Fast variability in MAXI J1820+070 to probe the nature of the inner accretion flow

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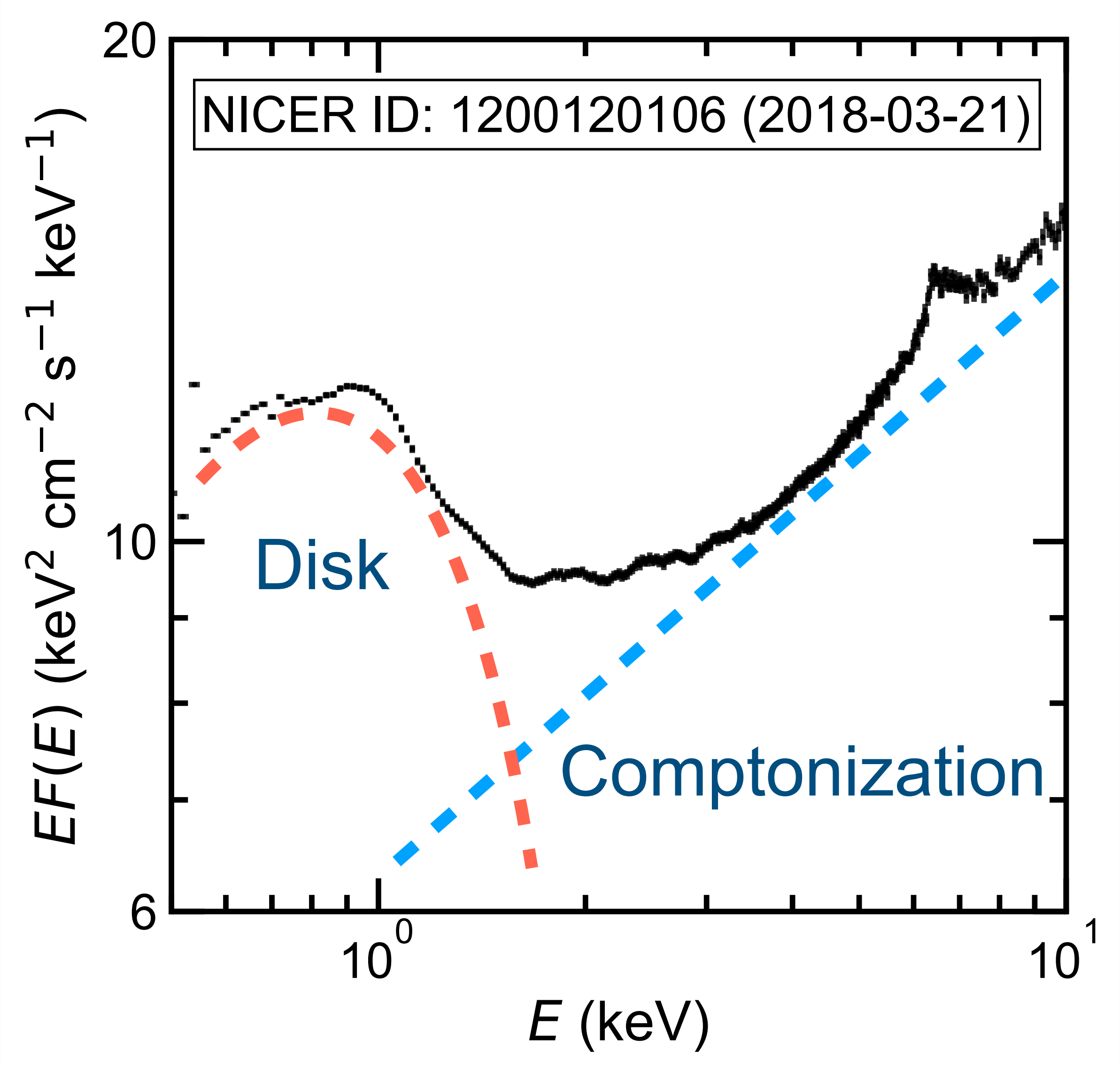
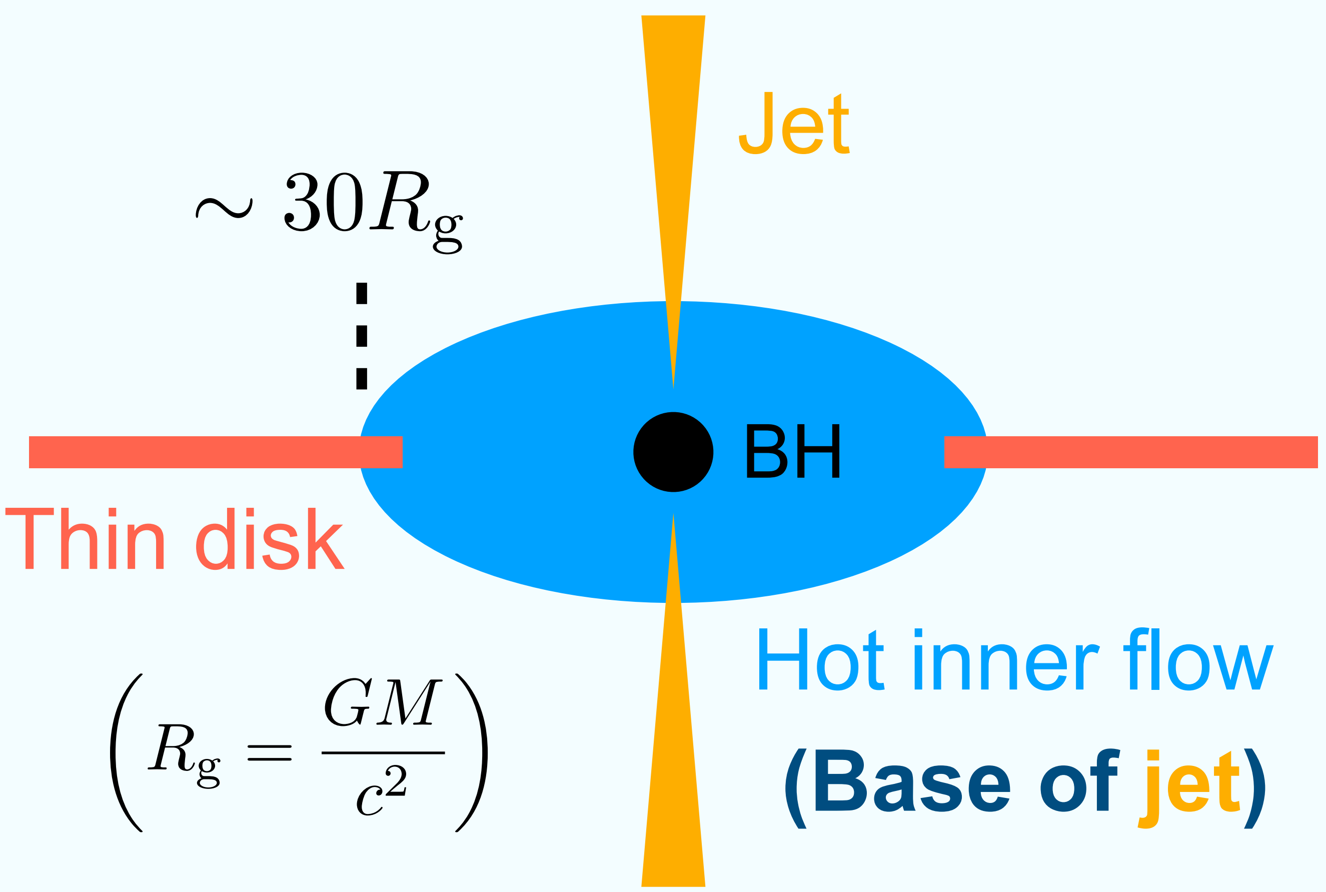
Low/hard state of black hole binaries

BHB MAXI J1820+070



Truncated disk model



- Nature and geometry of the hot inner flow are controversial.
- It is difficult to constrain them with spectral fit alone.

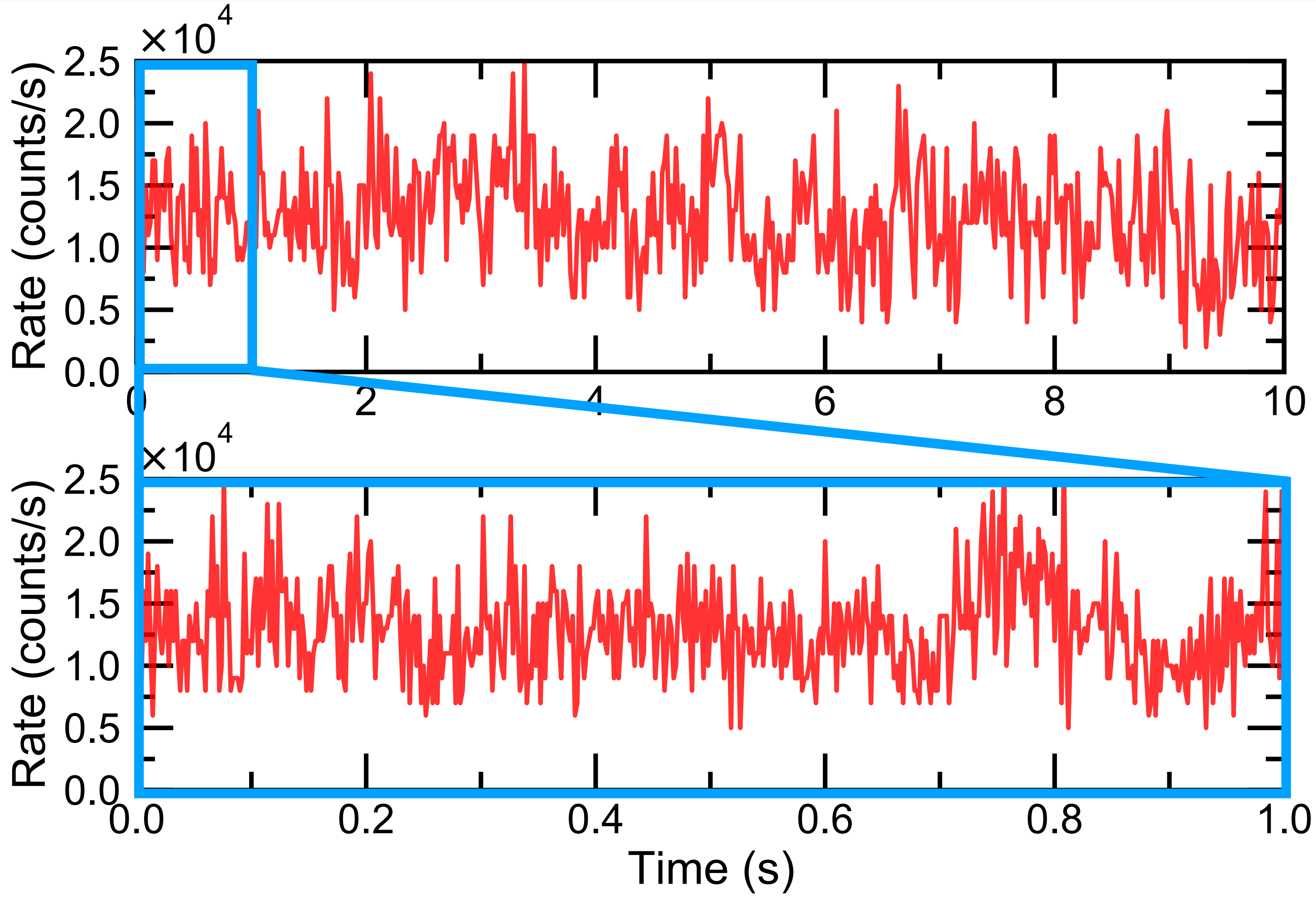
Fast variability is a key.

