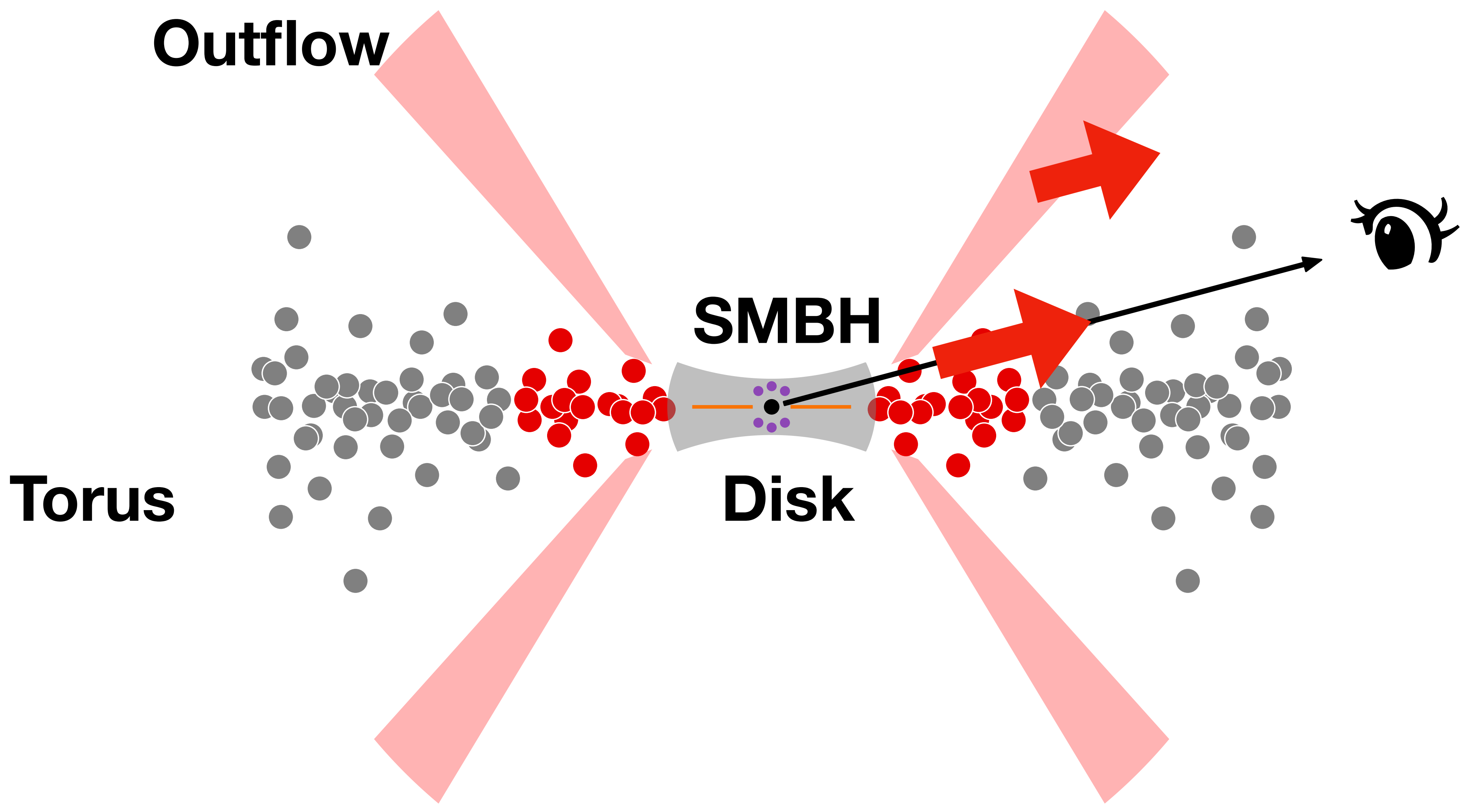
March 1st, 2024
ブラックホール大研究会 @ 御殿場

XRISM Study on Ionized Absorbers of Seyfart Galaxies

小川 翔司 (ISAS/JAXA)

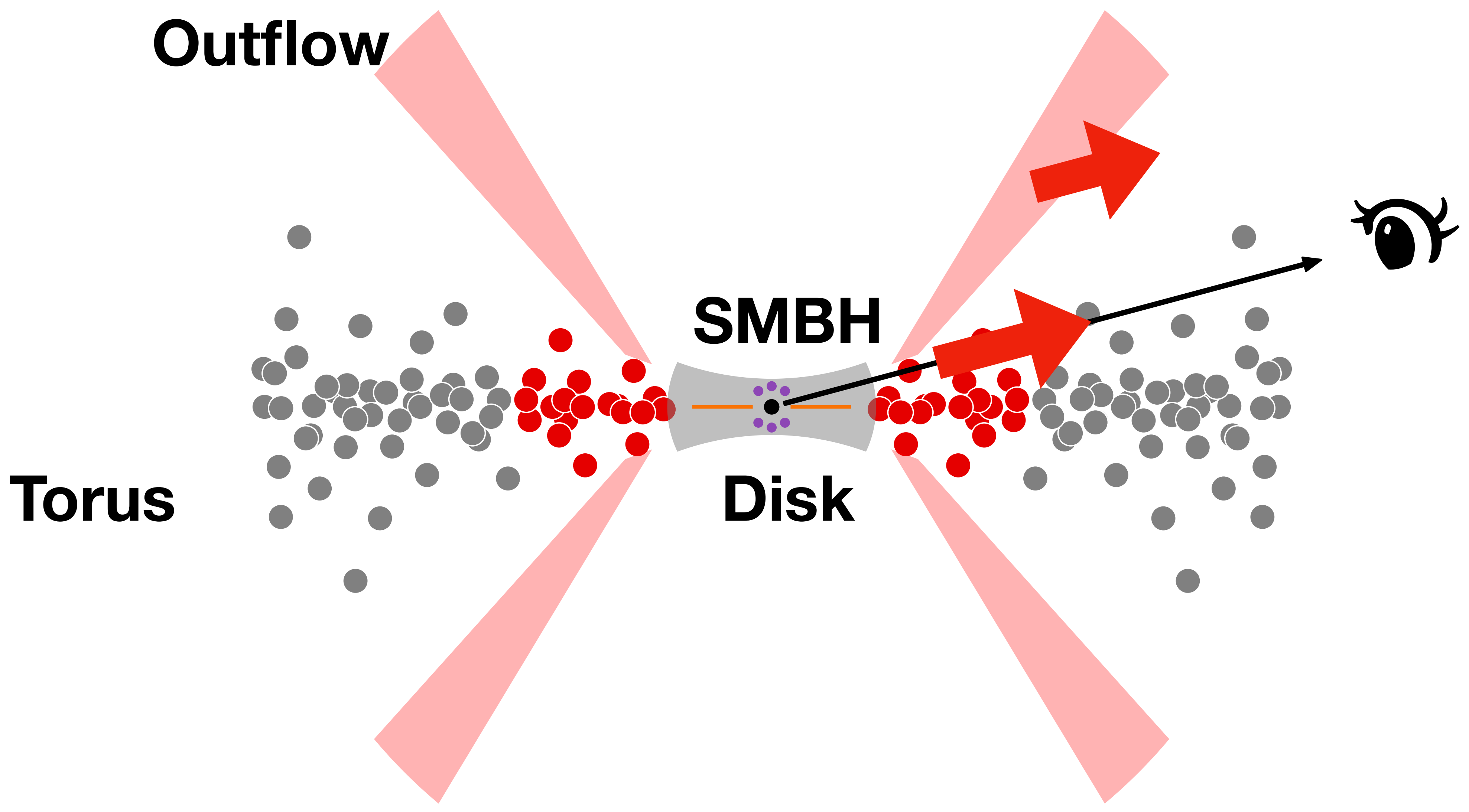
AGN Structure

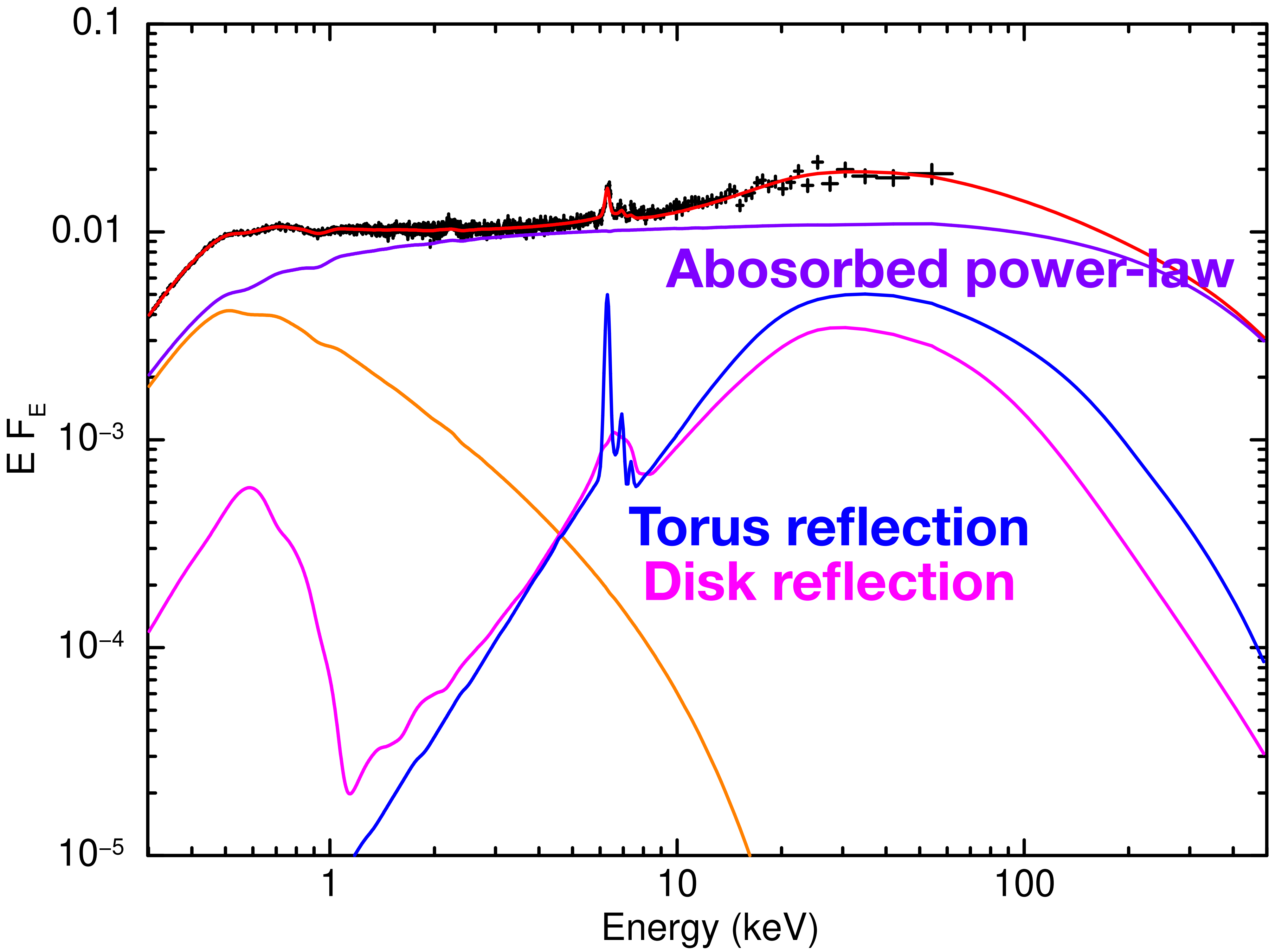


AGN Structure

- Supermassive blackhole, Accretion Disk, Torus, Outflow

X-ray Spectrum of AGN





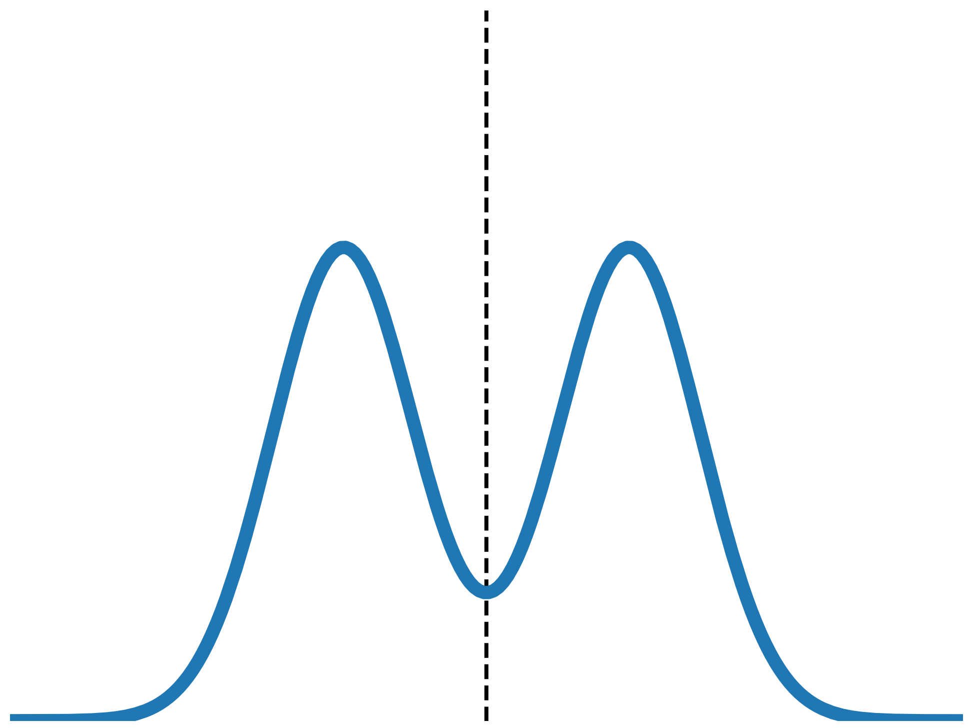
X-ray spectrum of an AGN carries information on:

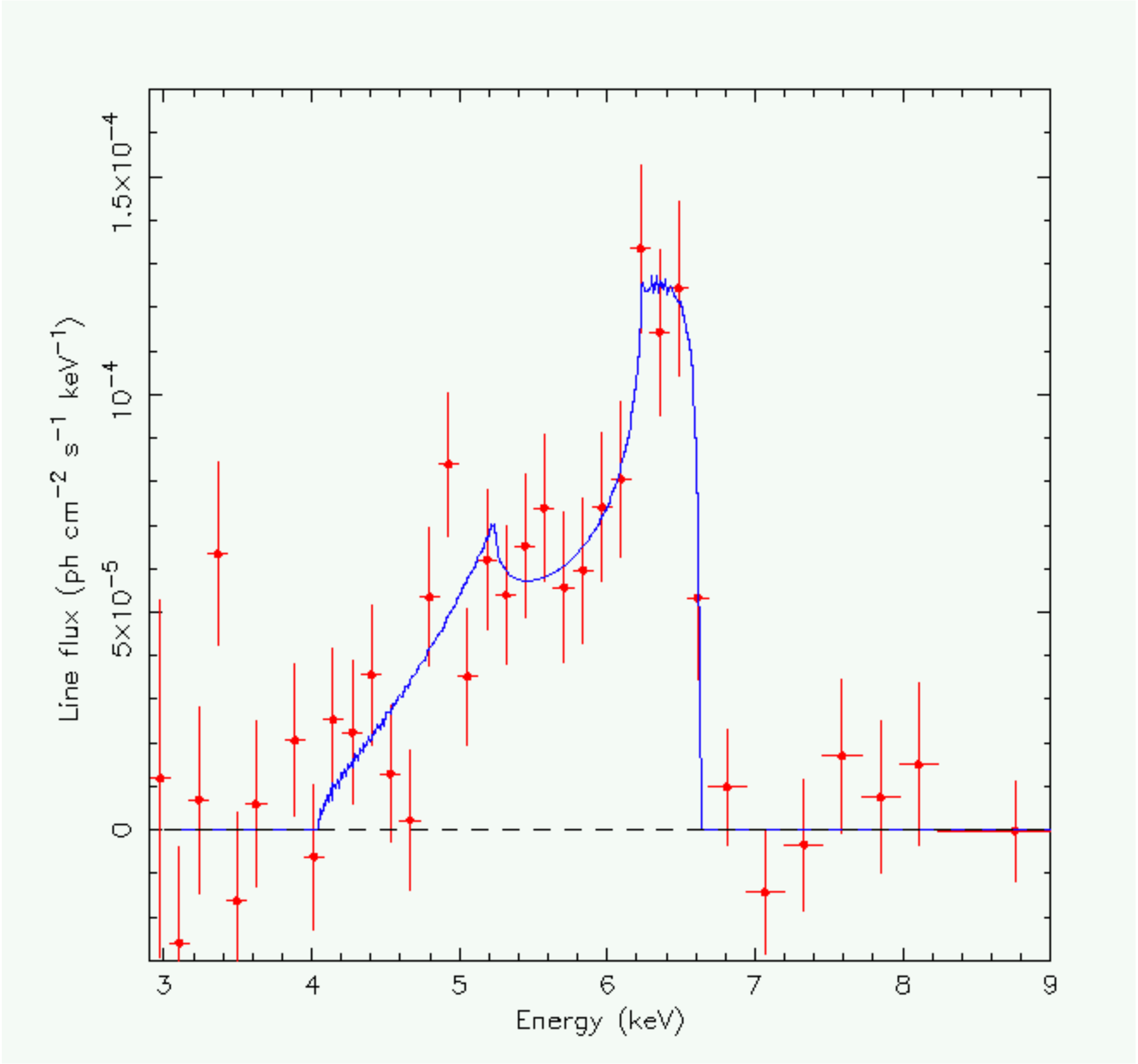
- All material with various temperatures and ionization states
- Line-of-sight materials (absorption feature)
- Torus and/or accretion disk (reflection component)

