The Extremes of Black Hole Accretion
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@ESAC

Variabilities of the X-ray Broad Iron Spectral Features in AGN and BHB

Misaki Mizumoto[1,2]

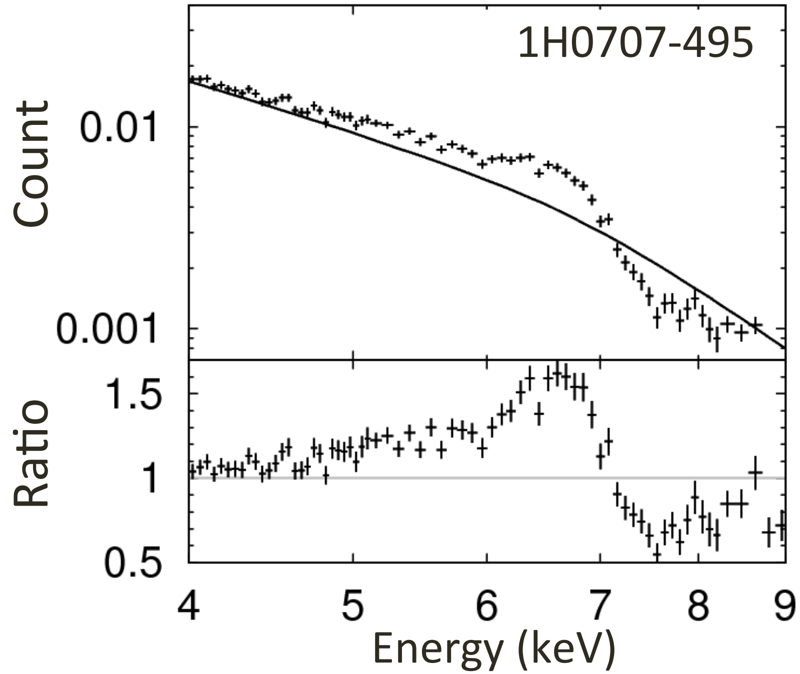
Ken Ebisawa[1,2], Masahiro Tsujimoto[1], Hajime Inoue[3]

1. ISAS/JAXA 2. Univ. of Tokyo 3. Meisei Univ.

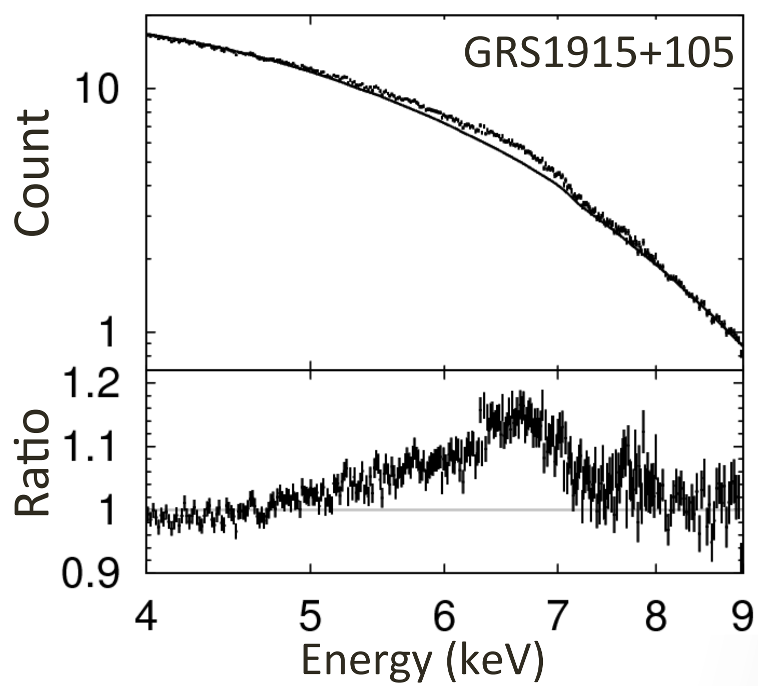
1. Introduction

X-ray broad iron spectral feature

AGN (Seyfert galaxies) (~$10^6 M_\odot$)



BHB (~$10 M_\odot$)



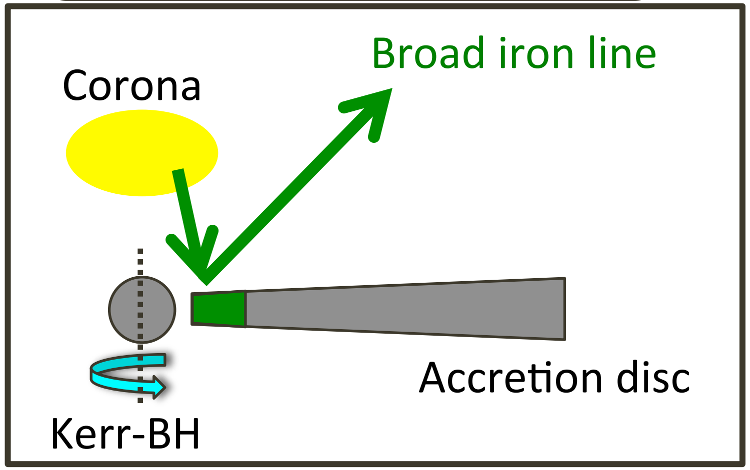
What makes these spectral features?

