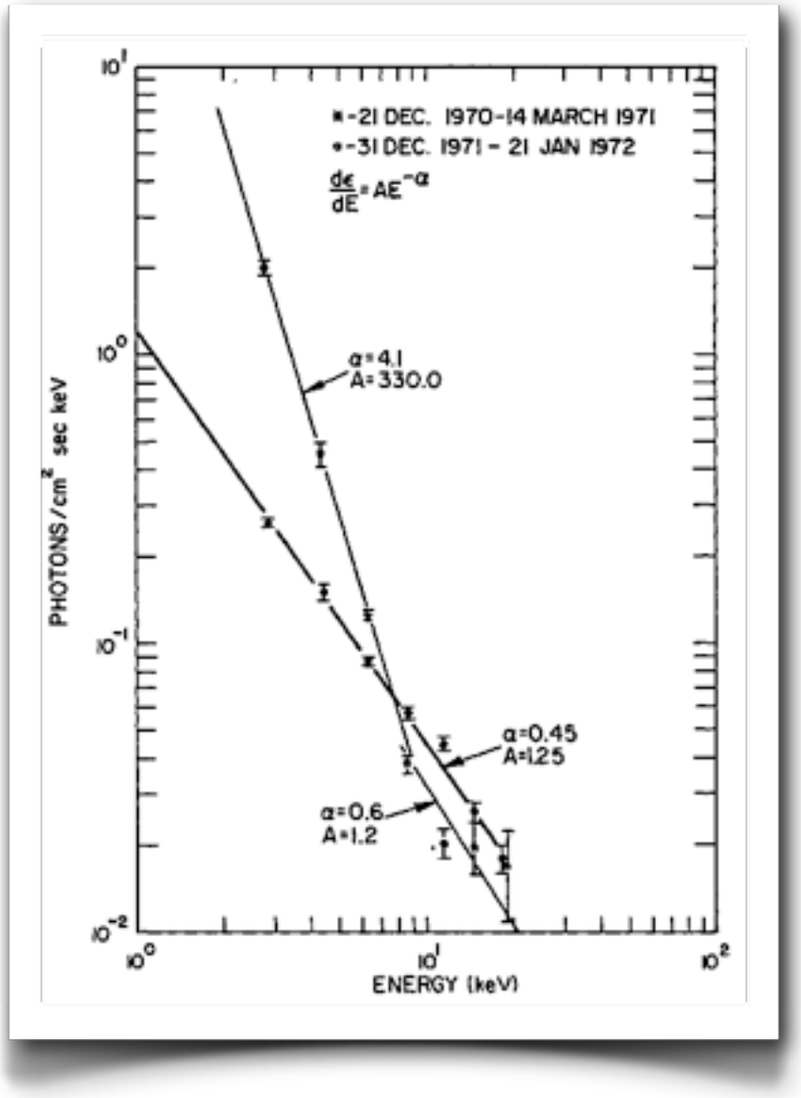
States and state transitions in X-ray binaries

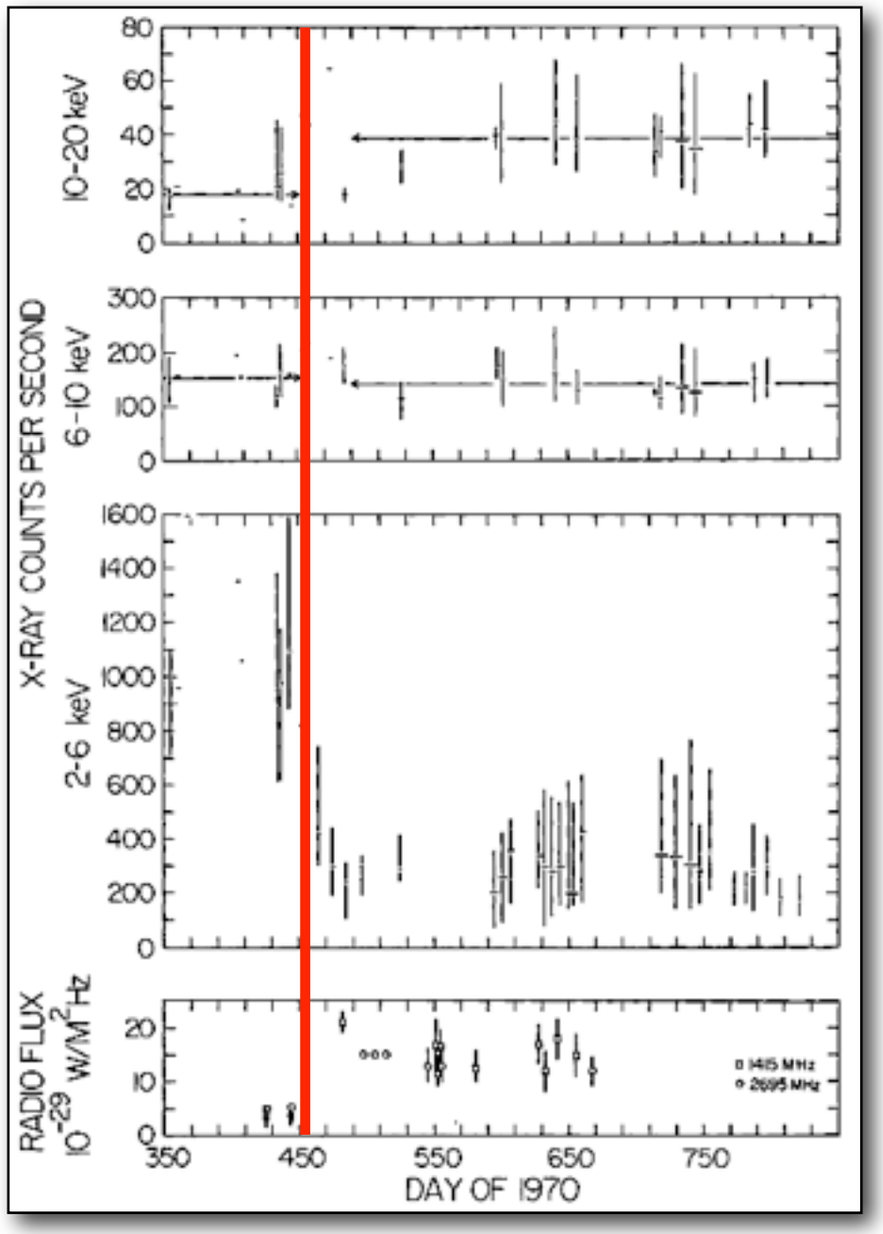
Tomaso Belloni
(INAF - Osservatorio Astronomico di Brera)

HIGH ENERGY VIEW OF ACCRETING OBJECTS: AGN AND X-RAY BINARIES Άγιος Νικόλαος OCT. 12 2010

Accretion onto stellar-mass black holes

- The notion of separate states is very old
- High and low state from Uhuru





Tananbaum et al. (1972)

Two very successful models

High state

Black Holes in Binary Systems. Observational Appearance

N. I. Shakura
Sternberg Astronomical Institute, Moscow, U.S.S.R.

R. A. Sunyaev
Institute of Applied Mathematics, Academy of Sciences, Moscow, U.S.S.R.

Received June 6, 1972

Low state

Comptonization of X-rays in Plasma Clouds. Typical Radiation Spectra

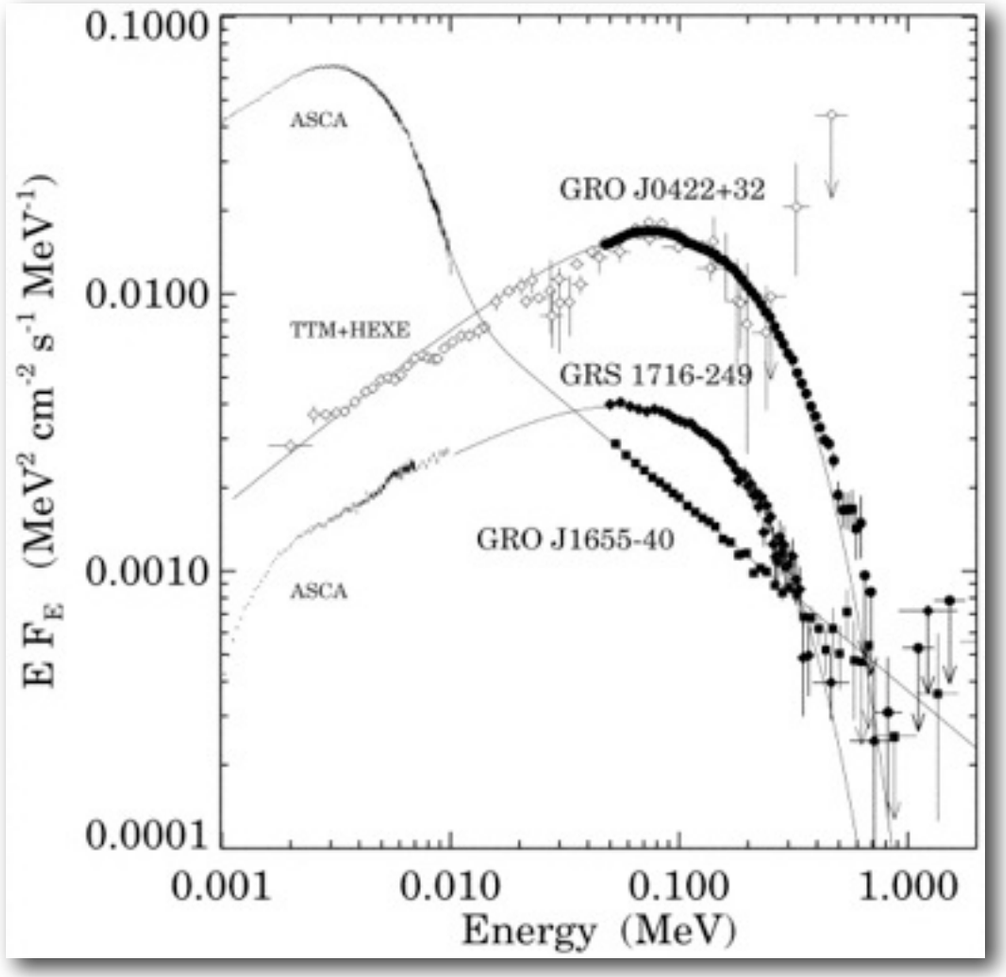
R. A. Sunyaev and L. G. Titarchuk
Space Research Institute, USSR Academy of Sciences, Profsoyuznaja 84/32, Moscow 117810, USSR

Received March 30, 1979

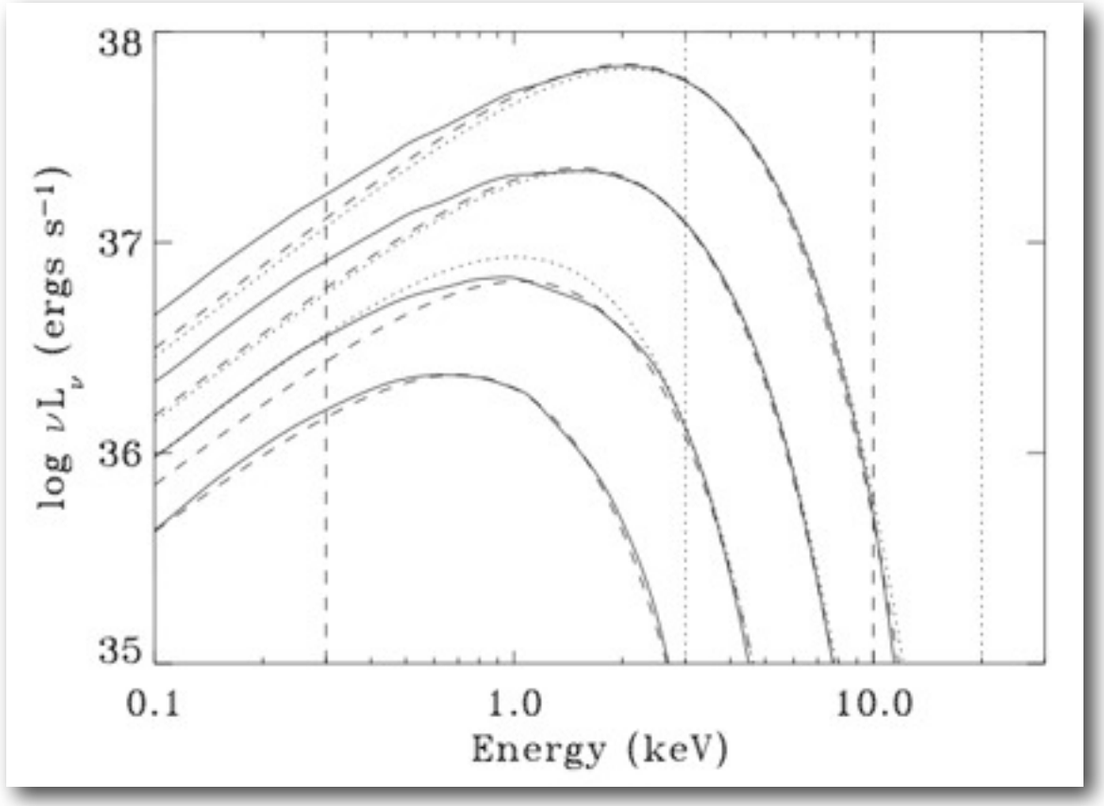
Soft state

- Thin disk model a spectacular success

- Still an additional component is present (always?)



Grove et al. (1998)

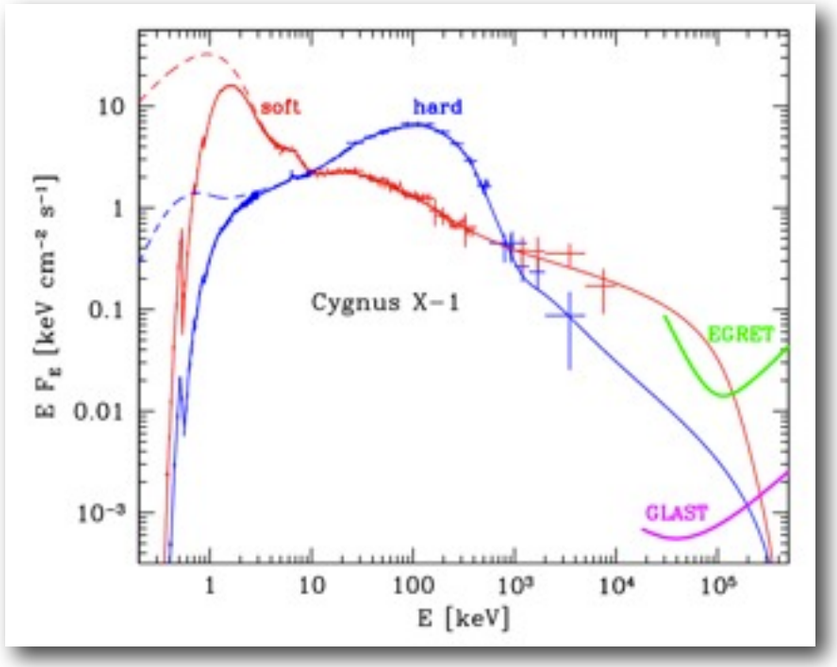


Davis et al. (2005)

