The Suzaku View of Cyg X-1 over the Two Spectral States

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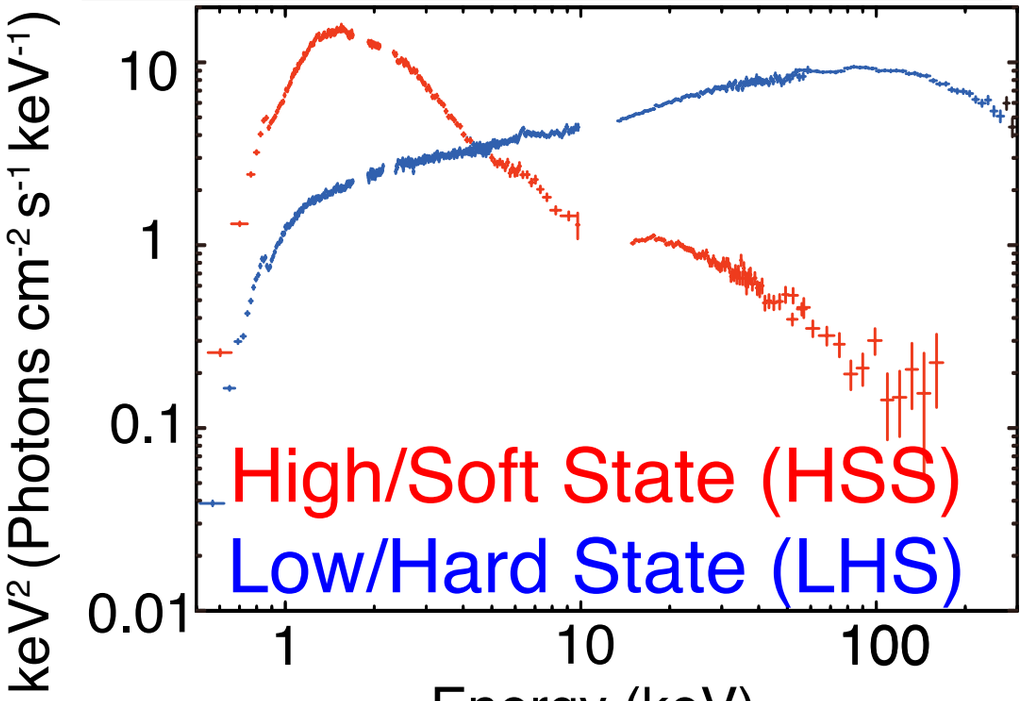
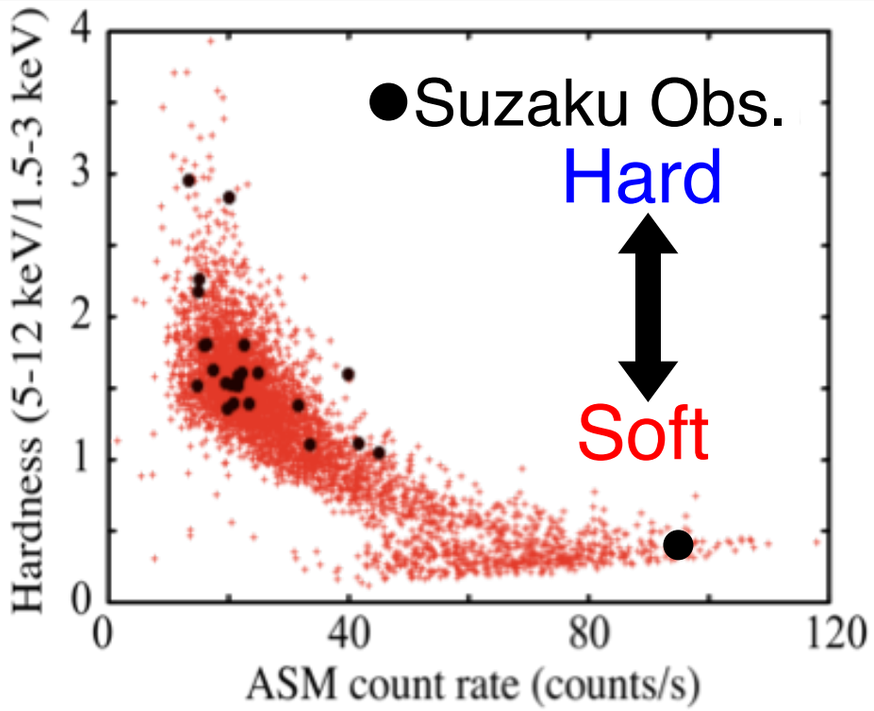
Cyg X-1 Observations with Suzaku

Energy spectra with Suzaku



Count vs hardness with RXTE ASM



- Hard X-rays by inverse Comptonization and soft X-rays from a cool disk simultaneously observable
- 480 ks exposure with 25 LHS and 1 HSS observations, proposed by
  - SWG (AO0, AO5 ToO)
  - M.Nowak (AO1-3)
  - J.Miller (AO4)
  - S.Yamada(AO4, AO6 scheduled)
- Various results obtained with the LHS data
  - A truncated cool disk intruding halfway into an inhomogeneous corona (Makishima+ 2008)
  - Studies of variable components on short and long time scale (Yamada Ph.D.)
  - Characterization of hard X-ray behavior in the LHS with all 25 obs. combined with RXTE ASM count rate (C_{ASM}) (Torii+ 2011)

This time, we focus on the hard X-ray band

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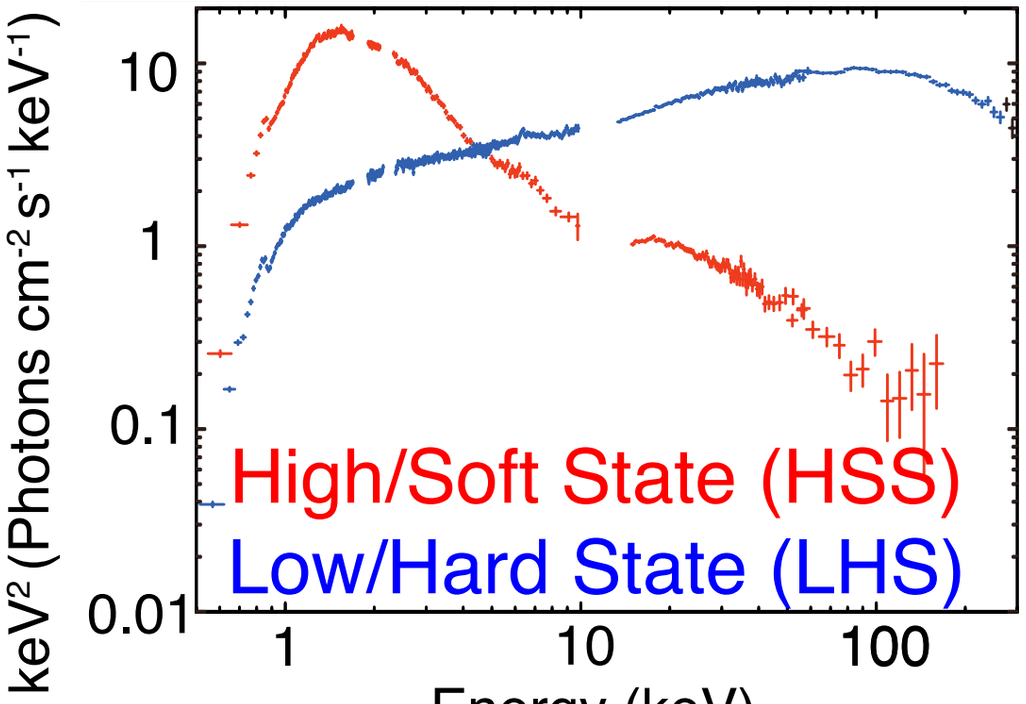