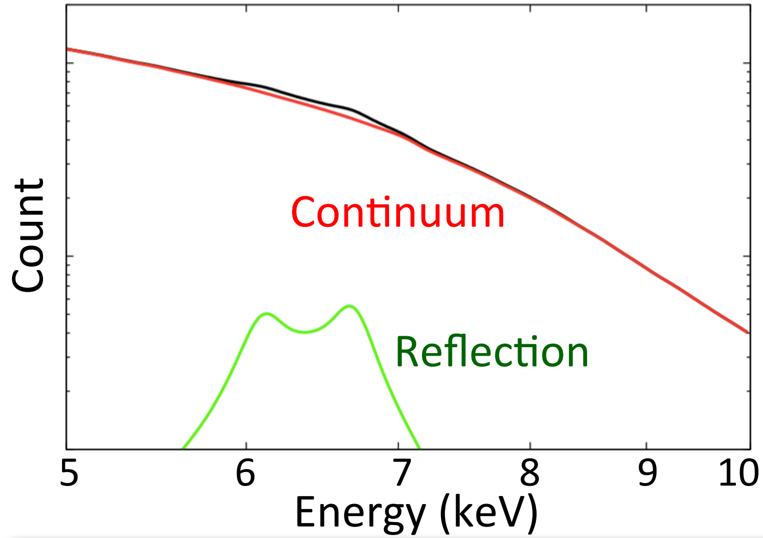
Relativistic reflection model

Partial covering model

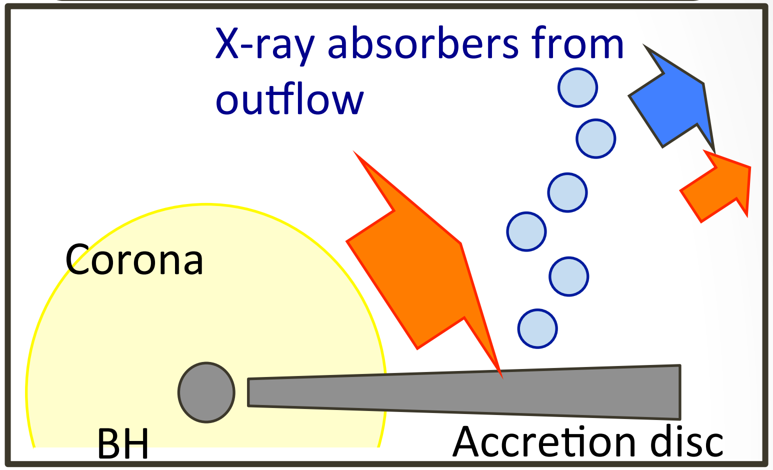
Spectral models

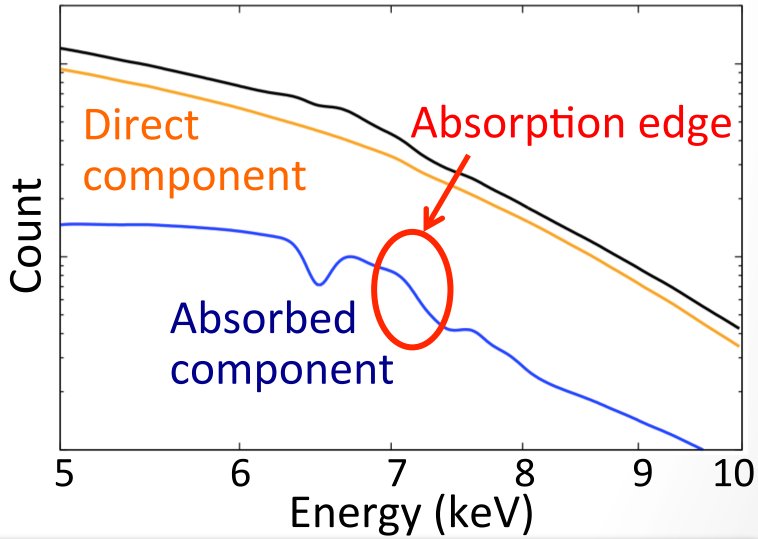
Relativistic reflection model





Partial covering model

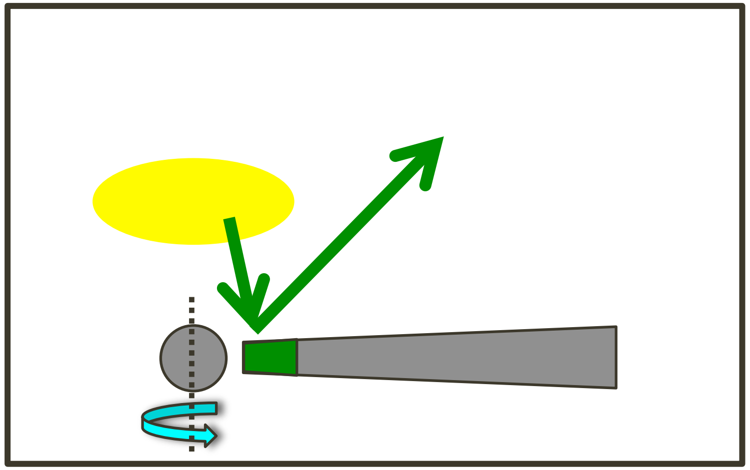




Both models can explain time-averaged spectra.
→Investigate spectral variation

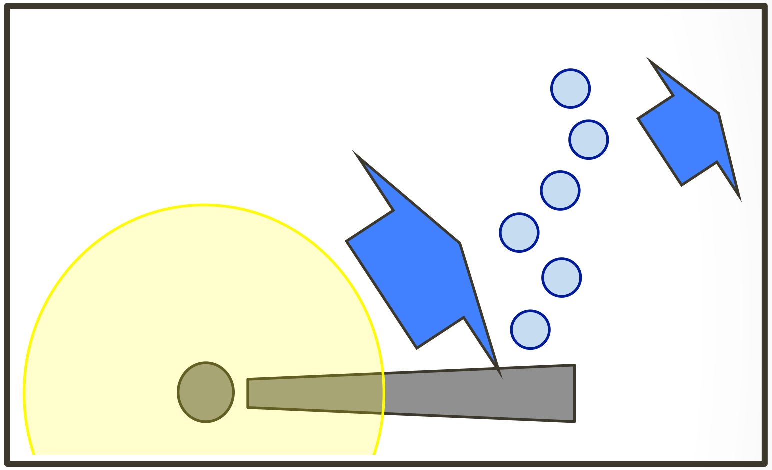
Expected spectral variations

Relativistic reflection model



Variation of a distance between a corona and a BH

Partial covering model

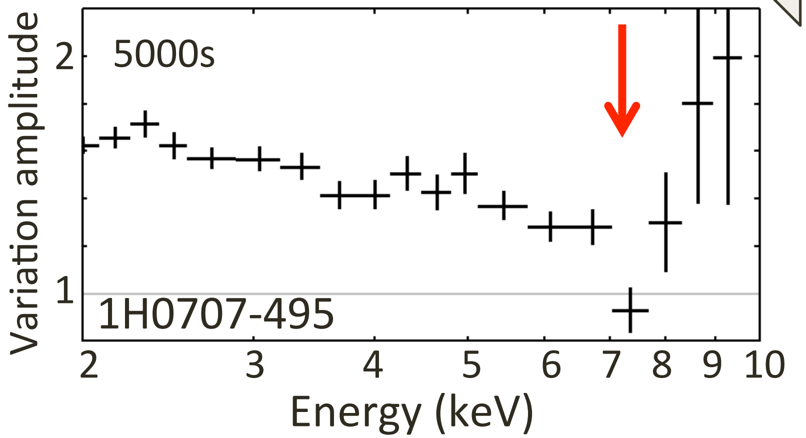


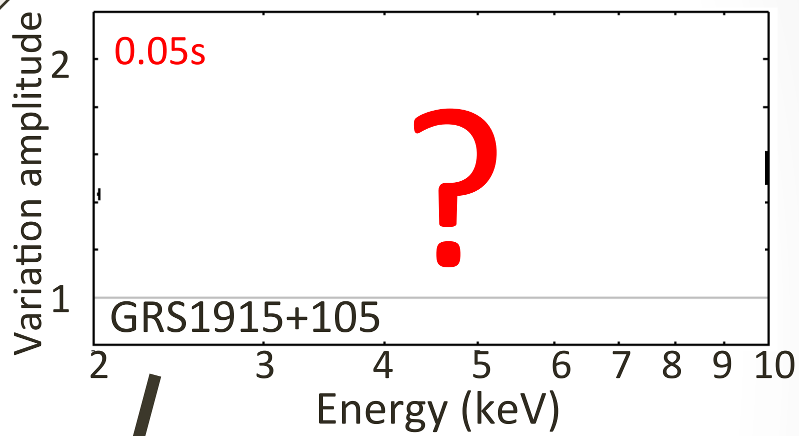
Variation of outflow absorbers