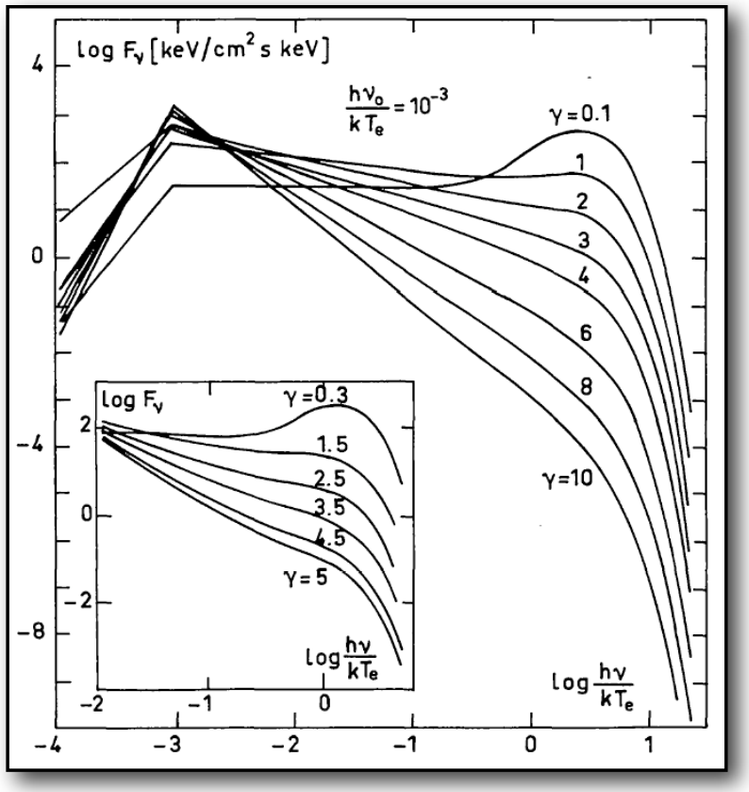
- A quiet disk

Hard state

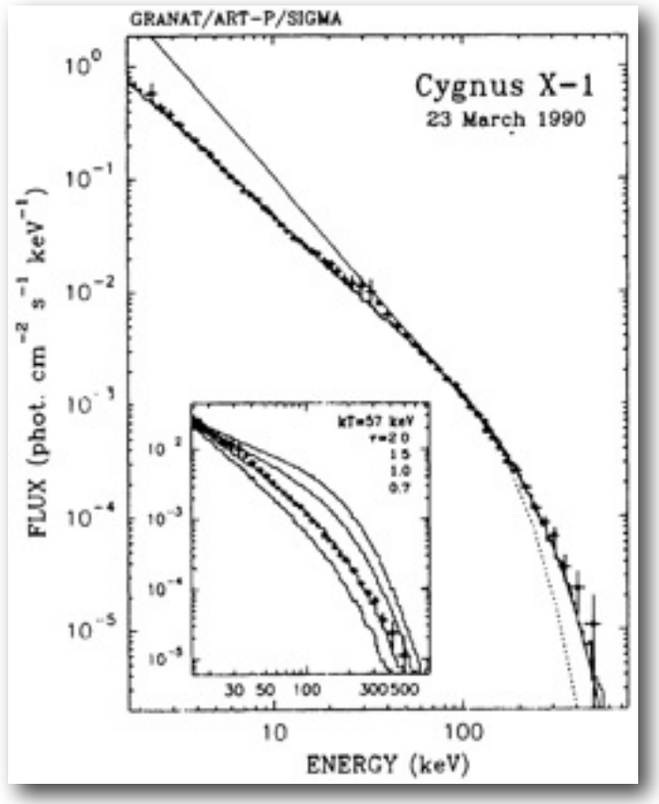
- Lots of complications
- Hybrid models
- Jet models



Zdziarski & Gierliński (2004)



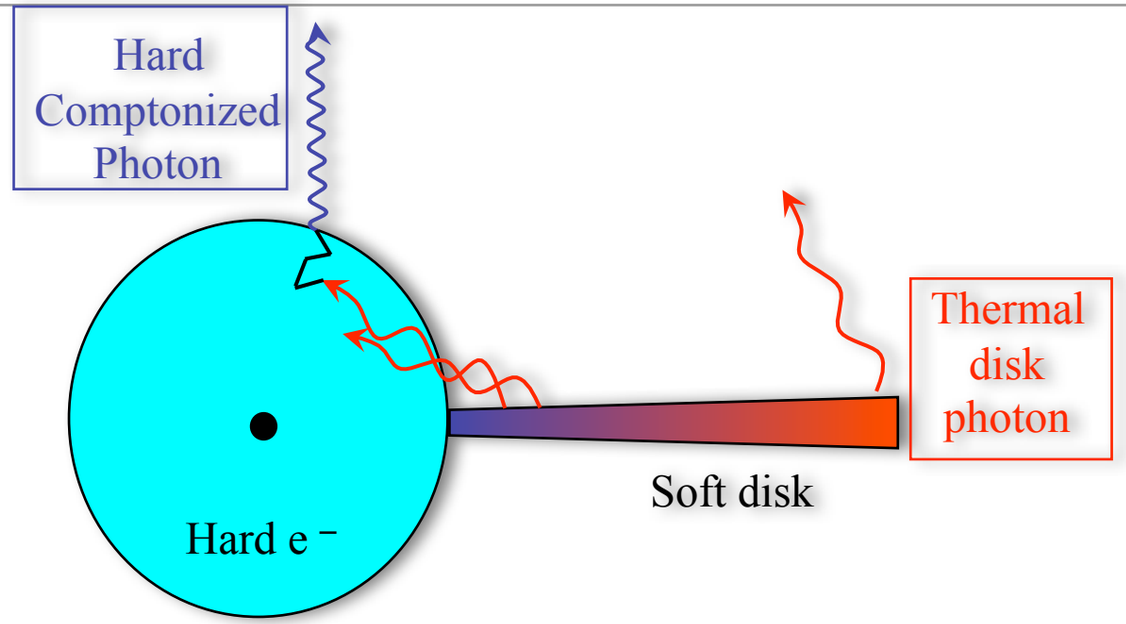
Sunyaev & Titarchuk (1980)

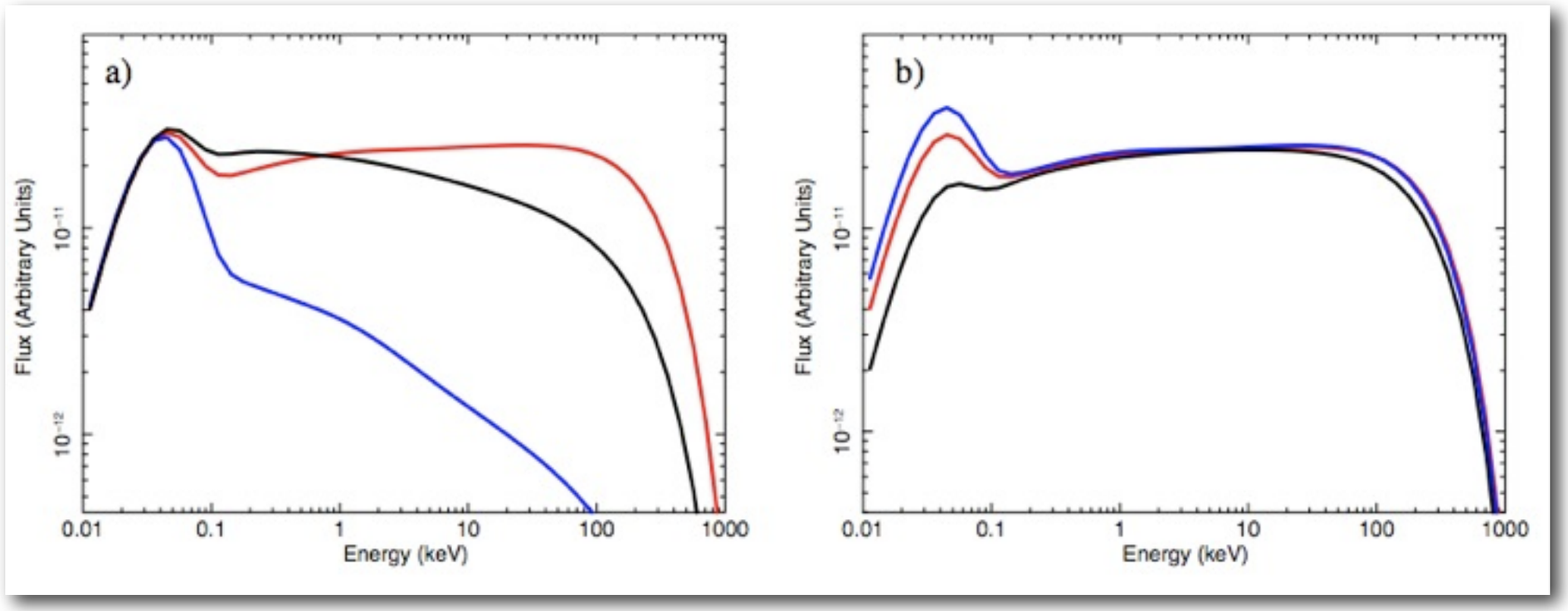


Sunyaev & Trümper (1979)

- A restless flow

Geometry unclear

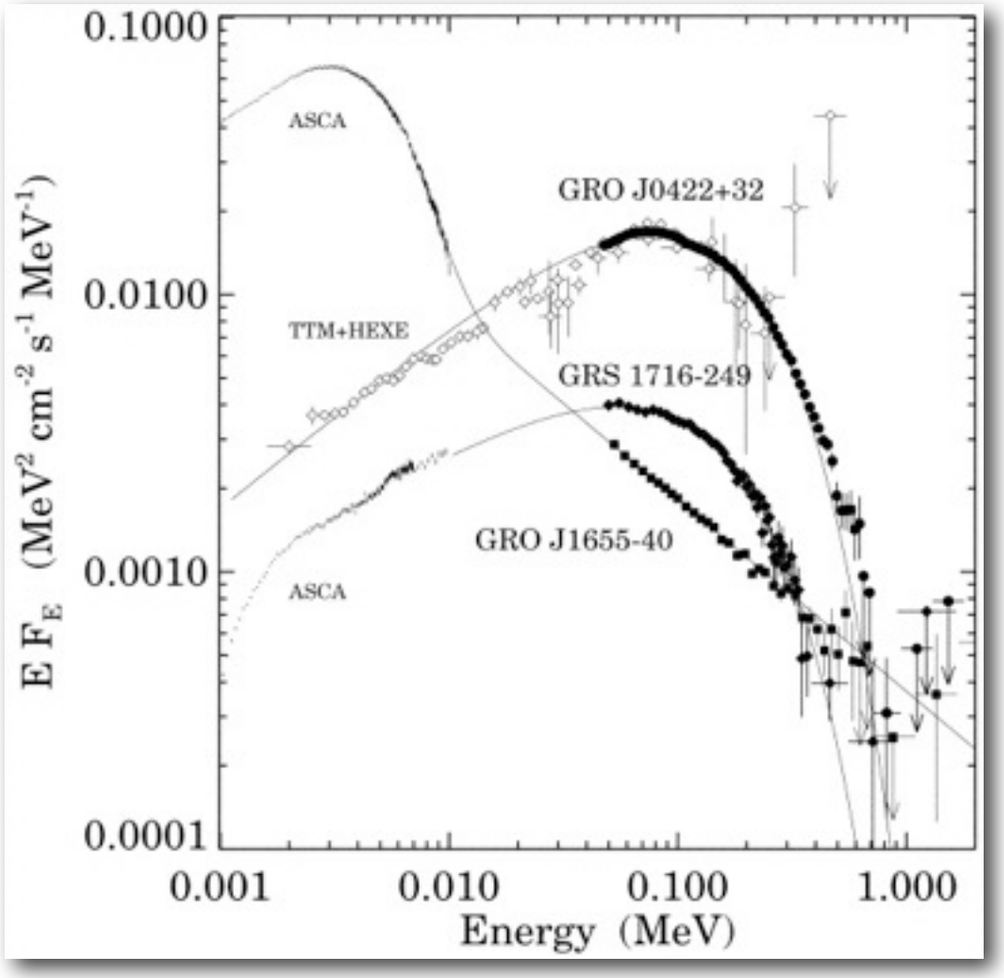




Petrucci (2009)

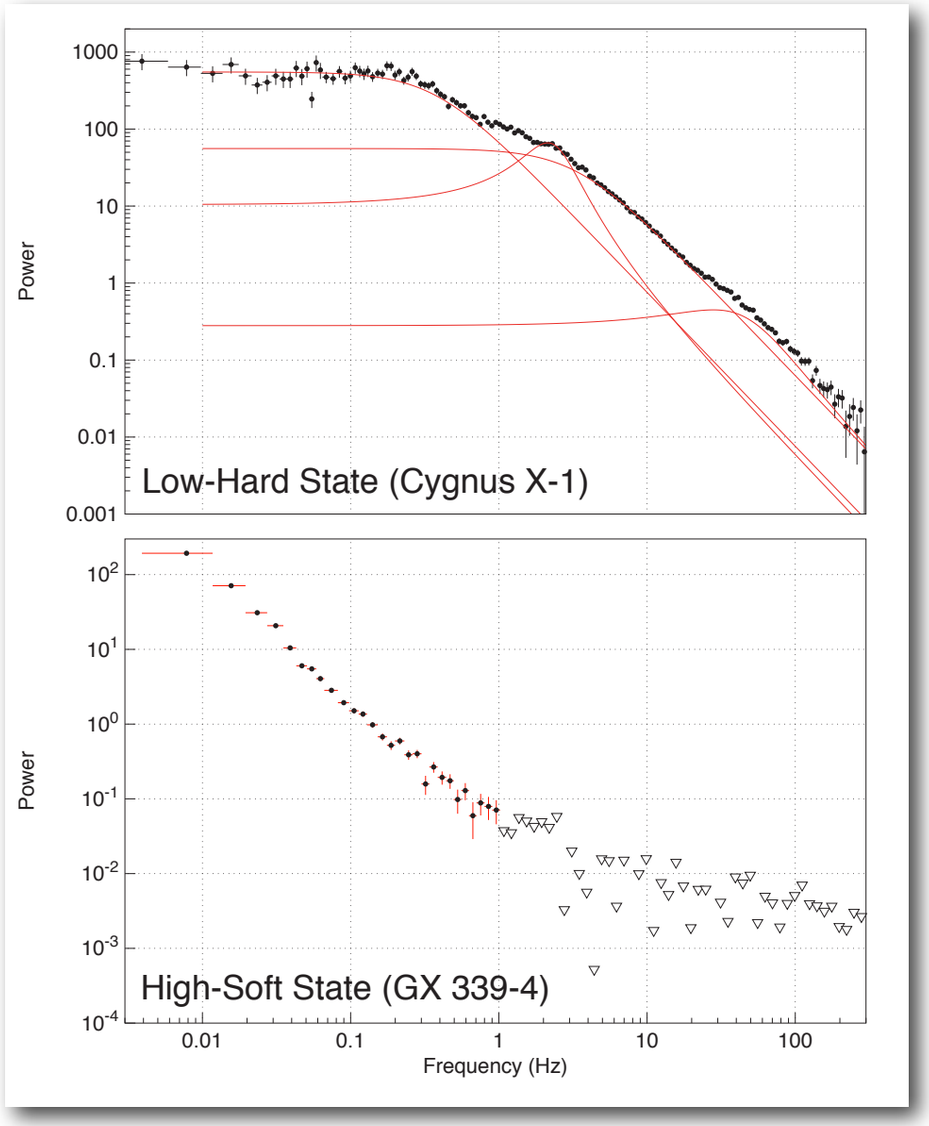
How do you go from one to the other?

