State Transition in Supermassive Black Hole Accretion Explaining Changing-Look AGN

2019 August 6

Osaka University, Japan

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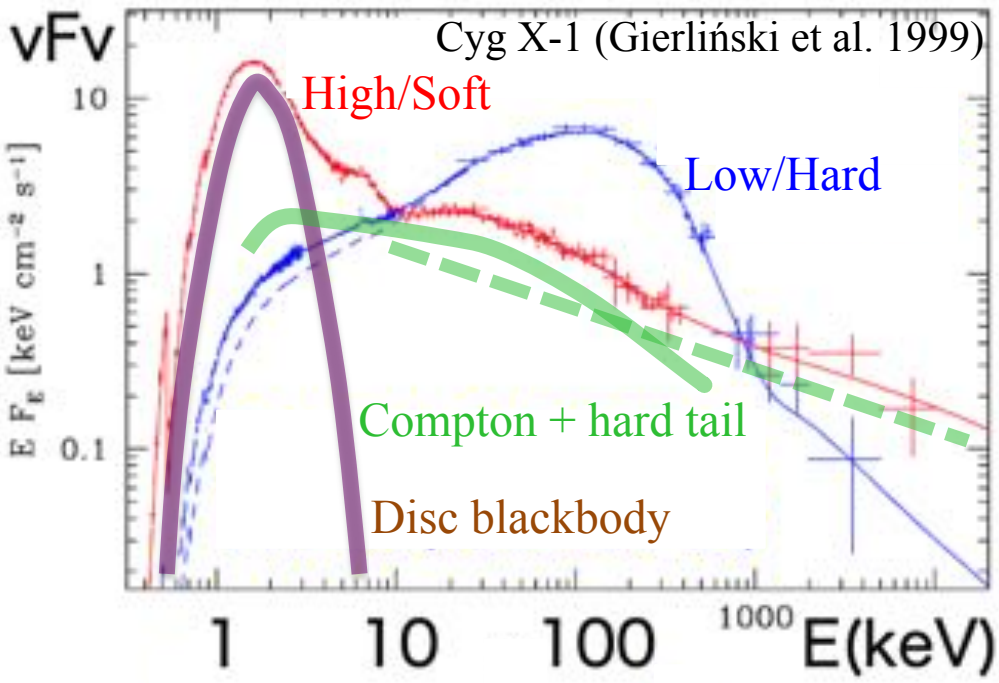
0. Outline

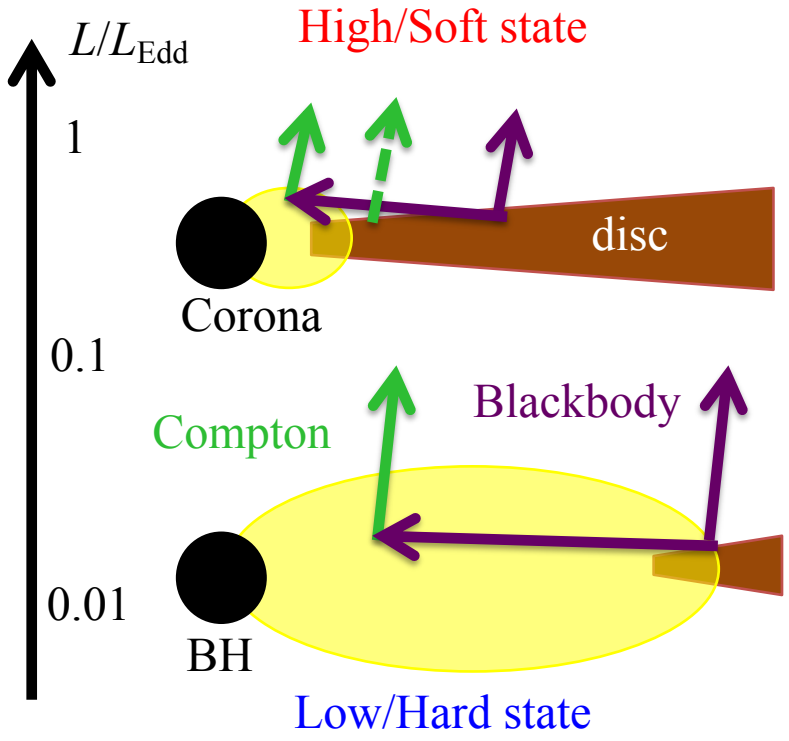
1. Introduction: State transition of BH accretion flows
2. State transition in SMBH accretion
3. Remaining issues and forthcoming X-ray mission

1. Introduction

~State transition of BH accretion flows~

1. X-ray Spectrum of BH Binary

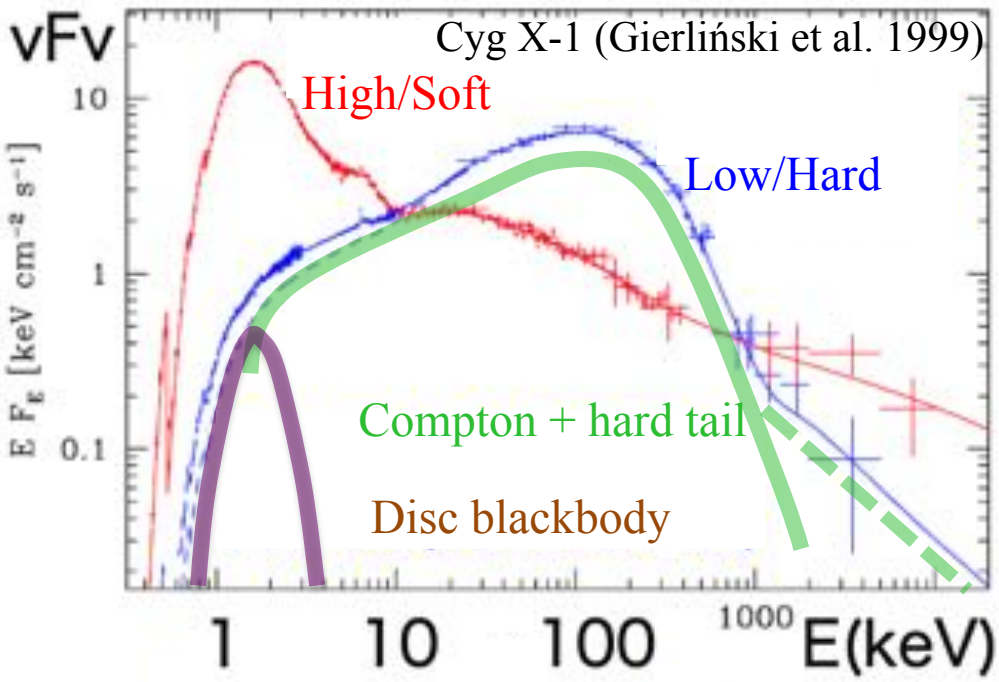


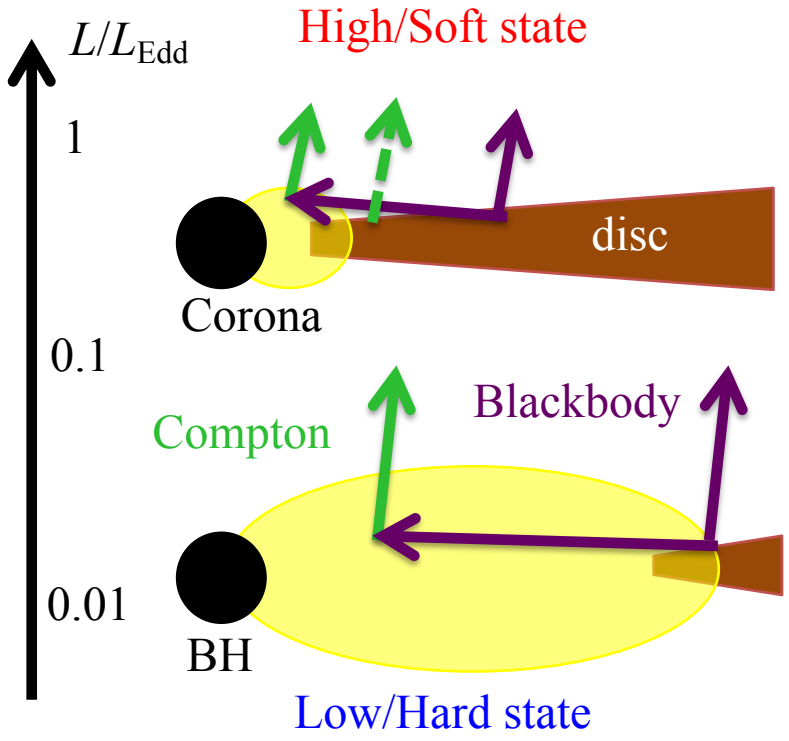


☆ X-ray spectrum includes disc black body and inverse Compton which has high E cutoff at several hundreds keV (e.g., Yamada, + , Noda et al. 2013)

☆ With mass accretion rate, spectral state changes. Disc evaporates into corona, or corona condenses to disc, changing inner radius (e.g., Done et al. 2007)

