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

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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
Both models can explain time-averaged spectra.

→ Investigate **spectral variation**
Expected spectral variations

Relativistic reflection model

Partial covering model

Variation of a distance between a corona and a BH

Variation of outflow absorbers

Which model can explain spectral variations more naturally?
Comparison of AGN with BHB

AGN (~10^6 M☉)  X10^5  BHB (~10 M☉)

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.
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

Wide iron feature
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

Dotted lines show absorbed components.

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

Absorbers with $N_H=8.9 \times 10^{23}$ cm$^{-2}$ and $\log \zeta = 2.5$ cover 30% of the X-ray source.
1. Determine the time-scale $\Delta T$, and create a light-curve with a bin-width of $\Delta T$.

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 $\Delta T$.

Investigate spectral variations correlated with observed X-ray flux.
Comparison of AGN with BHB

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.”

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

Can the partial covering model explain the observation?
What is not normalized?

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

<table>
<thead>
<tr>
<th></th>
<th>AGN</th>
<th>BHB</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH mass (M)</td>
<td>~10^6 M⊙</td>
<td>~10 M⊙</td>
<td>×10^5</td>
</tr>
<tr>
<td>Luminosity (L)</td>
<td>~10^{44} erg s⁻¹</td>
<td>~10^{39} erg s⁻¹</td>
<td>×10^5</td>
</tr>
<tr>
<td>Variation of the continuum</td>
<td>~10^5 s</td>
<td>~10^0 s</td>
<td>×10^5</td>
</tr>
<tr>
<td>Location of the absorbers (r)</td>
<td>~10^{14} cm (500r_s)</td>
<td>~10^{11.5} cm (10^5r_s)</td>
<td>×10^{2.5}</td>
</tr>
</tbody>
</table>
Outflow types

AGN($\sim10^6 M_\odot$)  BHB($\sim10^1 M_\odot$)

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

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_☉)

BHB (~10^1 M_☉)

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

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.

\[
\begin{align*}
\text{AGN (} \sim \text{10}^6 \text{M}_\odot \text{)} & \quad \text{X10}^5 \\
\text{BHB (} \sim \text{10}^1 \text{M}_\odot \text{)}
\end{align*}
\]

- 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.

\[
\begin{align*}
\text{AGN (} \sim \text{10}^6 \text{M}_\odot \text{)} & \quad \text{Radiation-driven outflow} \\
\text{~500r}_s \\

\text{BHB (} \sim \text{10}^1 \text{M}_\odot \text{)} & \quad \text{Thermal-driven outflow} \\
\text{~10}^5 \text{r}_s
\end{align*}
\]