Which model can explain spectral variations more naturally?

Comparison of AGN with BHB

AGN (~$10^6 M_\odot$) ⟷ $\times 10^5$ ⟷ **BHB (~$10 M_\odot$)**





How can we investigate BHB's X-ray short-time spectral variation?

- **Energy resolution of CCD detectors**
- **Time resolution of ~ms**

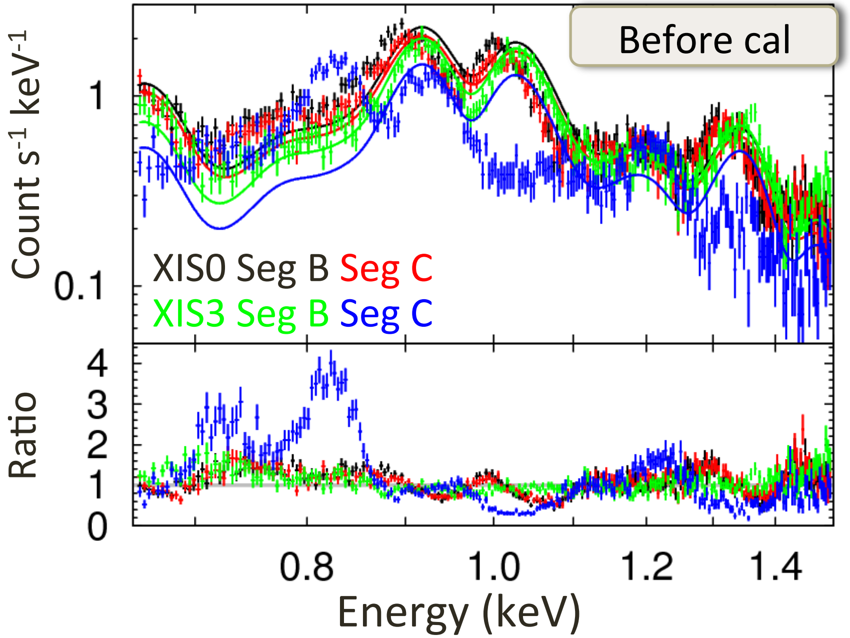
2. Observation & Results

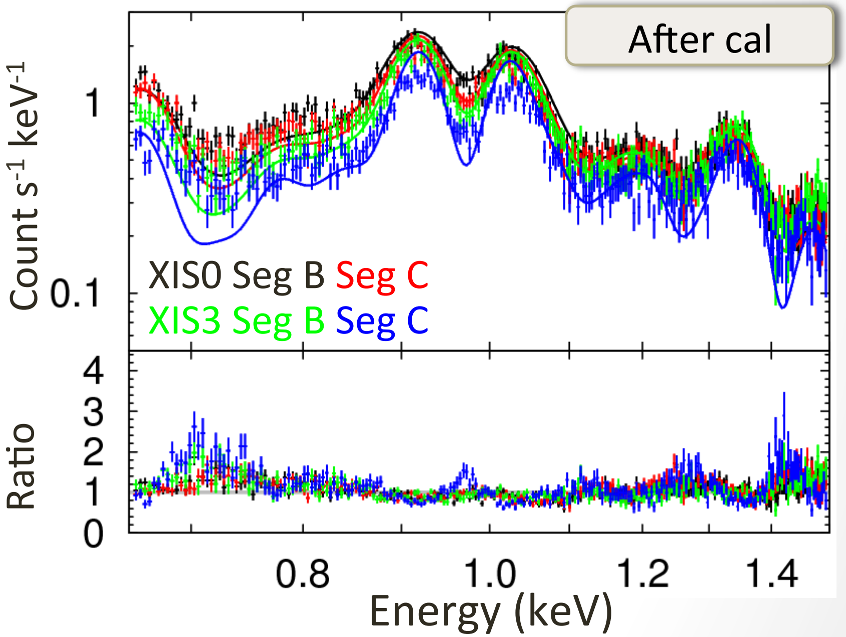
Suzaku XIS P-sum mode

- Events are stacked one-dimensionally
- $\Delta T = 7.8$ ms

Both CCD energy-resolution and high time-resolution

P-sum mode was not fully calibrated.
→We have analyzed P-sum calibration observations comprehensively and made P-sum mode data usable.



