A NICER Look at Spinning Black Holes

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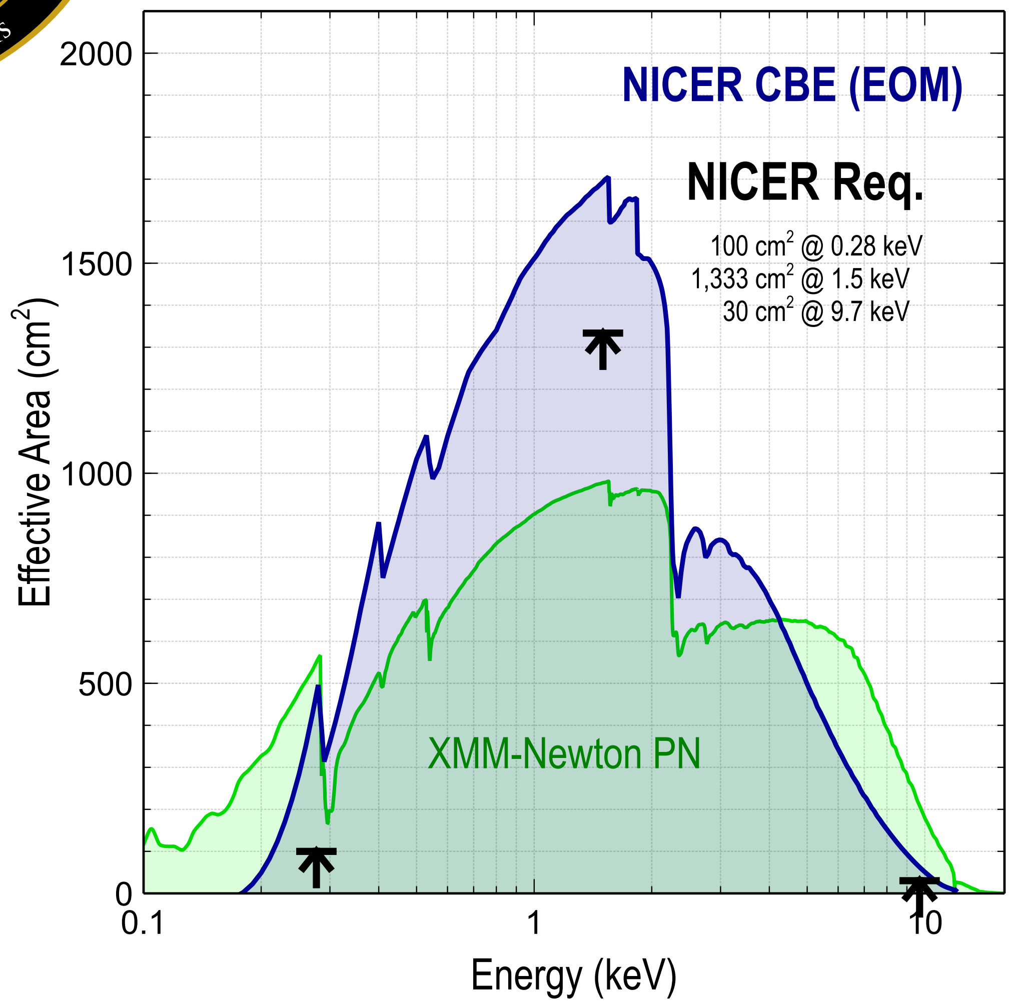
NICER specs

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

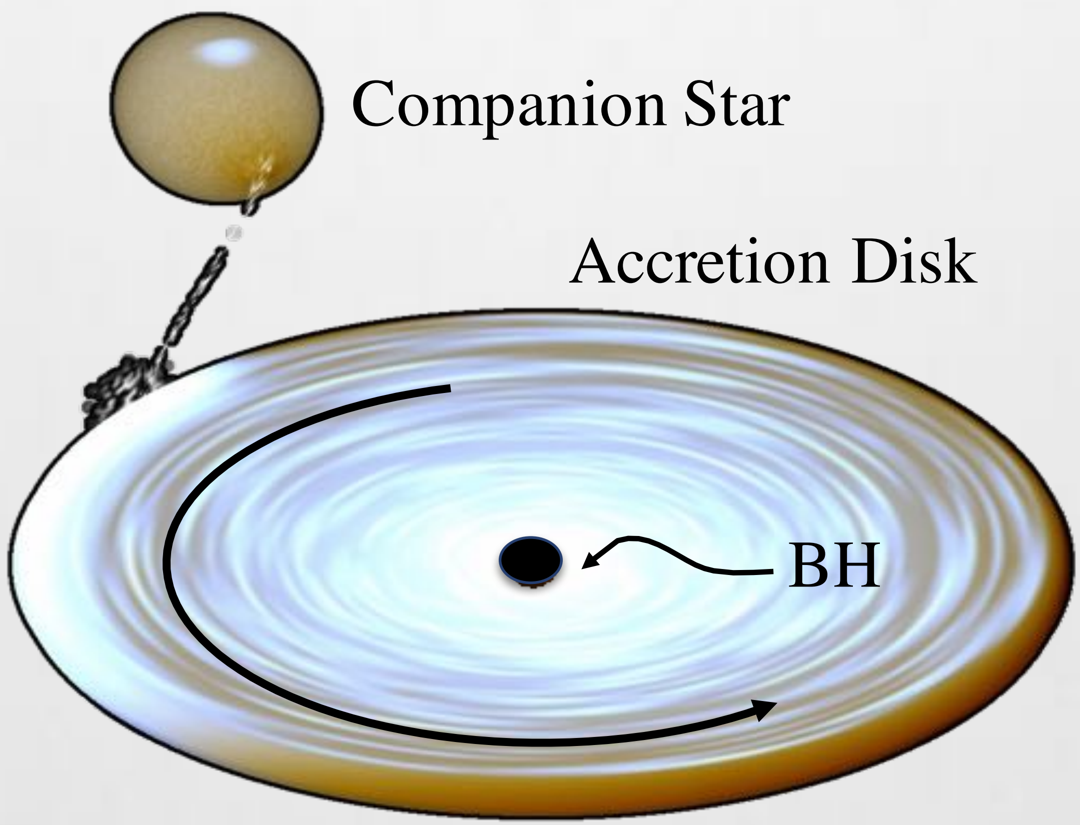
Sensitivity: 3×10^{-14} ergs s^{-1} cm^{-2}
(0.5–10 keV, 5σ in 10 ksec)
~30x better than RXTE,
~4x better than XMM

NO PILEUP!



Stellar Mass BHs

Typical BH Transient



(fig: R. Hynes, C. Markwardt)

