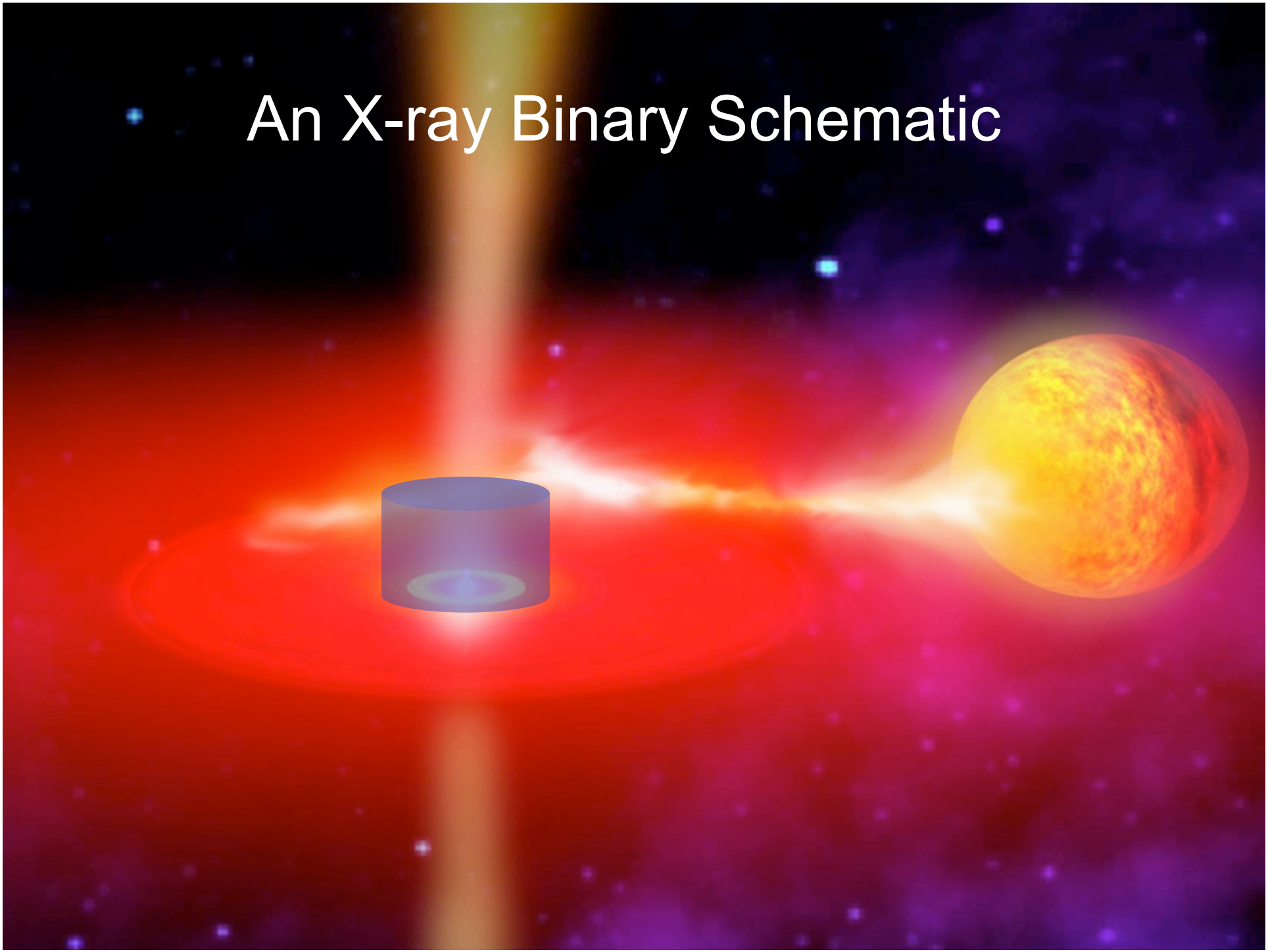
Disk-Jet Connections in Microquasars: Are we there yet?

Jon Miller (Michigan)

Outline

- Comptonizing coronae versus jets
- Disk-Jet correlations in GRS 1915+105
- More broadly: disk-jet, or jet-jet?
- Where is the disk in the low/hard state?
- Brief concluding remarks

An X-ray Binary Schematic



Comptonization, coronae, & jets

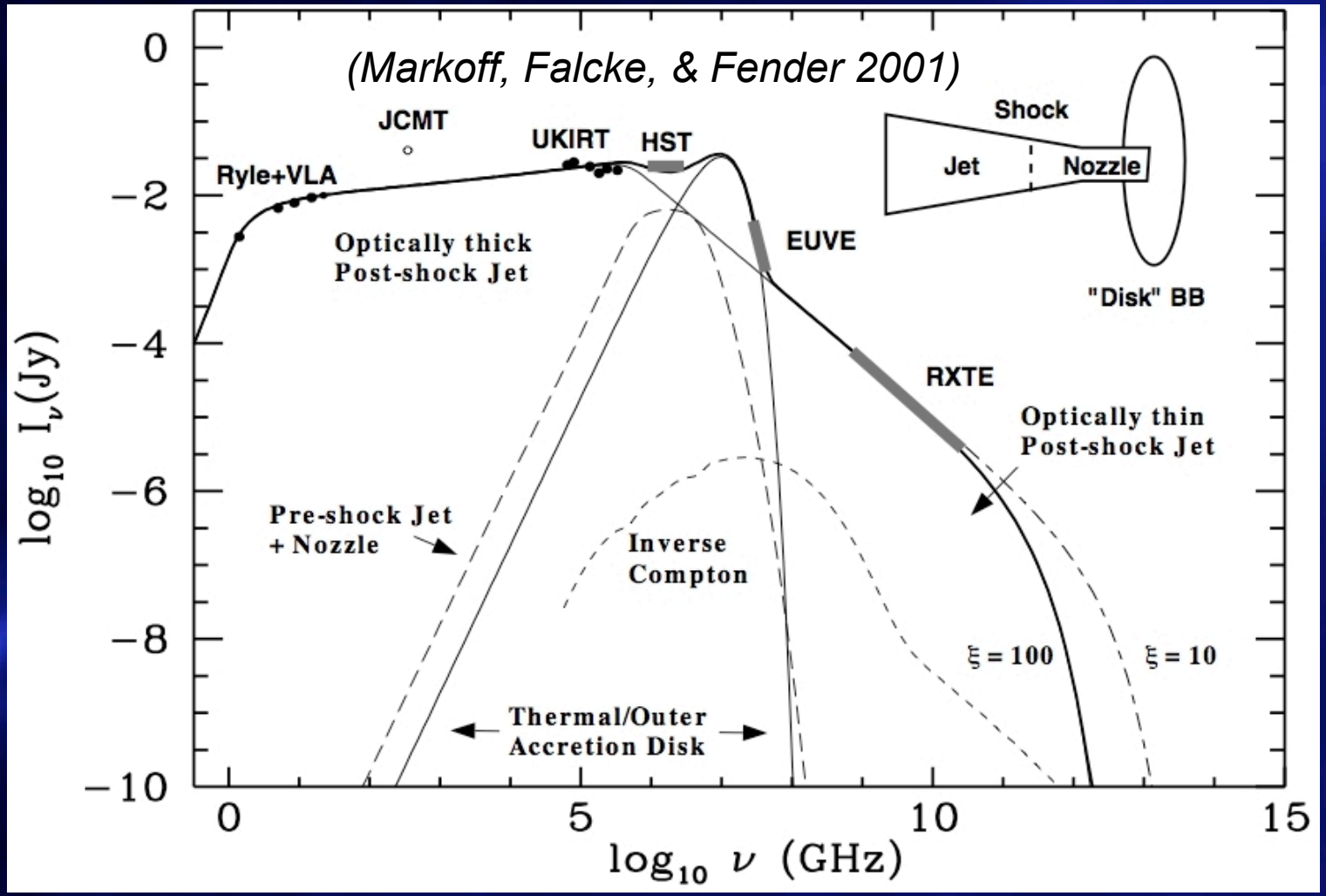
Convention:
Hard X-rays via Comptonization in a corona.

Radical alternative:
Jets supply radio-->X-rays (Markoff, Falcke, Fender 01)

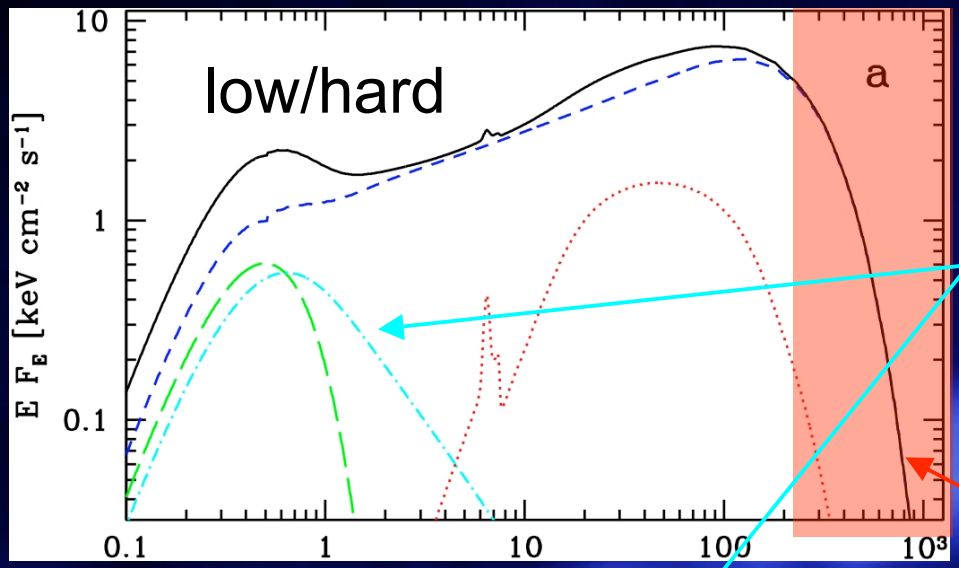
Quick reaction: MFF are *crazy*.

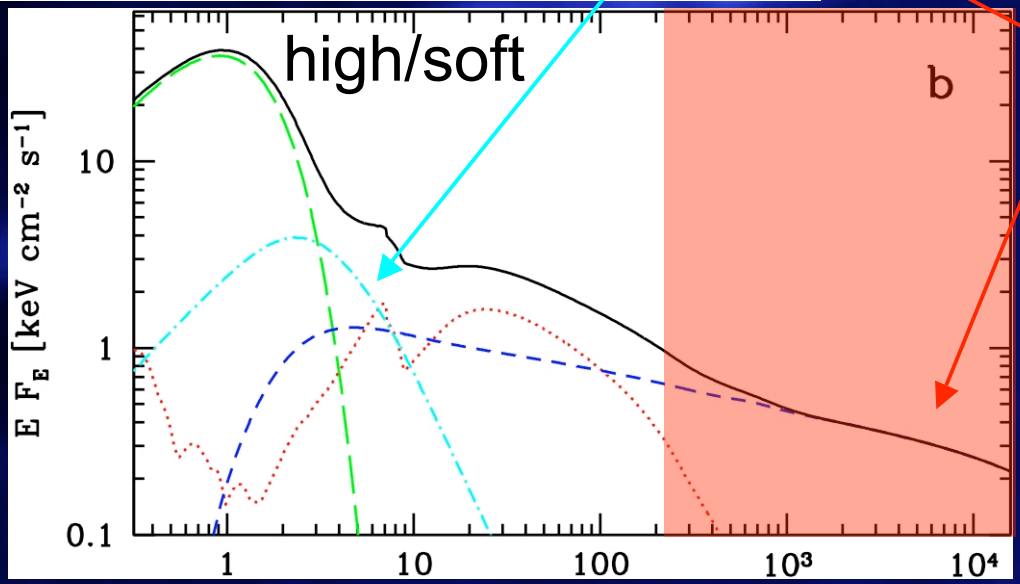
After further review: maybe not.
The “evidence” for thermal Comptonization is not great.