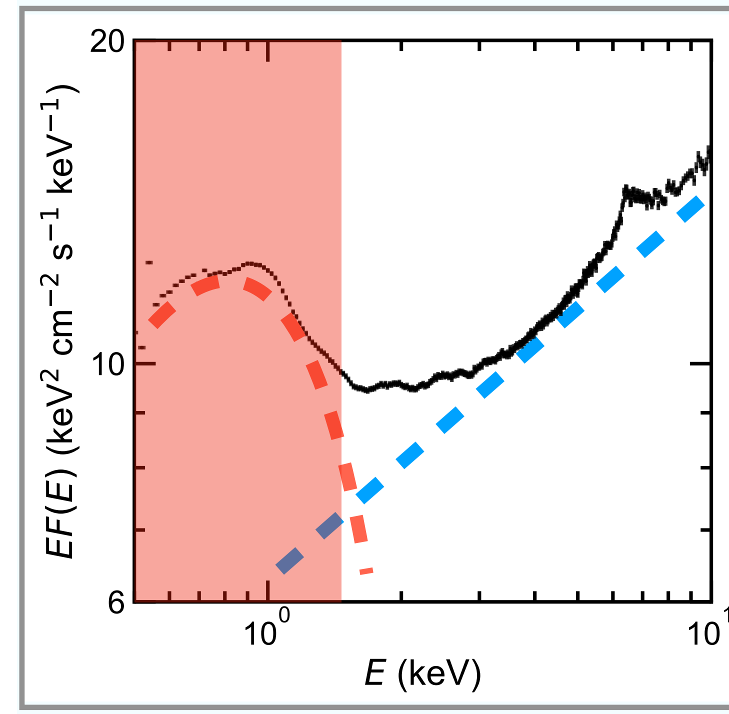
NICER captures disk variability

Time-scale   Light curves (0.5-1.5 keV → Disk)

~ 10 s

~ 1 s

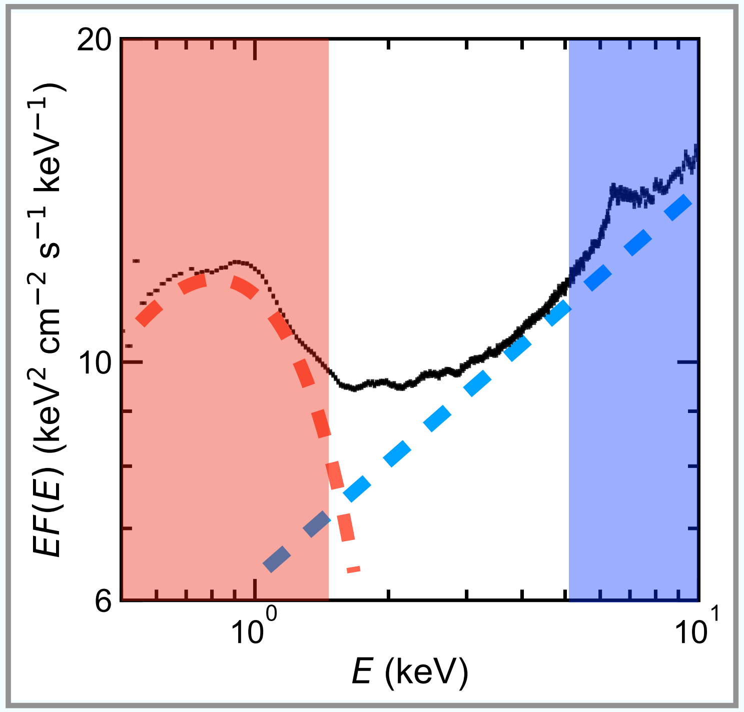


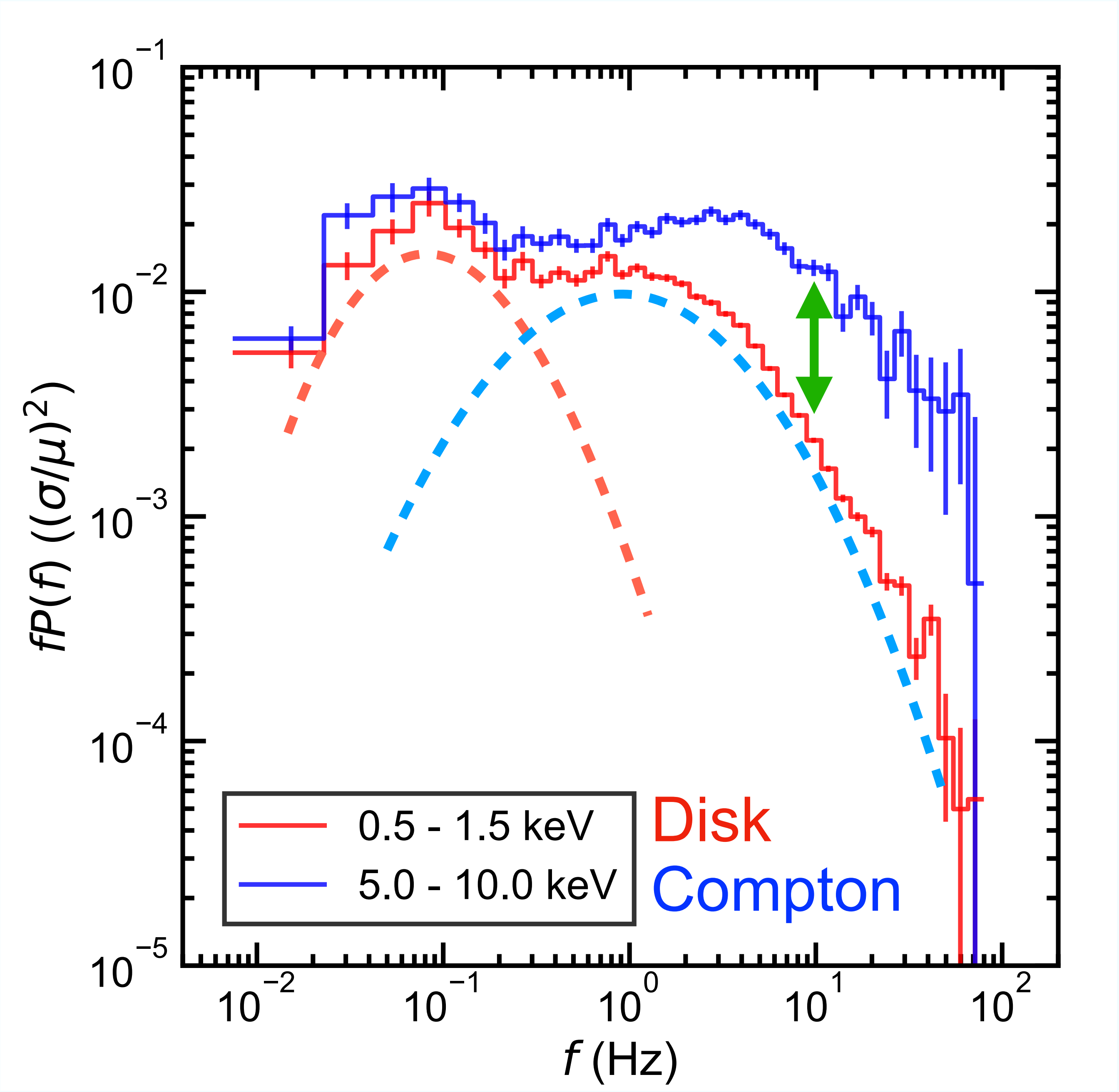


- Disk emission is highly variable. → Important diagnostic
- RXTE (> 3 keV) would *not* be able to detect disk variability.

NICER enables us to incorporate disk variability in timing studies.

Timing property ① — Power spectra

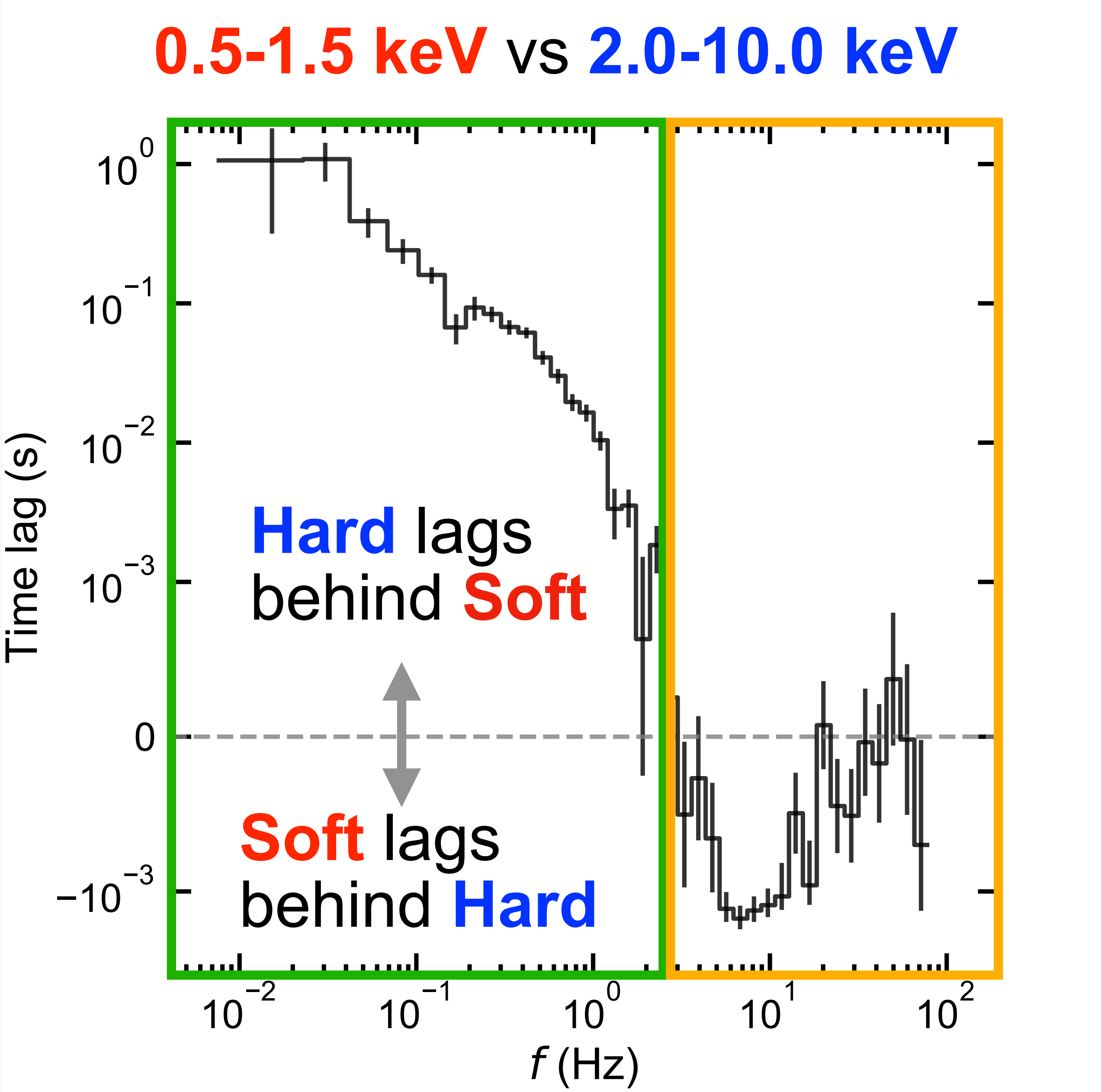




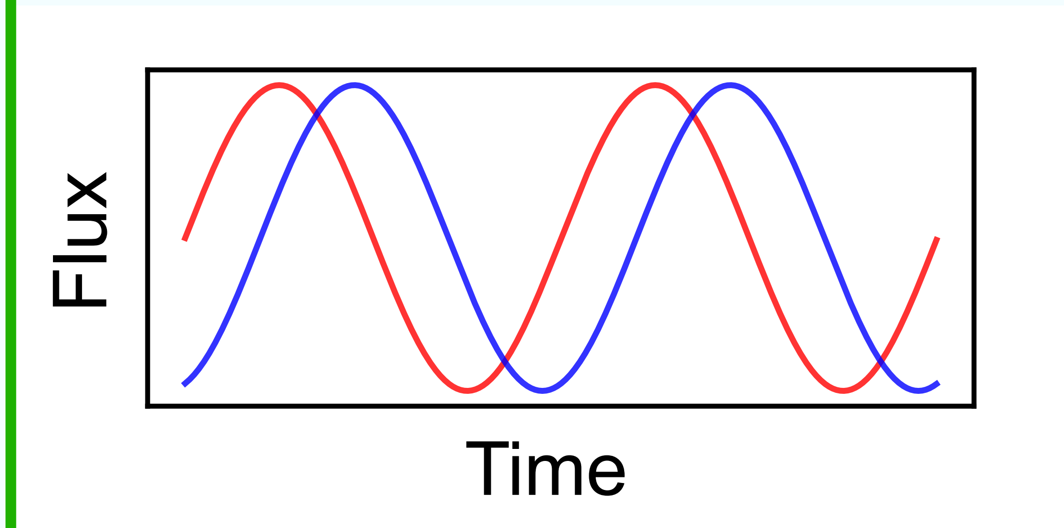
- Two broad-band variability components
- **Hard band** has much stronger power at high frequencies.