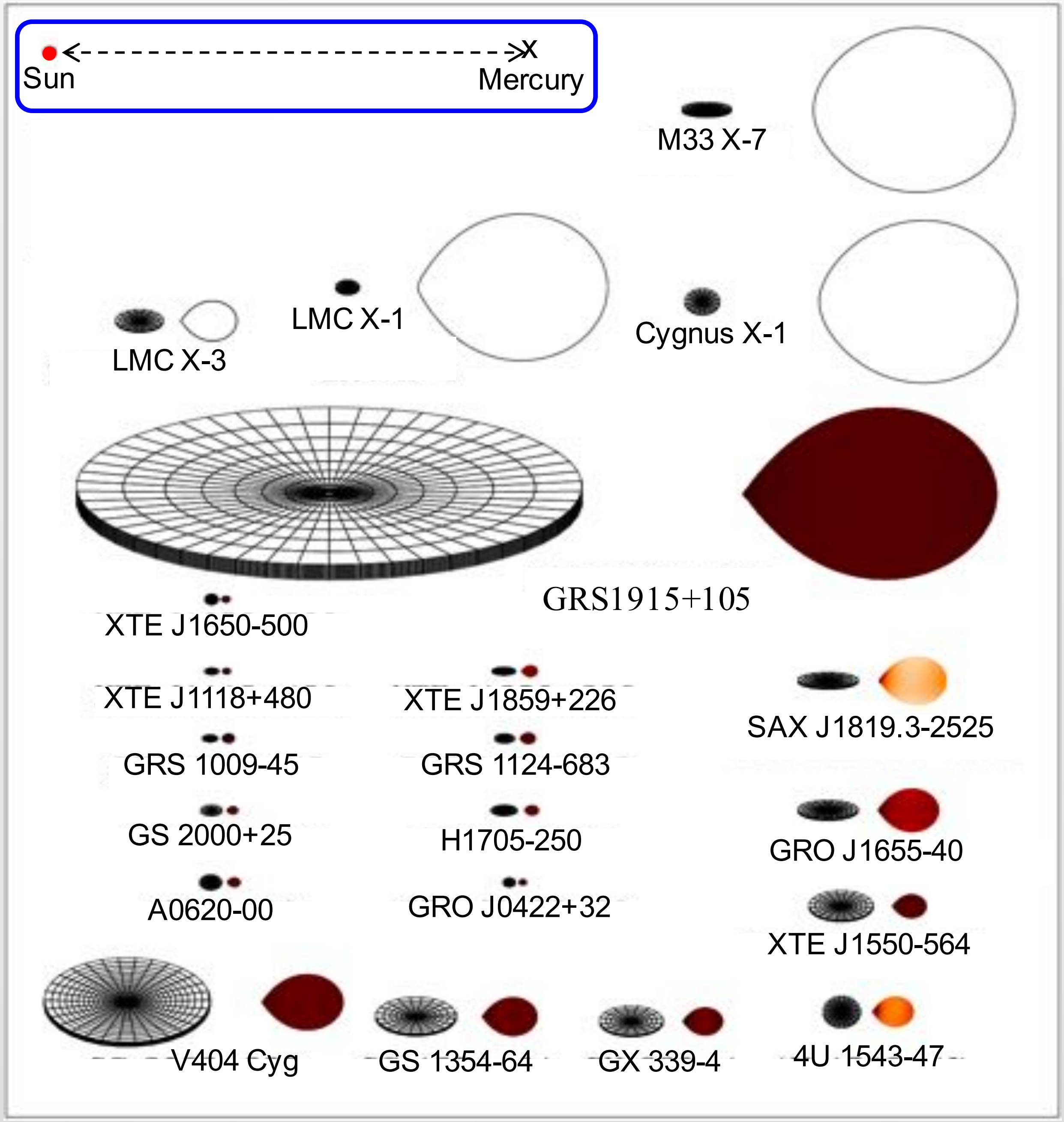
Black Holes are Simple

- Mass: M

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

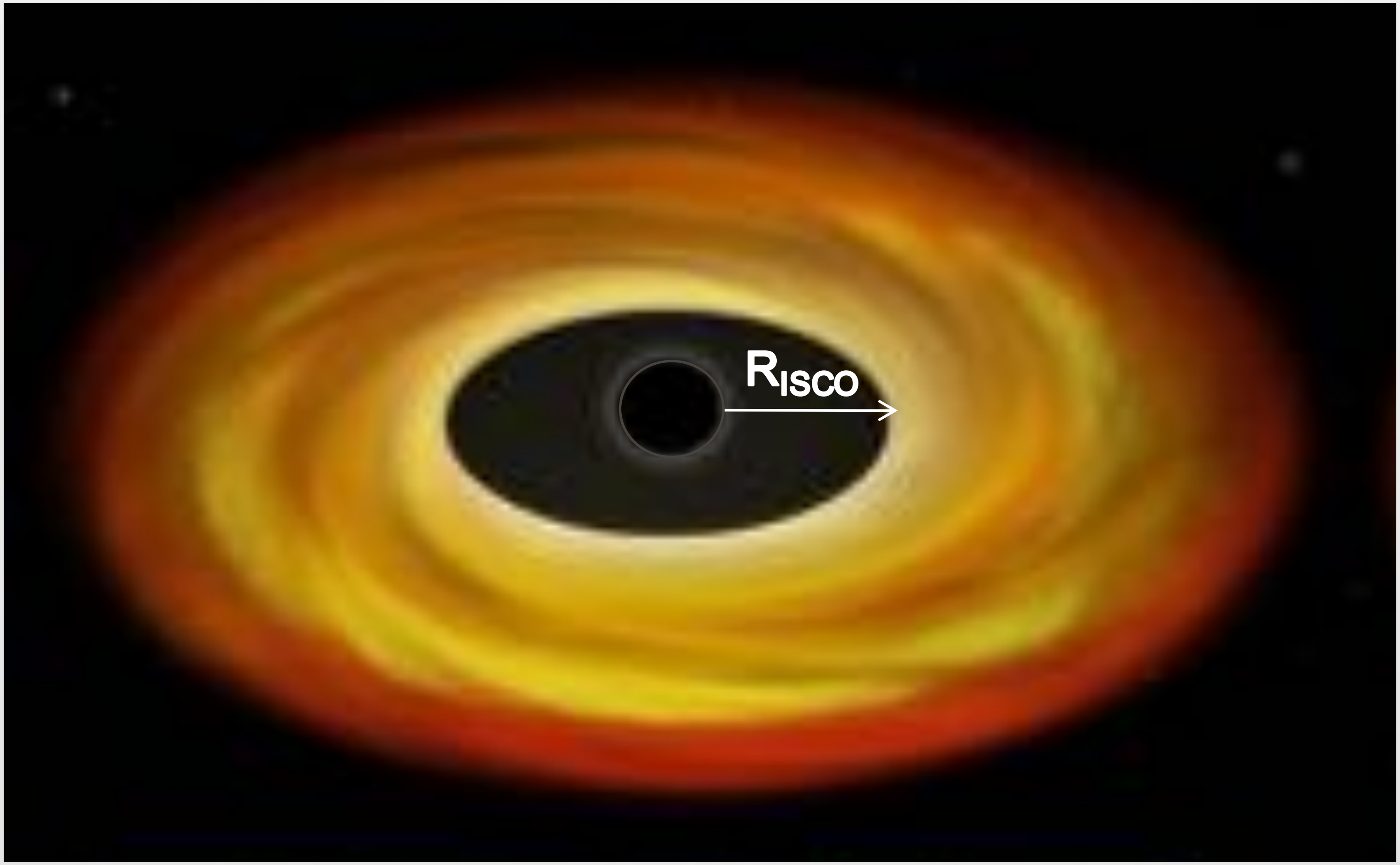
Charge neutralized and unimportant

The Black Hole Binary Zoo

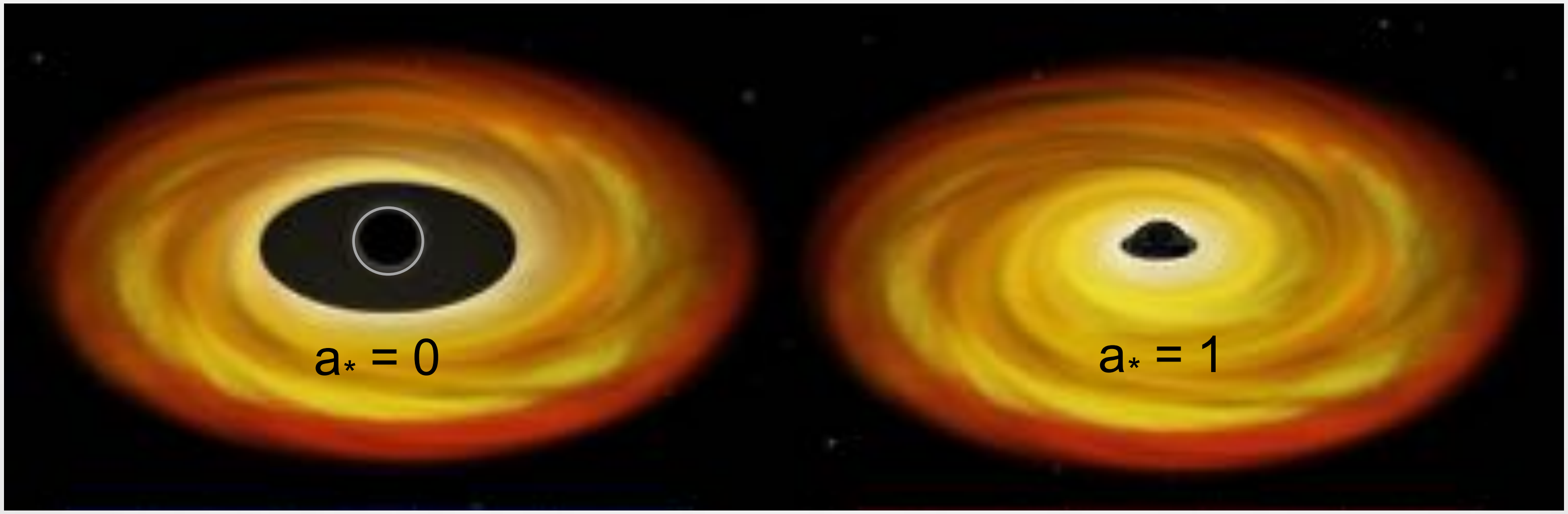


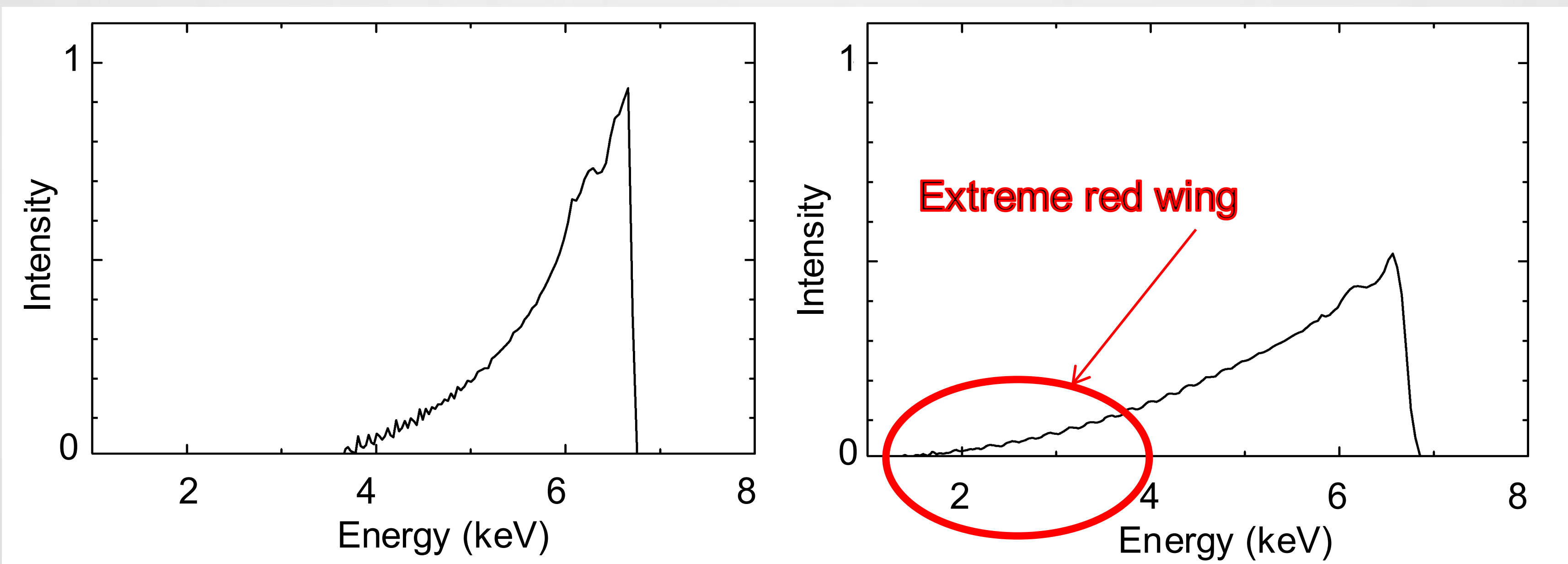