Jet-dominated emission model for XTE J1118+480 in the low/hard state



“Evidence” for thermal Comptonization





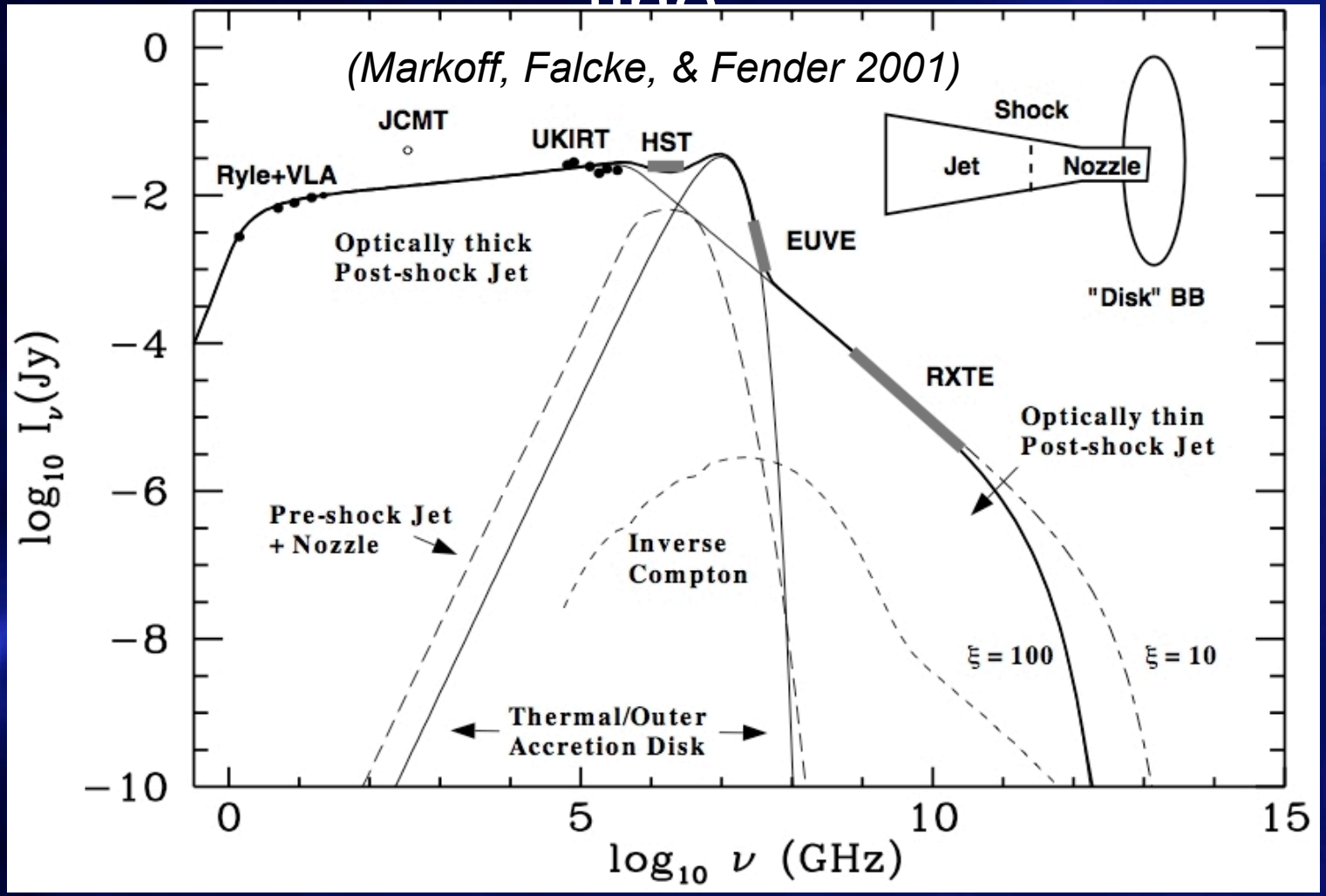
No X-ray spectrum actually requires 3 continuum components. Disk, power-law, reflection?, done.

How to “require” thermal Compt:
(1) force disk to a small value
(2) run near power-law from high E
(3) fill middle with thermal Compt.

In practice, little or no signal above 200 keV.

Background issues are paramount; turn-over is very suspect.

From the standpoint of spectral fitting and related statistics, this is fine

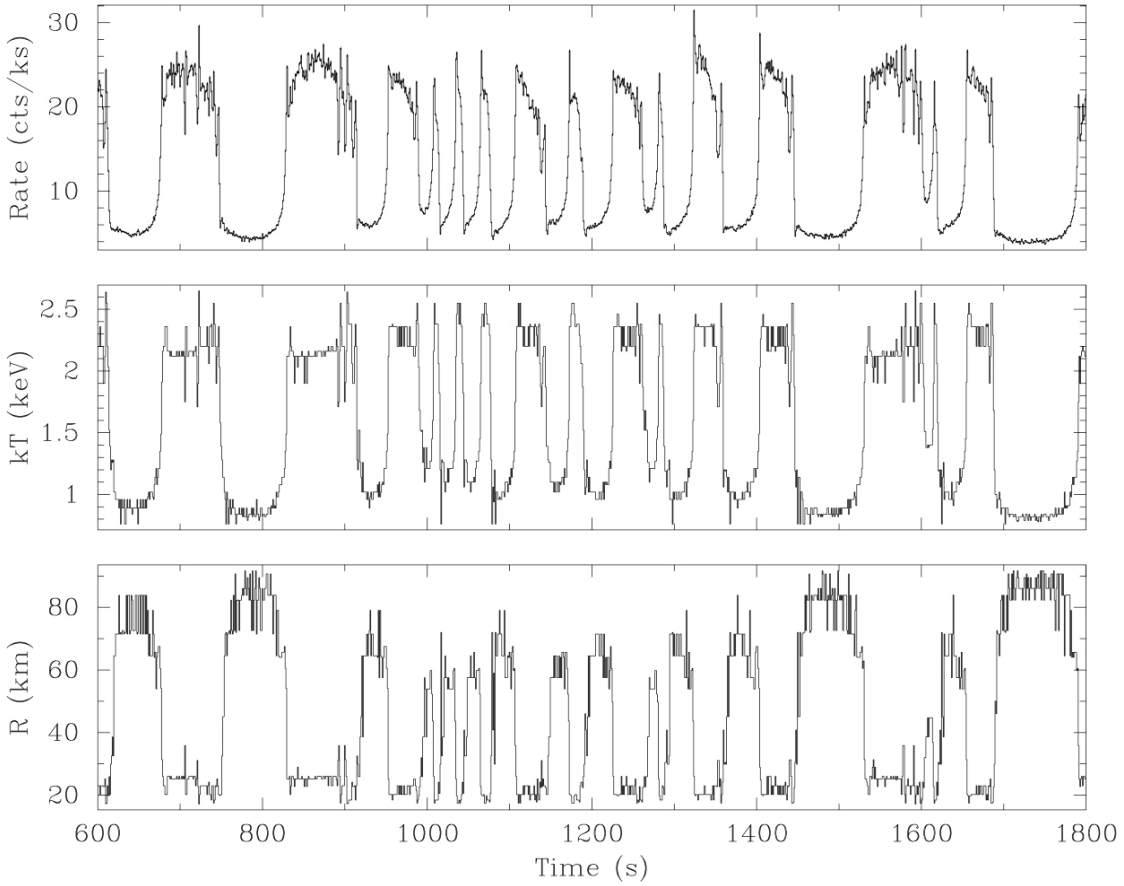


So jets may be very important, perhaps even in X-rays.

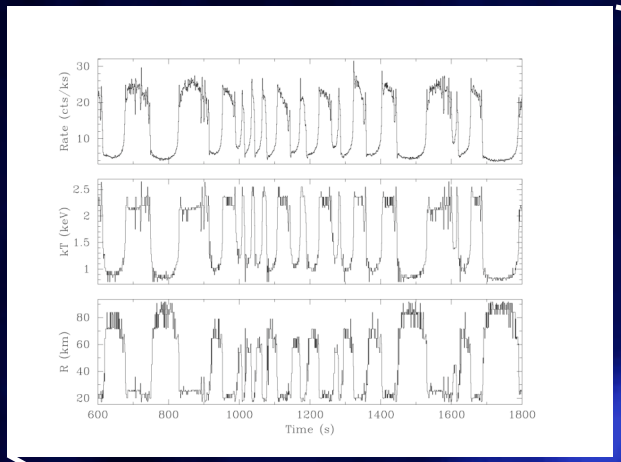
What is the status of disk-jet connections?

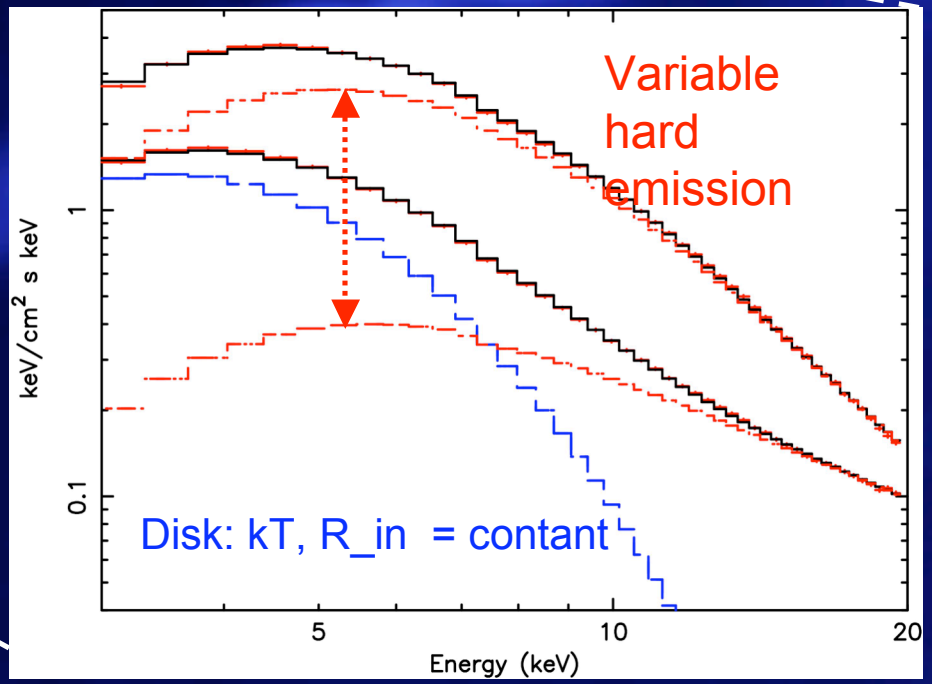
Disk ejection cycles in GRS 1915+105 [?]

