Accretion Physics in Stellar-Mass Compact Objects

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with contributions from Randall Smith & the panel

Targets

- Accreting stellar-mass black holes, neutron stars, white dwarfs.
- ULXs and X-ray binaries in nearby galaxies.

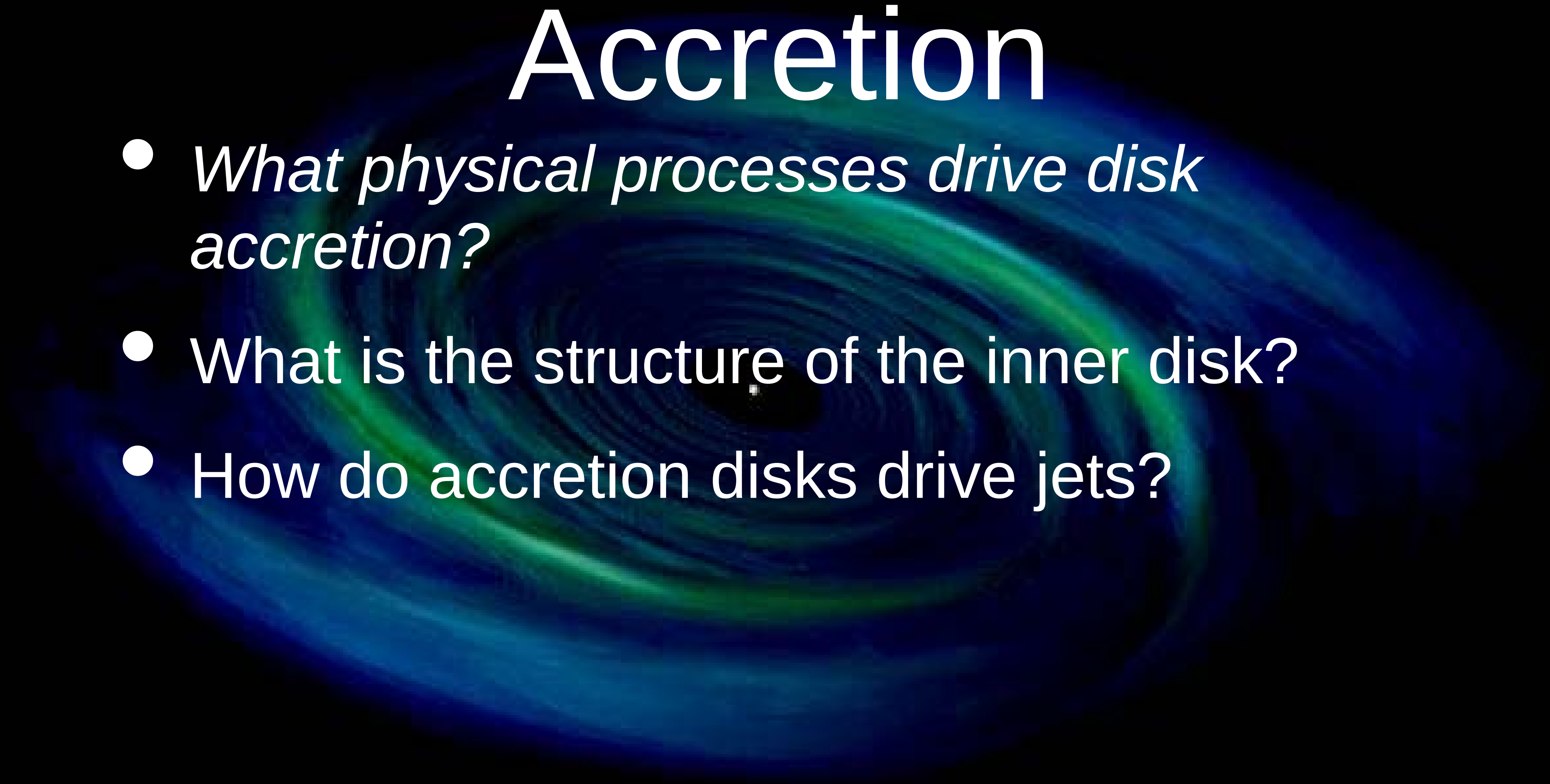
- These sources are convenient local proxies for the much larger class of super-massive black holes.

Two big ideas:

- Disk accretion onto super-massive black holes supplies 10-20% of the total ionizing flux in the universe.
- *What physical processes make that possible?*
- The majority of super-massive black holes are quiescent, and not fed by standard disks.
- *What is the nature of low-level accretion?*

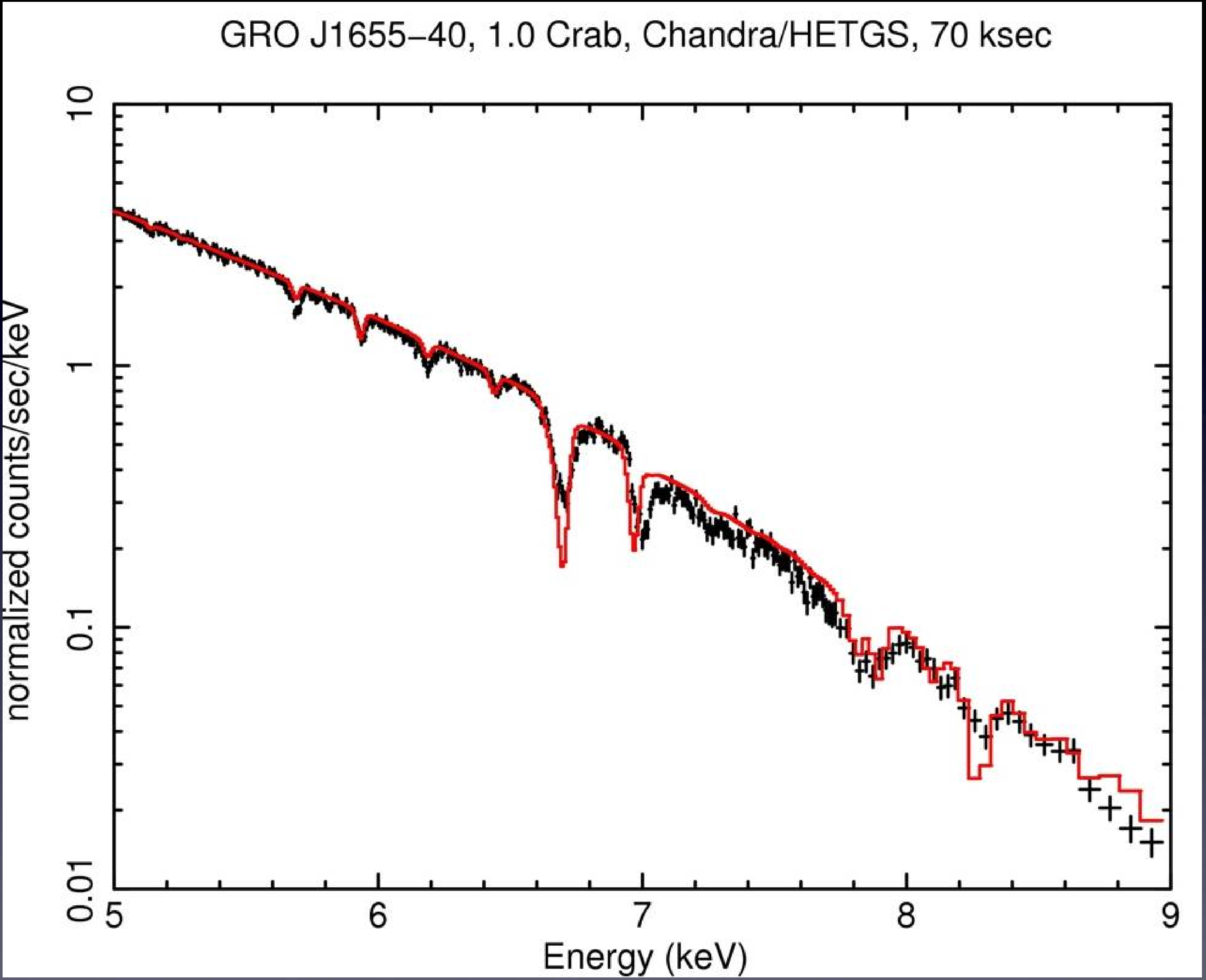
Focal Point 1: Physics of Disk Accretion

