# A NICER Look at Spinning Black Holes

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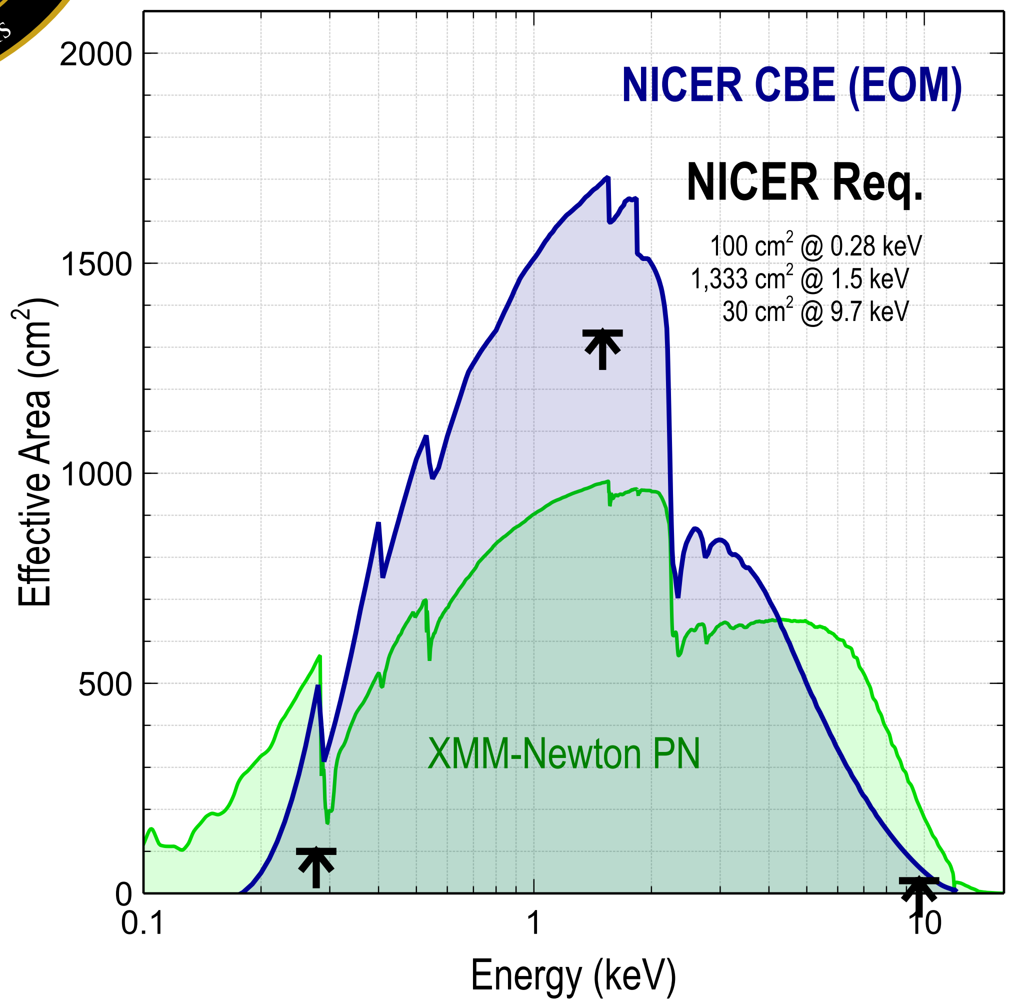
# NICER specs

***Energy resolution:***
85 eV @ 1 keV,
137 eV @ 6 keV
*Similar to XMM and Chandra*

***Time-tagging resolution:***
< 300 nsec (absolute)
*~25x better than RXTE*
*~100–1000x better than XMM*

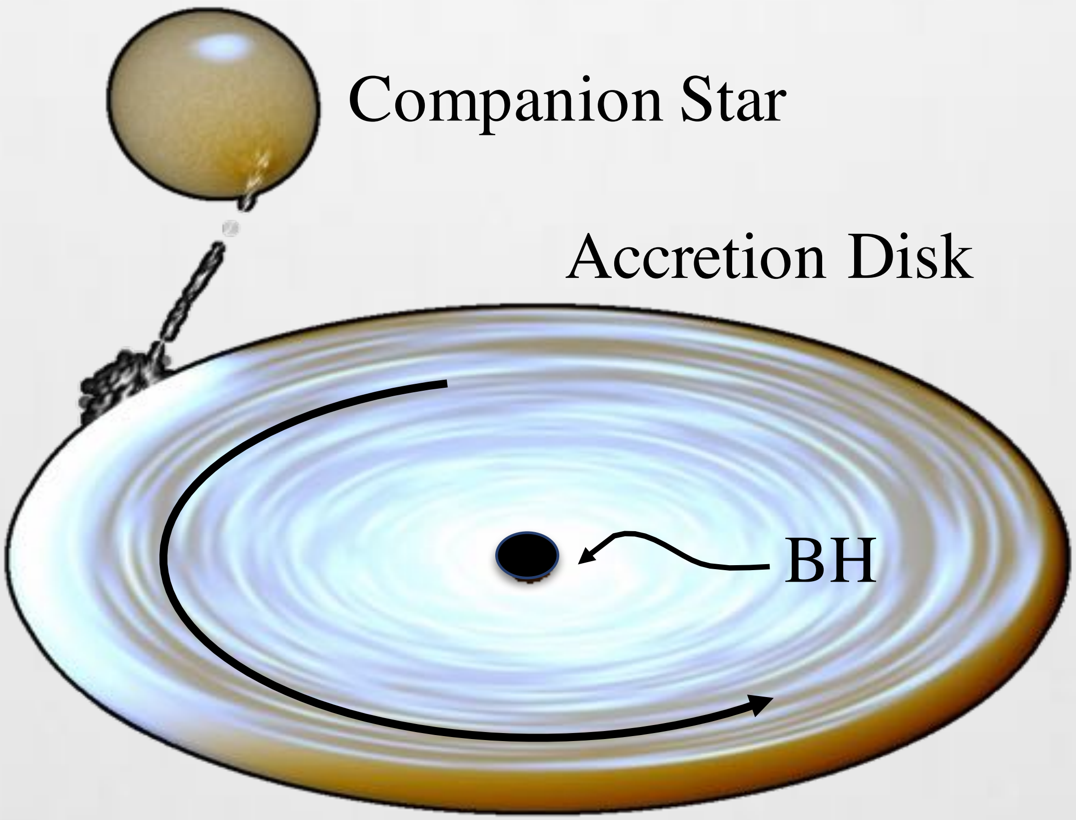
***Sensitivity:*** $3 \times 10^{-14}$ ergs $s^{-1}$ $cm^{-2}$
(0.5–10 keV, 5σ in 10 ksec)
*~30x better than RXTE,*
*~4x better than XMM*

NO PILEUP!



# Stellar Mass BHs

# Typical BH Transient




(fig: R. Hynes, C. Markwardt)

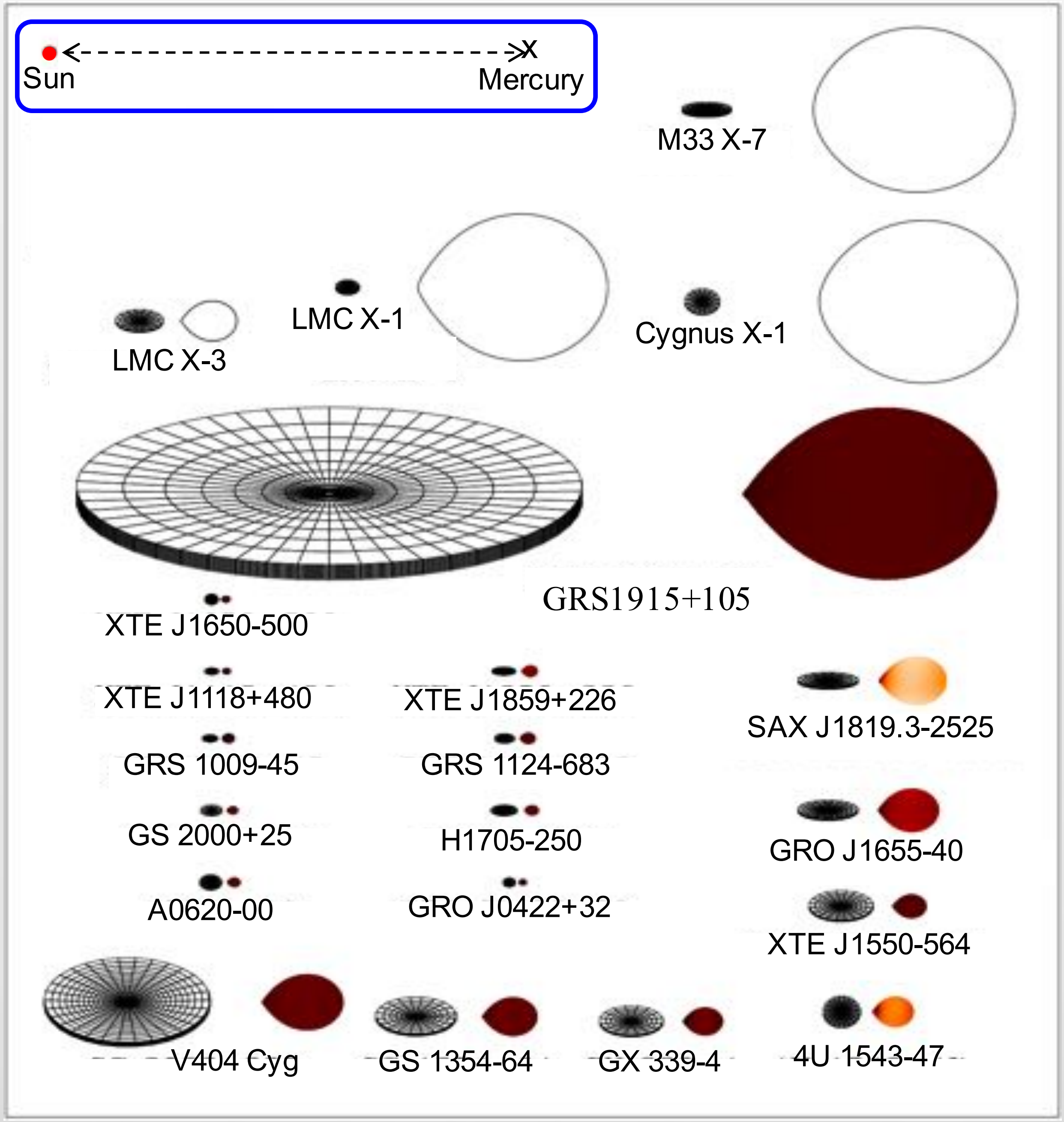
# Black Holes are Simple

- Mass: M

- Spin: $a_*$ ($J = a_* GM^2/c$)

