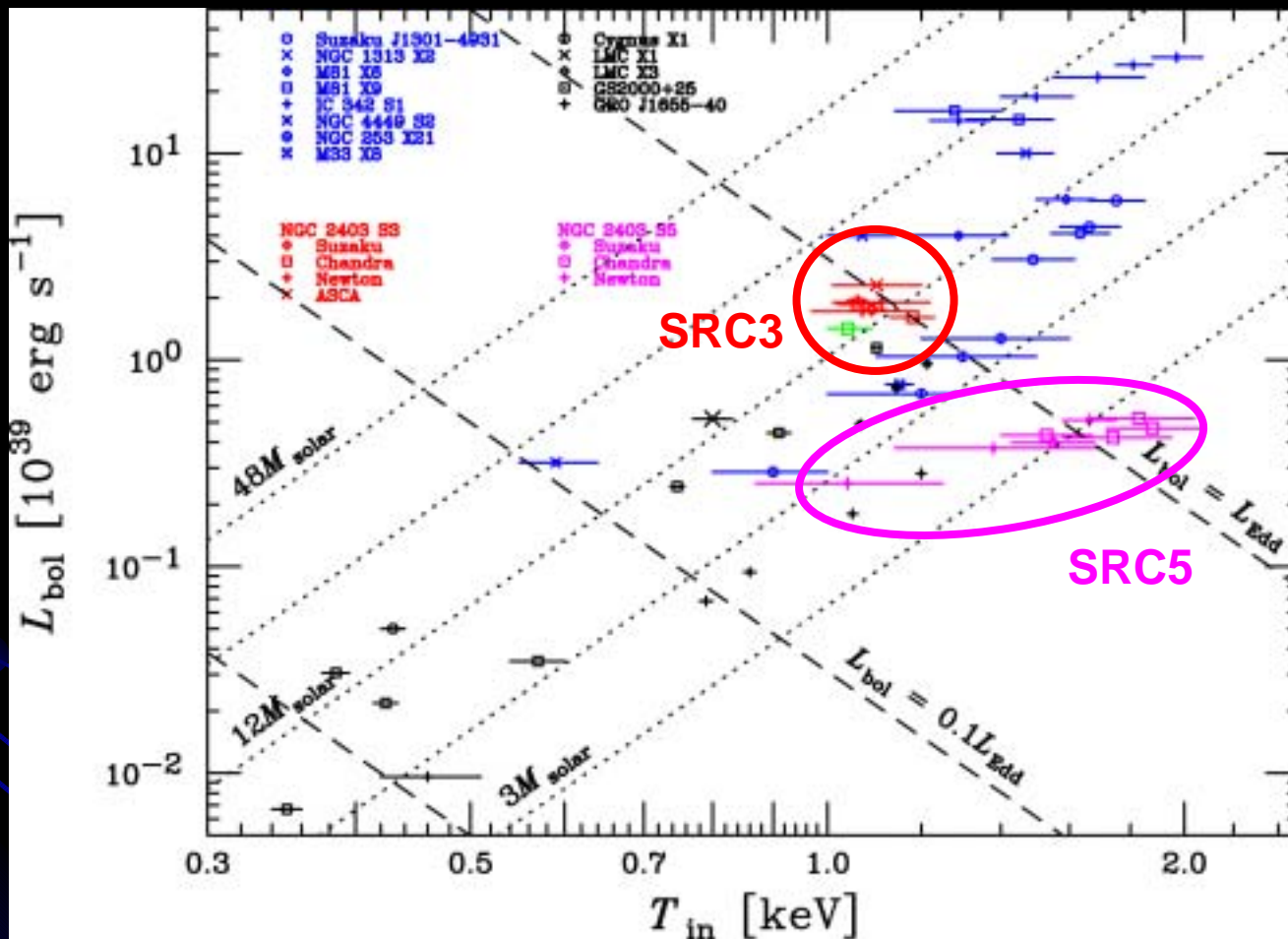
- Spiral galaxy (SABcd) at a distance of 3.2 ± 0.4 Mpc (Freedman & Madore 1988)
- Several bright X-ray sources, including ULX. (Fabianno & Trinchieri 1987)
- *Suzaku* observation on March 16th, 2006 during SWG phase
- ASCA observation in 1997 (Kotoku et al., 1999)
- Discovery of a supernova SN2004dj motivated a series of *Chandra*, *XMM-Newton* observations

Suzaku Spectrum of SRC3



- *Suzaku* XIS spectrum of NGC 2403 SRC 3
 - is successfully described with multi-temperature black body emission from accretion disk (Multi-color disk model; MCD).
 - $T_{\text{in}} = 1.09 \pm 0.03$ keV
 - $R_{\text{in}} = 116.9 + 5.9 - 5.5$ km
 - $L_{\text{bol}} = 1.75 \times 10^{39}$ ergs s⁻¹
 - is not fitted with a PL model.