- *What physical processes drive disk accretion?*
- What is the structure of the inner disk?
- How do accretion disks drive jets?

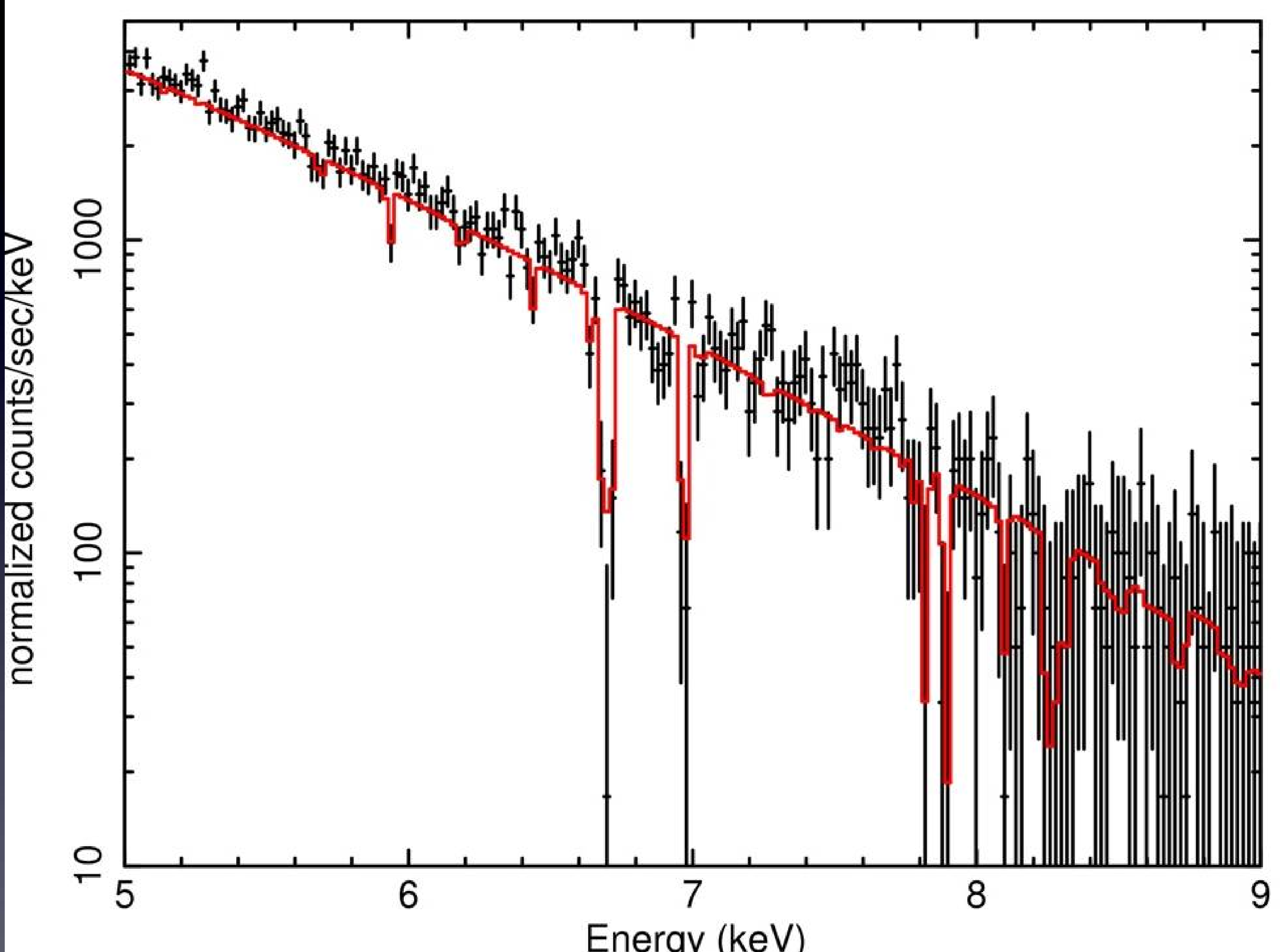


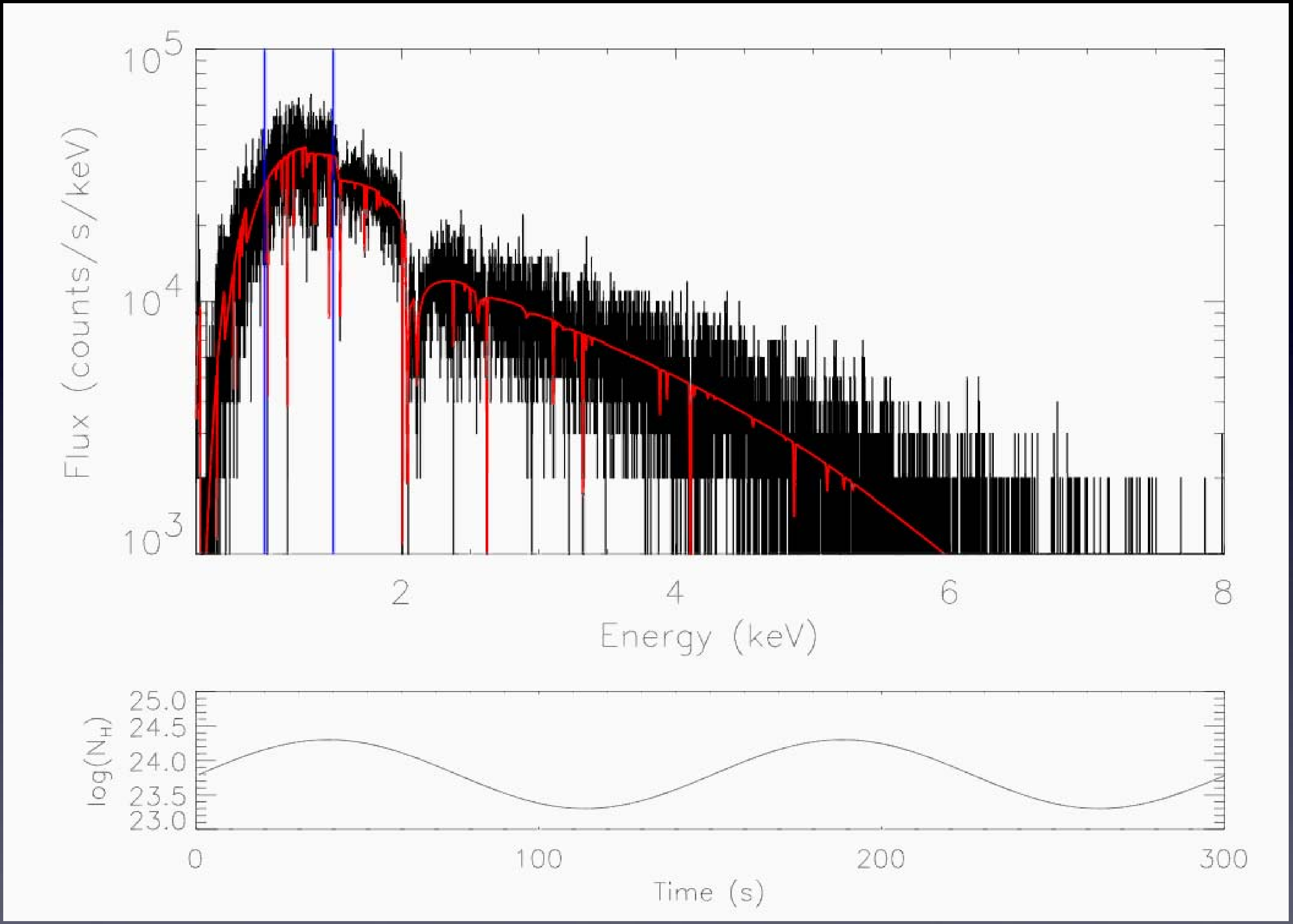
Fundamental Disk Physics

- Theory: MRI or MHD winds drive disk accretion.
- We need to *prove* it. But how?
- The answer is blowing in the wind:
- Magnetic winds originate close to black holes, and their variability properties can reveal their specific nature.
- *Resolution, collecting area, <u>livetime</u>.*


GRO J1655−40, 1.0 Crab, Chandra/HETGS, 70 ksec
normalized counts/sec/keV
10
1
0.1
0.01
5
6
7
8
9
Energy (keV)

3 seconds = 30,000 R_Schw = P_orb @ 200 R_Schw





10^5
10^4
10^3
Flux (counts/s/keV)
2
4
6
8
Energy (keV)
25.0
24.5
24.0
23.5
23.0
log(N_H)
0
100
200
300
Time (s)