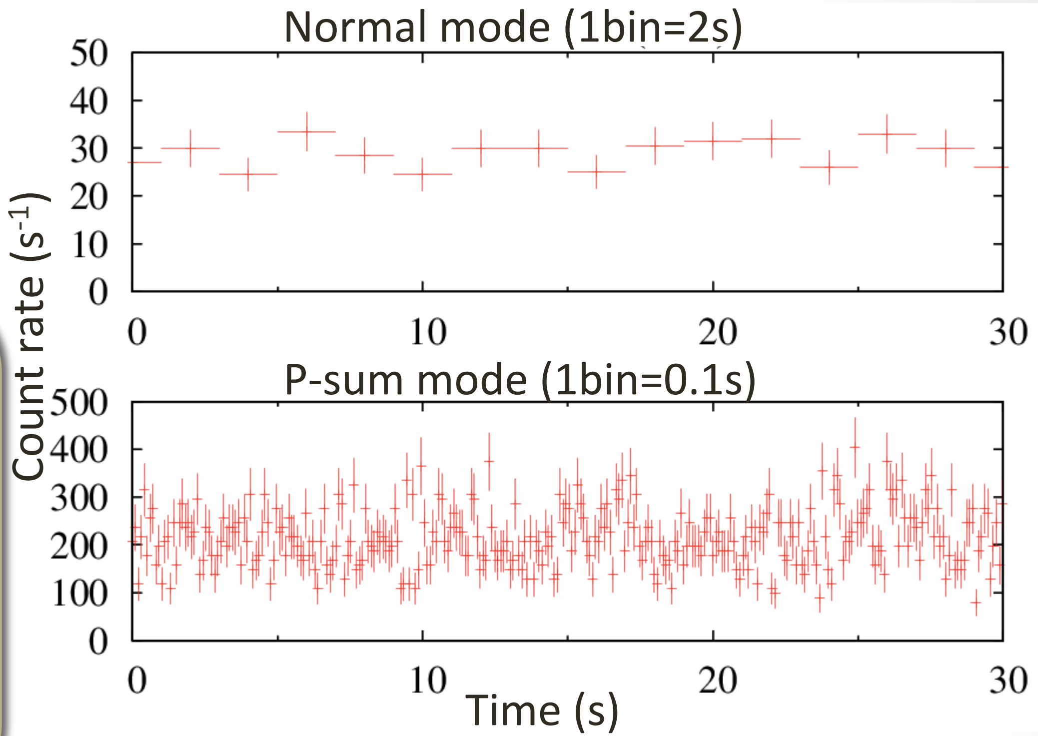


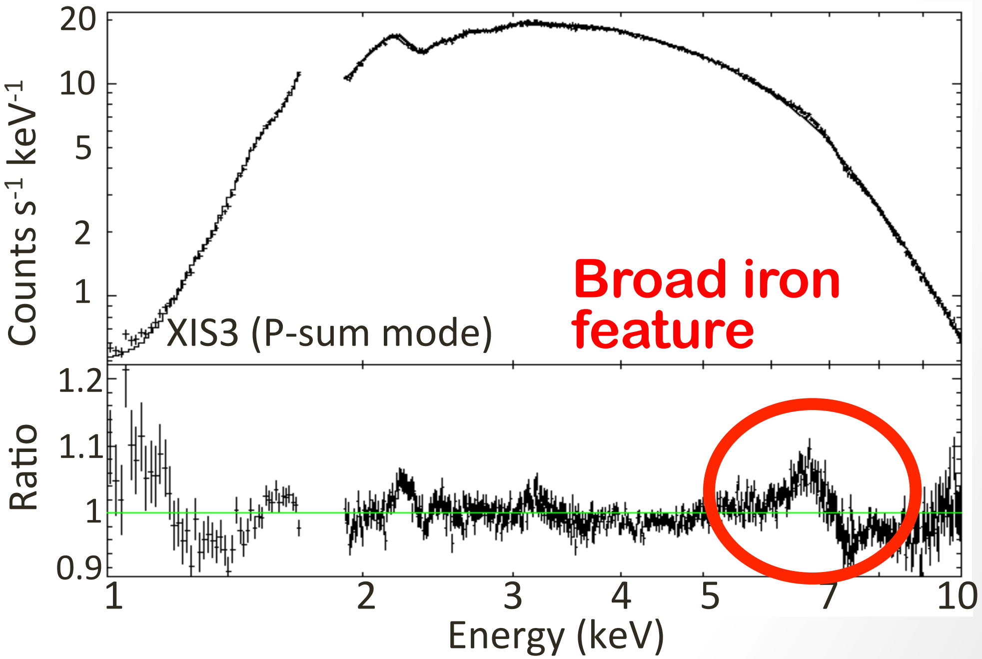
This result and the analysis recipe have been released.