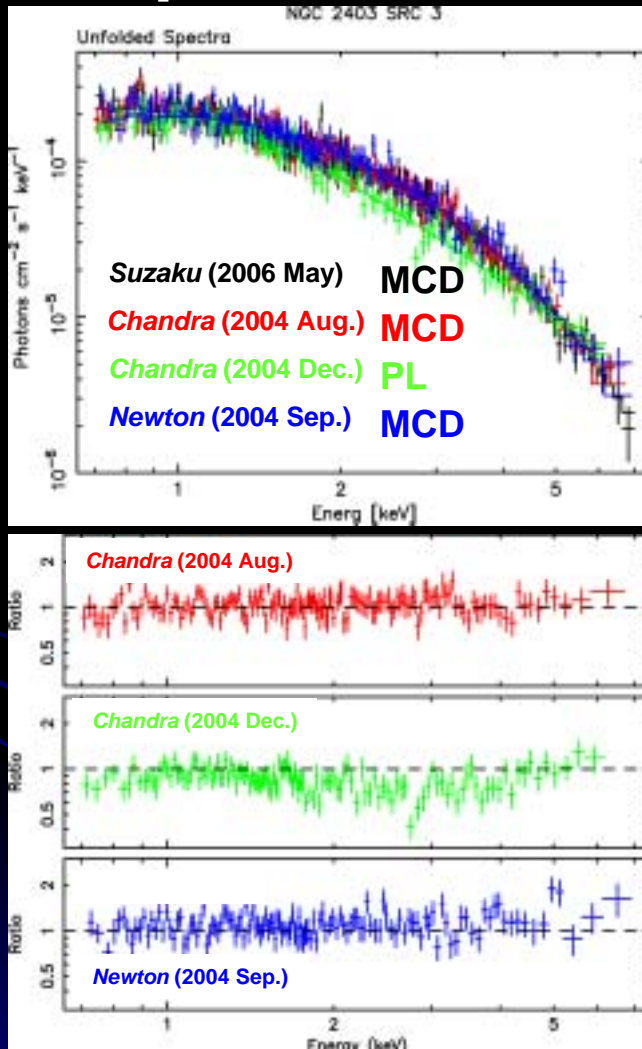
Relation between L_{bol} and T_{in}



(Kotoku et al. 2000, Makishima et al. 2000, Isobe et al. 2007 and reference therein)