Timing property ② — Time lags

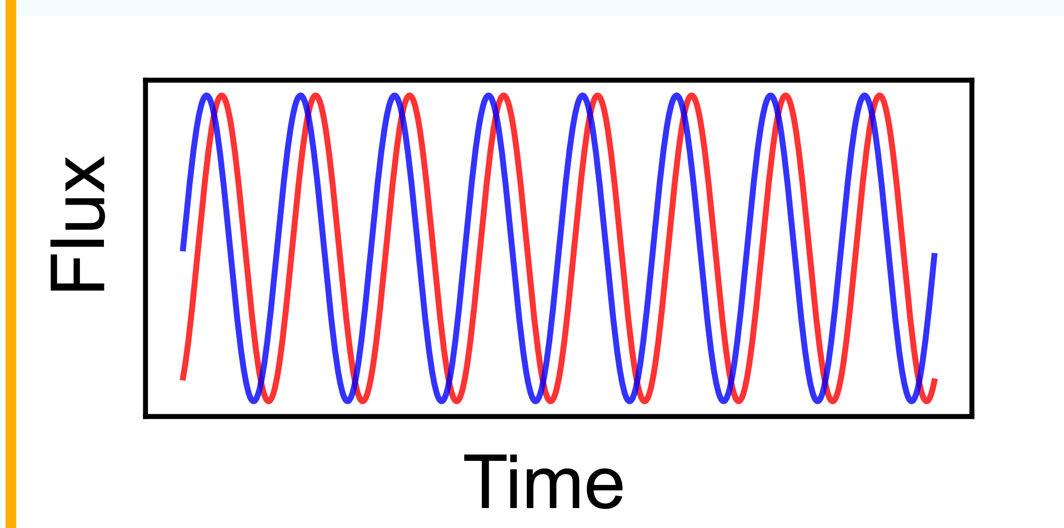
Lag-frequency spectrum



Hard lag at low frequencies.

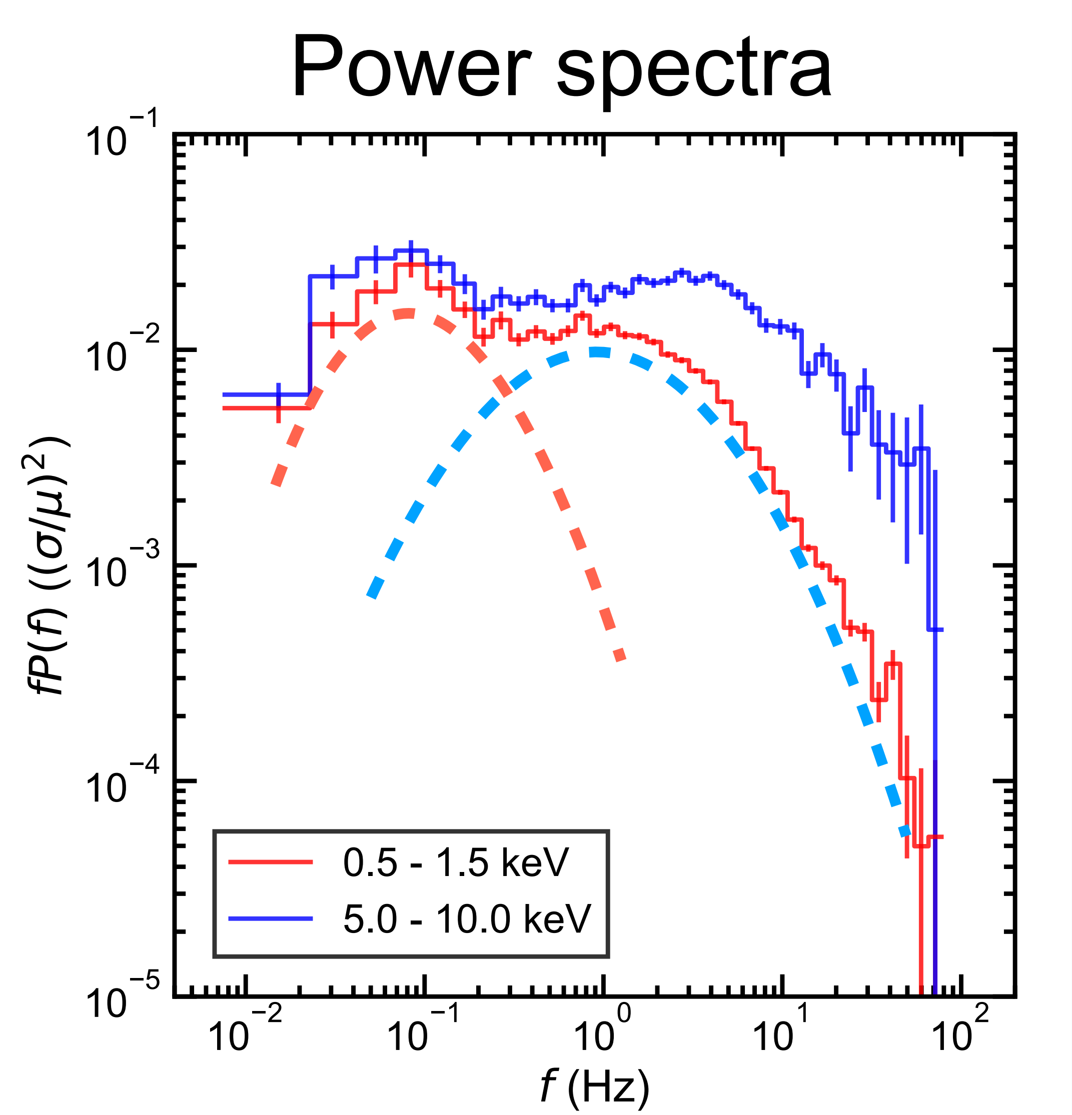


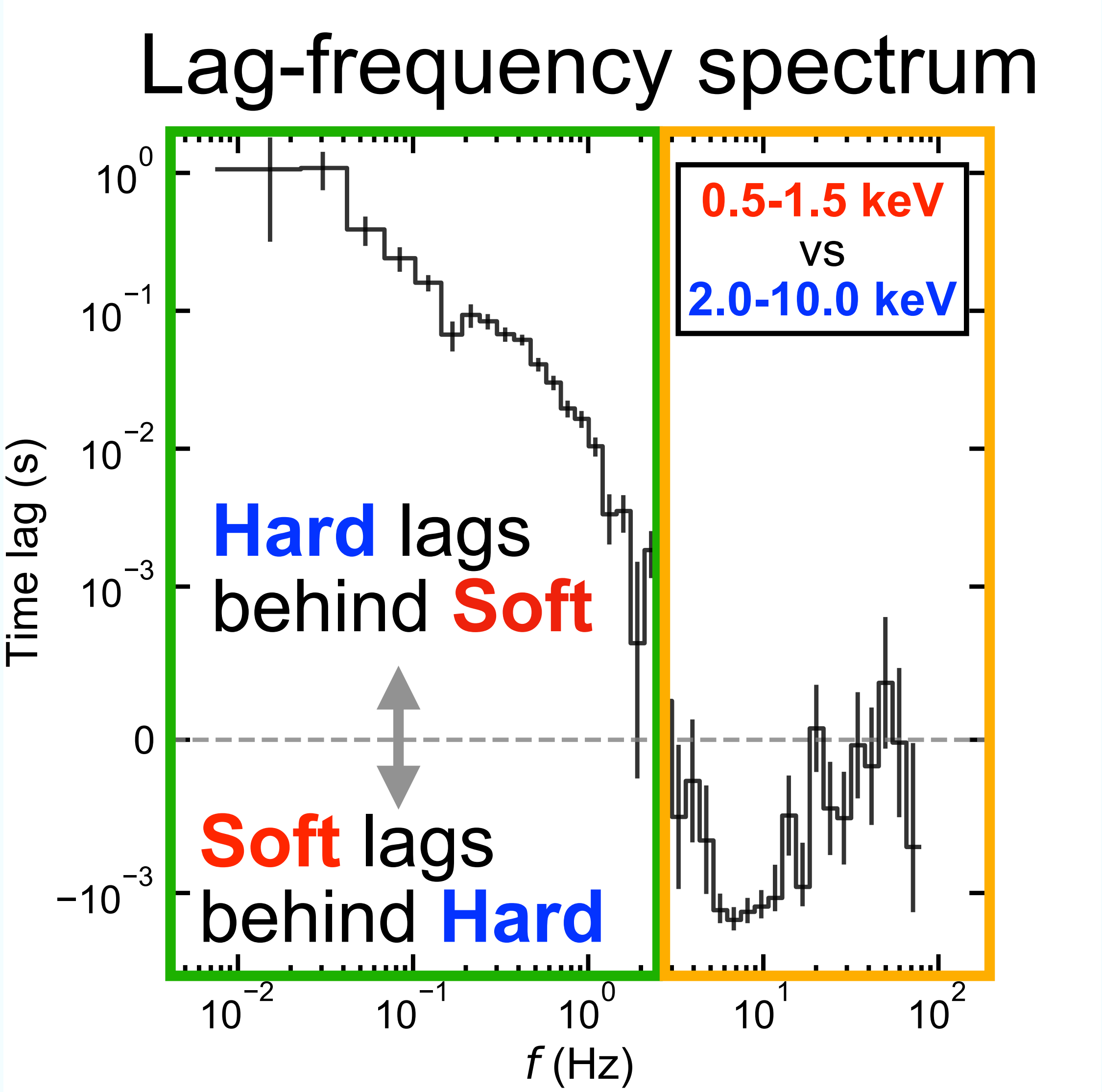
Soft lag at high frequencies.



Causal relationship between soft and hard bands switches.