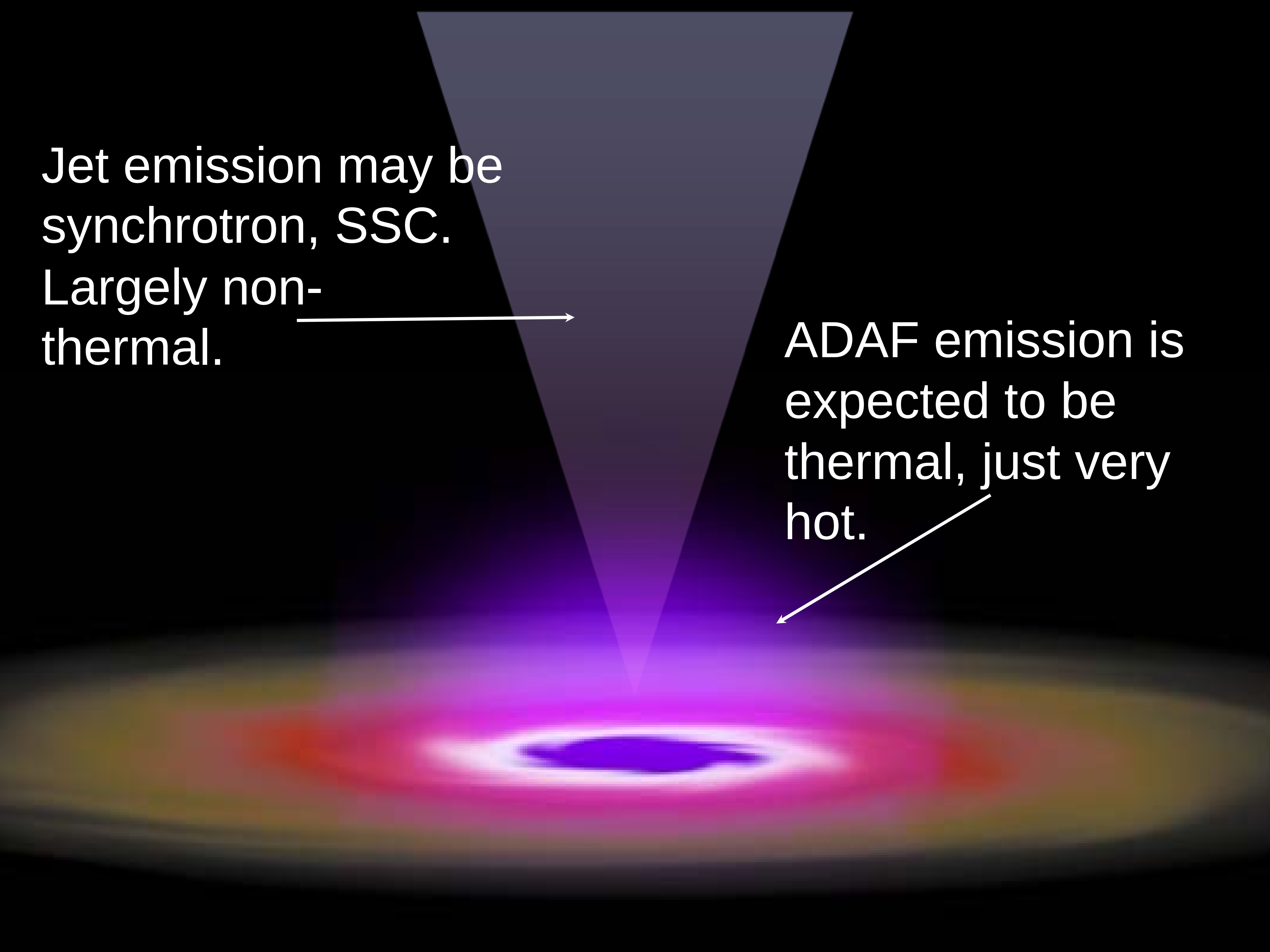
Prospects

- 5 or more black hole transients in 5 years.
- 5 or more neutron star transients in 5 years.
- 30 persistent neutron stars can be surveyed.
- At least 30 good white dwarf systems to be surveyed.

- For 8-10 Msec, excellent archive of accretion spectra.

Focal Point II: "Quiescent" Accretion

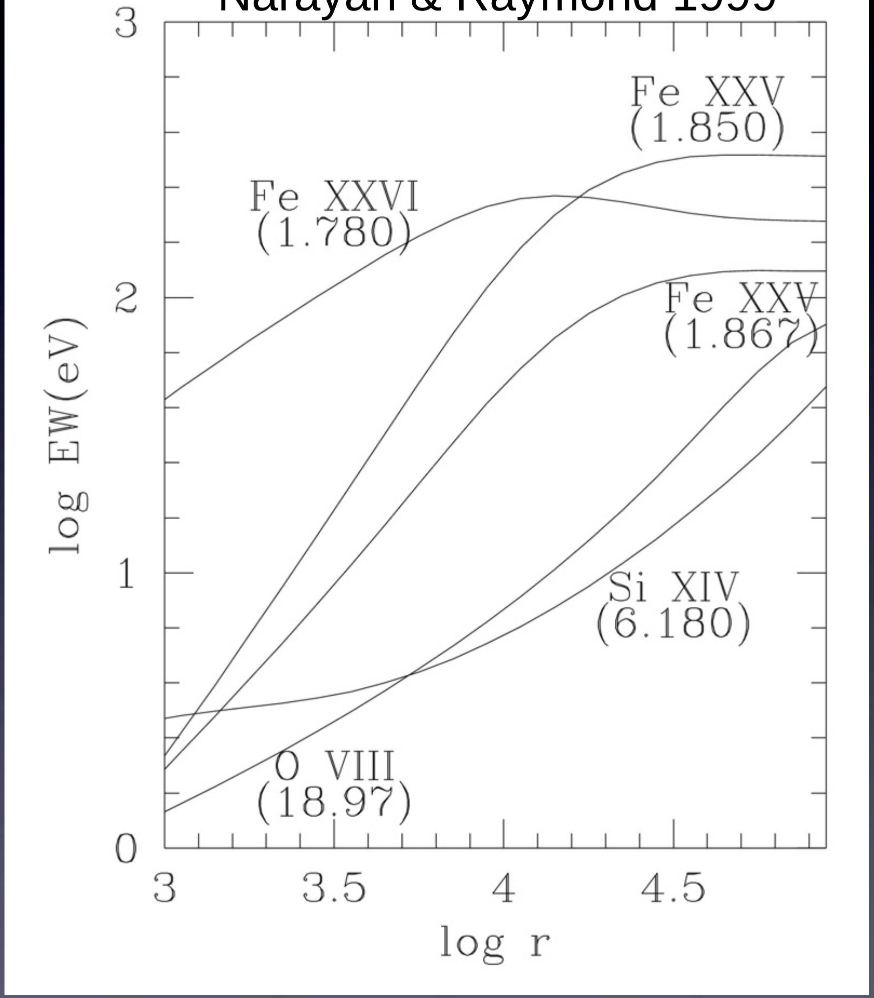
- Which physical processes dominate?
- How much mass actually accretes?


Jet emission may be synchrotron, SSC. Largely non-thermal.
ADAF emission is expected to be thermal, just very hot.