1. X-ray Spectrum of BH Binary





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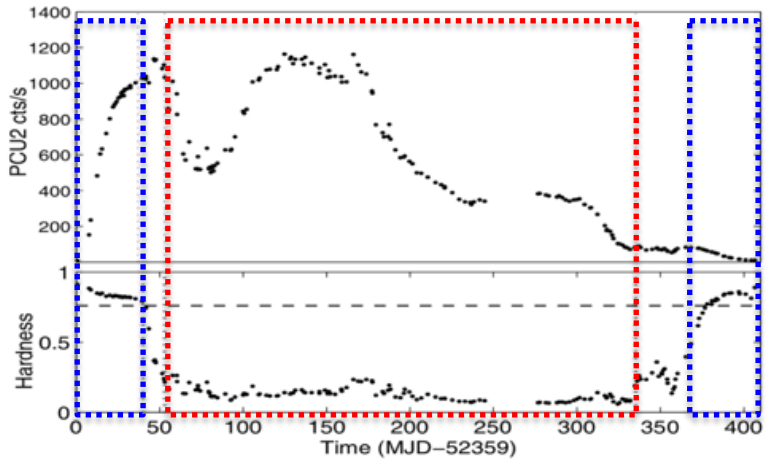
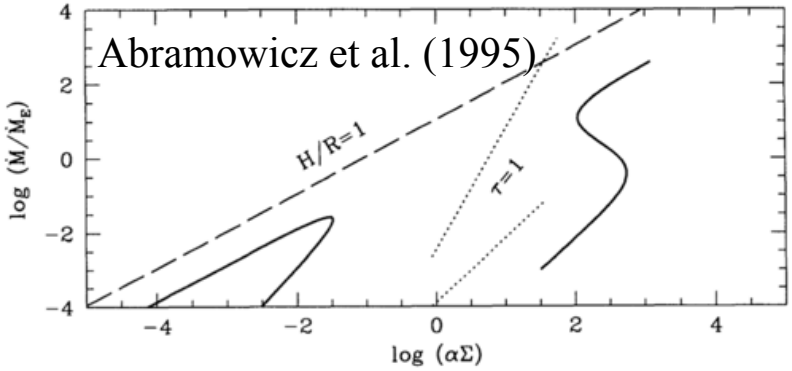
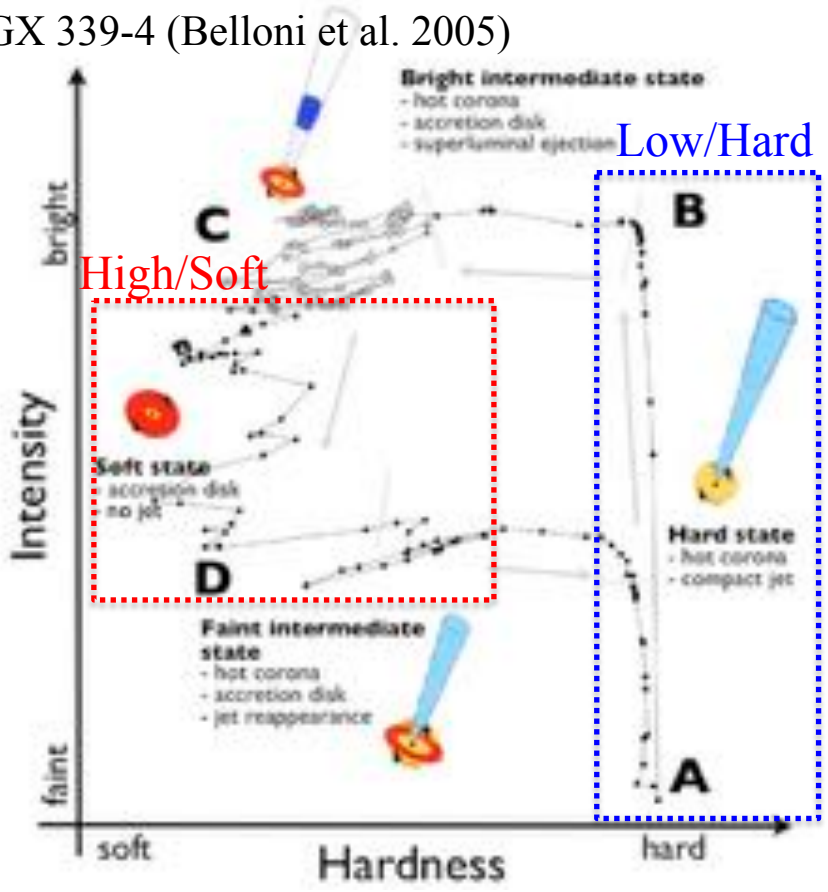
2. State Transition in BHB Accretion

Low/Hard High/Soft Low/Hard





GX 339-4 (Belloni et al. 2005)



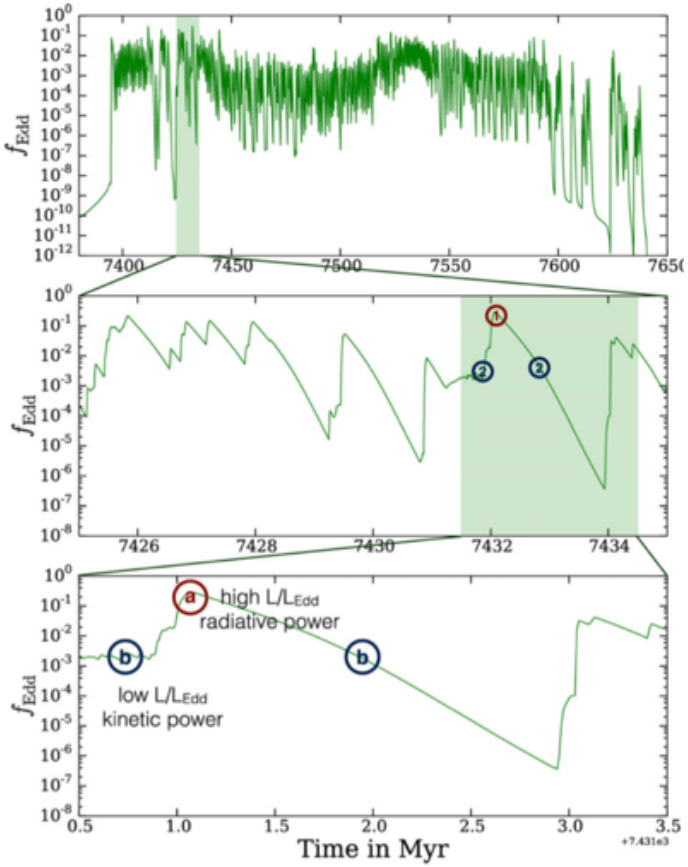
☆ Transition happens during X-ray outburst in which L changes by an order of mag.

The High/Soft to Low/Hard transition happens at $L/L_{\rm Edd}$ ~ a few %

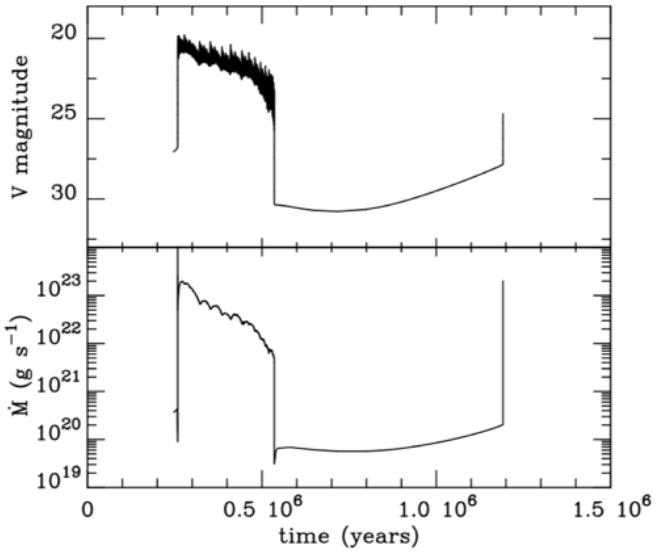
☆ T.scale of the transition is days to weeks (Viscous t.scale of disc at hundreds R_s)

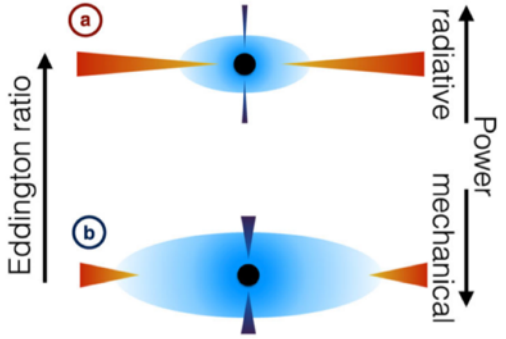
3. How About SMBH Accretion?