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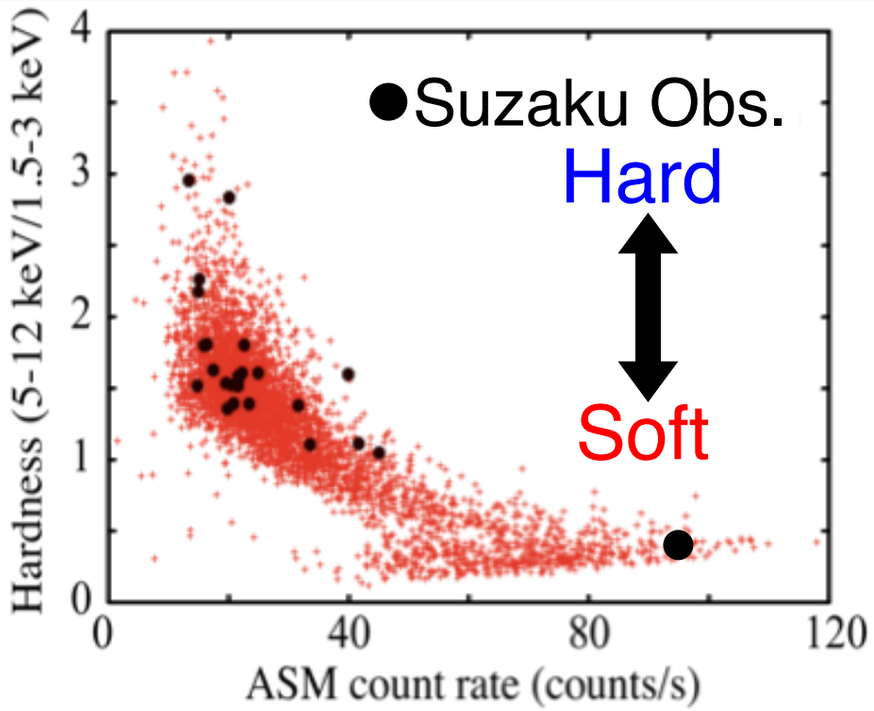

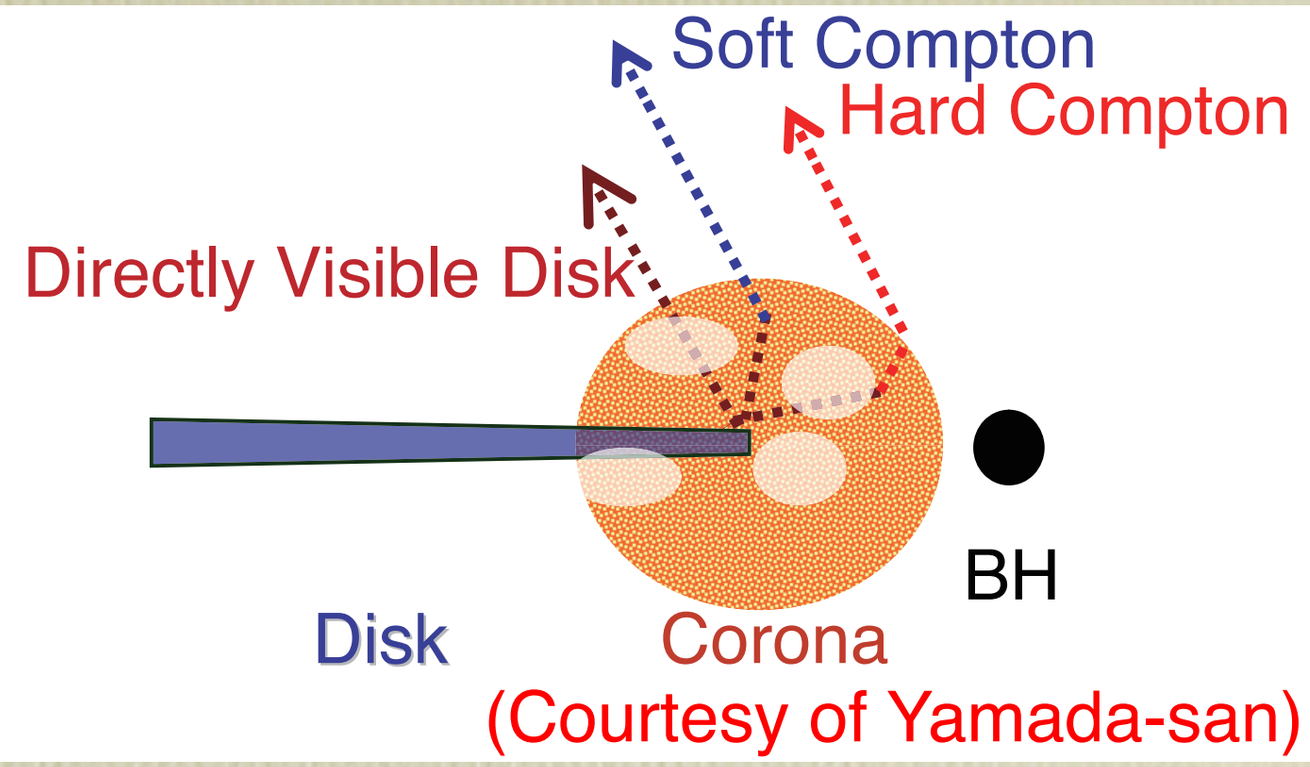

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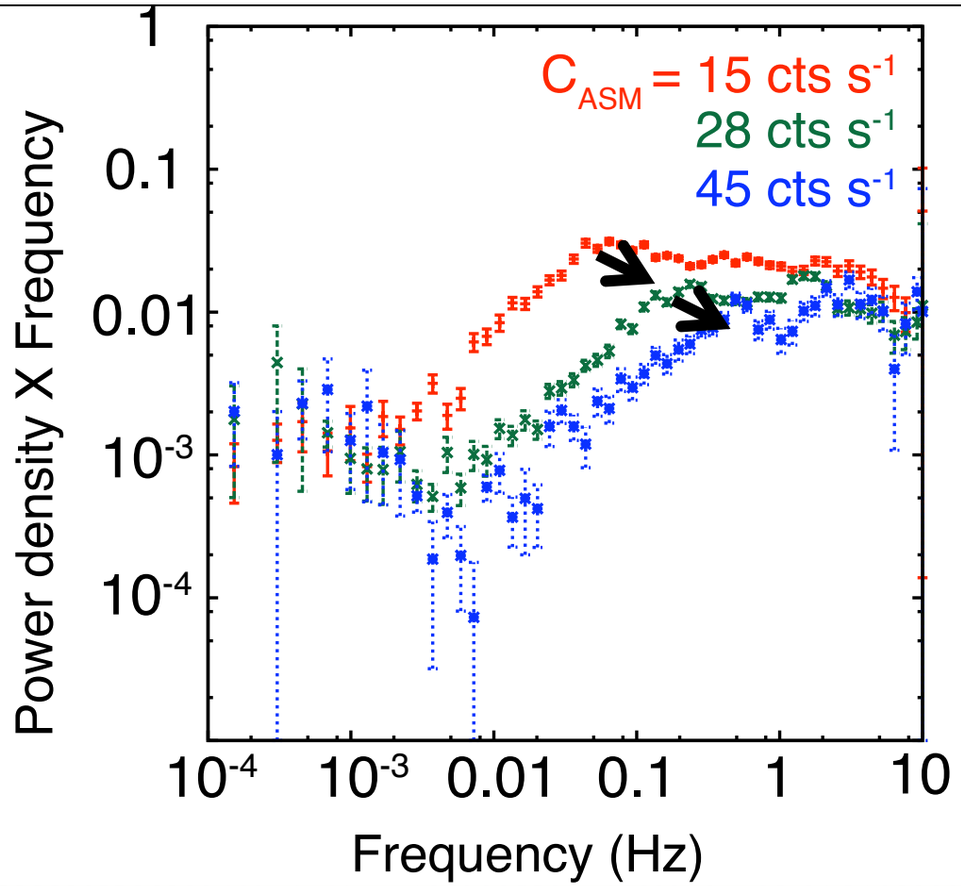
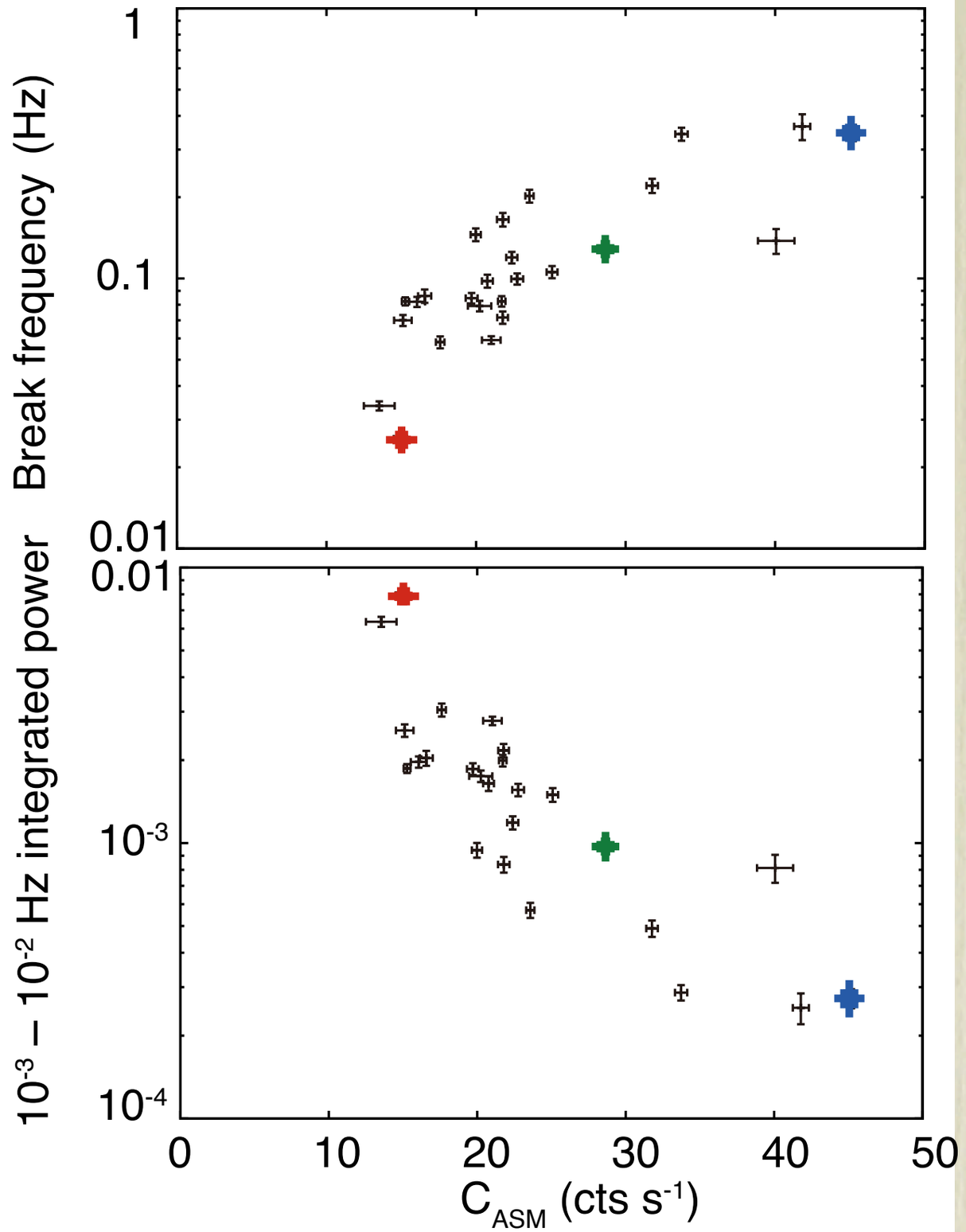
Timing Analysis in the LHS