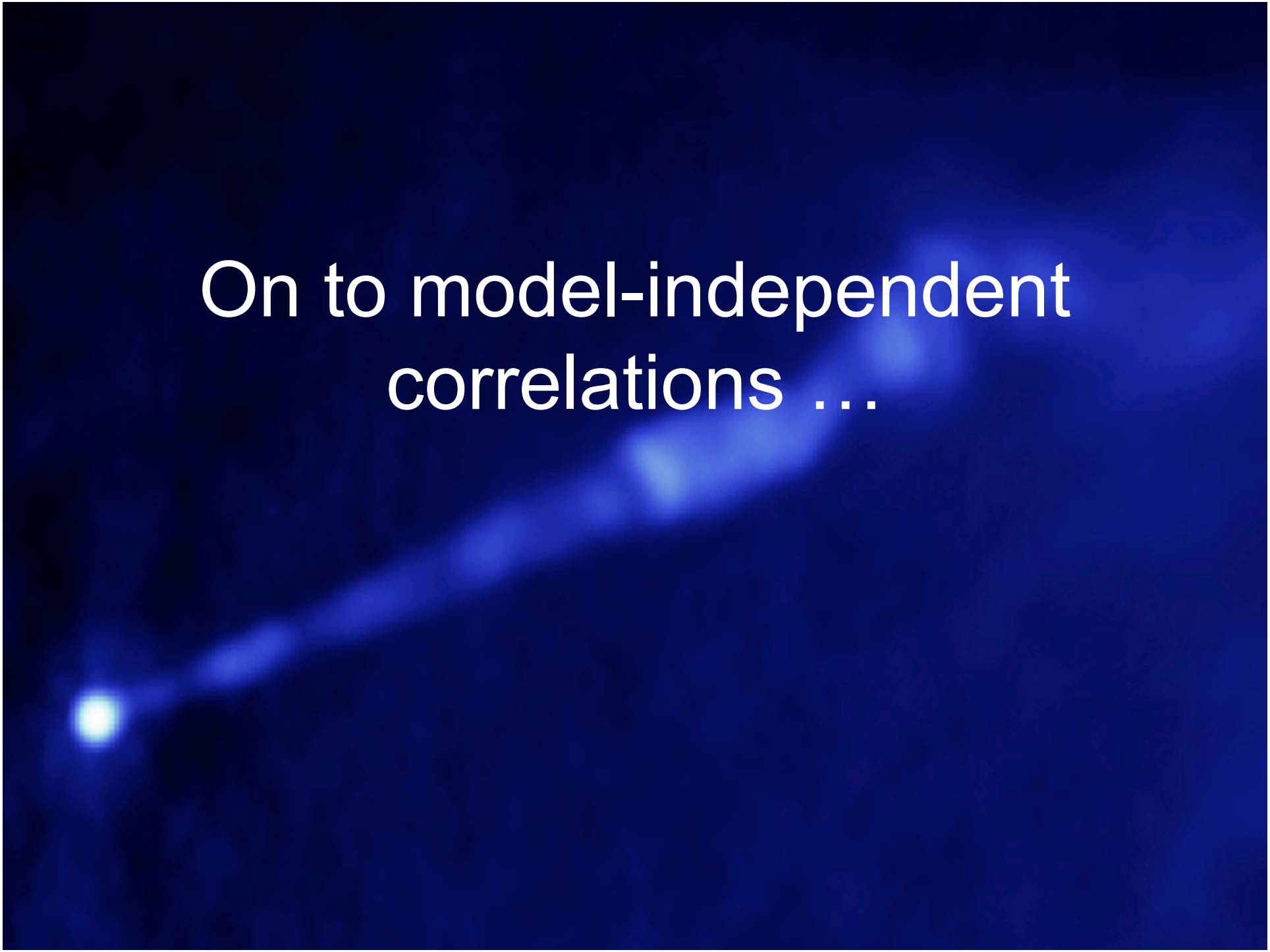
(Belloni 97, Fender & Belloni 04)



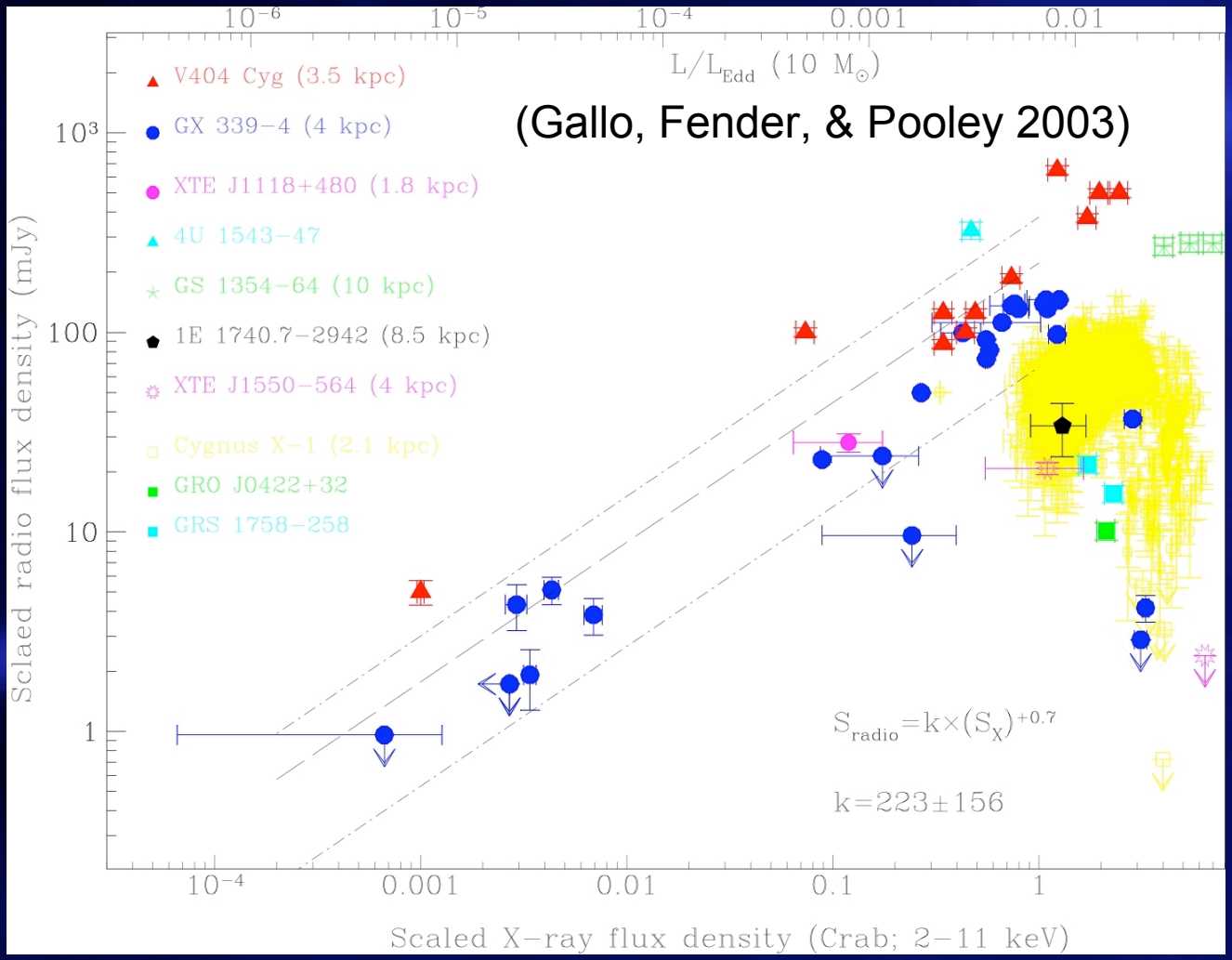
Spectra can be fit with a *constant* disk, and variable hard component. Disk ejection cycles? Maybe not.