Courtesy: J. Orosz

Measuring the Inner Disk Radius



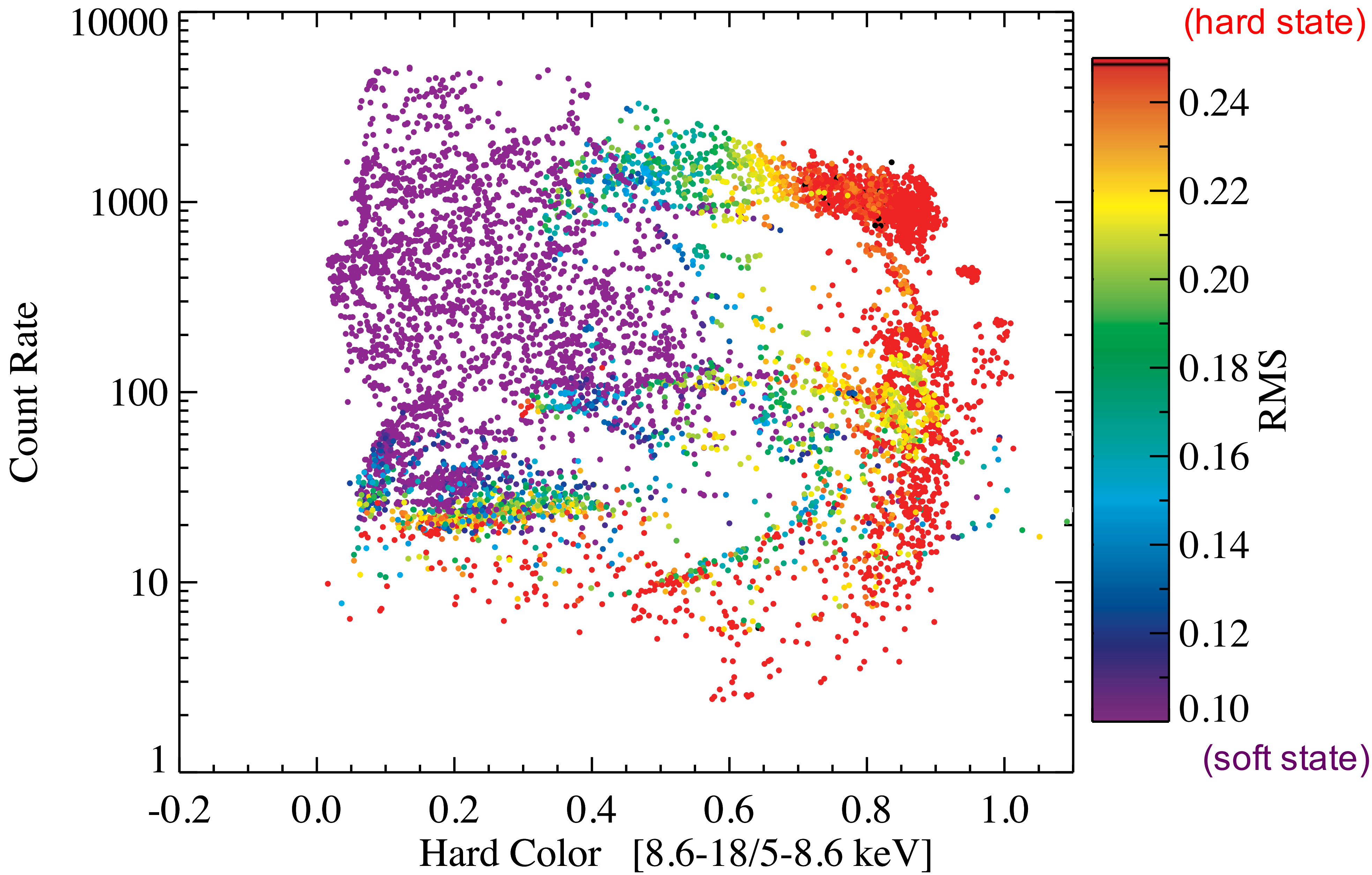
Continuum+Reflection Effects

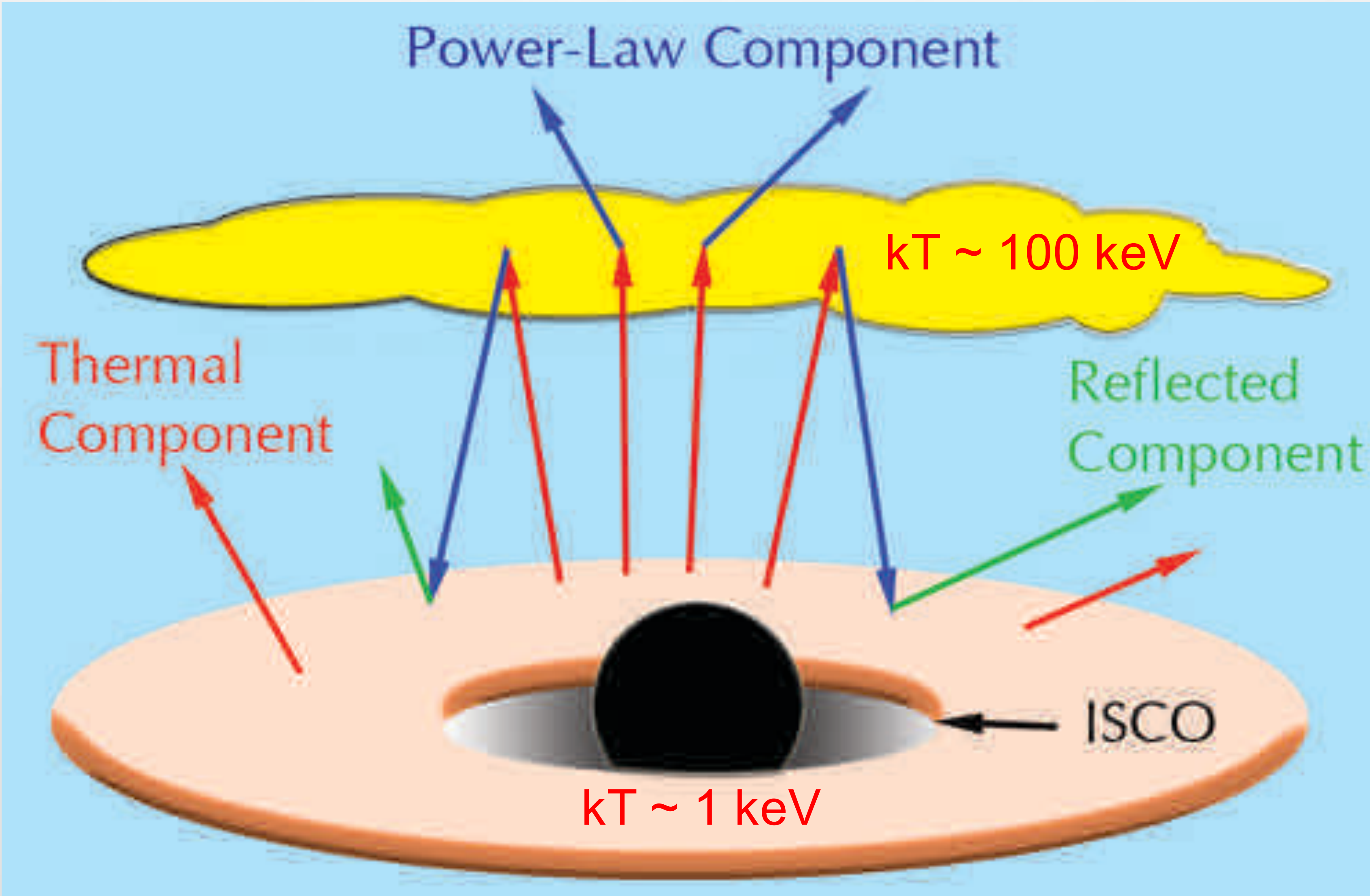




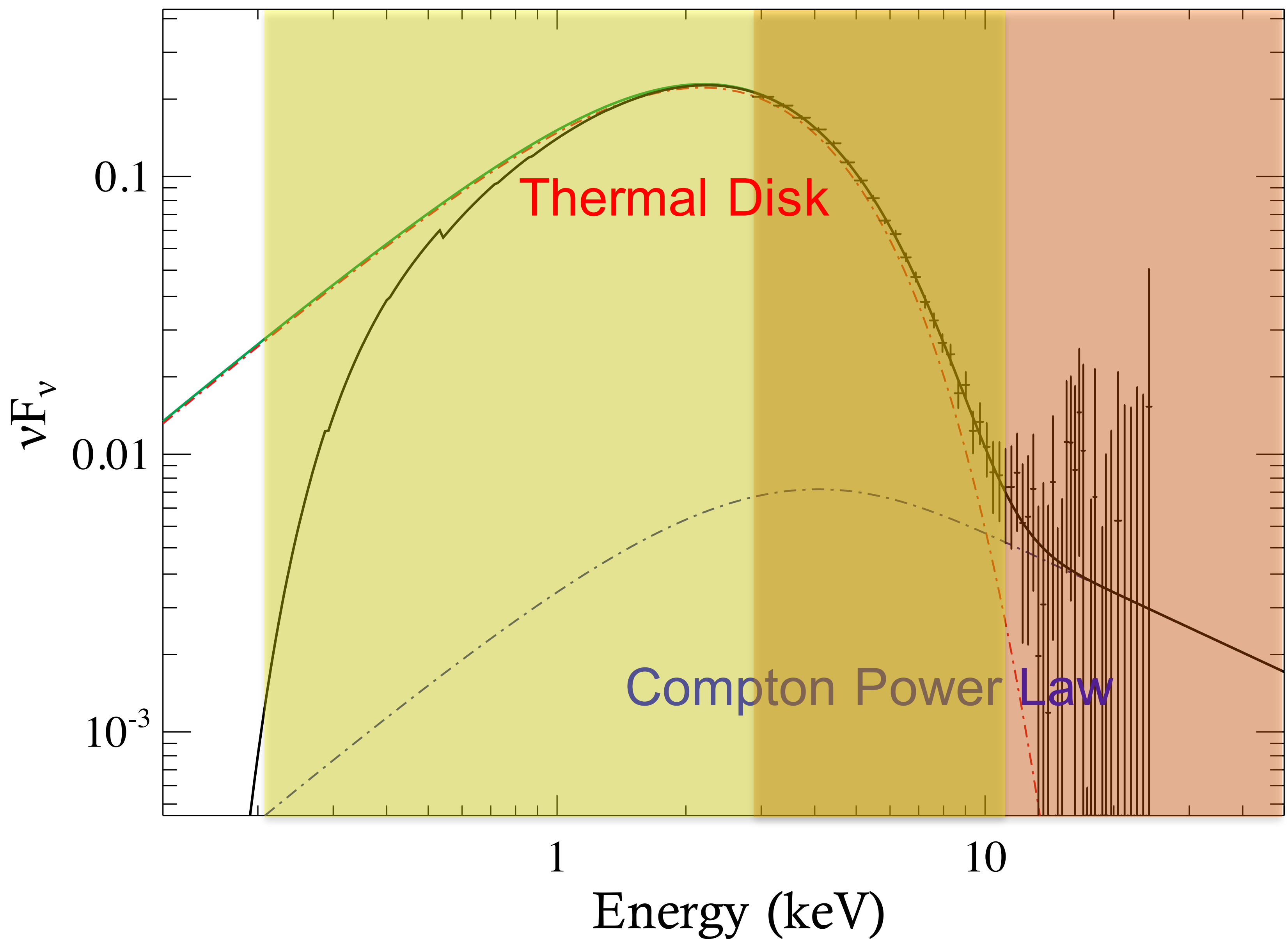
Black Holes are Complex

The RXTE Road Map

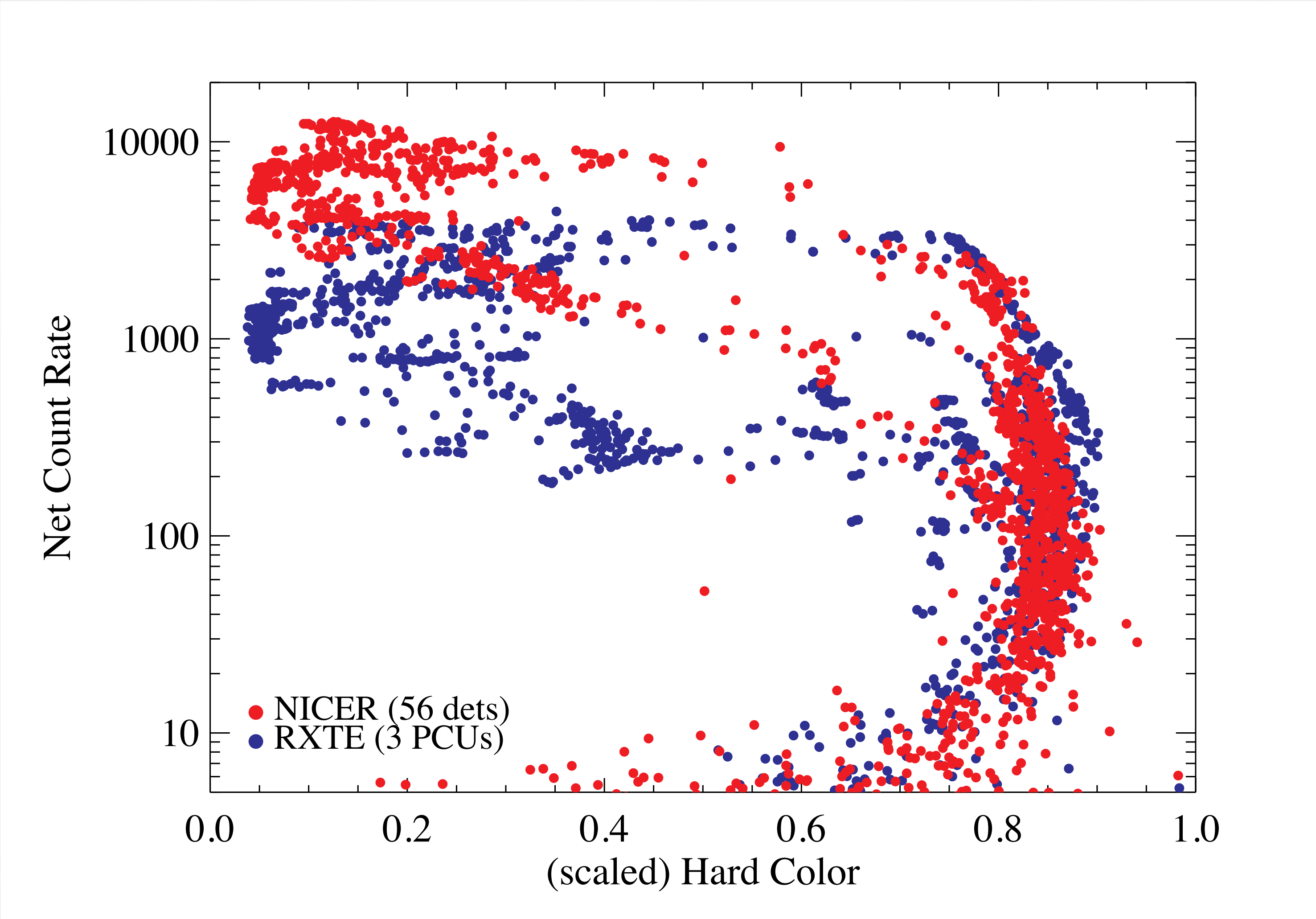