Power spectral density of HXD-PIN signal

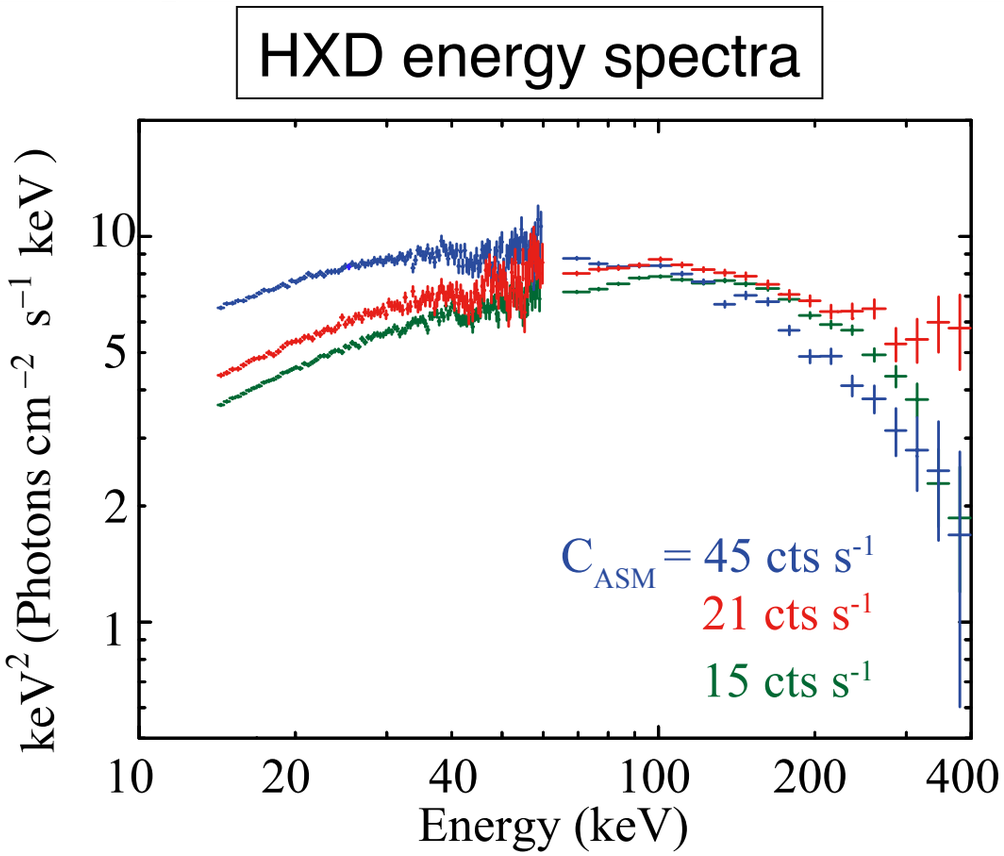


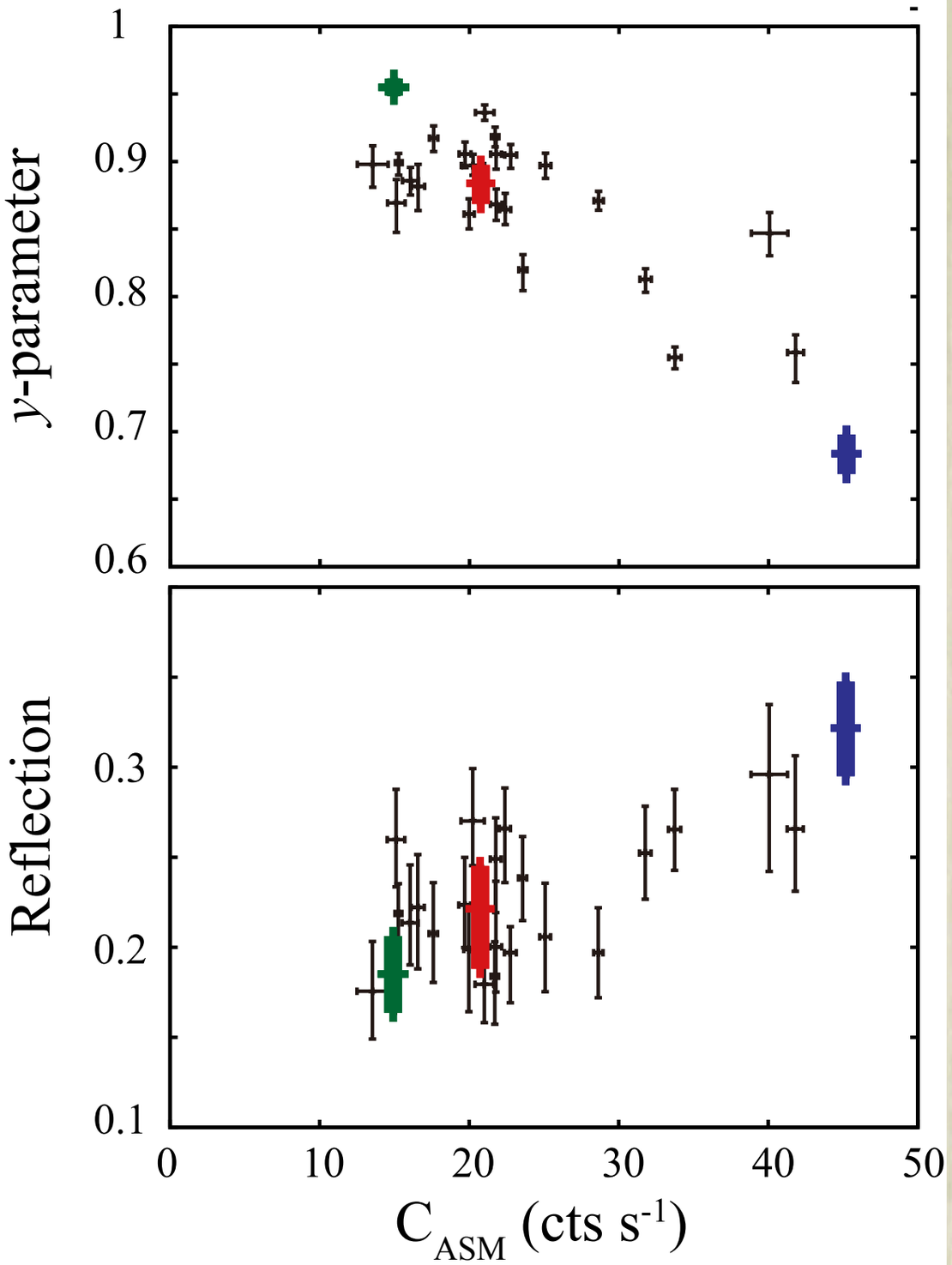


- Power spectral density (PSD) exhibits break frequencies at 0.05-0.5 Hz
- As soft X-ray flux (C_{ASM}) increases
  - Variation time scales shorten
  - Low frequency power (10^{-3}-0.01 Hz) decreases

Outer radius of the corona decreases

Spectral Analysis in the LHS





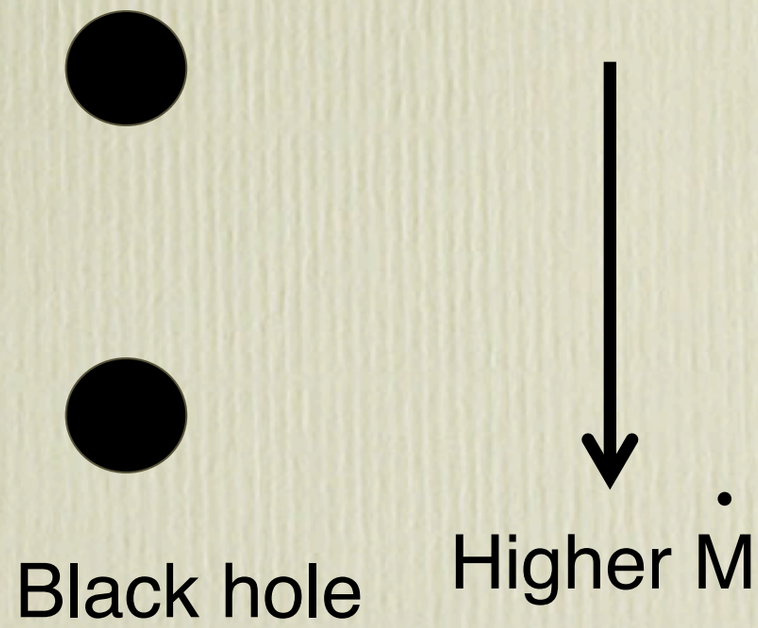
- ✦ All HXD energy spectra reproduced with
  - thermal Comptonization emission
  - reflection from a cold matter
- ✦ As soft X-ray flux (C_{ASM}) increases,