Light-curve & spectrum

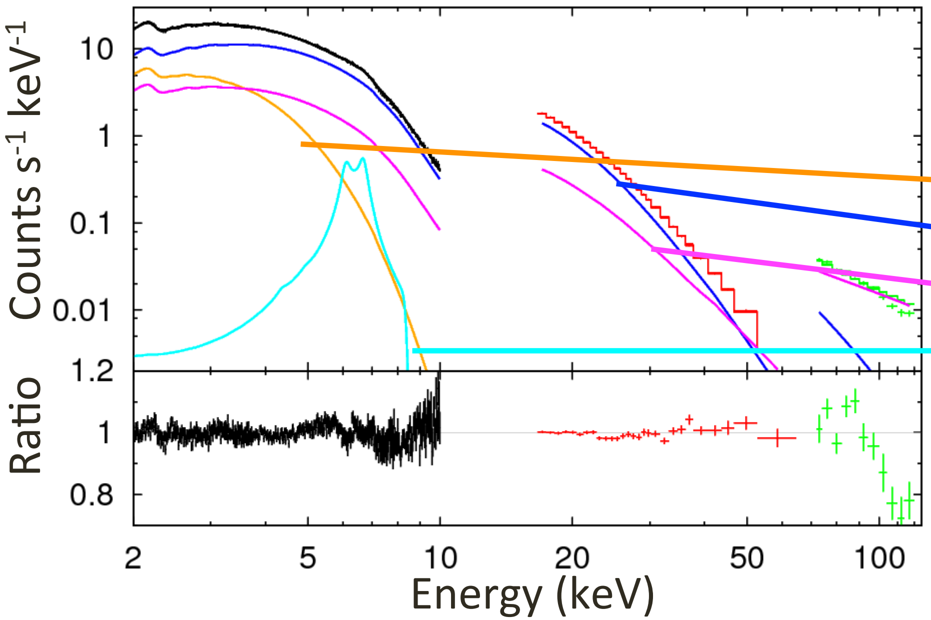
- **Object：**
  GRS1915+105
- **Date：2007.5.5**
- **XIS0,3：P-sum mode**
- **XIS1: Normal mode (1/4w + 1s burst)**

Variation at <1sec
＋
Energy resolution of CCD detectors





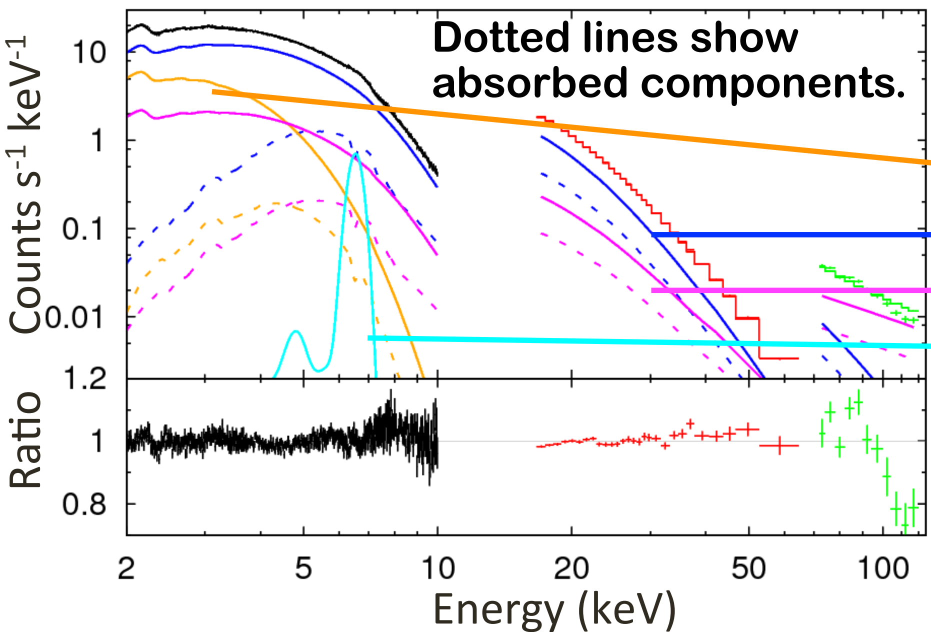
Model fitting



Relativistic reflection model

Multi-color disk
Thermal Compton + reflection
Non-thermal Compton + refl.
Disk-line