Spectra



Grove et al. (1998)

Timing

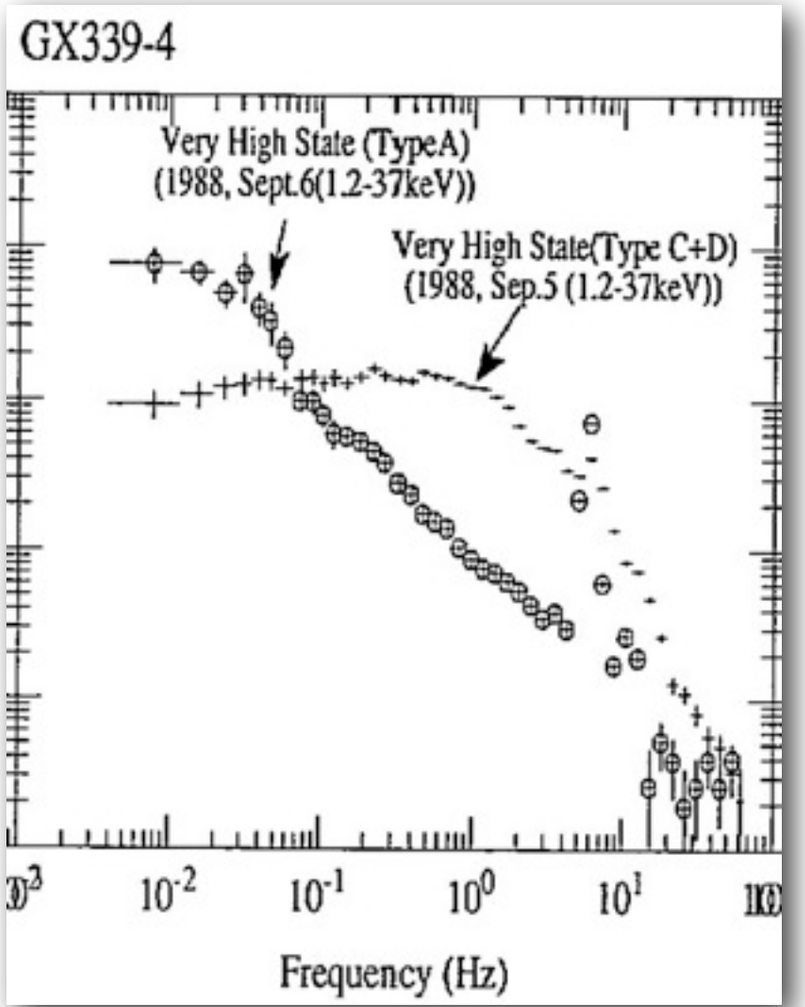


Belloni (2010)

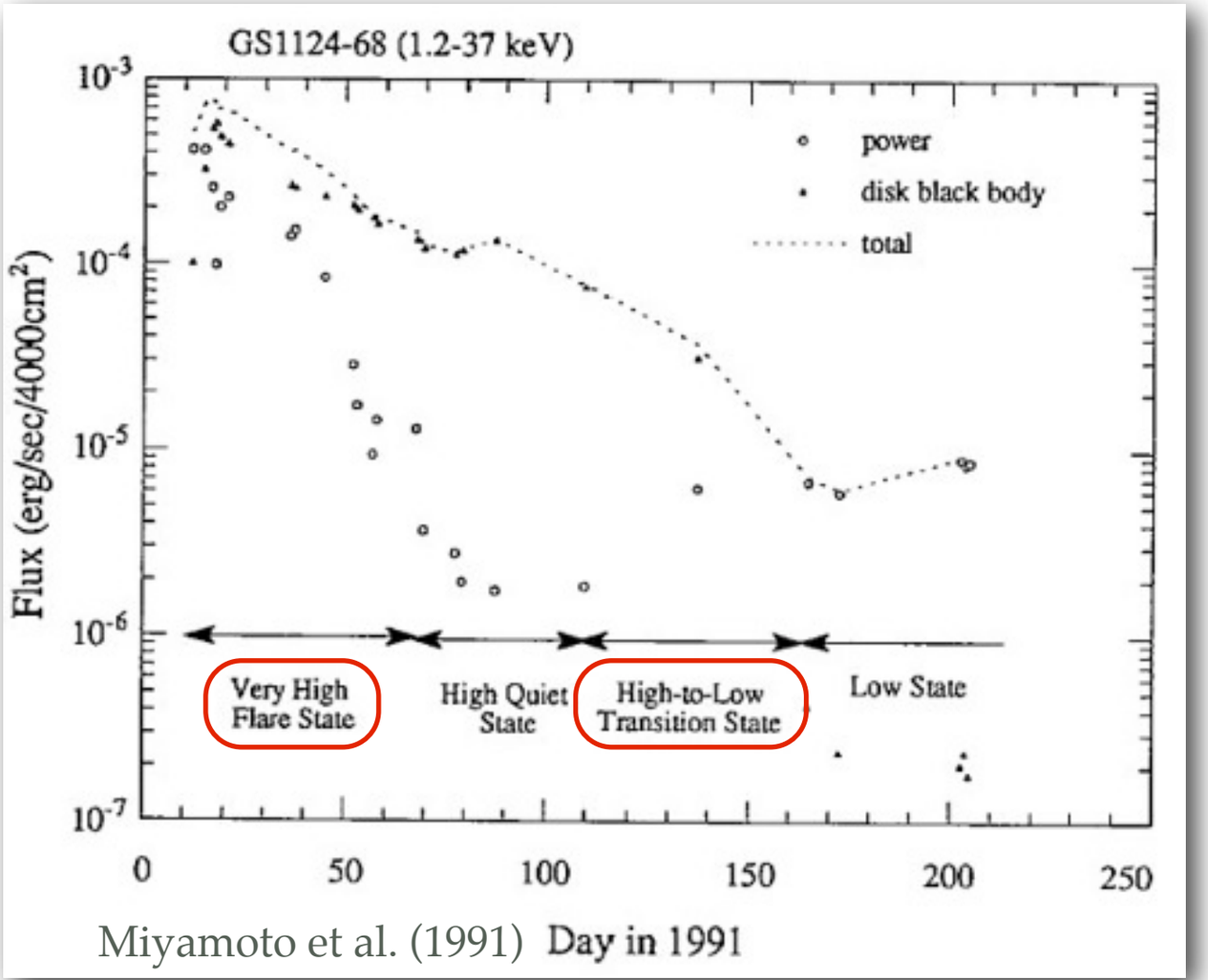
Lack of sources: GINGA

- More sources (transients), more states

- Very High State - Intermediate



Intermediate energy spectrum

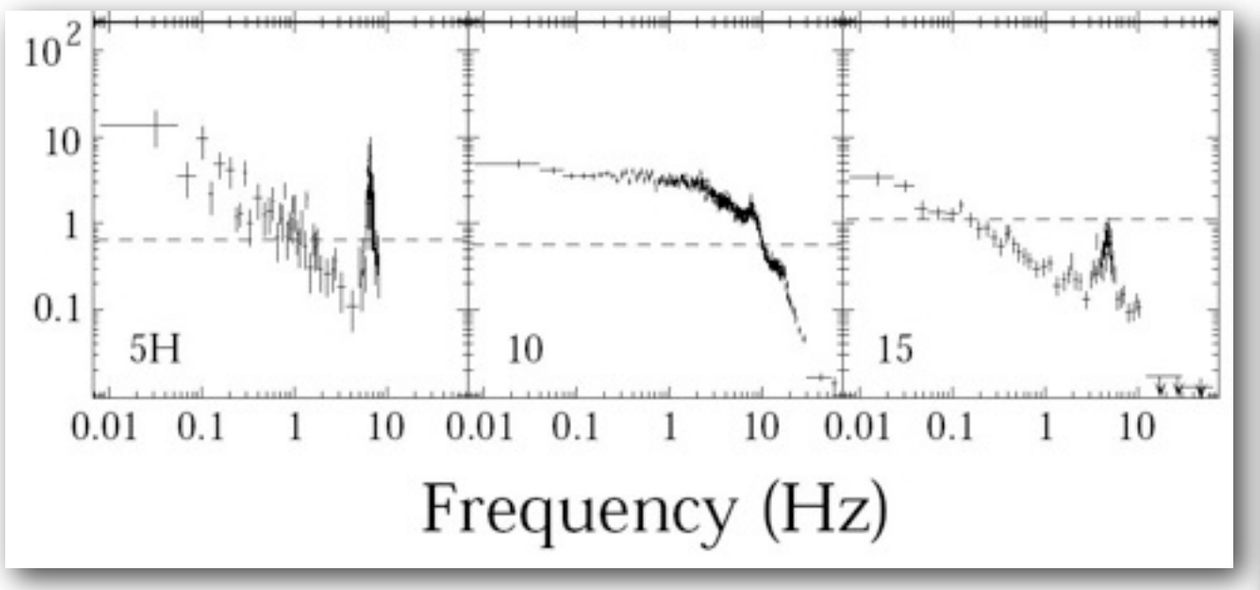


Miyamoto et al. (1991)

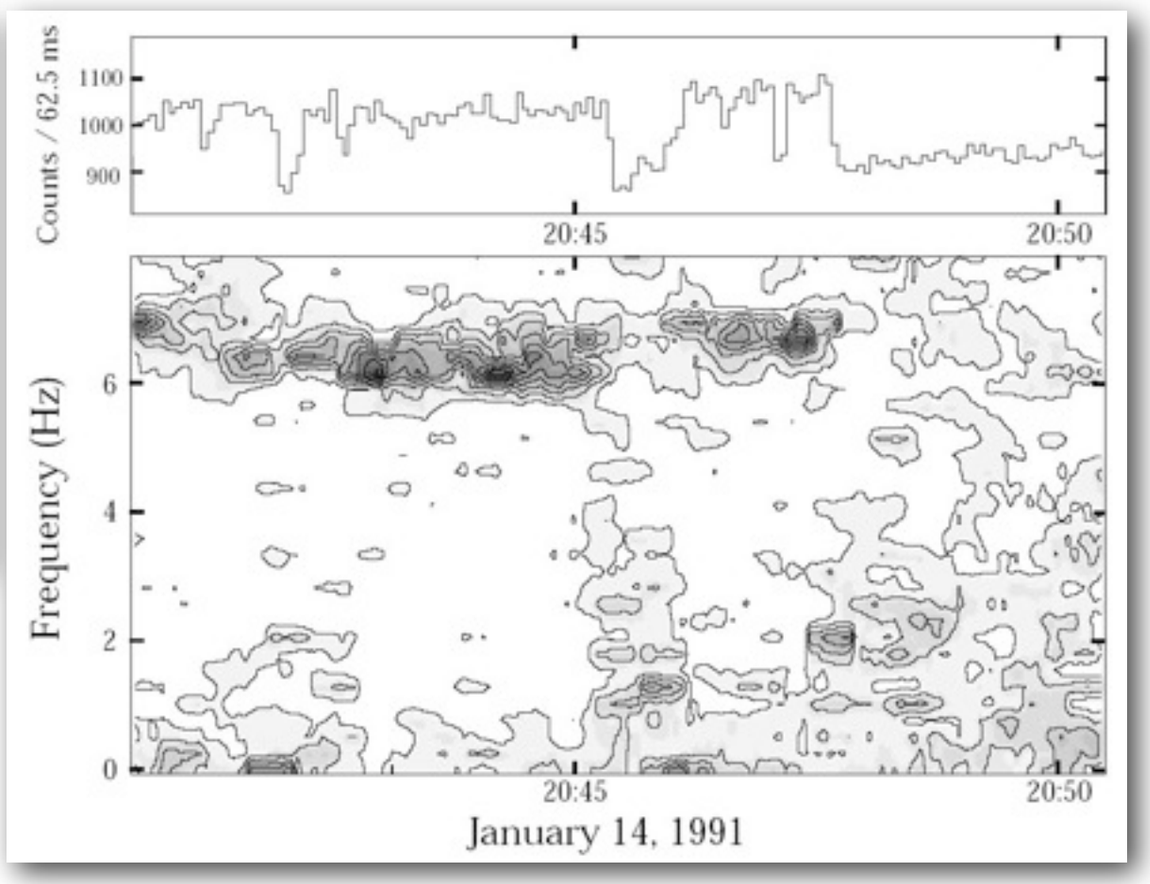
Interesting timing (finally)

- Two flavors of QPOs?

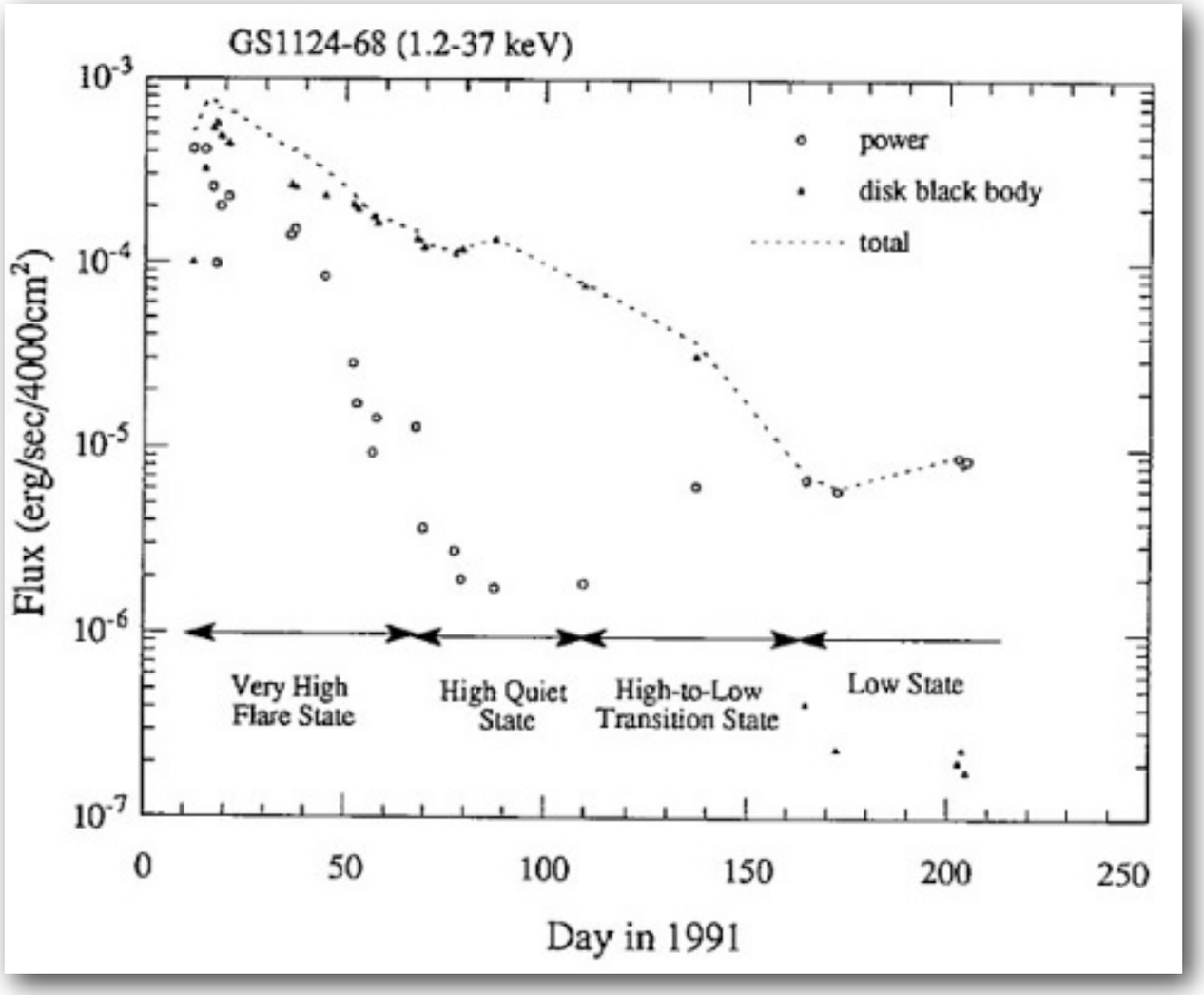
- Unfortunately, the coverage was not enough



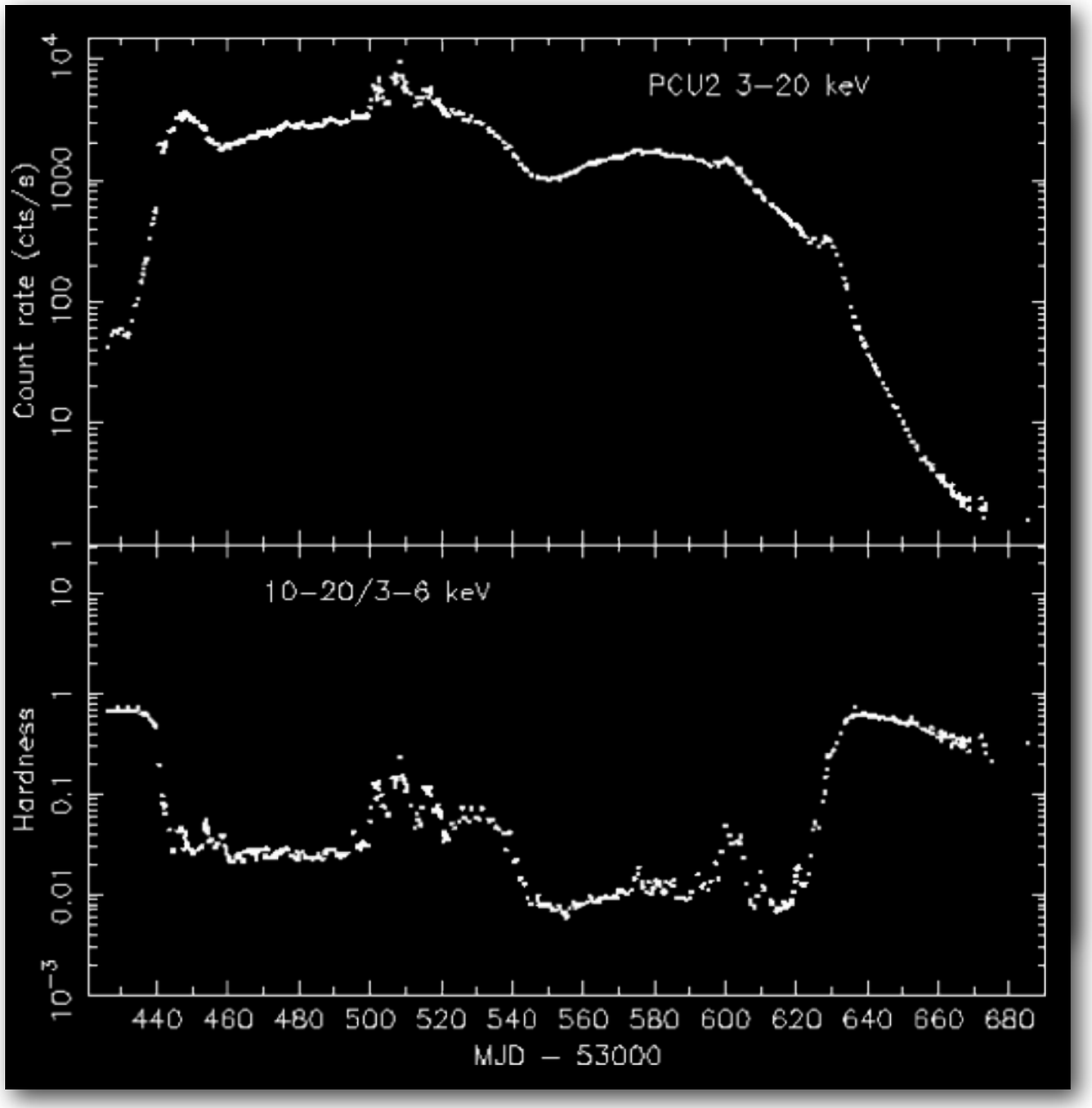
Takizawa et al. (1997)