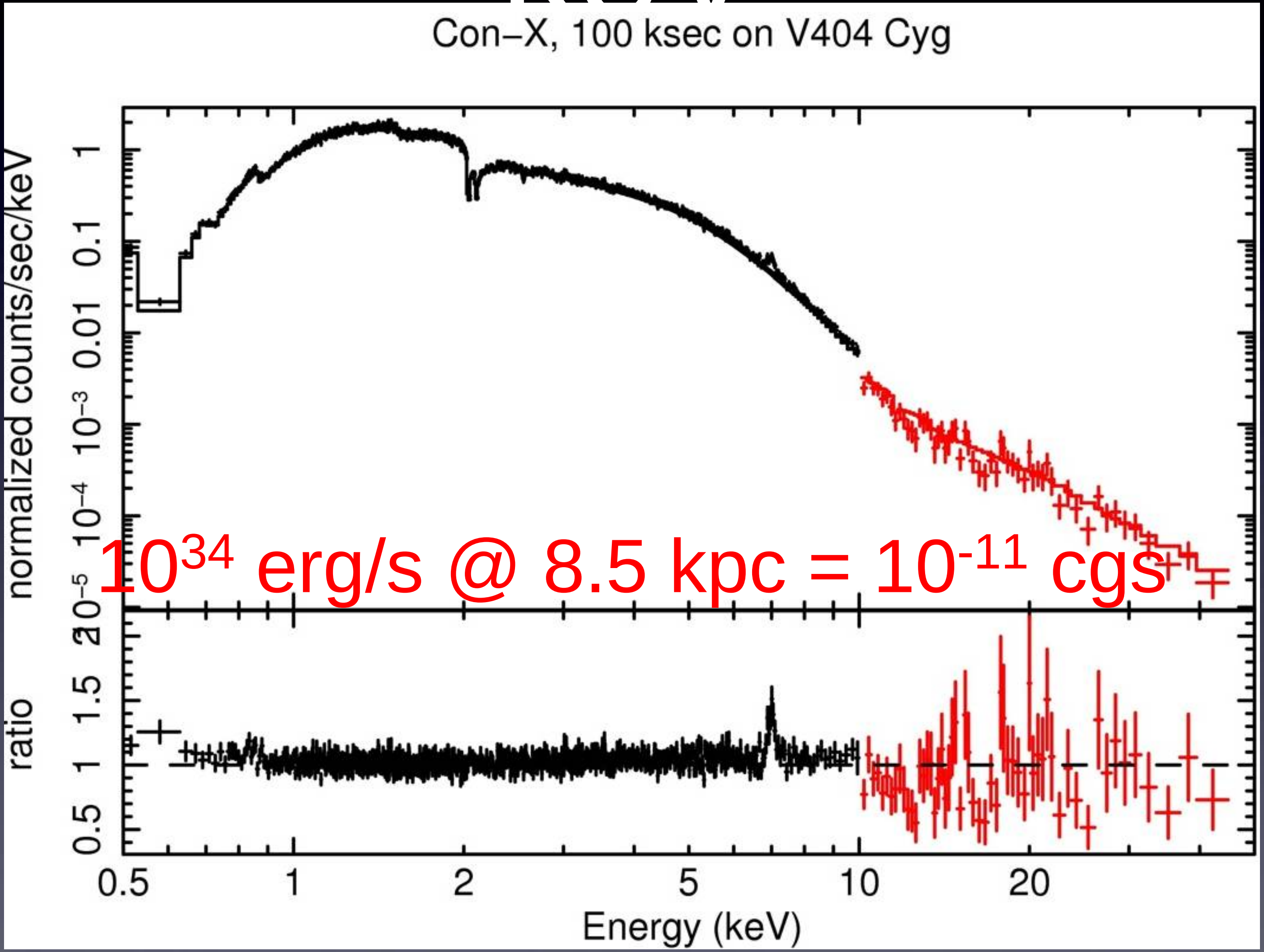
Deeper into ADAF models

- The picture at right is for Sgr A*, but would be similar for a binary like V404 Cyg.
- Line strengths and ratios give the size of the hot inner flow.
- An ADAF is a strictly collisional plasma.
- If the lines respond to the continuum, Compton sphere not ADAF.