Summary of timing properties



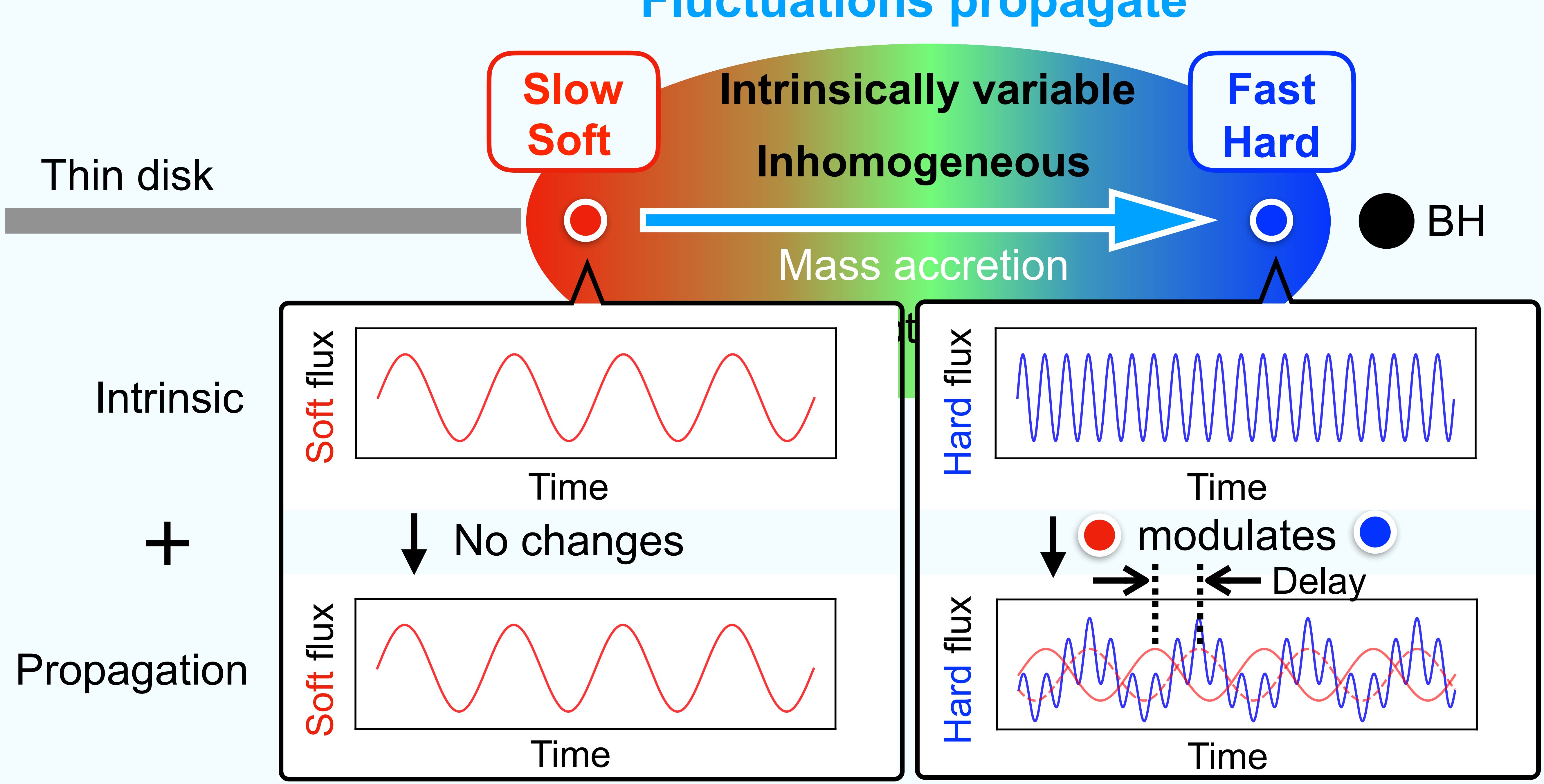


1. Broad-band power with double bumps
2. Hard lagging soft at low frequencies
3. Soft lagging hard at high frequencies

How do we explain these timing properties?

Propagation of fluctuations

(Lyubarskii 1997)

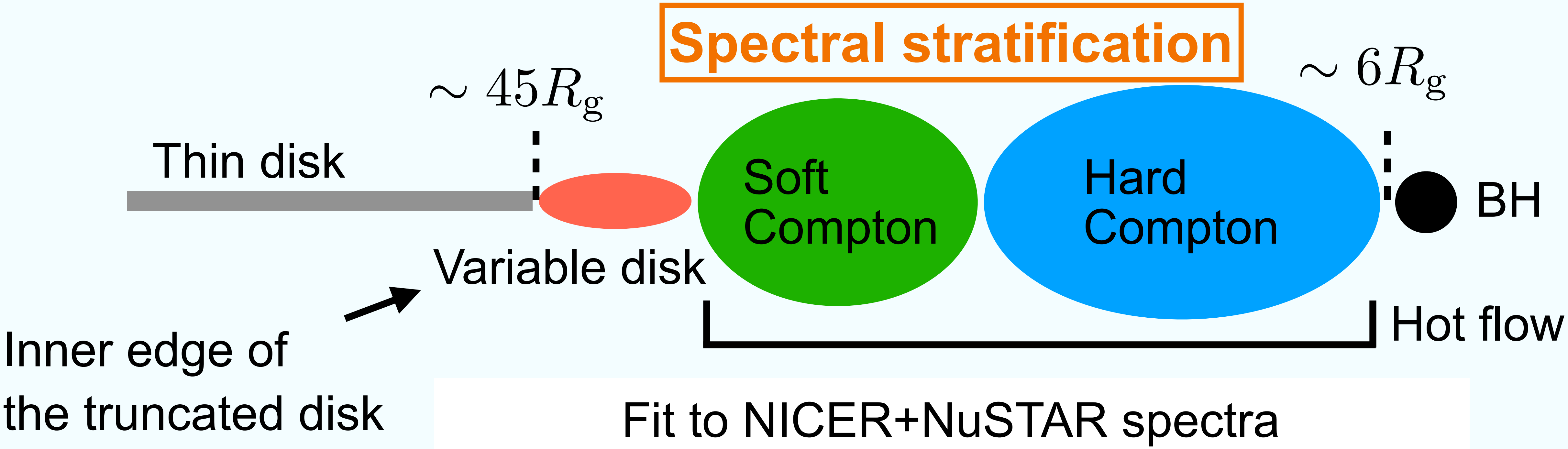


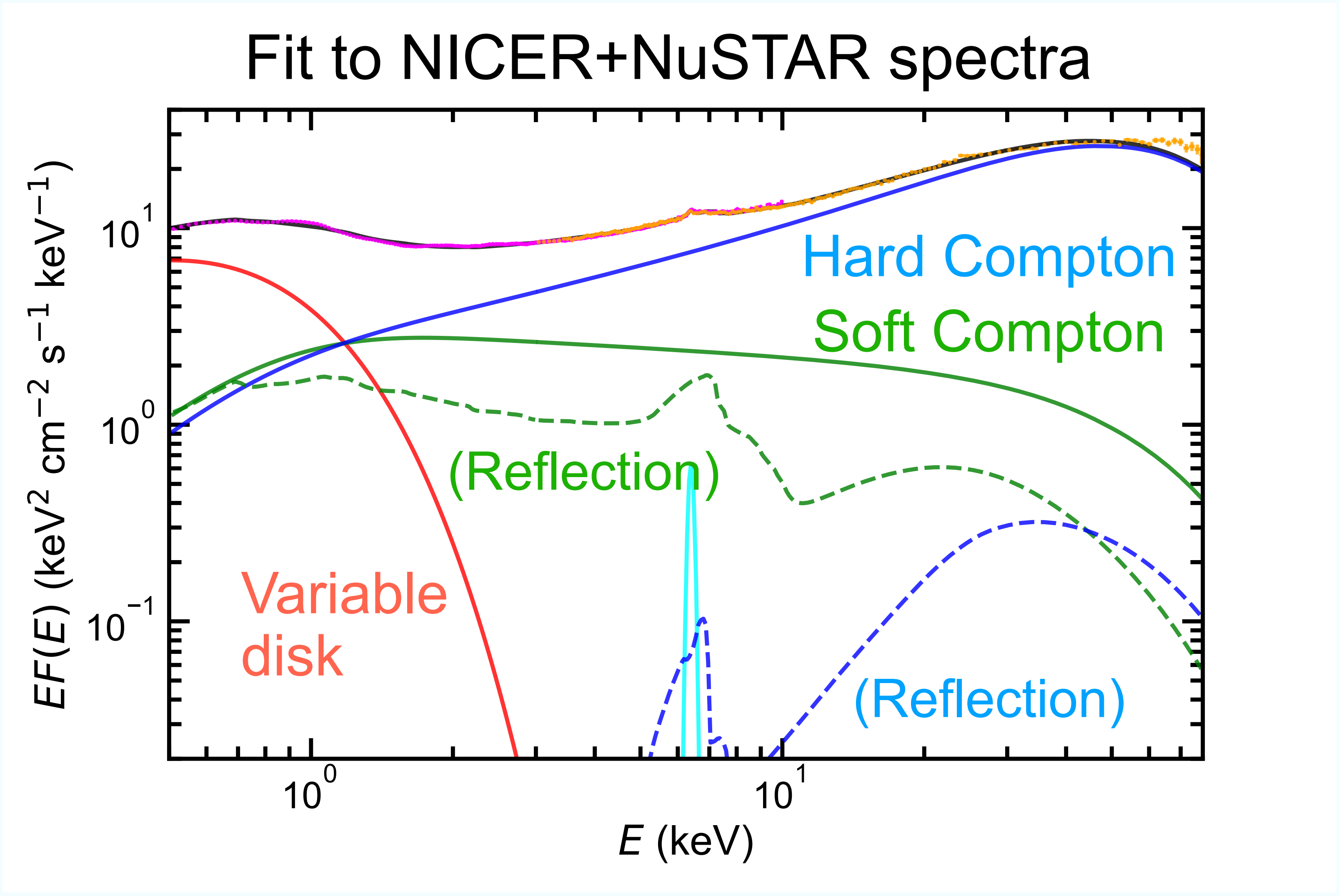
Broad-band variability (at least in hard bands)

Hard lagging Soft at low frequencies

We are developing a model.