Lack of coverage: RXTE

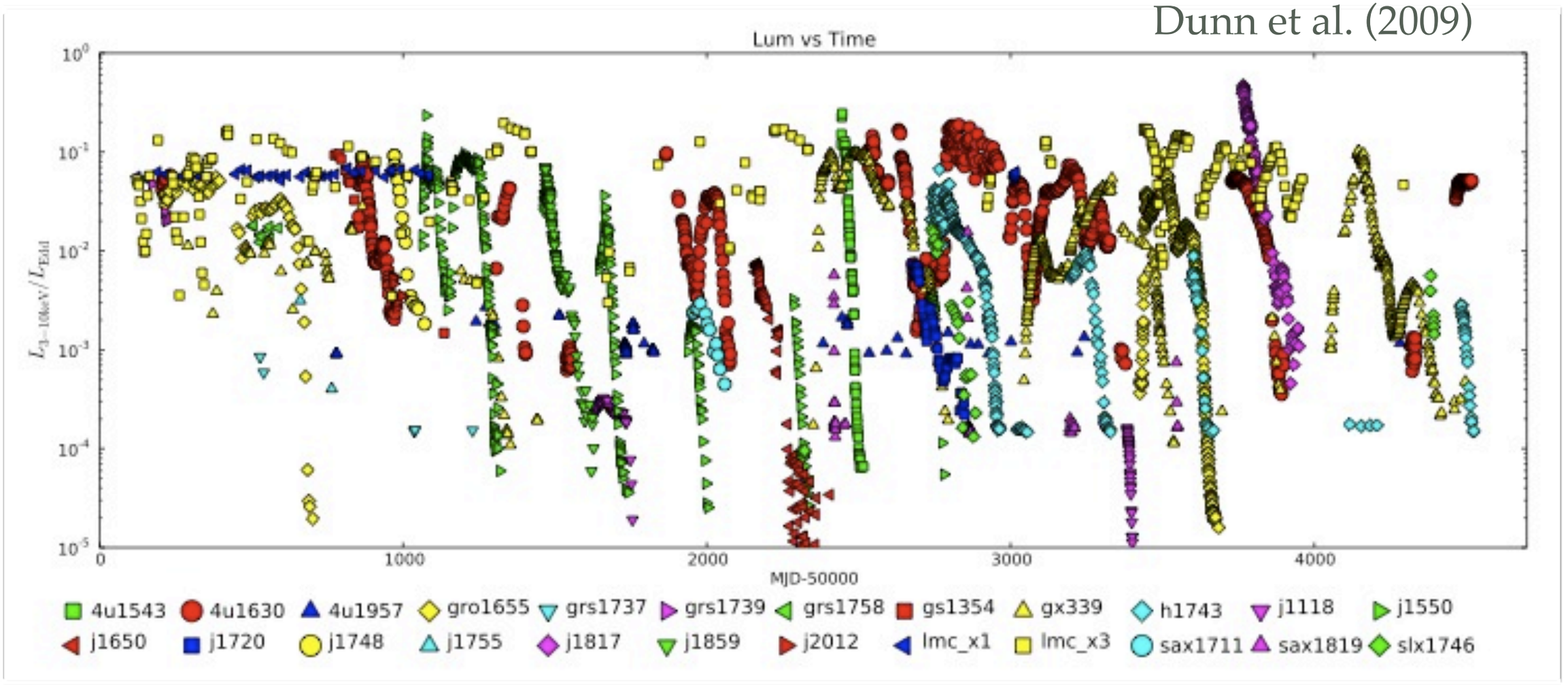


Lack of coverage: RXTE

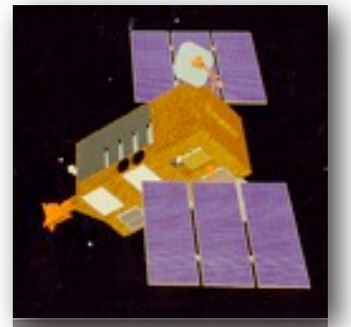


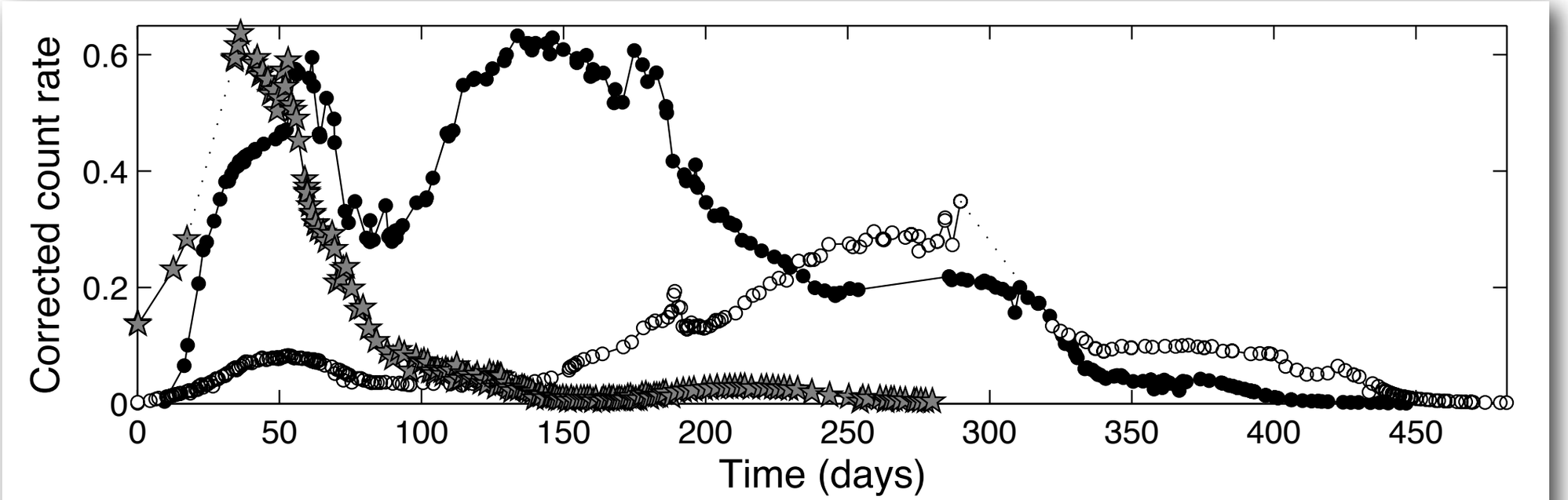
Complete RXTE dataset on BHT

Dunn et al. (2009)



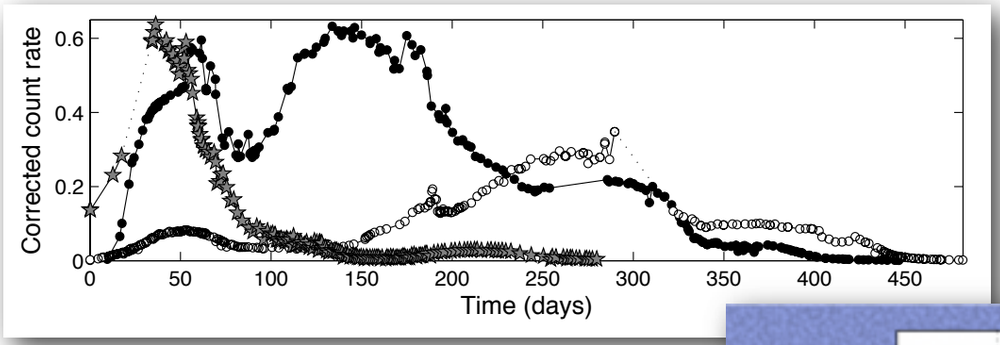
Time evolution is apparently intractable

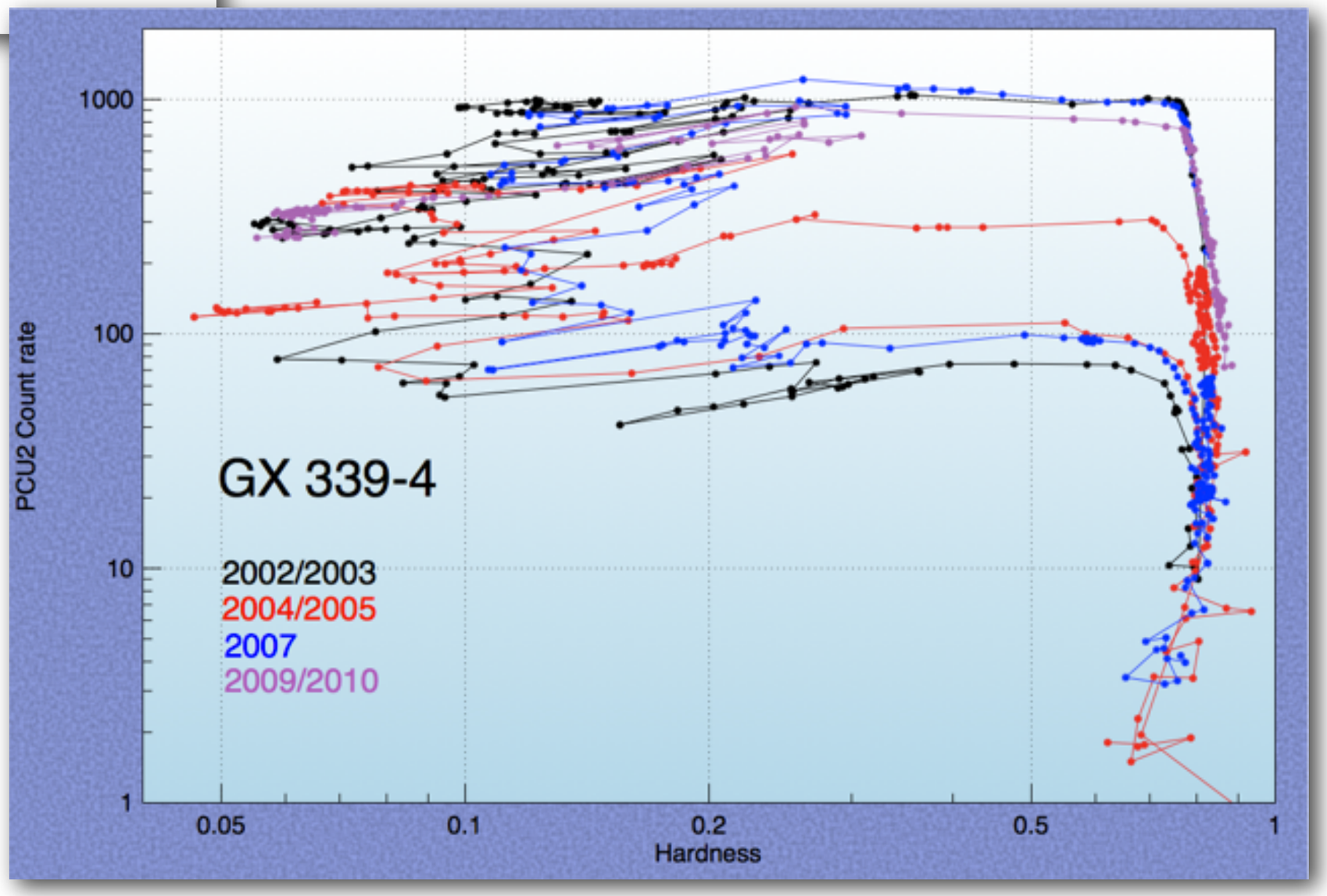




Belloni (2010)

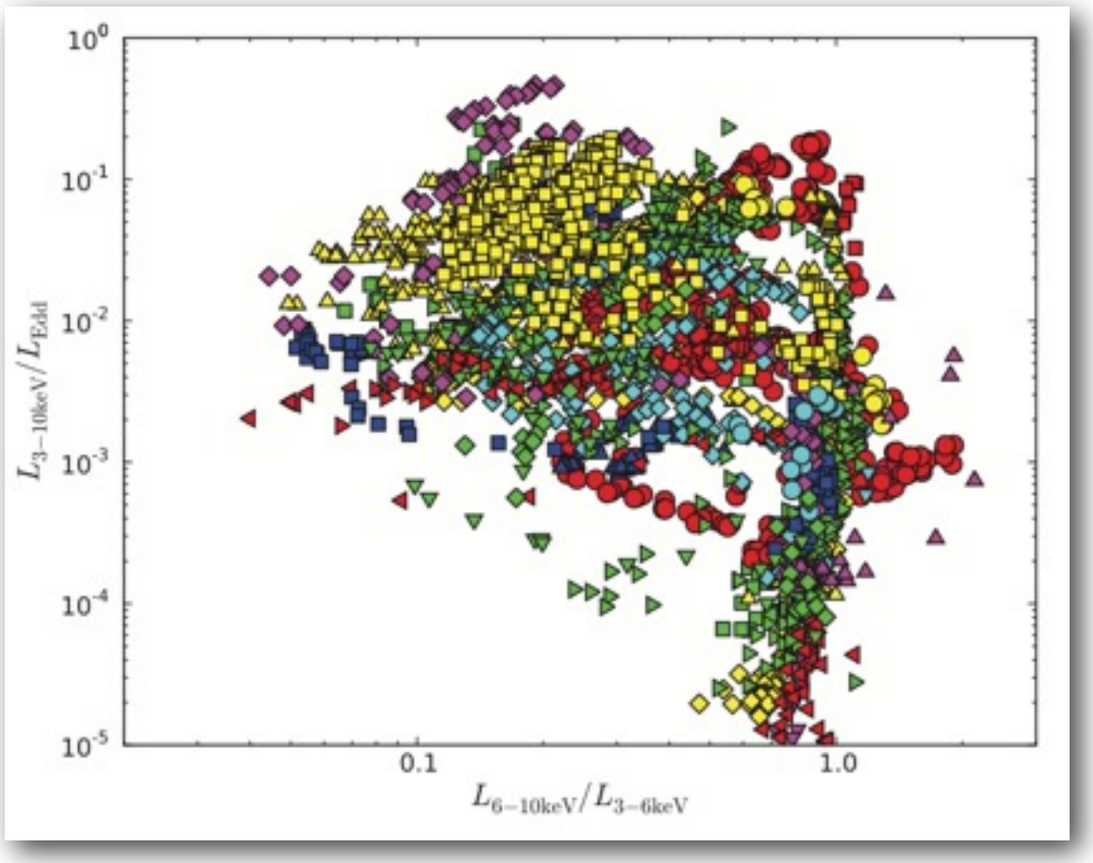
Time evolution is apparently intractable