  - *y*-parameter decreases (1.0 -> 0.6)
  - reflection solid angle increases (0.2 -> 0.3)

Coronal coverage of the disk is changing

Accretion Geometry in the LHS

✦When the mass accretion rate($\propto C_{ASM}$) increases

1. variation time scale shortens, low frequency power decreases
   →Outer radius of the corona decreases
2. reflection solid angle increases
   →The disk more deeply intrudes into the corona
3. *y*-parameter decreases
   →Increased seed photons degrade Comptonization efficiency



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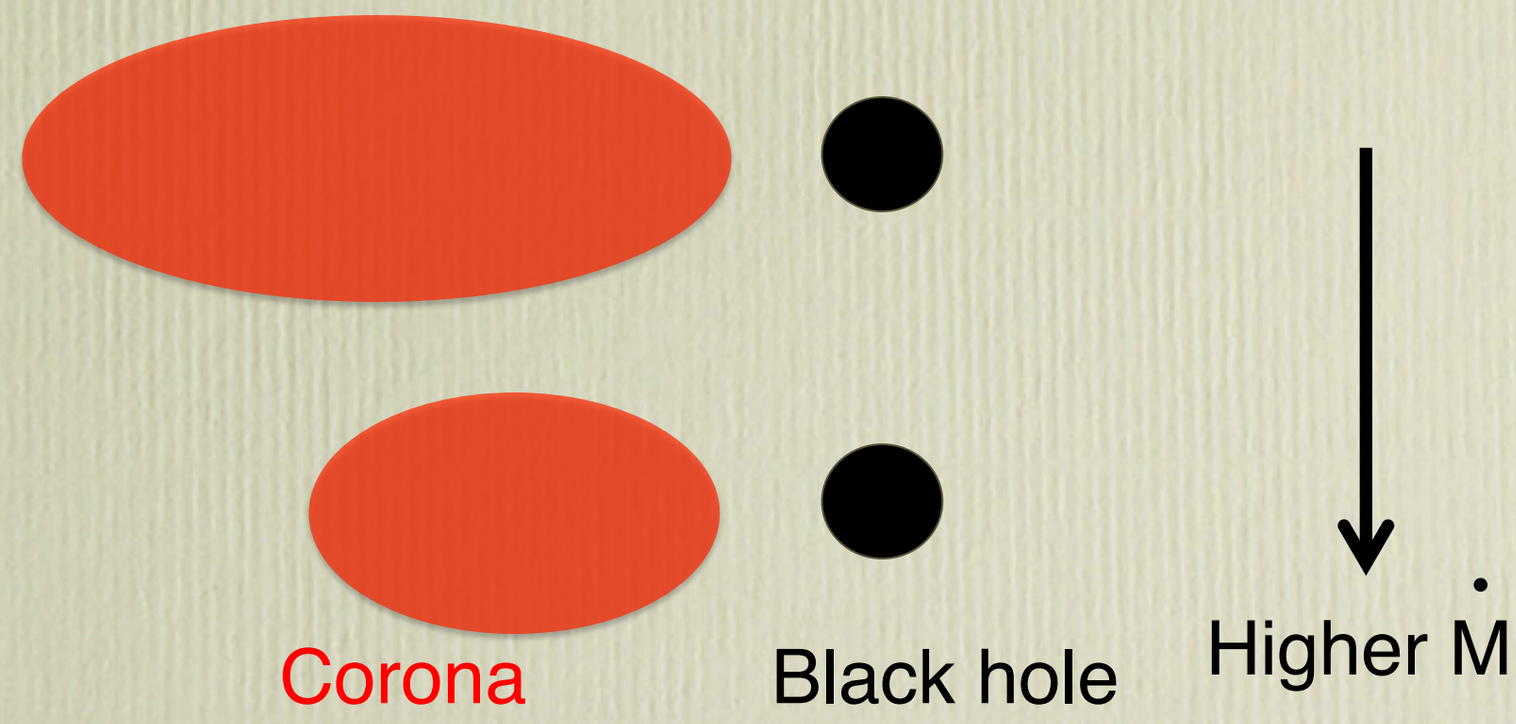