X-ray Spectral Model

Relativistic reflection (e.g., Tanaka+95)

- Reflection component from inner most region of accretion disk
  - Beaming effect
  - Gravitational redshift

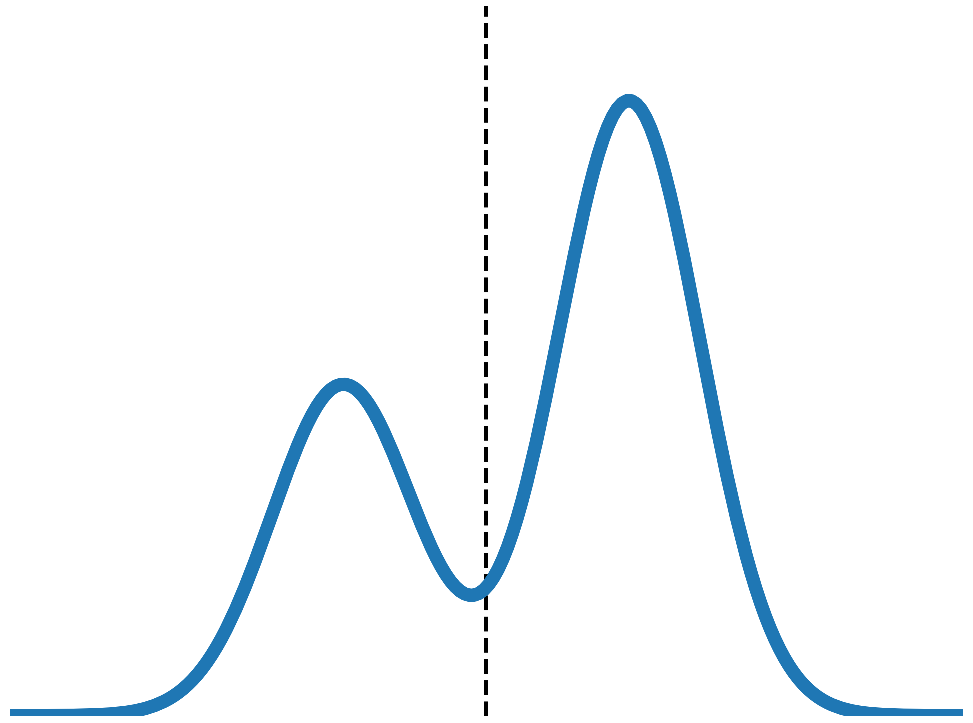


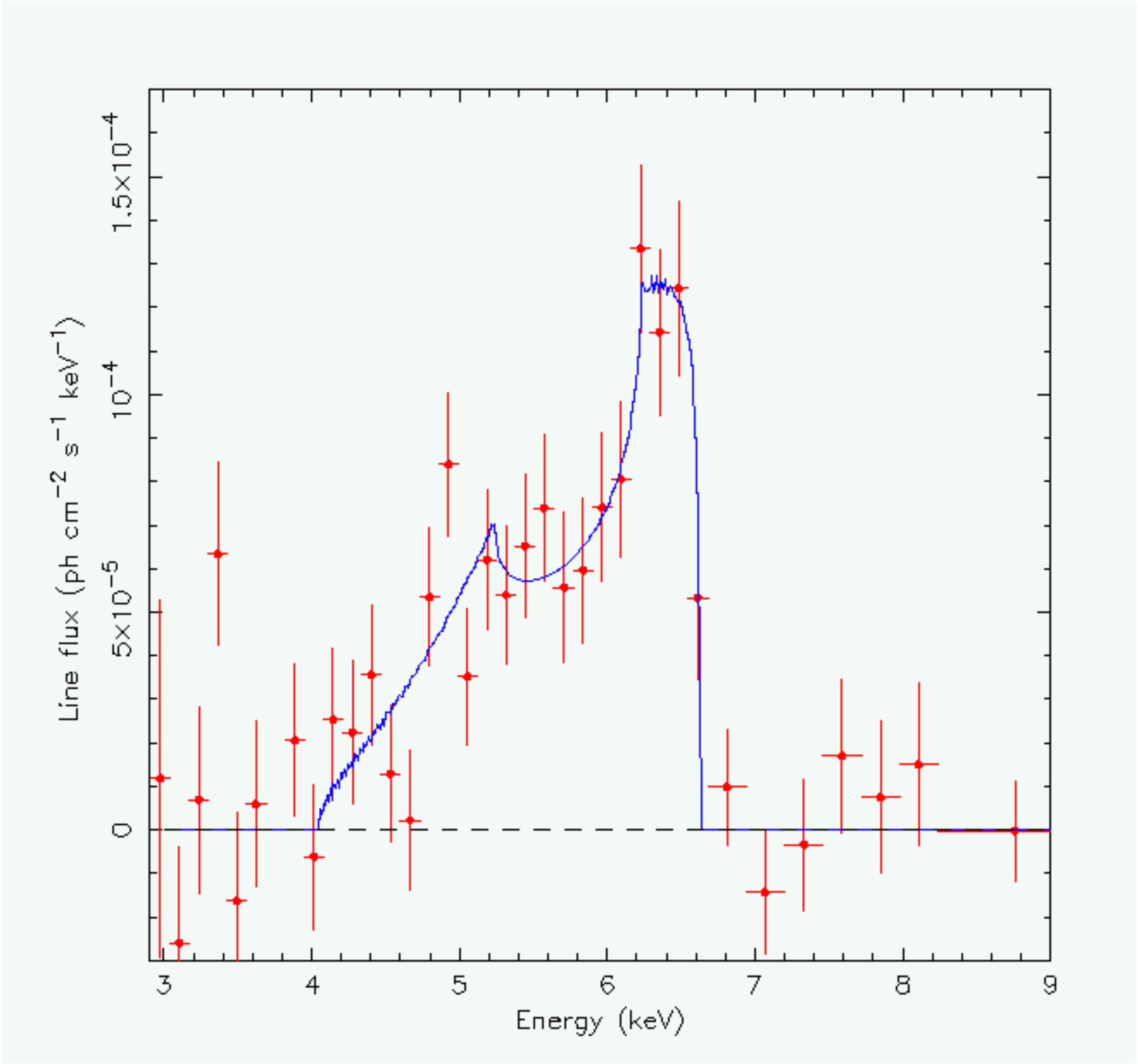


X-ray Spectral Model

Relativistic reflection (e.g., Tanaka+95)

- ✤ Reflection component from inner most region of accretion disk
  - Beaming effect
  - Gravitational redshift

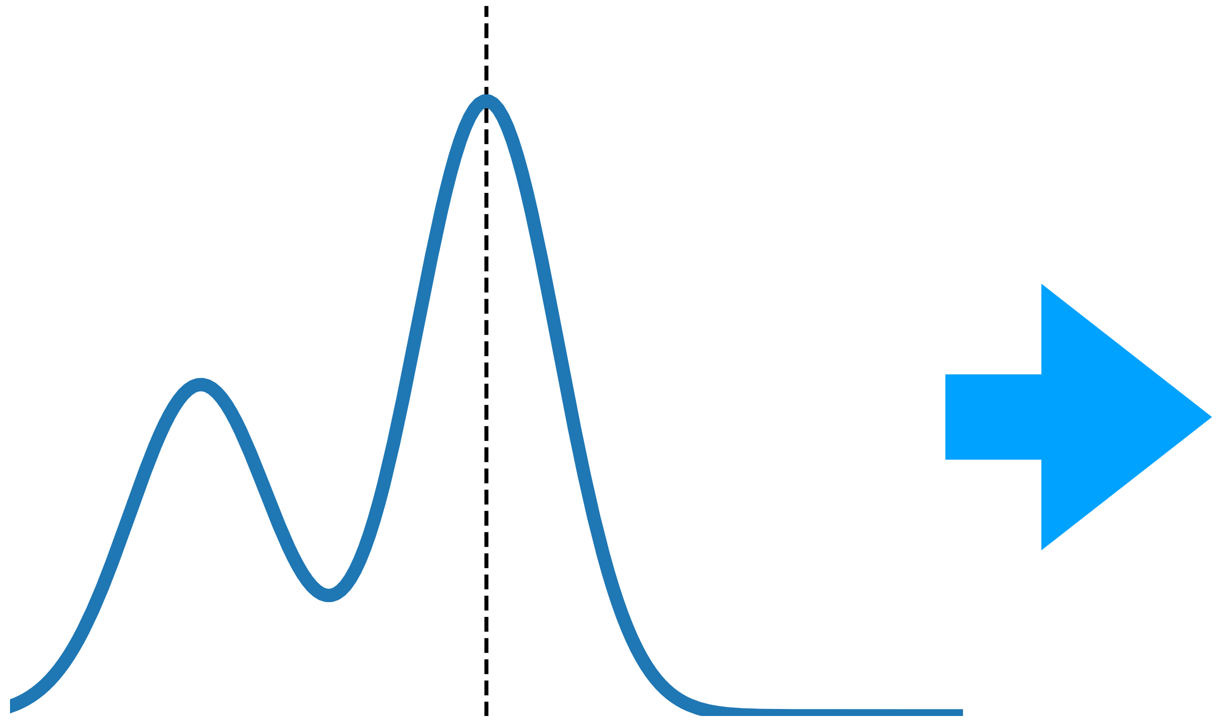


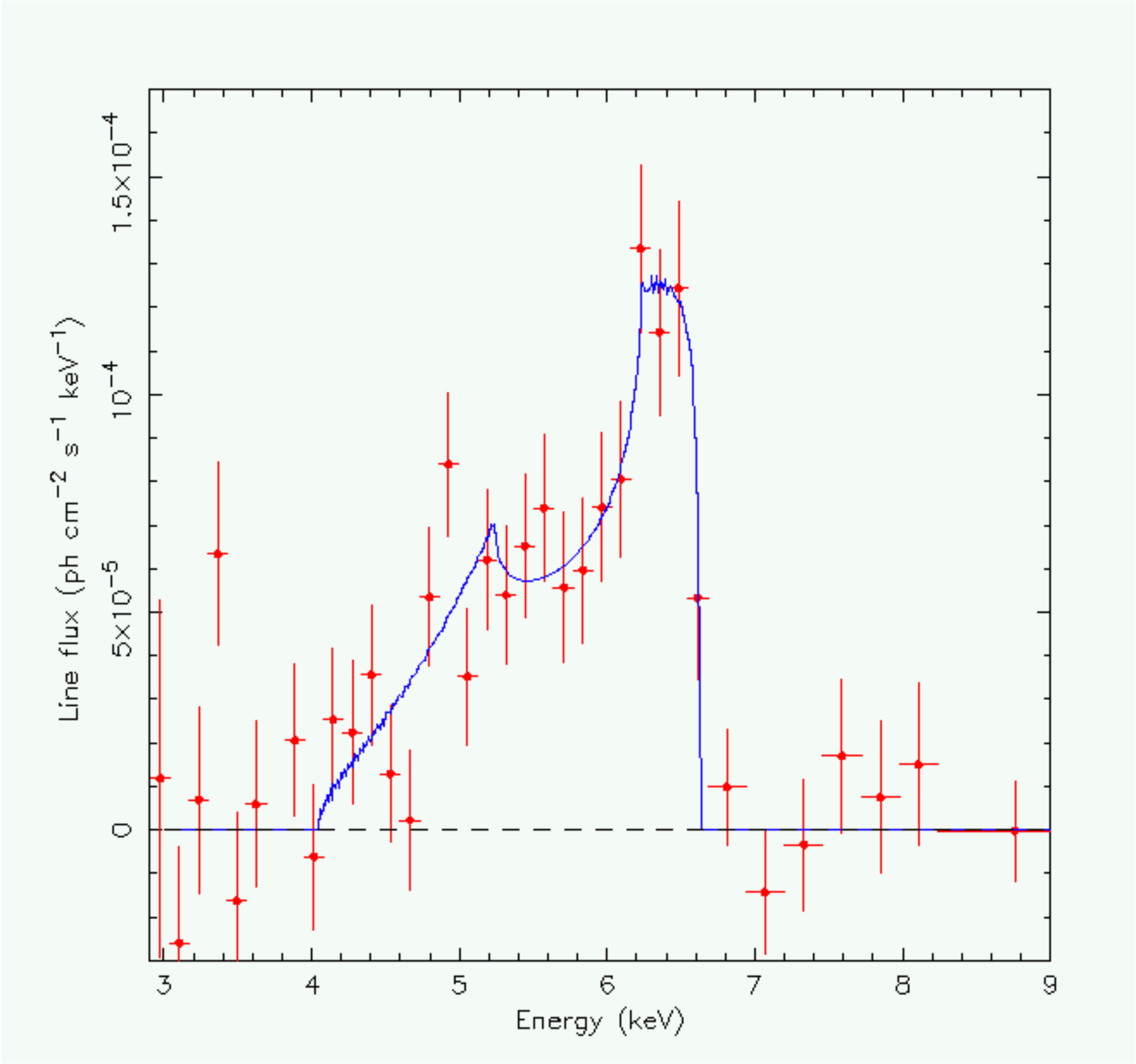


X-ray Spectral Model

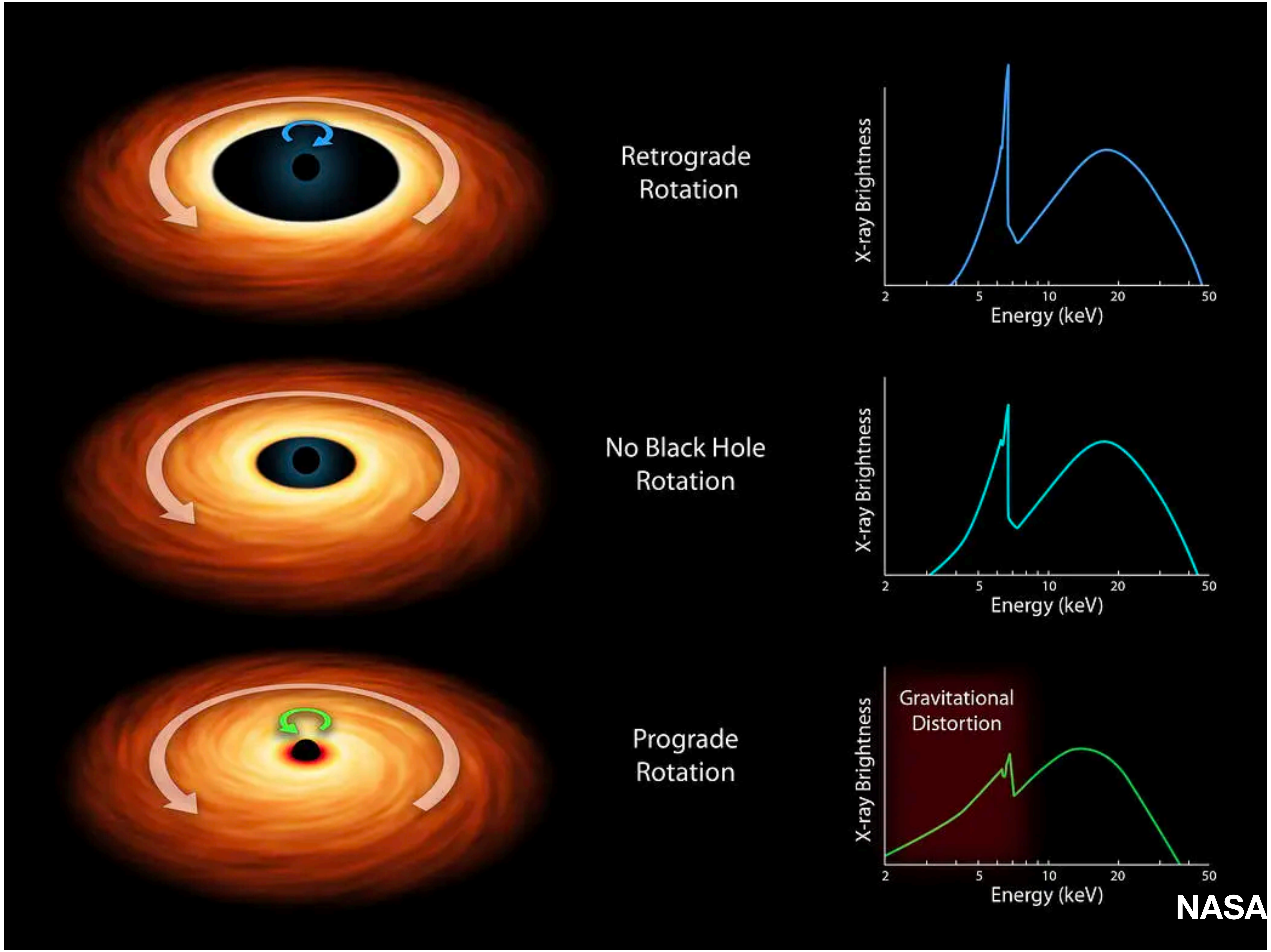
Relativistic reflection (e.g., Tanaka+95)