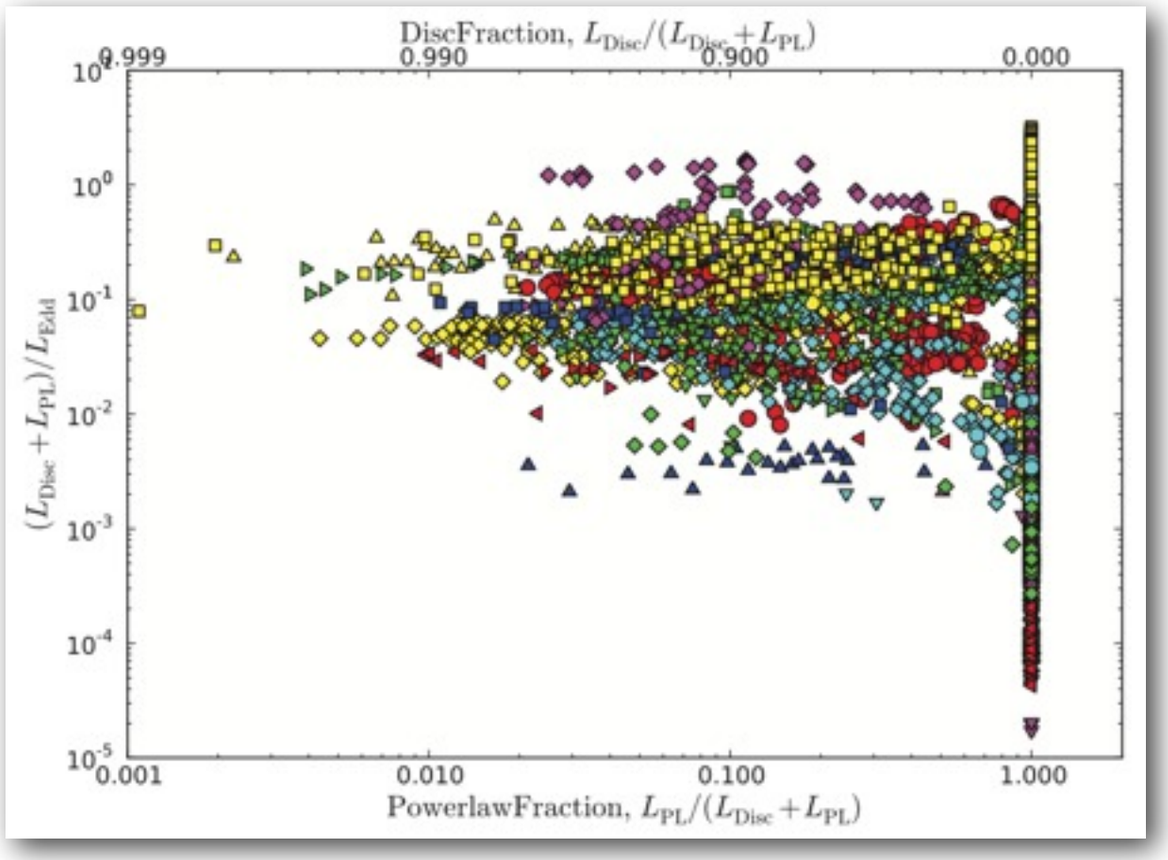




Belloni (2010)

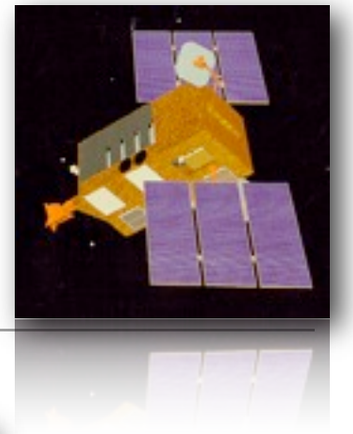
Model independent (as it must be)

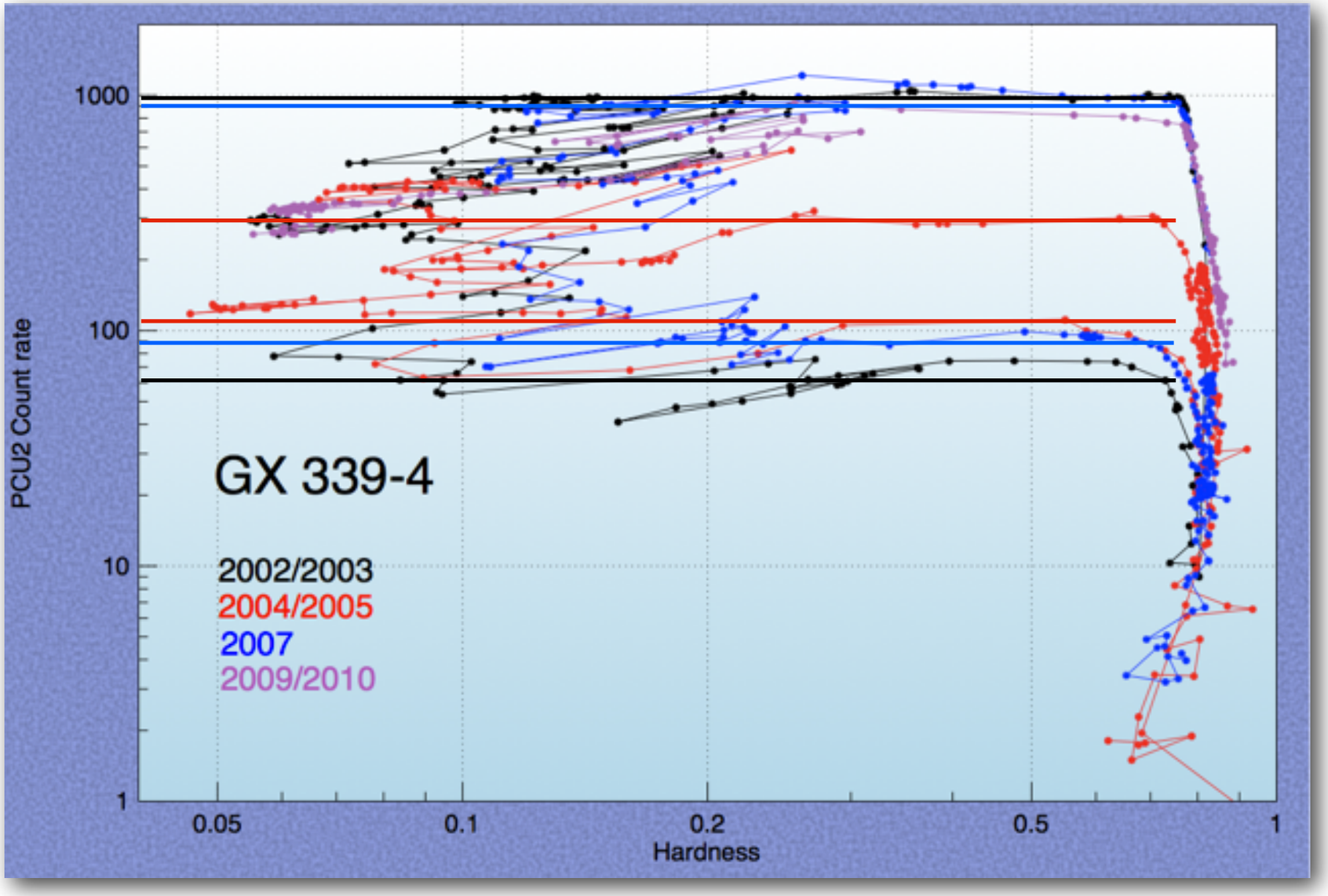




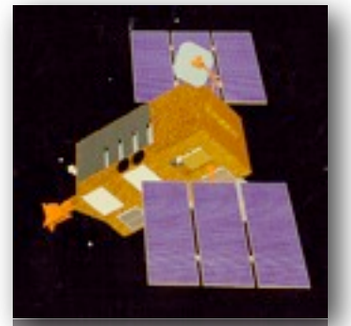
Dunn et al. (2010)

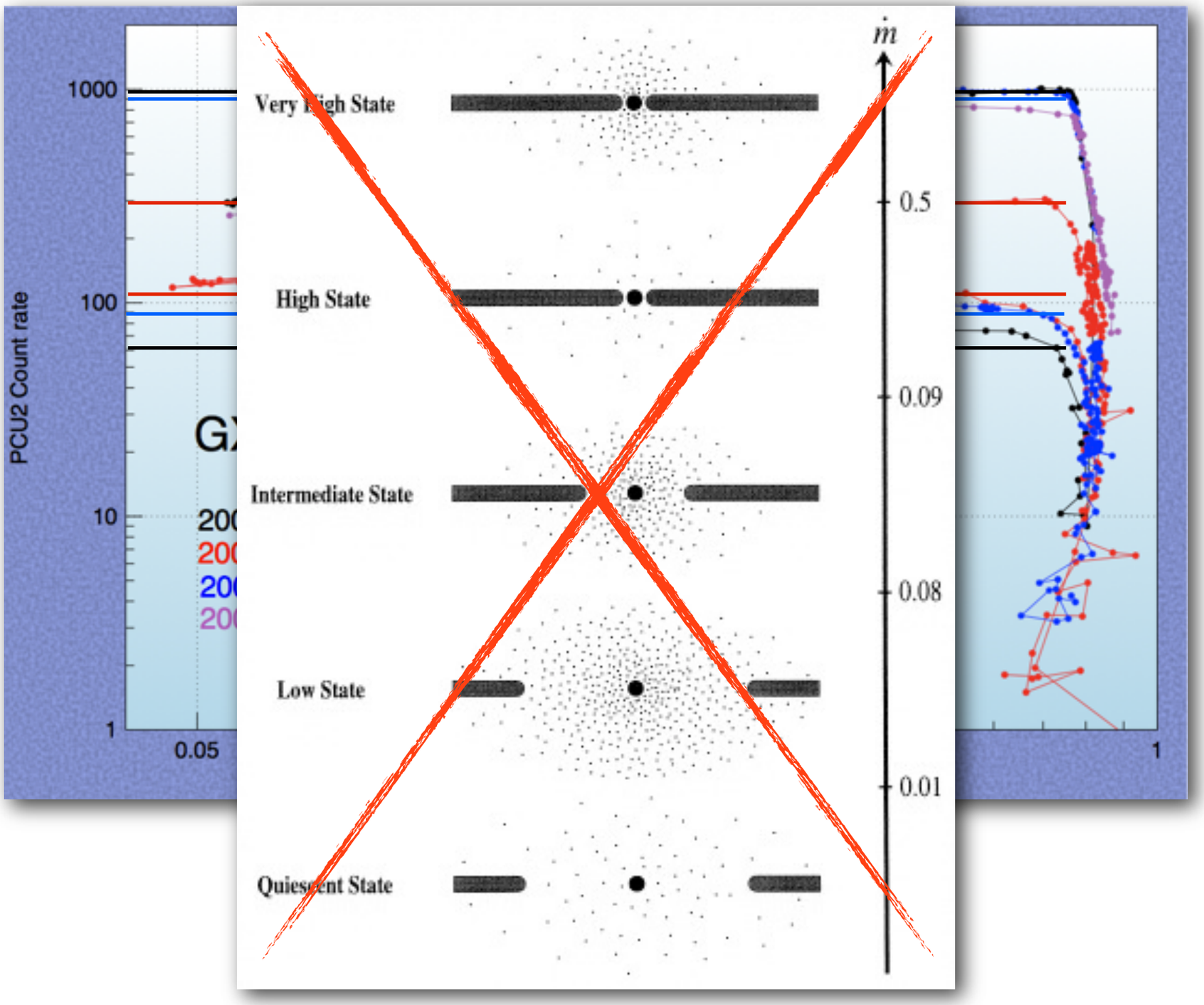
Hysteresis effect





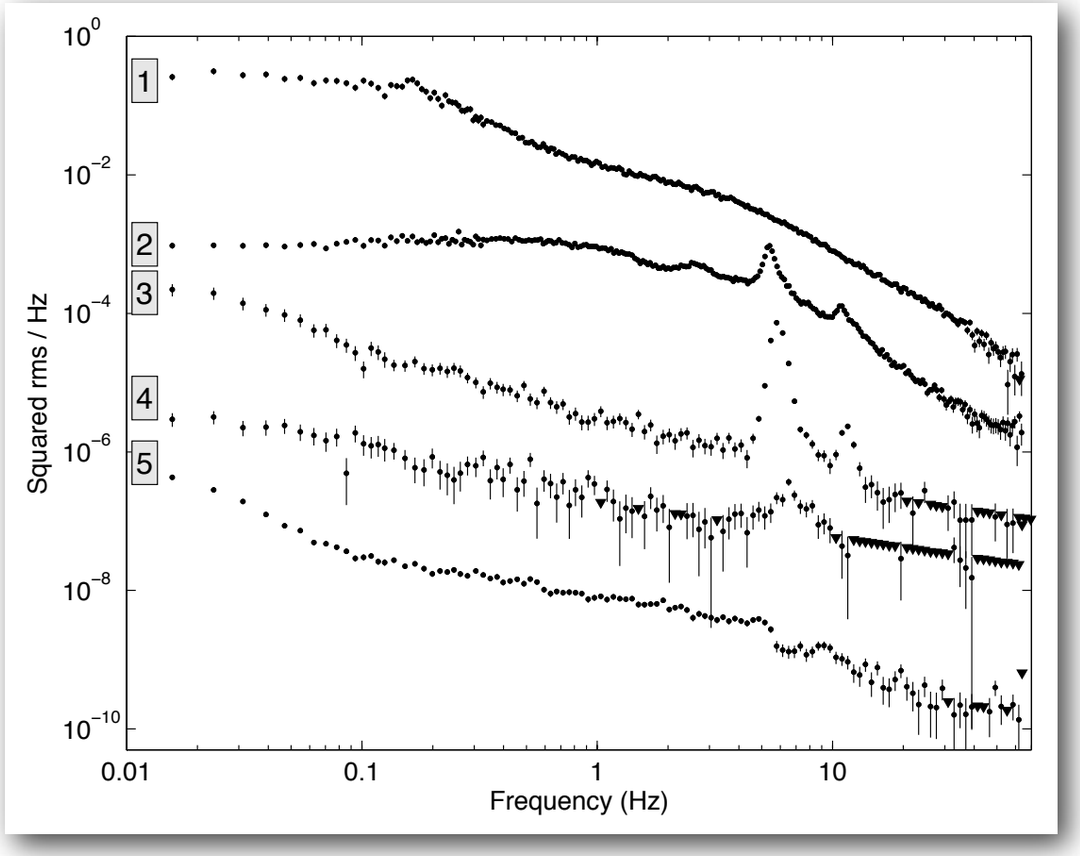
Hysteresis effect

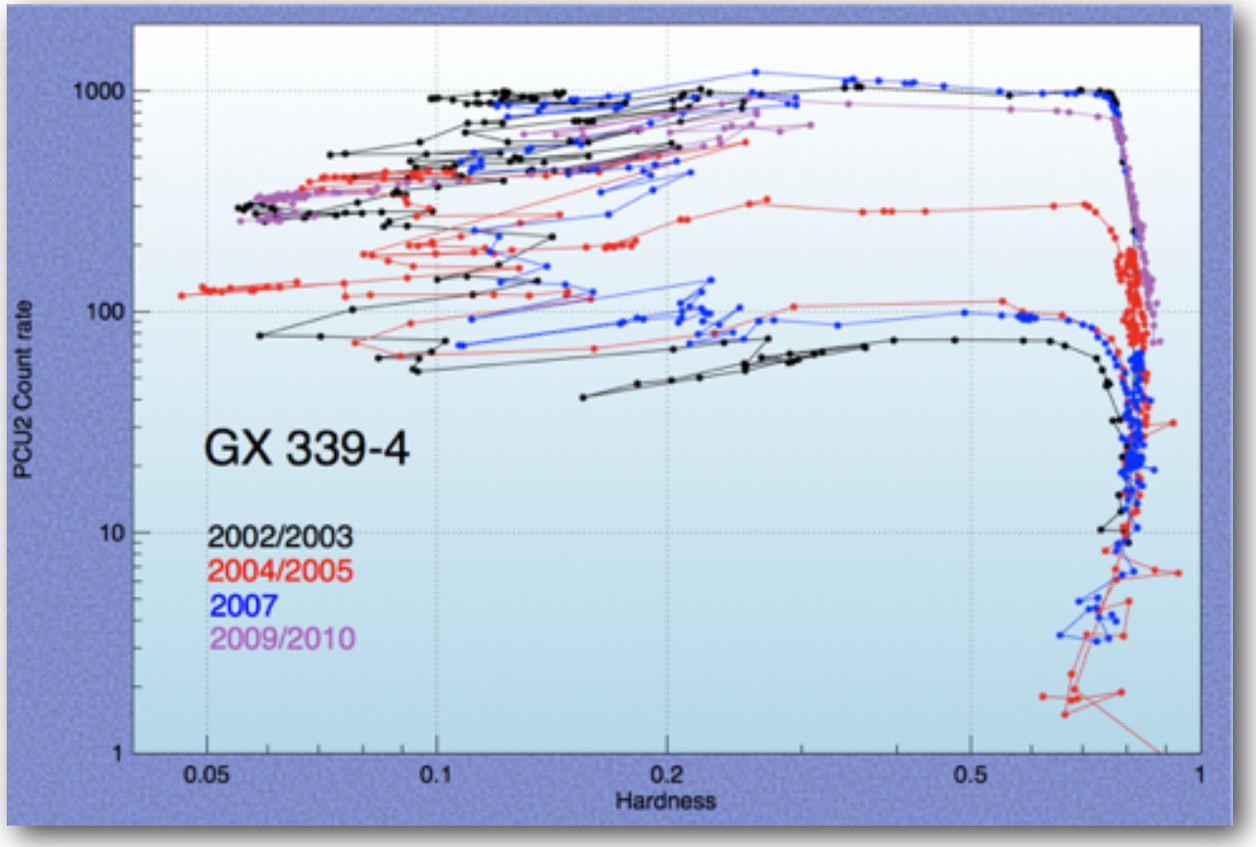




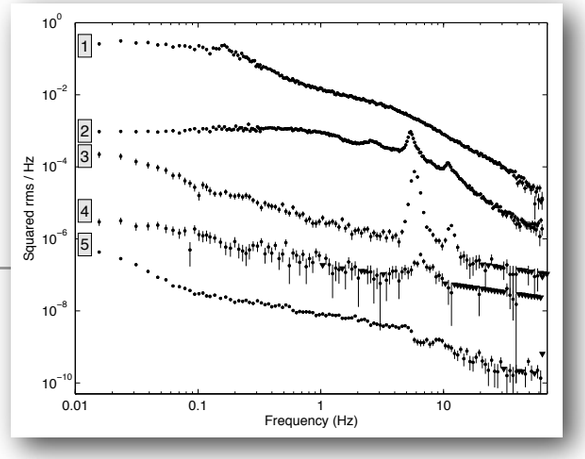
Outburst evolution

- So there is a nice evolution: what about states?
- Need to see sharp changes
- Fast time variability is and must be a guide