Power-Law Component
kT ~ 100 keV
Thermal Component
Reflected Component
ISCO
kT ~ 1 keV

NICER vs RXTE



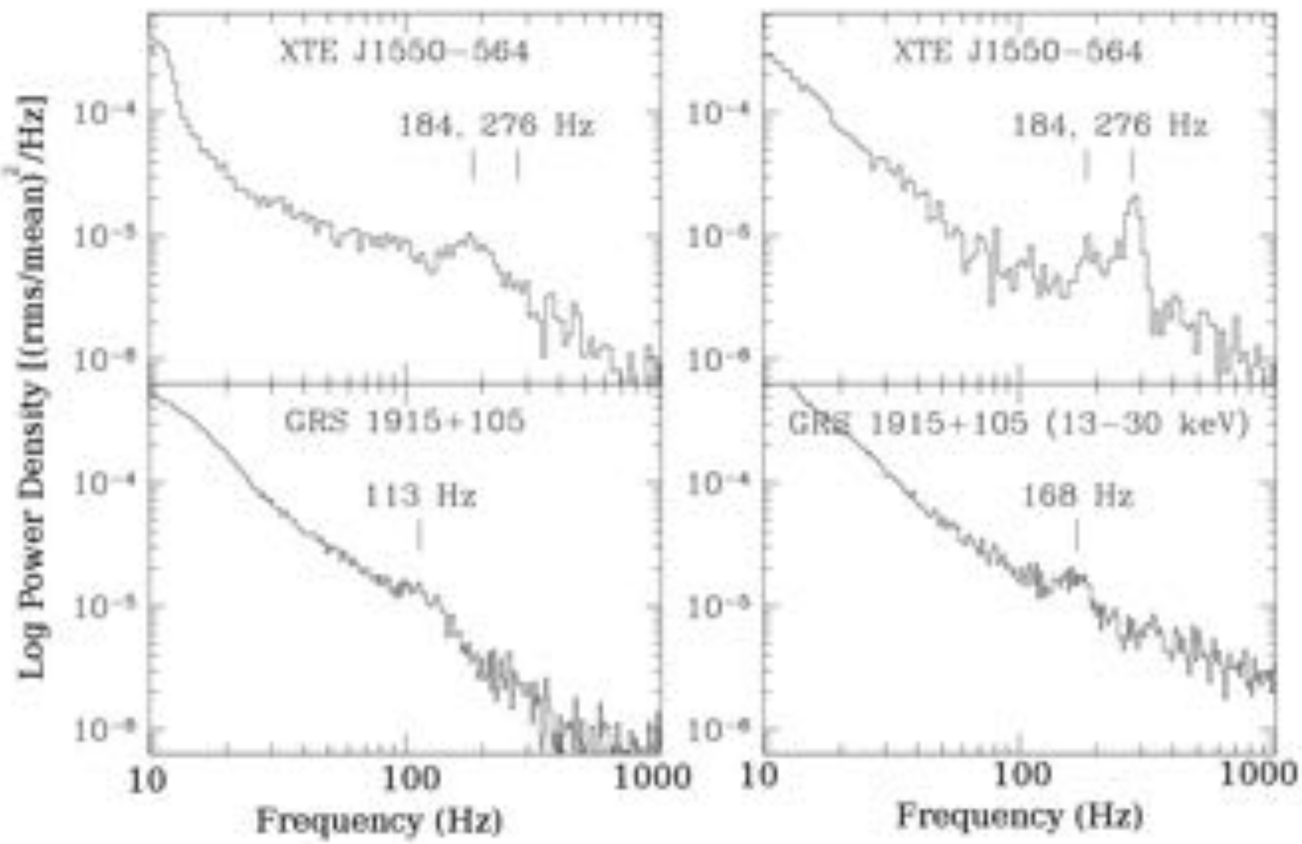
NICER vs RXTE for GX339-4

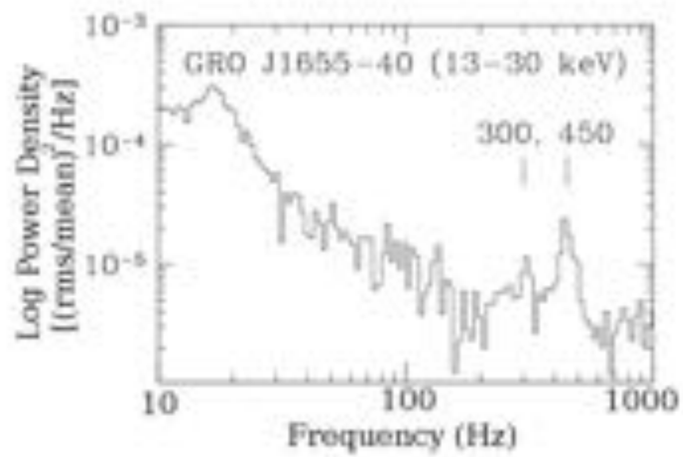


Punchline

NICER meets or exceeds RXTE count rates for black holes.