AGN cosmic time evolution (Novak et al. 2011)



AGN outburst simulation (Hameury et al. 2009)



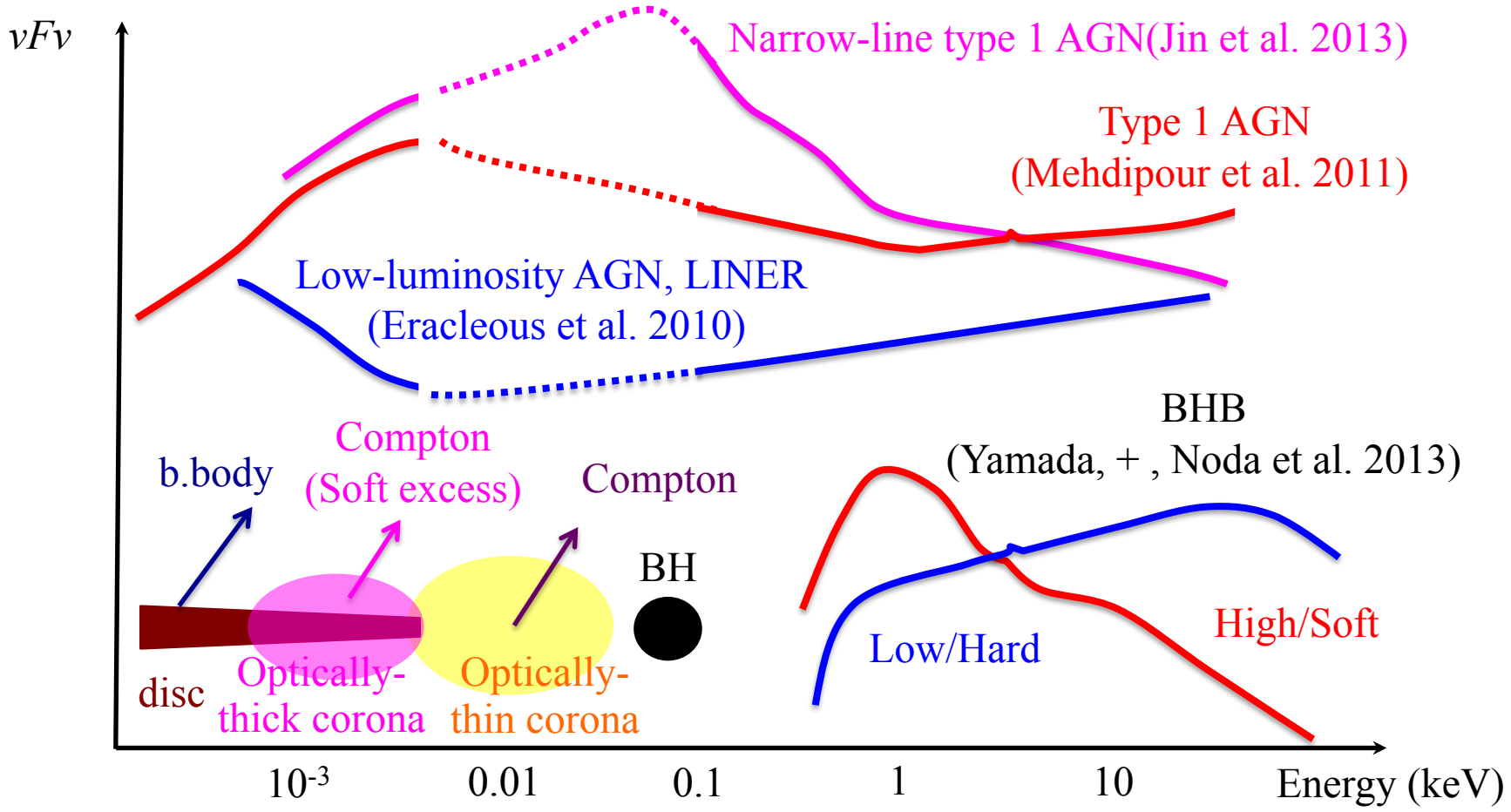


Schawinski et al. (2015)

☆ State transition in SMBH accretion has been expected to take ~$10^{5\text{-}7}$ years

☆ Is it impossible to observe state transition in SMBH accretion? ➔ Today's focus

4. Comparison of SED b/w AGN and BHB



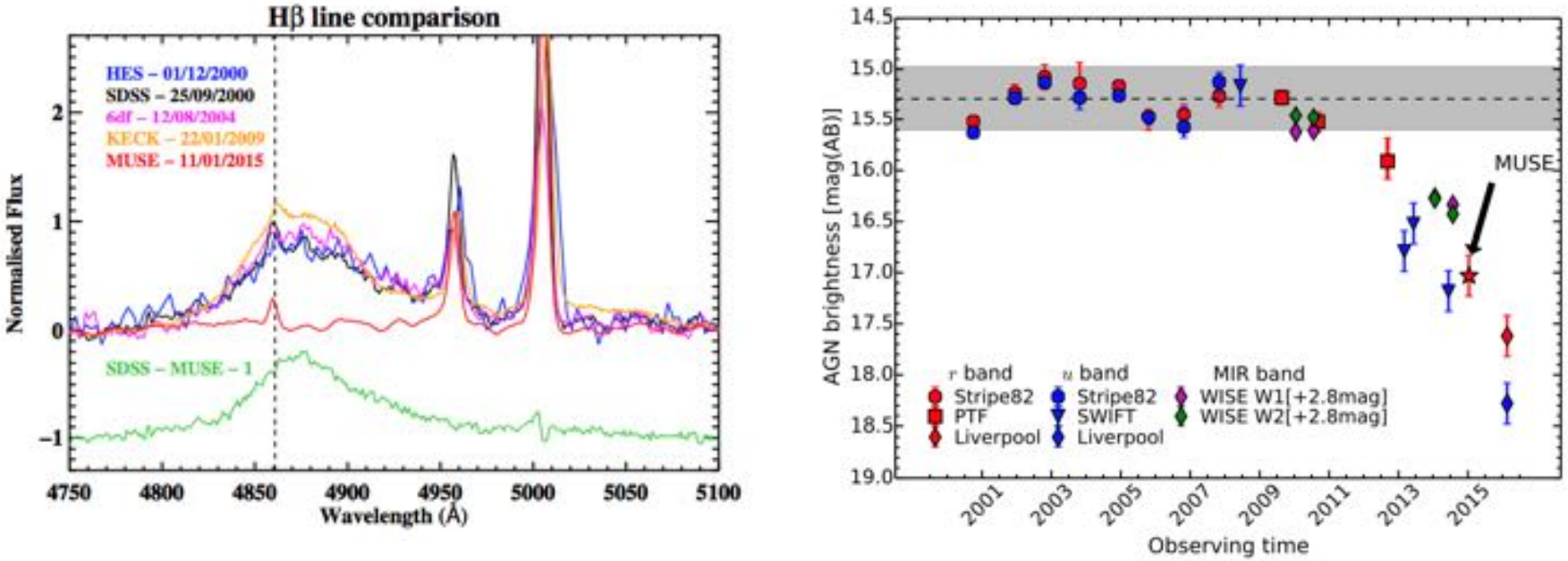
☆ Type 1 AGN SED includes disc b.body, hard X-ray Compton and soft excess

☆ Soft excess is thermal Compton by optically-thick corona ($kT_e \sim 0.1$ keV, $\tau \sim 15$)

(e.g., Noda et al. 2011; Petrucci et al. 2018; Kunota & Done 2018)

2. State Transition in SMBH Accretion

5. Changing-Look AGN



Changing-Look AGN Mrk 1018 (McElroy et al. 2016)

☆ Some AGNs change their types defined by broad emission lines in ~10 years (type 1 → 1.9 or 1.9 → 1) ➔ "Changing-Look AGNs (CLAGNs)"

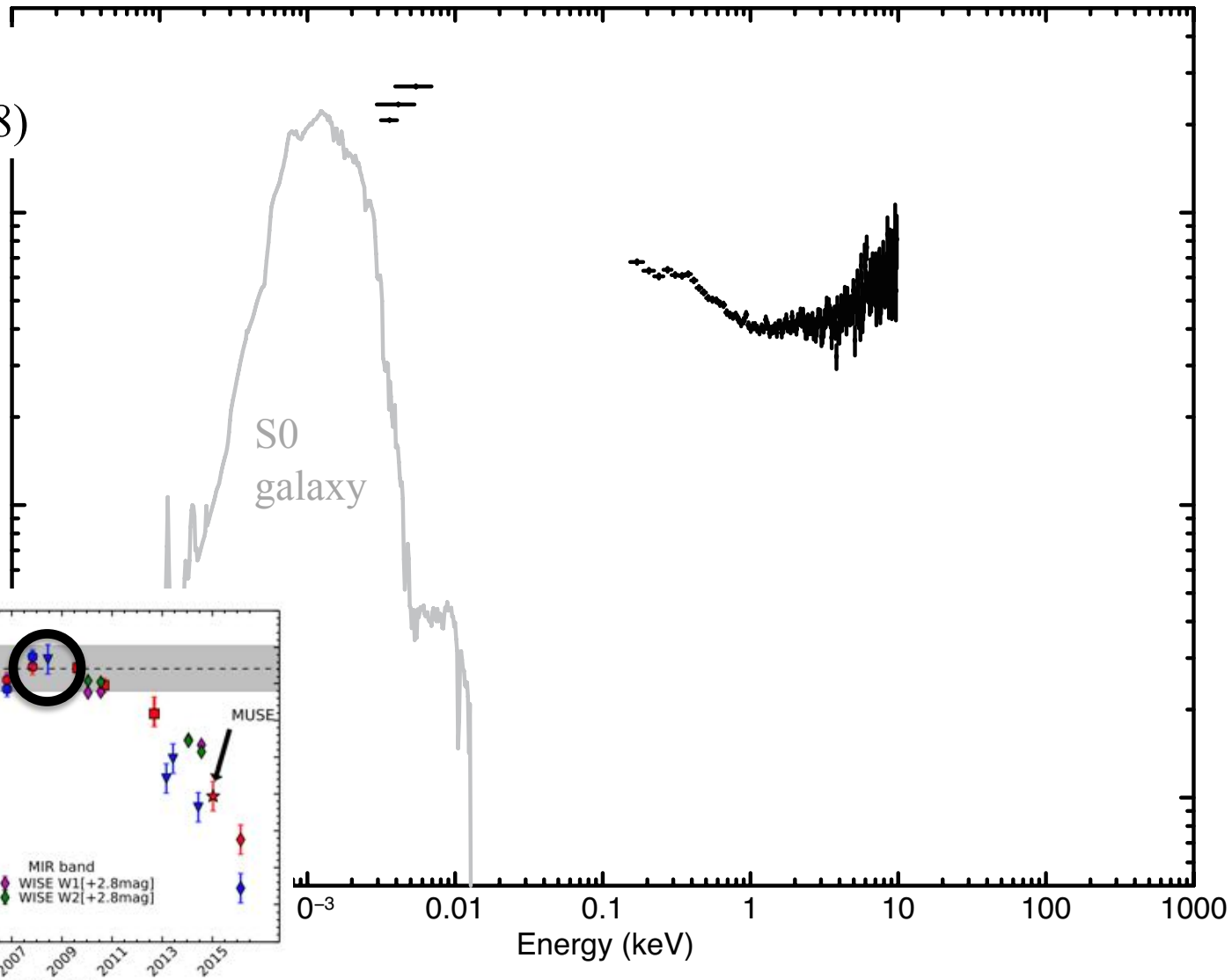
☆ In this study, we focused CLAGN spectral shape change in optical, UV, and X-ray