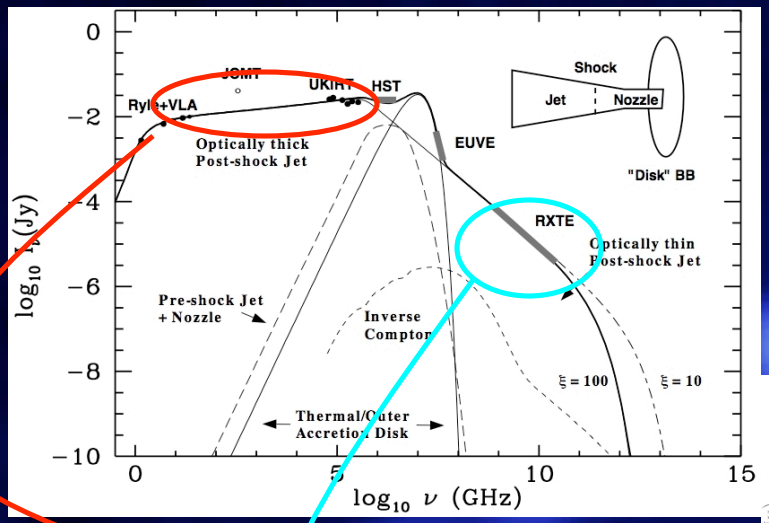


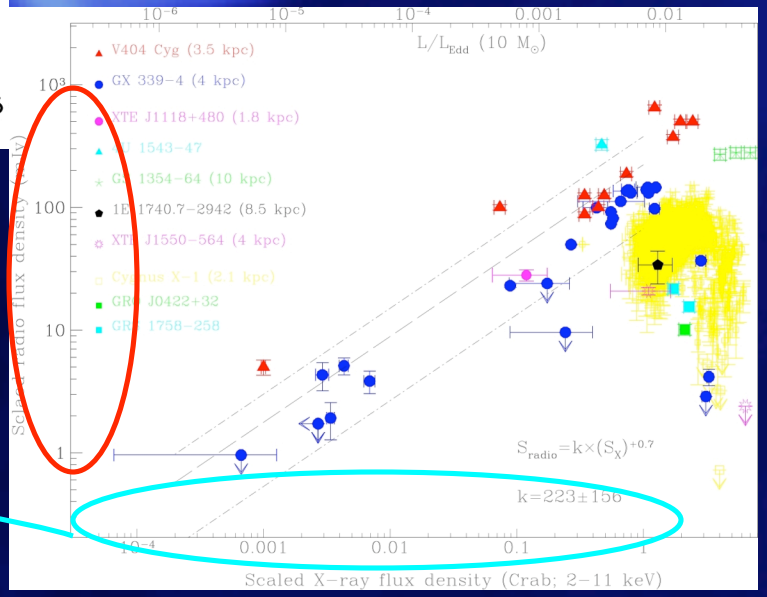

On to model-independent
correlations …

Radio vs X-ray luminosity

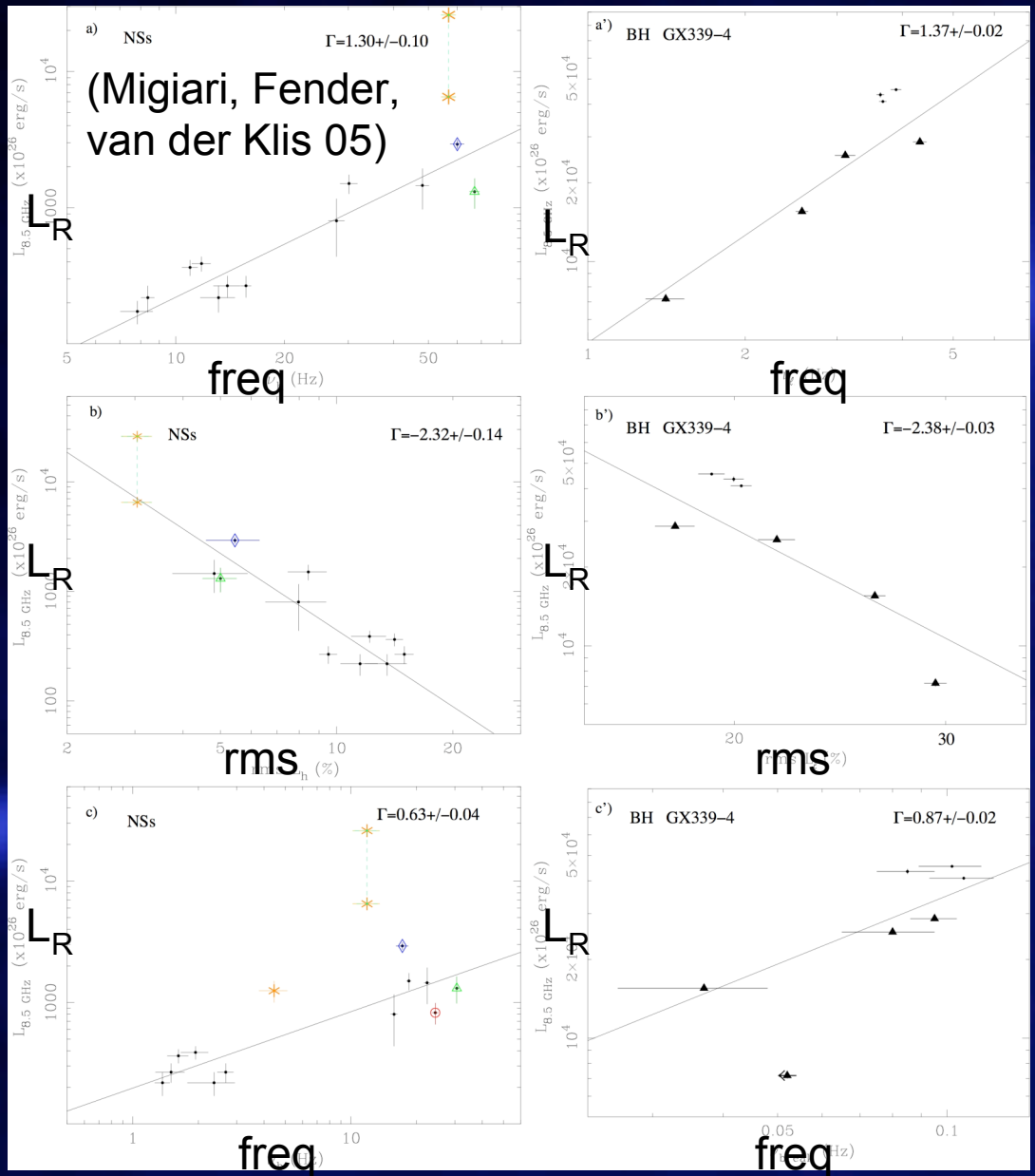


If jets do radio and X-rays: jet-jet, not disk-jet, connection

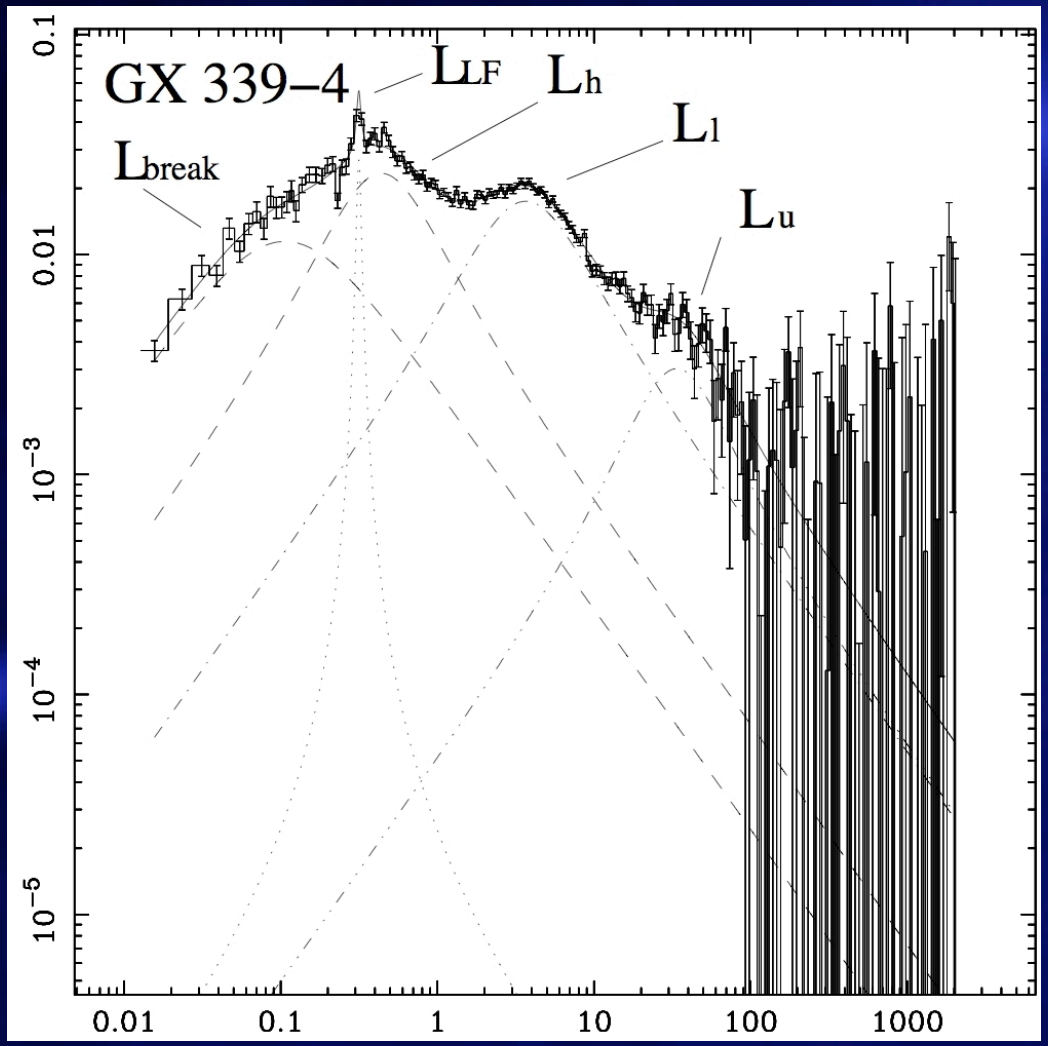




On to correlations with discrete features (more or less).


(Migiari, Fender, van der Klis 05)
a)
NSs
Γ=1.30+/−0.10
a')
BH GX339−4
Γ=1.37+/−0.02
b)
NSs
Γ=−2.32+/−0.14
b')
BH GX339−4
Γ=−2.38+/−0.03
c)
NSs
Γ=0.63+/−0.04
c')
BH GX339−4
Γ=0.87+/−0.02
L_R
freq
rms

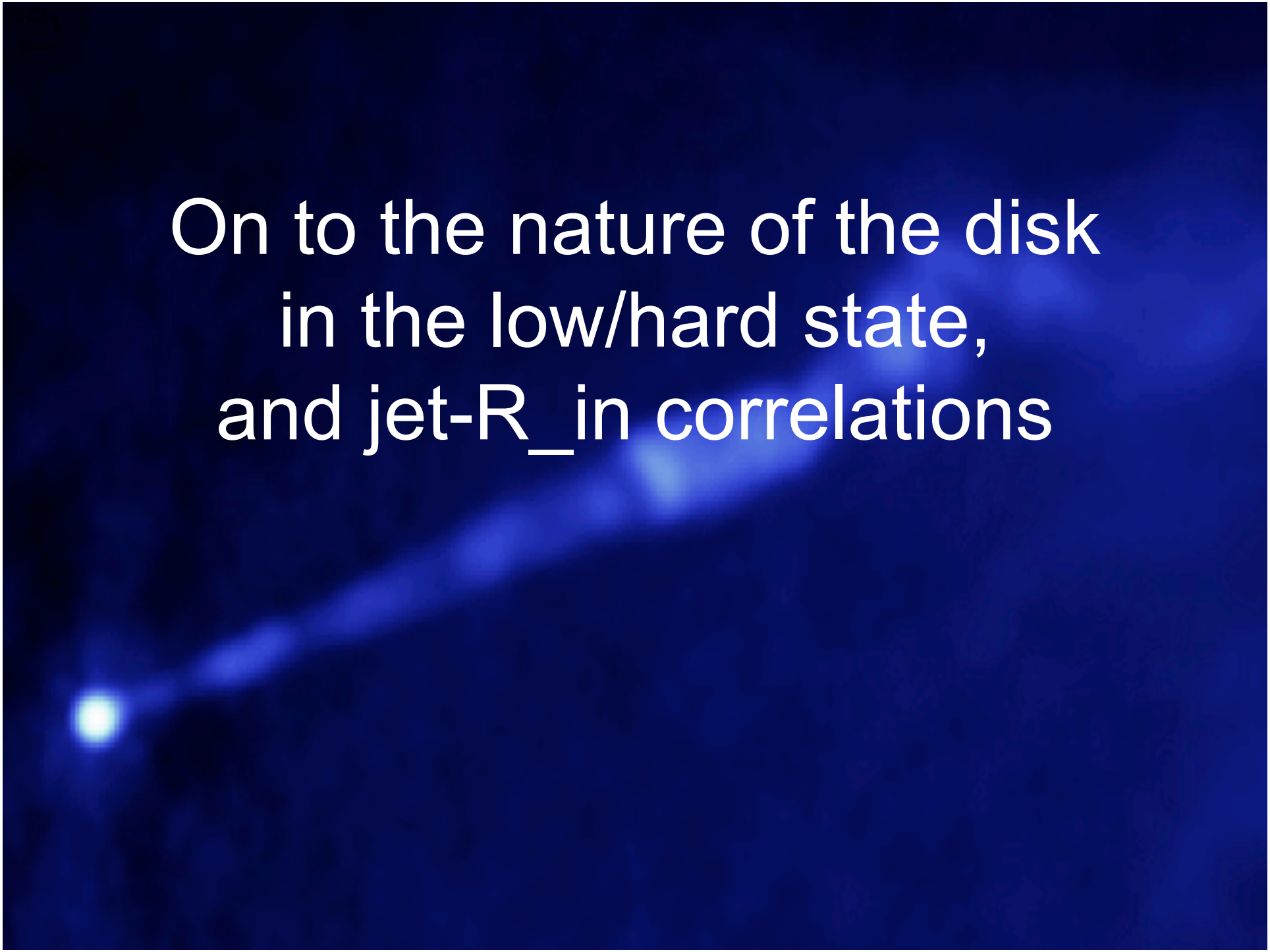
A Lorentzian does not a QPO make



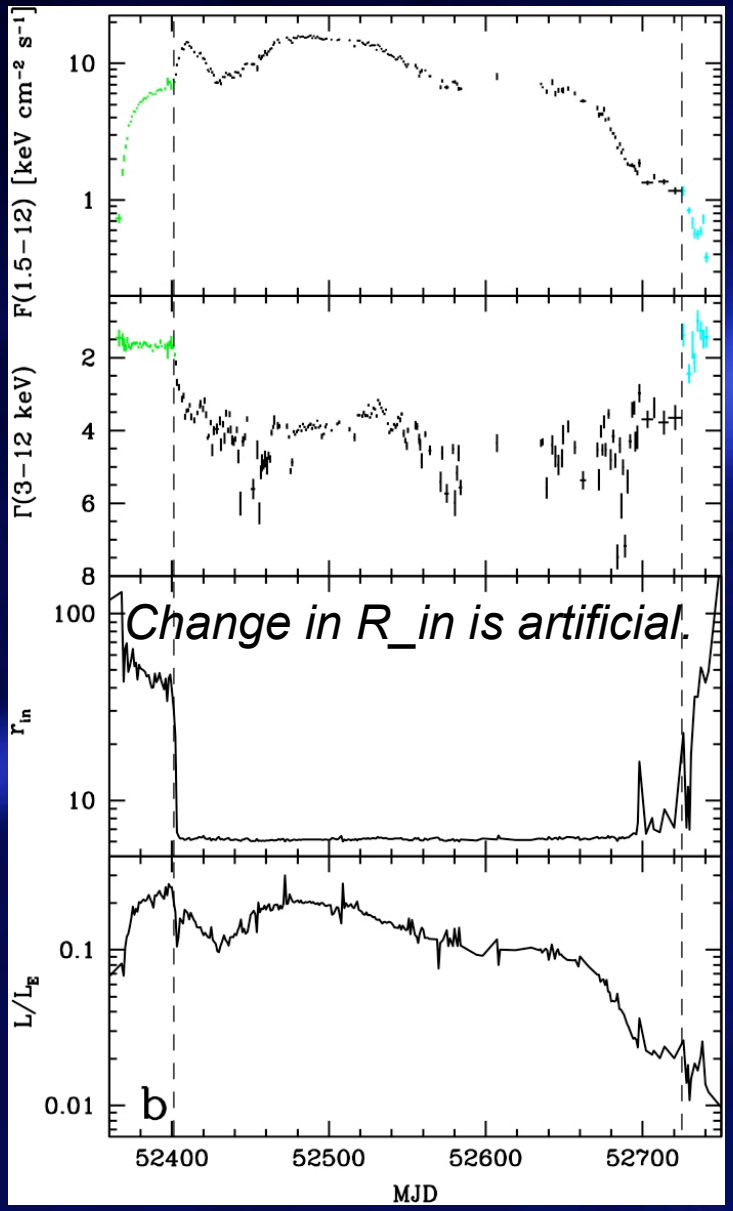
Excellent idea, but take note:

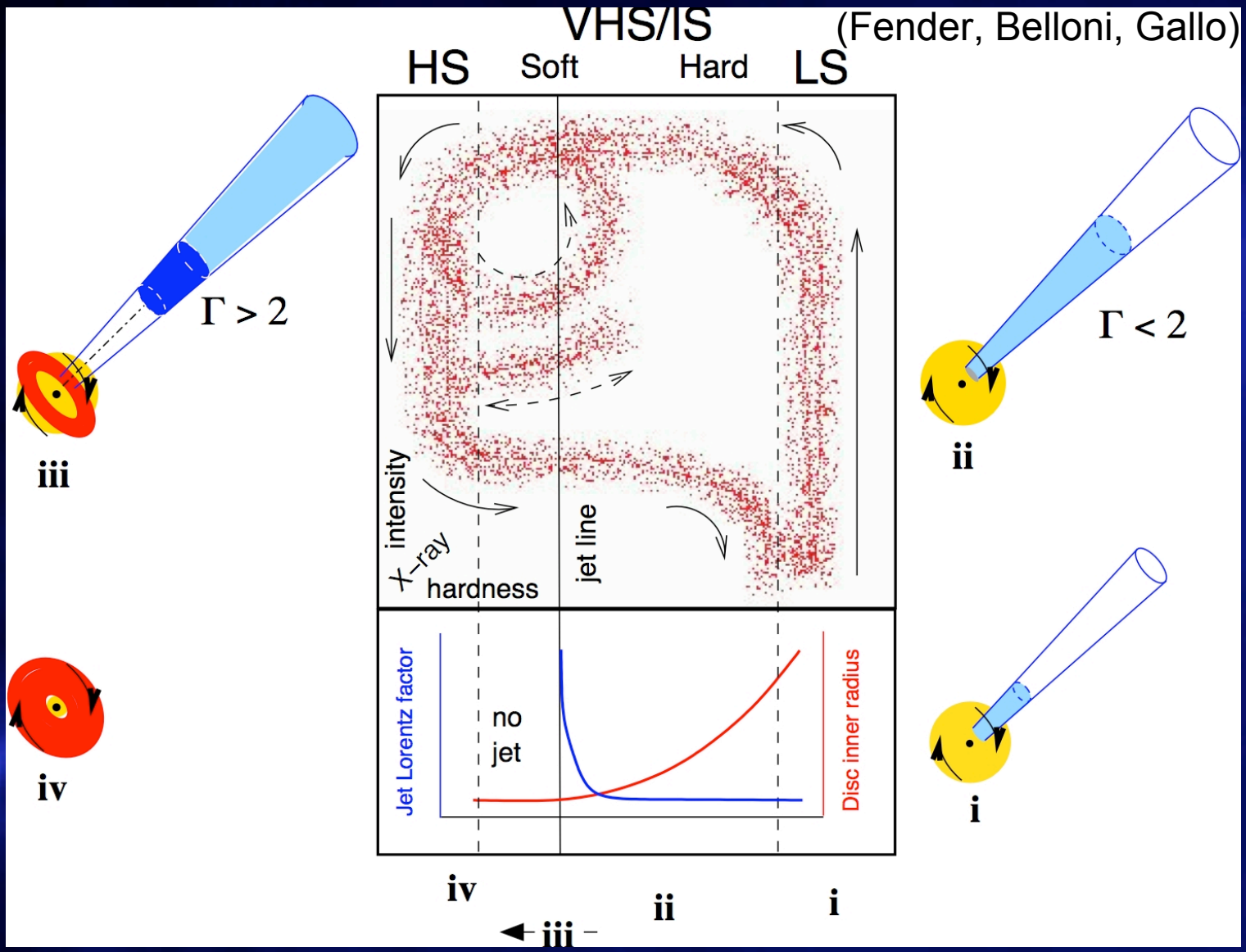
- We only claim to understand kHz QPOs in NSs and 180-450 Hz QPOs in BHs.
- Lorentzians are not QPOs. Are they disk freqs?
- Lorentzians method a semi-model-dependent one.

- Peaked timing features correlate with X-ray flux, hardness. (QPOs are spectrally HARD.)
- Radio flux correlates with X-ray flux, hardness.
- Unless radio flux correlates with timing parameters BETTER than either correlate with X-ray flux and hardness, any correlation is at best indirect, and may not point to a disk-jet connection.

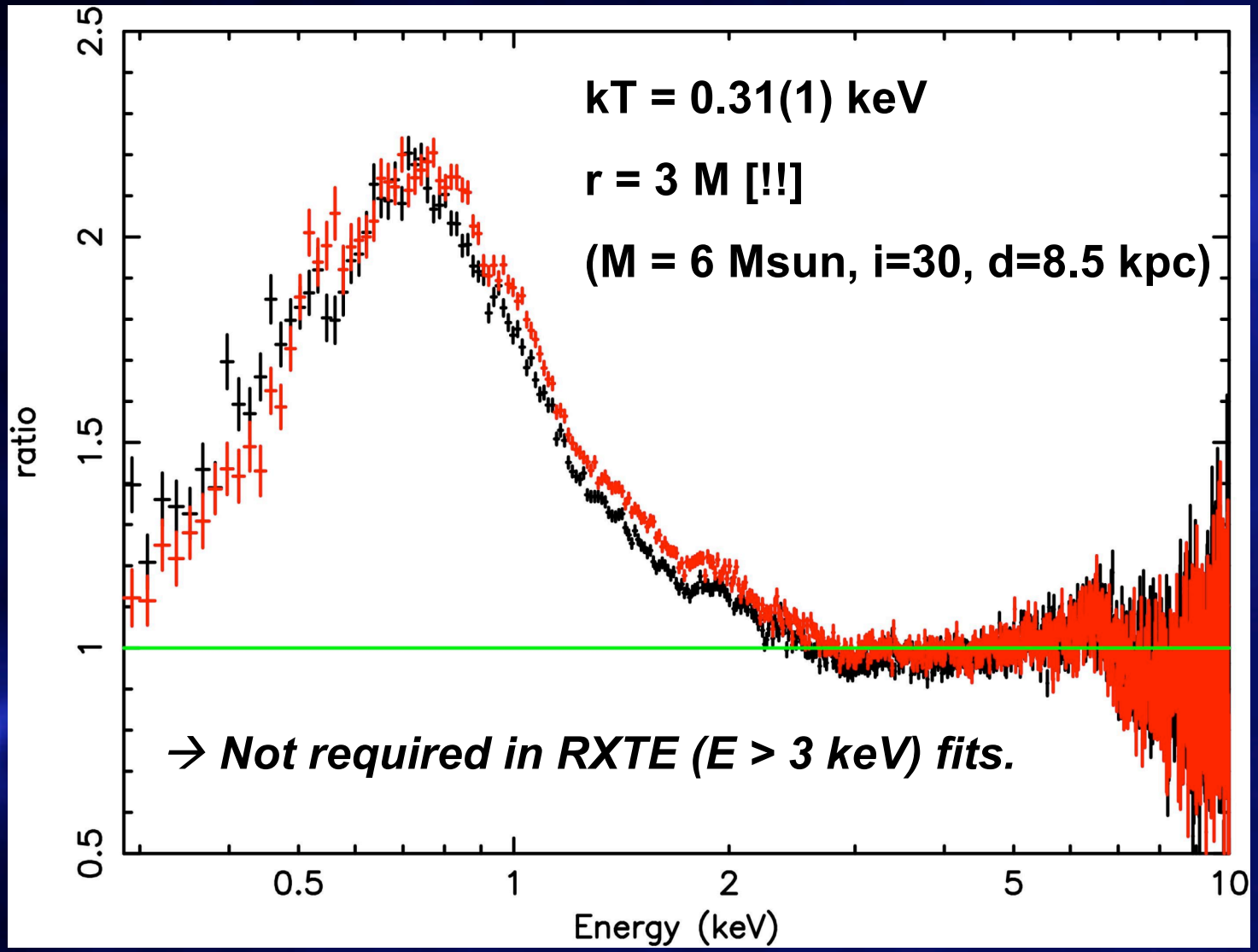

On to the nature of the disk
in the low/hard state,
and jet-R_in correlations

GX 339-4 (Zdziarski et al. 2004)

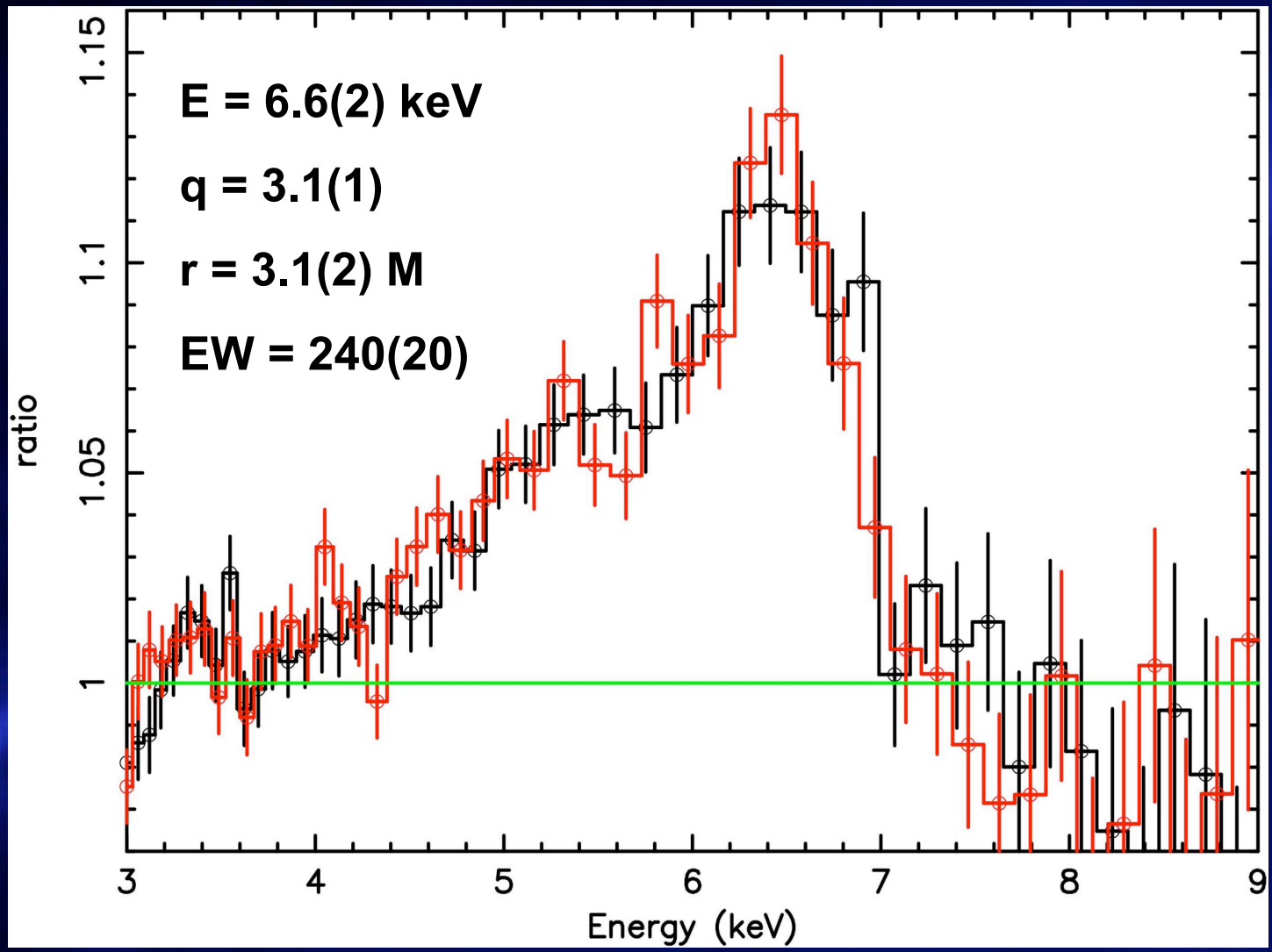



VHS/IS
(Fender, Belloni, Gallo)
HS
Soft
Hard
LS
Γ > 2
iii
Γ < 2
ii
intensity
X-ray
hardness
jet line
iv
Jet Lorentz factor
no
jet
Disc inner radius
i
iv
ii
i
iii