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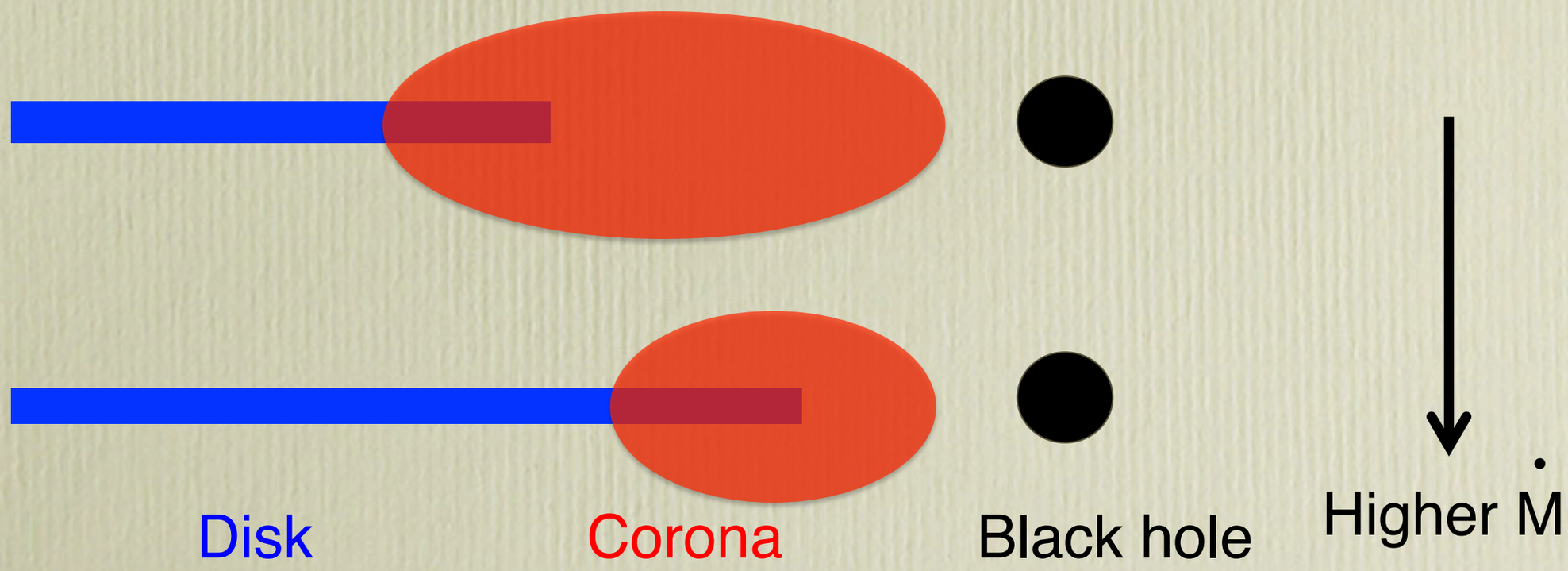

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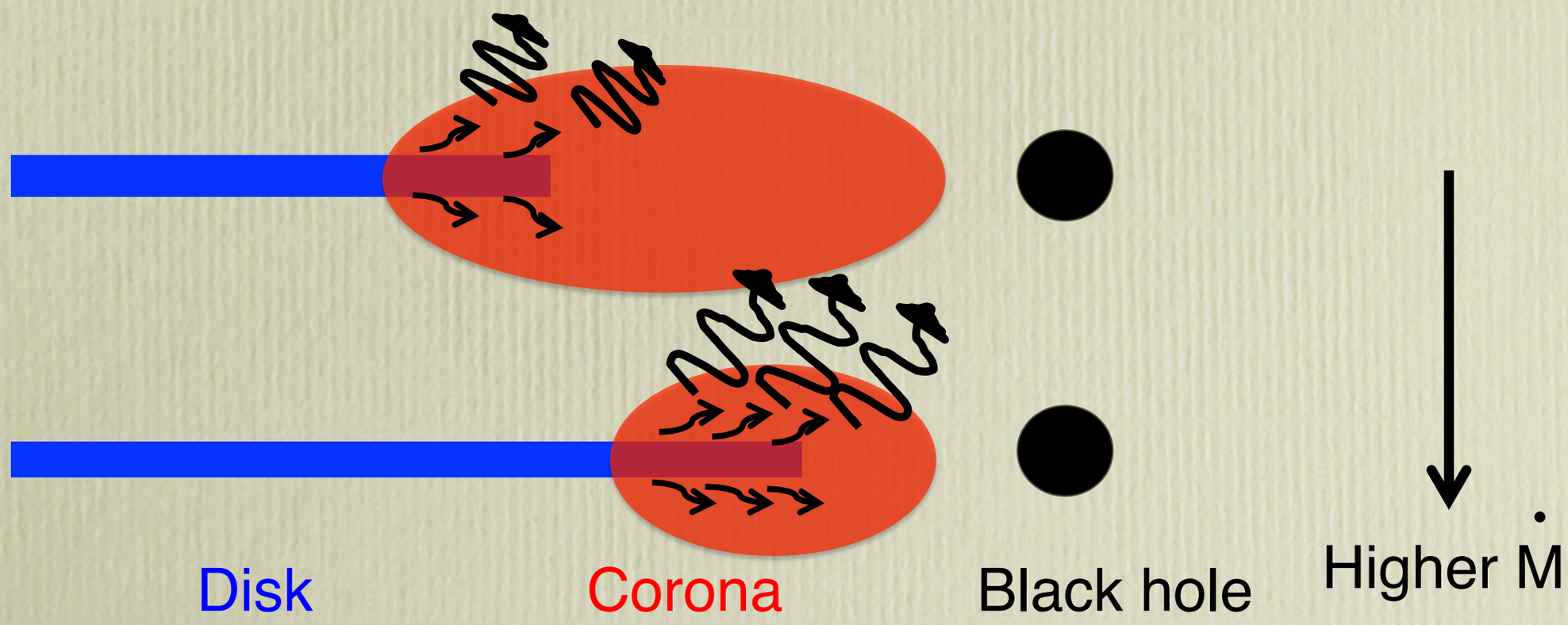