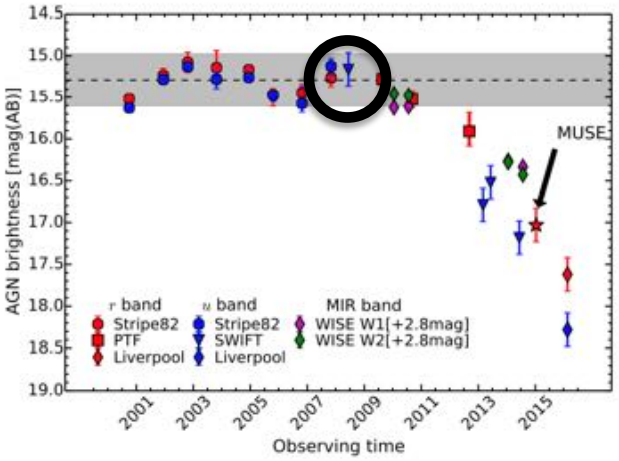
☆ Following type change of Mrk 1018 type 1 (2008) to 1.9 (2016), *XMM-Newton* and *Swift* observed multiple times ➔ We modeled multi-wavelength spectra

6. Optical/UV/X-ray Spectral Change

XMM-Newton/OM & EPIC-PN de-absorbed spectra (Noda & Done 2018)

2008 Type 1
($L/L_{\rm Edd} \sim 0.08$)





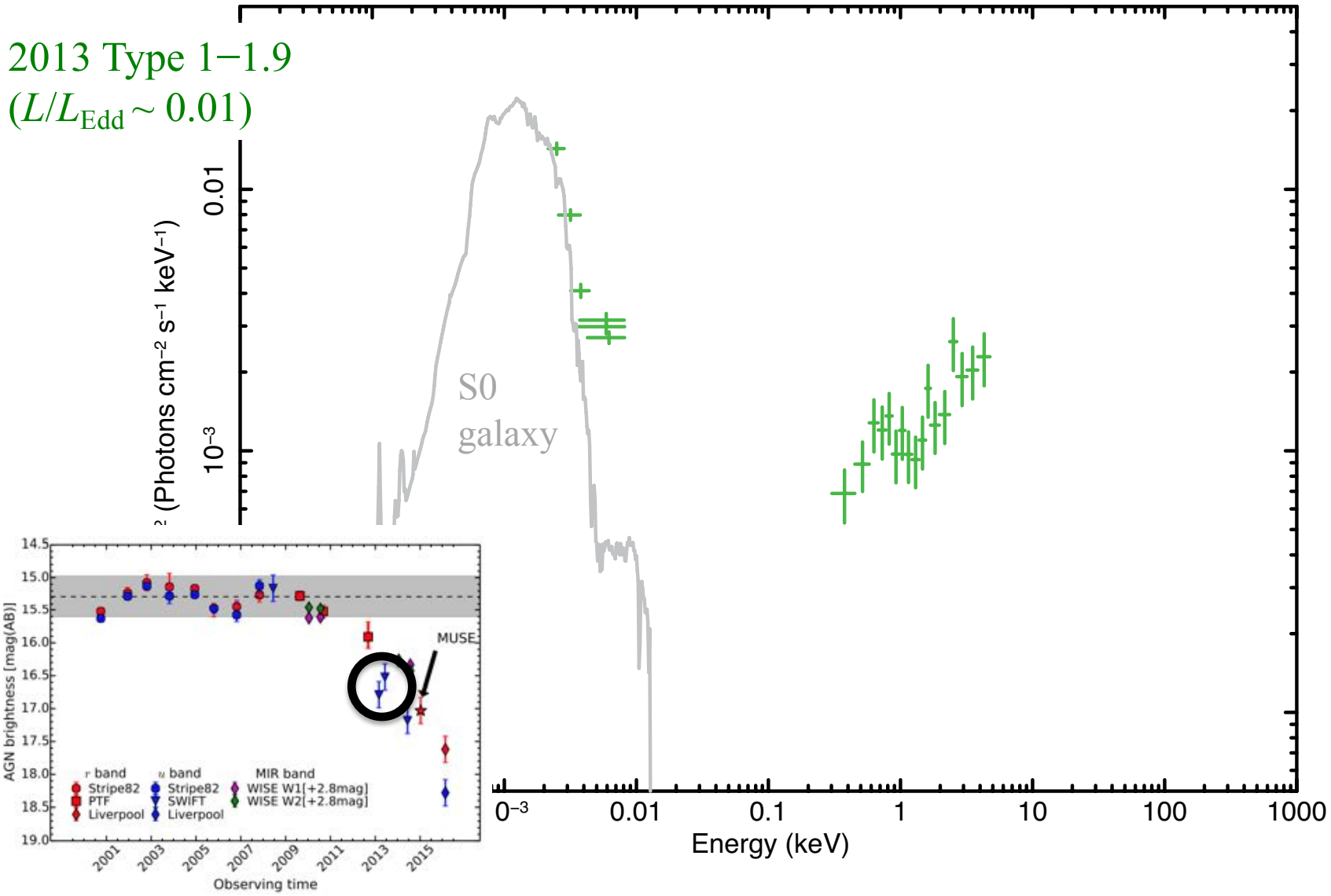
6. Optical/UV/X-ray Spectral Change

(Noda & Done 2018)

Swift/UVOT & XRT de-absorbed spectra

2013 Type 1−1.9

($L/L_{\rm Edd} \sim 0.01$)

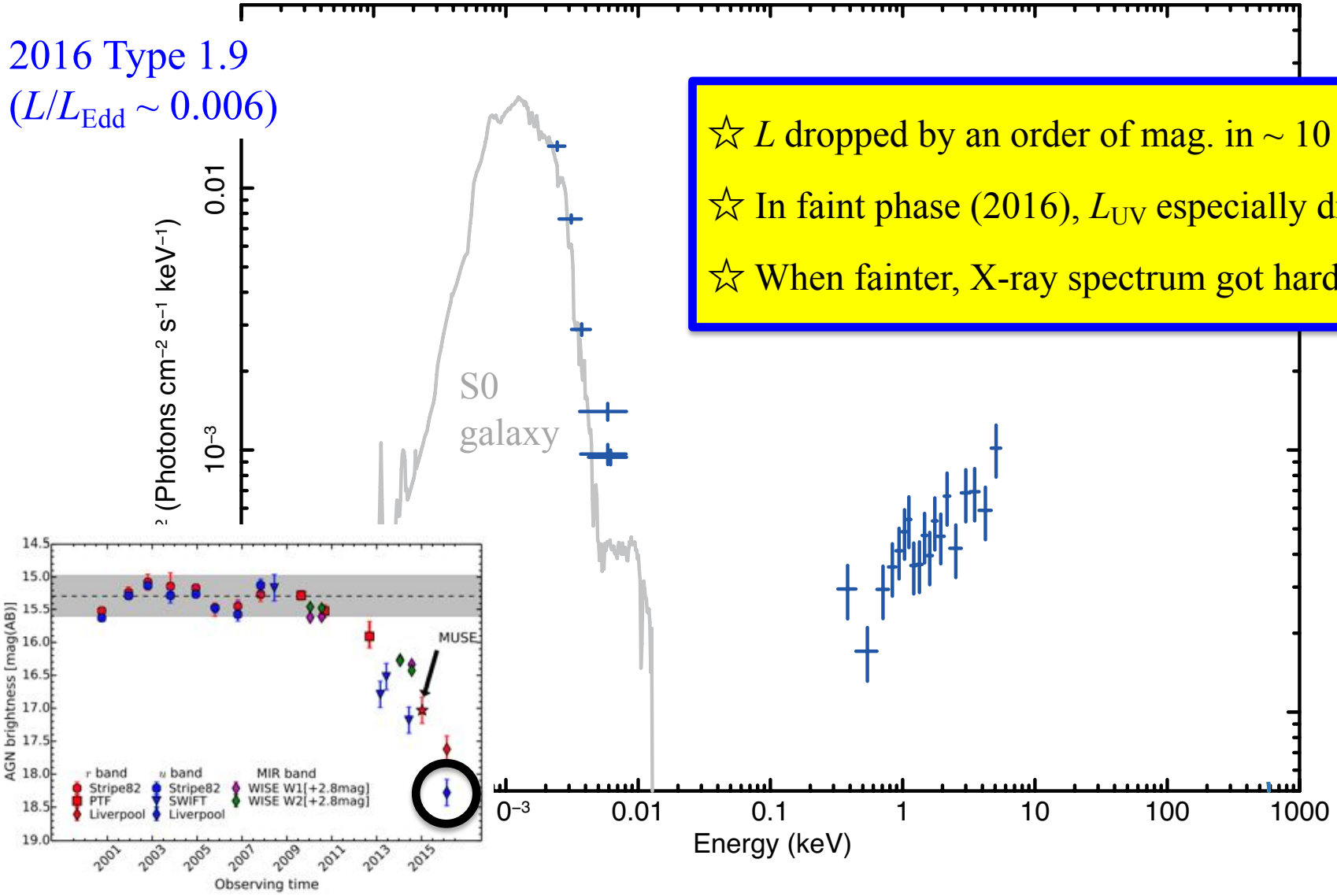


6. Optical/UV/X-ray Spectral Change

(Noda & Done 2018)