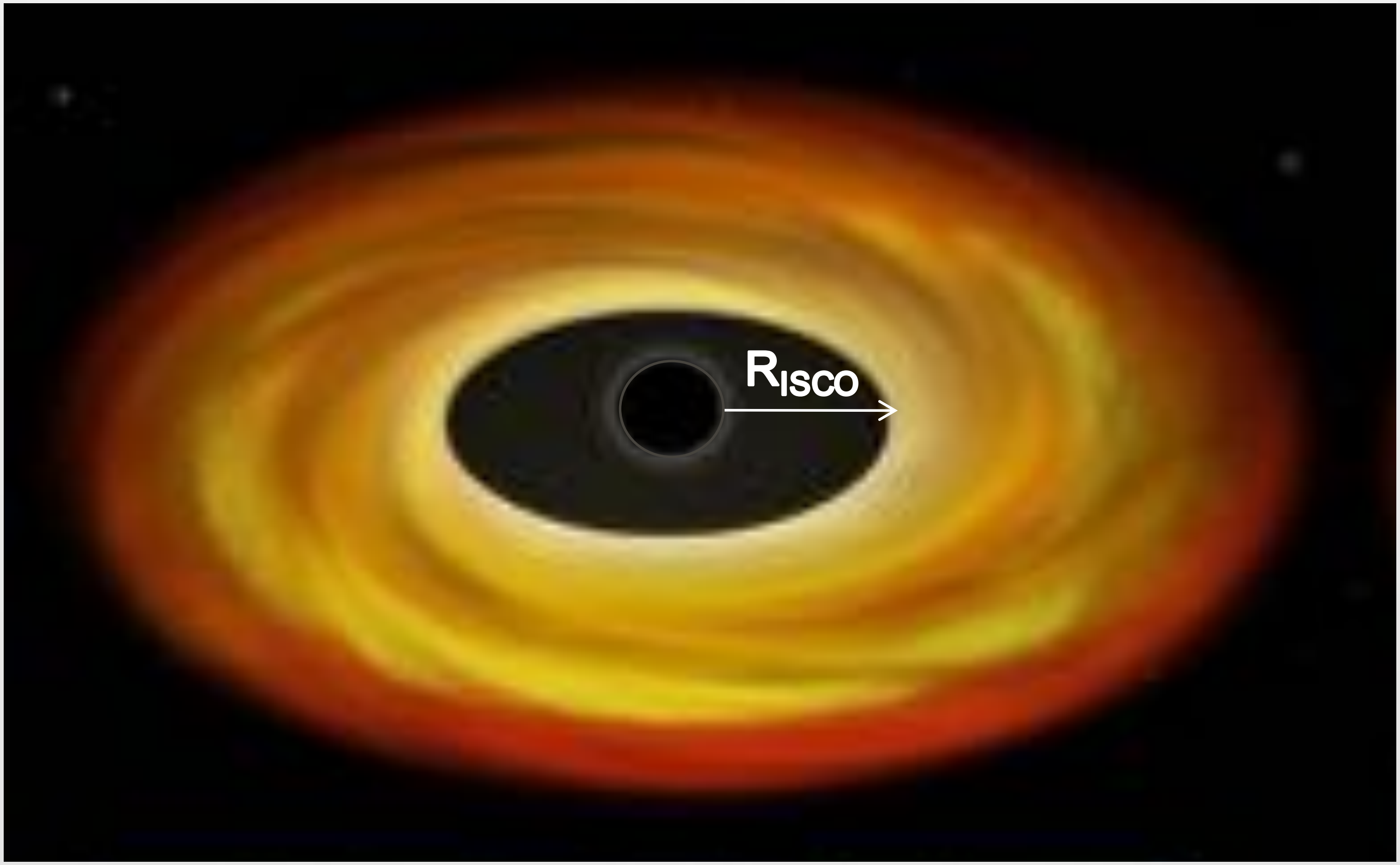
Charge neutralized and unimportant

# The Black Hole Binary Zoo

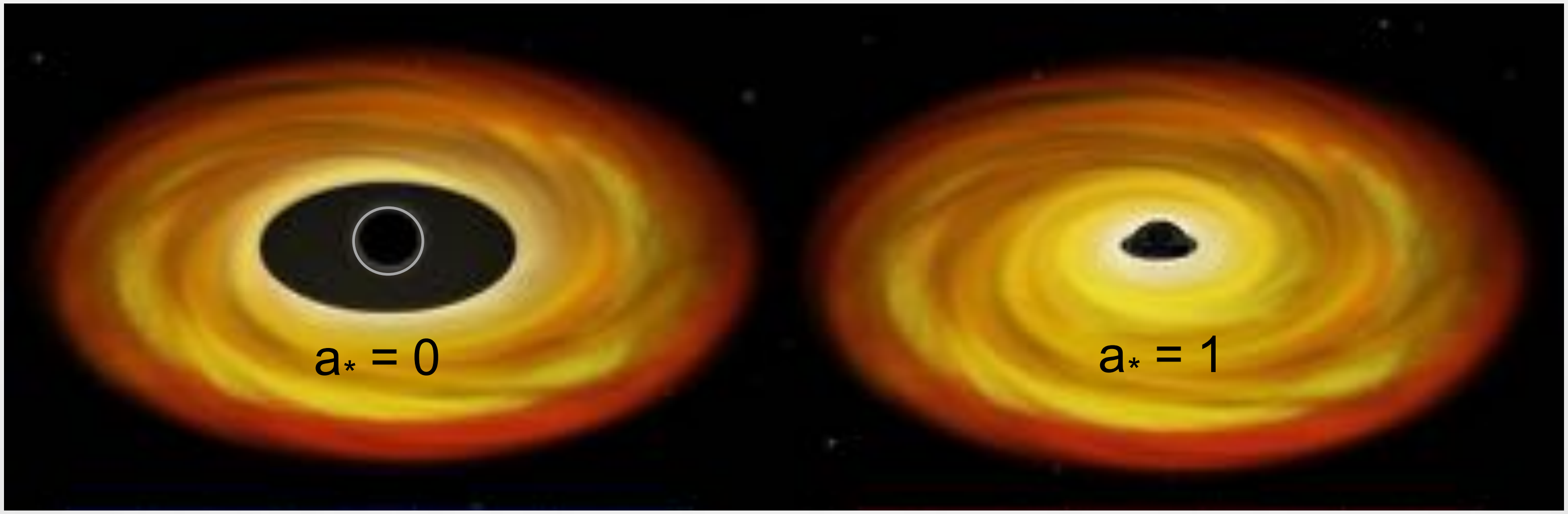


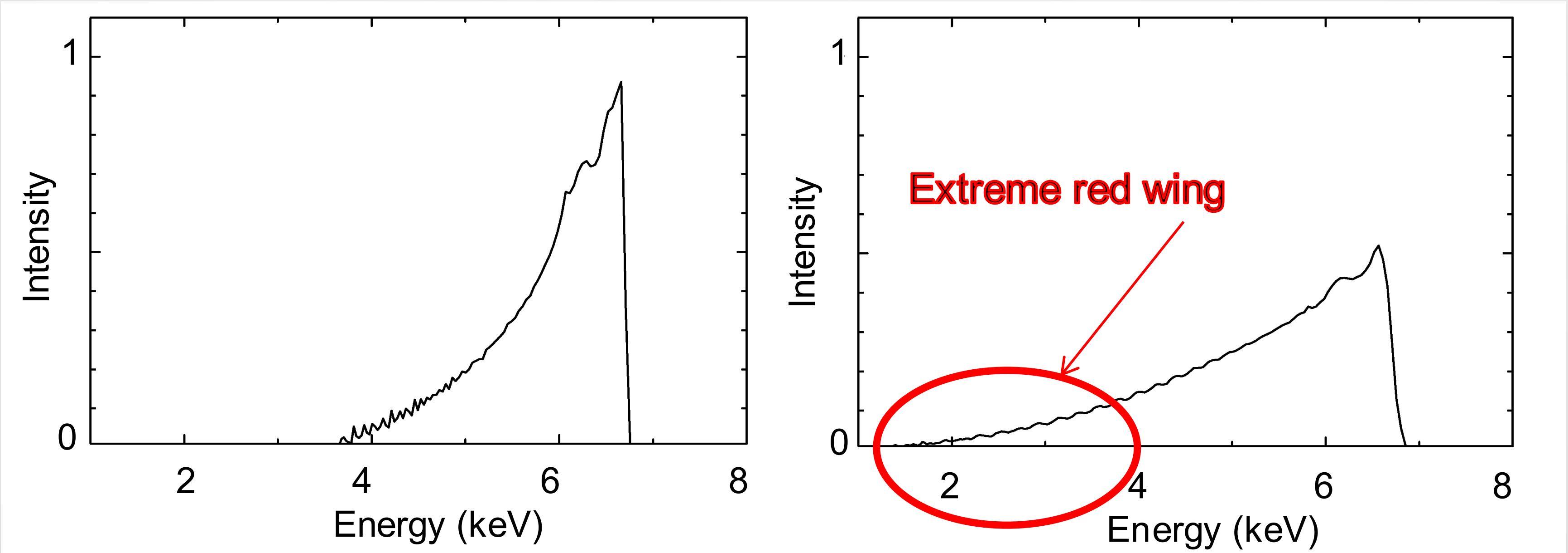

Courtesy: J. Orosz

# Measuring the Inner Disk Radius



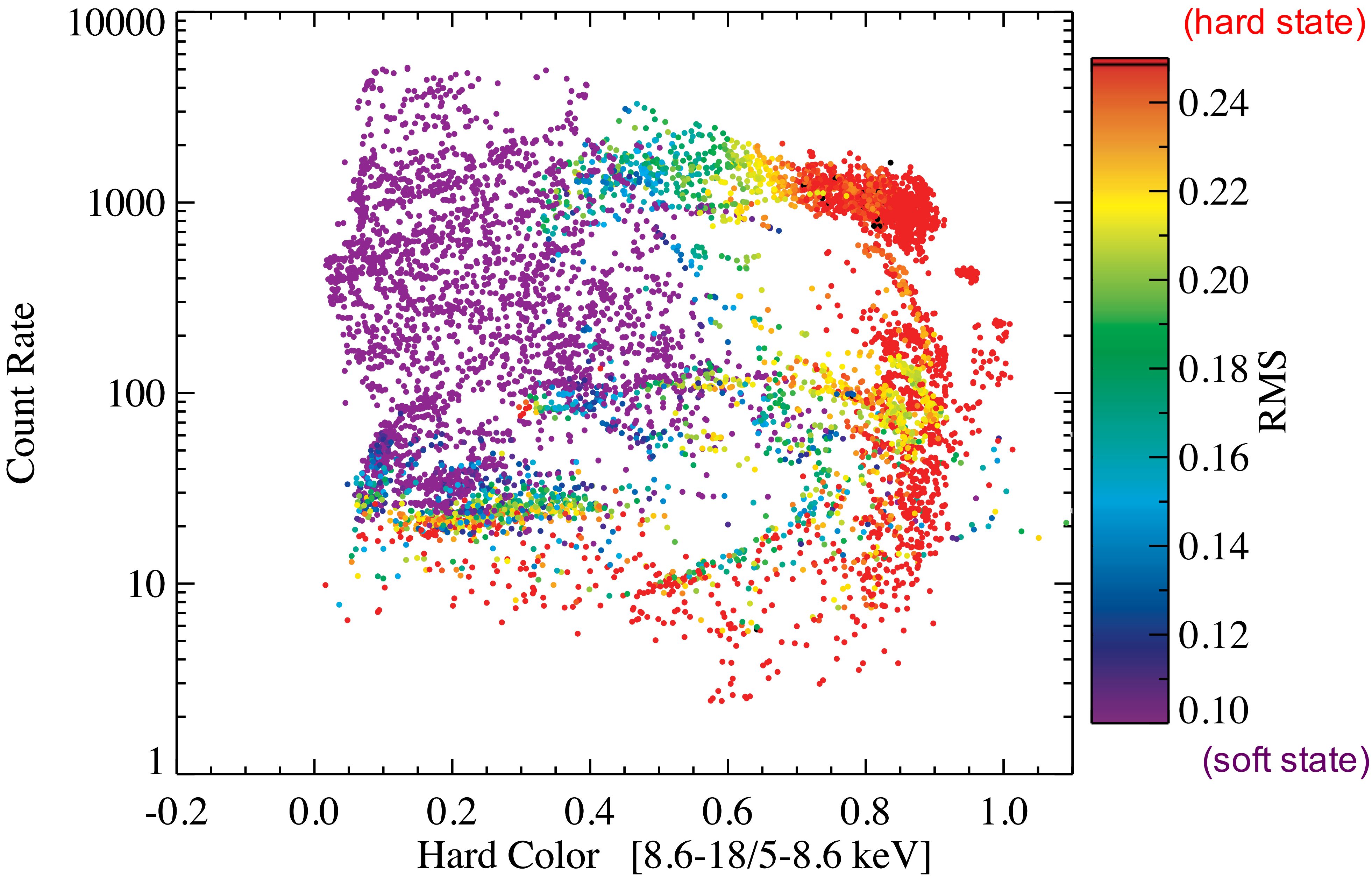