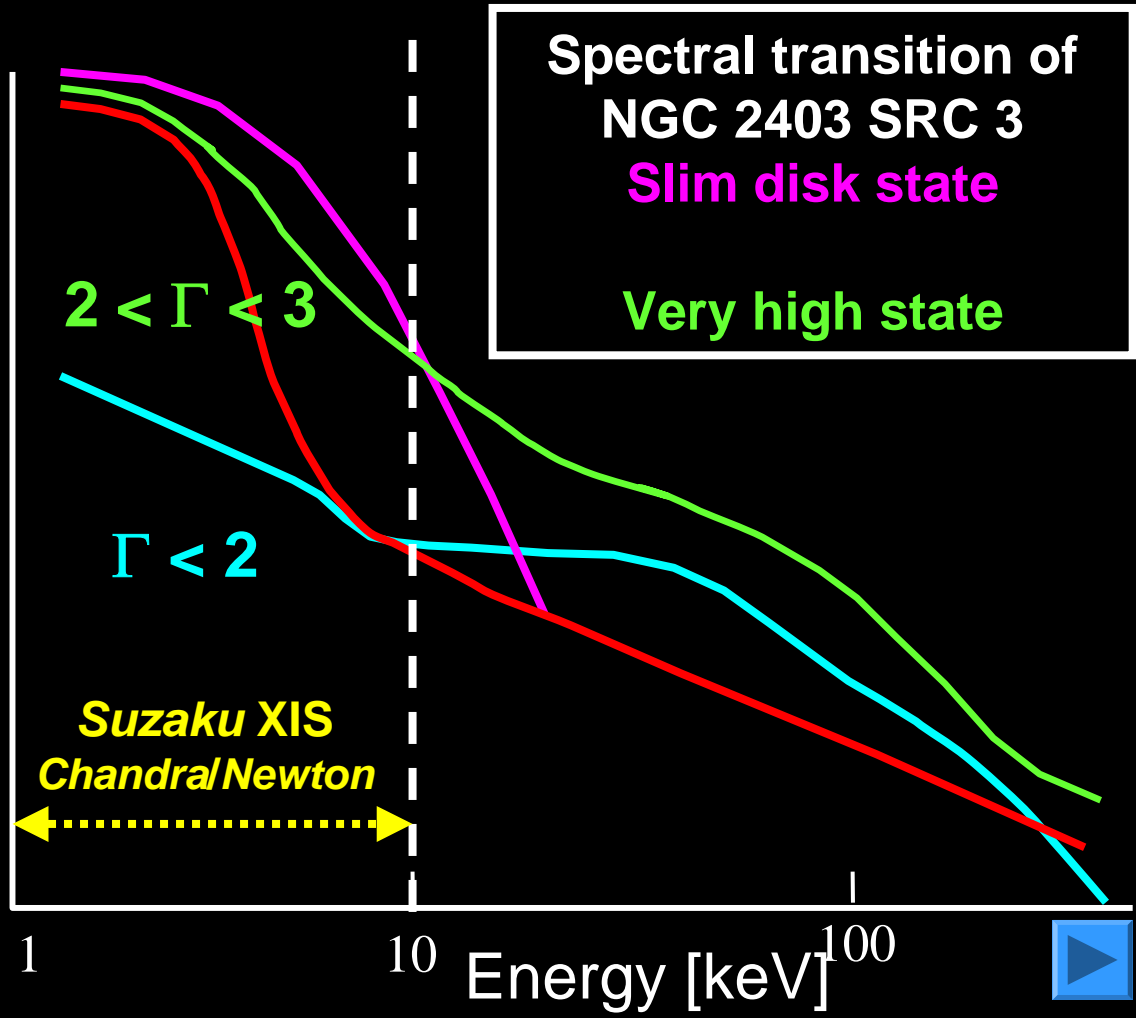
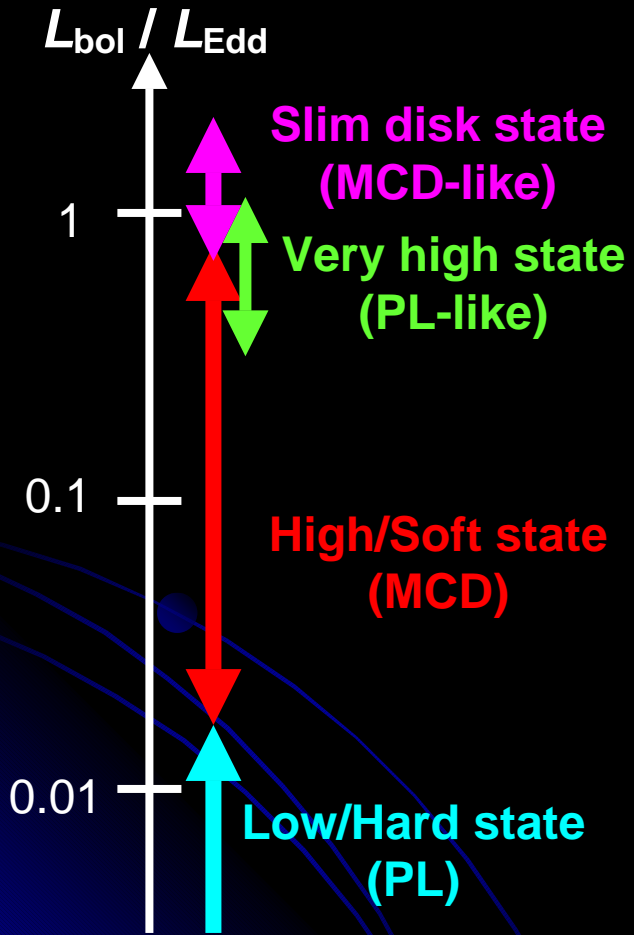