Spin in the Time-Domain



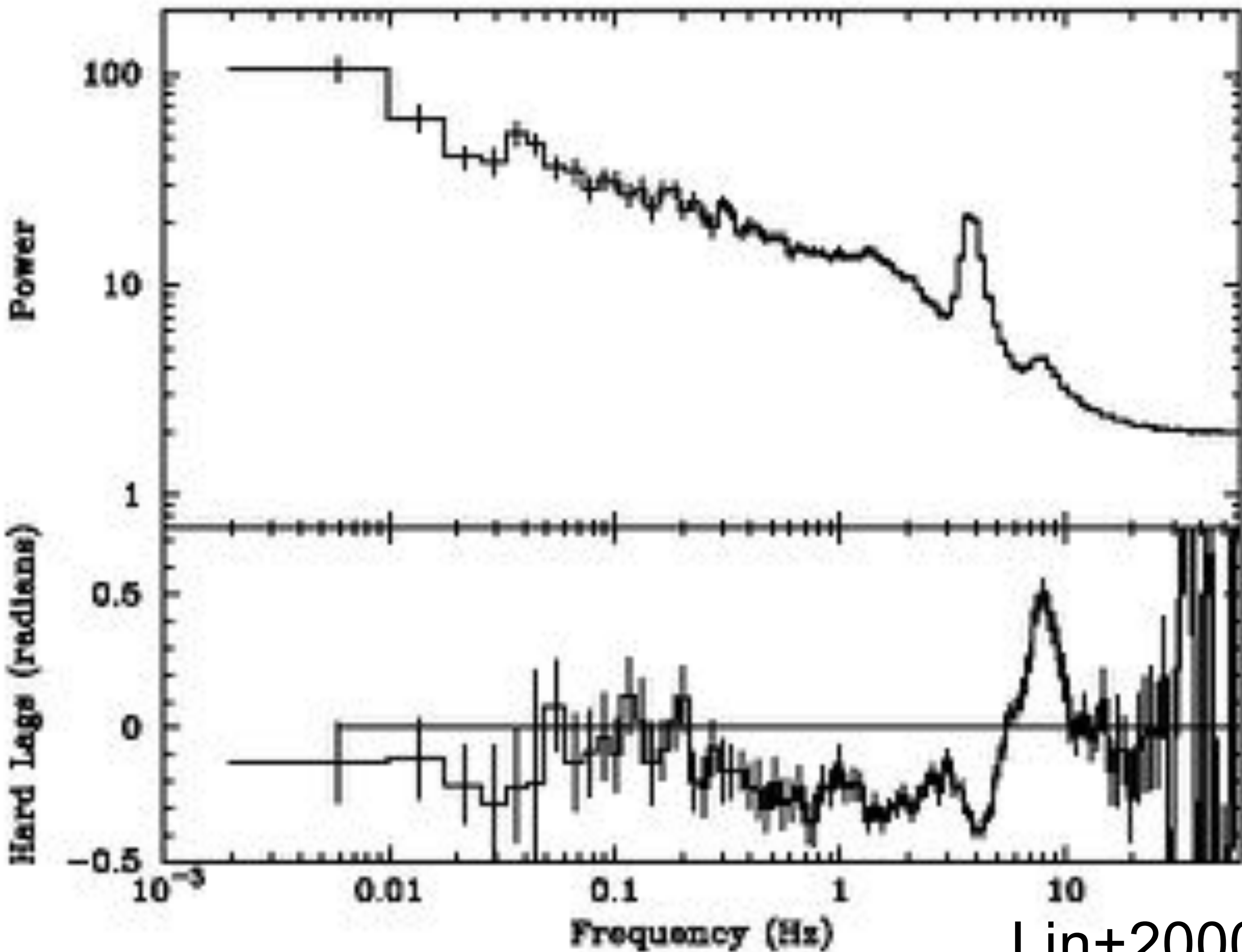


McClintock & Remillard (2006)

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

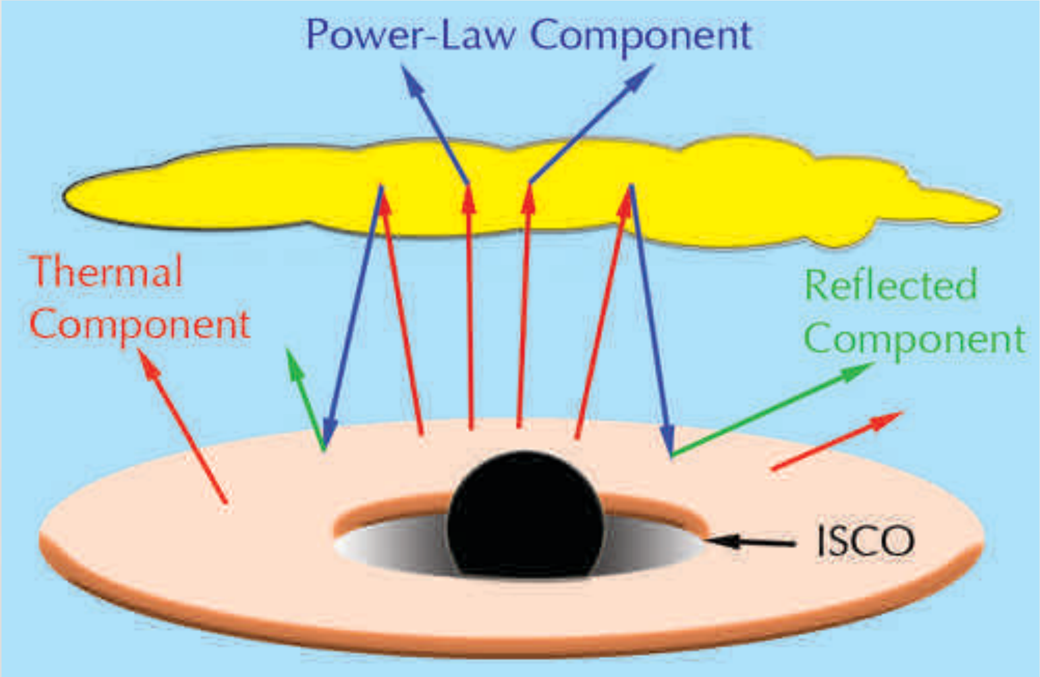
GRS 1915+105



Lin+2000

Spectral Modeling

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

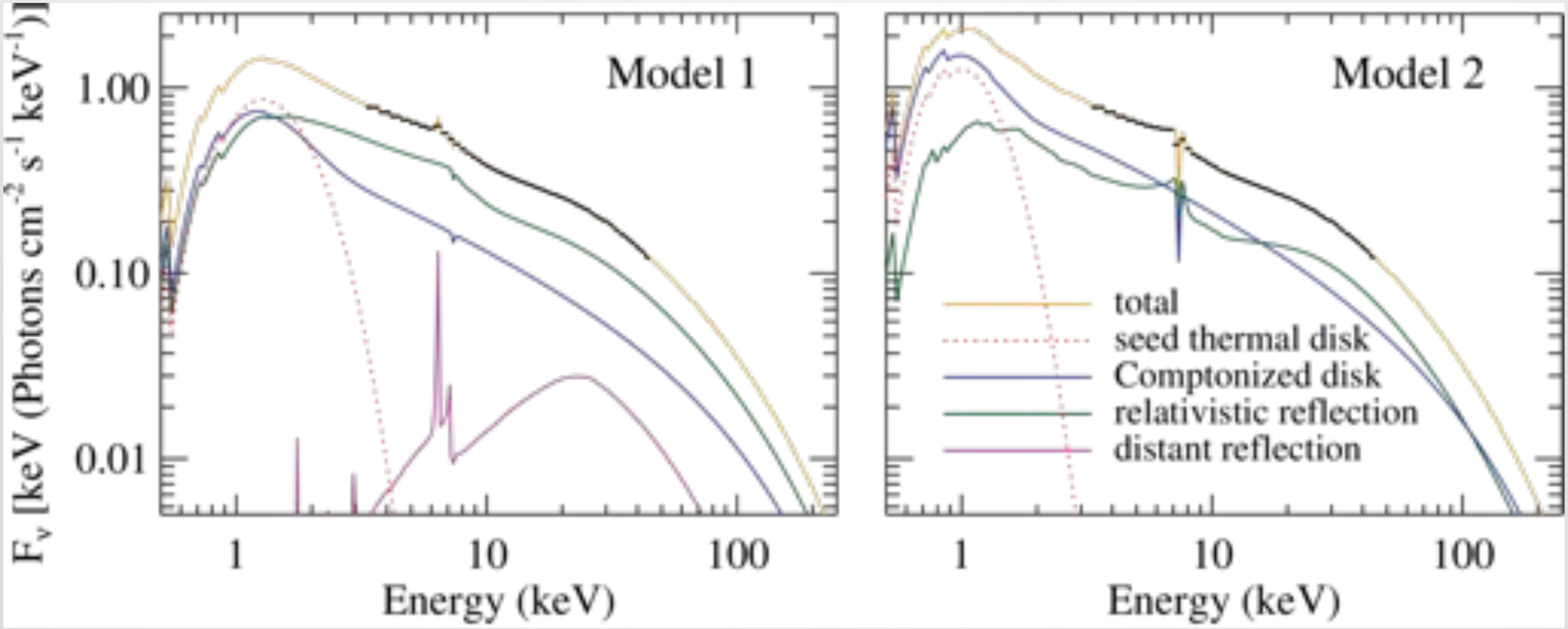


- All photons are properly tallied
- Components can be mutually informed
- Any photon from the inner-disk (reflection and thermal photons) encounters the corona

Fundamental questions addressed

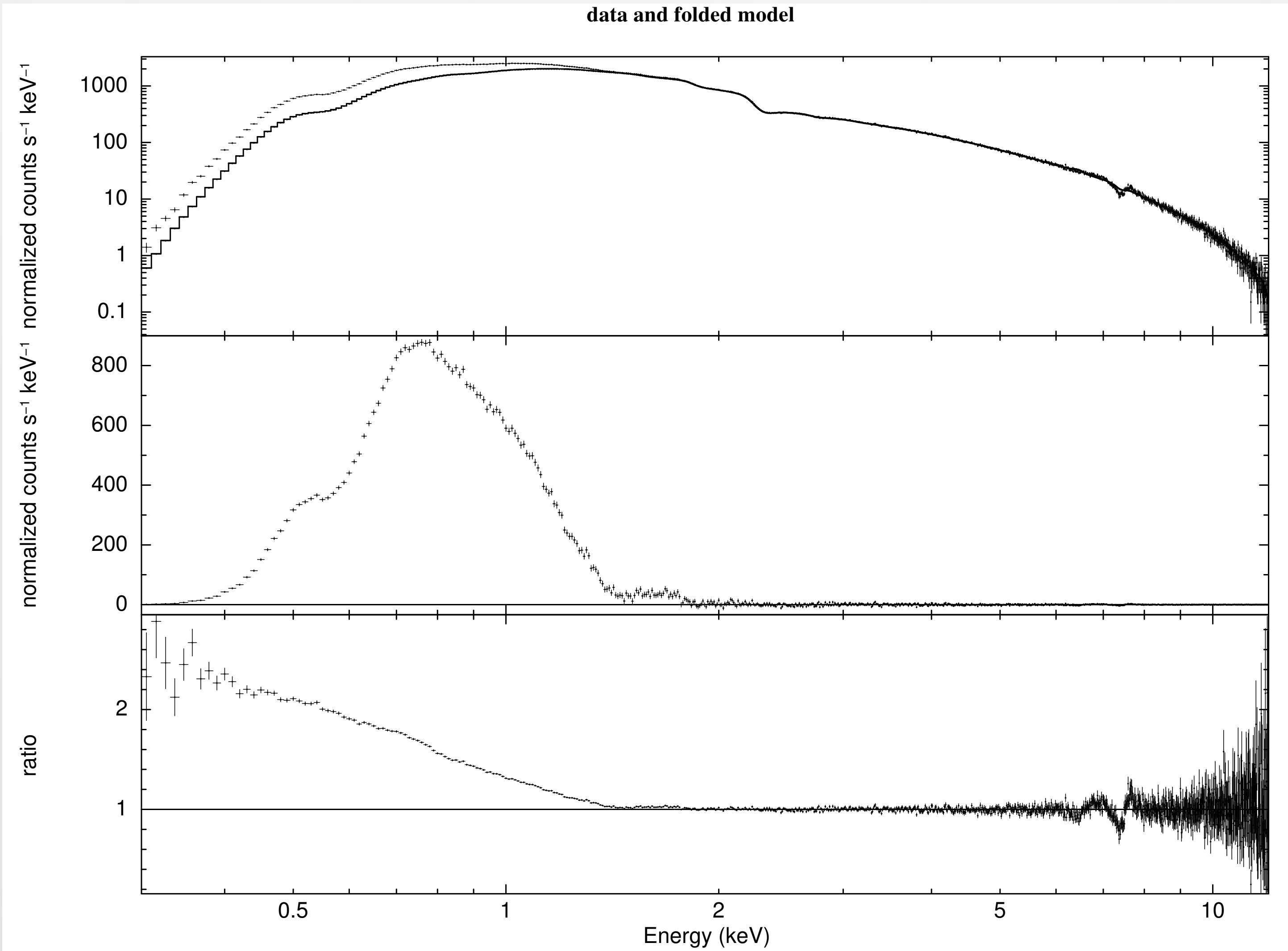
- Is the disk truncated in (bright) hard states?
  - Three strong constraints: photon counting, relativistic line broadening, and disk temperature
- Do different components yield the same spin?