Narayan & Raymond 1999



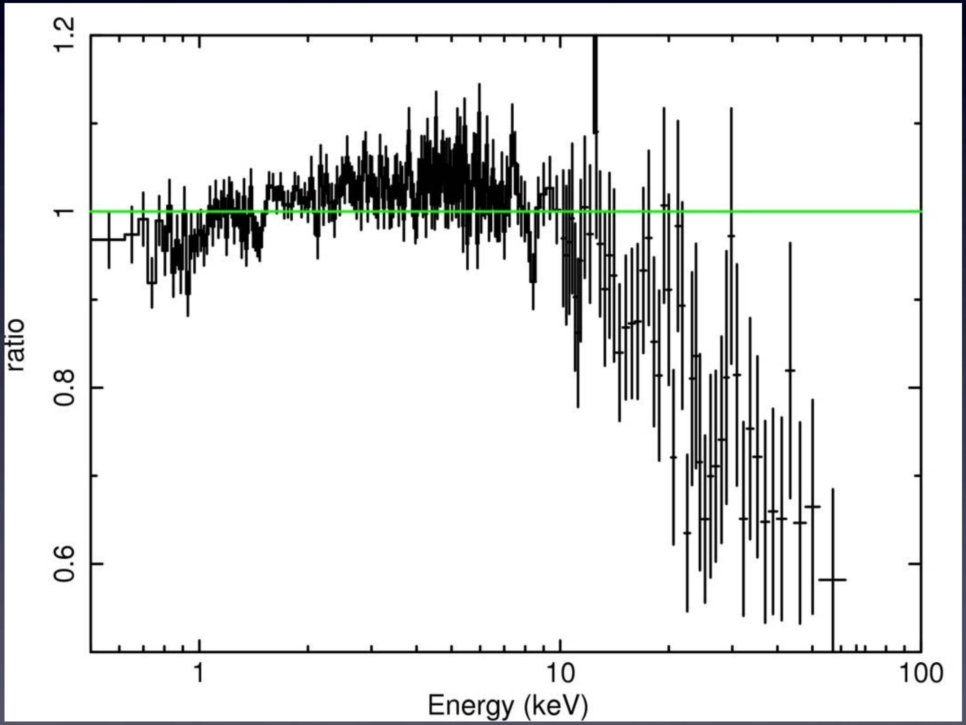
V404 Cyg out to 50 keV



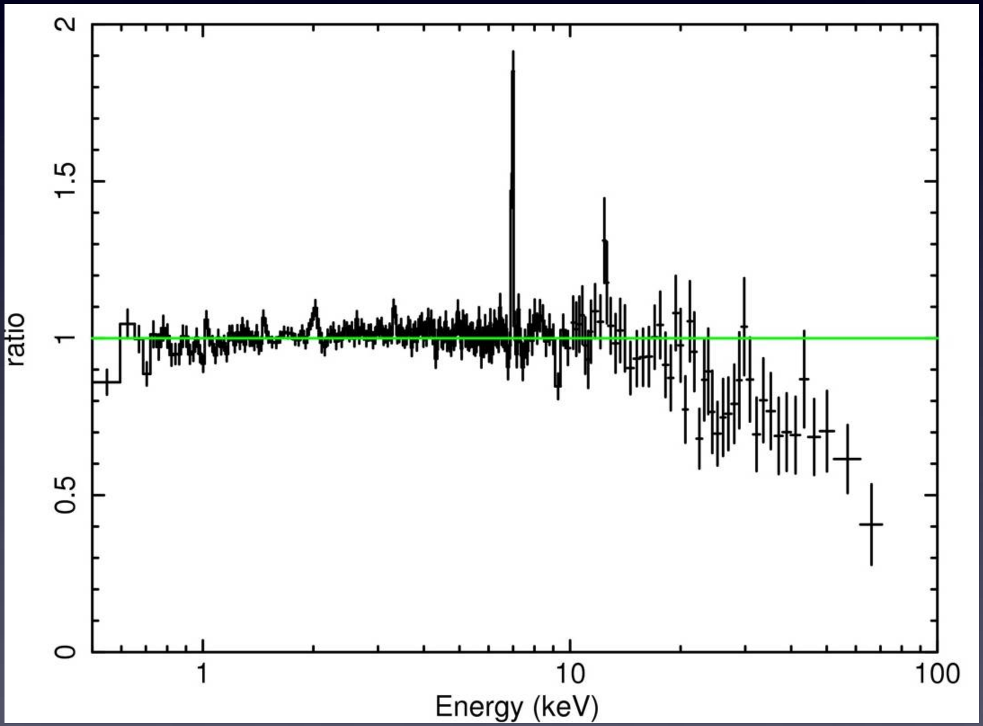
10^{34} erg/s @ 8.5 kpc = 10^{-11} cgs

Towards physics

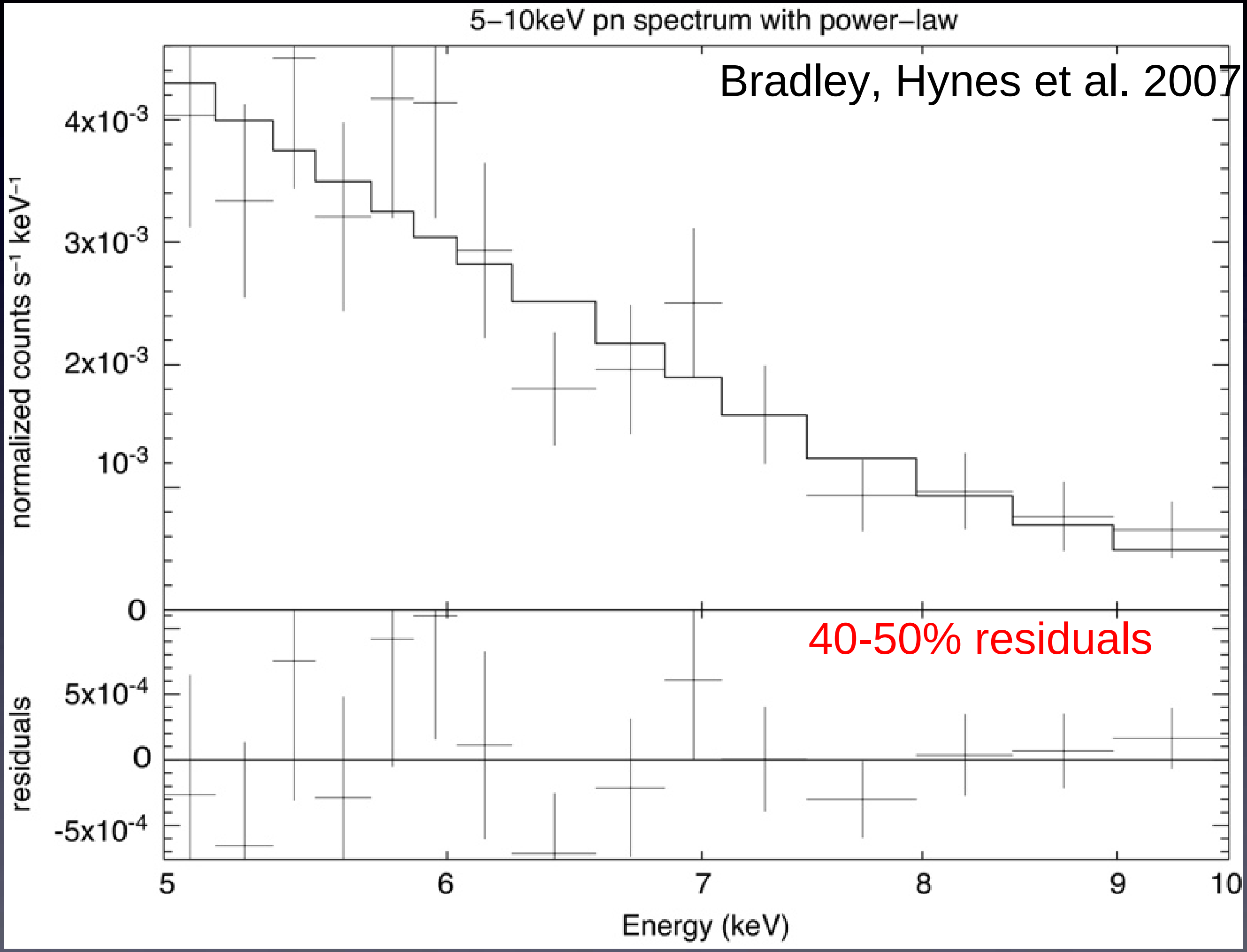
10^9 K Bremsstrahlung fit with a power-law



ADAF (Bremsstrahlung) plus a wind = Fe XXVI



XMM on V404 Cyg



Prospects

- 5 or more black hole transients in 5 years.
- 5 or more neutron star transients in 5 years.
- Very large sample of faint accretors in Galactic Center.

- Sample of 20-30 Galactic sources will be easy in 2 Msec.

Bright Sources:

Phenomenon	Binaries	AGN
X-ray lines	1975	1978
QPOs	1985	2008
Broad Fe	1986	1995

Summary

- IXO will reveal the *physics* of disk accretion, and low L_X accretion.
- Insights will extend to AGN, LLAGN, and quiescent SMBH.
- Bright sources best exploit the discovery space of new instruments.
- Most important instrumental concerns:
  (1) pixels that retain resolution at high count rates,
  (2) high livetime fraction,
  (3) retaining the hard X-ray detector,
  (4) gratings down to 0.1 keV (for CV science).