Swift/UVOT & XRT de-absorbed spectra

2016 Type 1.9
($L/L_{\rm Edd} \sim 0.006$)



☆ L dropped by an order of mag. in ~ 10 years

☆ In faint phase (2016), $L_{\rm UV}$ especially dropped

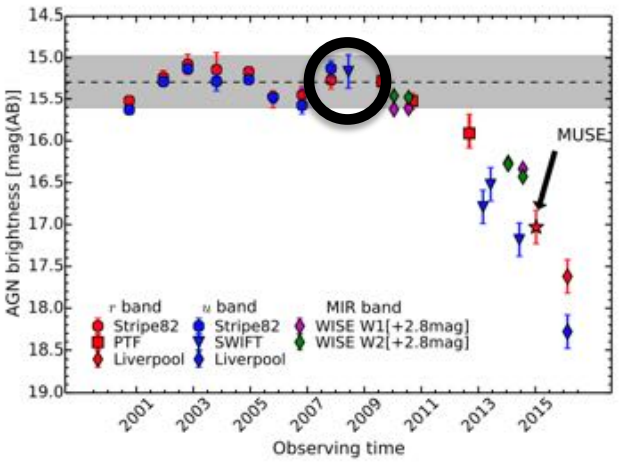
☆ When fainter, X-ray spectrum got harder

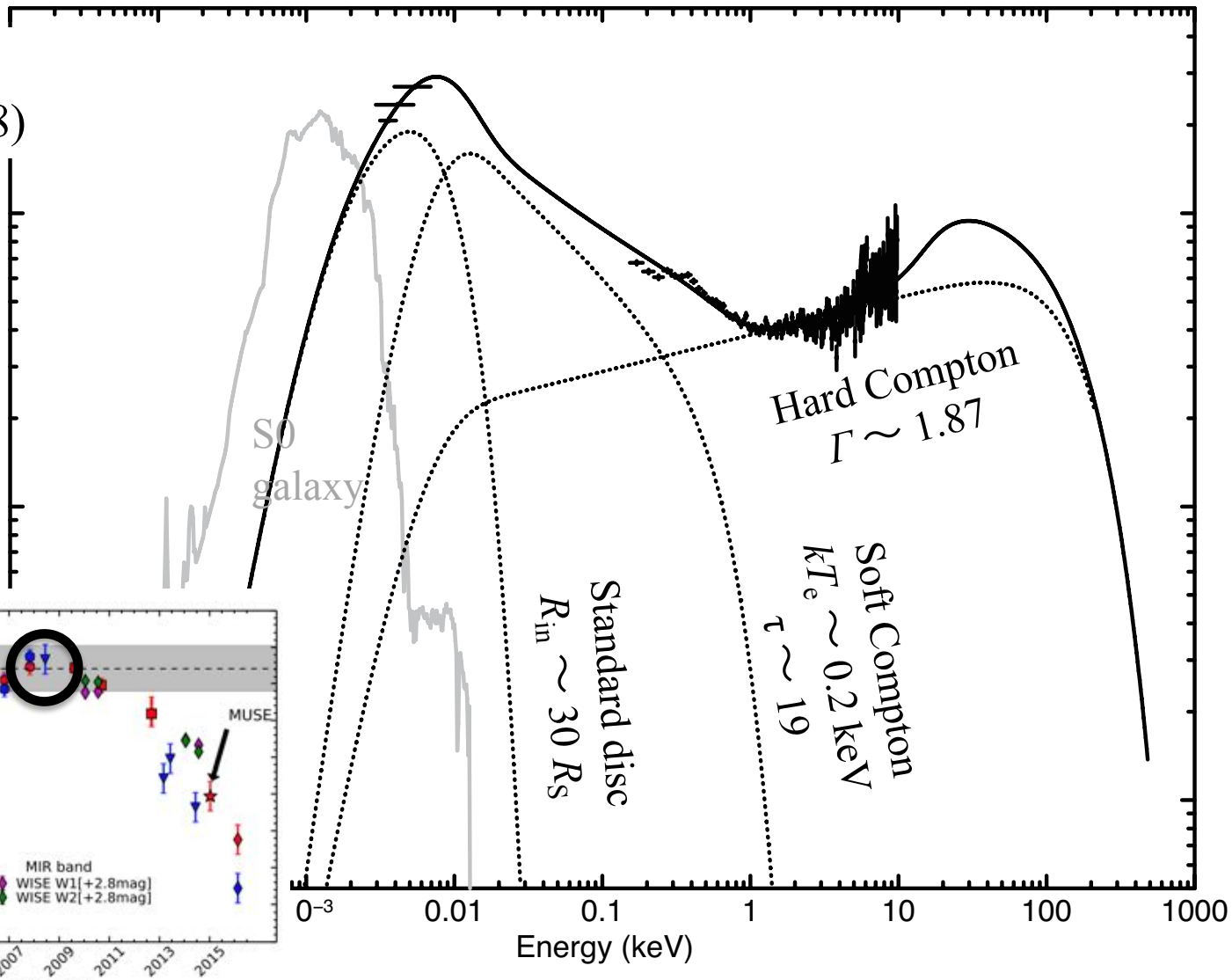
7. DiscBB + Soft excess + Hard Compton Model

(Noda & Done 2018)

XMM-Newton/OM & EPIC-PN de-absorbed spectra

2008 Type 1
($L/L_{\rm Edd} \sim 0.08$)





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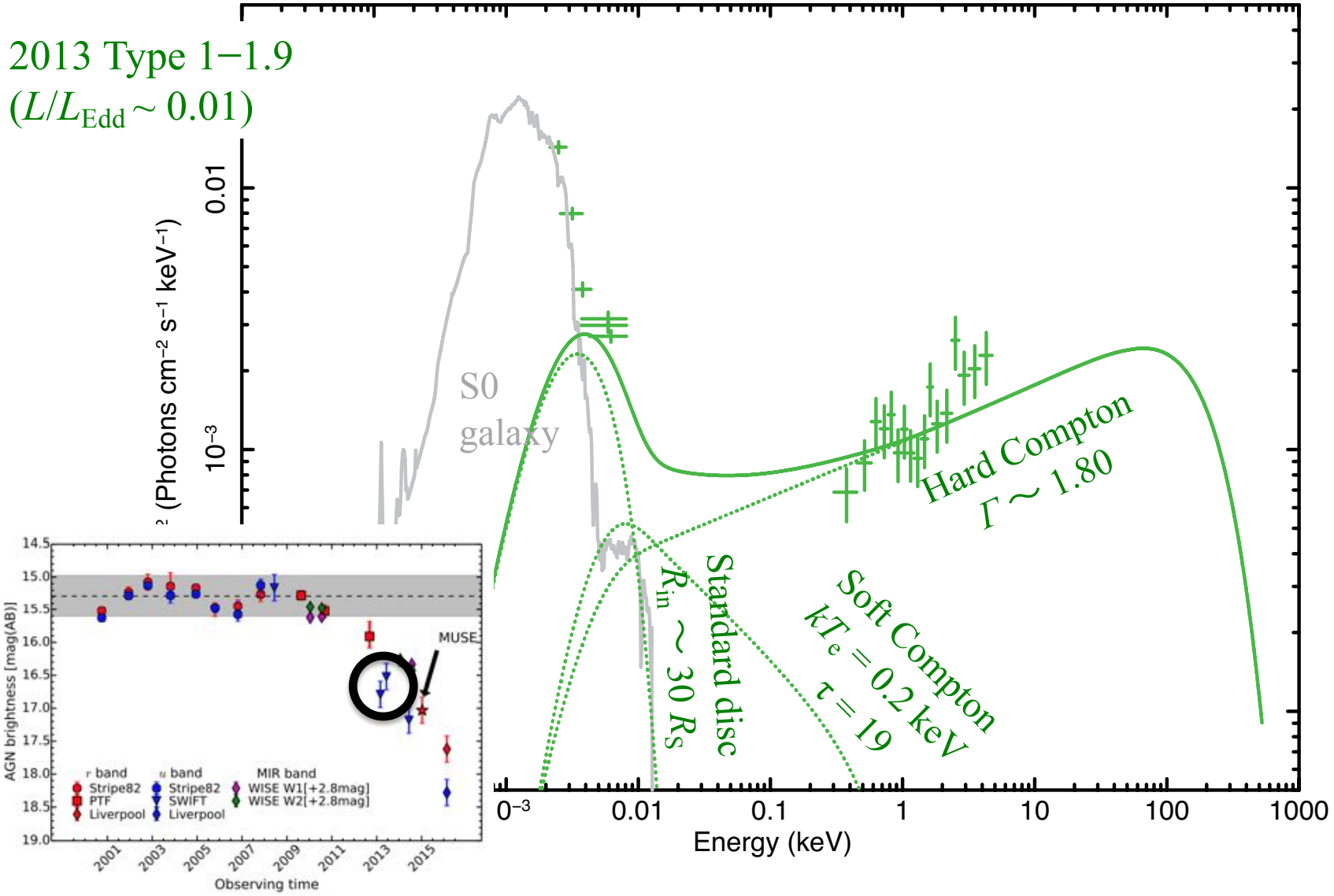