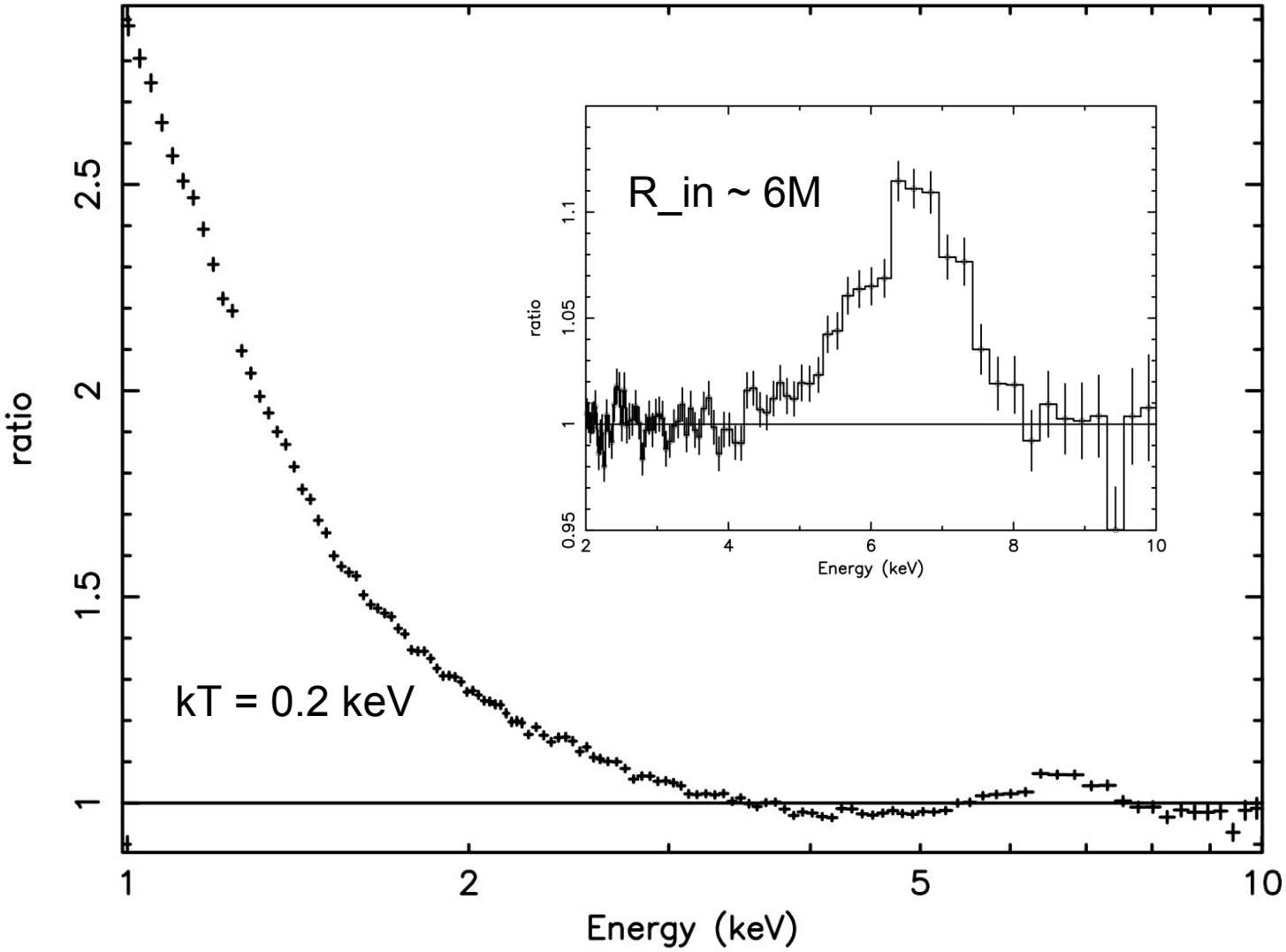
A long, hard look at GX 339-4:



The Fe K line says the disk is at the ISCO.

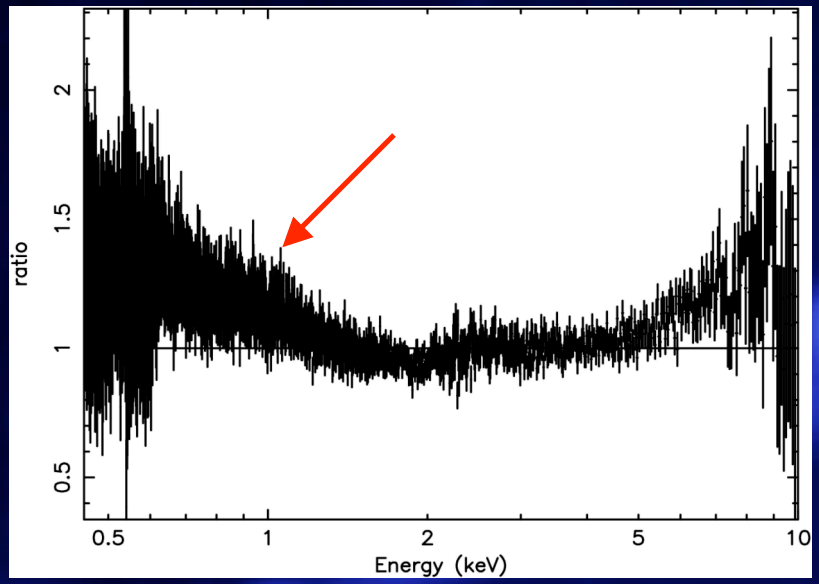


Cygnus X-1 in the “low/hard” state:

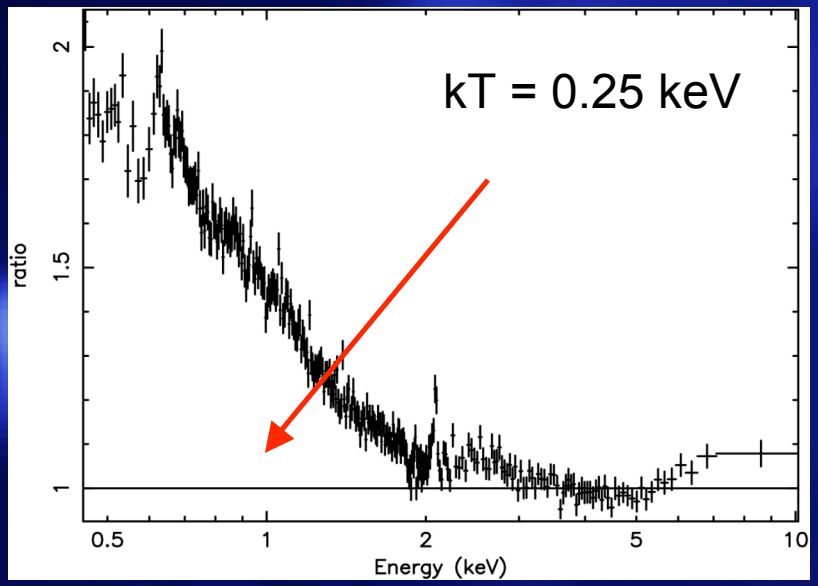


XTE J1118+480 in the “low/hard” state:

No rebinning.



15 counts/bin.



- Chandra spectrum shown as ratio to 2-10 keV power-law.
- Spectrum requires a cool disk; disk models imply R_in ~ 6M.
- Data rule-out a narrow Fe K line.
- BUT: data allow EW = 150 eV relativistic line (note: 81 deg incl.)

Taking stock of the low/hard state:

Source	L_X/L_Edd	Fe line
GX 339-4	0.015	2-3M
Cygnus X-1	0.005	6M
XTE J1118+480	0.002	??
V4641 Sgr	0.002	6M

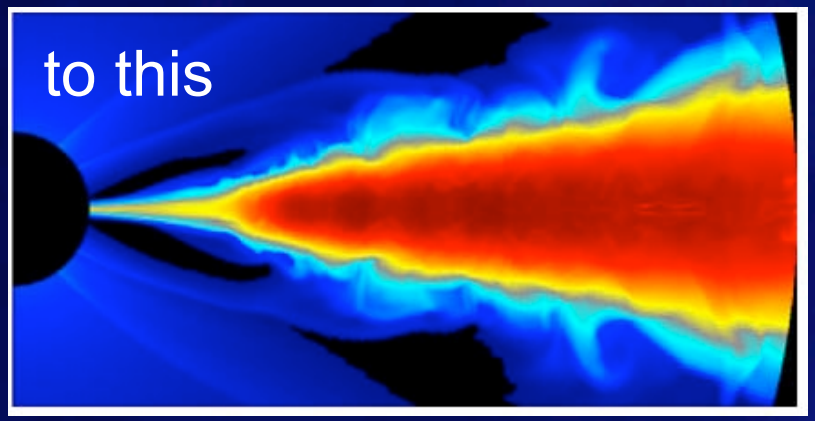
- → Rel. lines indicate disks are not necessarily truncated in the low/hard state.
- → Disk continuum components are required if you measure down to 1 keV.
- → The state transition may have more to do with the corona/jet than the disk.
- → Need a more careful look at LLAGN like M81* and NGC 4258.


But there is always M87 …

Change your mental image?