# Continuum+Reflection Effects

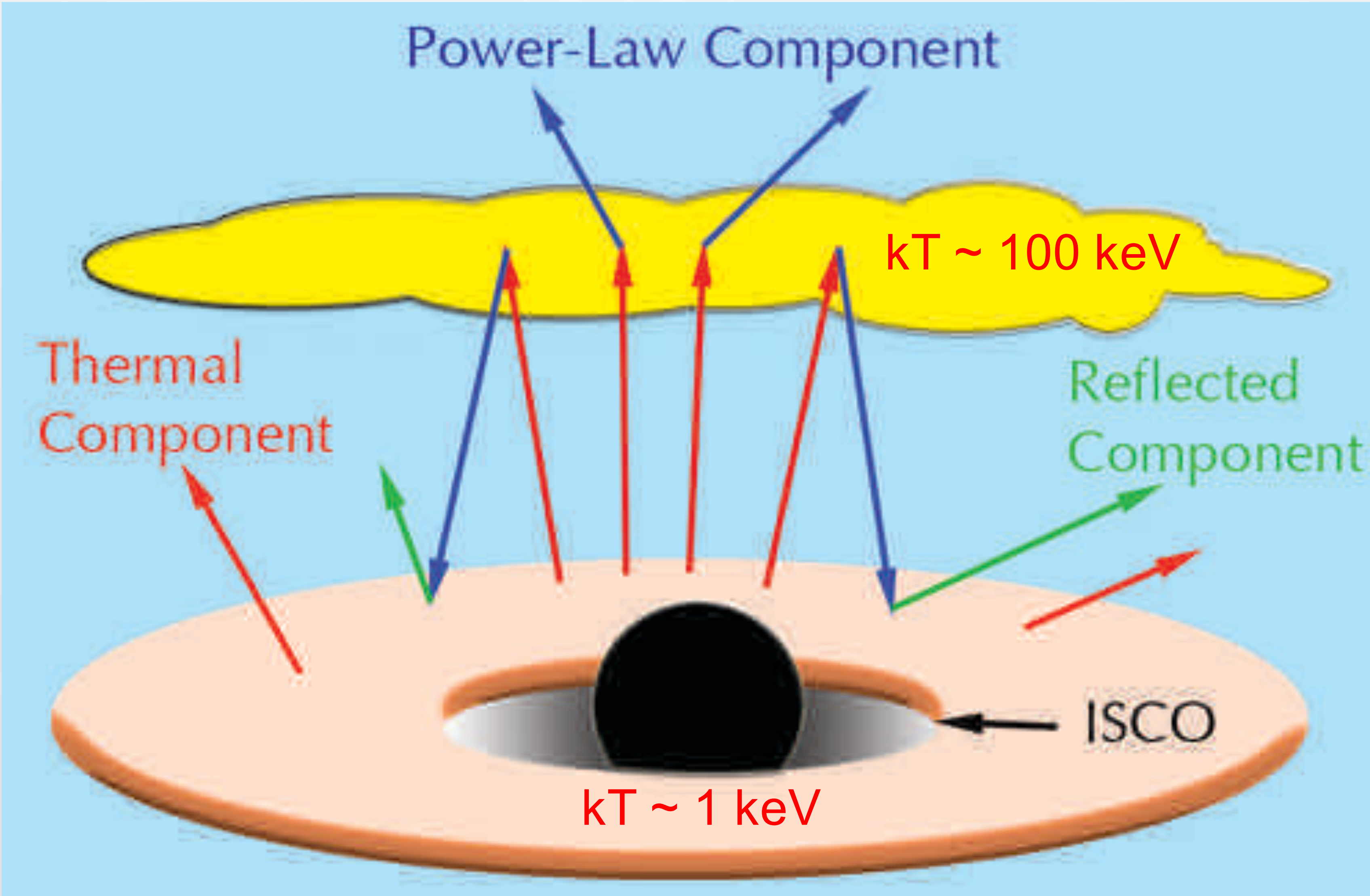


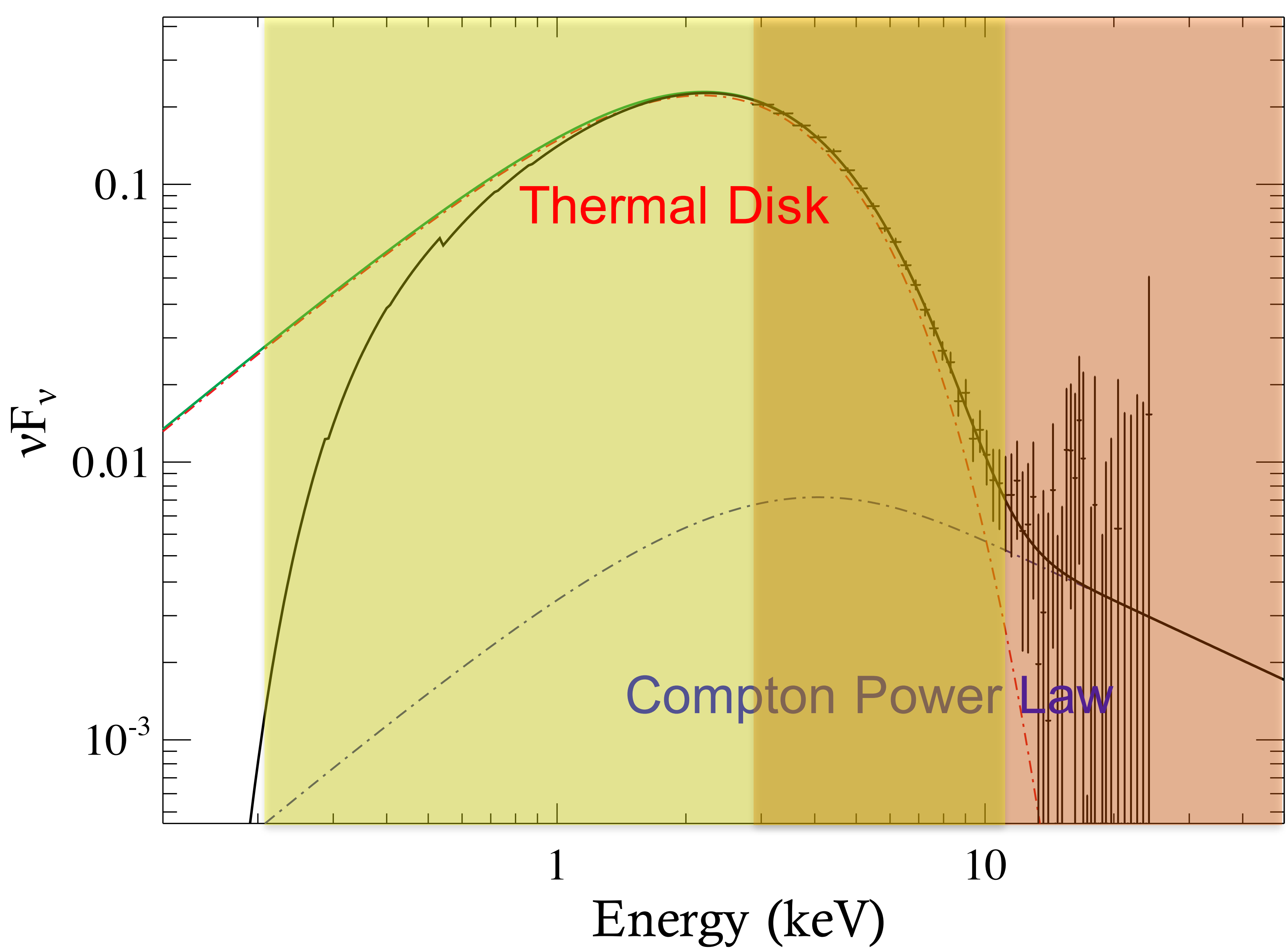
# Black Holes are Complex

# The RXTE Road Map

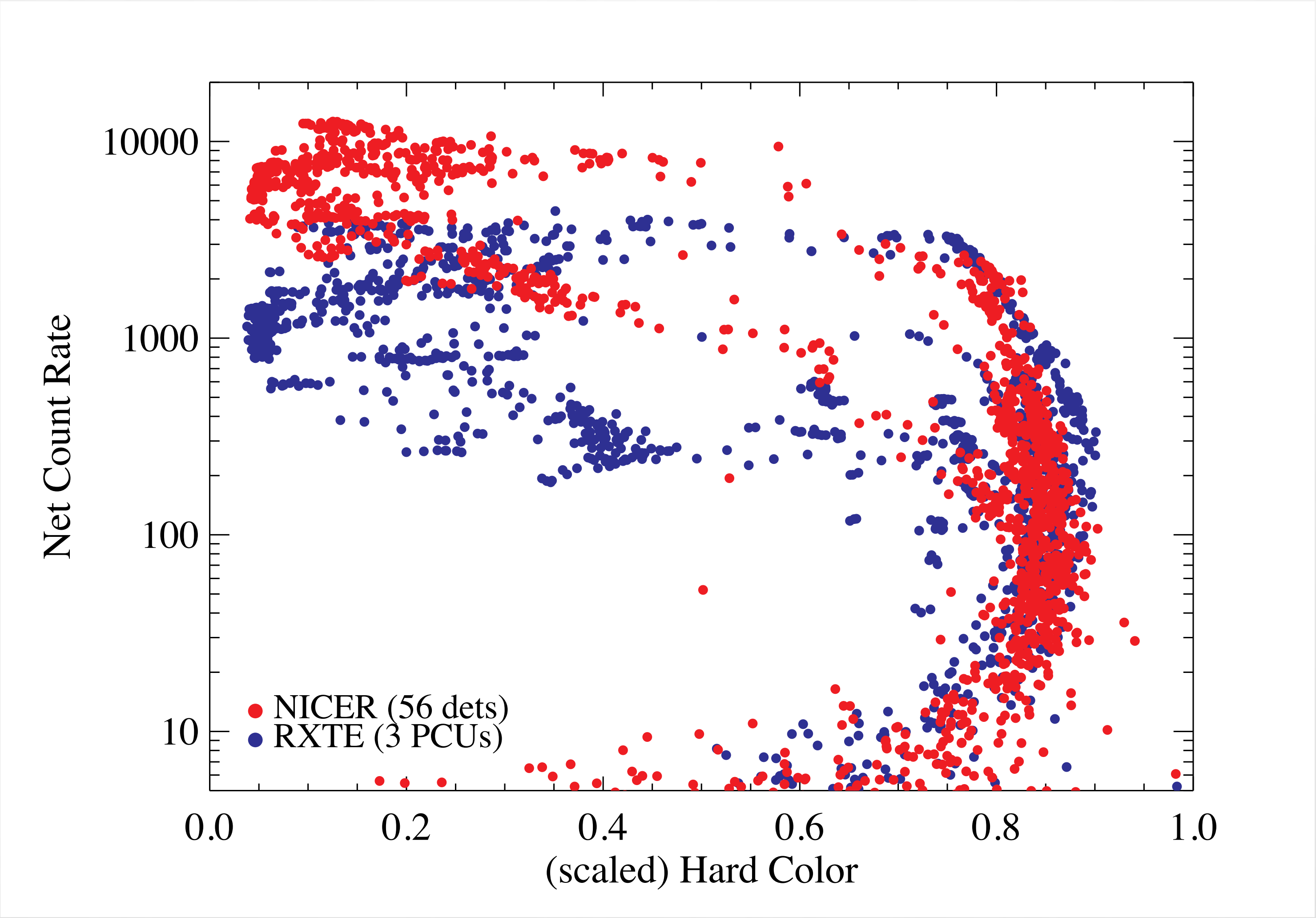



Power-Law Component
kT ~ 100 keV
Thermal Component
Reflected Component