- Reflection component from inner most region of accretion disk
  - Beaming effect
  - Gravitational redshift





Disk line

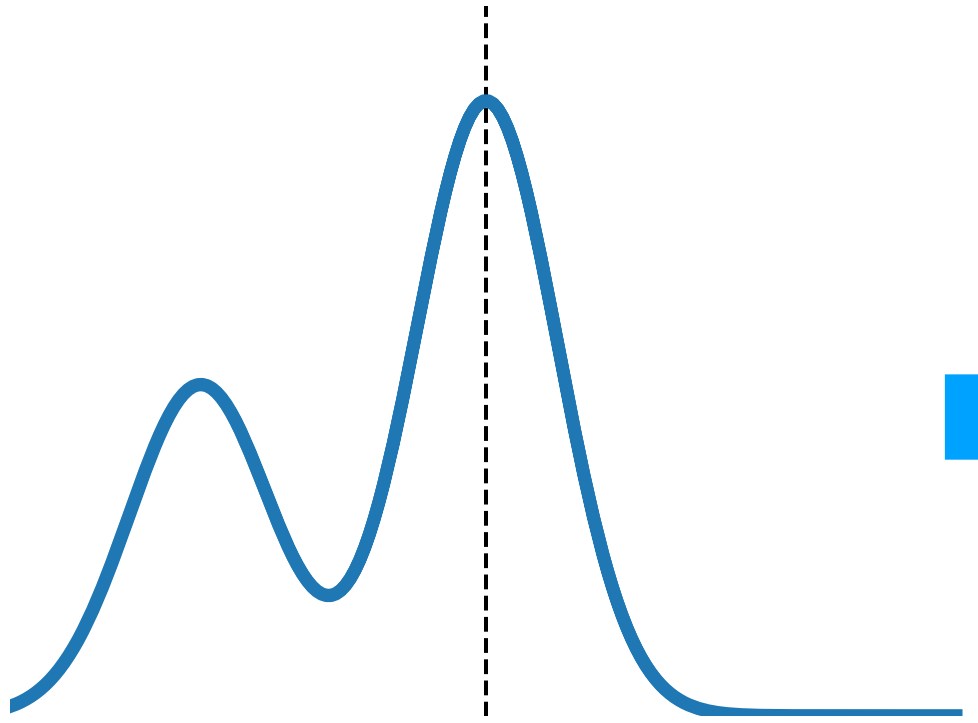


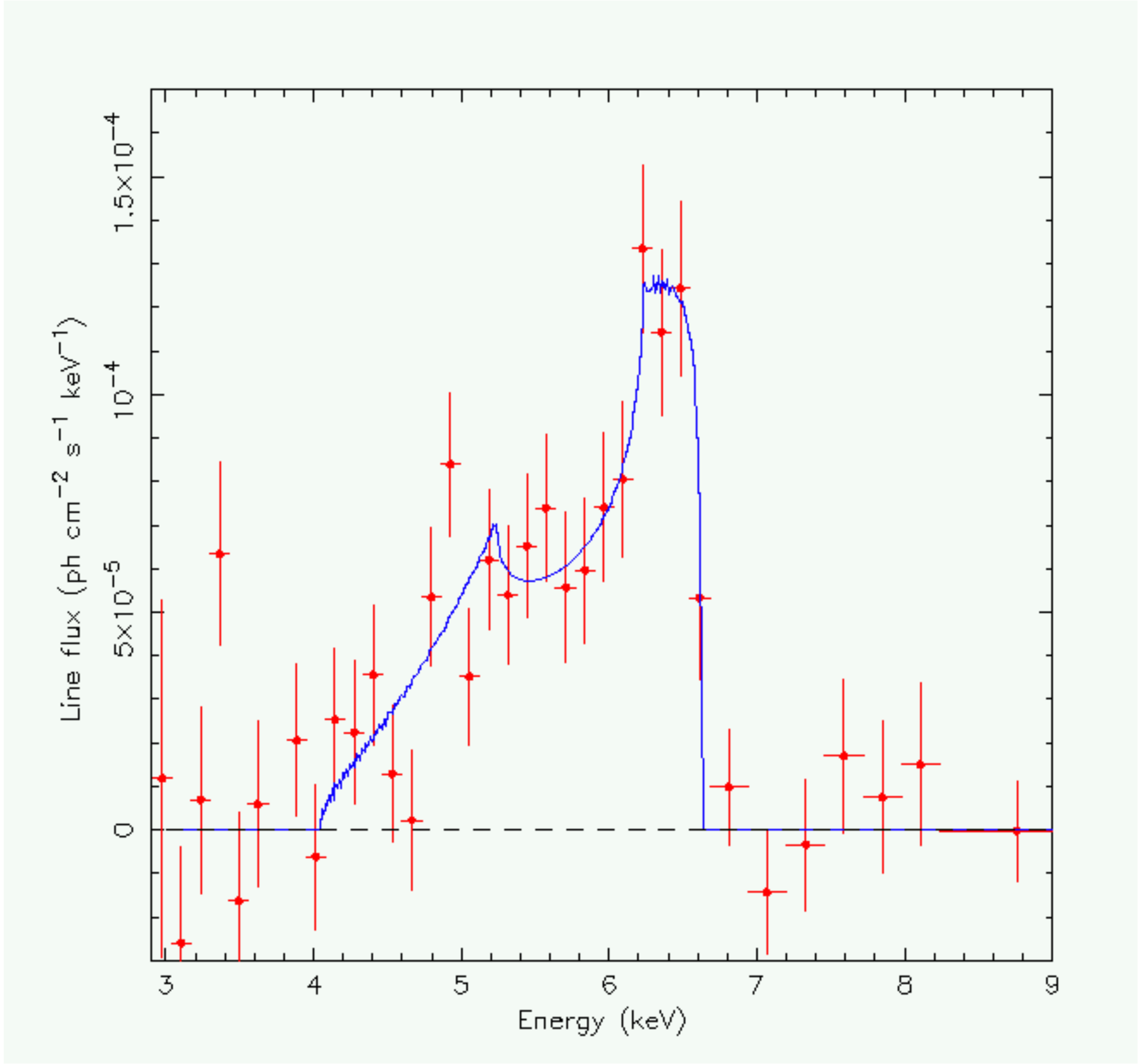
Retrograde Rotation
No Black Hole Rotation
Prograde Rotation
X-ray Brightness
Energy (keV)
2
5
10
20
50
Gravitational Distortion
NASA

Two Spectral Model

Relativistic reflection (e.g., Tanaka+95)

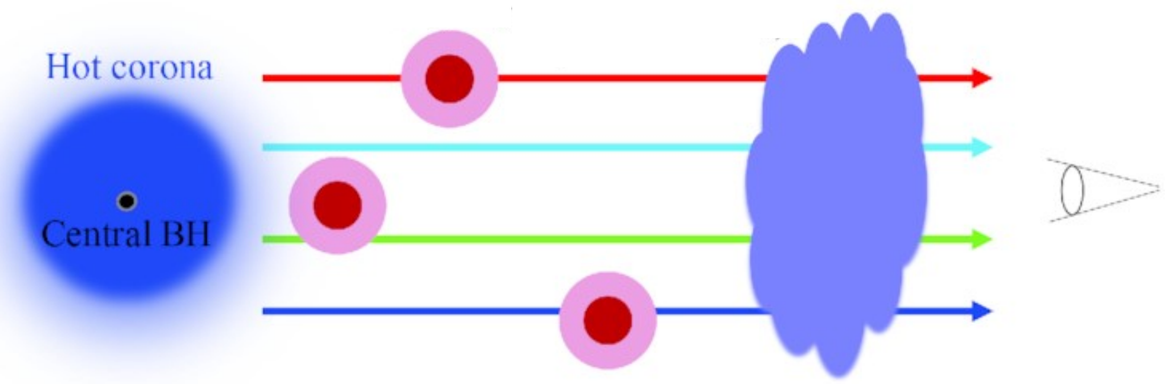
- Reflection component from inner most region of accretion disk
  - Beaming effect
  - Gravitational redshift
- High abundance: 2-10*solar
- Highly spinning: a > 0.99



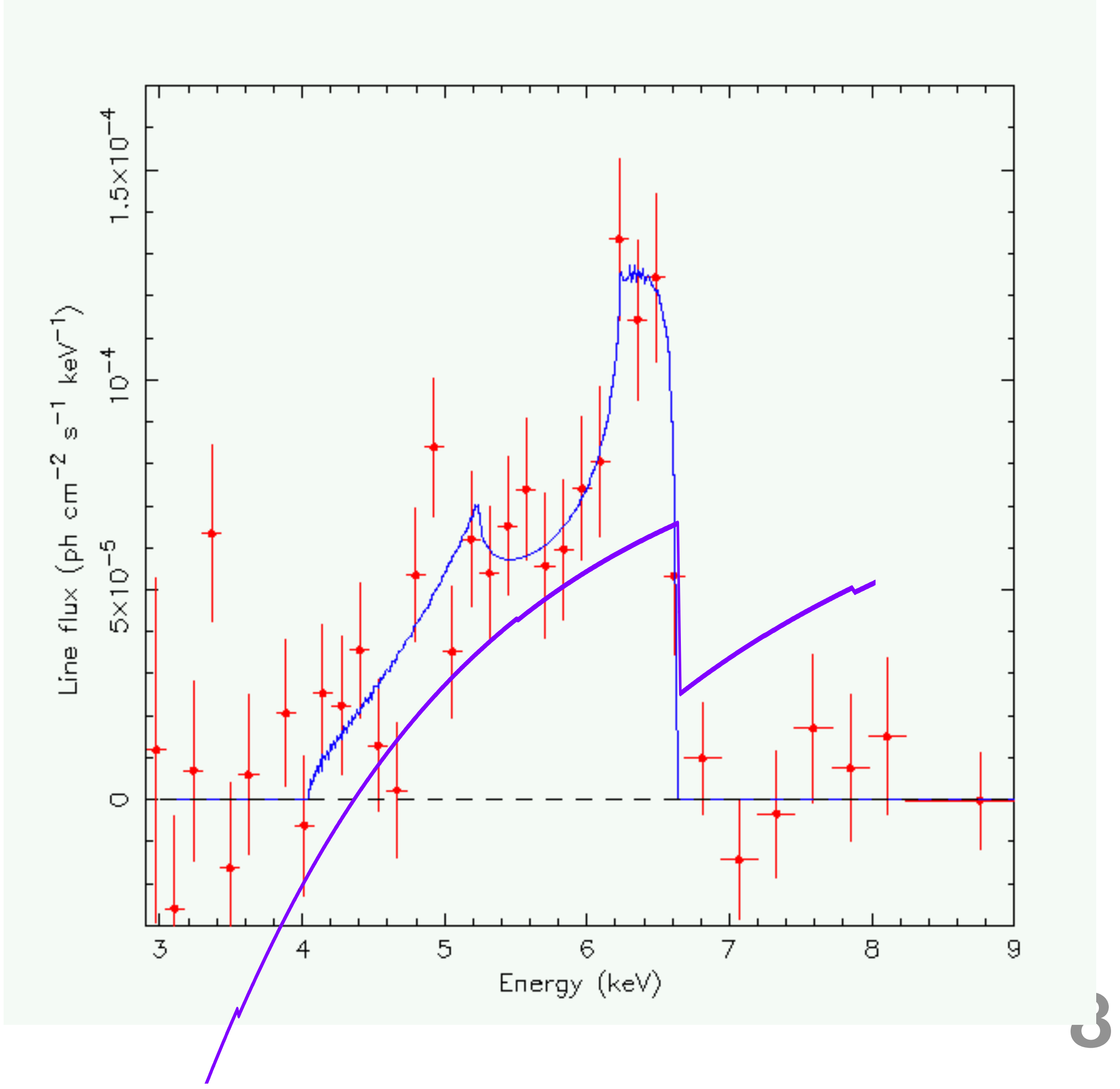


Partial covering (e.g., Miyakawa+12)

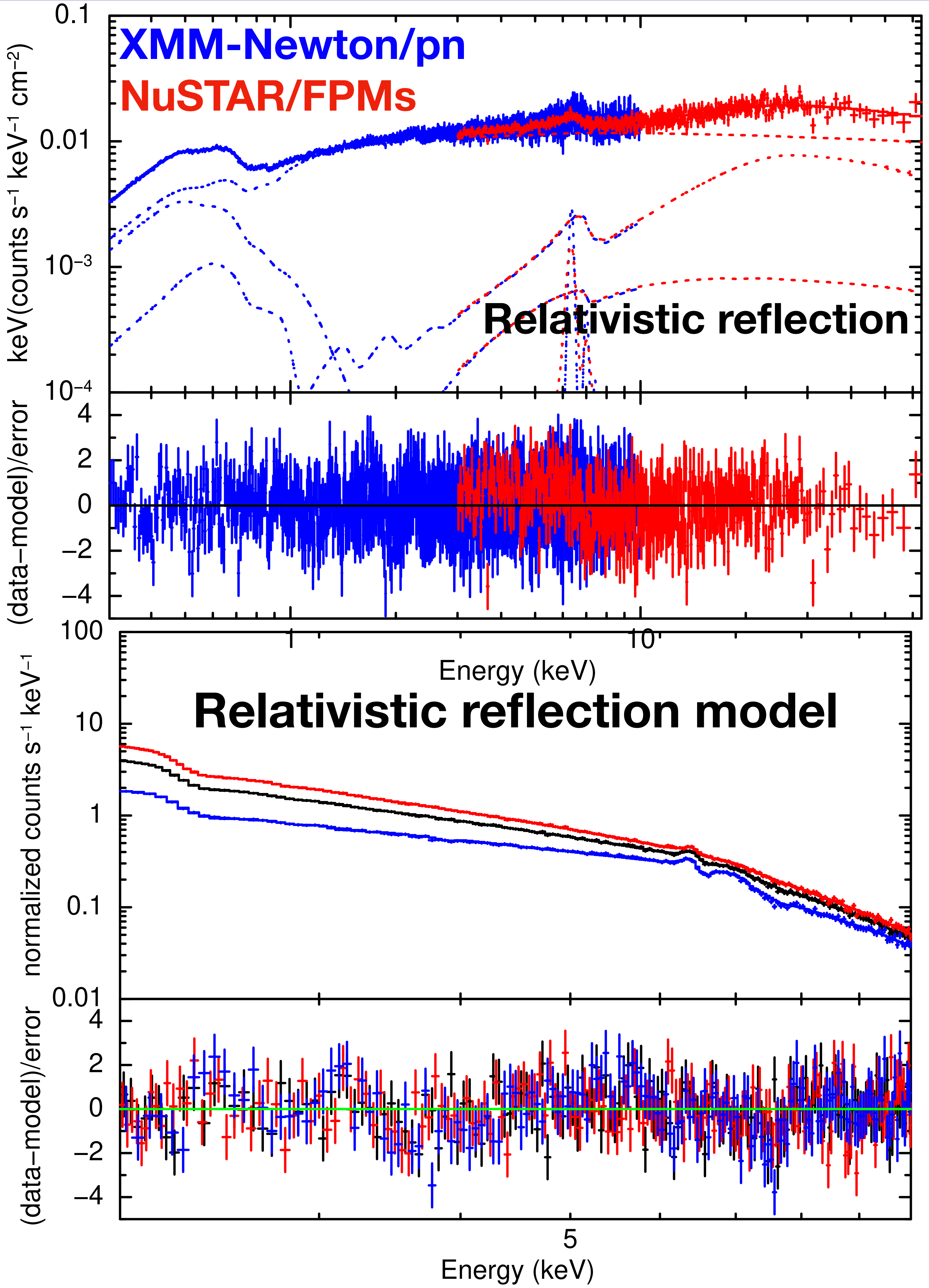
- Absorbed Continuum shape can mimic Broad Fe Kα with current CCD energy resol