GX 339-4 Bright Hard State with RXTE



Enter NICER

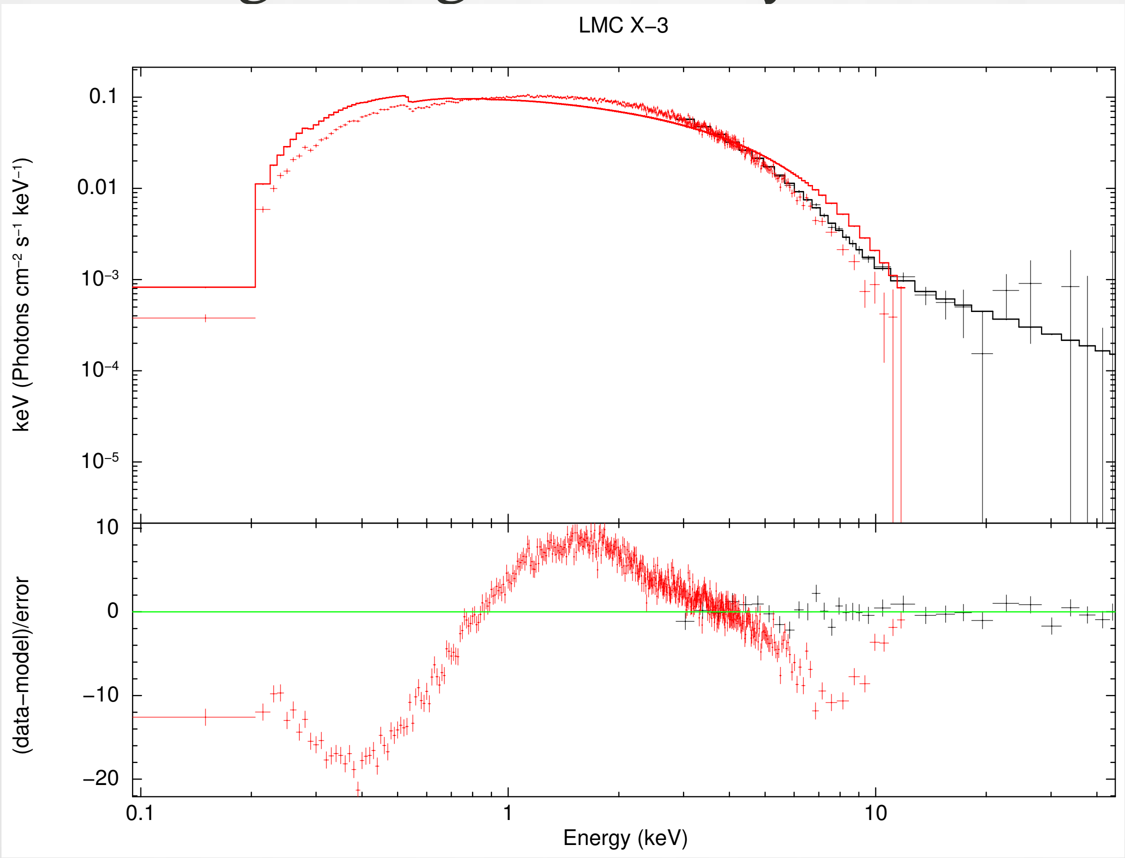
- In only 2ks:



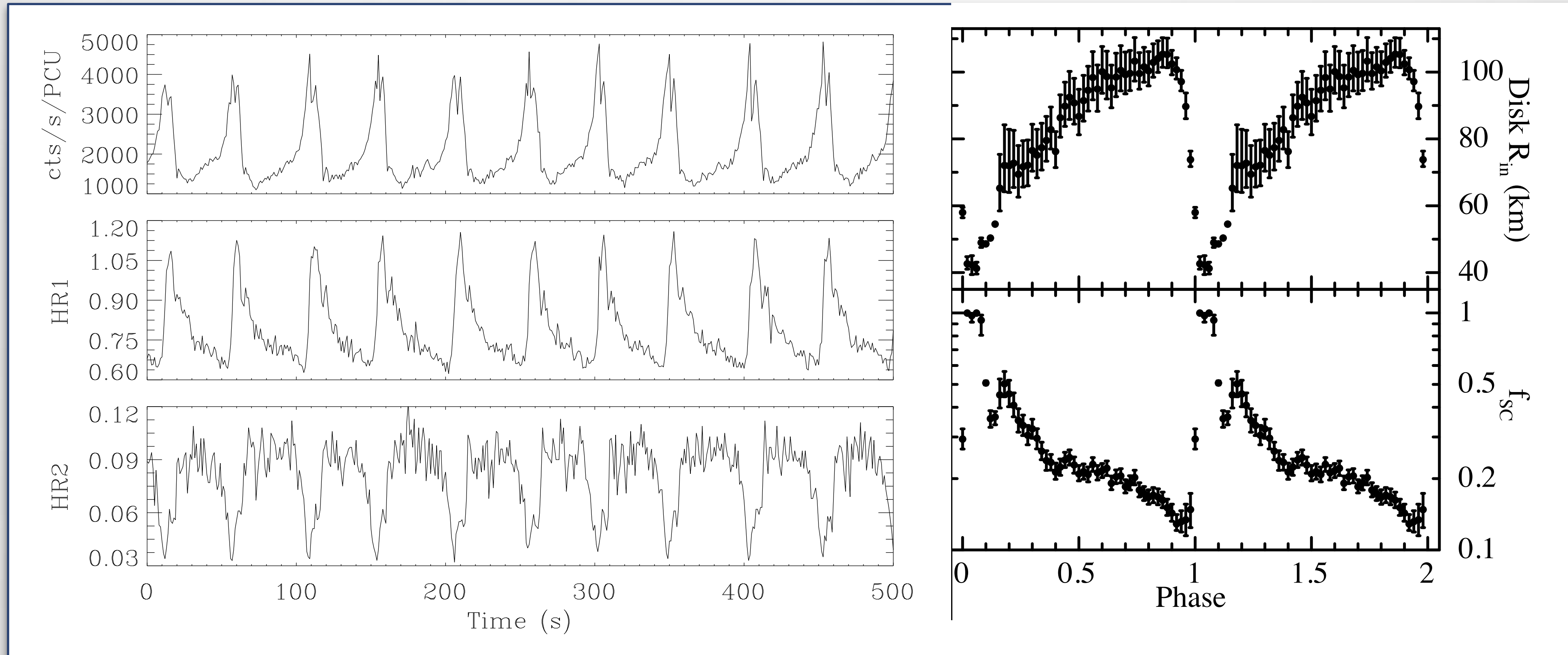
Accretion Disk Structure

Probing Disk Structure

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

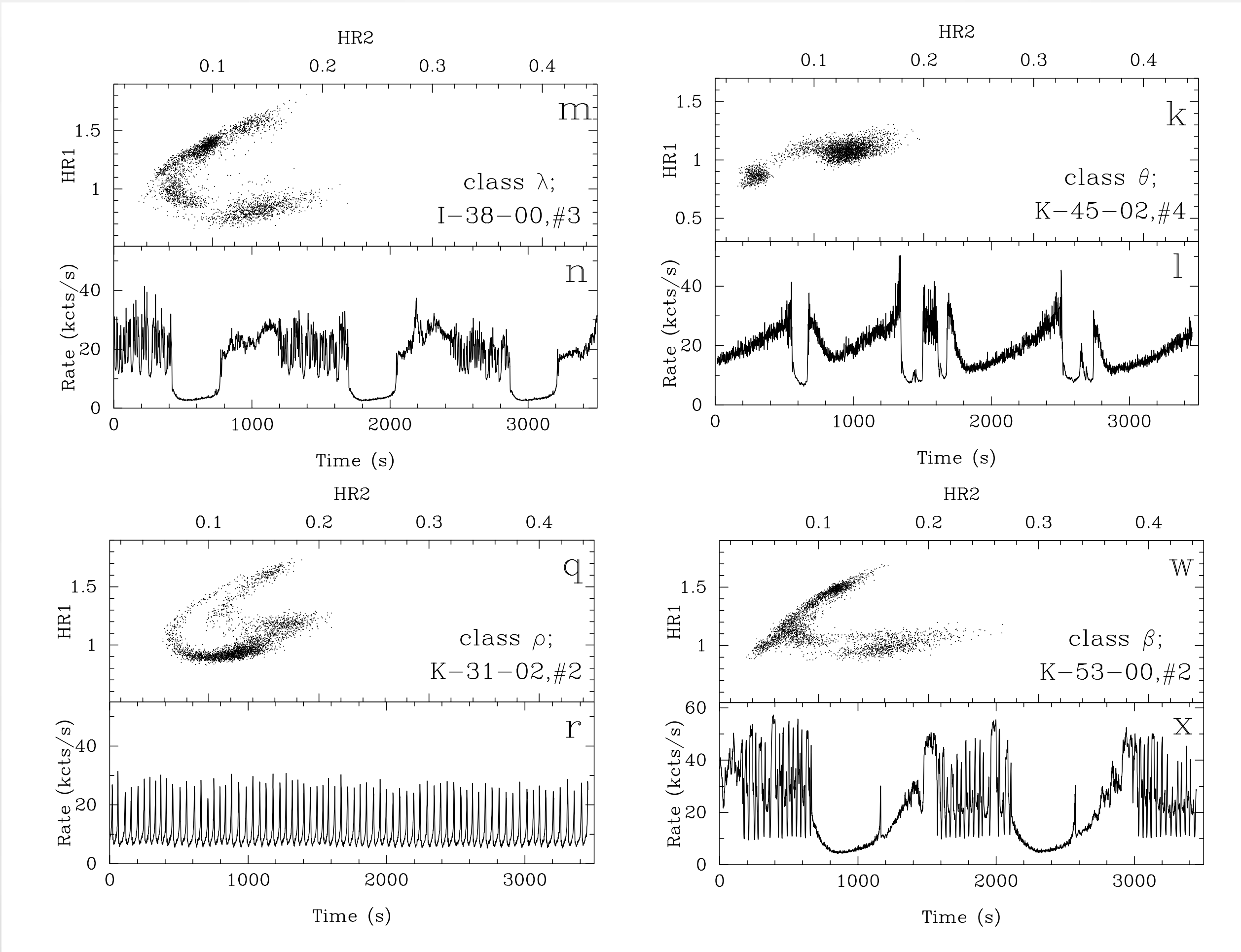


Disk Instabilities



GRS 1915+105 Heartbeats (Neilsen+2011)

GRS 1915+105 variable modes



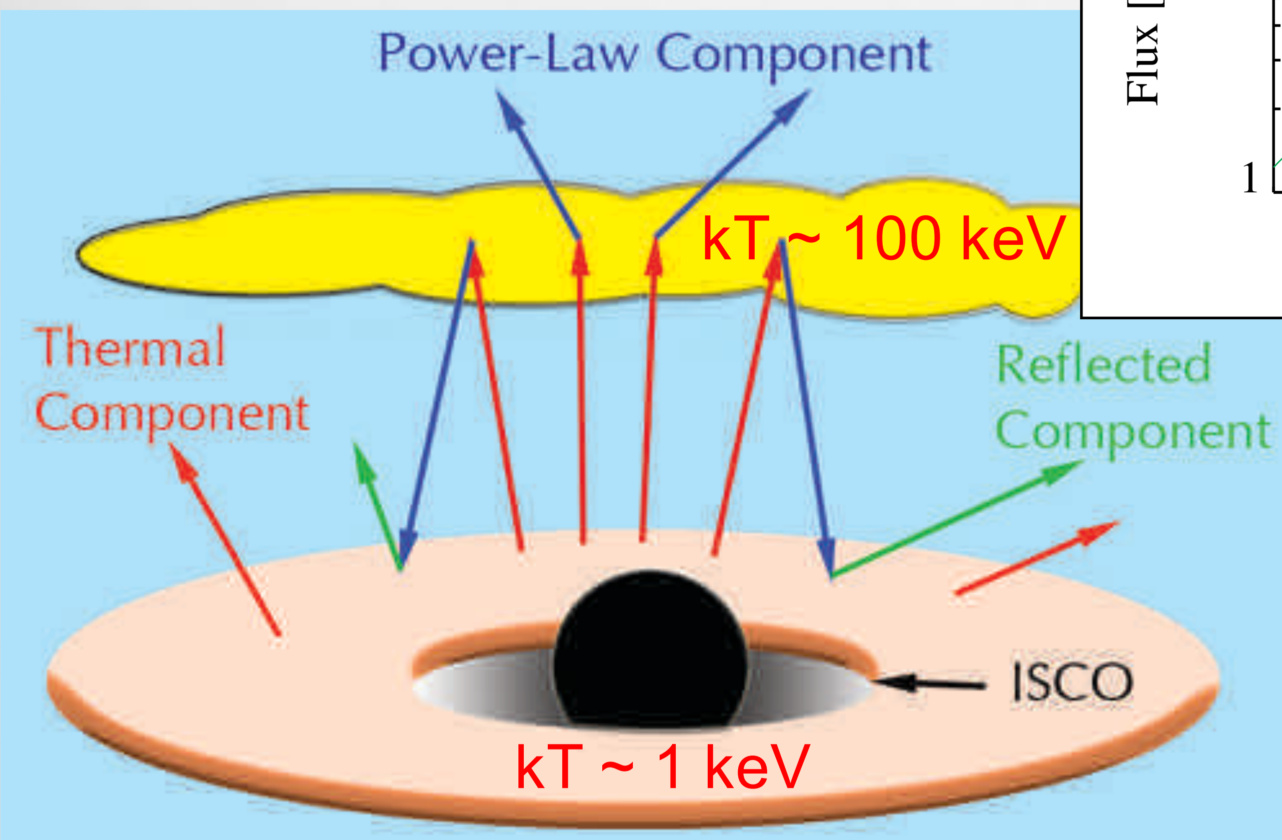
Belloni+2000

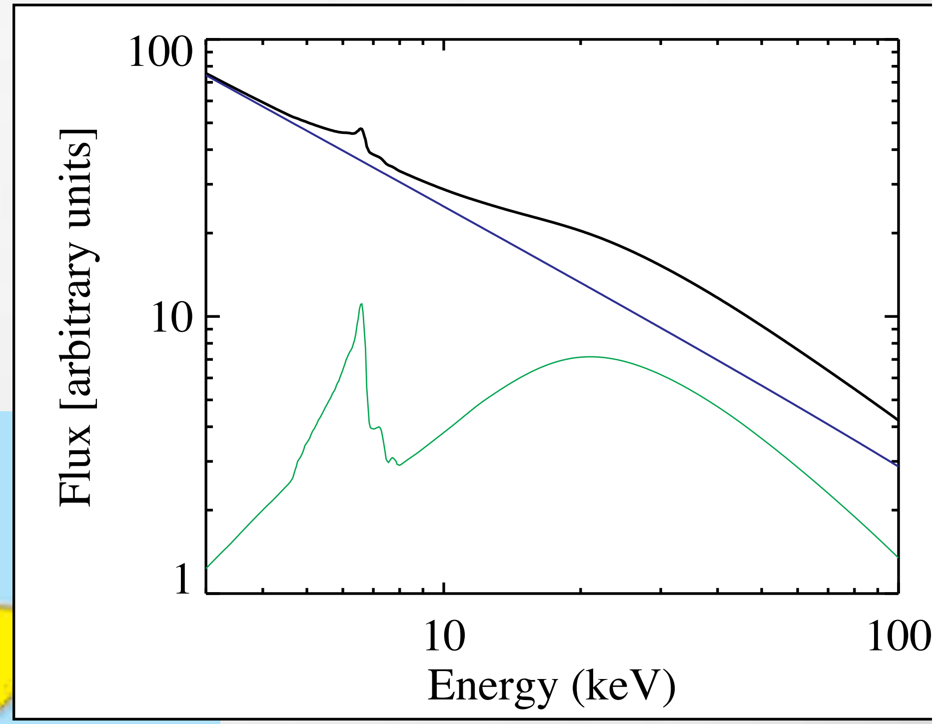
Spectrally resolving the viscous timescale