ISCO
kT ~ 1 keV

# NICER vs RXTE



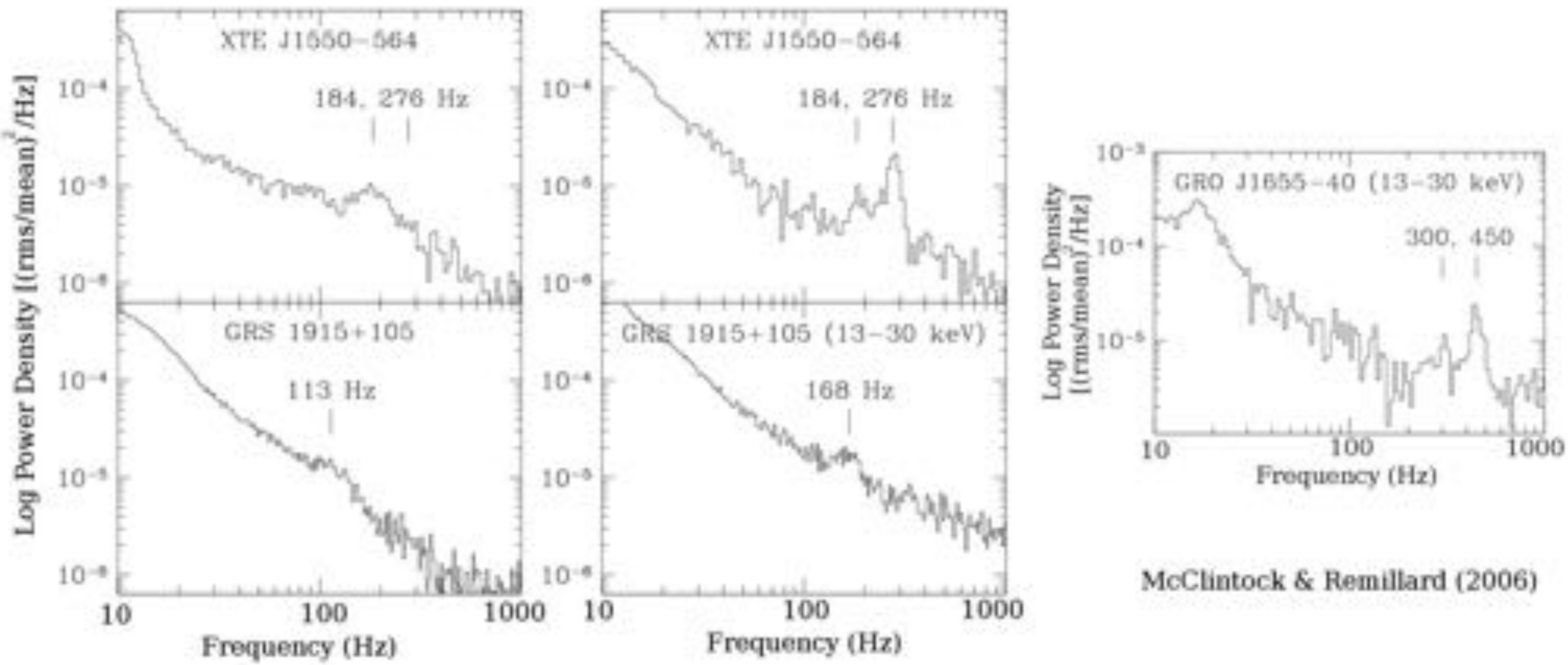
# NICER vs RXTE for GX339-4



# Punchline

**NICER meets or exceeds RXTE count rates for black holes.**

# Spin in the Time-Domain

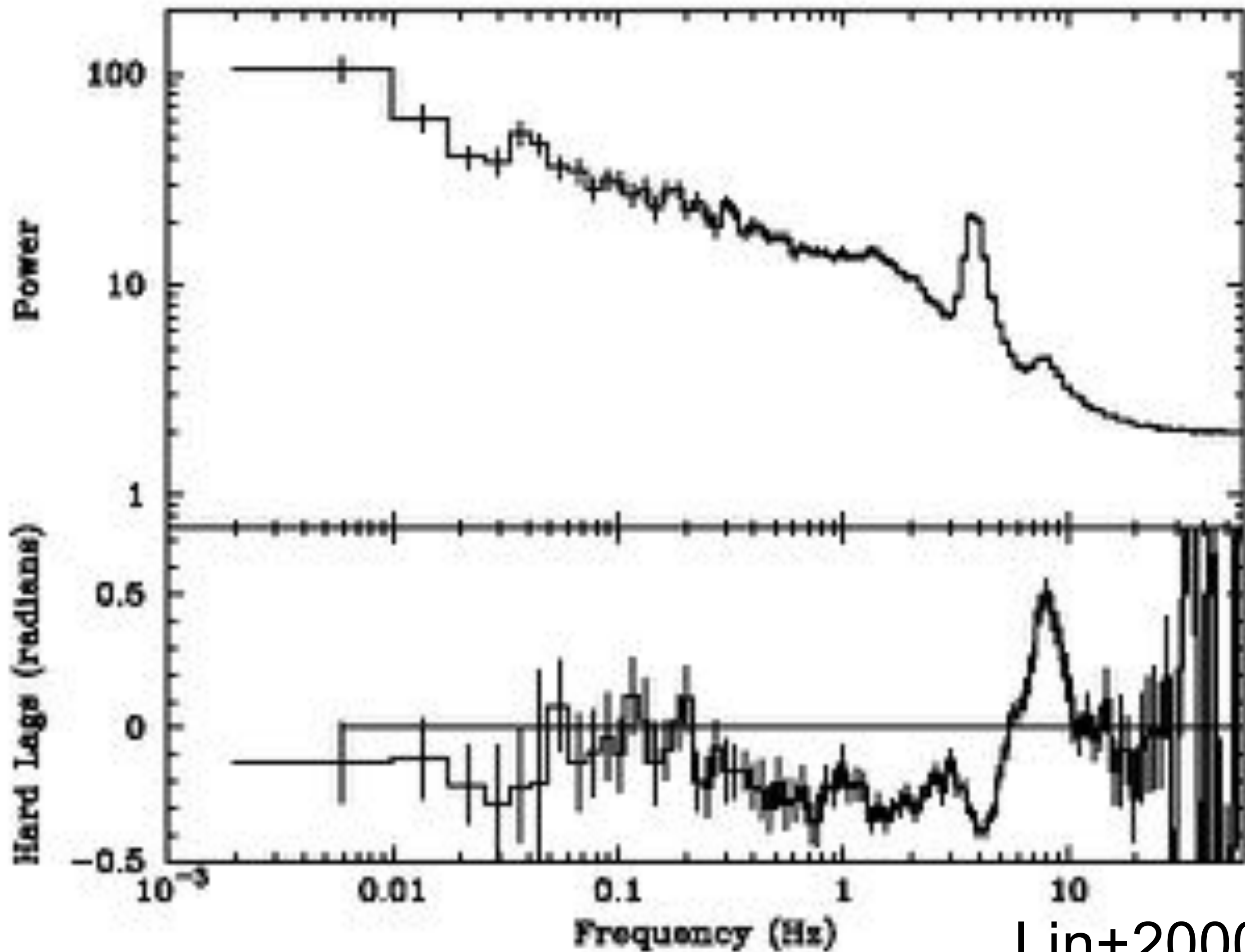



McClintock & Remillard (2006)