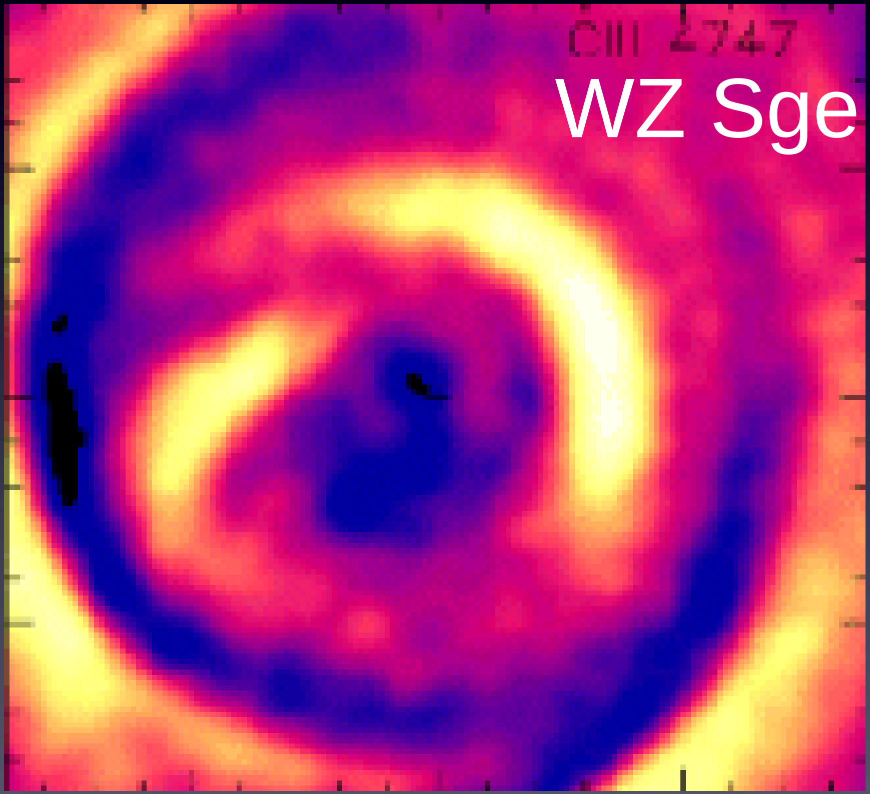
Additional Science

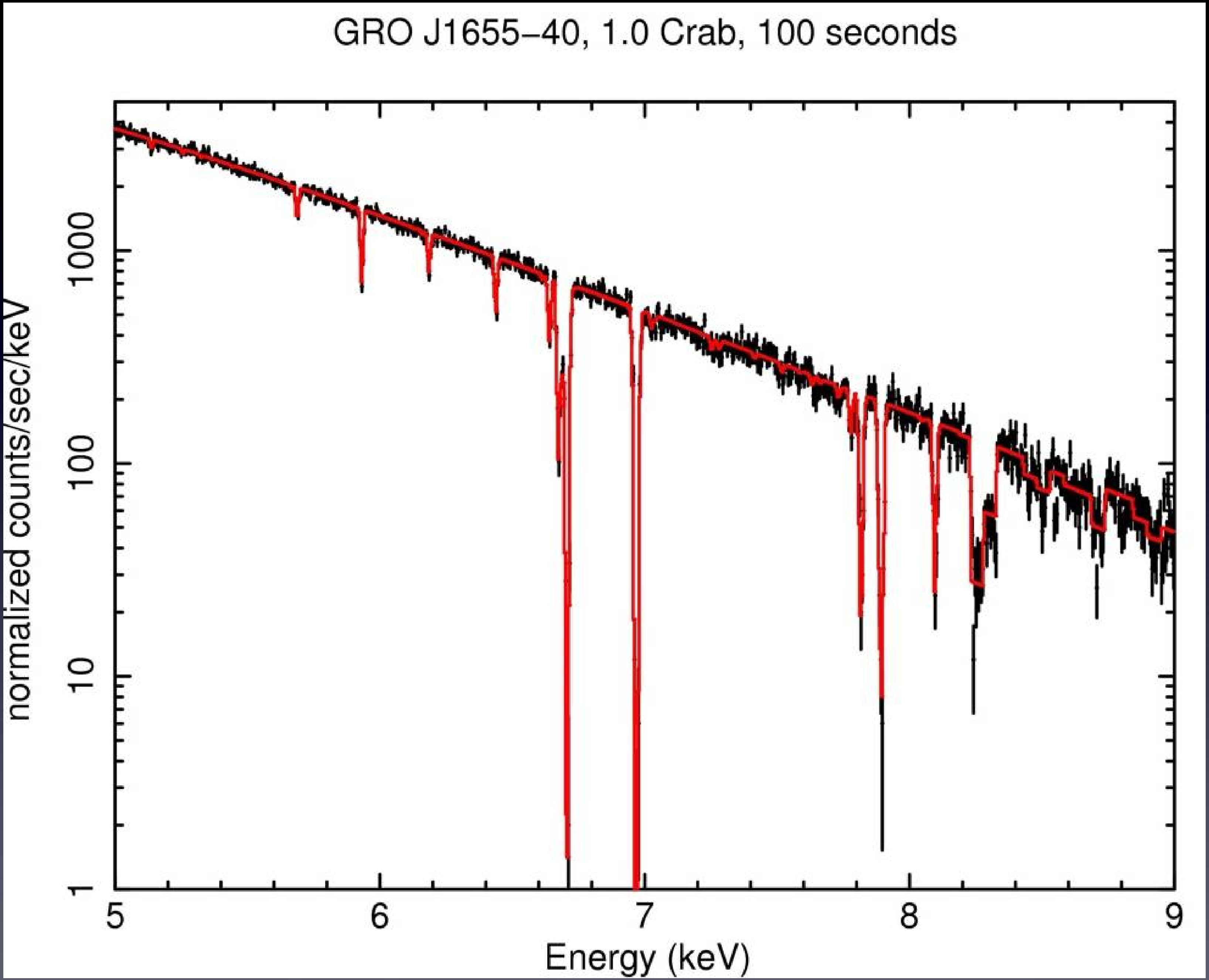
- Are ULXs IMBHs? ⟷ Very very interesting, but statistical gains hampered by systematics.
- Super-Eddington accretion. ⟷ “Slim” disks are hard to discern observationally.
- Timing studies. ⟷ Con-X is excellent for timing. We don’t yet understand QPOs.
- Galactic center. ⟷ Many sources, but limited spectroscopic potential.

Inner disk structure

- Optical tomograms of dwarf novae disks show spiral waves. Amazing stuff.

- Constellation-X makes it possible to combine timing and spectroscopy in an analogous way for black holes and neutron stars.