Spectral transition of SRC3



- Only the *Chandra* data obtained in December, 2004 showed the PL-like spectrum.
 - $\Gamma = 2.37 \pm 0.07$
- The X-ray flux of the observation is slightly smaller than the *Suzaku* observation by 15 %.
- Spectral transition between the MCD-like and the PL-like states is
 - Frequently observed in Galactic black holes.
 - Observed in some well-studied ULXs. (e.g. Kubota et al. 2001)

Spectral states of black holes



Slim disk scenario for SRC 3

Standard disk (in MCD)

- Radial temperature profile
 - $T \propto r^{-0.75}$

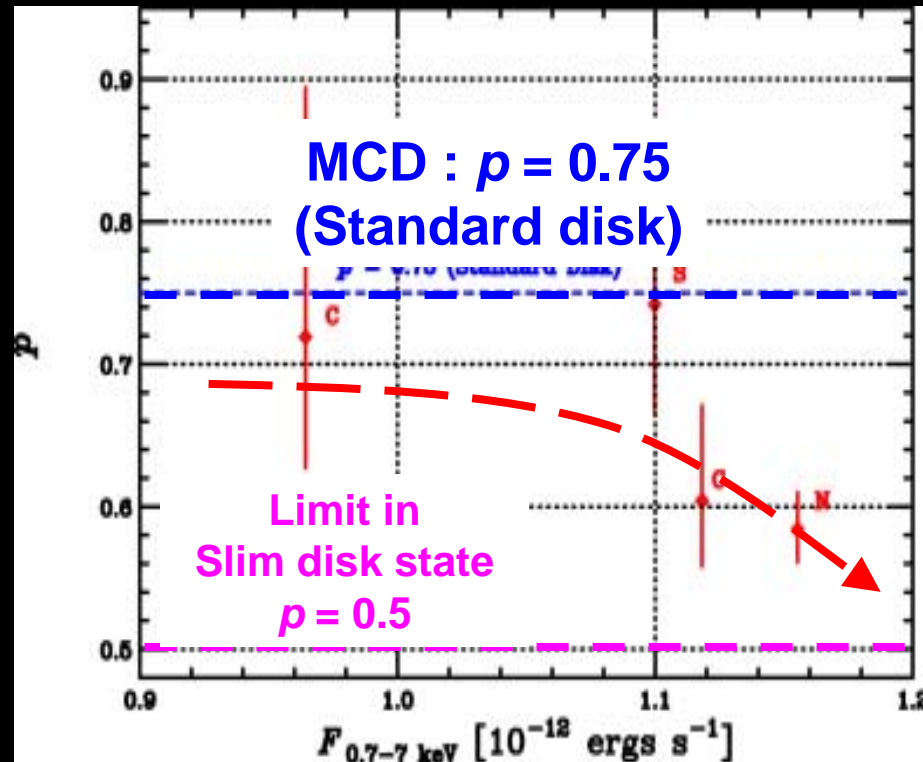
Slim disk

- Advection and/or photon trapping become important.

Flat profile (Watarai et al. 2000)

- $T \propto r^{-p}$ with $0.5 < p < 0.75$
(p-free disk model; Mineshige et al. 1994, Vierdayanti et al. 2006)

Summary of p-free disk fitting



Summary

- We examined the spectral variation of the ULX, NGC 2403, in nearly 10 years, using *ASCA*, *Suzaku*, *Chandra* and *XMM-Newton*.
- NGC 2403 SRC3 showed the **MCD-like spectra**, except for one *Chandra* observation.
 - $T_{\text{in}} = 1.09 \pm 0.03$ keV
 - $R_{\text{in}} = 116.9 + 5.9 - 5.5$ km (in the *Suzaku* Observation)
 - $L_{\text{bol}} = 1.75 \times 10^{39}$ ergs s⁻¹
- We found the **transition to the PL-like spectrum** in the *Chandra* observation, conducted on December 2004, with the flux about 10 % lower than the other observations.
 - $\Gamma = 2.37 \pm 0.07$
- The spectral transition of NGC 2403 SRC 3 can be naturally explained to be a transition between **Very High state (PL-like) and slim disk state (MCD-like)**.