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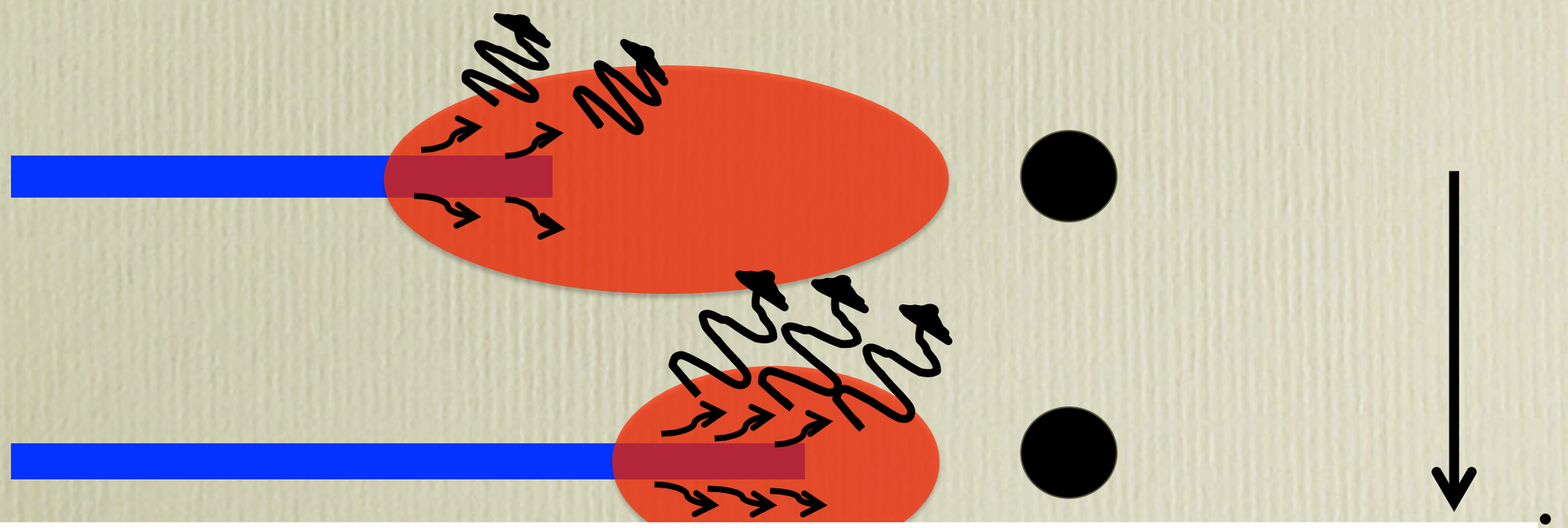
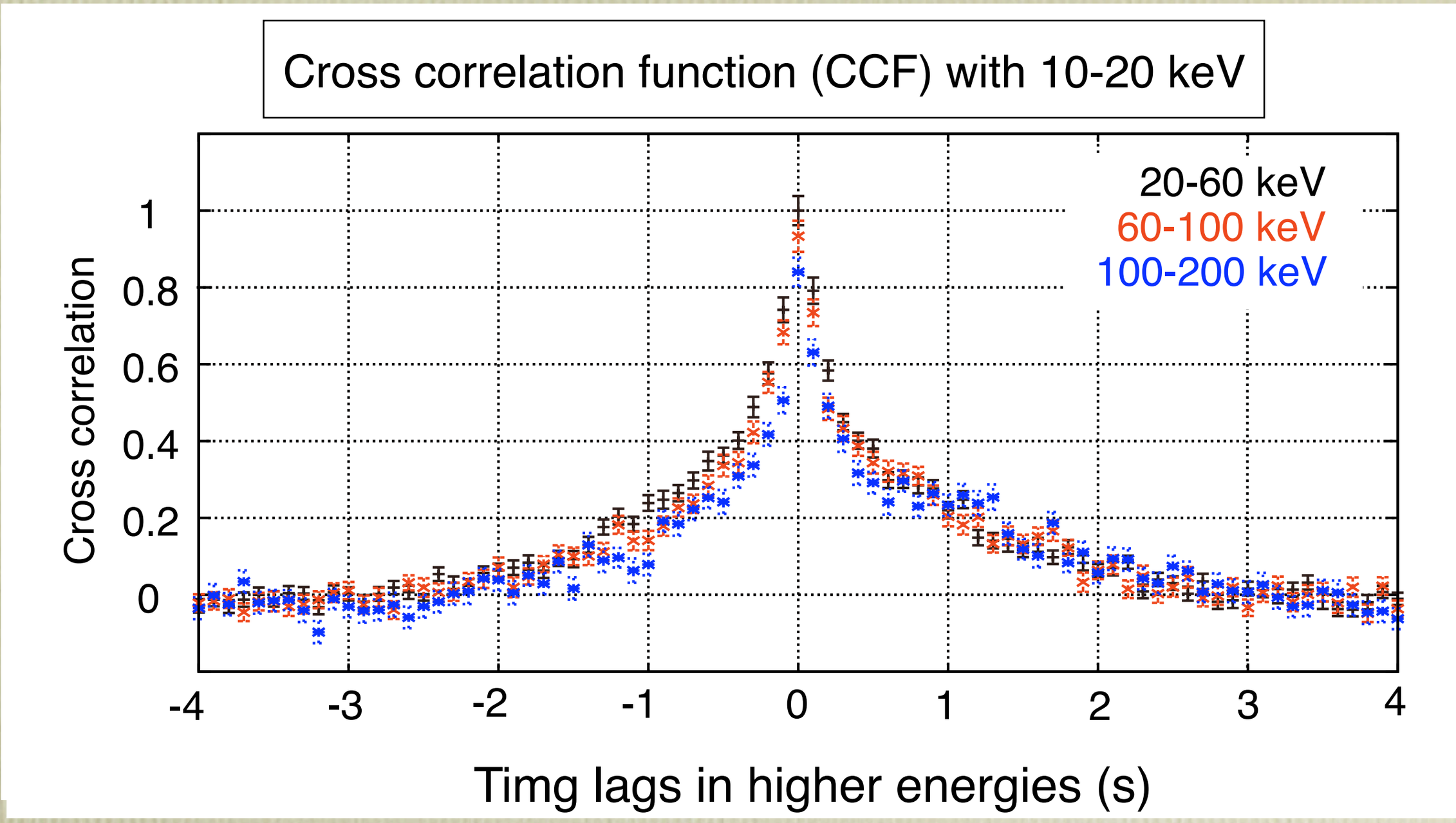


To investigate internal structure of the corona,
we studied energy dependence of variability further

Energy Dependence of Variability



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- ✦ Faster variations in higher energies
- ✦ More significant delays in higher energies

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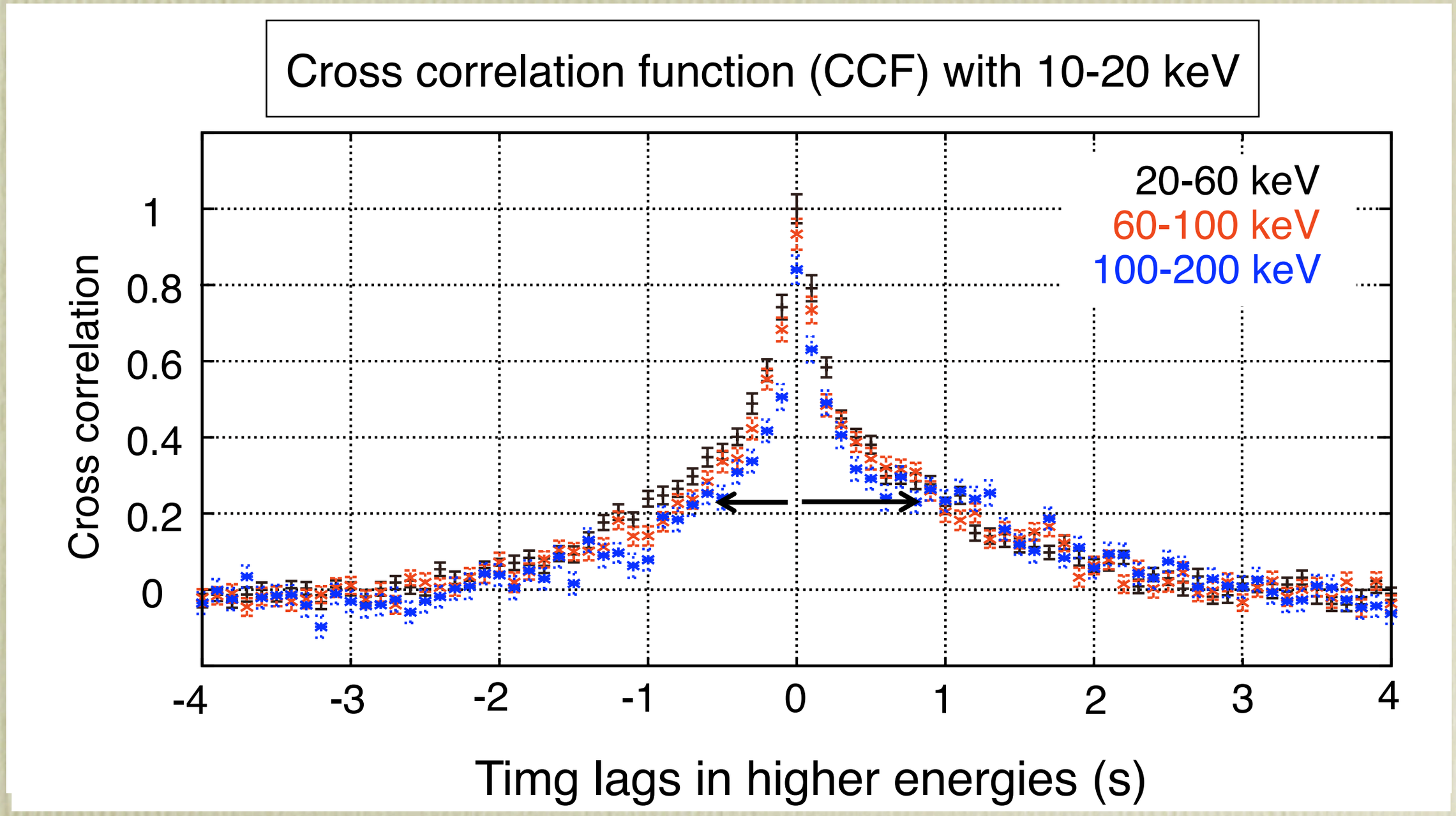

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Accretion Geometry Considering CCF