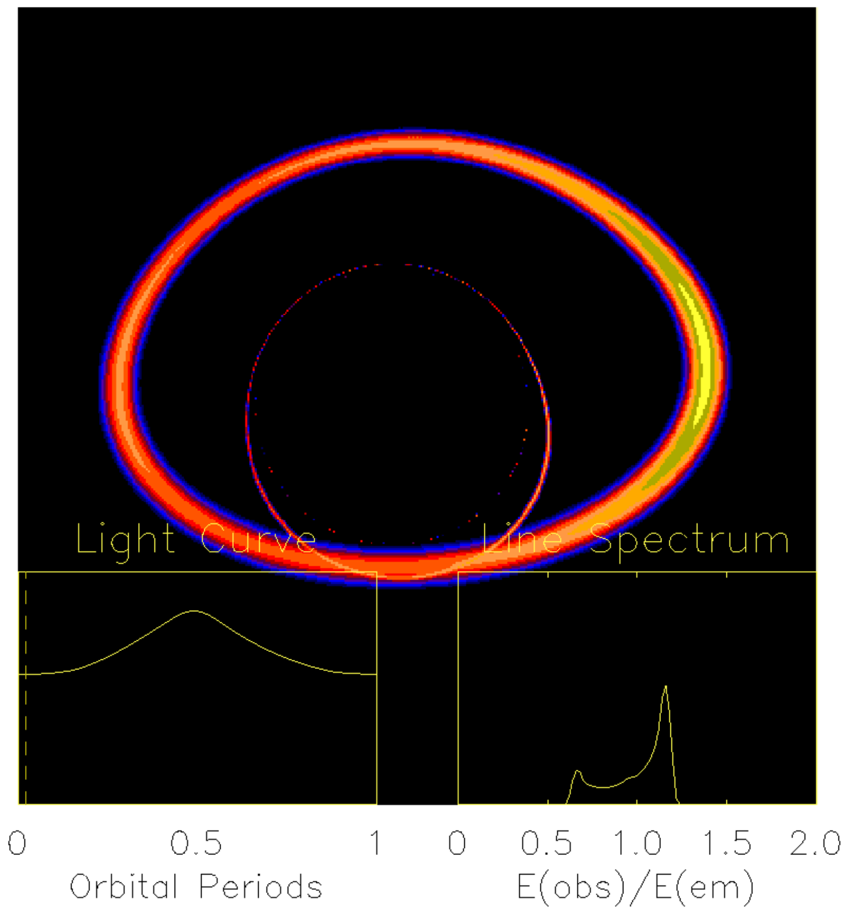




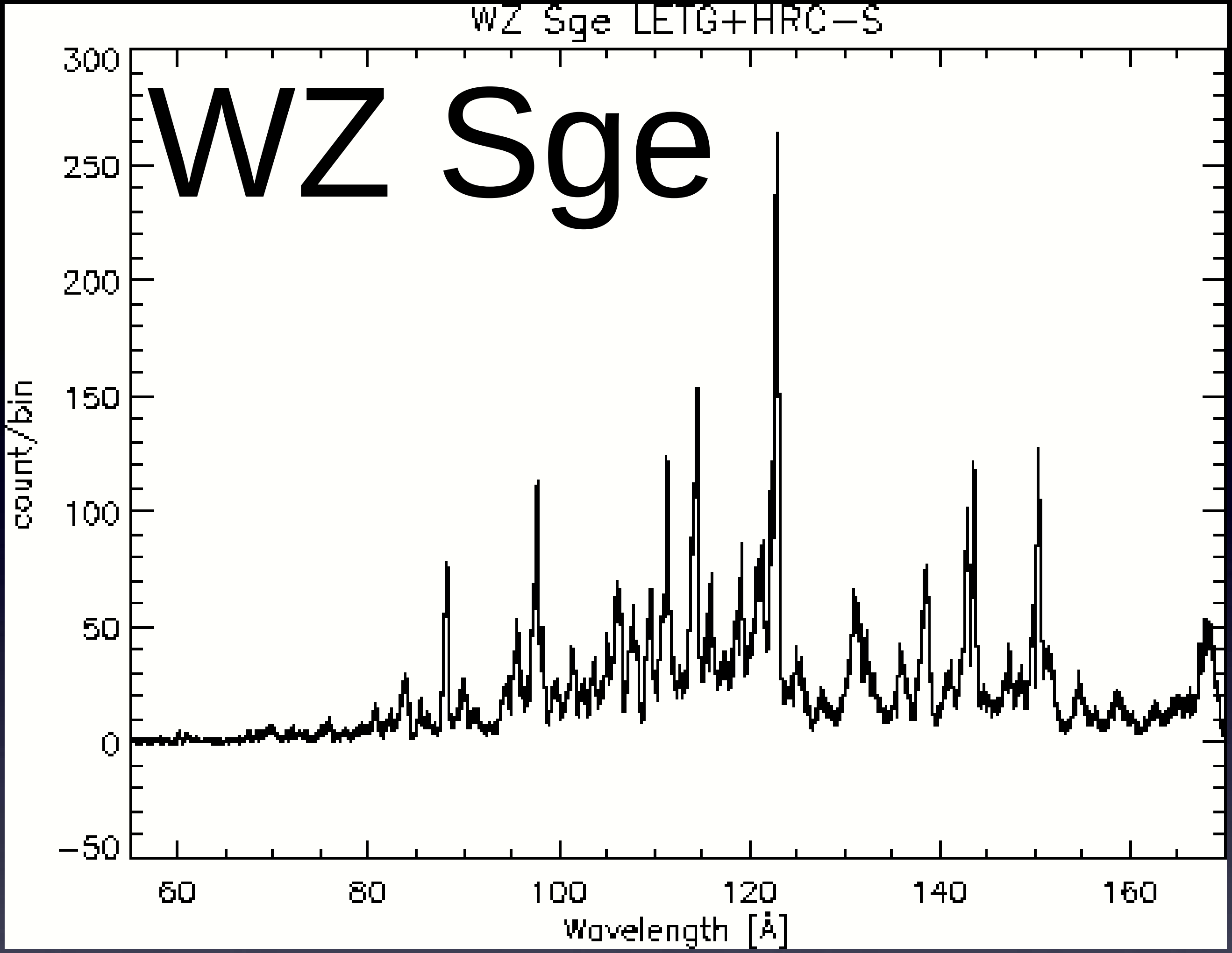
GRO J1655−40, 1.0 Crab, 100 seconds
normalized counts/sec/keV
1000
100
10
1
5
6
7
8
9
Energy (keV)

Warps leave a mark

- Theory is back and forth on inner disk warps.
- A warp in the inner disk has specific consequences for iron line shape and variability.
- This is a viable model for low-frequency QPOs.
- Line flux variations with QPO phase are seen in one system with RXTE.



Schnittman et al.



"Coronal emission may turn on in outburst as the disk becomes more magnetically active. In this case soft X-ray outburst emission might allow us to study the MRI in action."

-- Wheatley & Mauche 2005

Gratings coverage down to 0.1 keV would really help.

V404 Cyg flares at 10^{-5} Eddington