From this

to this

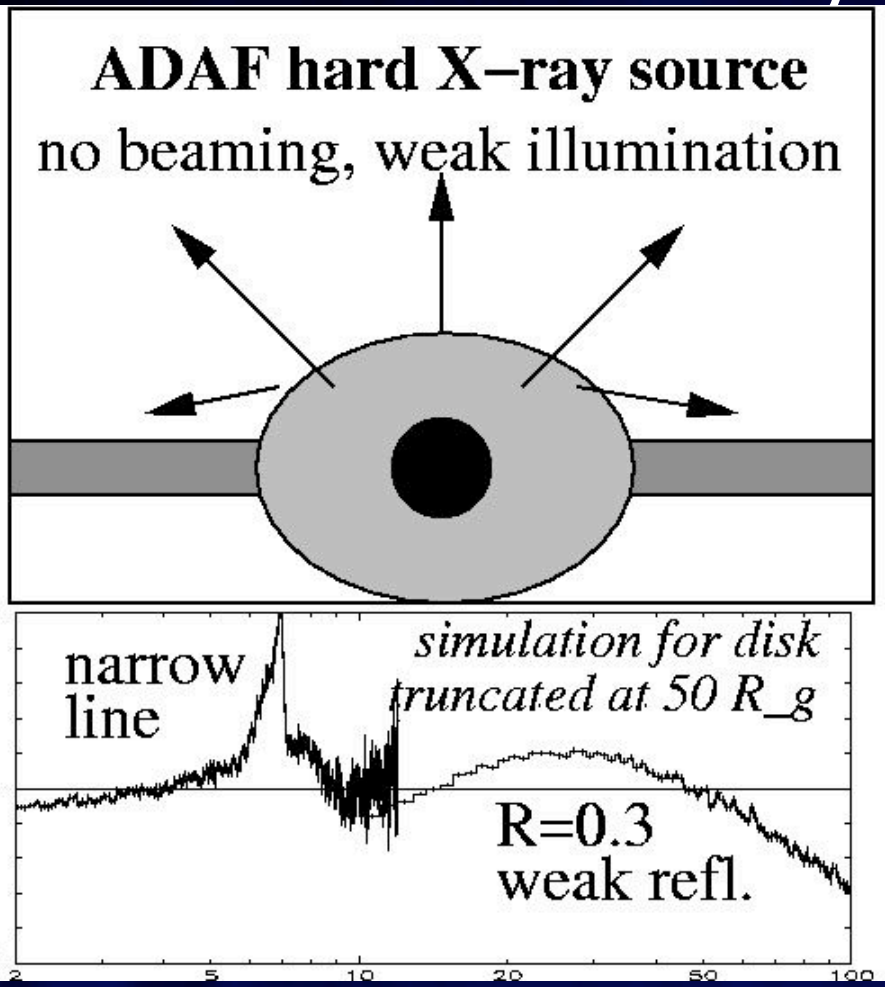


Summary

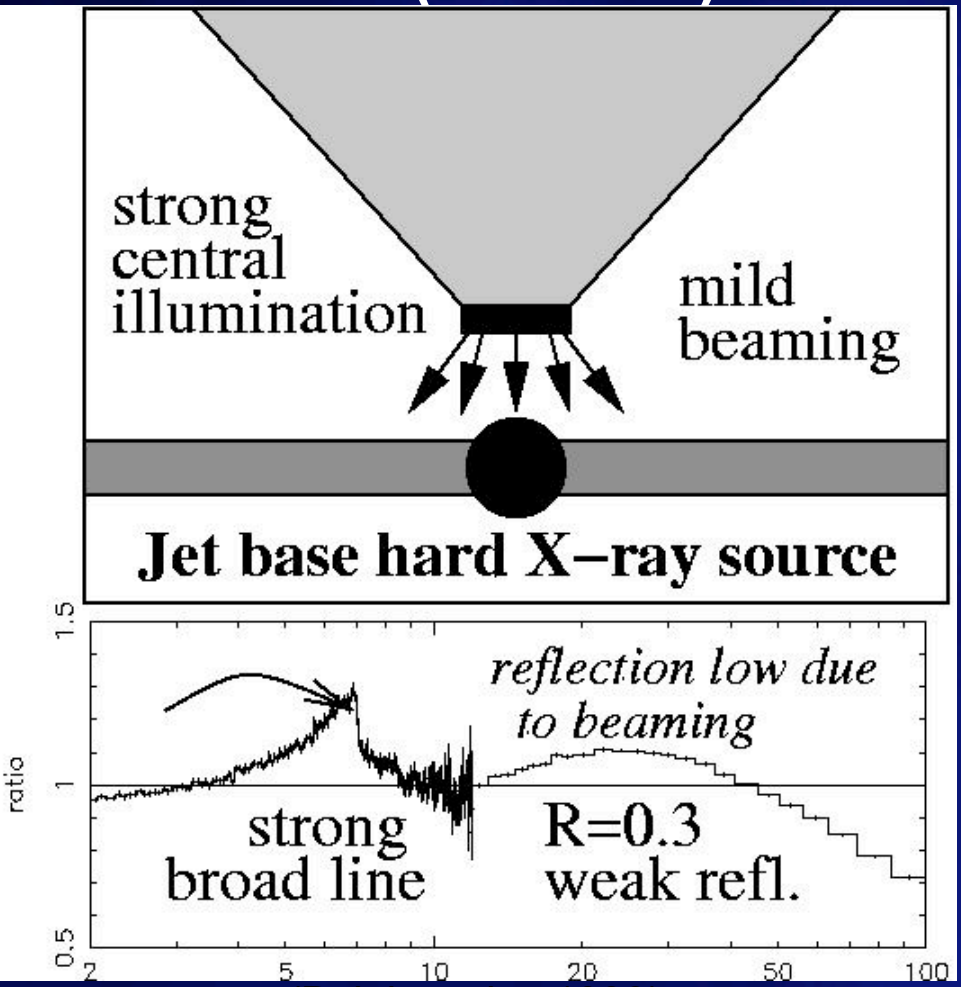
- Jet-dominated flows no less plausible than coronal Comptonization, from a fitting perspective.
- BUT: Initial indications for disk-jet connections may be incorrect, or less direct than hoped for.
- There is no sharp change in disk radius across states. Jets do not depend on R_in.

  Remember: low/hard state $\not\equiv$ ADAF
- New work focusing on more discrete features may offer more insight; statistical care still needed.
- We need to keep RXTE alive to continue making real progress. Tell your friends.

Low luminosity accretion (low m)

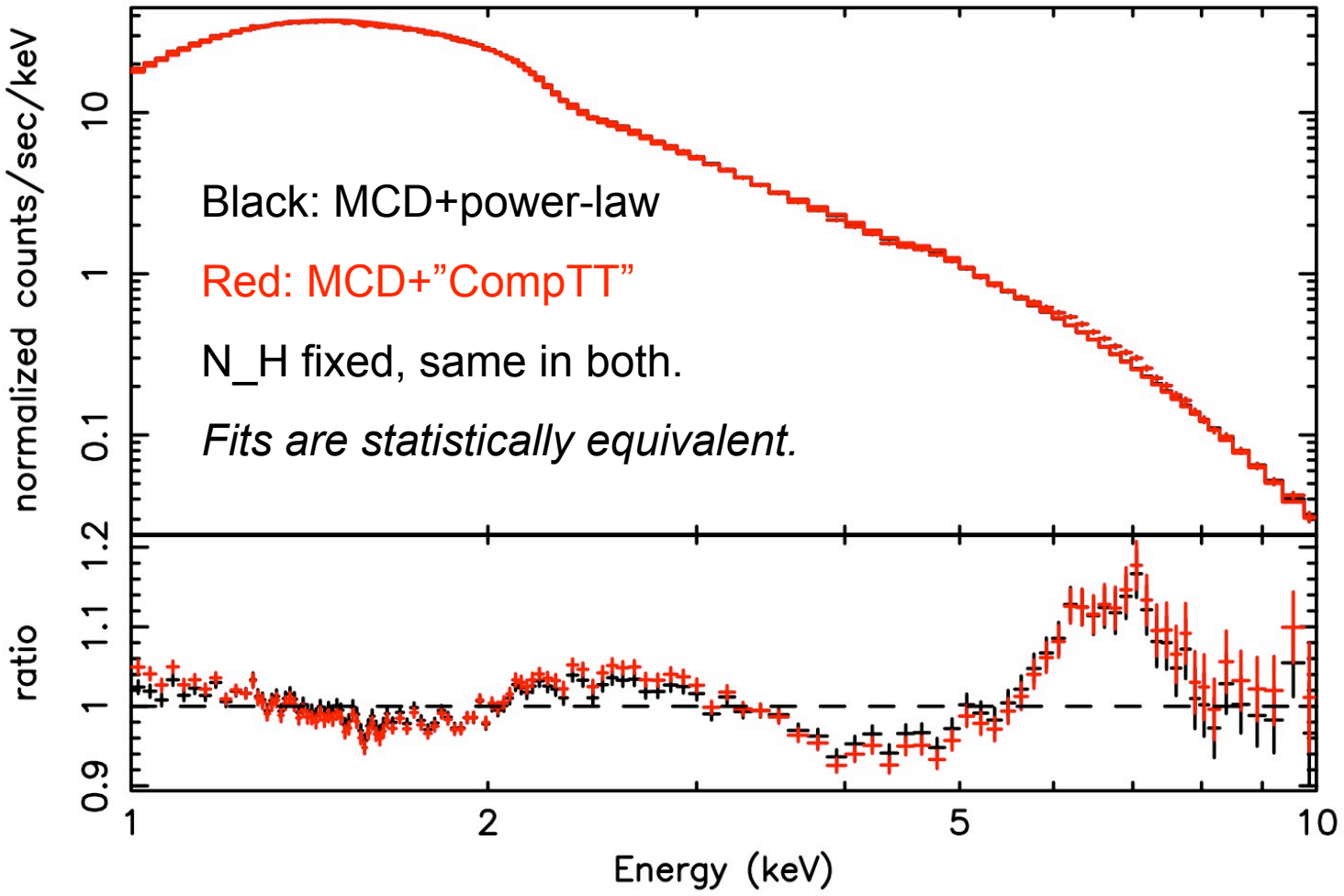


(Esin 1997,1998,2001)

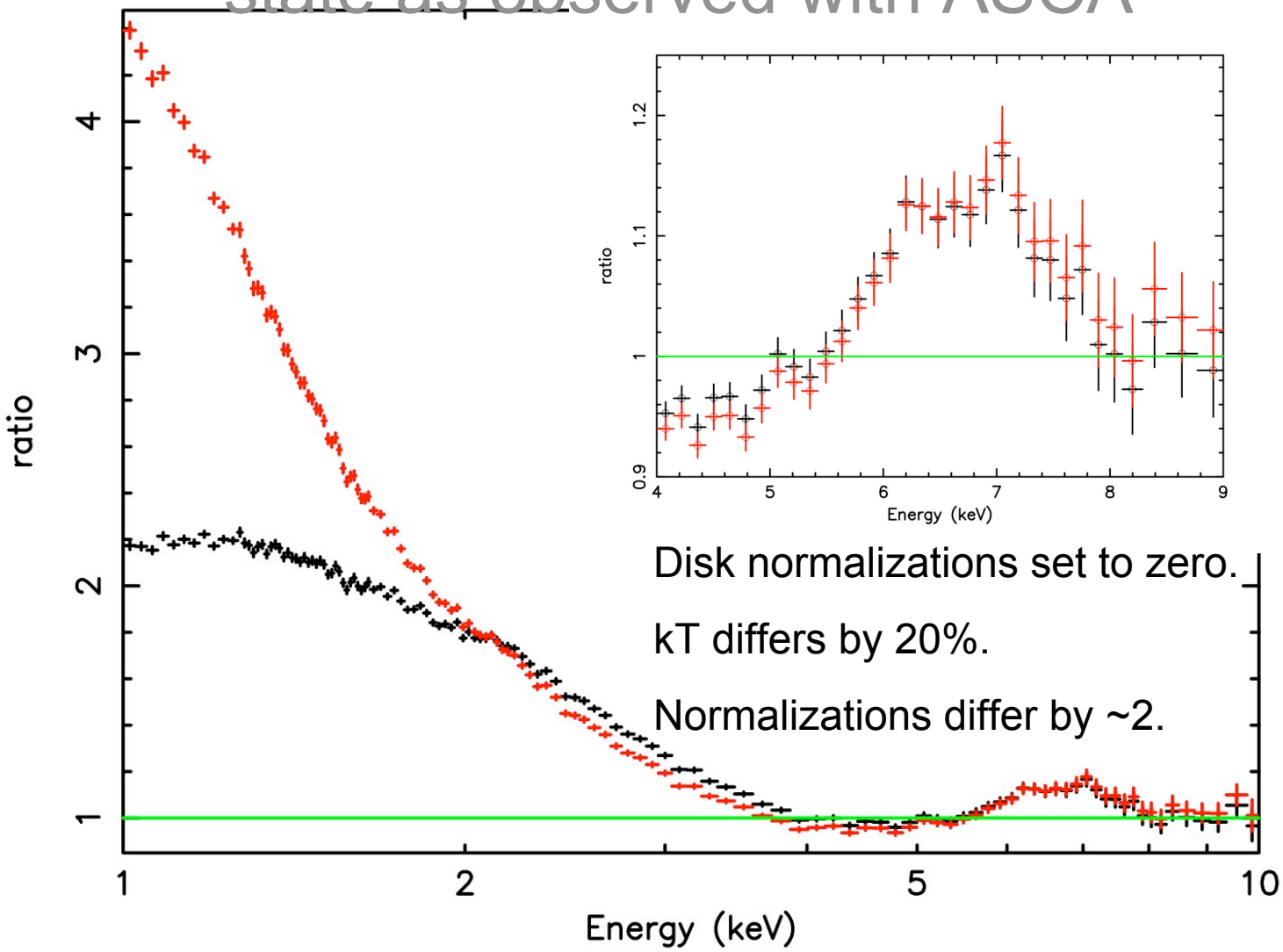


(Beloborodov 1999)
(Miller et al. 2001)