- Kerr-BH with a=0.998

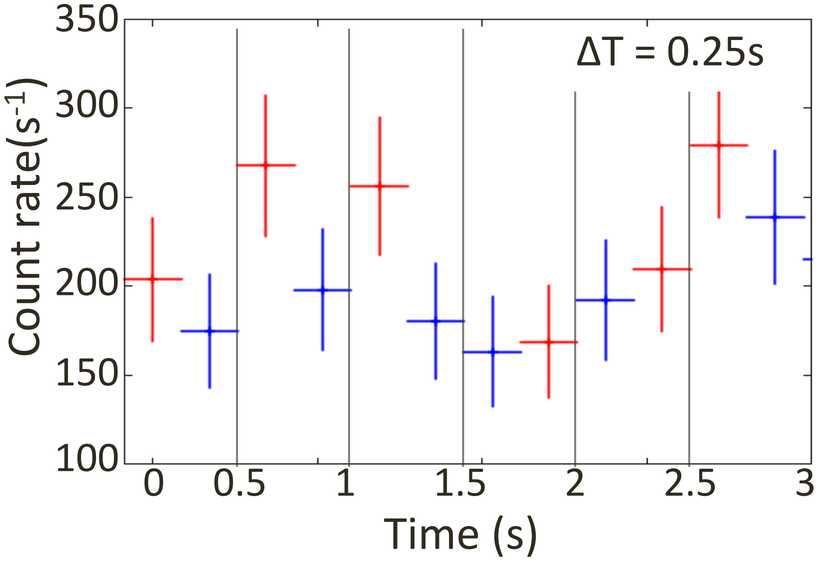


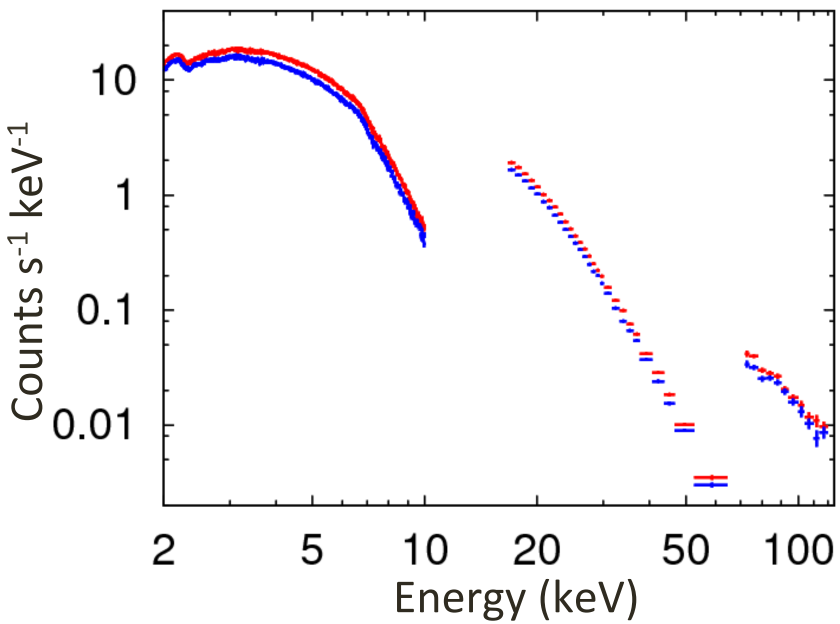
Partial covering model

Multi-color disk
Thermal Compton
Non-thermal Compton
Narrow line

Absorbers with $N_H = 8.9\times10^{23}$ cm^{-2} and log ξ = 2.5 cover 30% of the X-ray source.

Difference variation function method





DVF method (Inoue et al. 2011)

1. Determine the time-scale ΔT, and create a light-curve with a bin-width of ΔT

2. Compare every two adjacent bins and define the bright/faint phase.

3. Extract bright/faint phases and compare two spectra.

4. Repeat this method with various ΔT.

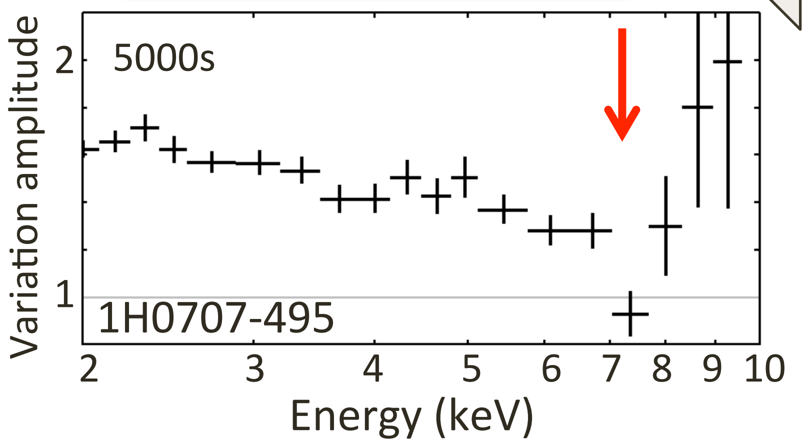
Investigate spectral variations correlated with observed X-ray flux

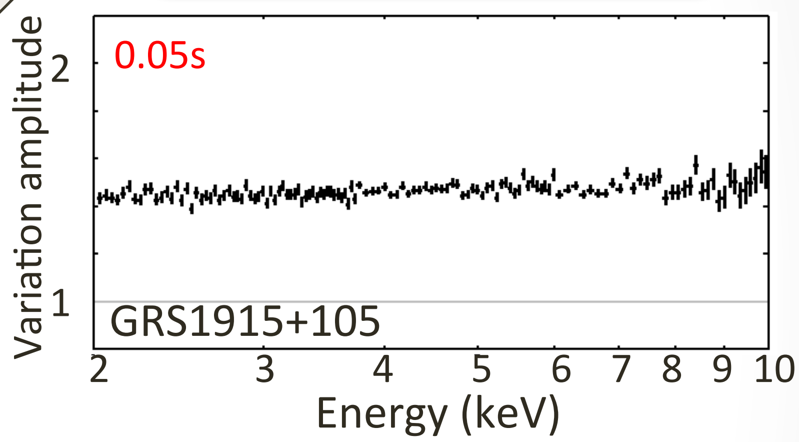
Comparison of AGN with BHB

AGN (~$10^6 M_\odot$)

X10^5

BHB(~$10M_\odot$)





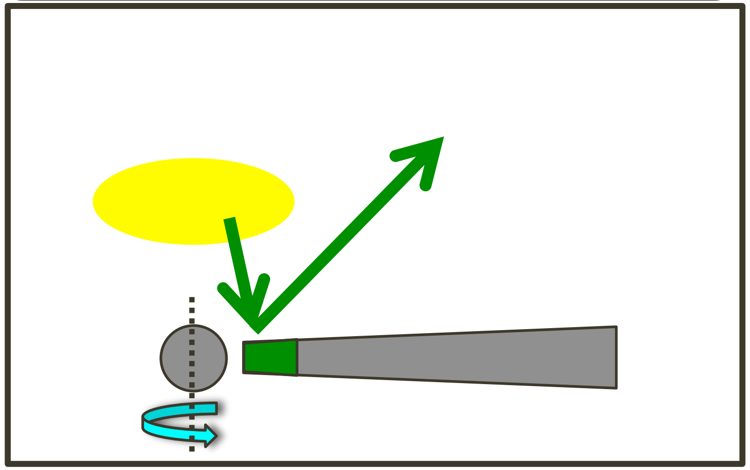
X-ray spectral variation of BH is not normalized by its mass!

No iron structure is seen in BHB's spectral variation at any timescale from 8ms to 63000s.

3. Discussion

“The X-ray spectral variation is not normalized by the BH mass.”