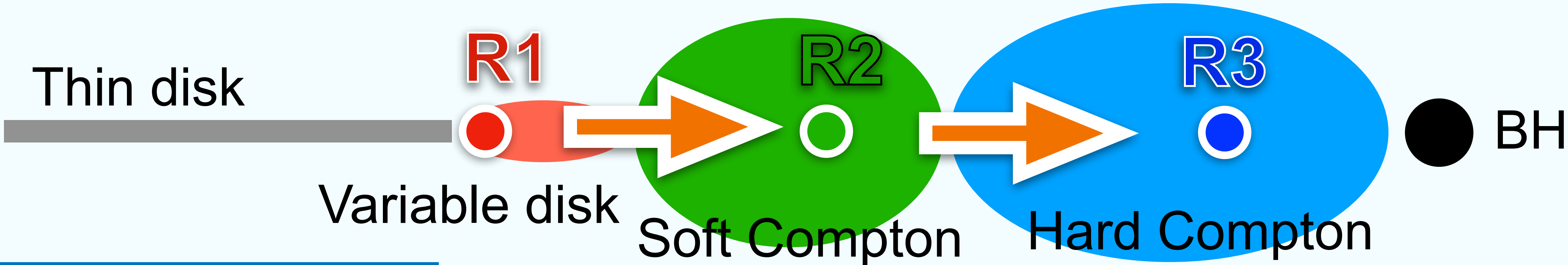
Modelling variable flow





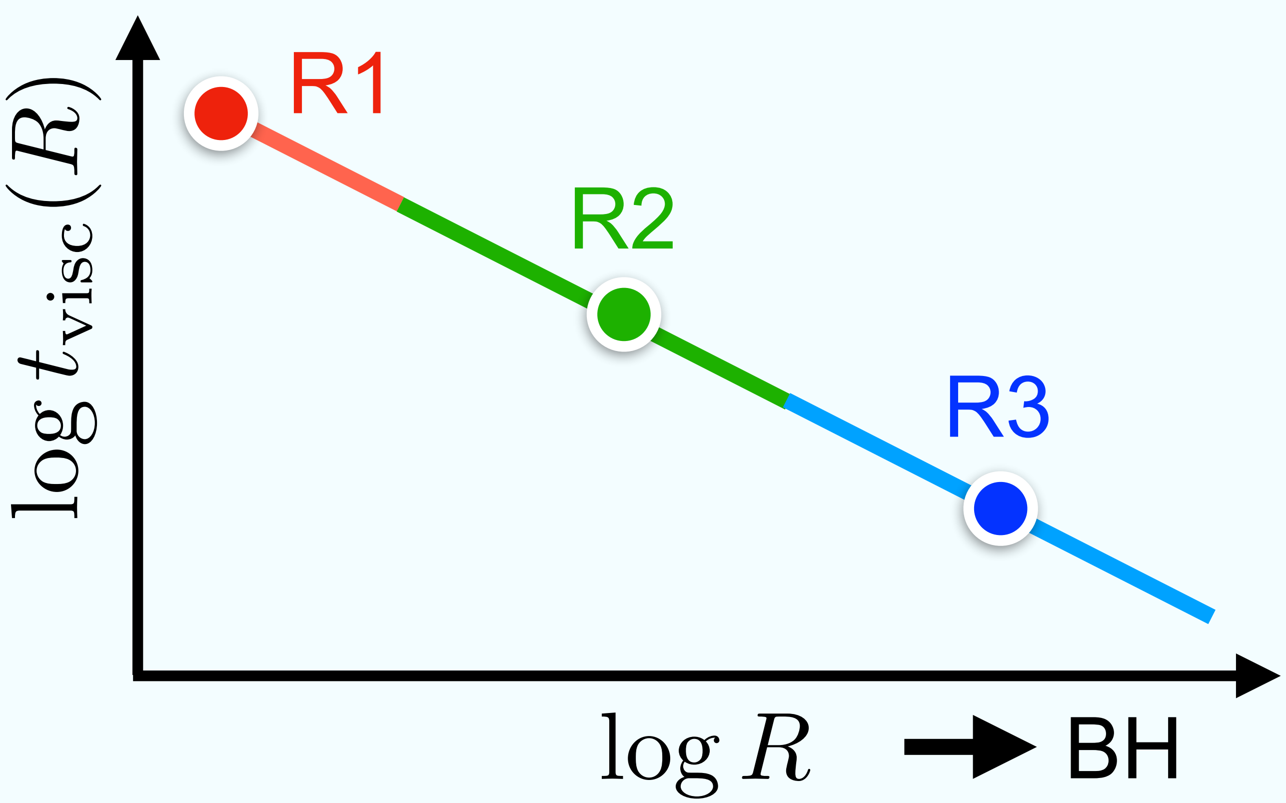
Our timing model uses the spectral components.