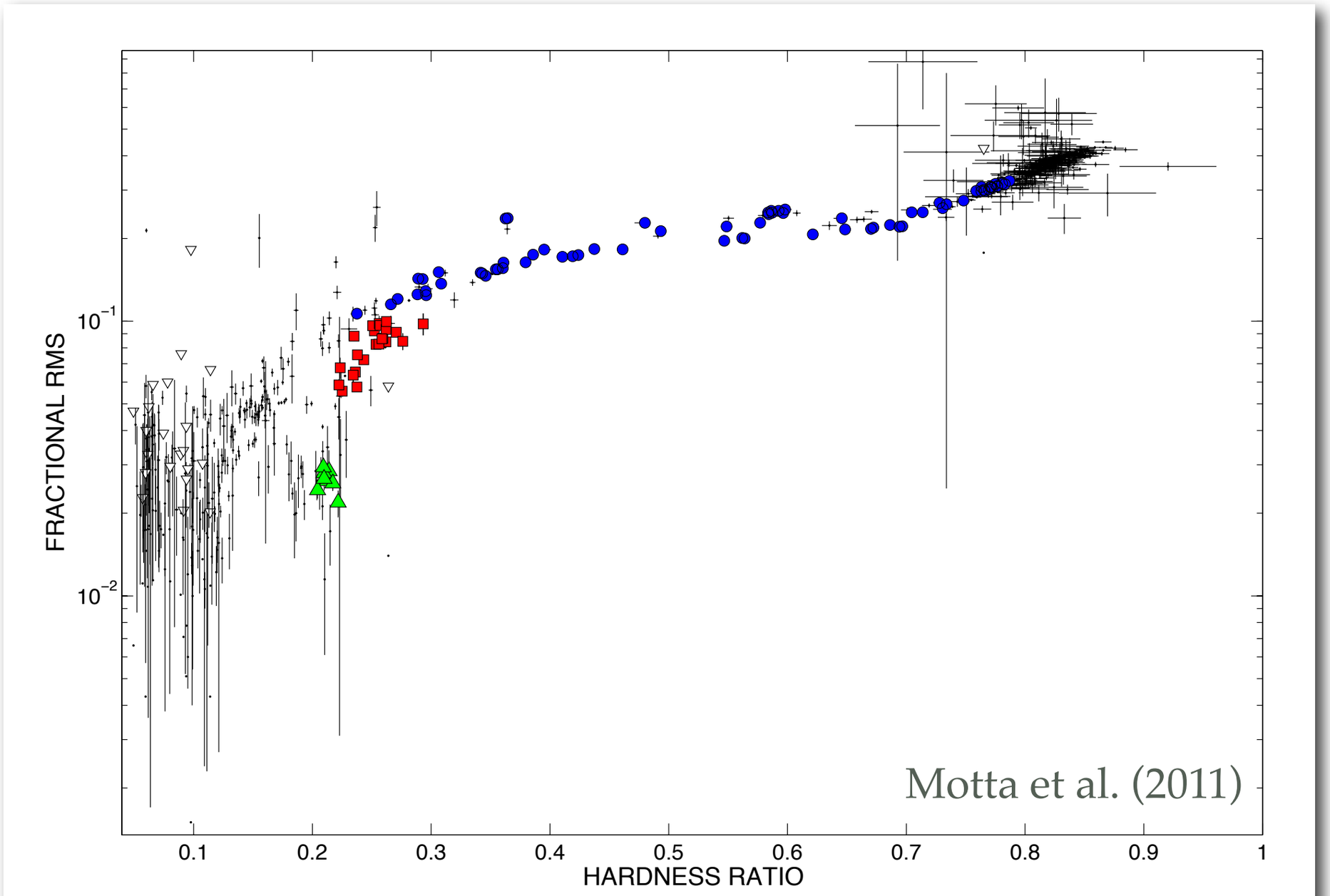




A look at timing features

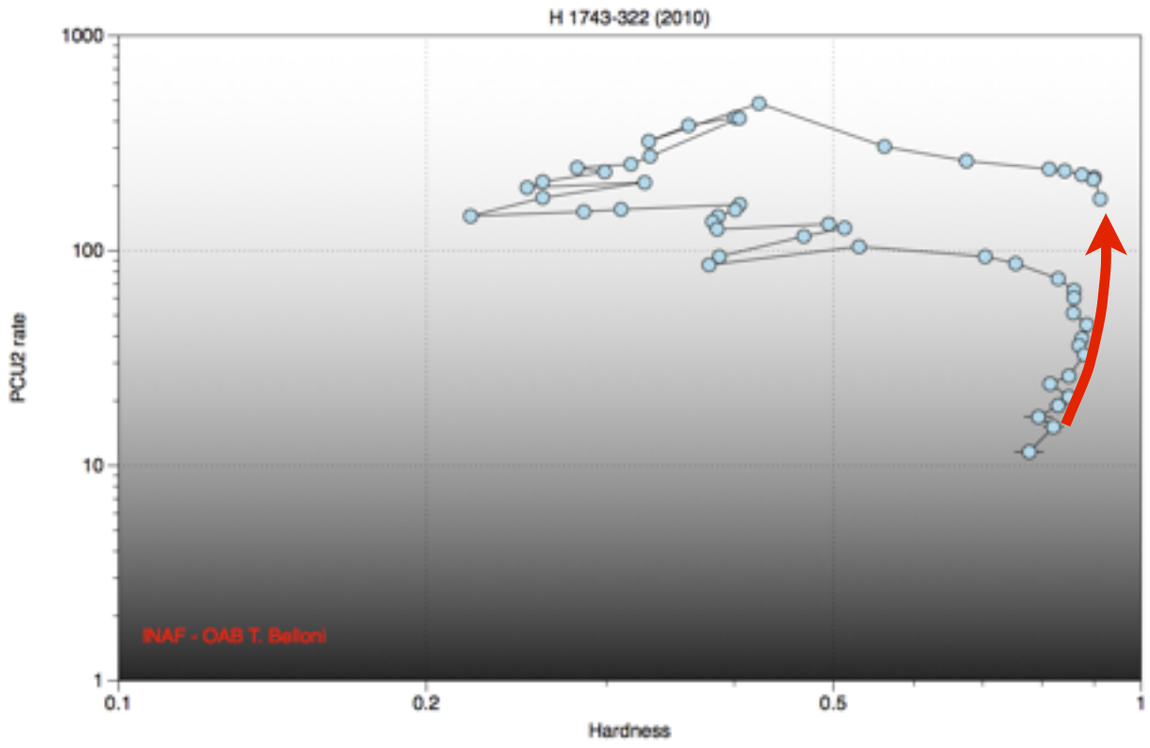


- A second diagram: Hardness-Rms (HRD)

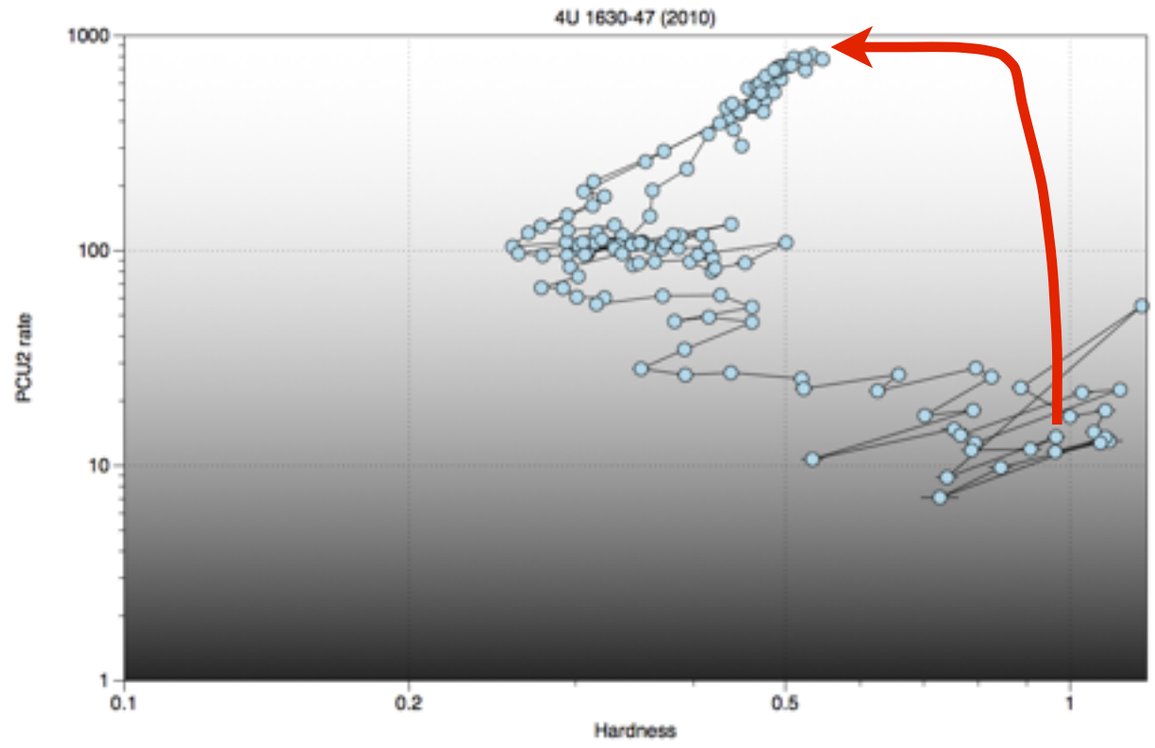


Time evolution

- Some sources behave well, some do not - states are the same
- First branch(es) missing - fast?