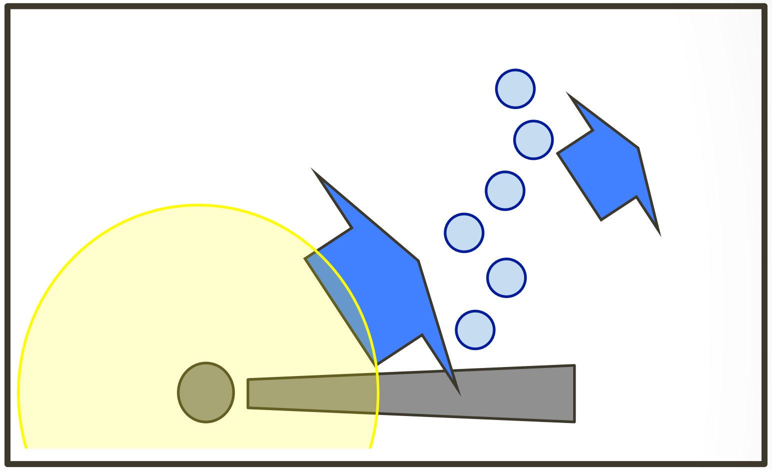
Relativistic reflection model



Variation is normalized by a BH mass.
(e.g. Miniutti & Fabian 2004)

Cannot explain the observation

Partial covering model



Can the partial covering model explain the observation?

What is not normalized?

X-ray luminosity

Assuming that $r \approx \Delta r$

$$\xi = \frac{L}{nr^2} = \frac{L}{(nr)r} \approx \frac{L}{(n\Delta r)r} = \frac{L}{N_H r}$$

Column density

number density

Location of the absorbers

$$r \approx \frac{L}{\xi N_H}$$

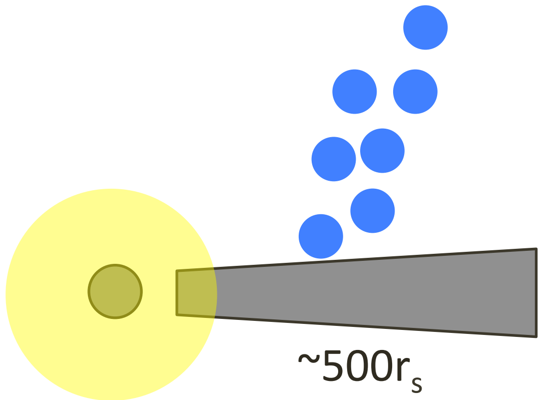
Spectral fitting

	AGN	BHB	Ratio
BH mass (M)	~$10^6 M_\odot$	~$10 M_\odot$	×10^5
Luminosity (L)	~10^{44} erg s^{-1}	~10^{39} erg s^{-1}	×10^5
Variation of the continuum	~10^5s	~10^0s	×10^5
Location of the absorbers (r)	~10^{14}cm ($500r_s$)	~$10^{11.5}$cm ($10^5 r_s$)	$\boxed{\times 10^{2.5}}$

Location of the absorbers is
not normalized by a BH mass.

Outflow types

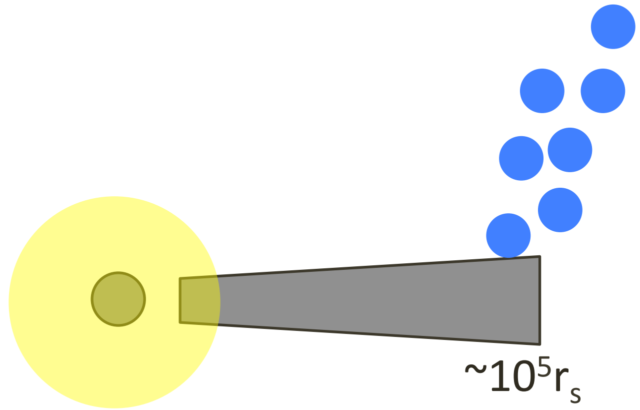
AGN(~$10^6 M_\odot$)



Radiation-driven outflow

driven by UV photons from an accretion disc (Nomura et al. 2013)

BHB(~$10^1 M_\odot$)



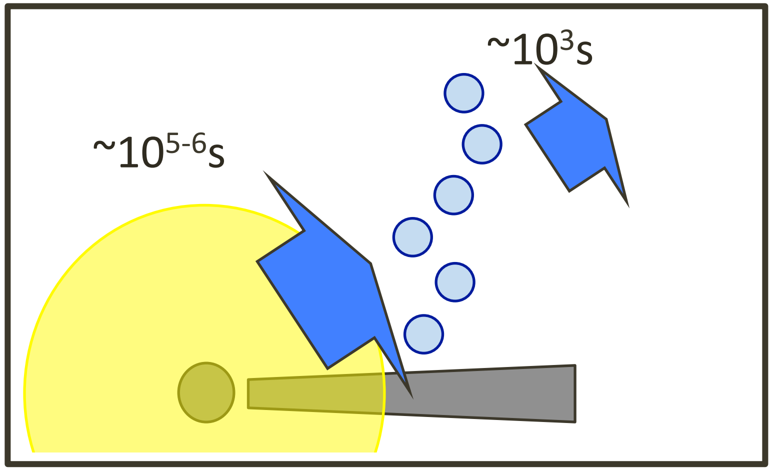
Thermal-driven outflow

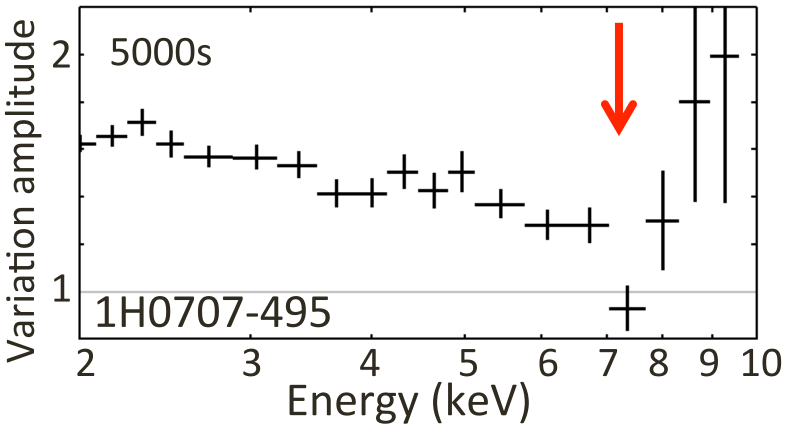
driven where the thermal energy is larger than the binding energy (Begelman et al. 1983)

The location of the absorbers reflects the outflow types.