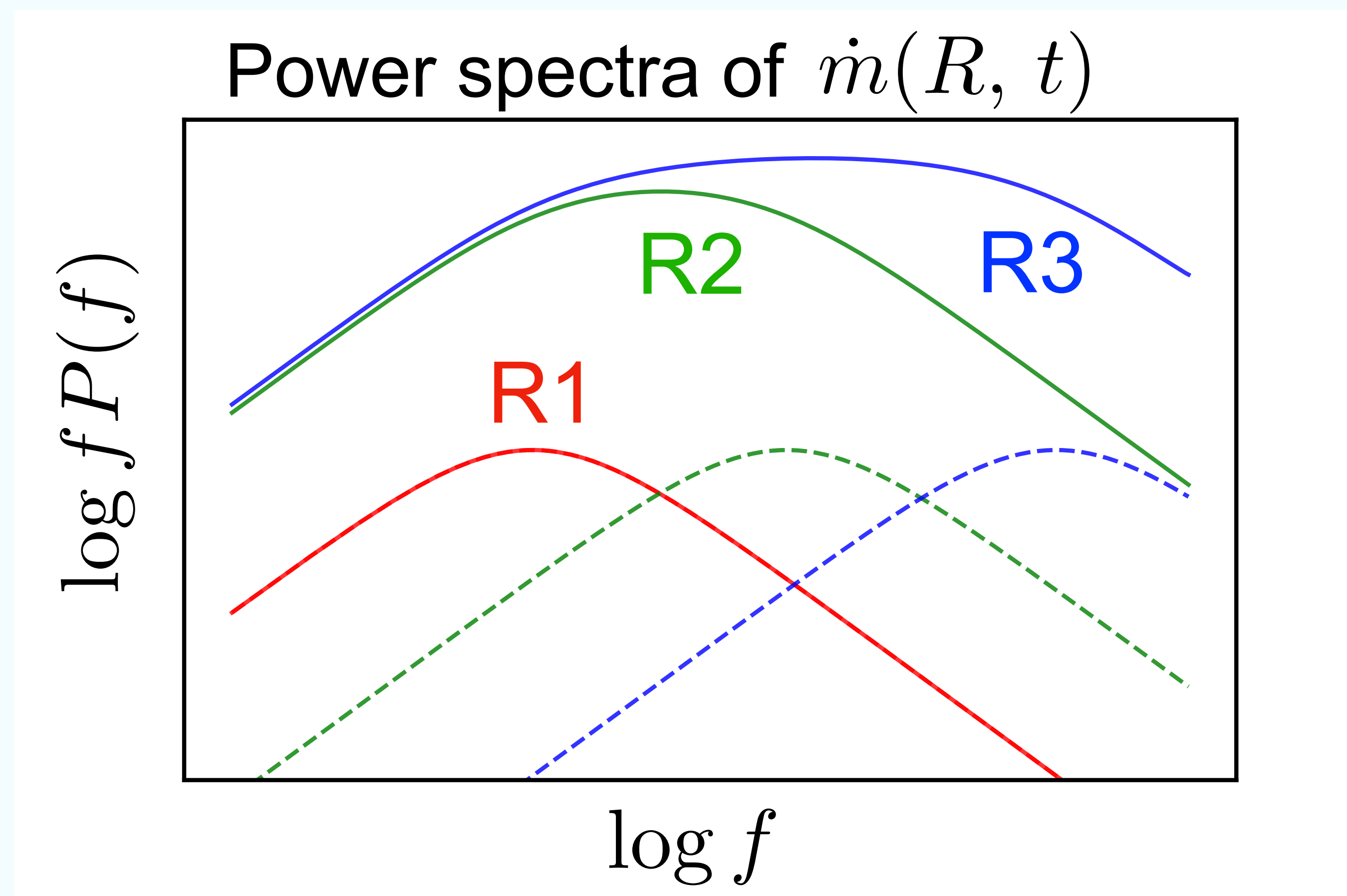
Modelling propagating fluctuations



Viscous time-scale stratification

Mass accretion $v_{\rm r}(R) = R/t_{\rm visc}(R)$



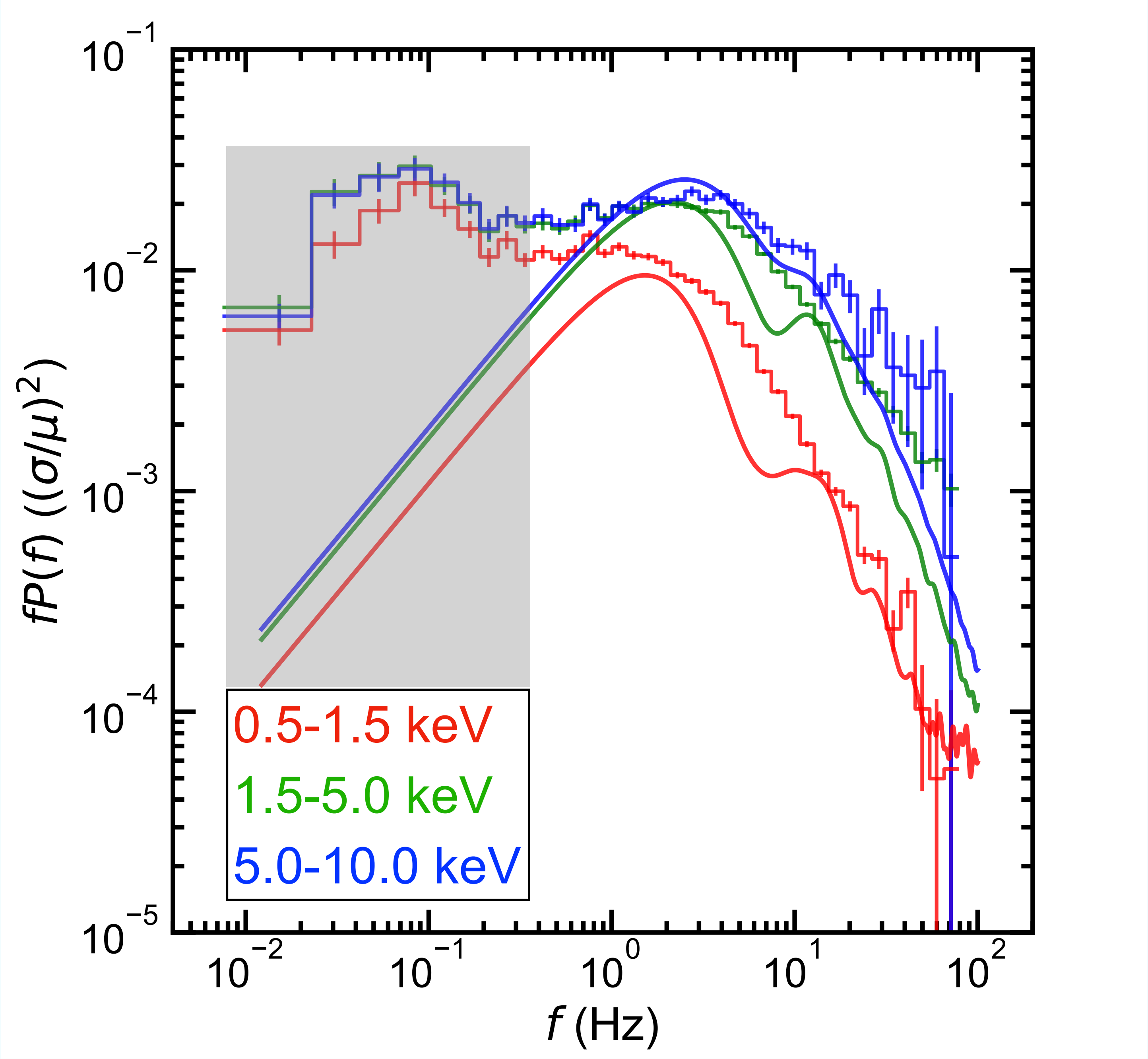


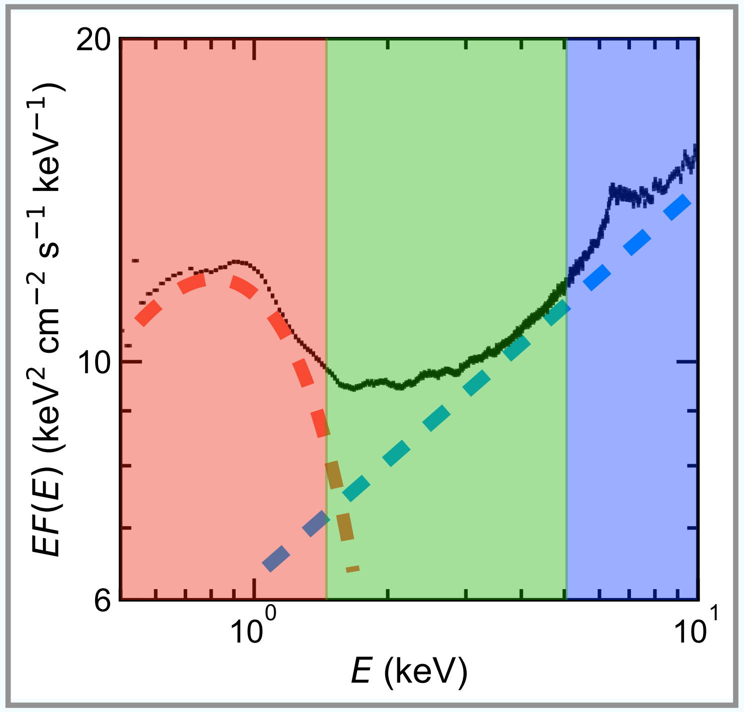
Spectral decomposition

Variability of $\dot{m}(R,\, t)$

→ Variability of flux

Comparison with observation

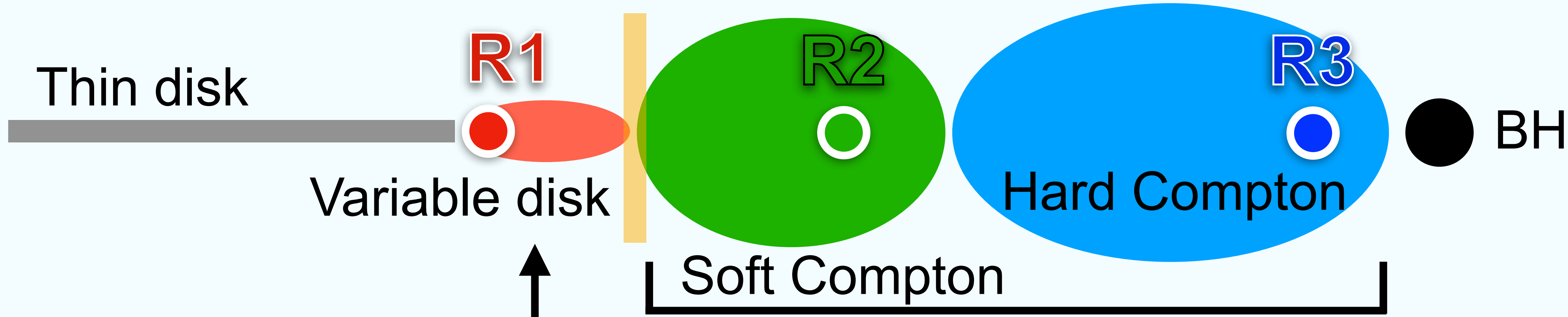




- Faster variability component is reproduced.
- But model produces a single bump, neglecting the slower one.

What produces double bumps?