7. DiscBB + Soft excess + Hard Compton Model

(Noda & Done 2018)

Swift/UVOT & XRT de-absorbed spectra

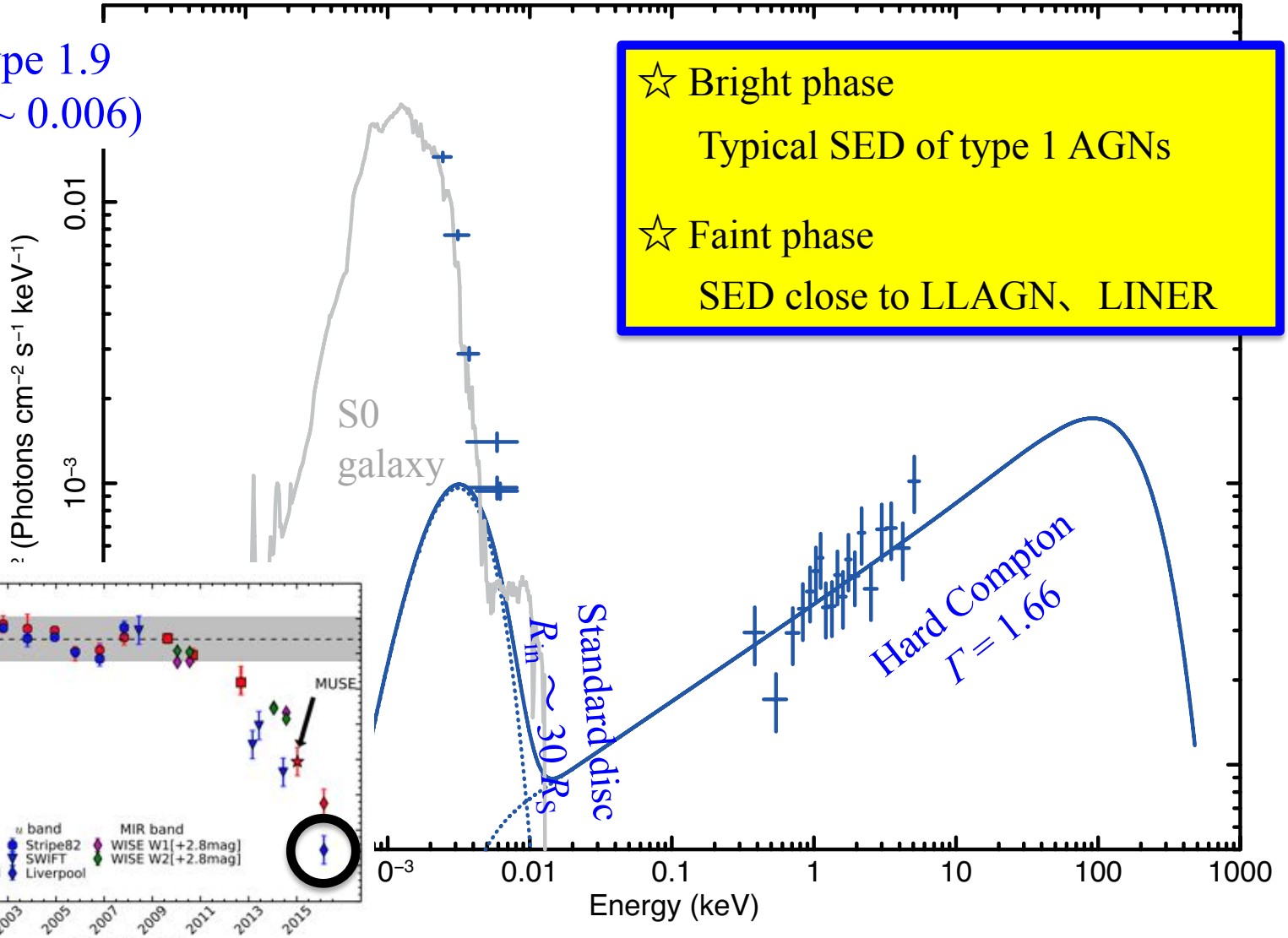
2016 Type 1.9
($L/L_{\rm Edd} \sim 0.006$)

☆ Bright phase

Typical SED of type 1 AGNs

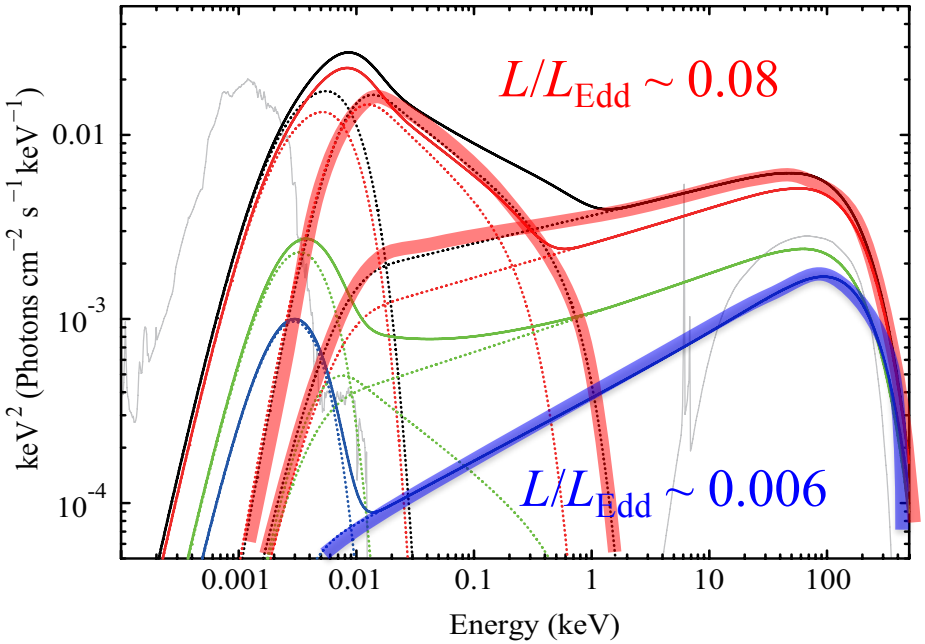
☆ Faint phase

SED close to LLAGN、LINER

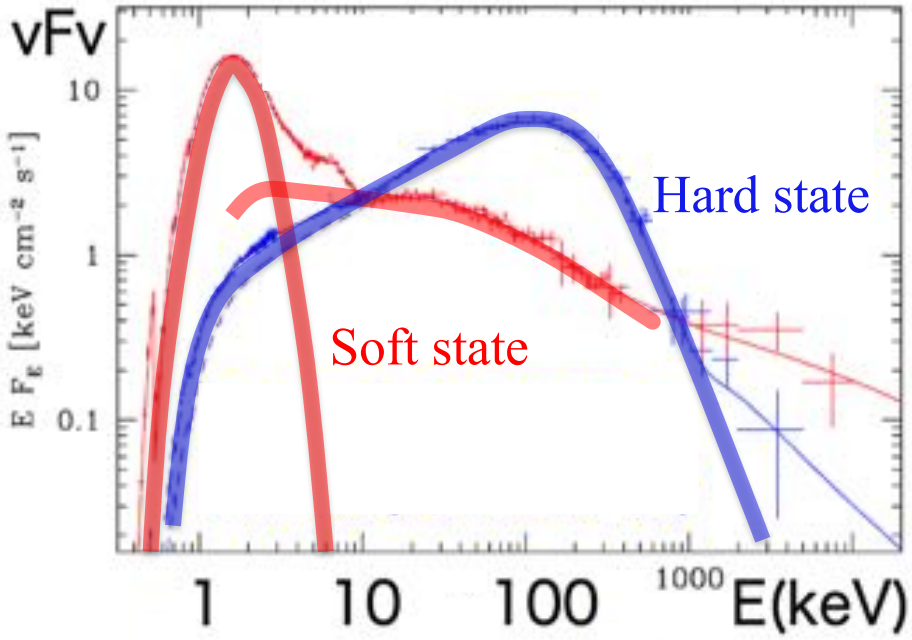


8. State Transition in SMBH Accretion

Mrk 1018 (Noda & Done 2018)



Cyg X-1 (McConnell et al. 2002)