Interpretation of spectral variation

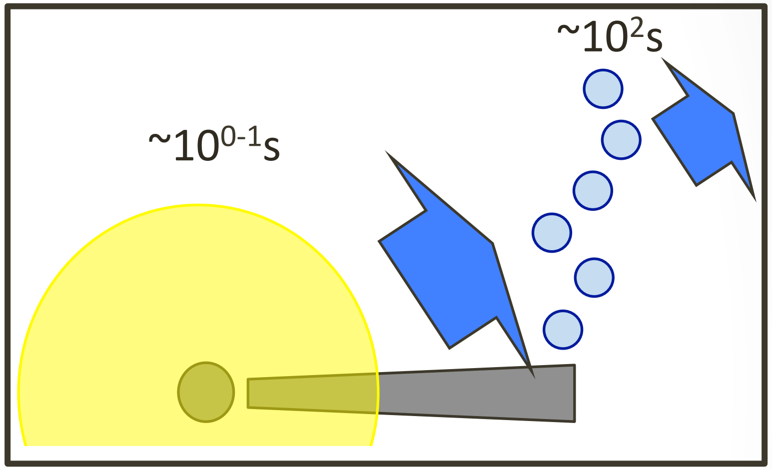
AGN(~$10^6 M_\odot$)

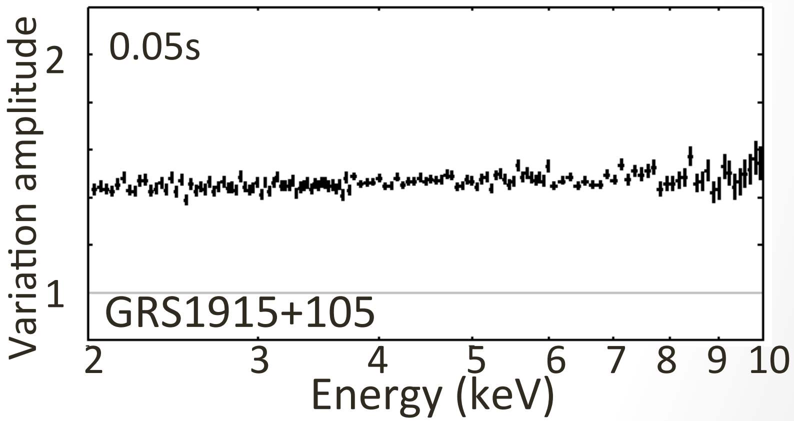




Only the absorbers are variable within an observation.
(e.g. Mizumoto et al. 2014)

BHB(~$10^1 M_\odot$)





Both the absorbers and the X-ray source are variable.

4. Conclusion

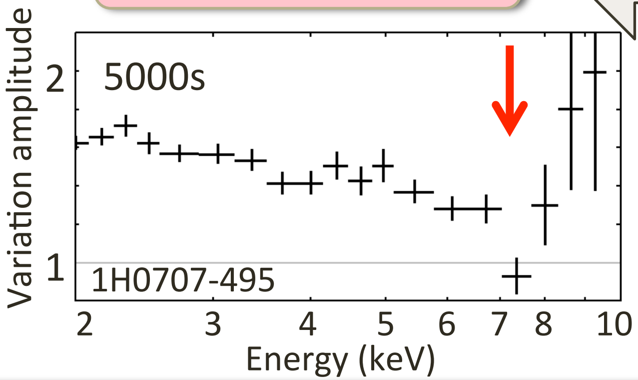
Conclusions

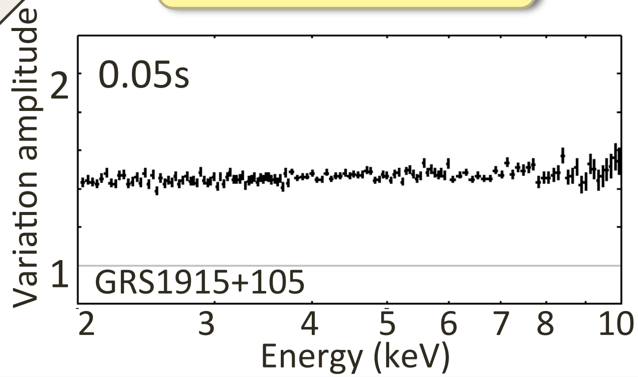
- X-ray spectral variation of BH is not normalized by its mass.

AGN (~$10^6 M_\odot$)

X10^5

BHB(~$10^1 M_\odot$)

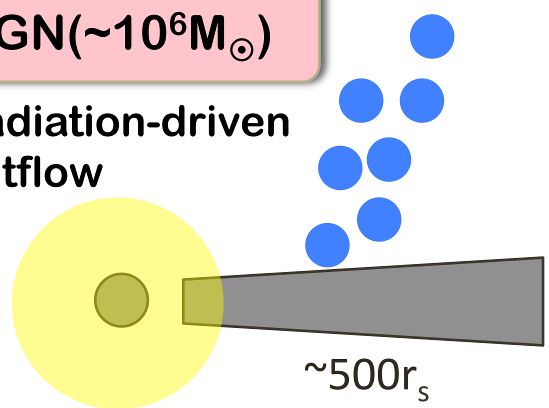




- **The difference of spectral variation can be naturally explained by a partial covering model.**
- **The difference is considered to show the difference of outflow types.**

AGN(~$10^6 M_\odot$)

Radiation-driven outflow



BHB(~$10^1 M_\odot$)

Thermal-driven outflow