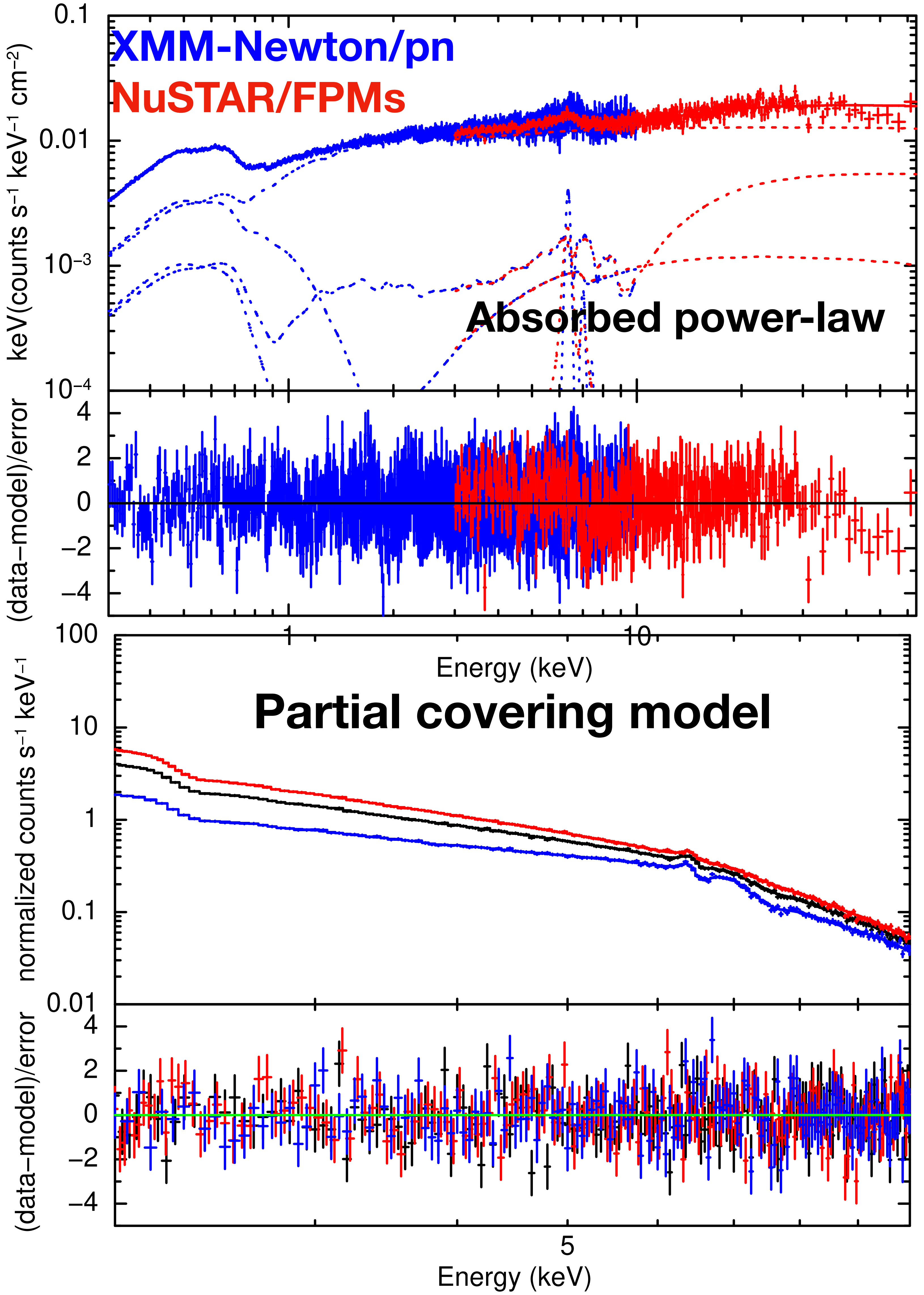


Midooka+22



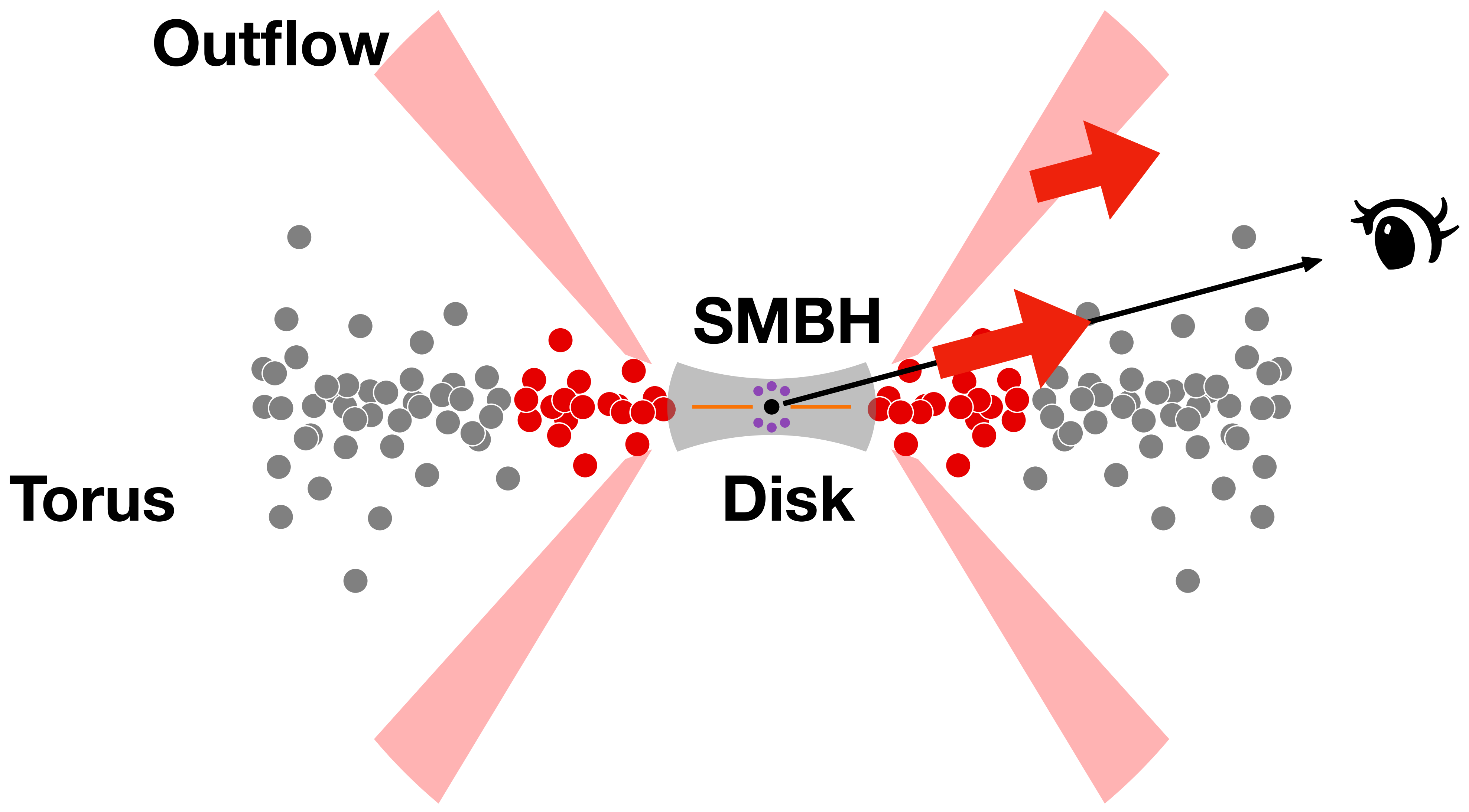
Ogawa+19

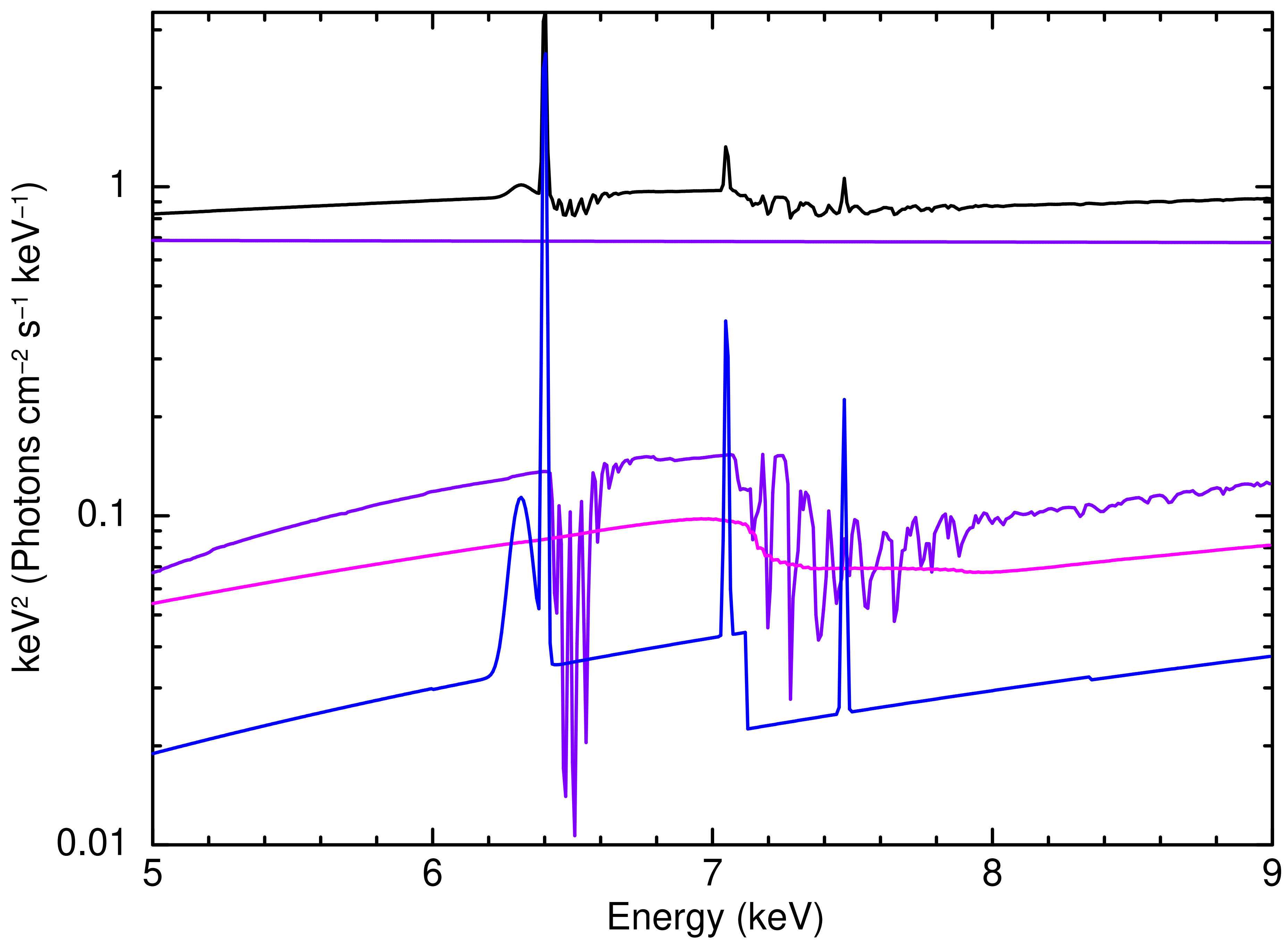




- Broadband (0.3–70 keV) spectra are reproduced with two different models

Spectral Complex in Fe-K band

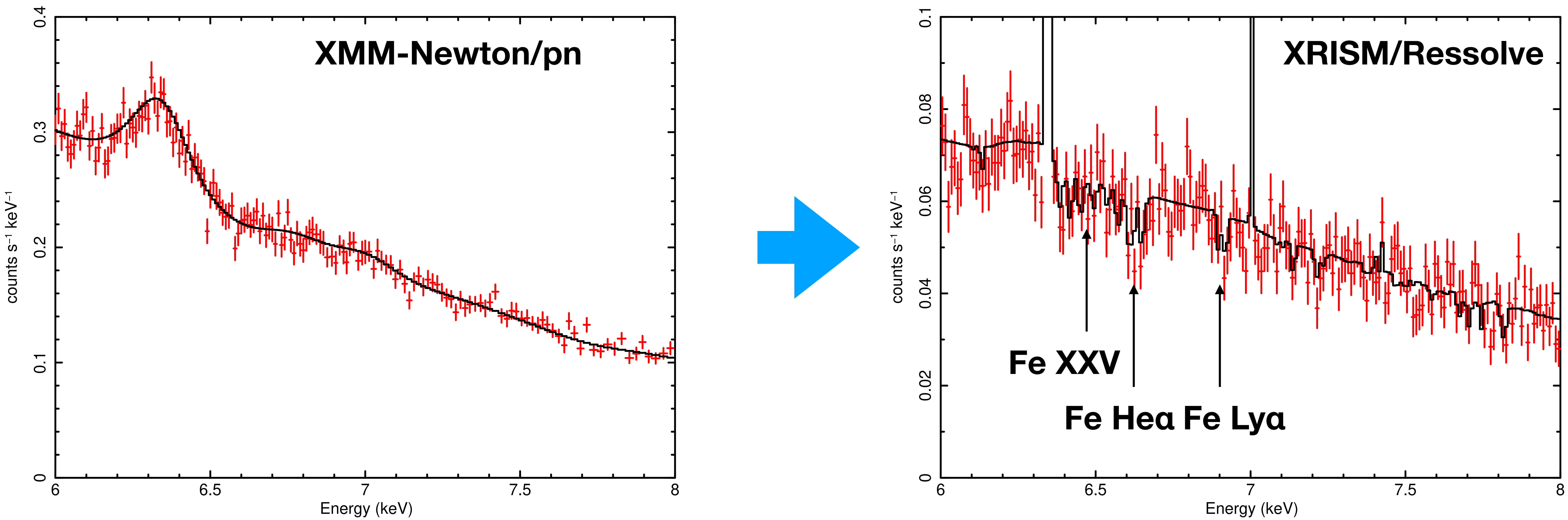




Spectral complex around 6 keV:

- Torus (disk) reflection accompanied by narrow fluorescence emission lines (Fe Kα@6.4 keV)
- Relativistic reflection from innermost region of the accretion disk
- Absorbed direct component
- XRISM/Resolve enables us to separate these component

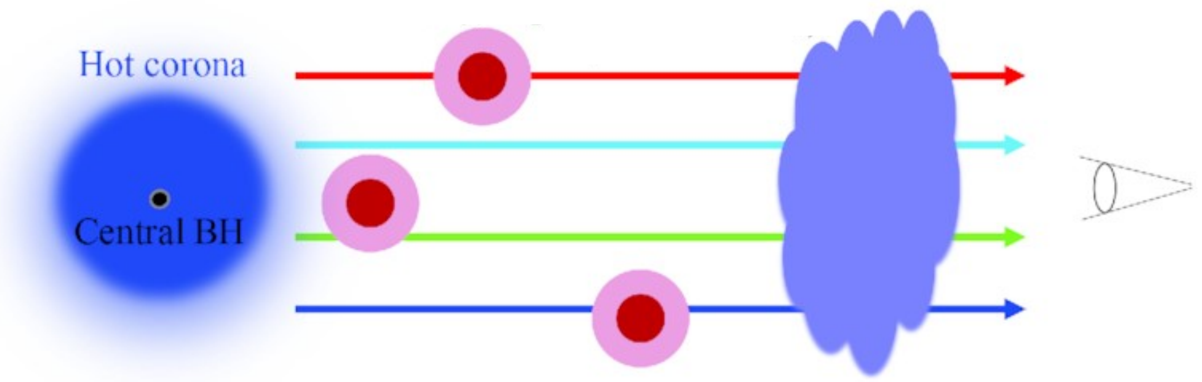
XRISM High Energy Resolution Observation