✦Higher energy photons show

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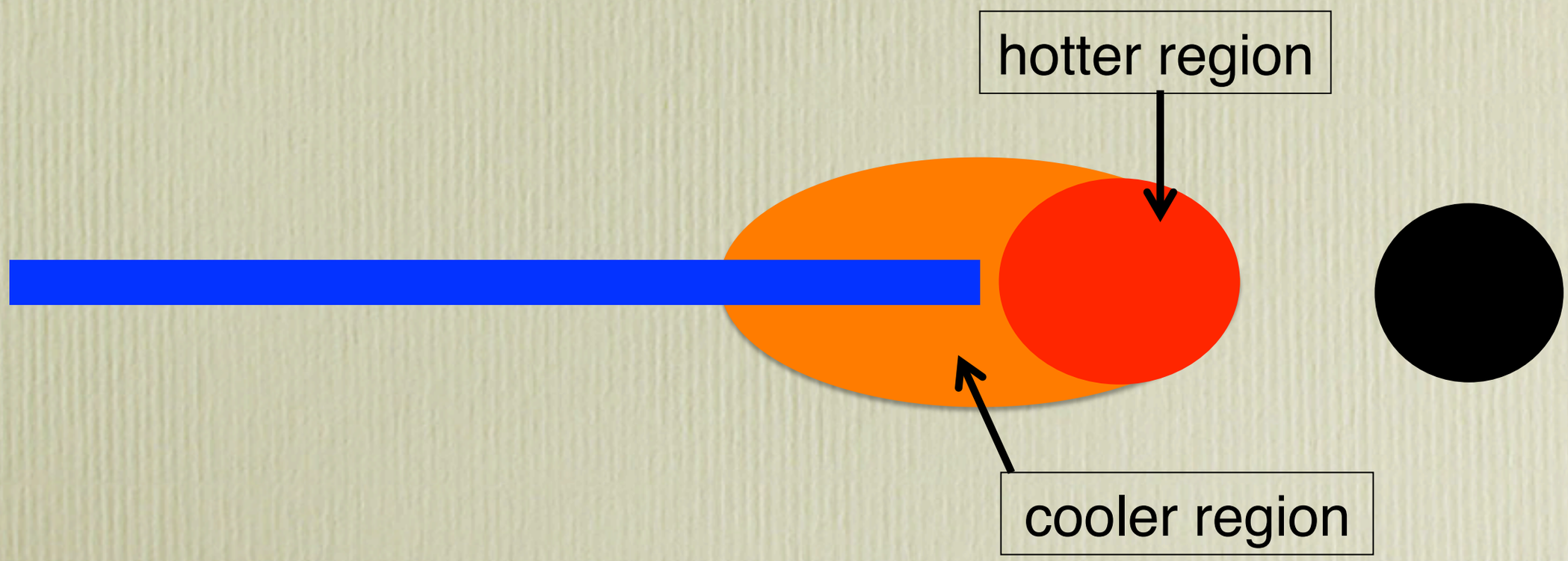
→Hotter region locates nearer the black hole

2. more significant delays

→Variations of accreting blob propagate inward

(Lyubarskii+ 1997)



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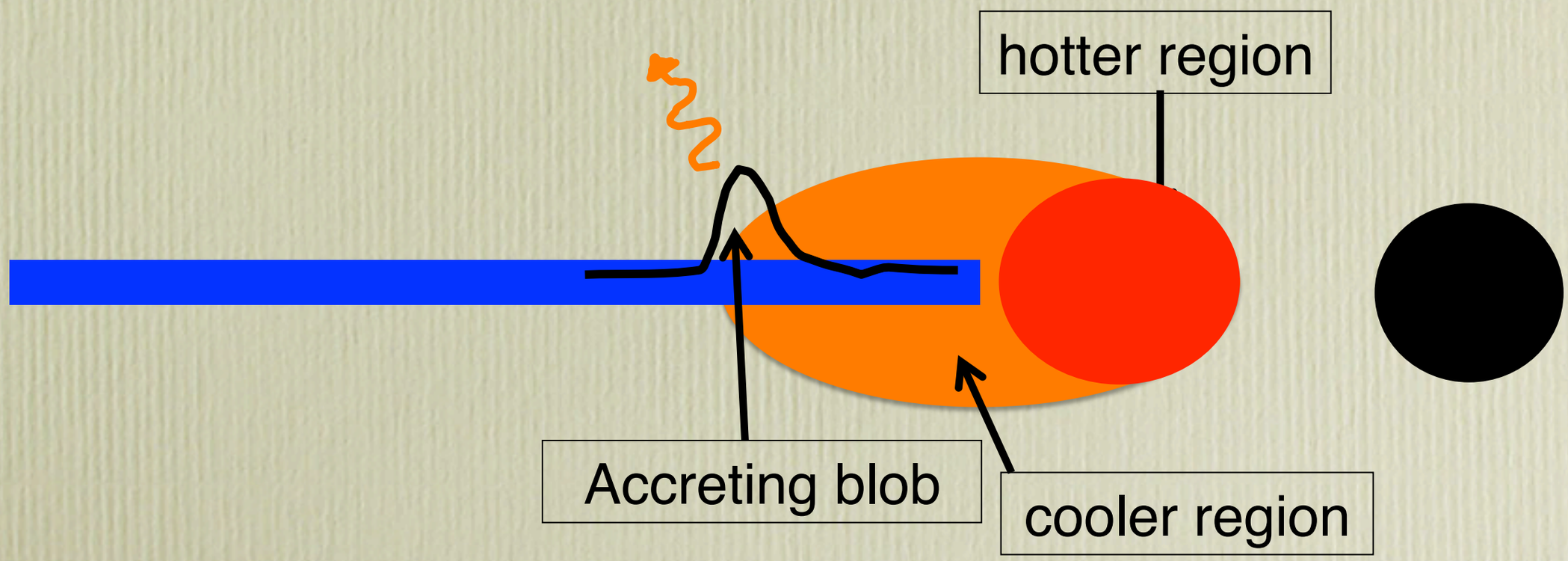