☆ SED change of CLAGN closely resembles that of BHB state transition

➔ **State transition in SMBH accretion !**

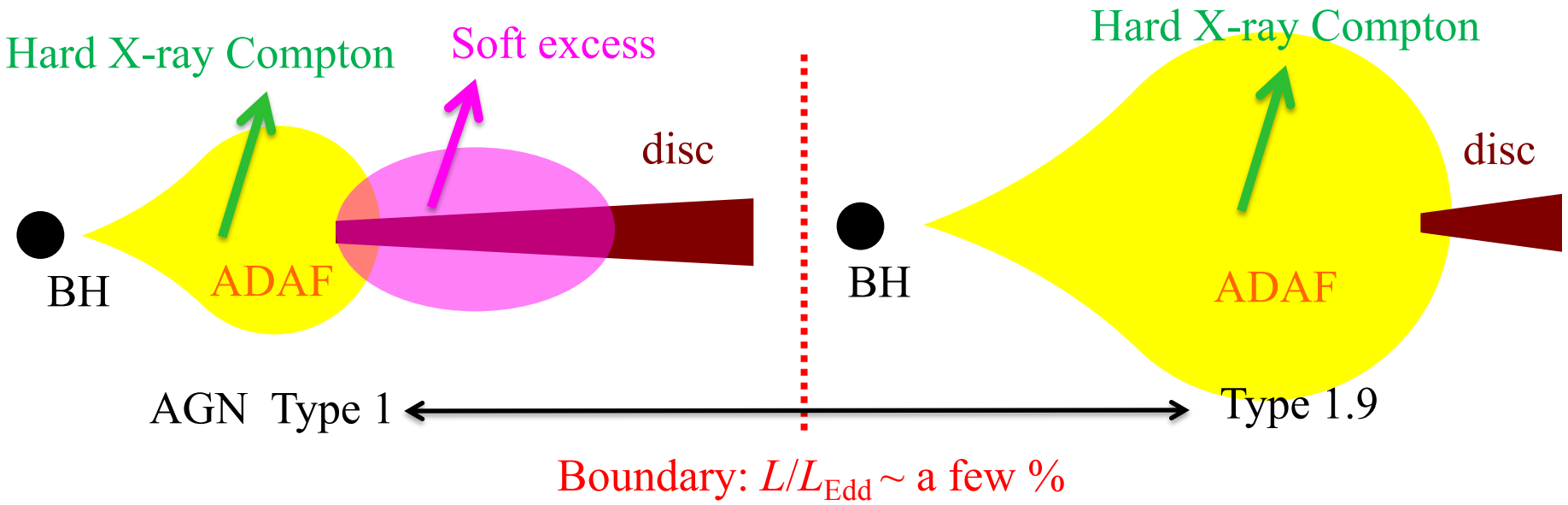
Not only disc but also soft excess region evaporate into corona

☆ Soft excess emission which contains most of UV photons powering BLR drastically changes its flux in the state transition

➔ **The state transition causes changing-look phenomenon**

9. State Transition Picture & Predictions

(Noda & Done 2018)



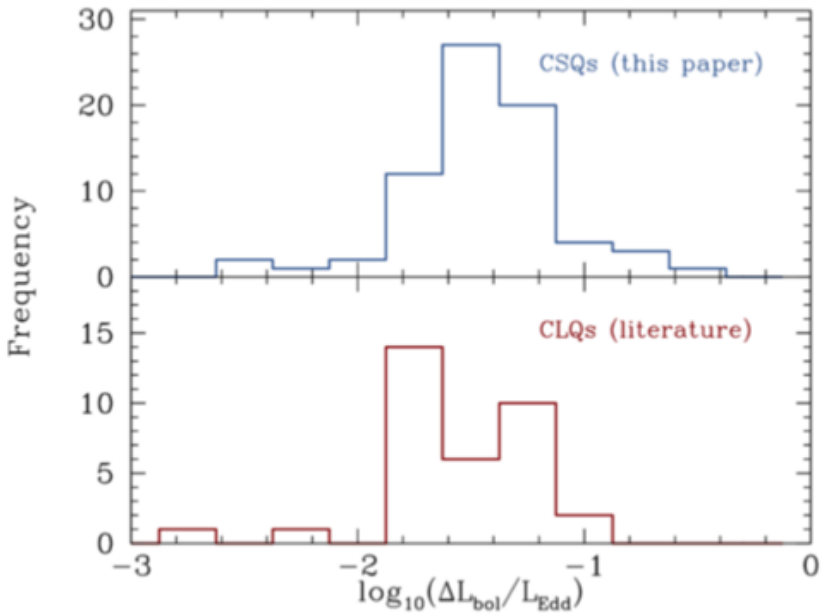
☆ Warm corona producing soft excess possibly evaporates into ADAF

☆ If CLAGNs are due to the state transition, we can predict followings

- $L/L_{\rm Edd}$ values of CLAGNs are distributed around ~ a few %
- Sources crossing $L/L_{\rm Edd}$ ~ a few % show changing-look phenomena (Noda & Done 2018 predicted NGC 3516 and NGC 3227 as examples)

10. Verification of Our Predictions

Graham et al. (2019)



☆ L/L_{Edd} Values of CL(S)AGNs are actually distributed around a few %

☆ Objects crossing L/L_{Edd} ~ a few % show CL phenomena (Noda & Done 2018 predicted NGC 3227 and NGC 3516)

➔ **Very likely, state transition !**

(see also Ruan's talk)

Monthly Notices of the ROYAL ASTRONOMICAL SOCIETY
MNRAS **485,** 4790–4803 (2019) doi:10.1093/mnras/stz692

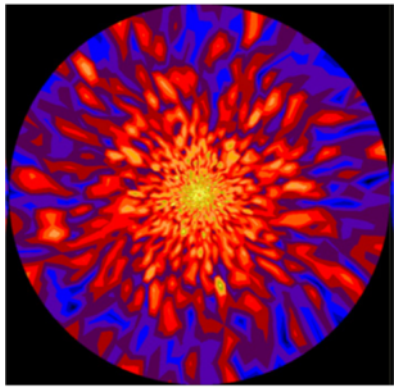
Long-term optical spectral monitoring of a changing-look active galactic nucleus NGC 3516 – I. Continuum and broad-line flux variability

A. I. Shapovalova,[1]† L. Č. Popović,[2,3] V. L. Afanasiev,[1] D. Ilić,[4]★ A. Kovačević,[4] A. N. Burenkov,[1] V. H. Chavushyan,[5] S. Marčeta-Mandić,[4] O. Spiridonova,[1] J. R. Valdes,[5] N. G. Bochkarev,[6] V. Patiño-Álvarez,[5,7] L. Carrasco[5] and V. E. Zhdanova[1]

3. Remaining Issues and Forthcoming X-ray Mission

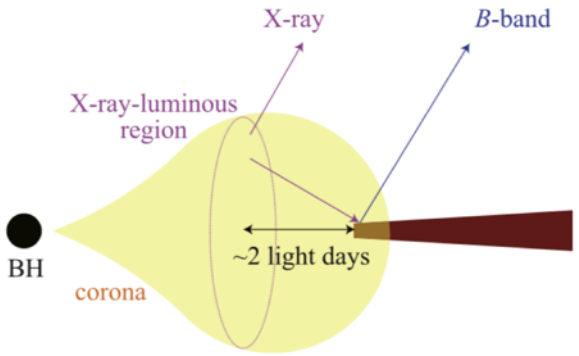
11. $L/L_{\rm Edd}$ Variation Timescale

Inhomogeneous disc

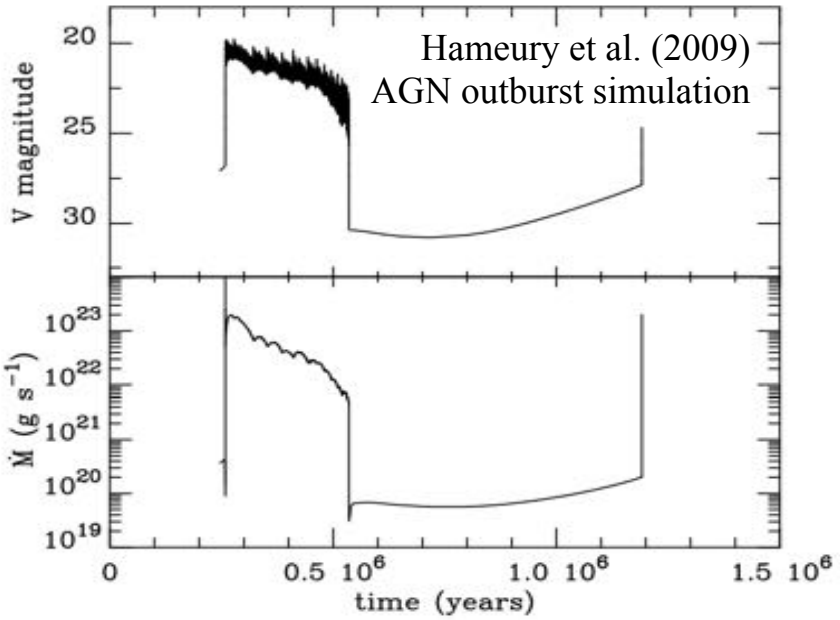


(e.g., Dexter et al. 2011)

X-ray disc irradiation



(e.g., Noda et al. 2016)



☆ $L/L_{\rm Edd}$ varies by an order of mag. in ~10 years (too short for disc viscous t.scale $t_{\rm vis}$)

With $M_{\rm BH} \sim 10^8\, M_\odot$, $t_{\rm vis} = (1/\alpha\Omega)(R/H)^2 \sim 10^{5\text{-}7}$ years at hundreds $R_{\rm s}$

☆ Although inhomogeneous disc or X-ray disc irradiation can explain t.scale, the amplitude cannot be explained. ➔ <u>More detailed disc model is necessary</u>

- Magnetic pressure ? (e.g., Dexter & Begelman 2018)
- Front propagation ? (e.g., Noda & Done 2018; Ross et al. 2018)
- Thermal timescale? (Czerny's talk)