- 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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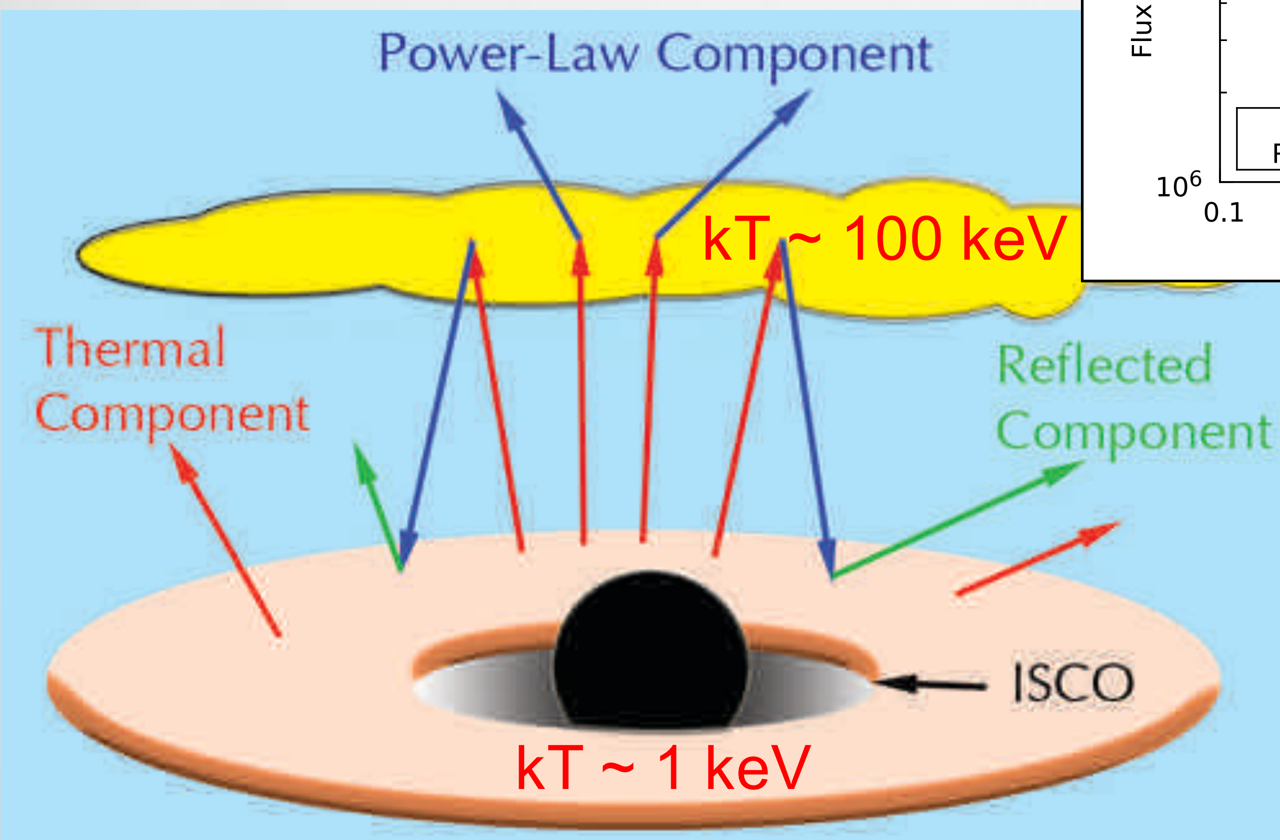
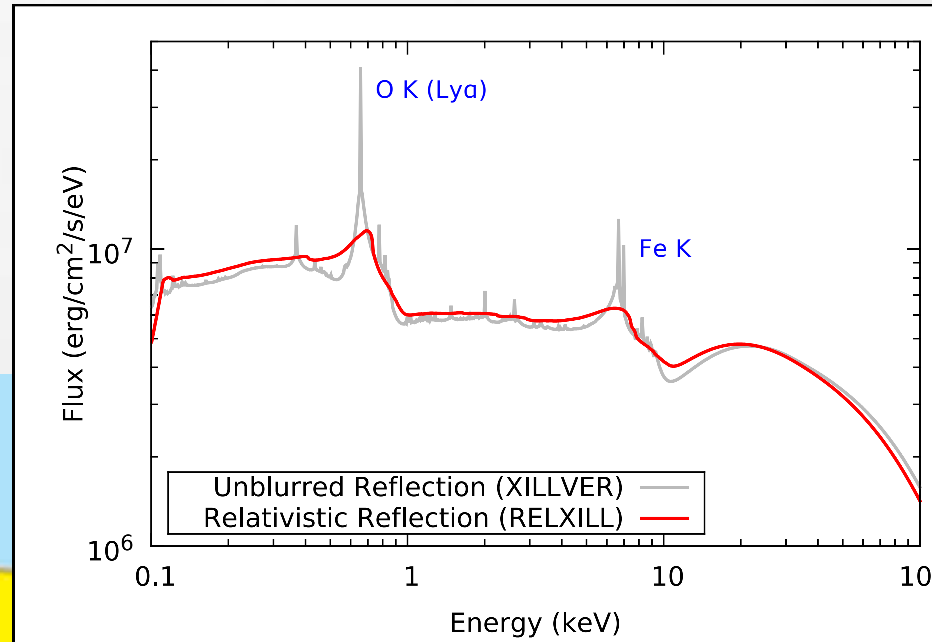
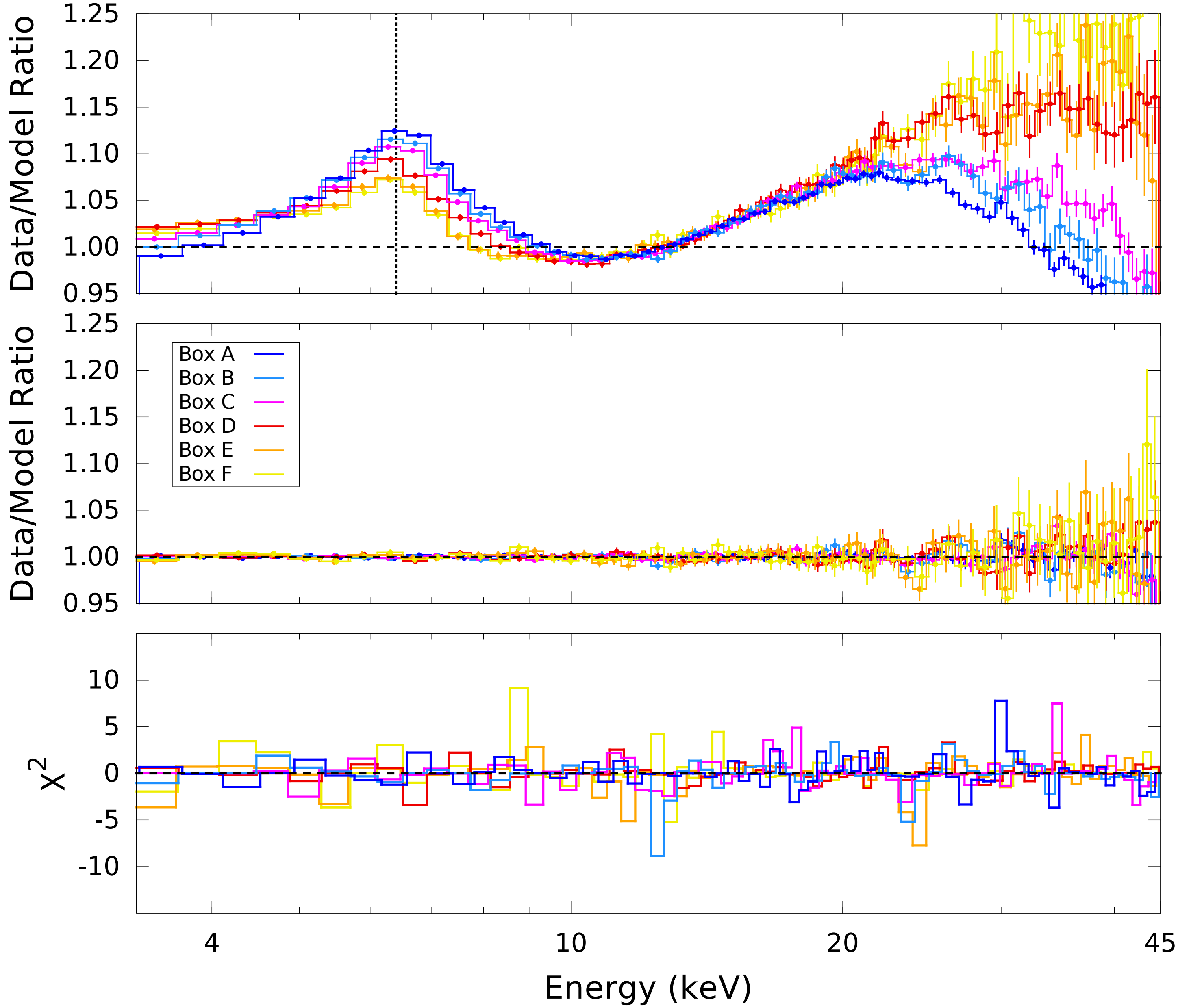
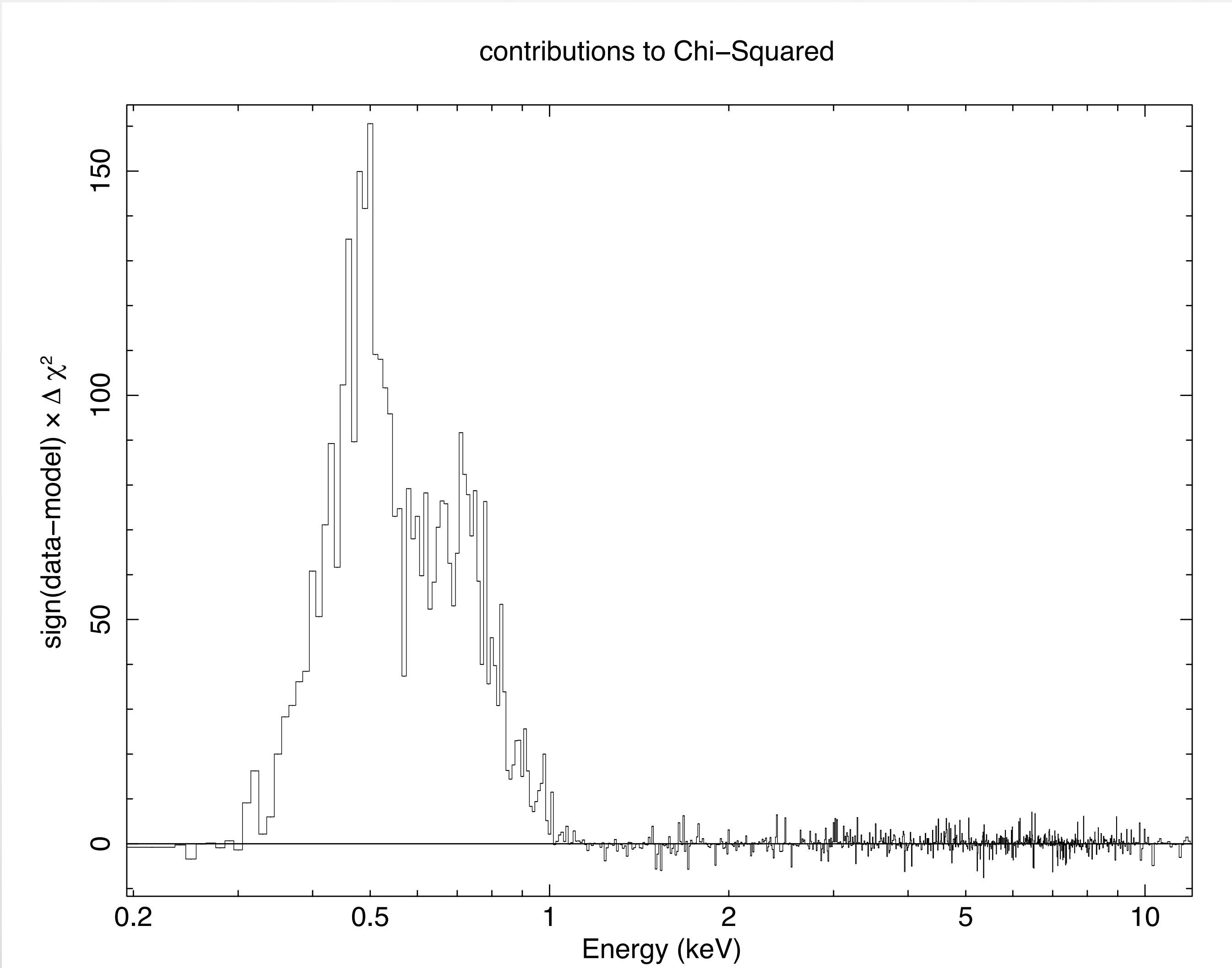






Garcia et al. 2015

Reflection in a 1 mCrab ULX spectrum with NICER



NICER's capability for probing accreting BHs

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