H 1743-322

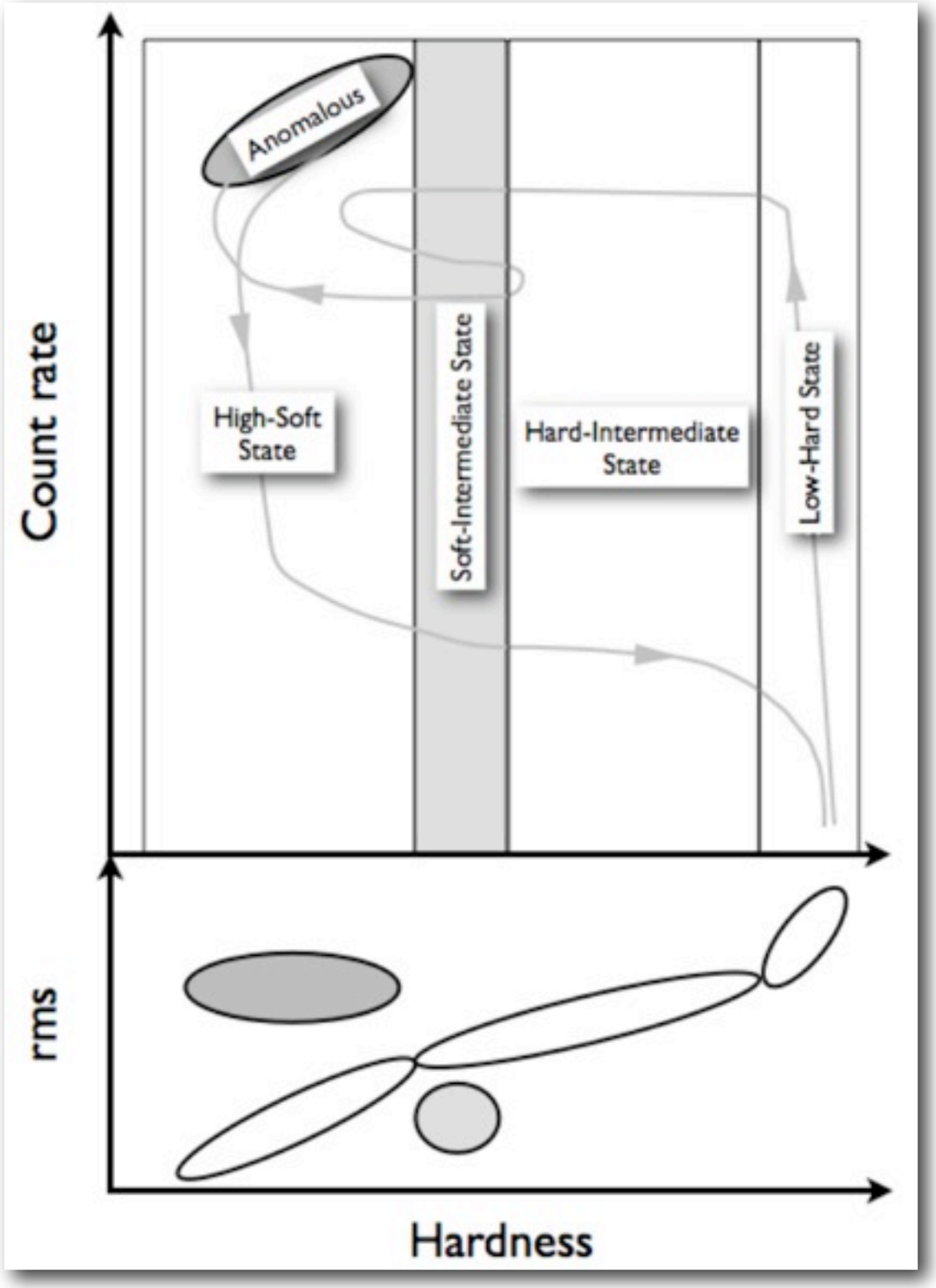


4U 1630-47

A state classification

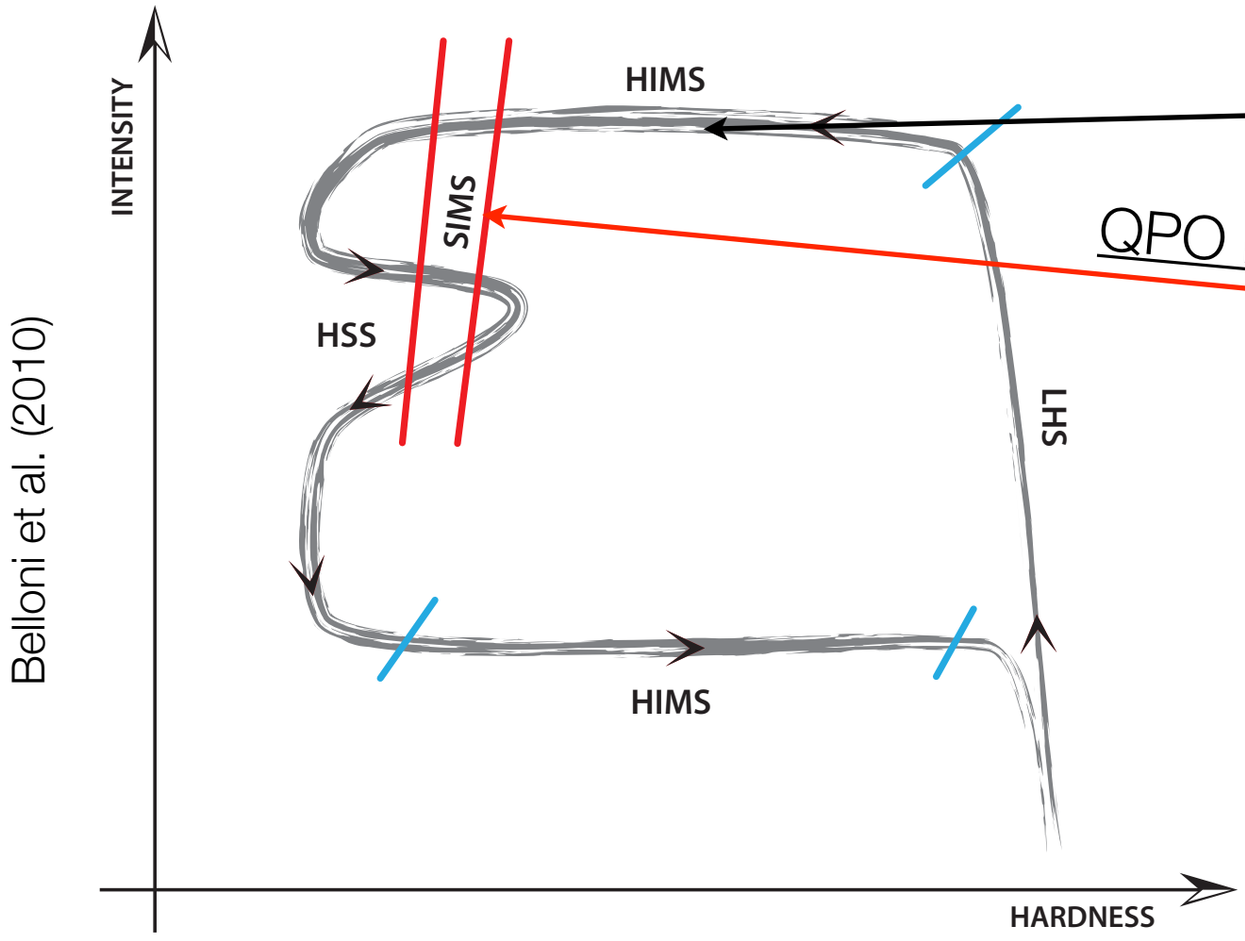
Belloni (2010)

- The spectral evolution is continuous
- Timing changes define states
- Hard State: strong variability
- HIMS: C-QPO + noise
- SIMS: AB-QPO + PL
- HSS: weak variability

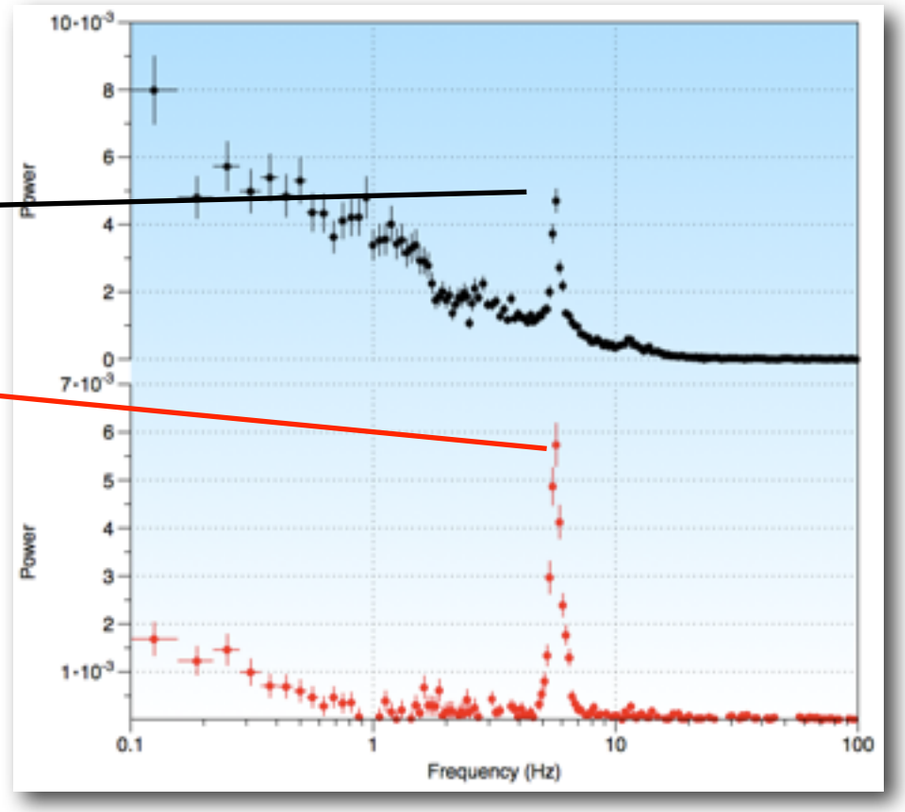


The QPO transition

- The HIMS-SIMS transition is the sharpest and most crucial
- Little spectral changes below 20 keV

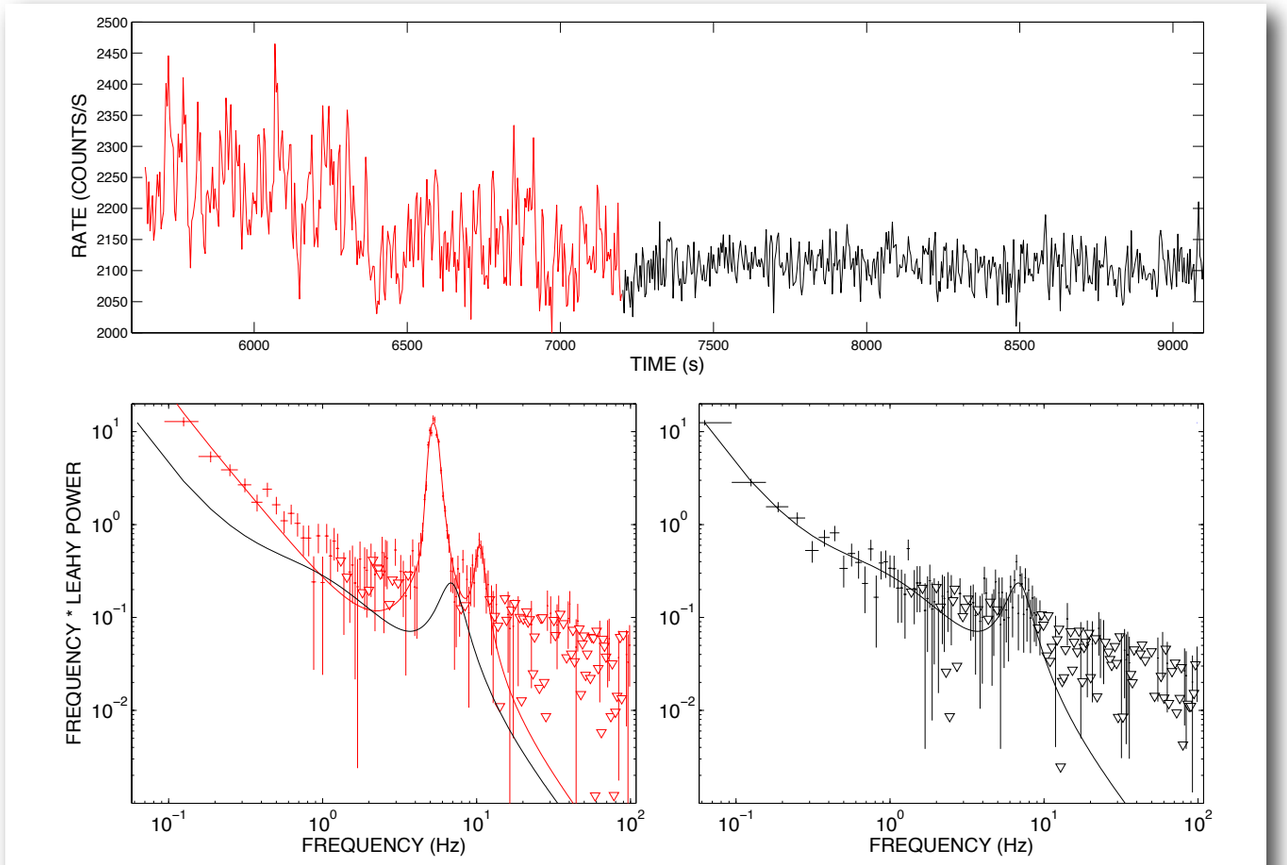


QPO line

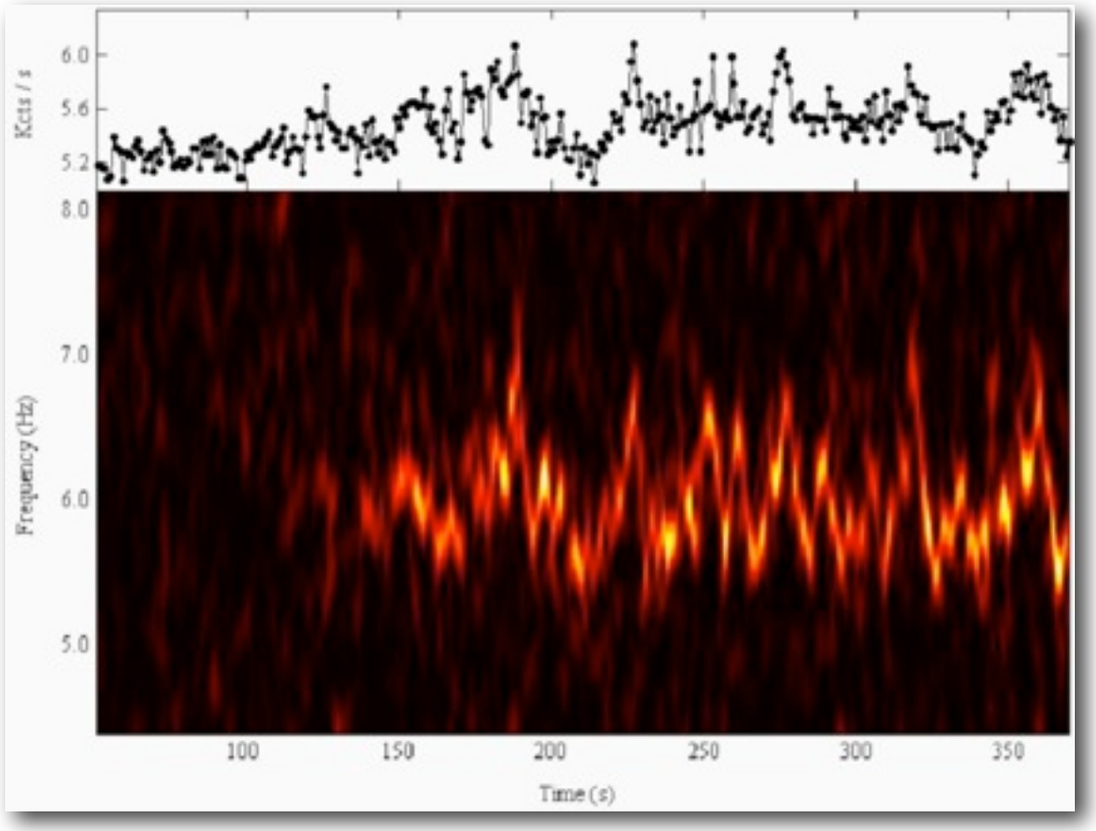


The QPO transition: FAST!

- Sharp changes in a matter of <u>seconds</u>



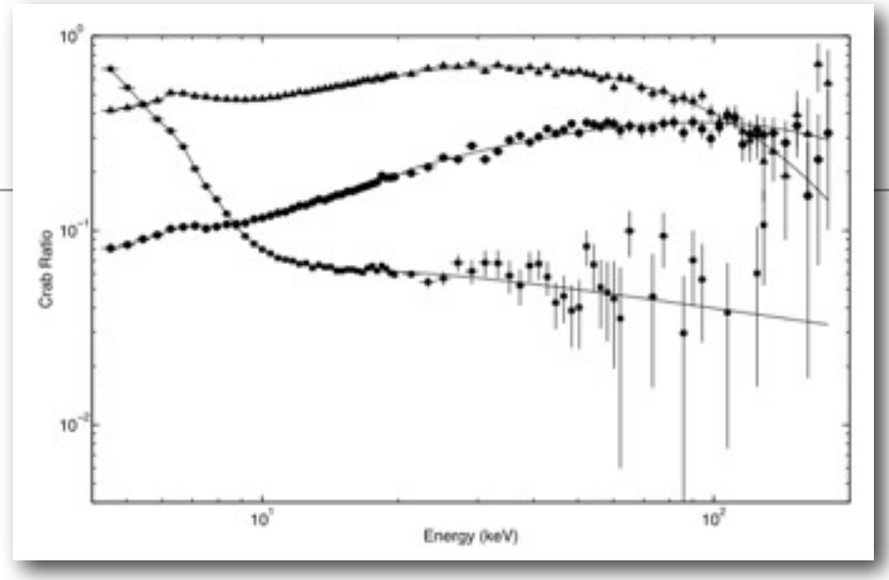
Motta et al. (2011)

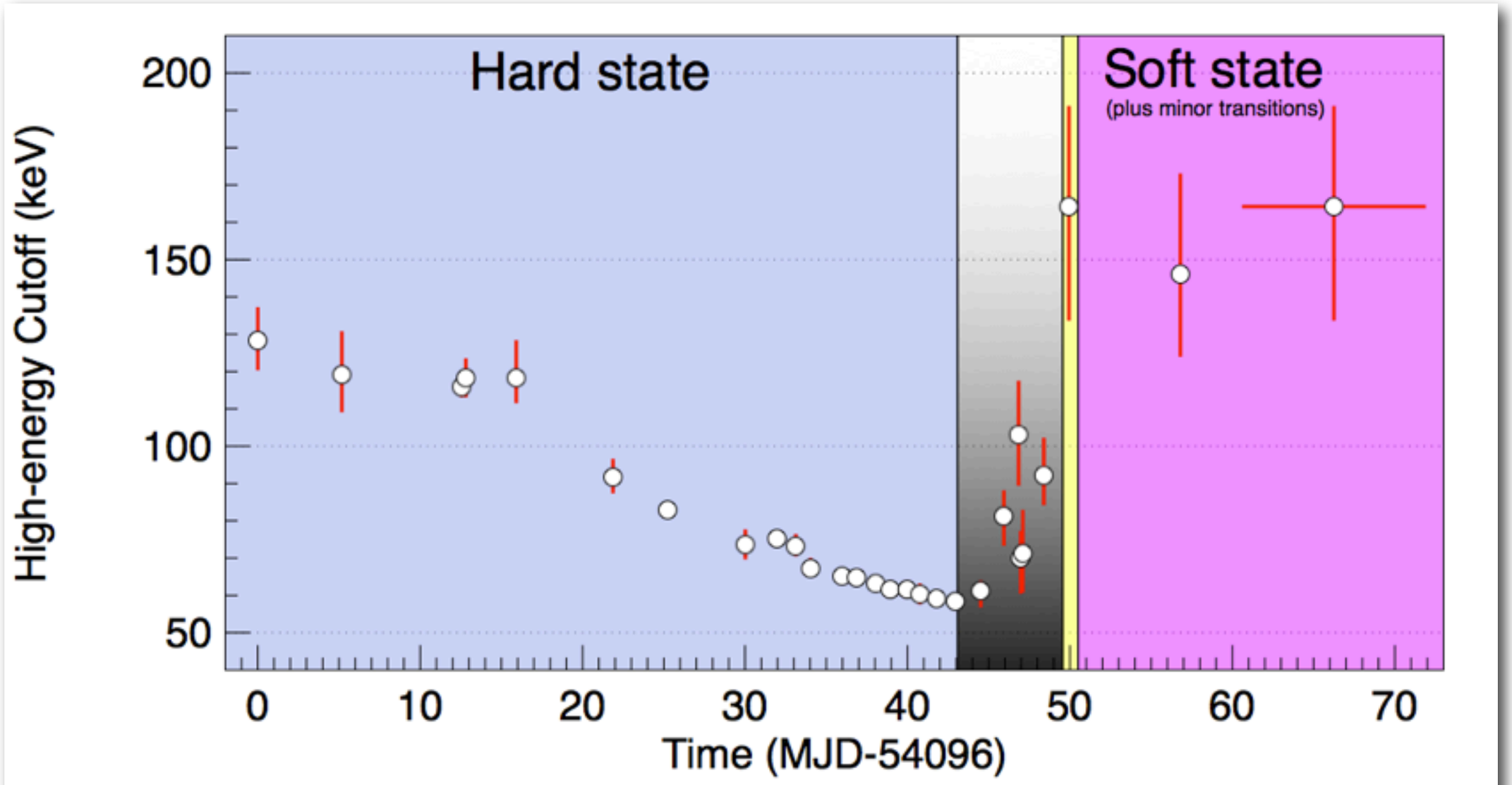


Nespoli et al. (2003)