# NICER and BH Spin

- Spins can be measured with three techniques: continuum-spectroscopy, reflection spectroscopy, and QPO timing
- NICER offers improved capability for each method
- Only instrument for which a simultaneous constraint with all three would be possible

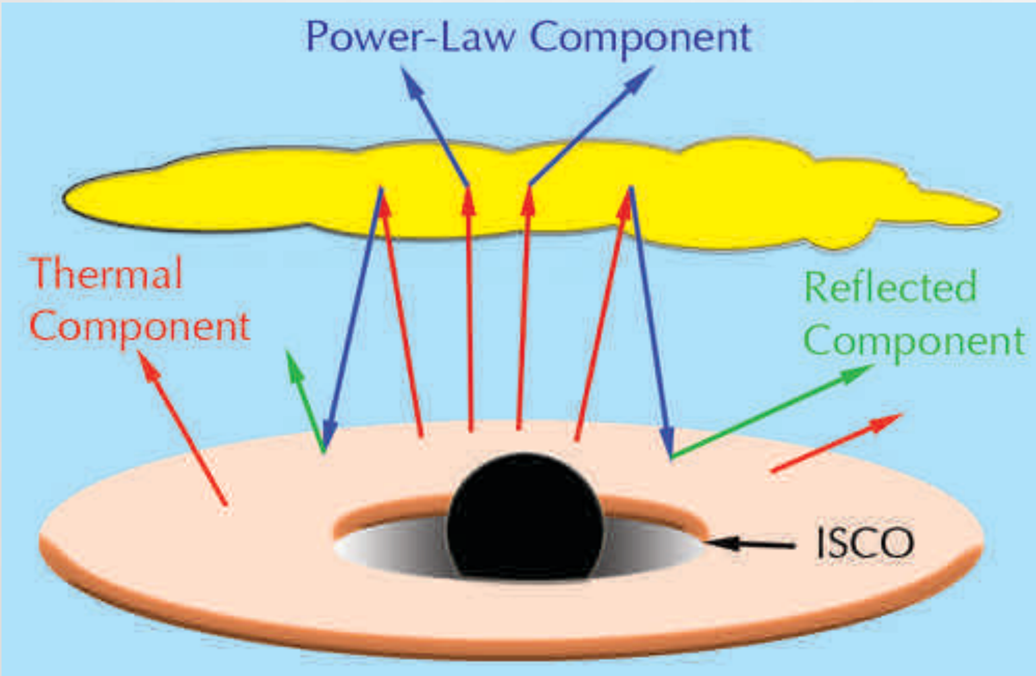
# GRS 1915+105




Lin+2000

# Spectral Modeling

- Will require new breed of self-consistent spectral models:

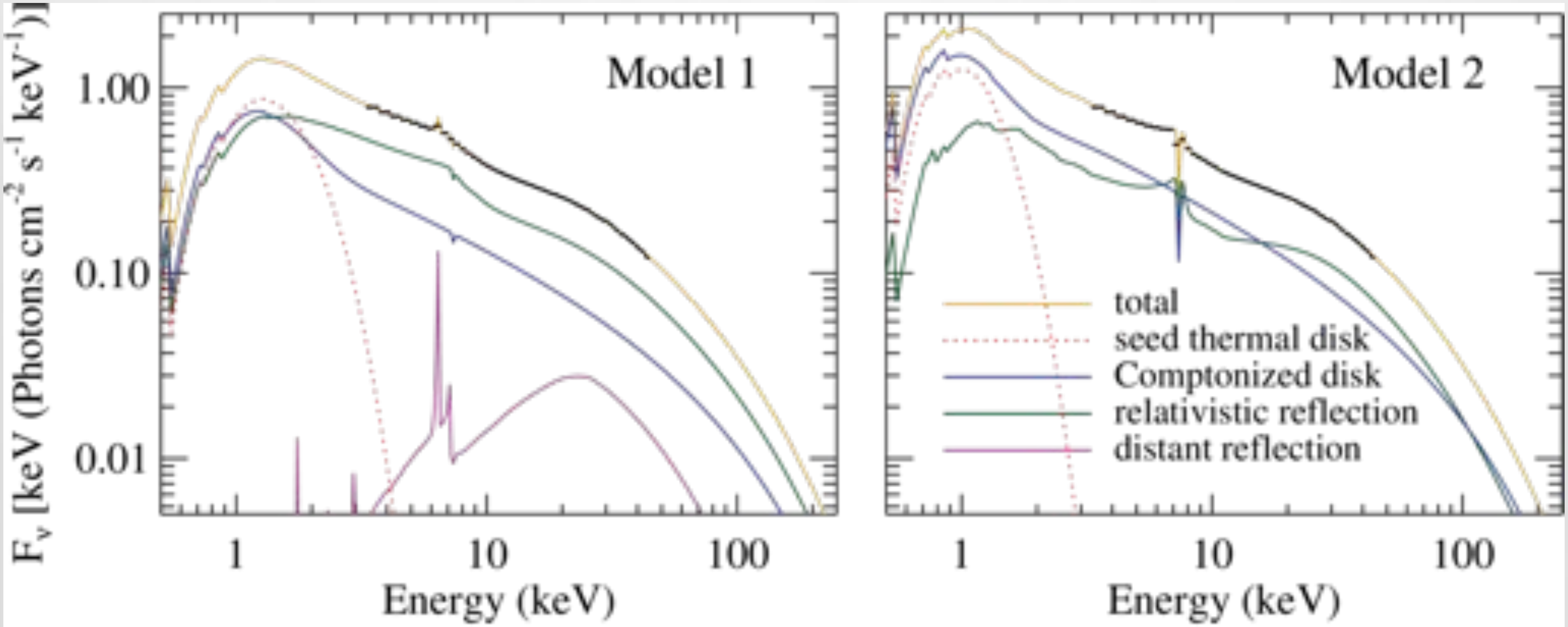



- All photons are properly tallied
- Components can be mutually informed
- Any photon from the inner-disk (reflection and thermal photons) encounters the corona

# Fundamental questions addressed

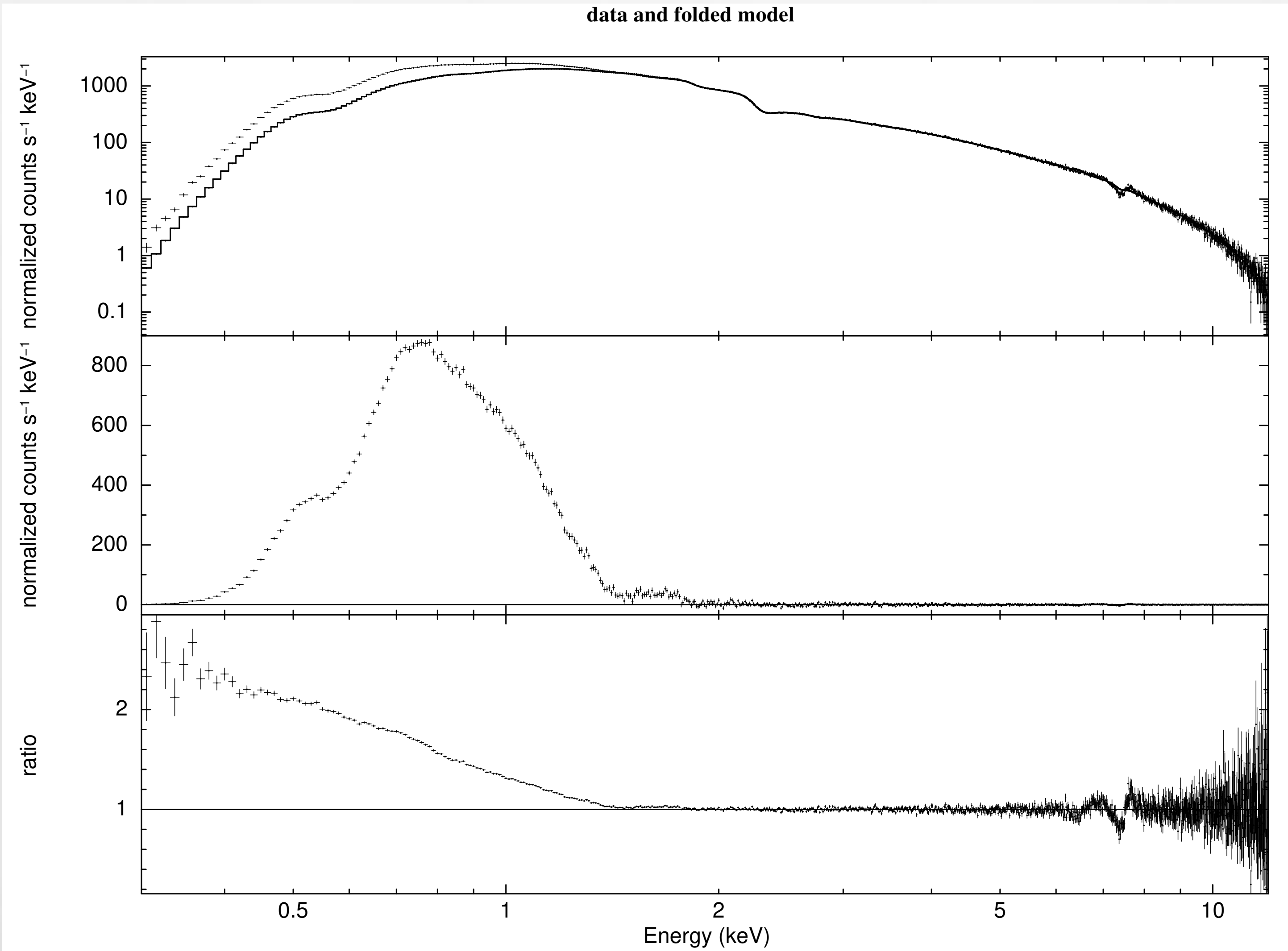
- Is the disk truncated in (bright) hard states?
  - Three strong constraints:  photon counting, relativistic line broadening, and disk temperature
- Do different components yield the same spin?