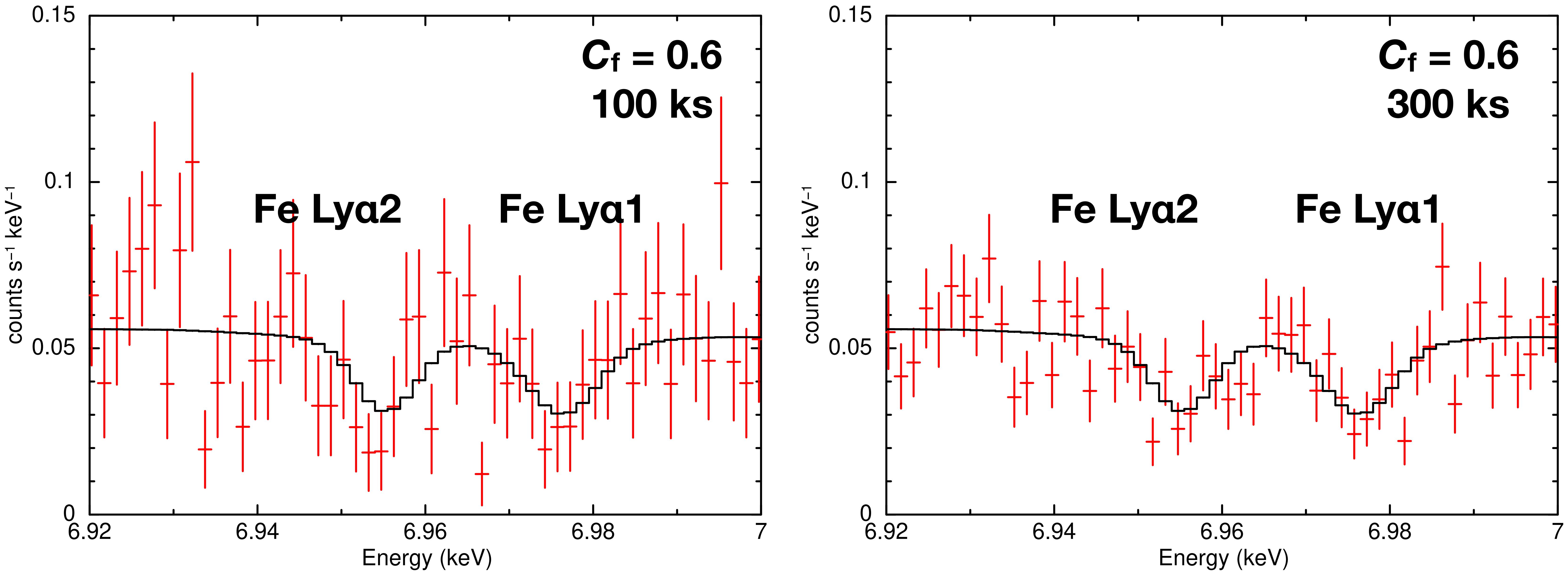
XRISM/Resolve

- ΔE@6keV ~ 5 eV
  - CCD (Suzaku, XMM-Newton): ΔE@6keV ~150 eV
- Narrow features of ionized absorbers can be easily detected with XRISM/Resolve

Direct Proof of Partial Covering Absorbers



Midooka+22

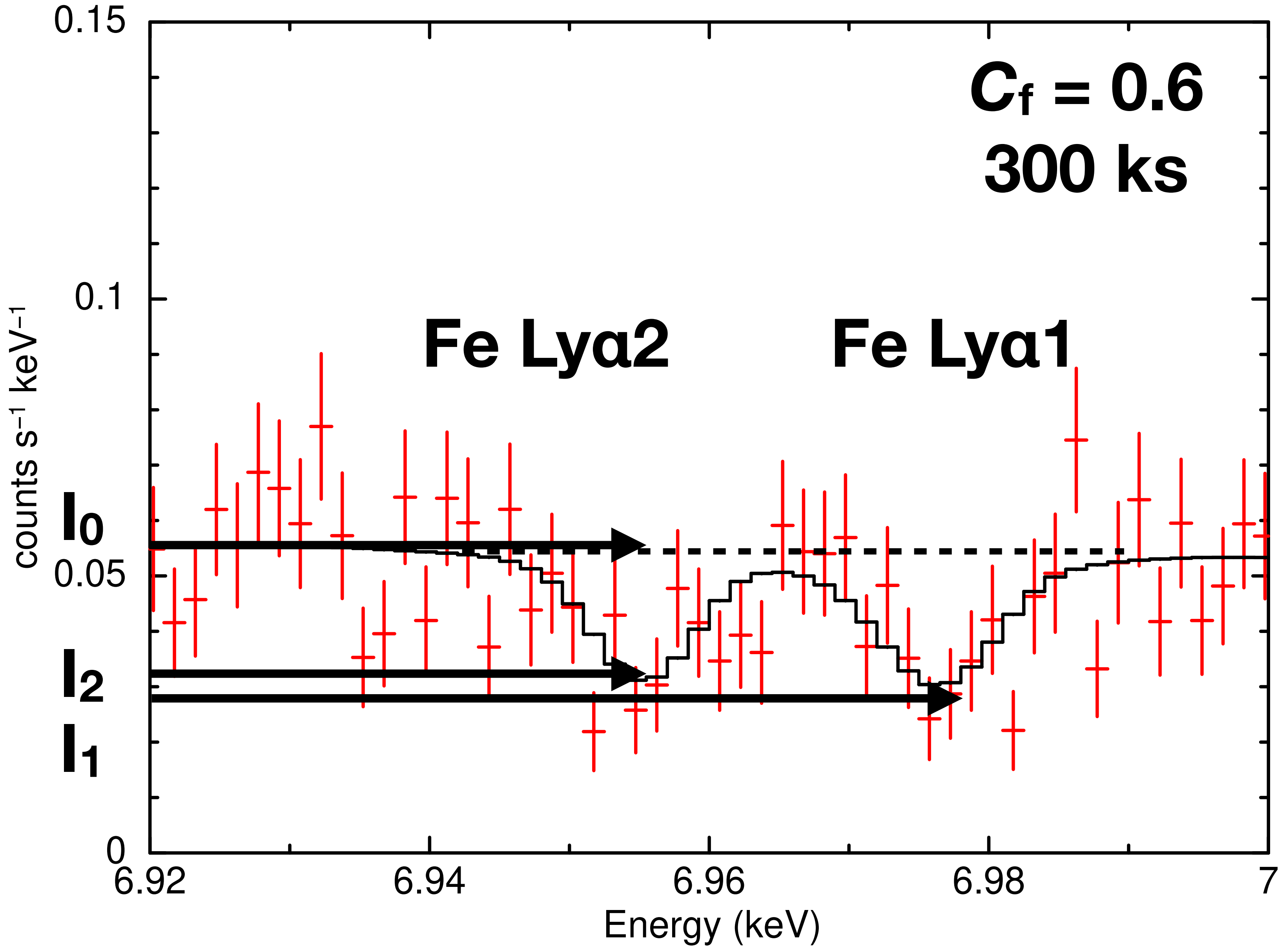


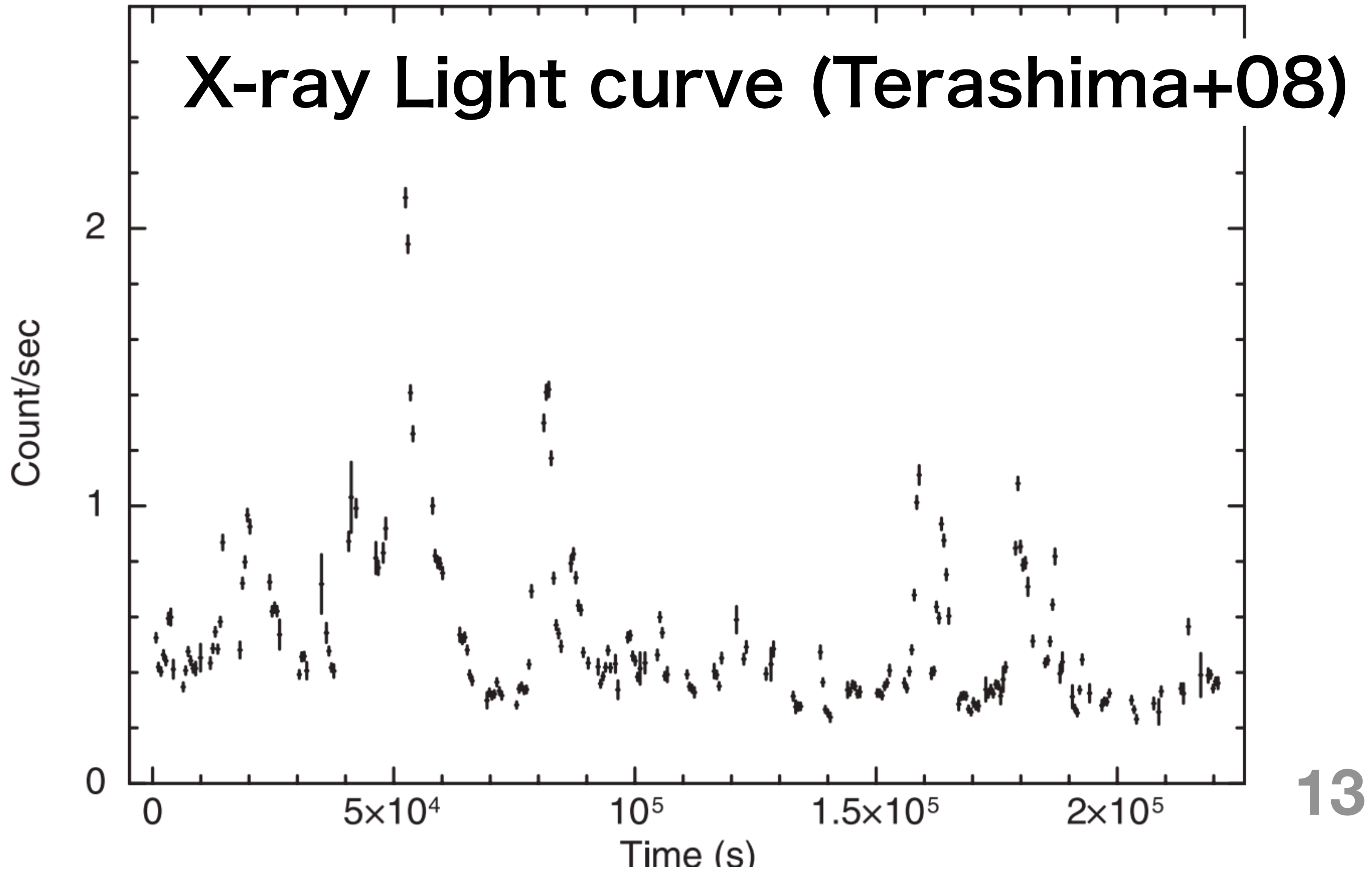
Estimation of covering factor

- XRISM/Resolve can resolve two or more lines from the same ions, e.g., Lyα doublet of Fe XXVI:
  - Fe Lyα1@6.97316 keV
  - Fe Lyα2@6.95197 keV
- Comparing the intensities of these lines → the covering factor of the partial absorber

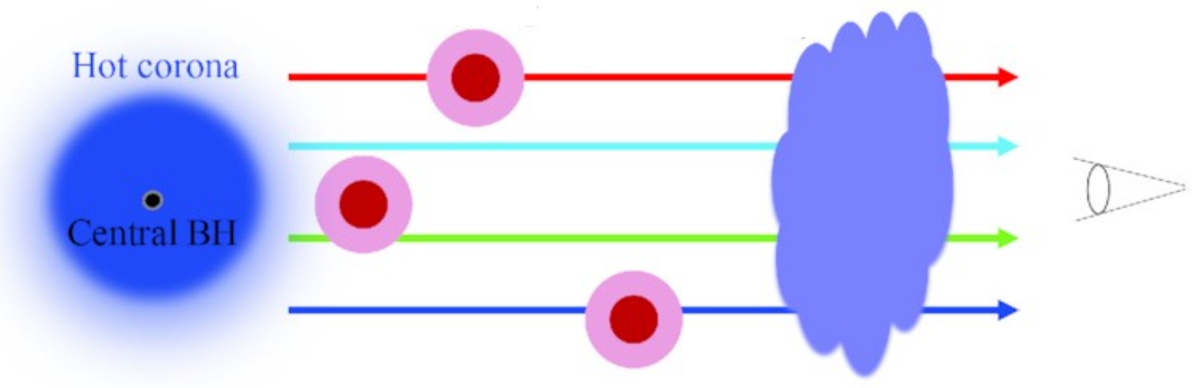
Estimating Covering Fraction

- Line intensity: $C_f I_0 (1-e^{-\tau})$
- Residual intensity: $I_1 = 1-C_f + C_f e^{-\tau}$
- Optical depth: $\tau_1/\tau_2 \sim 2$
- $C_f = \quad (I_2 - 1)^2 / (I_1 - 2I_2 + 1)$
- Time variability of covering fraction