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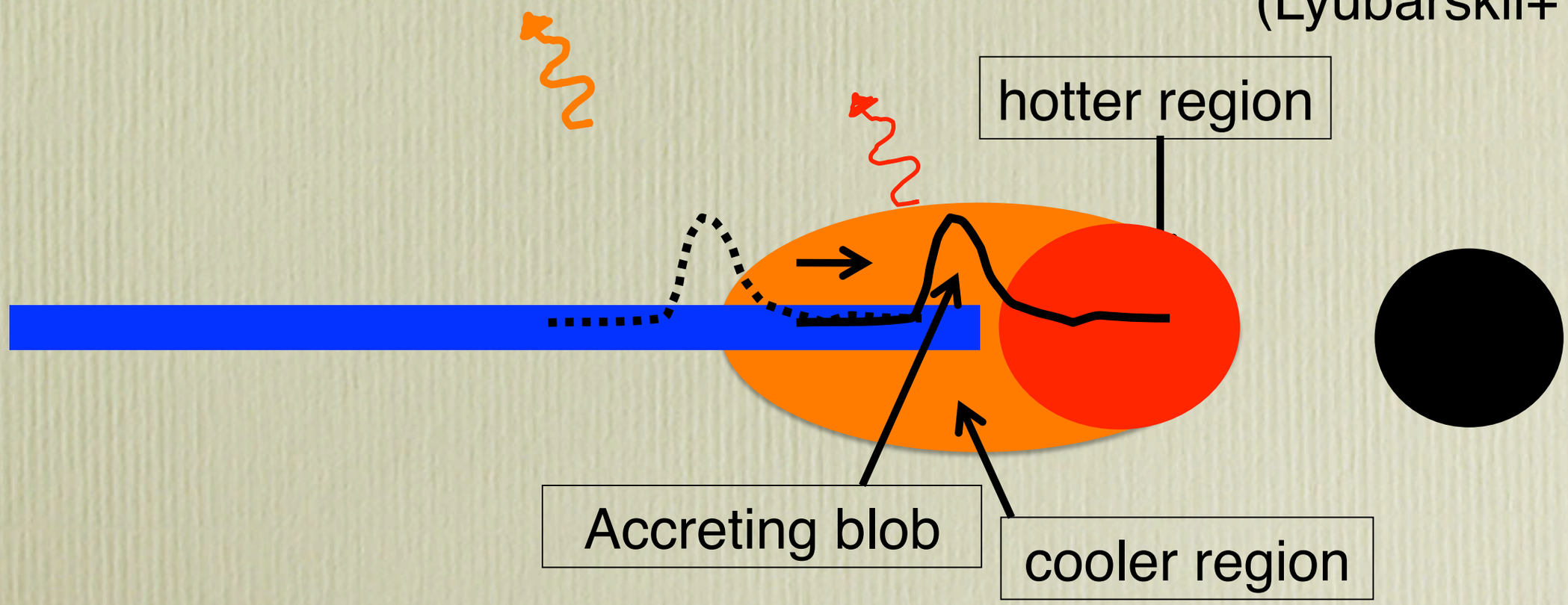
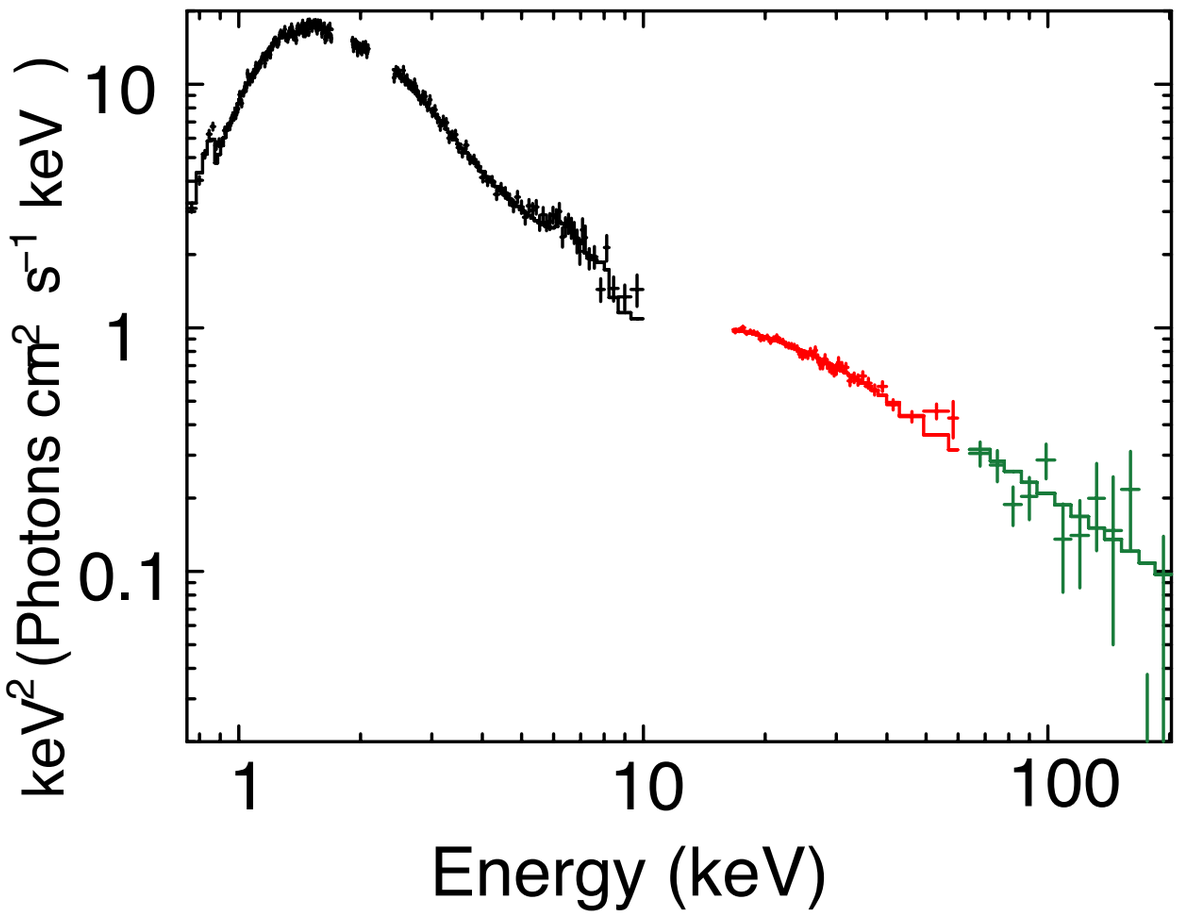


✦ Both regions emit both soft and hard X-rays, resulting in not a constant time lag but in an asymmetric CCF

Quick Analysis of HSS

Energy spectrum of HSS Cyg X-1



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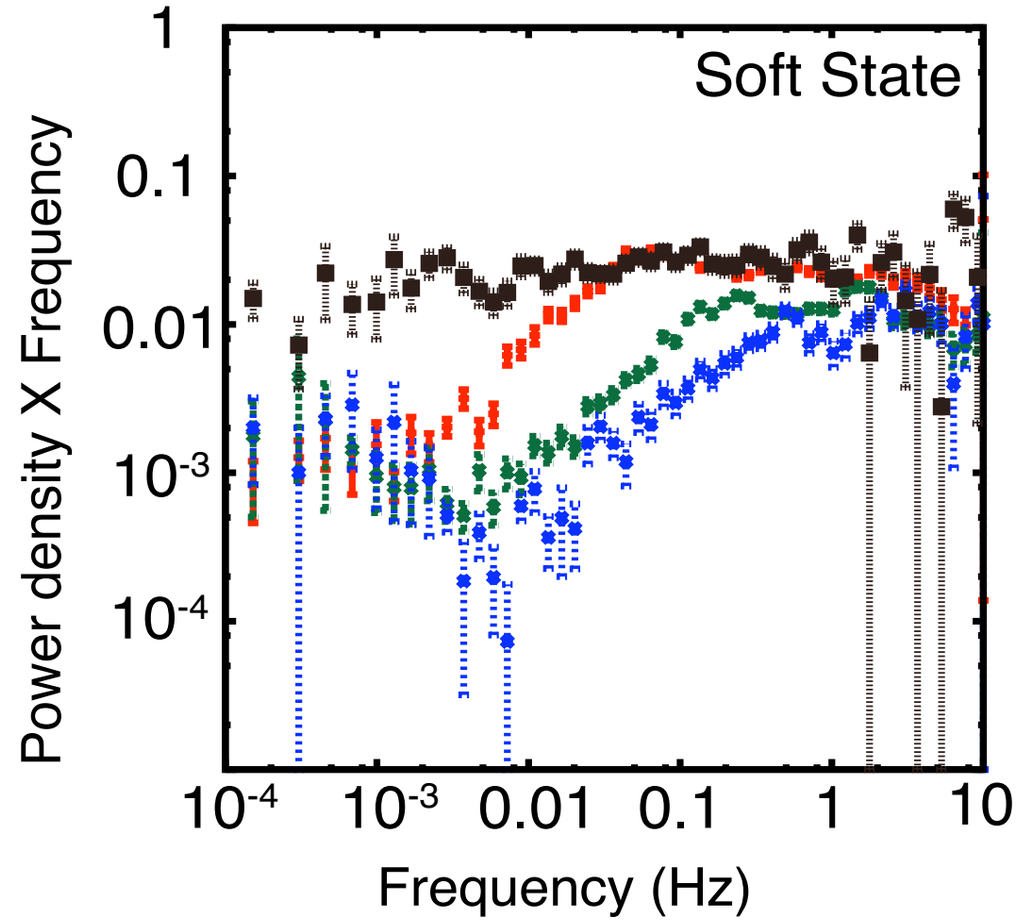

- A ToO observation triggered by MAXI
- HXD detected signals up to ~ 150 keV
- Preliminary spectral analysis indicates
  - disk blackbody ($kT_{bb} \sim 0.4$ keV)
  - steep power-law ($\Gamma \sim 2.8$)
  - reflection ($\Omega/2\pi \sim 1.0$)

- PSD has no break with f^{-1}

Almost reaching the softest end of the HSS

Detailed analysis of the HSS is ongoing

Summary

- ✦We analyzed 440 ks Suzaku data of Cyg X-1 in the LHS
- ✦As soft X-ray flux increased, Compton y-parameter and the low frequency variation decreased while the reflection solid angle and the break frequency increased
- ✦These results can be explained by decreasing outer radius of the corona and deeper penetration of the accretion disk into the corona
- ✦Higher energy photons vary more rapidly and have delayed components, compared to softer ones. This can be explained by taking into account falling time of accreting matter crossing two emitting regions with different Comptonization efficiency
- ✦40 ks data in the HSS is being analyzed