12. Does AGN Structure Change?

Following changing-look phenomena,

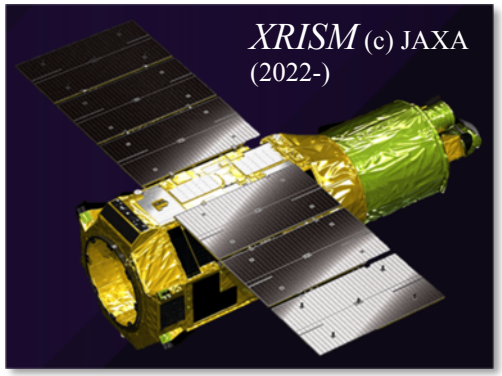
☆ Do BLR clouds appear/disappear? (e.g., Czerny & Hryniewics 2011)

☆ Does dusty torus geometry change? (e.g., Kokubo & Minezaki 2019)

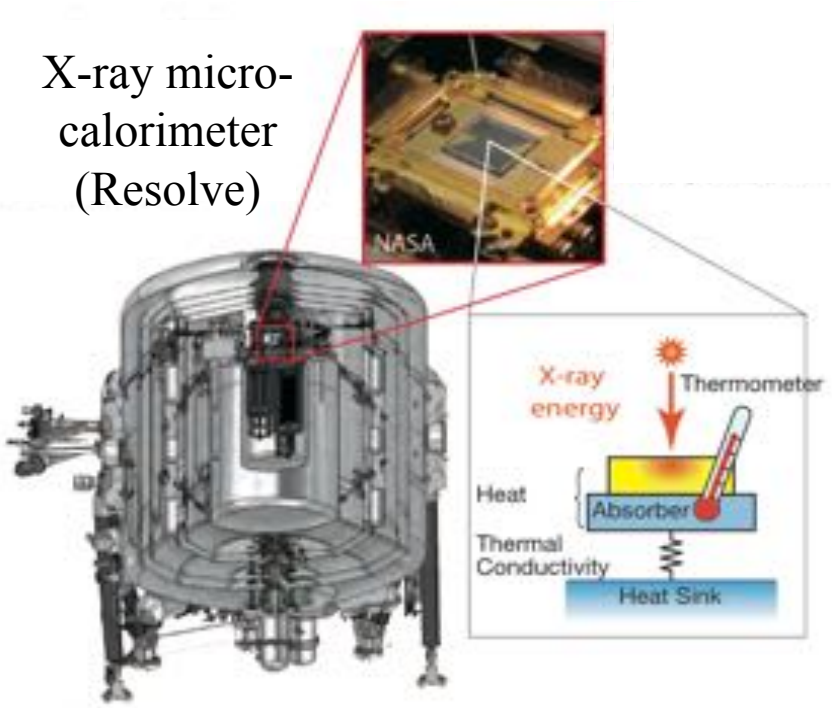
☆ Are disk winds proceeded/regulated? (e.g., Parker et al. 2018)

Promising probe is X-ray high-energy resolution spectroscopy around 6−7 keV

➔ **X-ray microcalorimeter has $\Delta E/E$ = 5 eV/6 keV** (CCD: $\Delta E/E$ = 150 eV/6 keV)

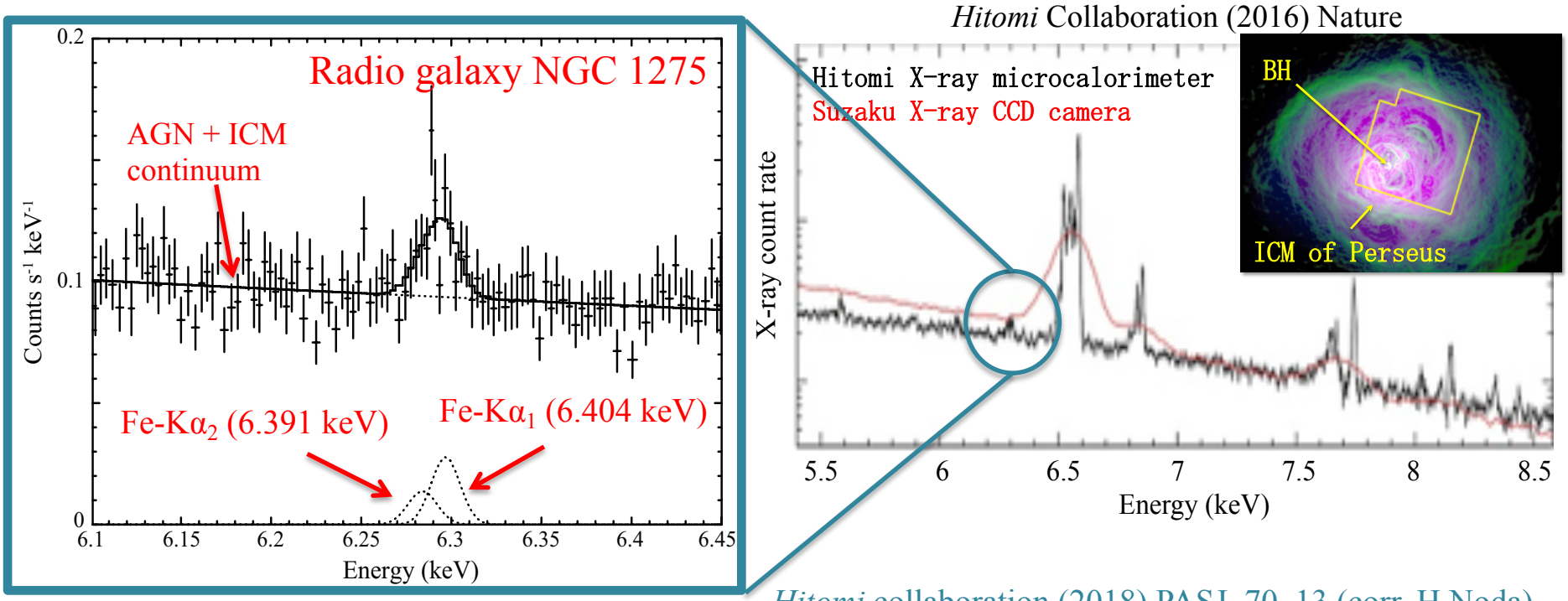


X-ray micro-calorimeter (Resolve)



- *Hitomi* was launched in 2016 (unfortunately, lost)
- *XRISM* will be launched in 2022 by JAXA, NASA ESA, and Universities

13. First X-ray Microcalorimeter Results on AGN



Hitomi collaboration (2018) PASJ, 70, 13 (corr. H.Noda)

☆ In 2016, we launched the X-ray calorimeter satellite *Hitomi*, and observed NGC 1275 with $\Delta E/E$ = 5 eV/6 keV (unfortunately, *Hitomi* was lost after the observation)

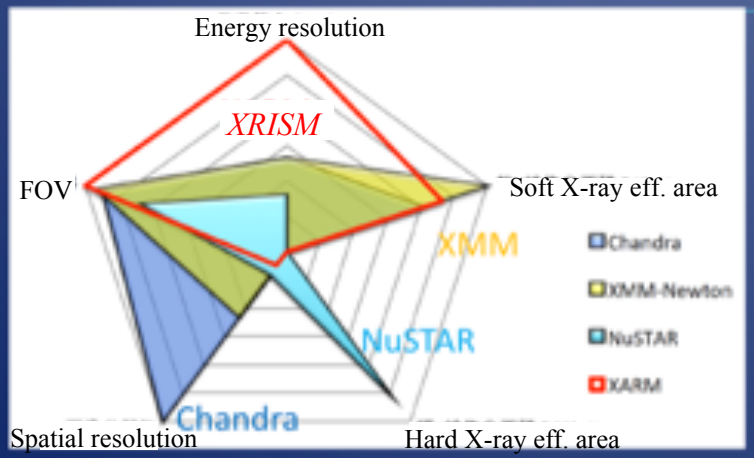
☆ *Hitomi* revealed $L/L_{\rm Edd} \sim 10^{-4}$, Fe-Kα v.width 500−1600 km/s, and eq.width ~ 20 eV
↔ Normal Seyferts have $L/L_{\rm Edd} \sim 10^{-1\text{-}2}$, v.width ~ 2500 km/s, and eq.width ~ 150 eV

☆ Fe-Kα from CND ➔ BLR is absent & low-cov. frac. torus (constraint to AGN structure)

14. Forthcoming X-ray Satellite *XRISM* (2022)

(c) Makoto Tashiro

Instrument	FOV/pix	ΔE (FWHM @6 keV)	Energy band
Resolve (XMA + X-ray microcalorimeter)	2.9′ □ / 6 x 6 pix	7 eV (goal 5 eV)	0.3 – 12 keV
Xtend (XMA + X-ray CCD)	38′ □/ 1280 x 1280 pix	< 250 eV at EOL (< 200 eV at BOL)	0.4 – 13 keV




H. Noda @ Osaka Univ. Clean room

For the launch in 2022, we are trying our best !

15. Summary

- Scaling with the BH mass, the state transition of SMBH accretion has been considered to take $10^{5\text{-}7}$ years.

- We modeled the optical/UV/X-ray spectra of Mrk 1018 following its changing-look phenomenon, and found the spectral shape change is similar to that in the BHB state transition.

- Changing-look AGNs are likely to be explained by state transition. However, timescale and amplitude of their $L/L_{\rm Edd}$ changes are still hard to be understood.

- It is also under debate if AGN structures, BLR, torus, and winds, change following changing-look phenomena. X-ray high-energy spectroscopy by *XRISM* X-ray microcalorimeter is key.

Thank you very much for your attentions!