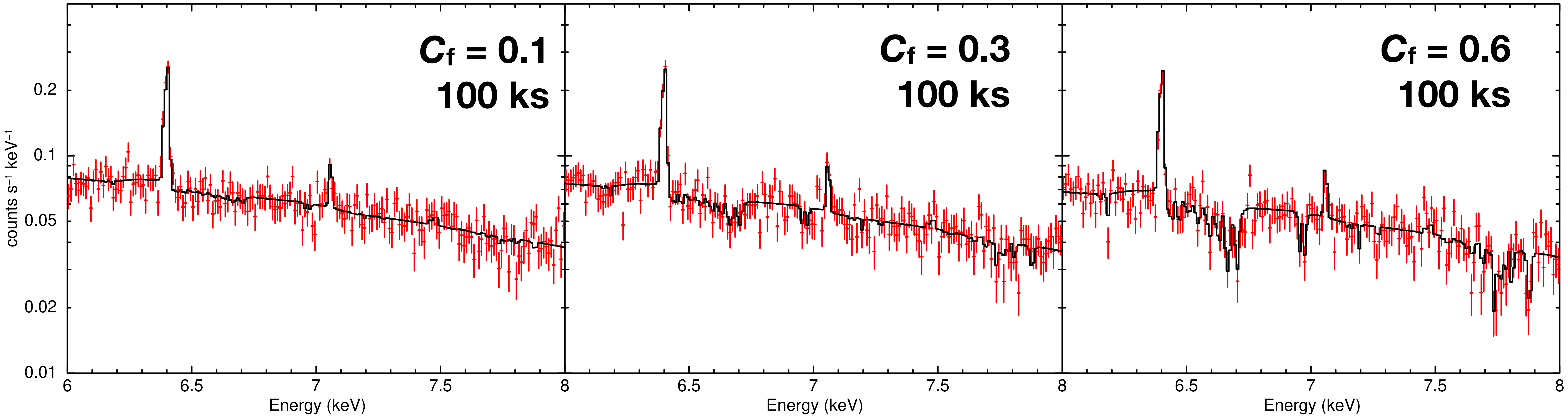




Strategy: Long-term Observation



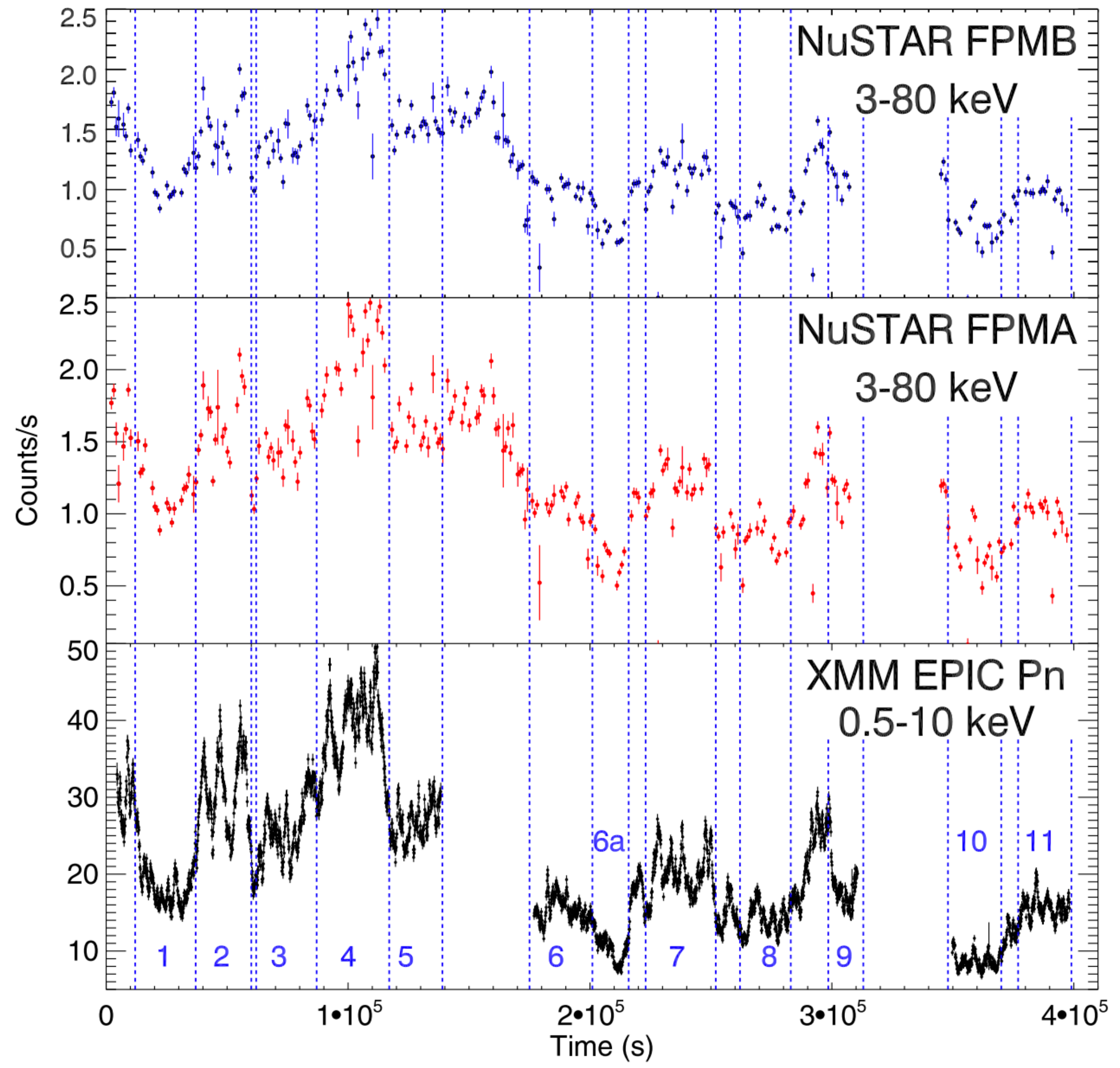
Midooka+22



Simulated spectra of XRISM/Resolve with GV (best-fit model: Ogawa+21)

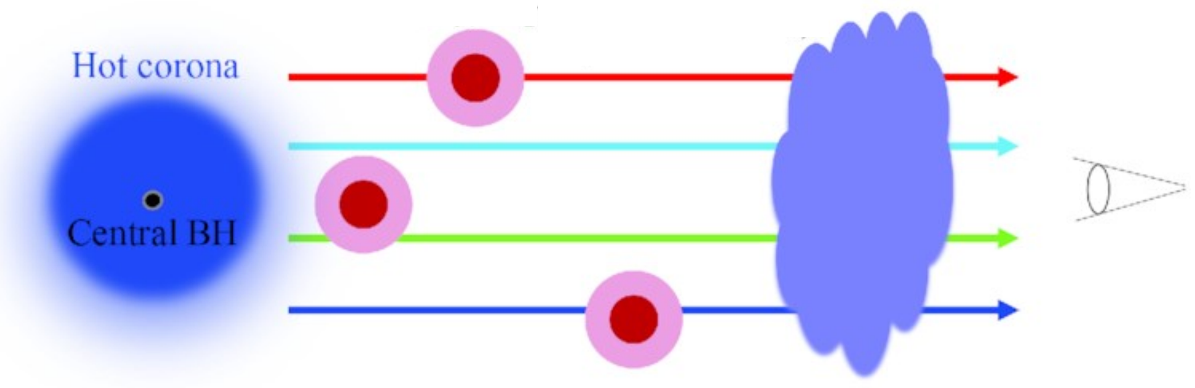
600 ks Observation of MCG-6-30-15

- To perform spectral fit to Intensity-sliced spectra
- To detect absorption features
- To test if partial absorber model is suitable

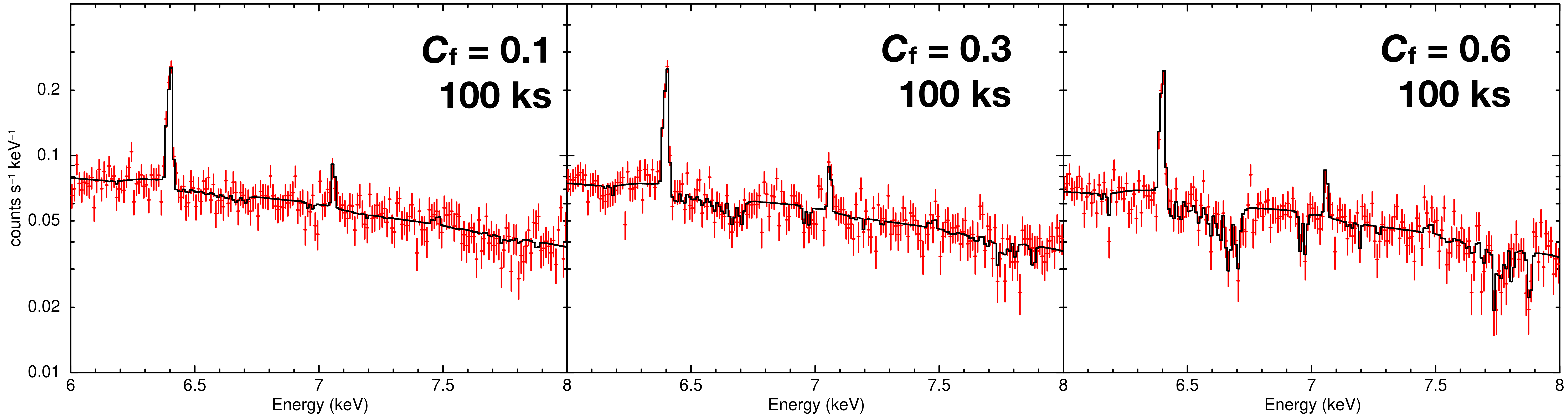


Light curve (Marinucci+14)

First Step: PV Observation



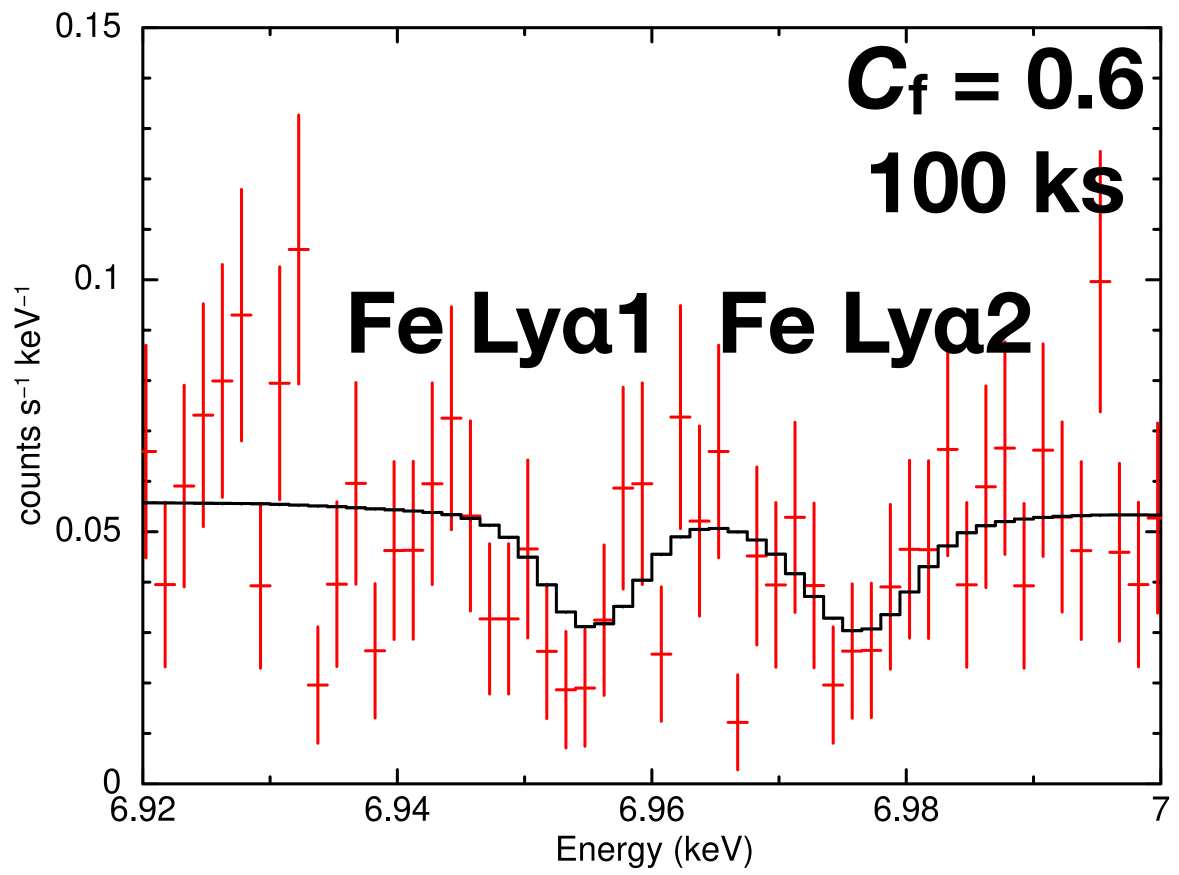
Midooka+22



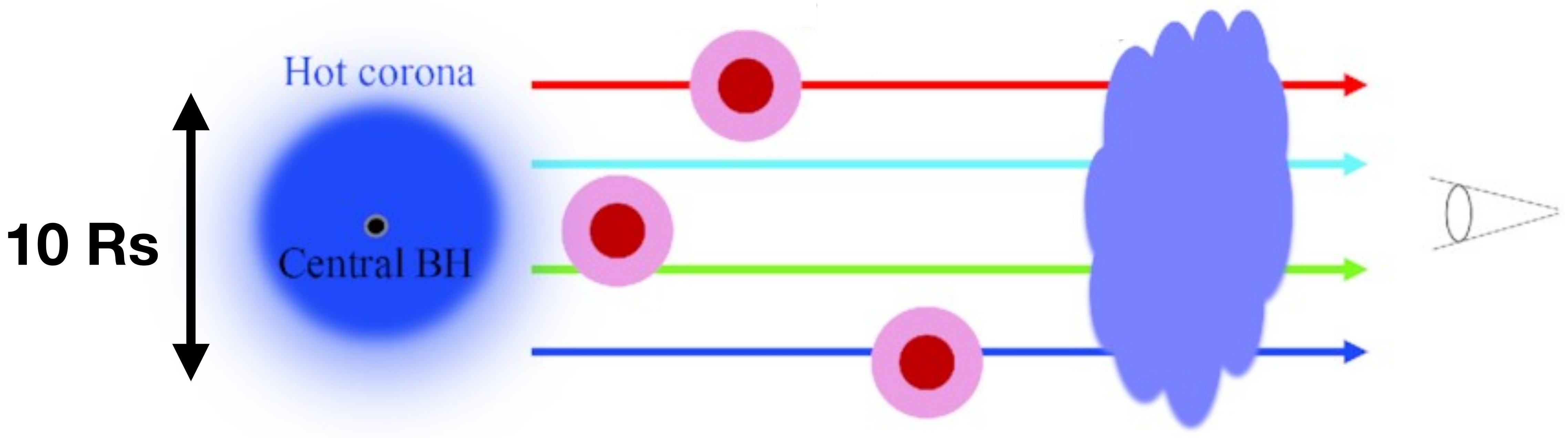
Simulated spectra of XRISM/Resolve with GV (best-fit model: Ogawa+21)

120 ks Observation MCG-6-30-15

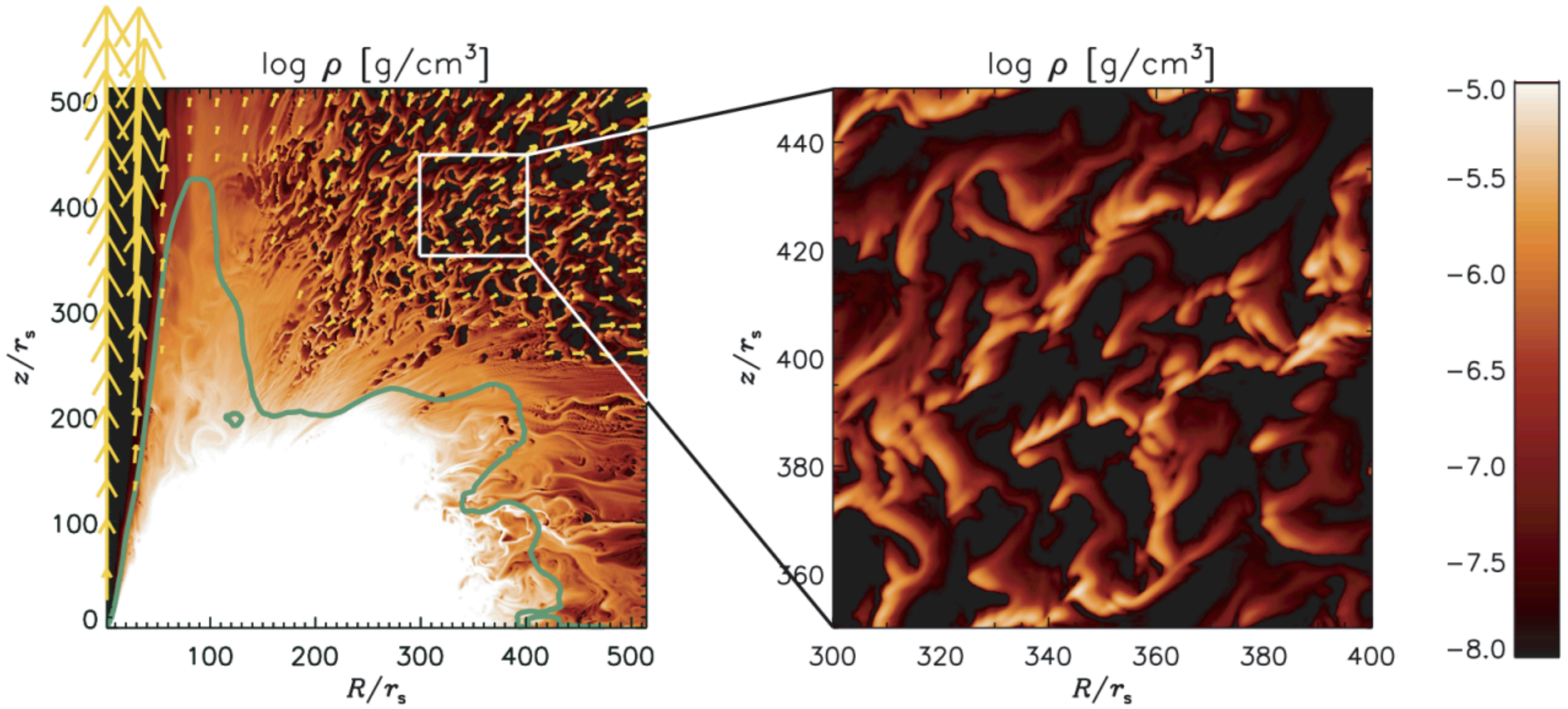
- Narrow absorption lines
  → Ionized absorber (AGN feedback)
- Narrow fluorescence emission lines (Fe Kα@6.4 keV)
  → Torus structure (AGN feeding)