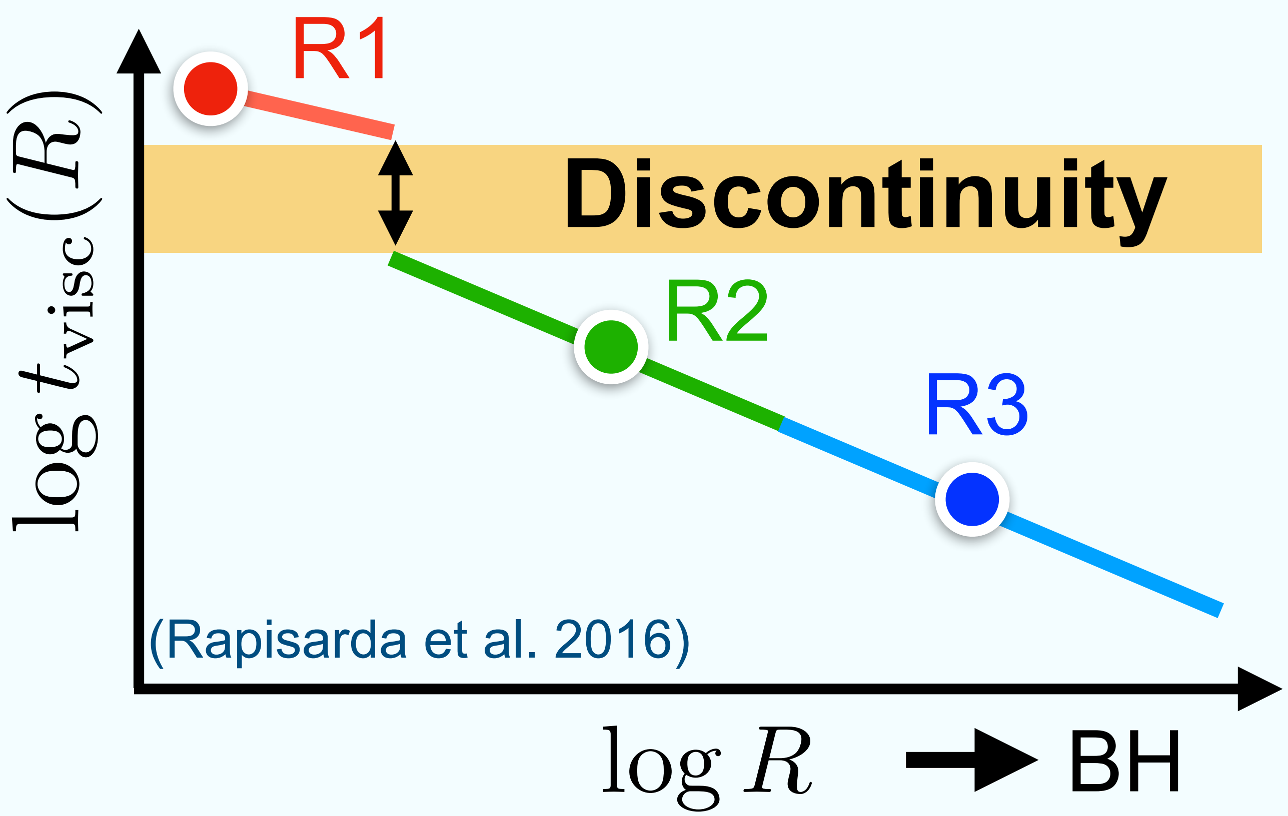
Different flow properties

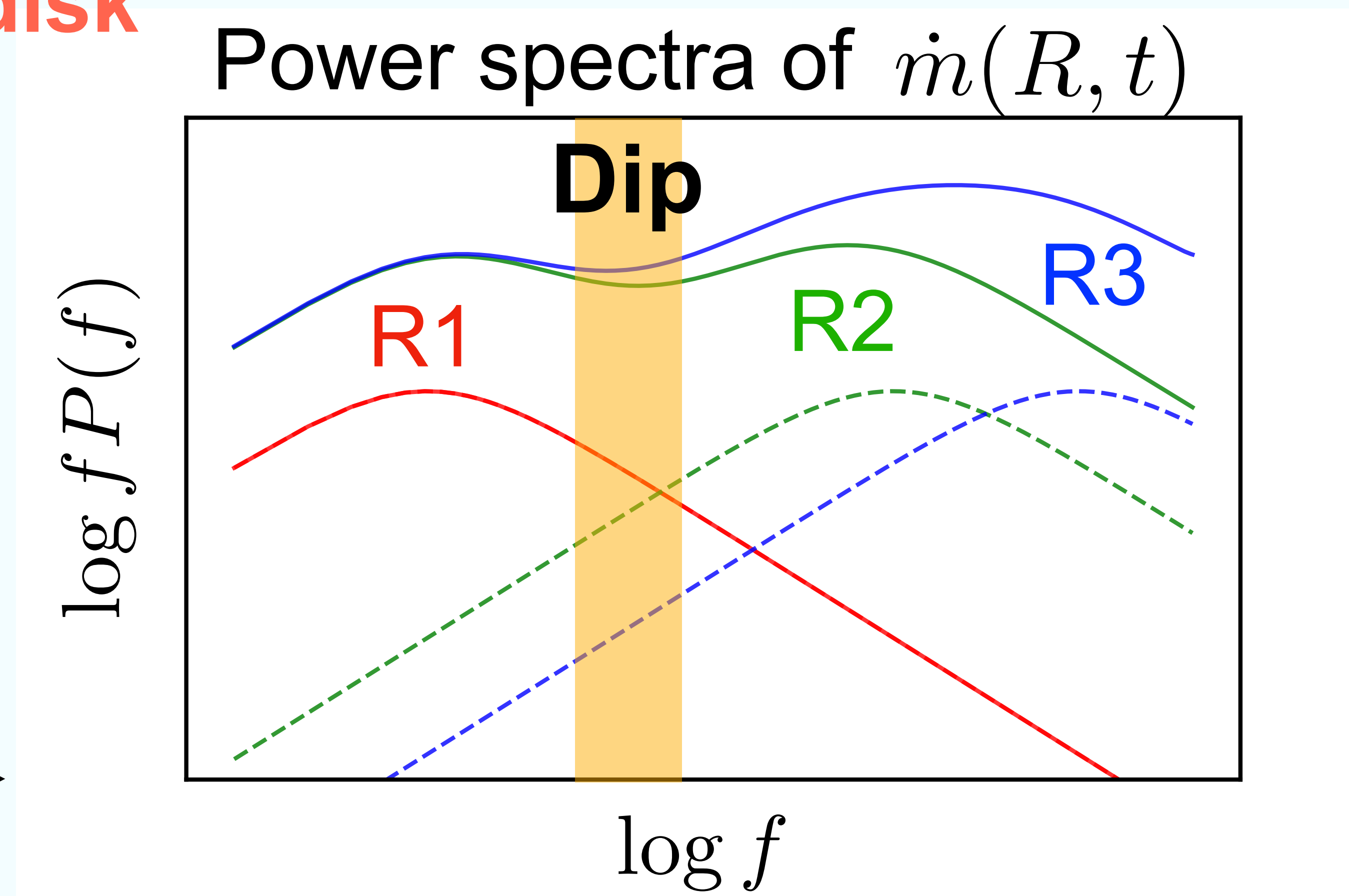


Different types of flow

Inner edge of the truncated disk

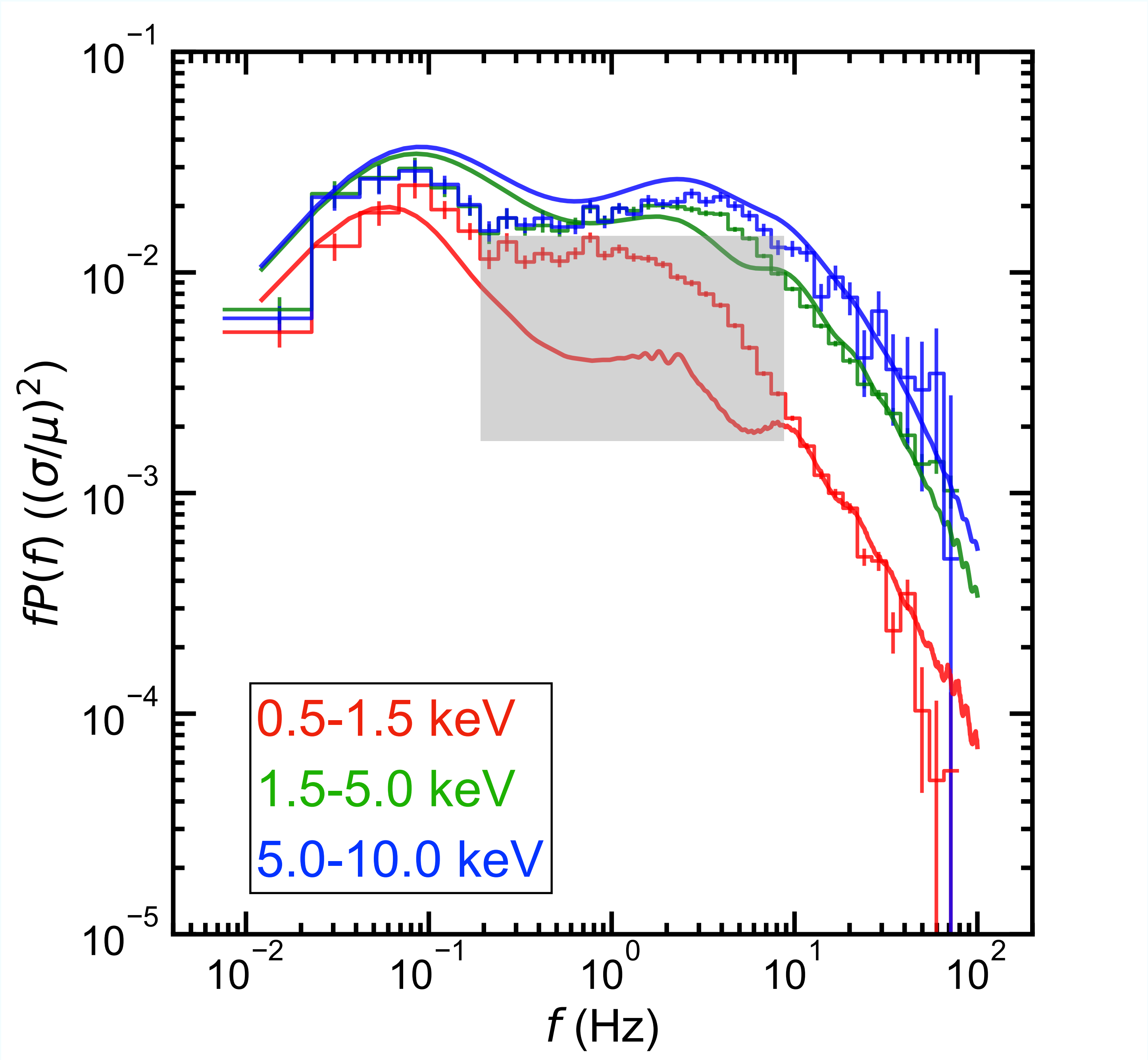
Hot flow

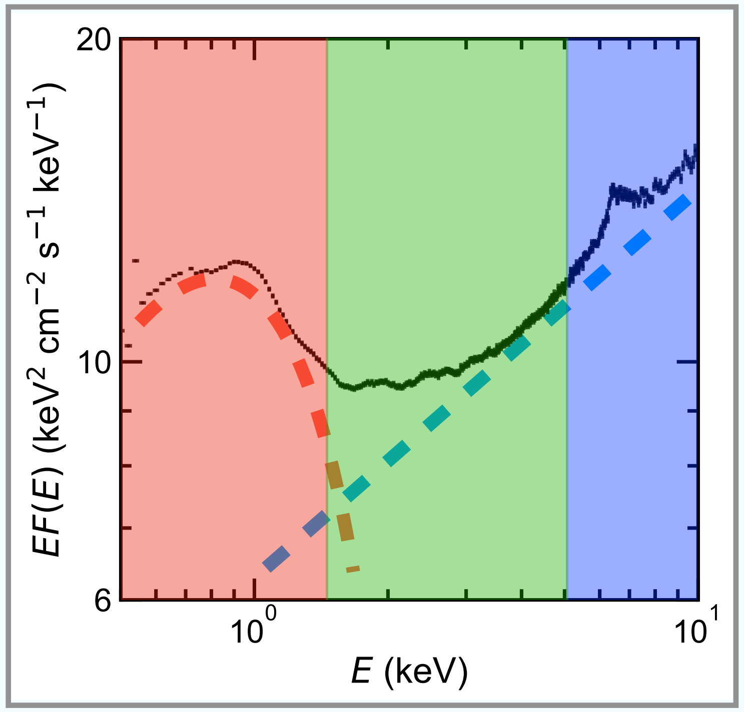




Discontinuity produces double bumps.

Comparison with observation



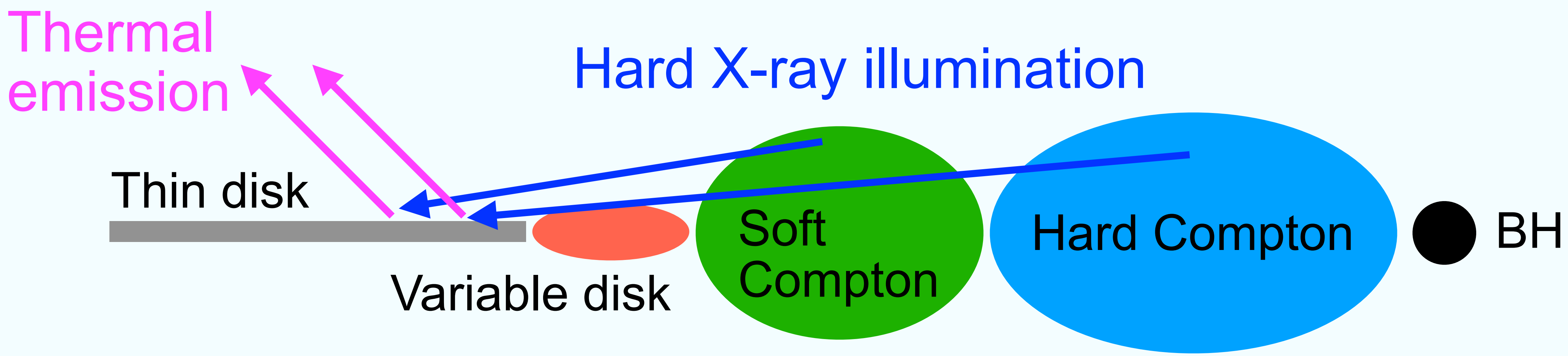


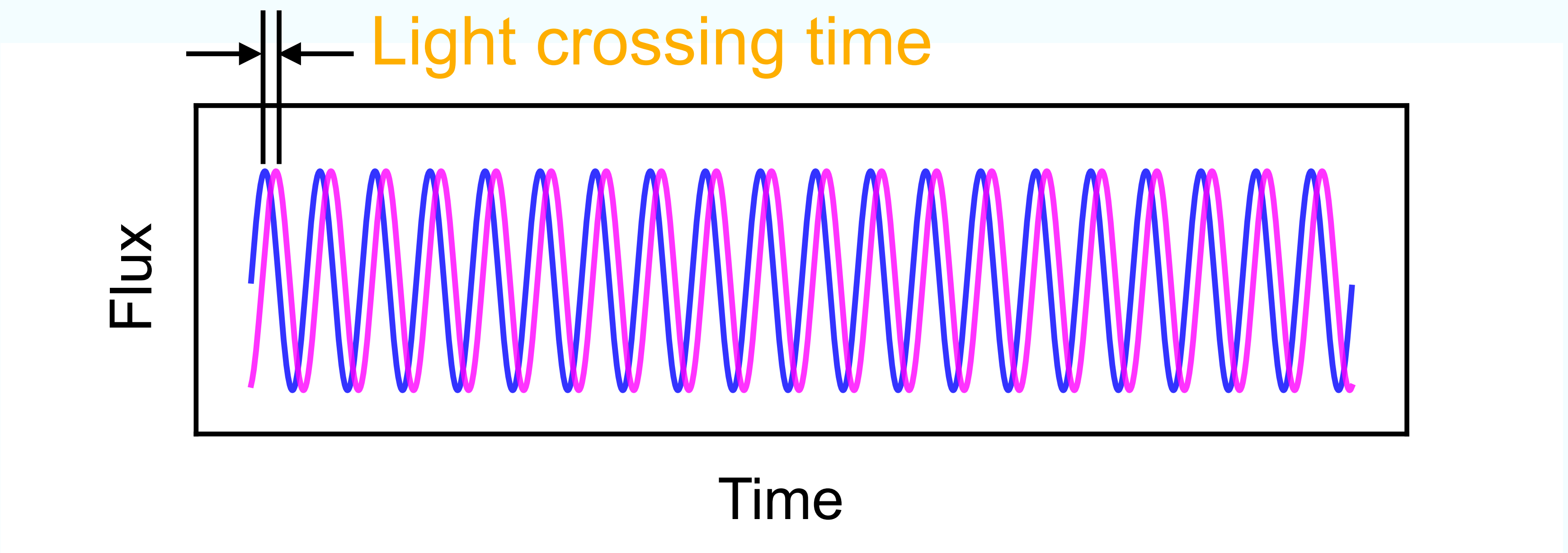
Disk variability
→Slower component
Hot flow variability
→Faster component

- Power spectra of higher energy bands are reproduced as a whole.
- But the soft band clearly lacks the power as the faster component.

What compensates for the loss of faster variability?

Including reflection





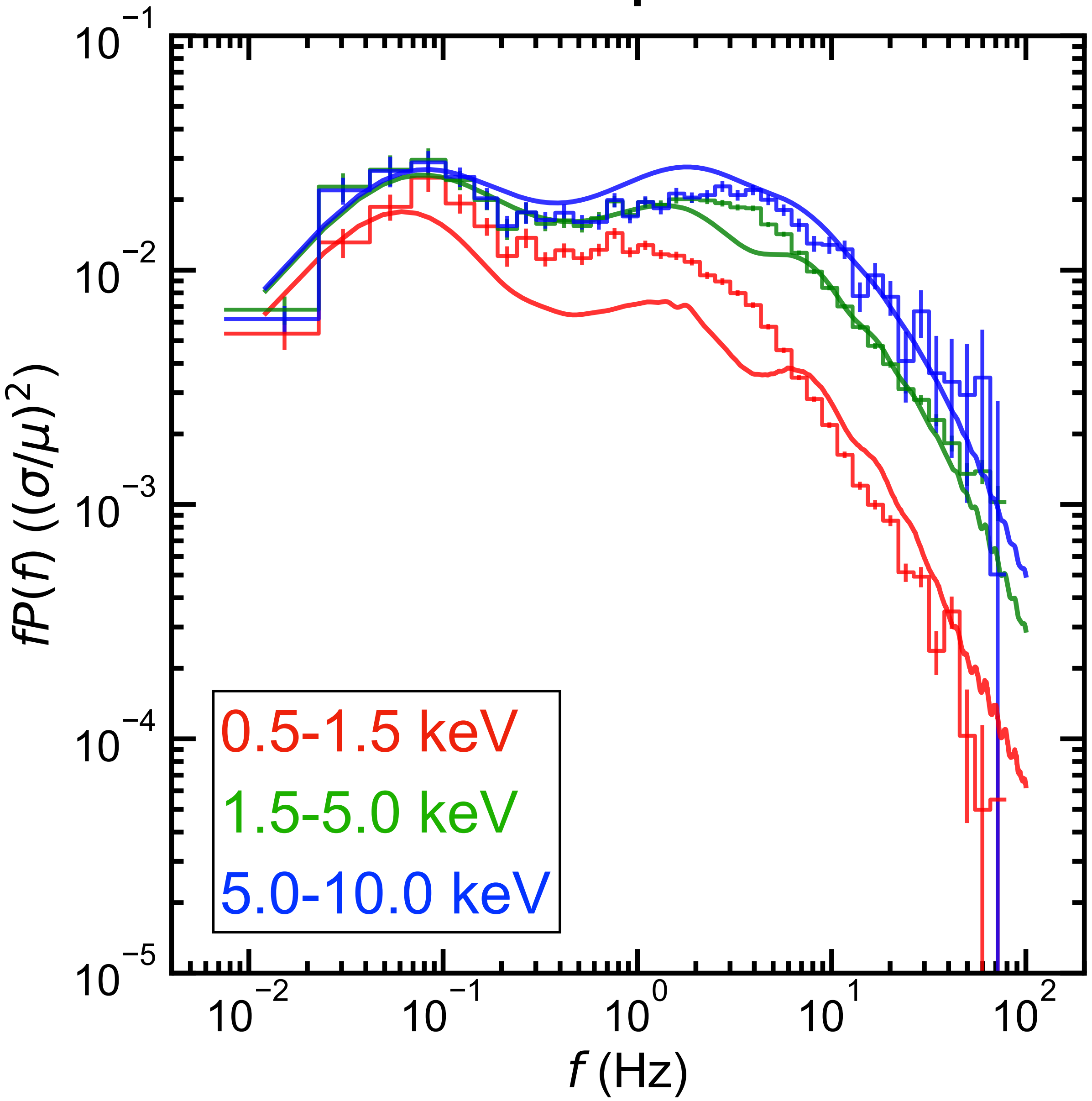
Thermal emission inherits the variability of the hard X-rays from the hot flow with delay.

Reflection accounts for faster variability in the soft band and soft lagging hard at high frequencies.