# GX 339-4 Bright Hard State with RXTE



# Enter NICER

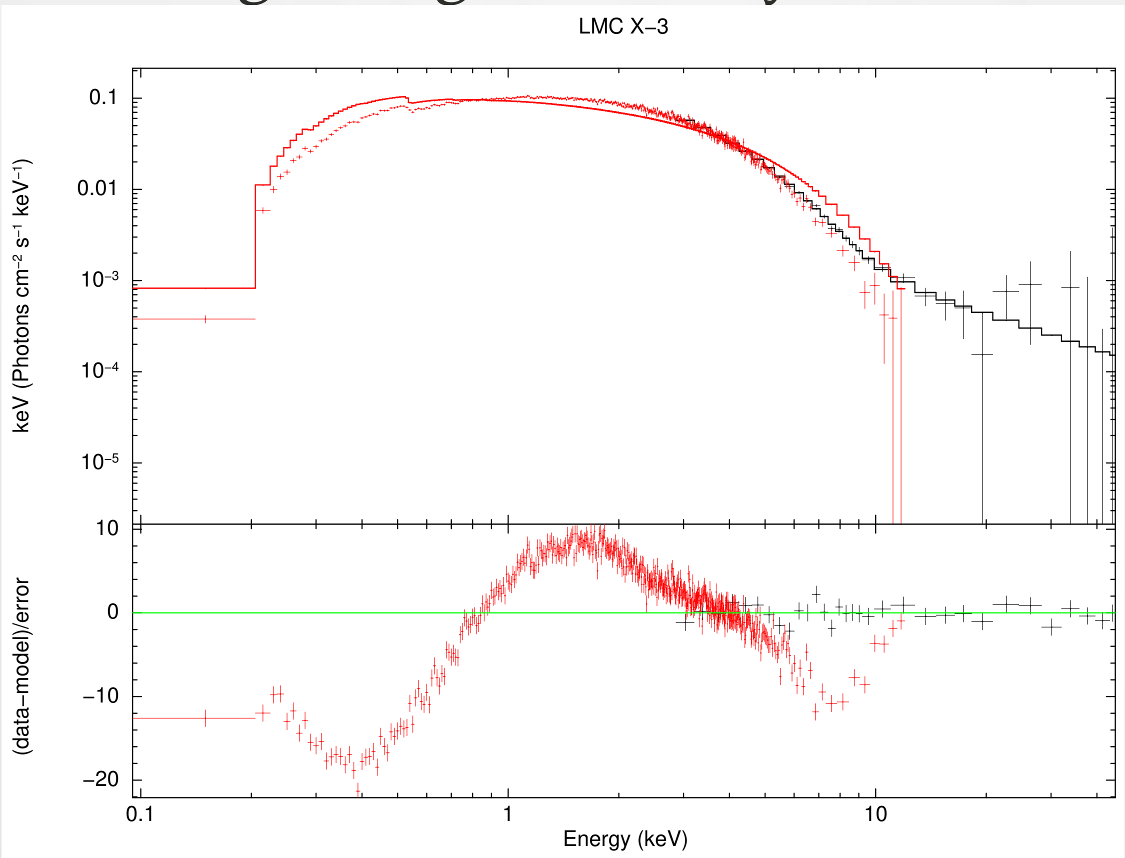
- In only 2ks:



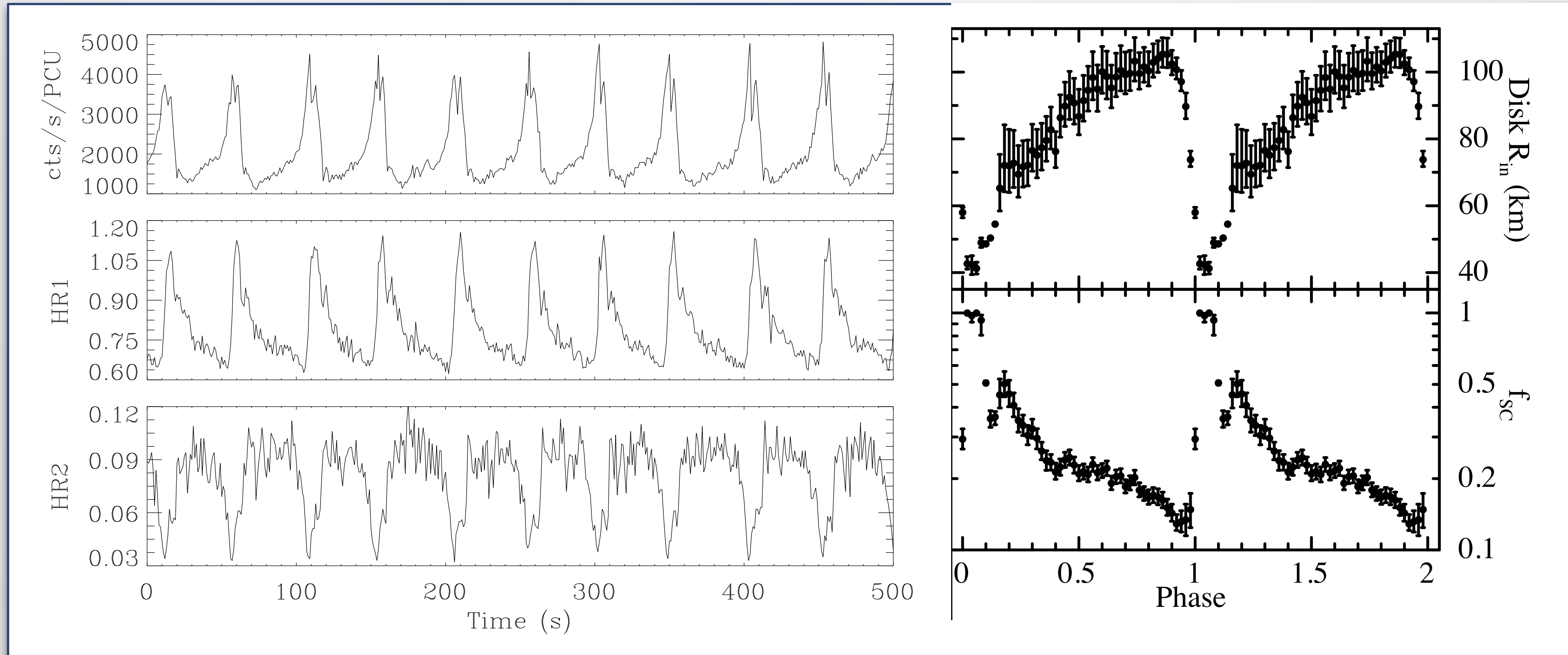
# Accretion Disk Structure

# Probing Disk Structure

- Can directly test for slim disk departure from thin-disk models with growing luminosity

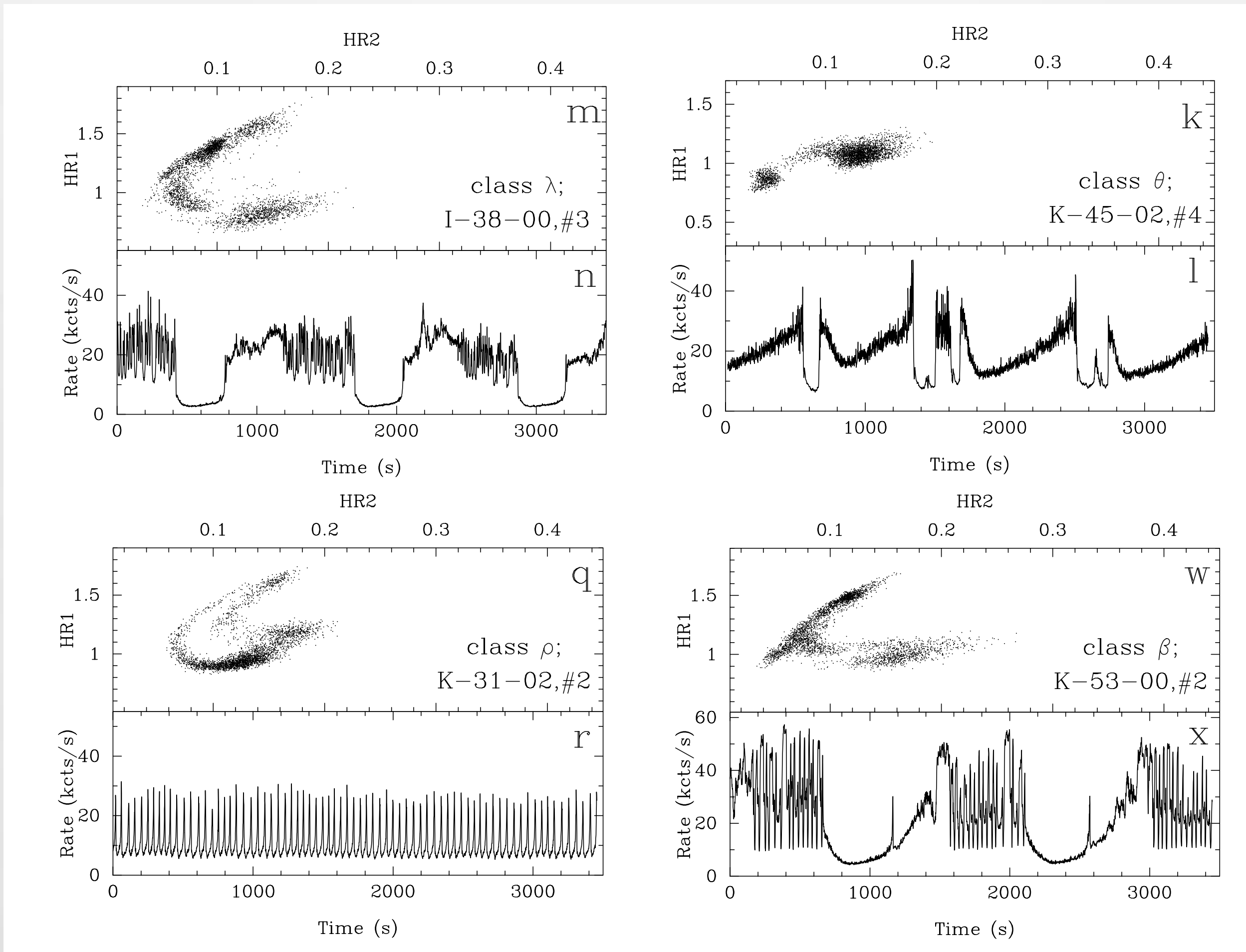


# Disk Instabilities




GRS 1915+105 Heartbeats (Neilsen+2011)