Origin of partial absorber



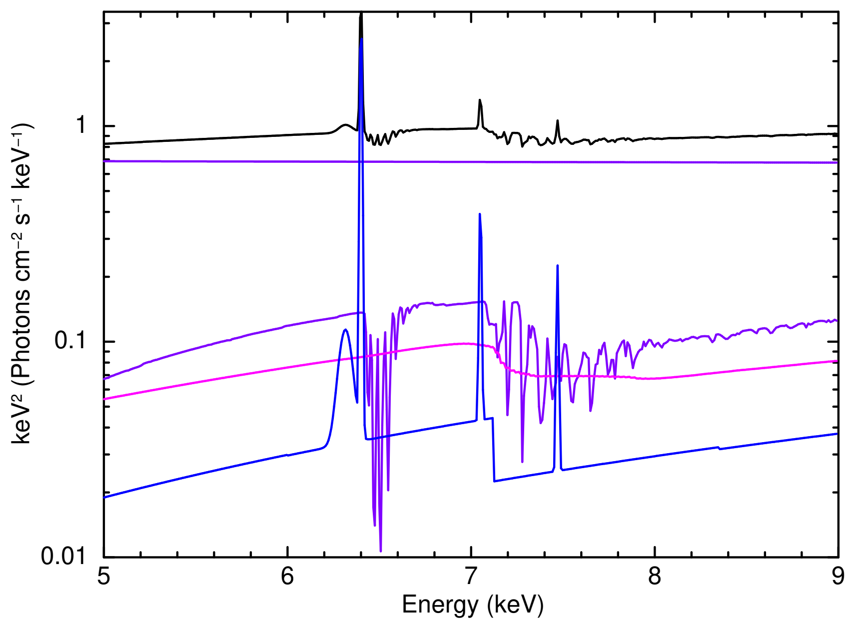
Midooka+22



Takeuchi+13

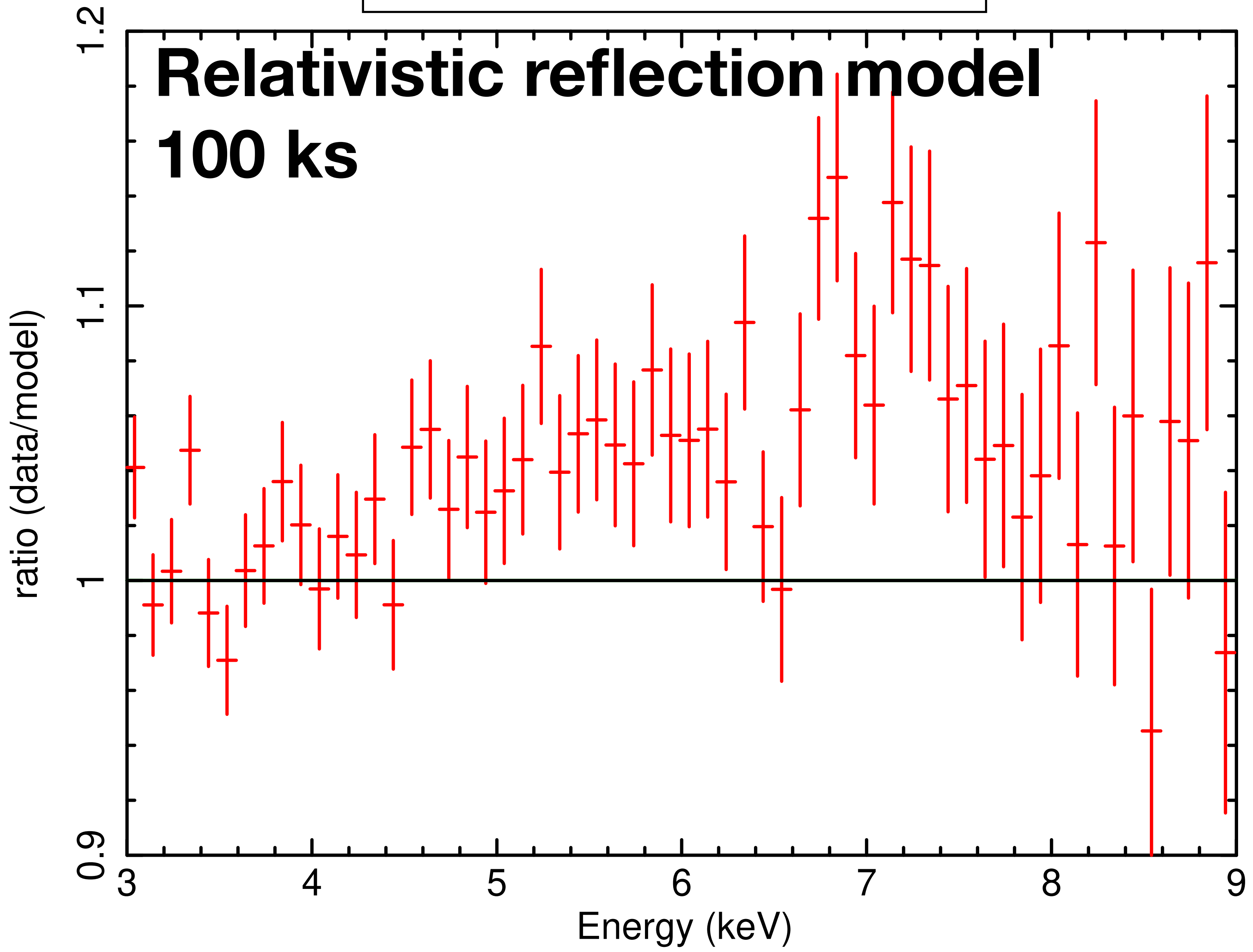
- Rayleigh–Taylor instability

Prospects: Broad Fe Kα



Observed spectrum − **Absorbed continuum + Torus reflection**

Accretion disk reflection?



Disk line parameters

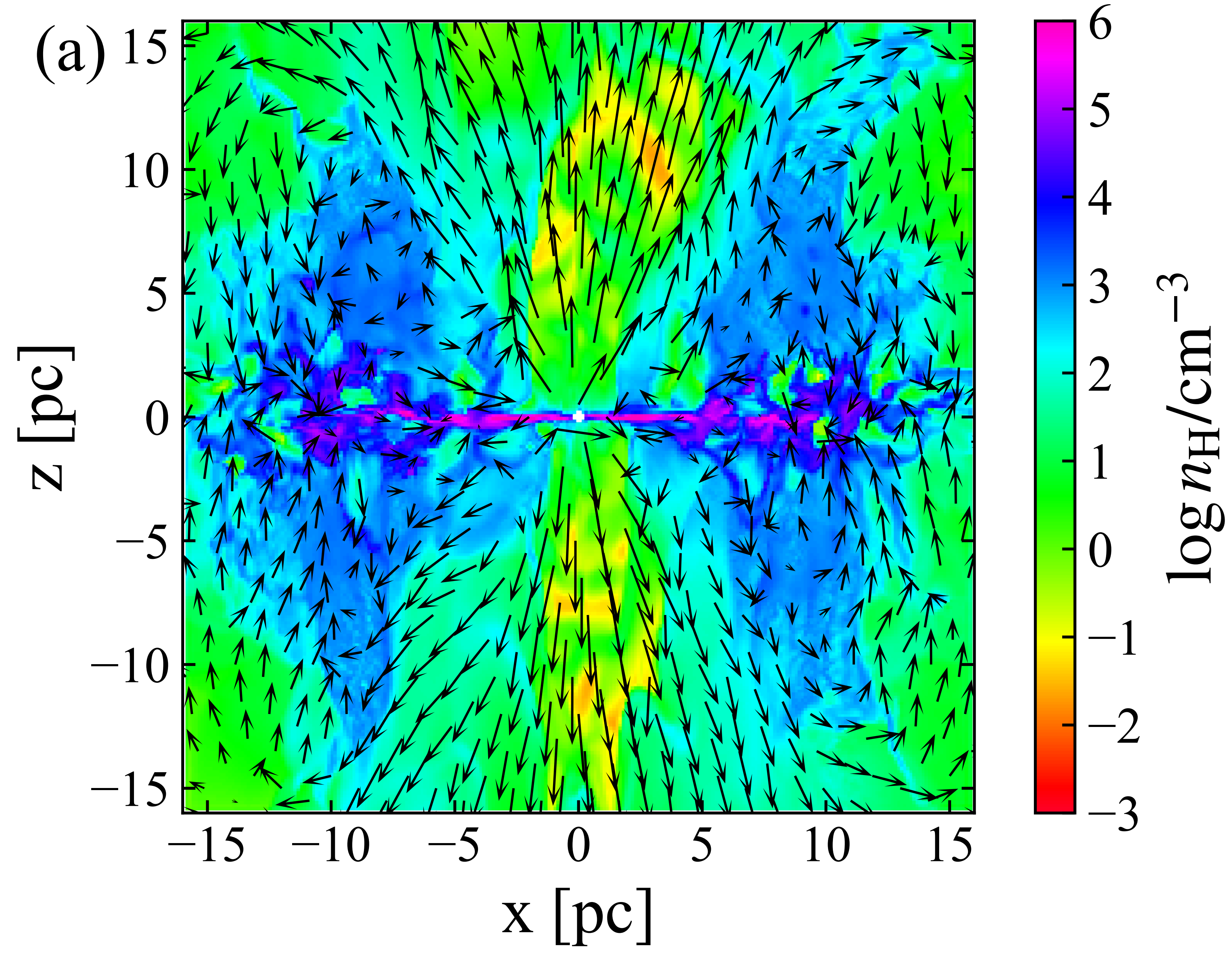
✤ XRISM/Resolve enables us to separate:

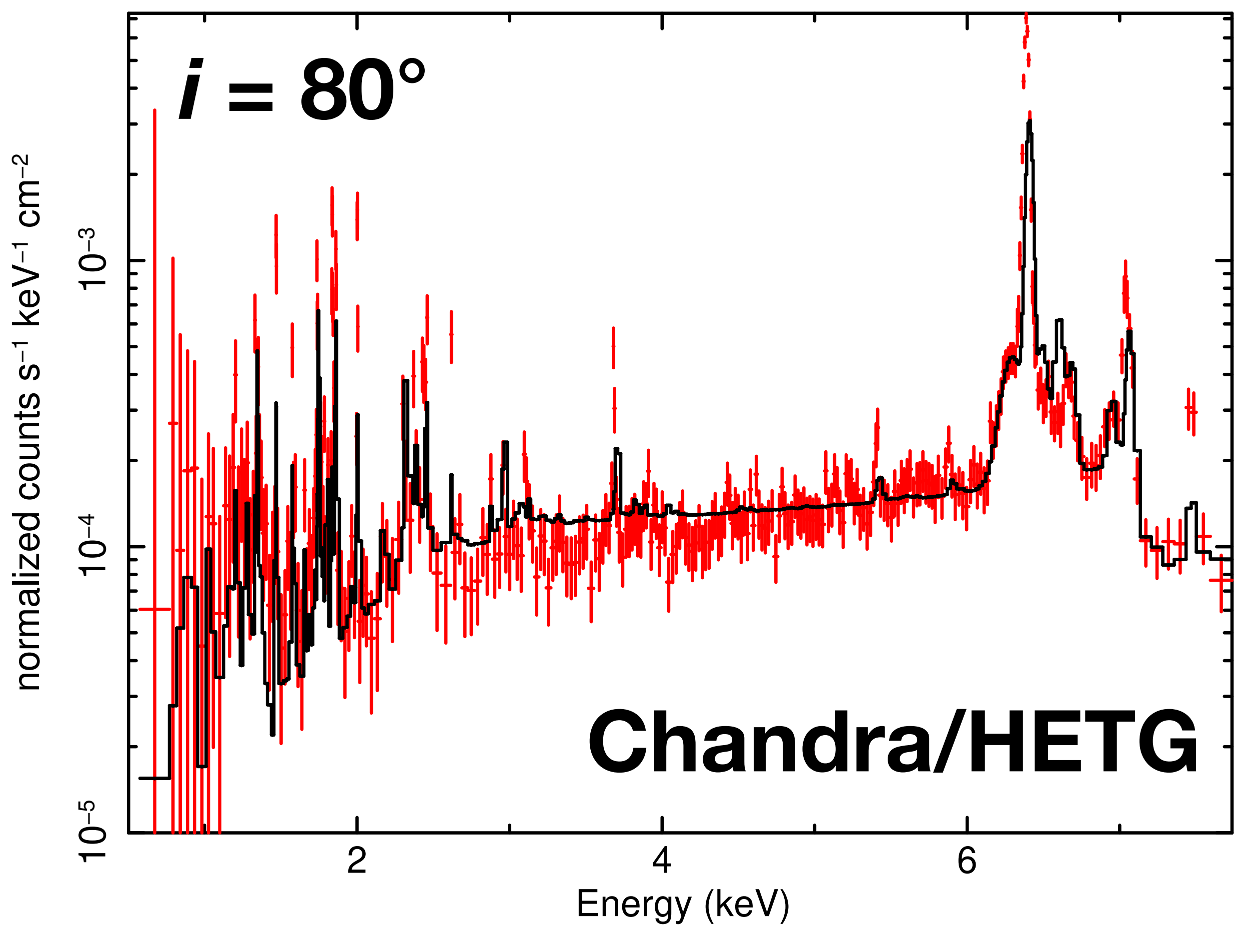
- Ionized absorbers
- Torus reflection accompanied by a narrow Fe Kα line at 6.4 keV
- Intrinsic continuum

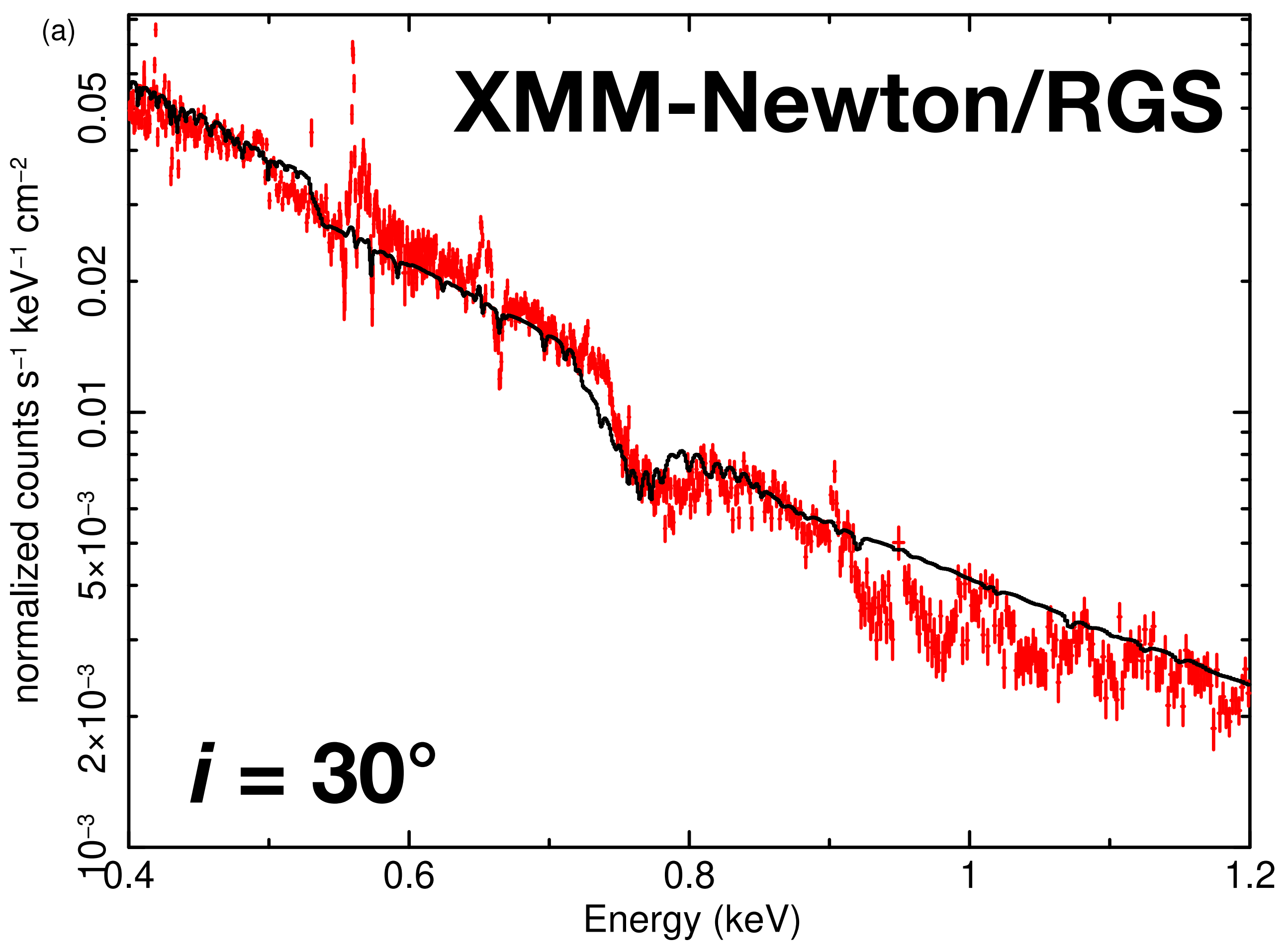
→ We can accurately estimate the relativistic reflection component (if any)