Cygnus X-1 in an intermediate (high/soft ??) state as observed with ASCA



Cygnus X-1 in an intermediate (high/soft ??) state as observed with ASCA

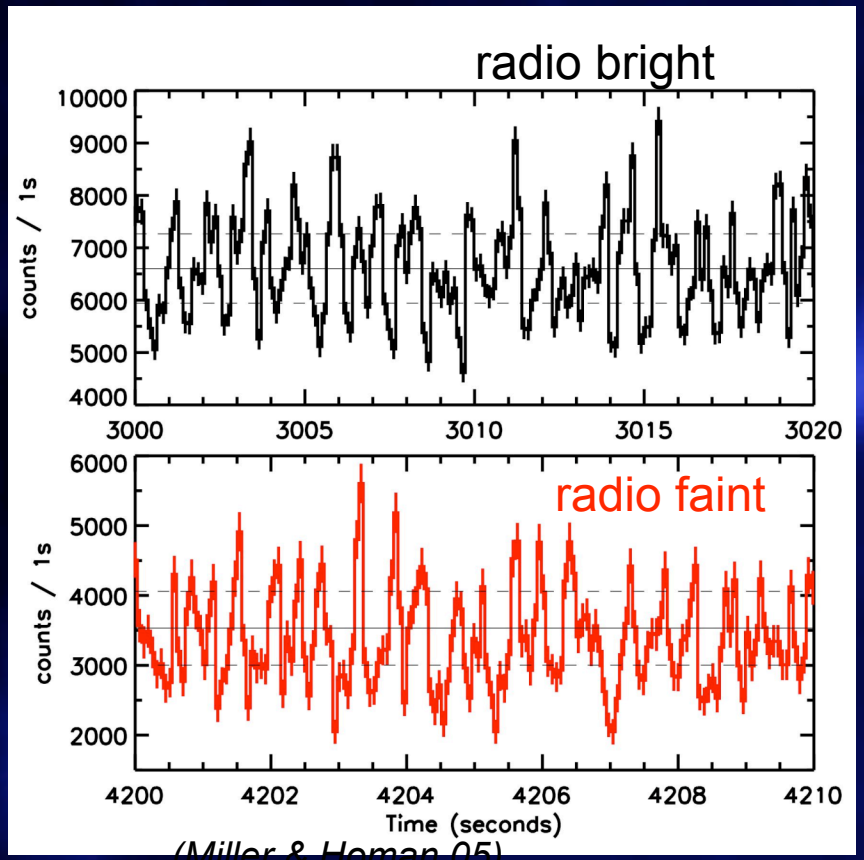


Disk normalizations set to zero.

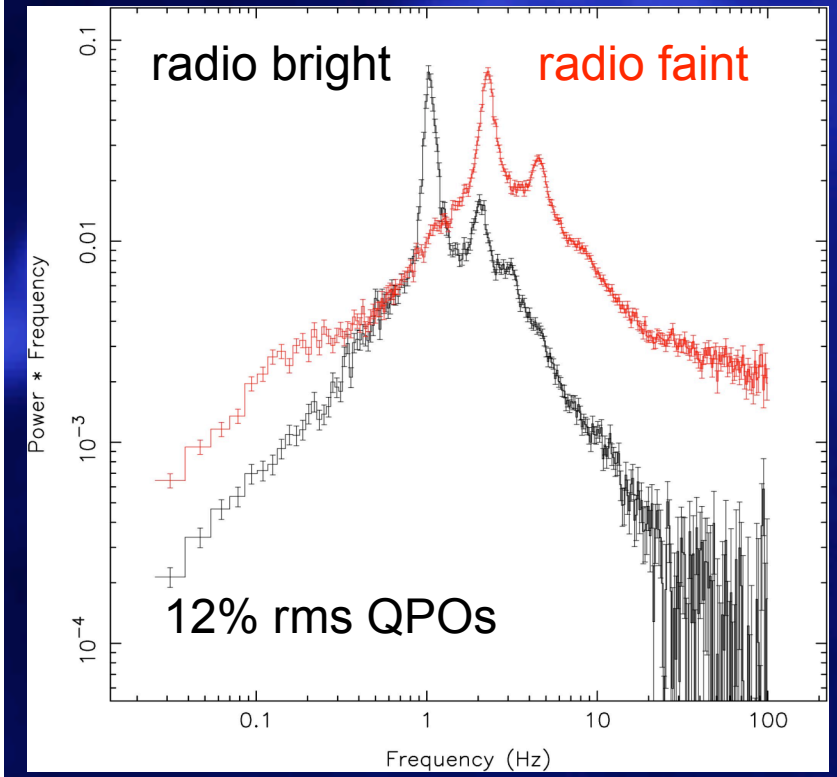
kT differs by 20%.

Normalizations differ by ~2.

QPO Phase-resolved spectroscopy



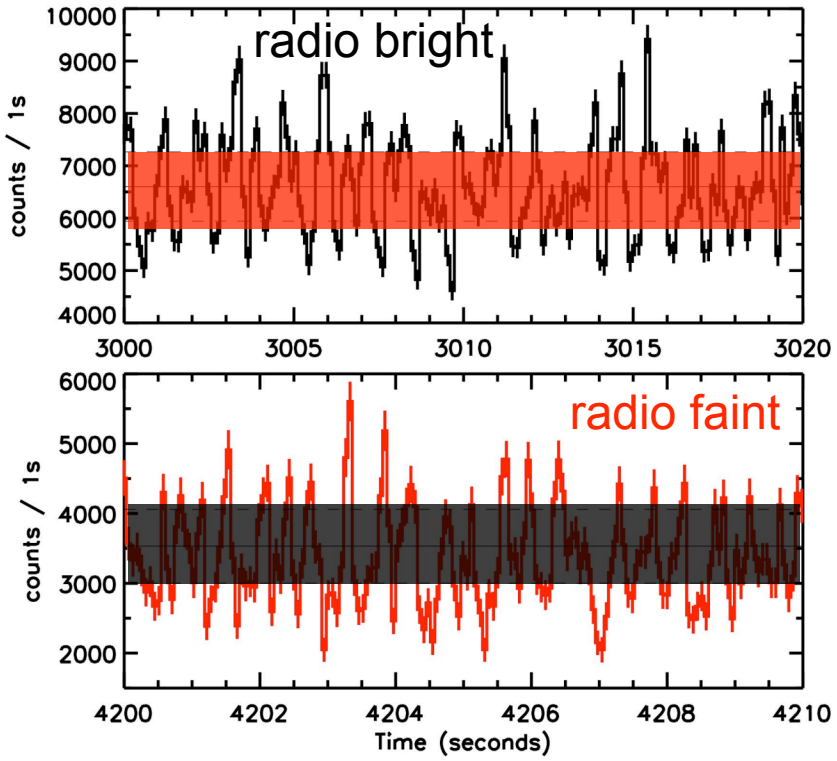
(Miller & Homan 05)

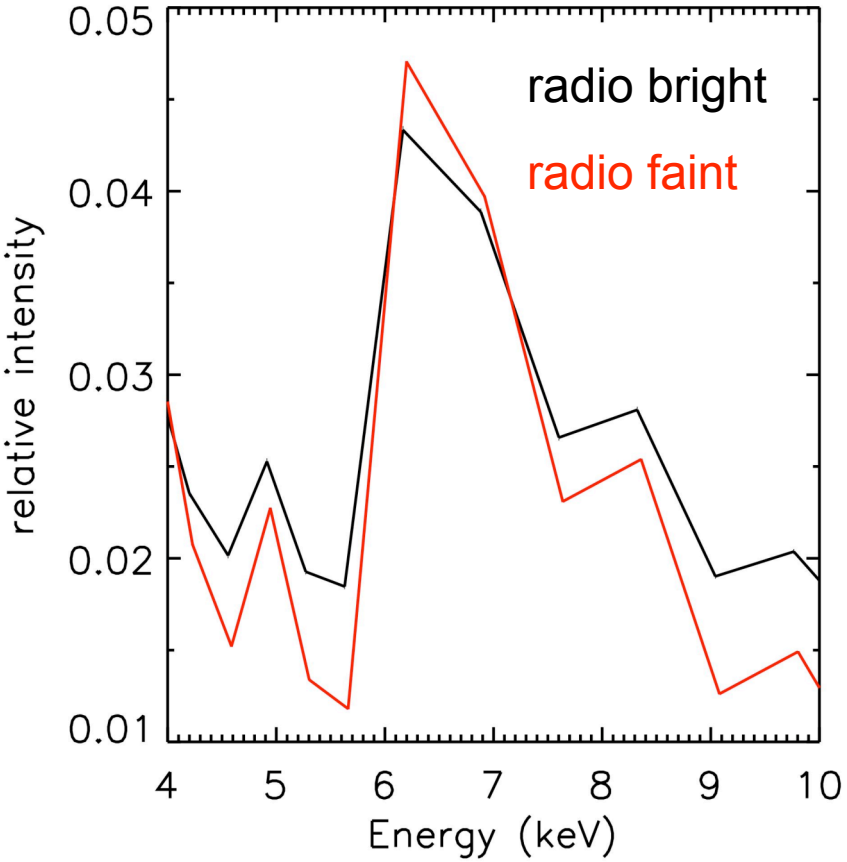


GRS 1915+105, RXTE

Difference Spectra: High – Low QPO Phase

The iron line is relatively more important at the top of the QPO than at the bottom – the line does not merely trace the overall flux.

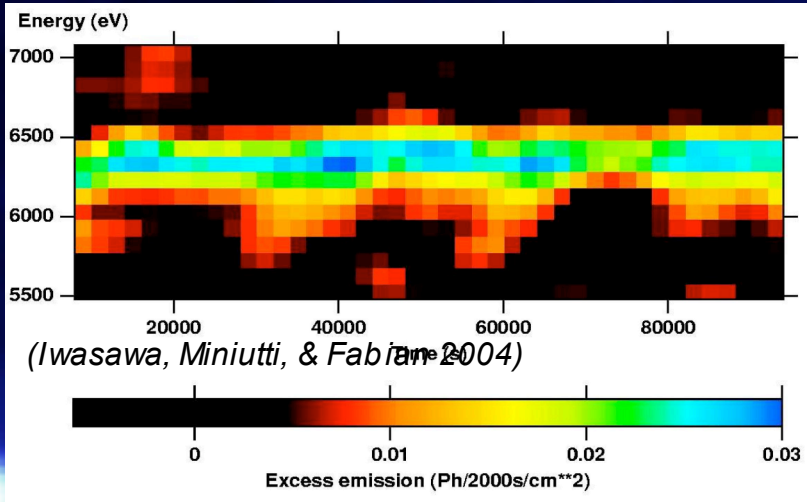




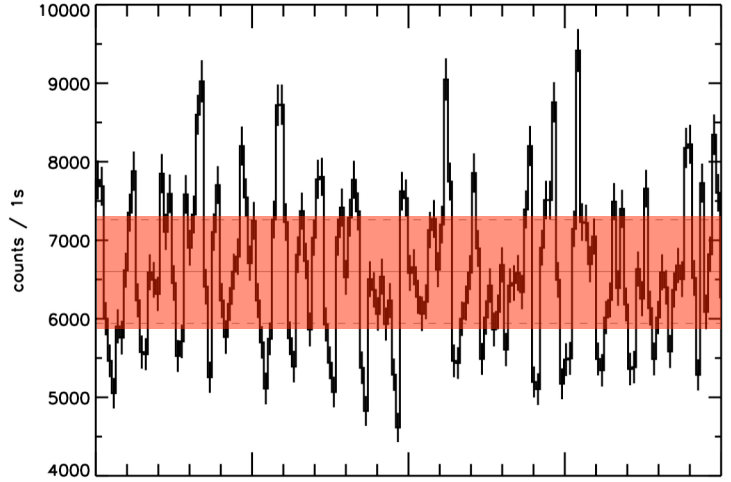
(Miller & Homan 05)

Evidence for disk structure from line variability:

Modulation of the Iron line flux in NGC 3516 (M ~ 10 Million Msun)



(Iwasawa, Miniutti, & Fabian 2004)



Modulation of the Iron line flux in GRS 1915+105 (M = 14 Msun)