# GRS 1915+105 variable modes



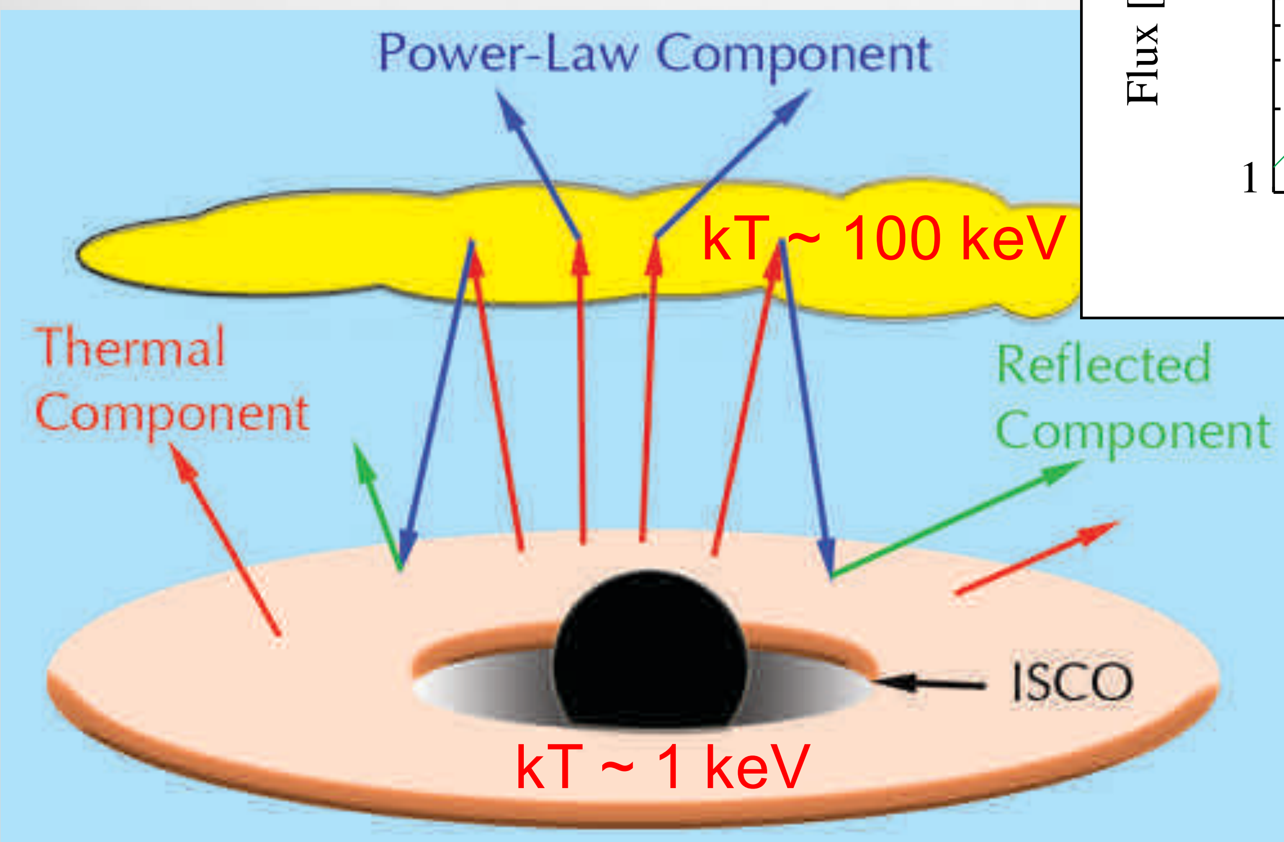

Belloni+2000

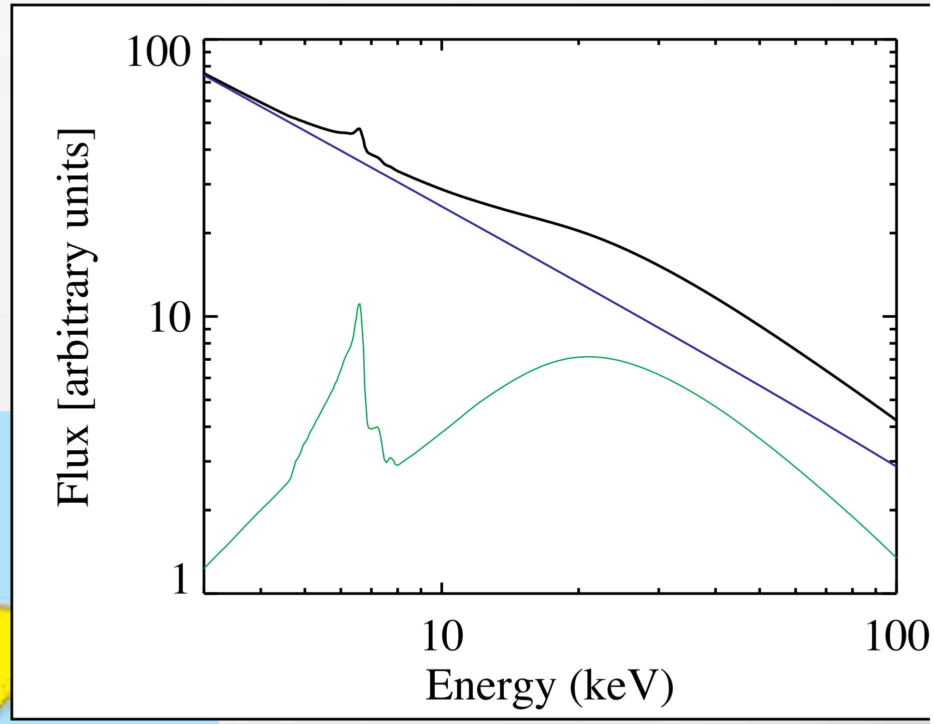
# Spectrally resolving the viscous timescale

- NICER will get a **~10% disk radius each second**
- Probes the viscous timescale for a scale near the ISCO, where most of the X-ray emission is produced.