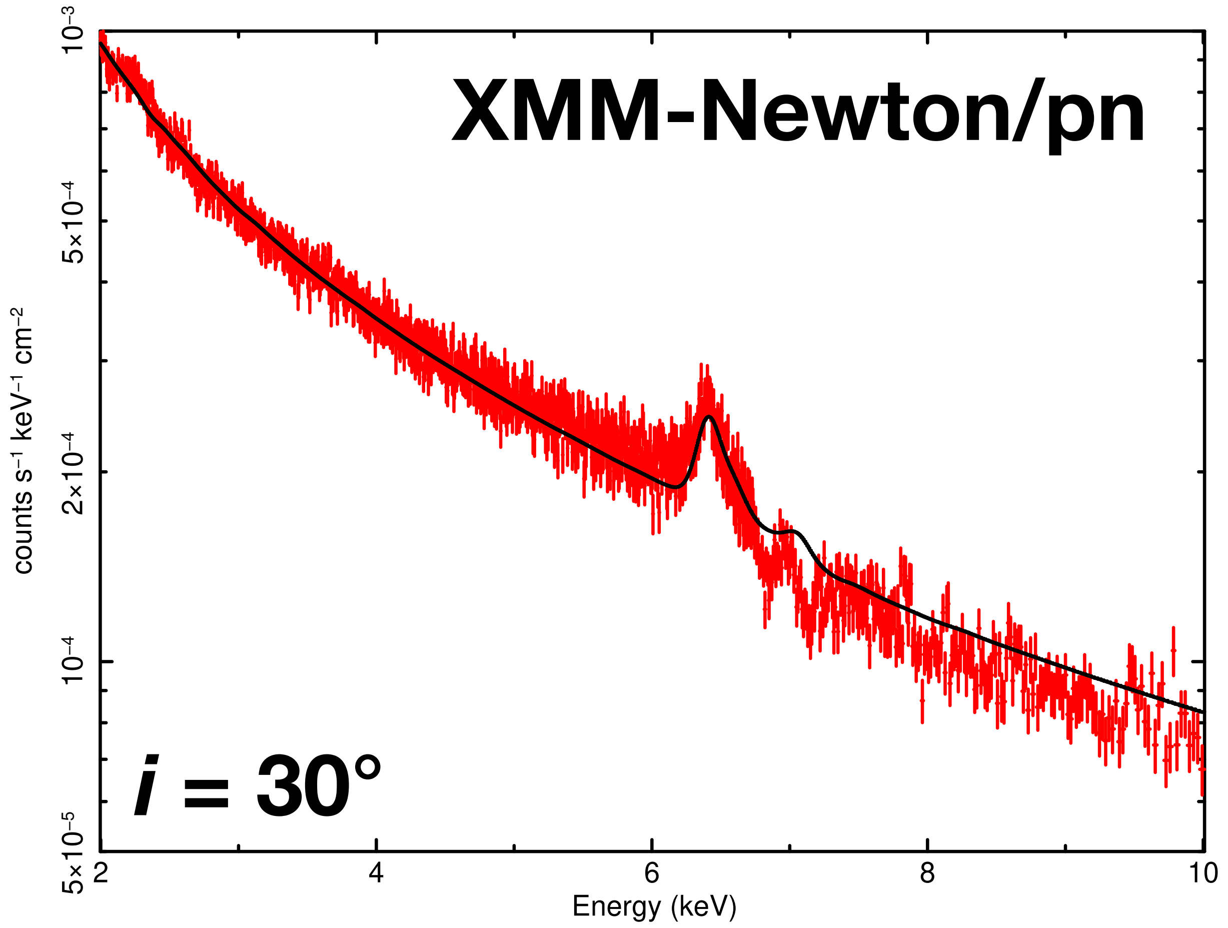
- Blackhole spin
- Innermost radius of accretion disk
- Inclination
- Metal abundances

Radiation-fountain Model



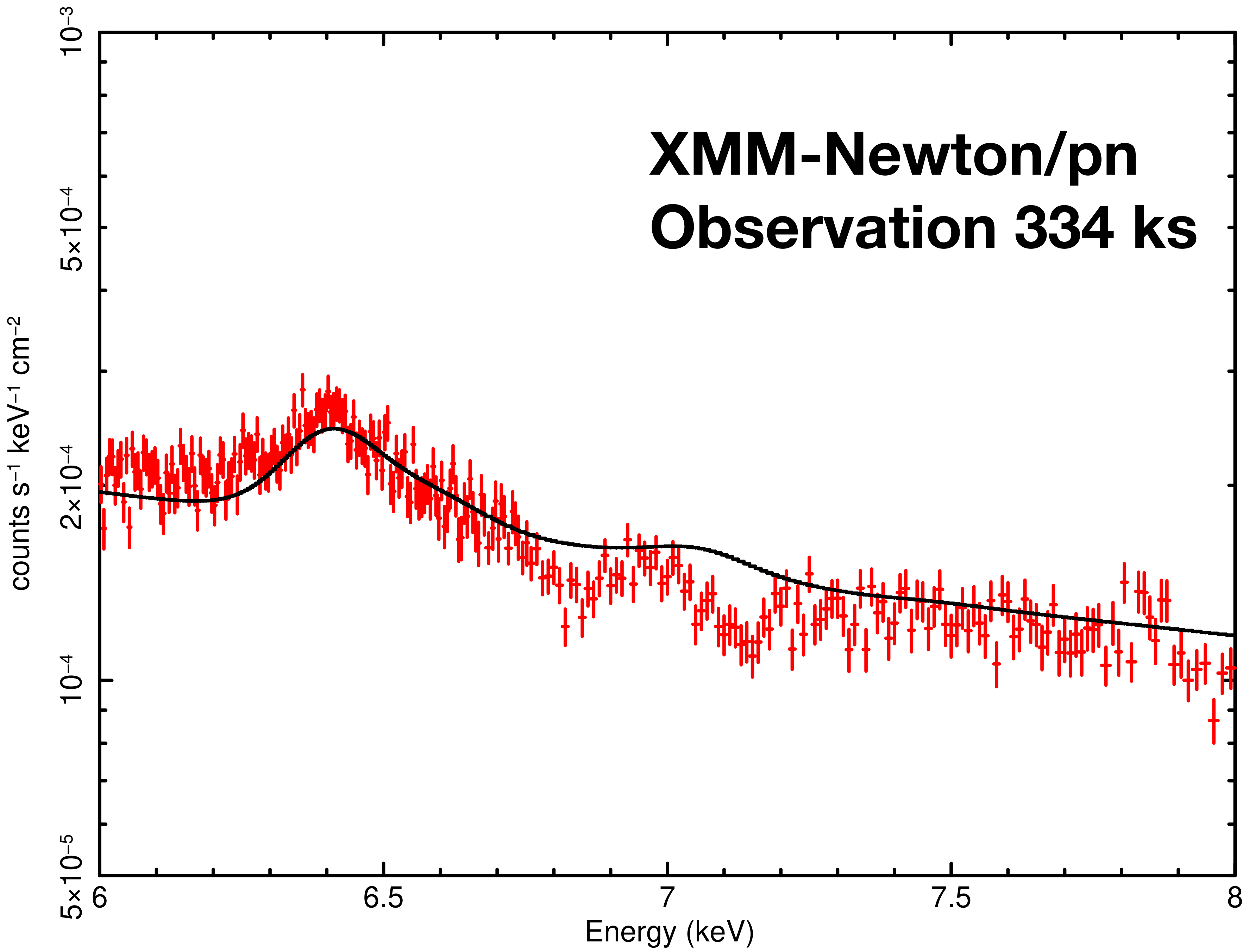




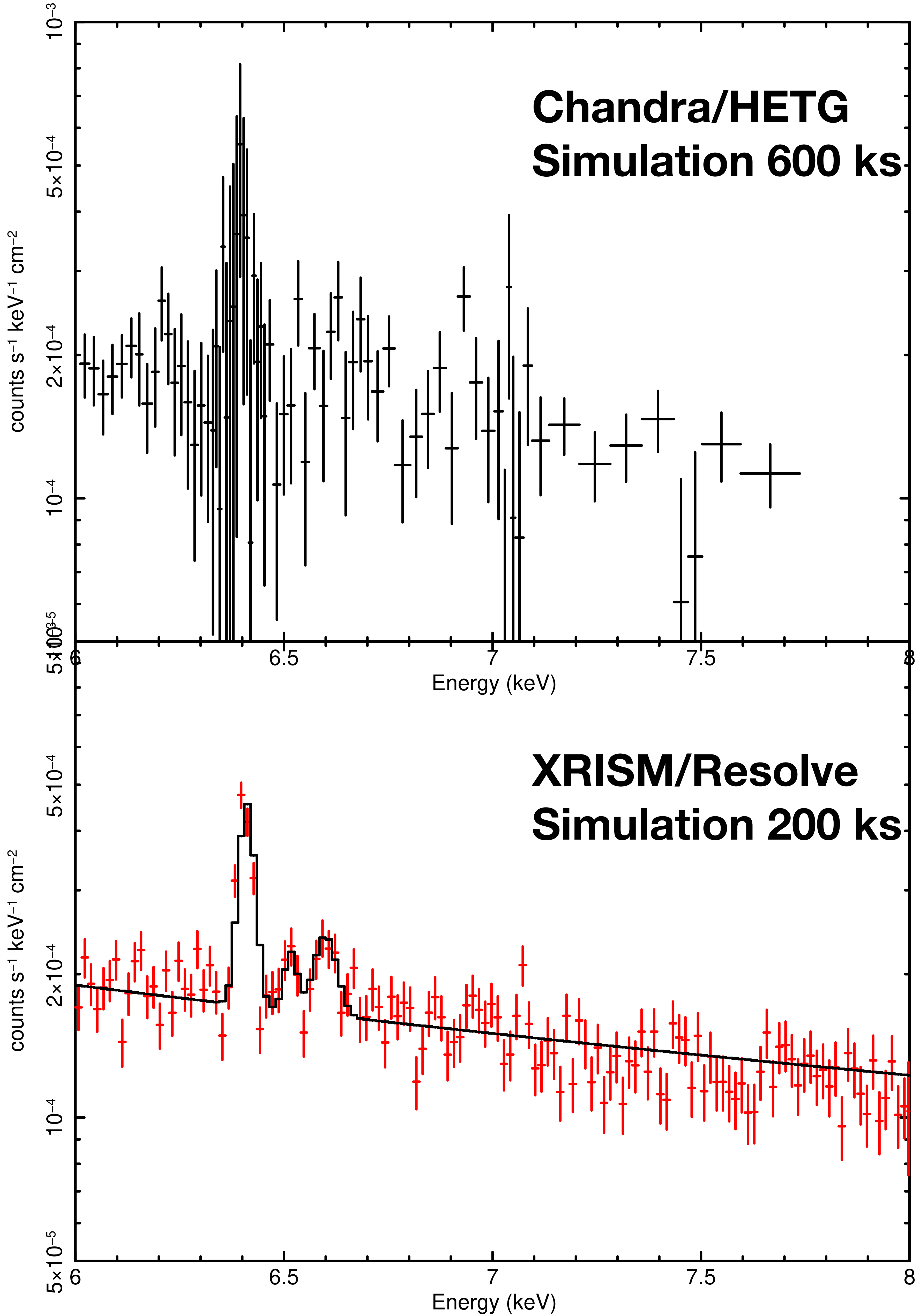


Ogawa+22

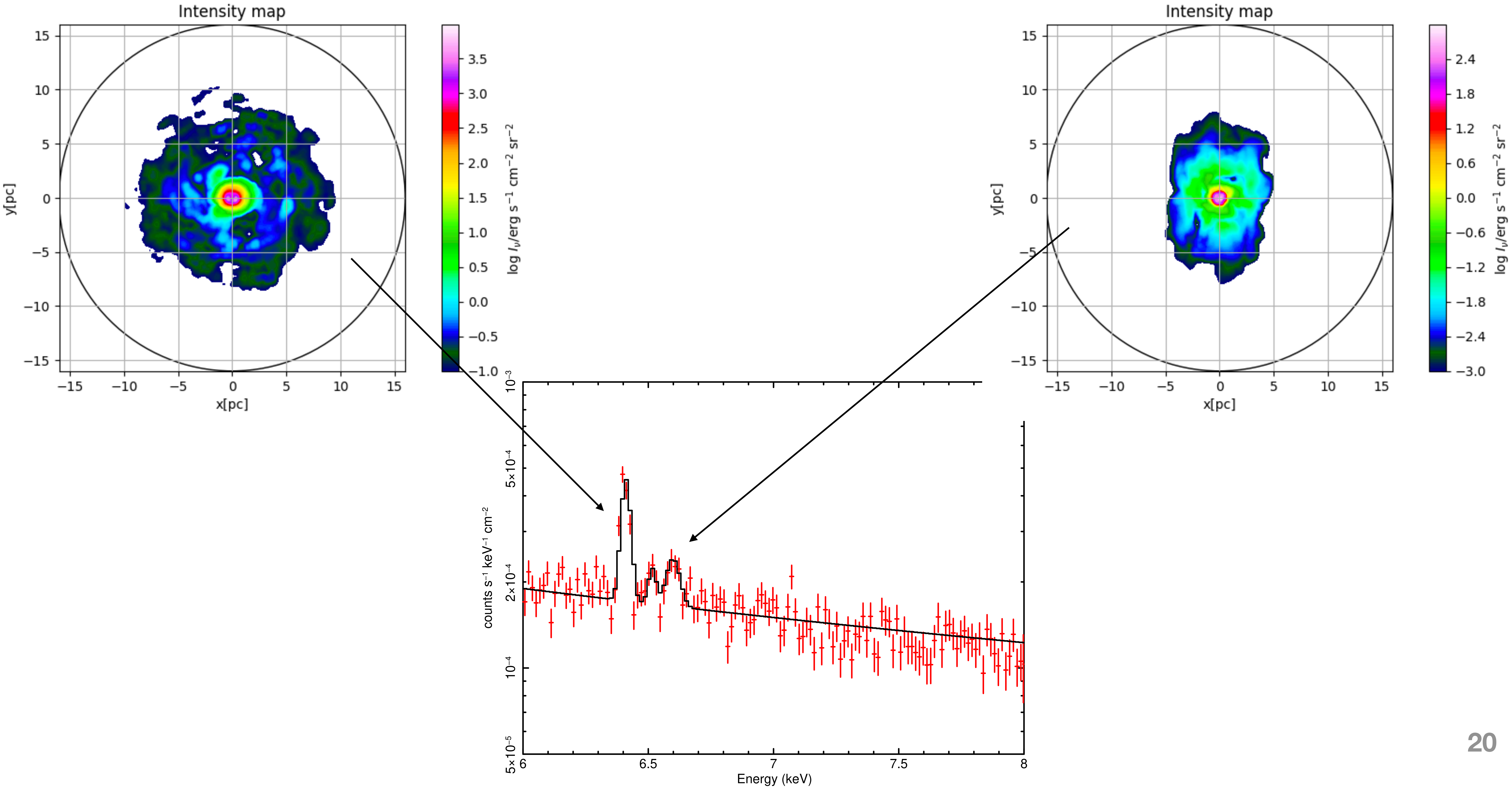
XRISM simulation



✤ XRISM/Resolve can resolve mildly ionized Fe Kα



Fe Kα map


Intensity map
y[pc]
x[pc]
log I_ν/erg s^{-1} cm^{-2} sr^{-2}
Intensity map
y[pc]
x[pc]
log I_ν/erg s^{-1} cm^{-2} sr^{-2}
counts s^{-1} keV^{-1} cm^{-2}
Energy (keV)

Summary

Aim of this research:

- To detect narrow features associated with ionized outflows and reveal their physical properties
- To separate between these narrow spectral features and the relativistic reflection signals from the accretion disk (if any)
- To correctly determine the innermost disk radius and black-hole spin from the "disk-line" profile

Long-term Observation of MCG-6-30-15

- To perform spectral fit to Intensity-sliced spectra
- To detect absorption features
- To test if partial absorber model is suitable