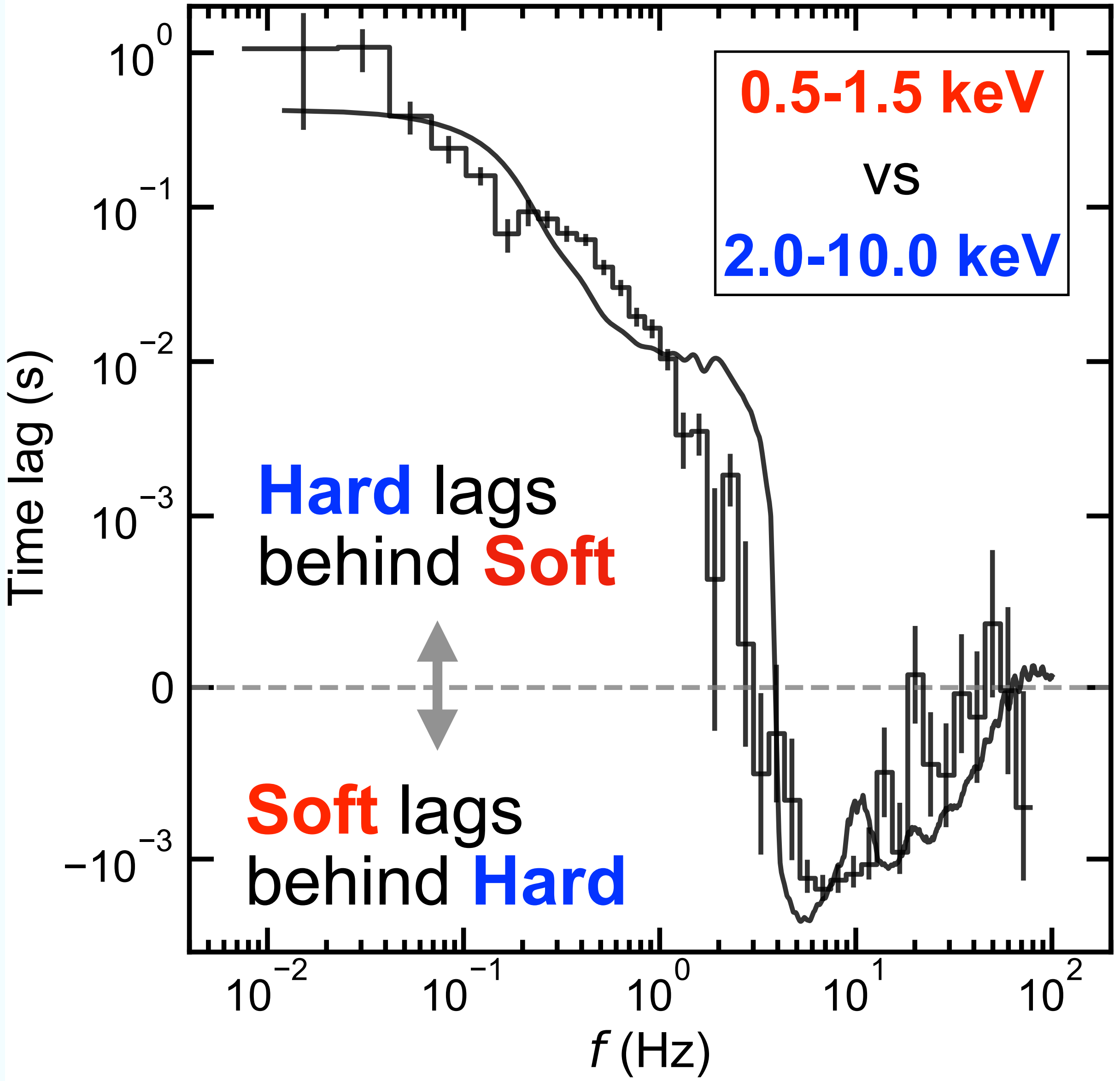
Comparison with observation

(Kawamura et al. in prep.)

Power spectra

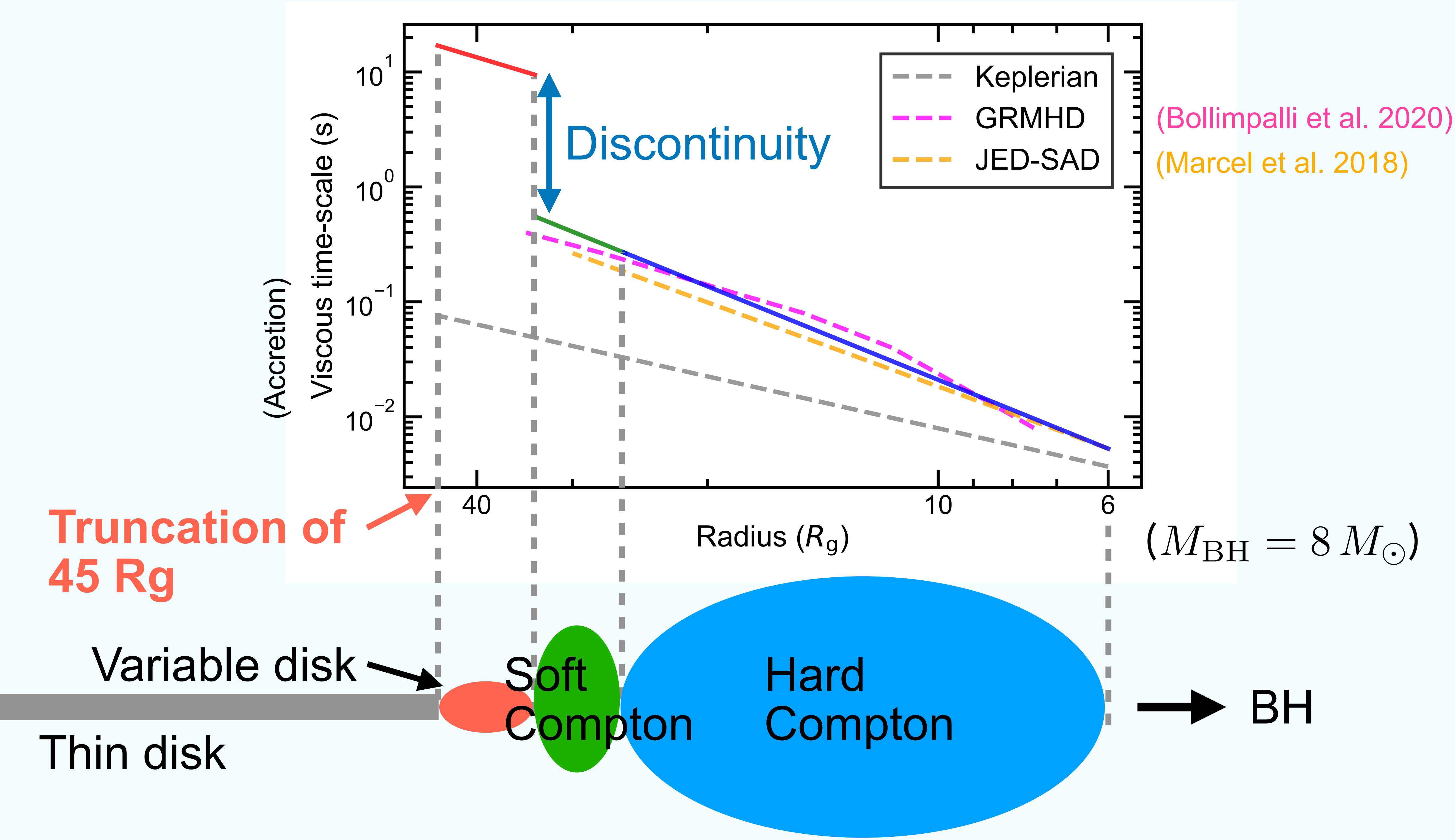


Lag-frequency spectra



Model reproduces both power spectra and frequency-dependent time lags.

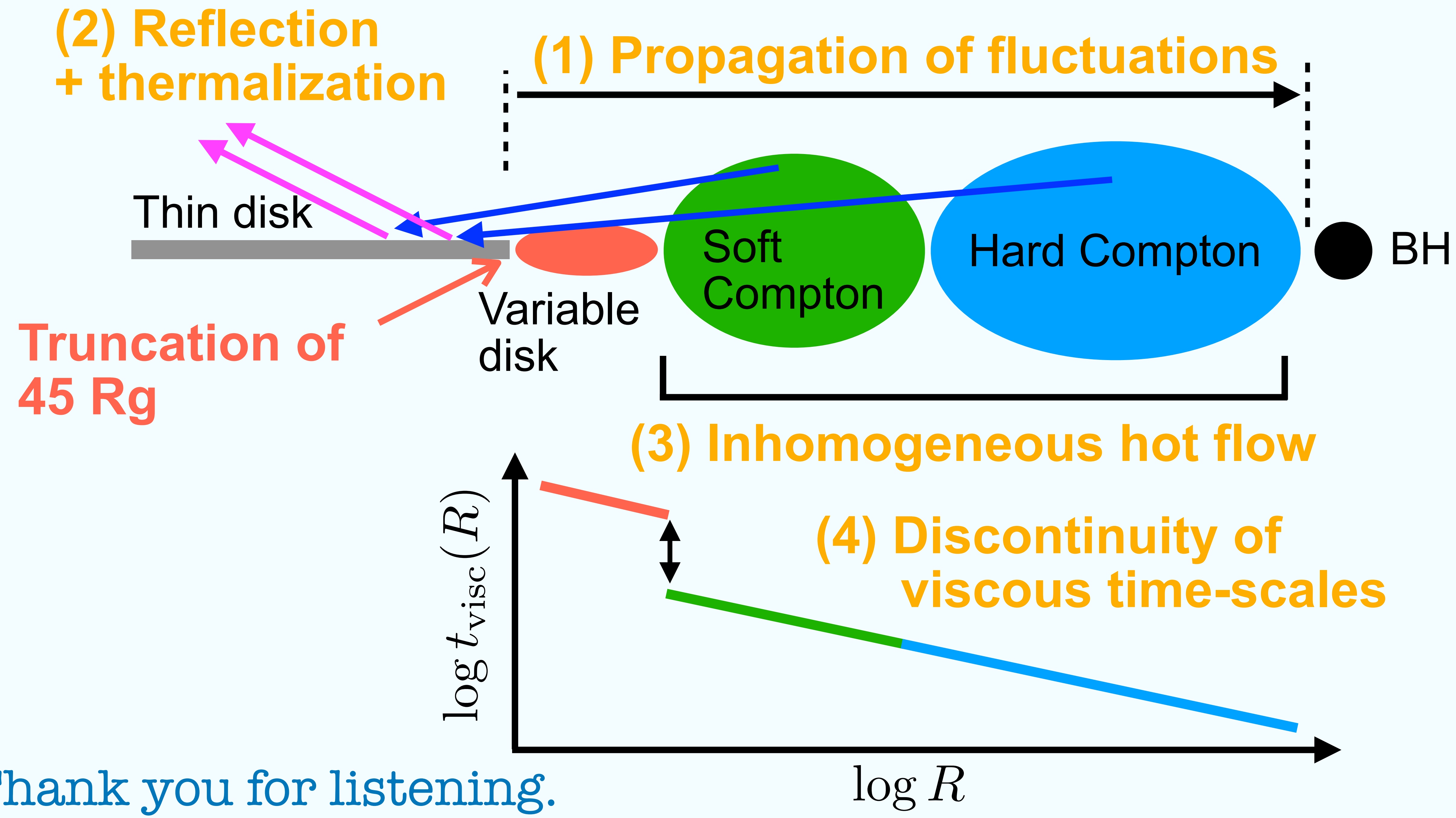
Derived viscous (accretion) time-scale



Derived viscous time-scale is consistent with multiple theoretical models.

Summary

- NICER allows the investigation into disk variability, as well as Comptonization variability in the low/hard state of MAXI J1820+070.
- Our model has succeeded in reproducing both power spectra and time-lags. Incorporating disk variability is an essential element.



Thank you for listening.