# Reflection Highlights

# Hot X-ray Corona Illuminating A Cold Disk



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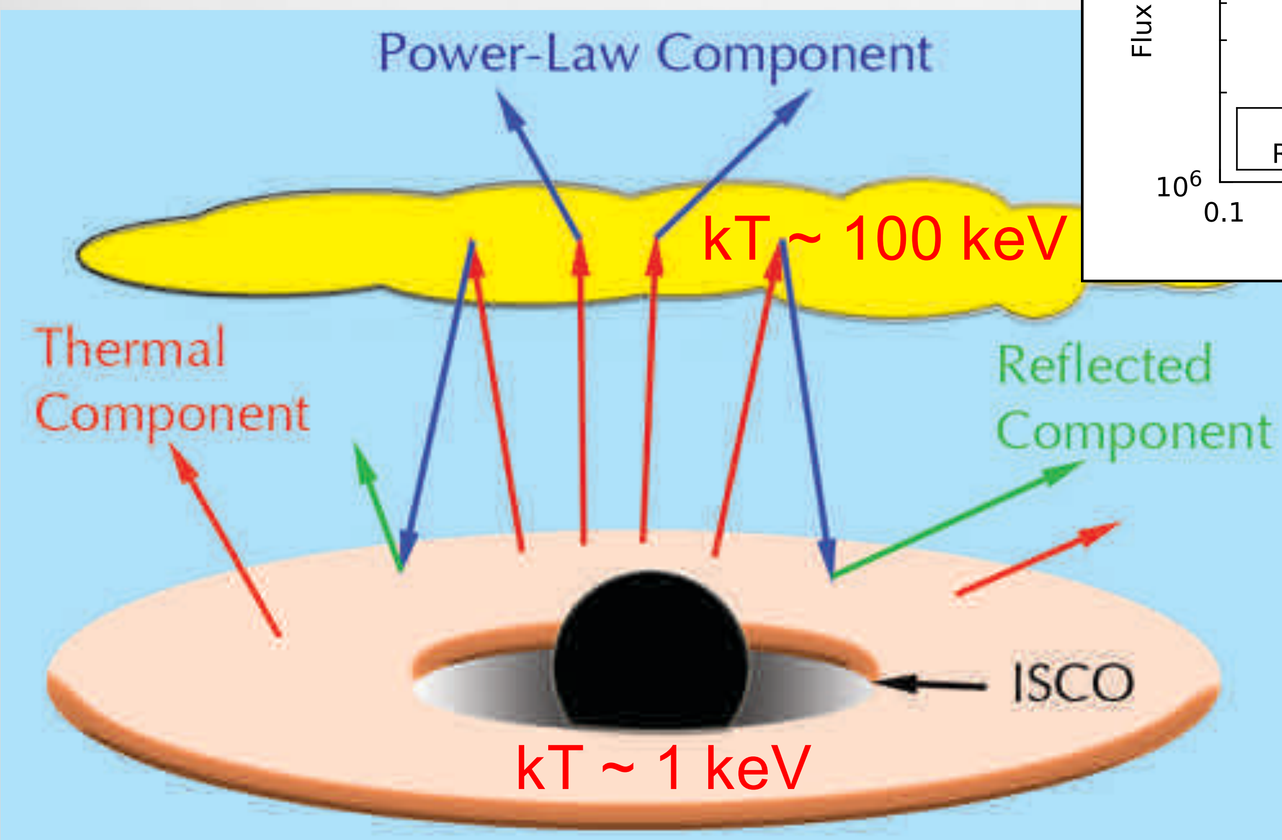
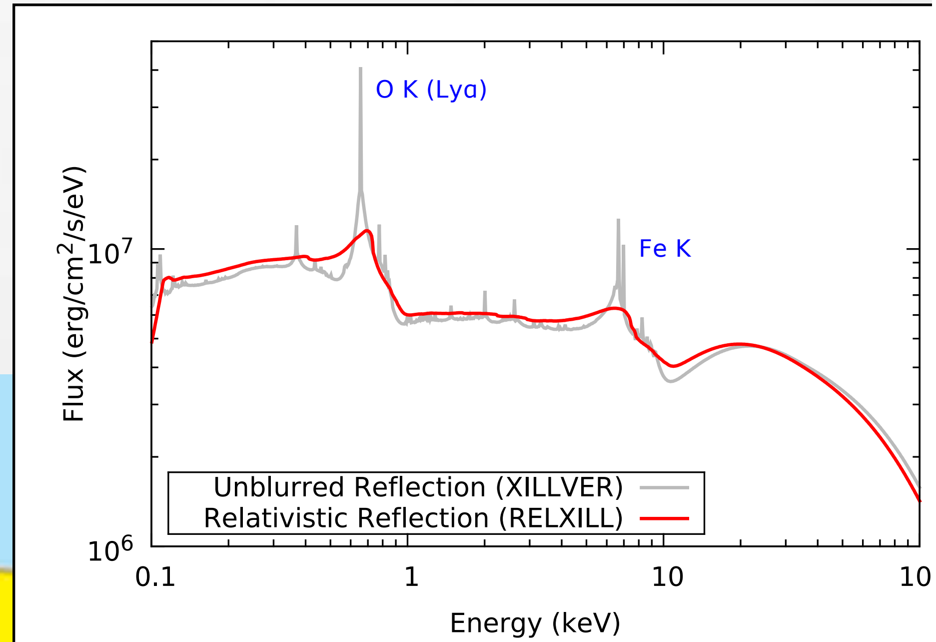
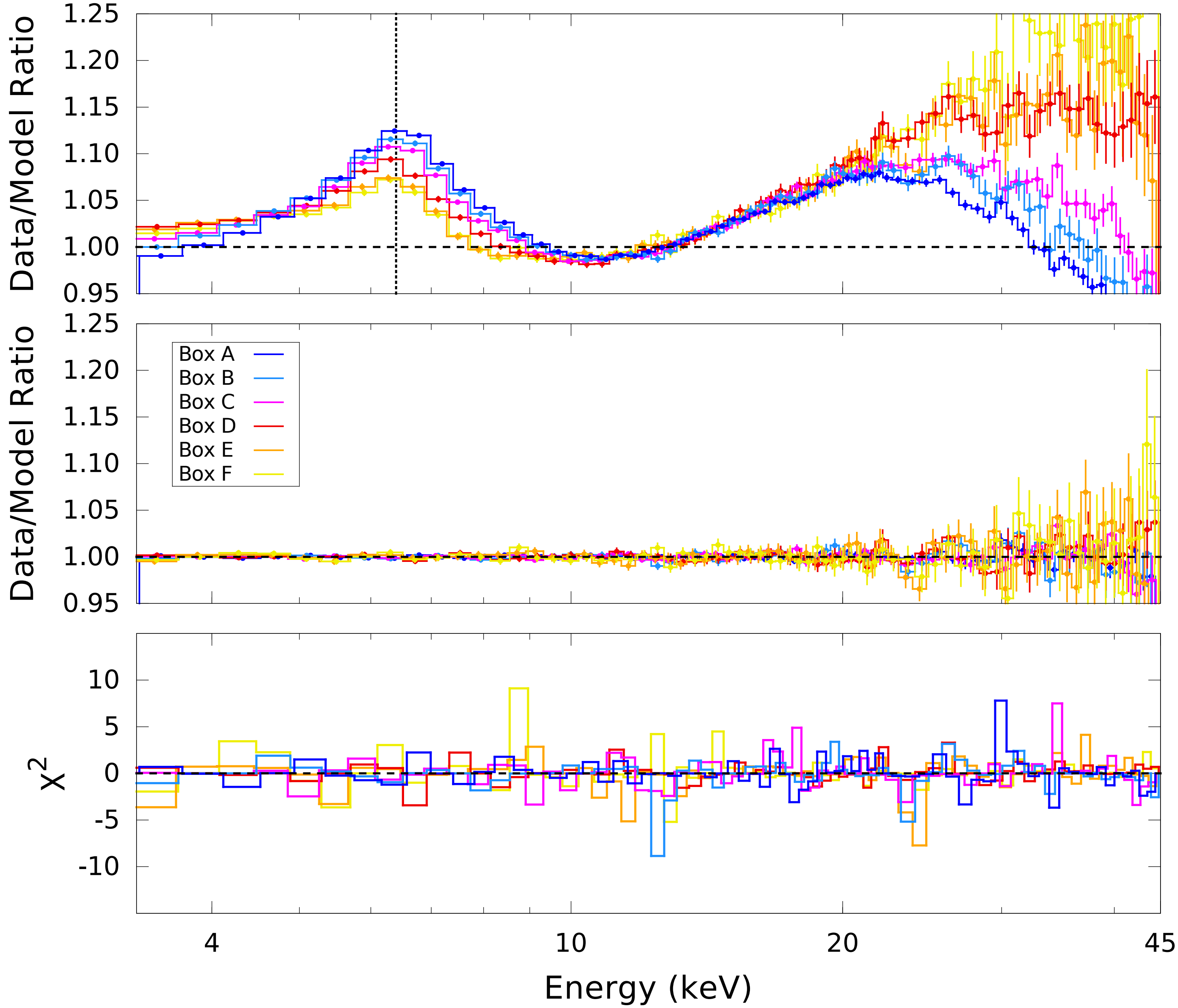
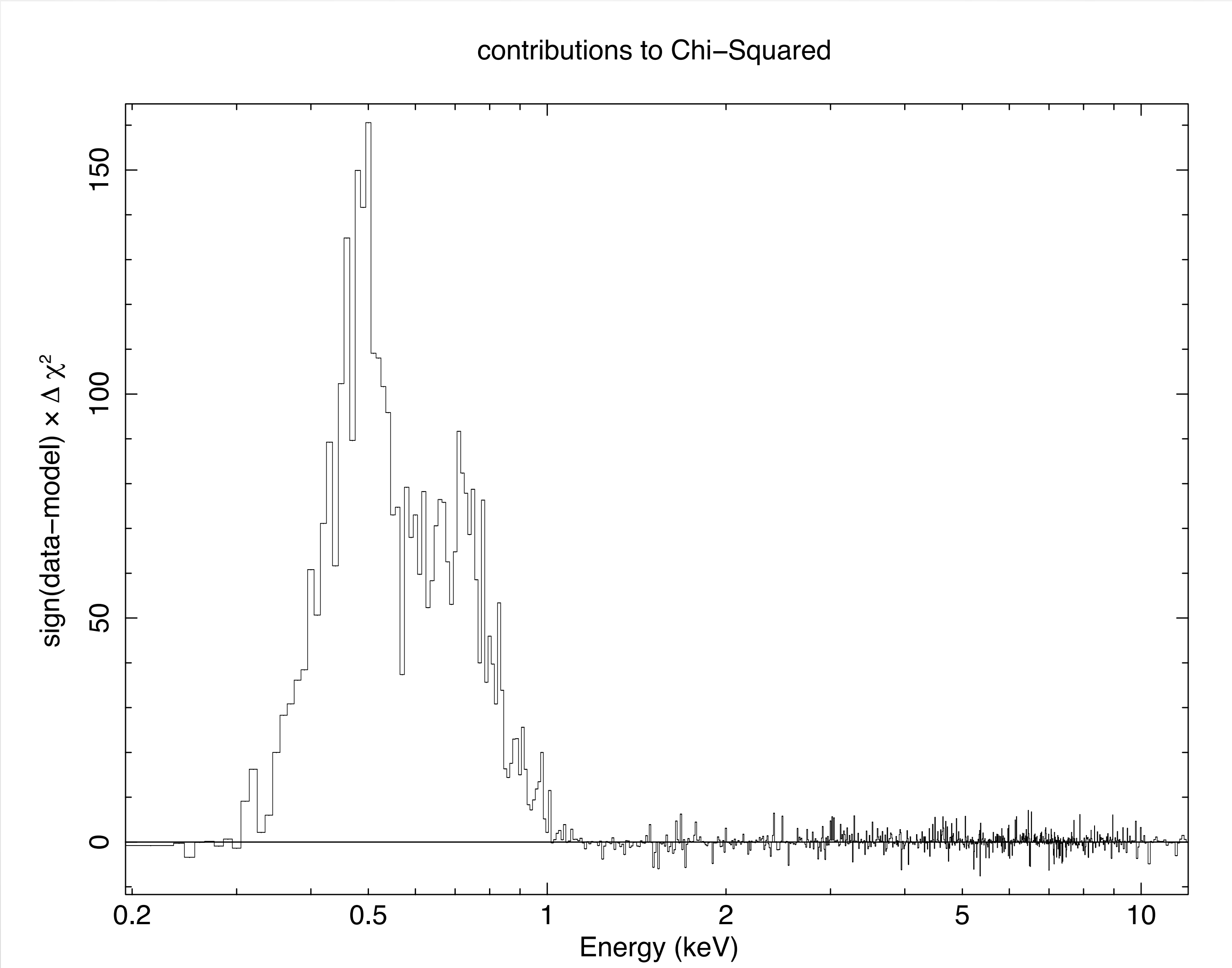





Garcia et al. 2015

# Reflection in a 1 mCrab ULX spectrum with NICER



# NICER's capability for probing accreting BHs

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|---|
| Ability to settle disk truncation controversy |
| Measure spin via thermal continuum, reflection, and timing methods |
| Count rates to match or surpass RXTE, sensitive to soft disk |
| Probe accretion variations on viscous timescale |
| Probe reflection using Fe-L (AGN) or O-K (stellar / ULX) |
| Spectral-timing modeling to constrain accretion / coronal geometry |
| Test HF-QPO models (particularly the disk origin) |
| Observe slim-disk / thin-disk transition directly |
| **Being free of pileup is crucial for stellar BH science** |