Spectral changes

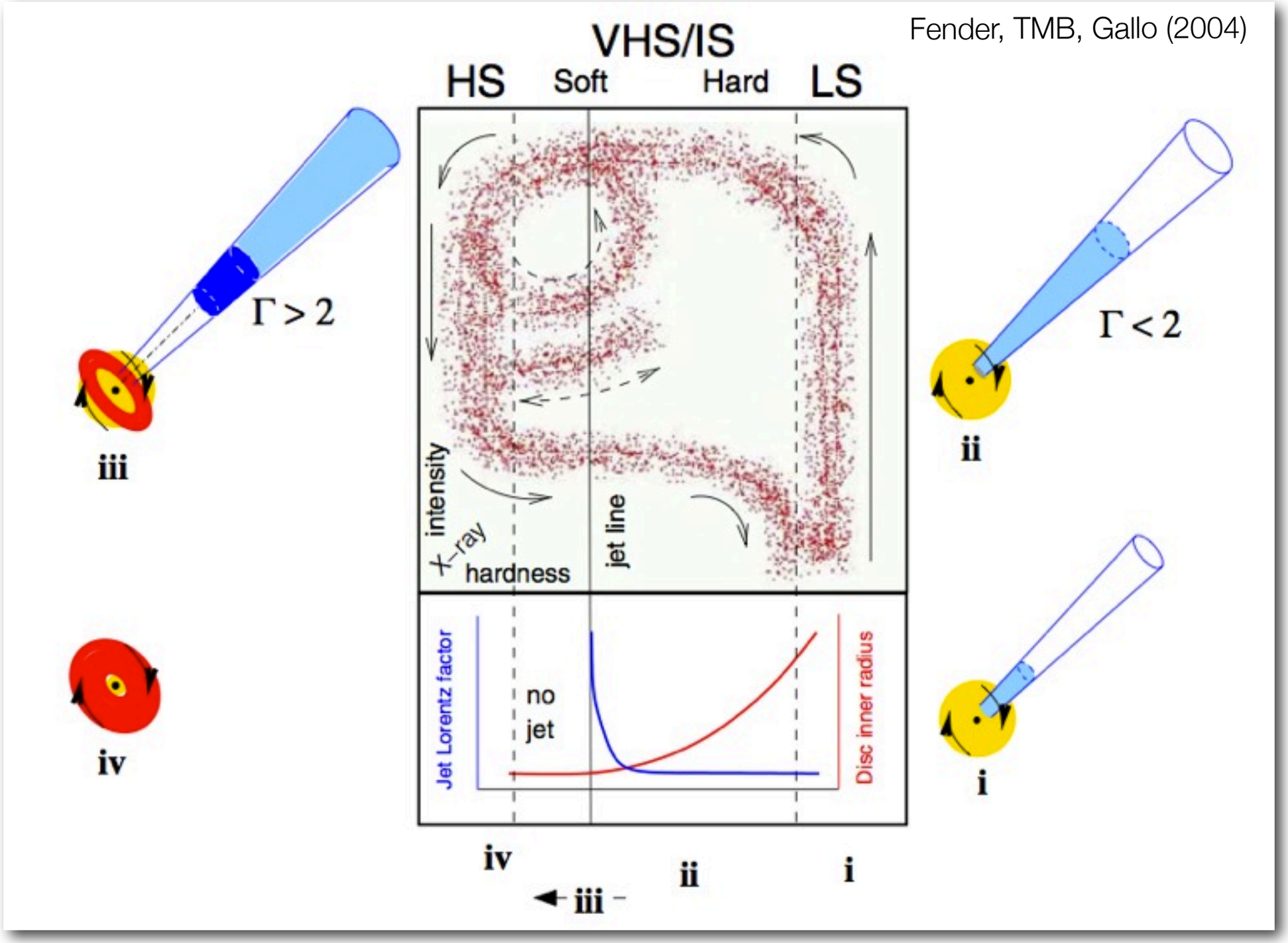
- Above 20 keV, a different picture
- Strong cutoff changes



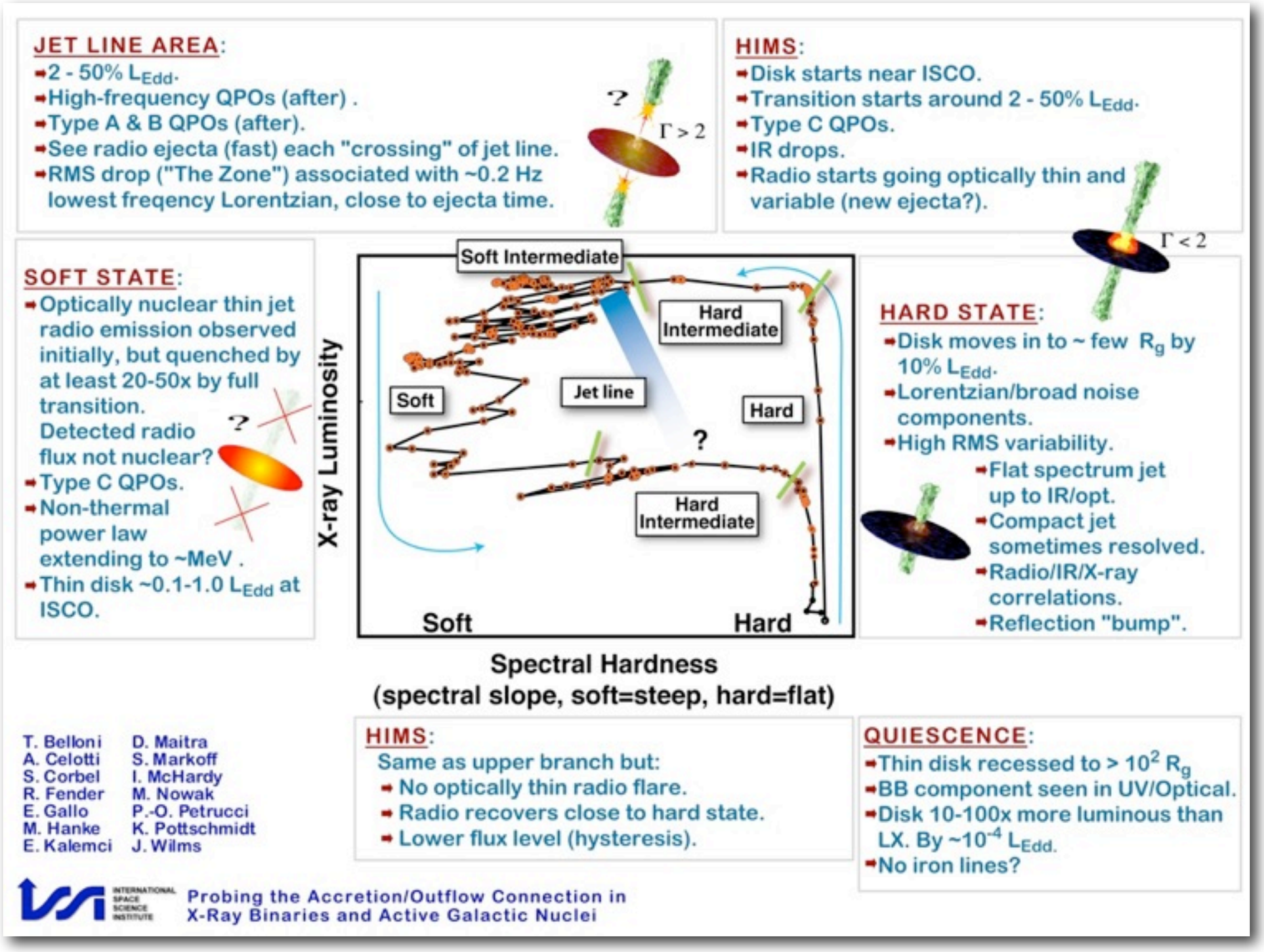


Motta, TMB, Homan (2009)

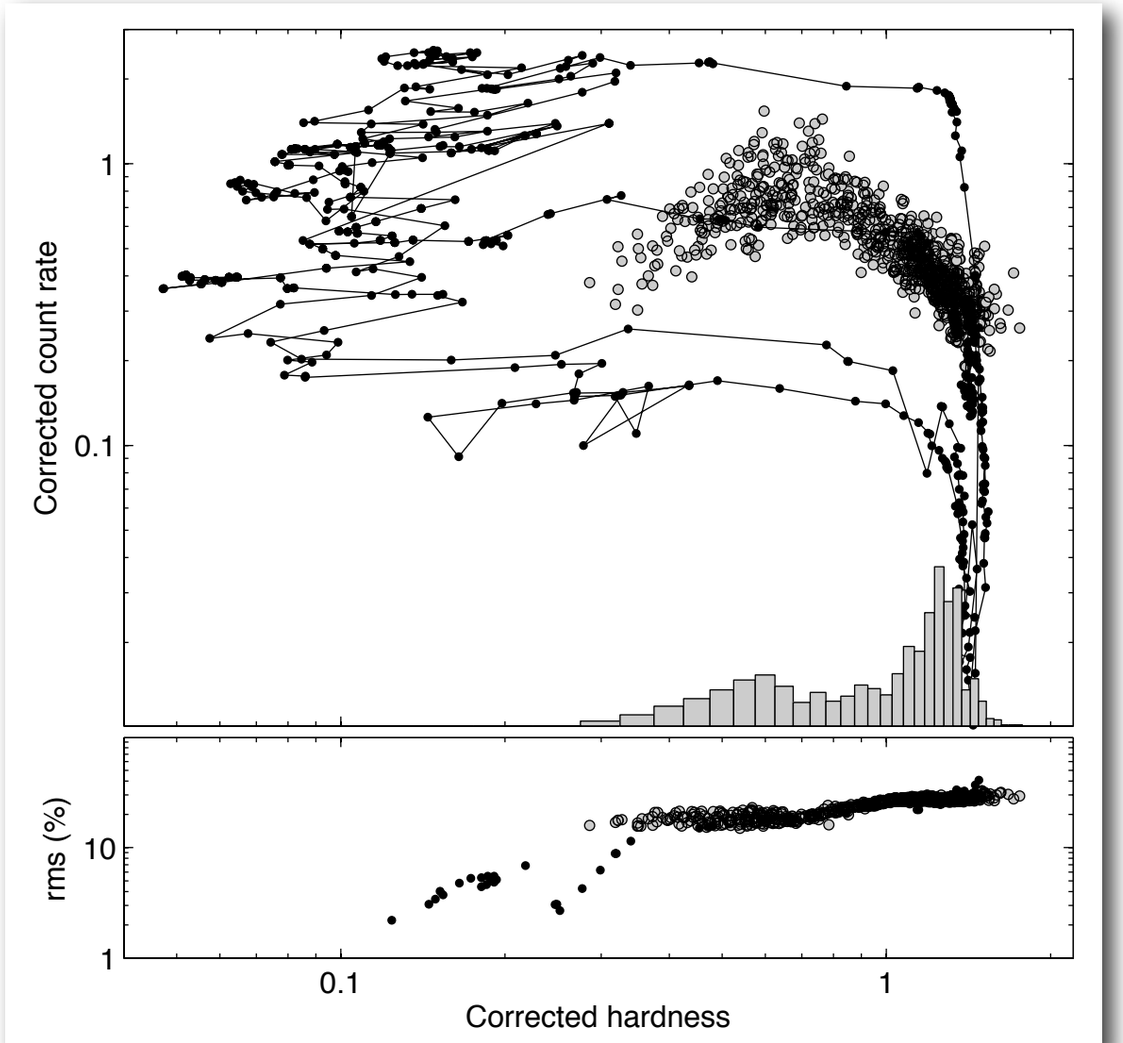
The radio jet connection



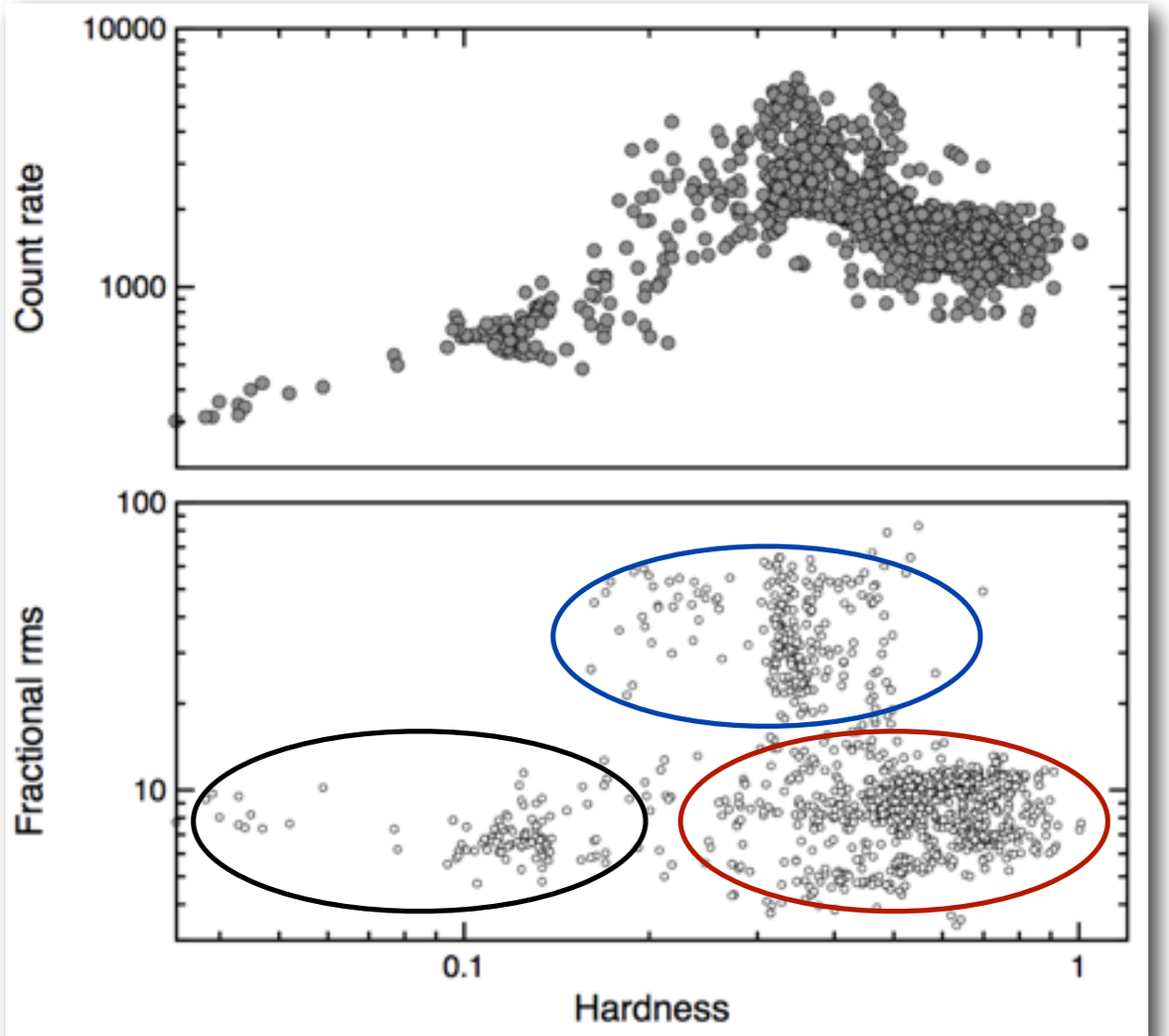
The radio jet connection



Other sources



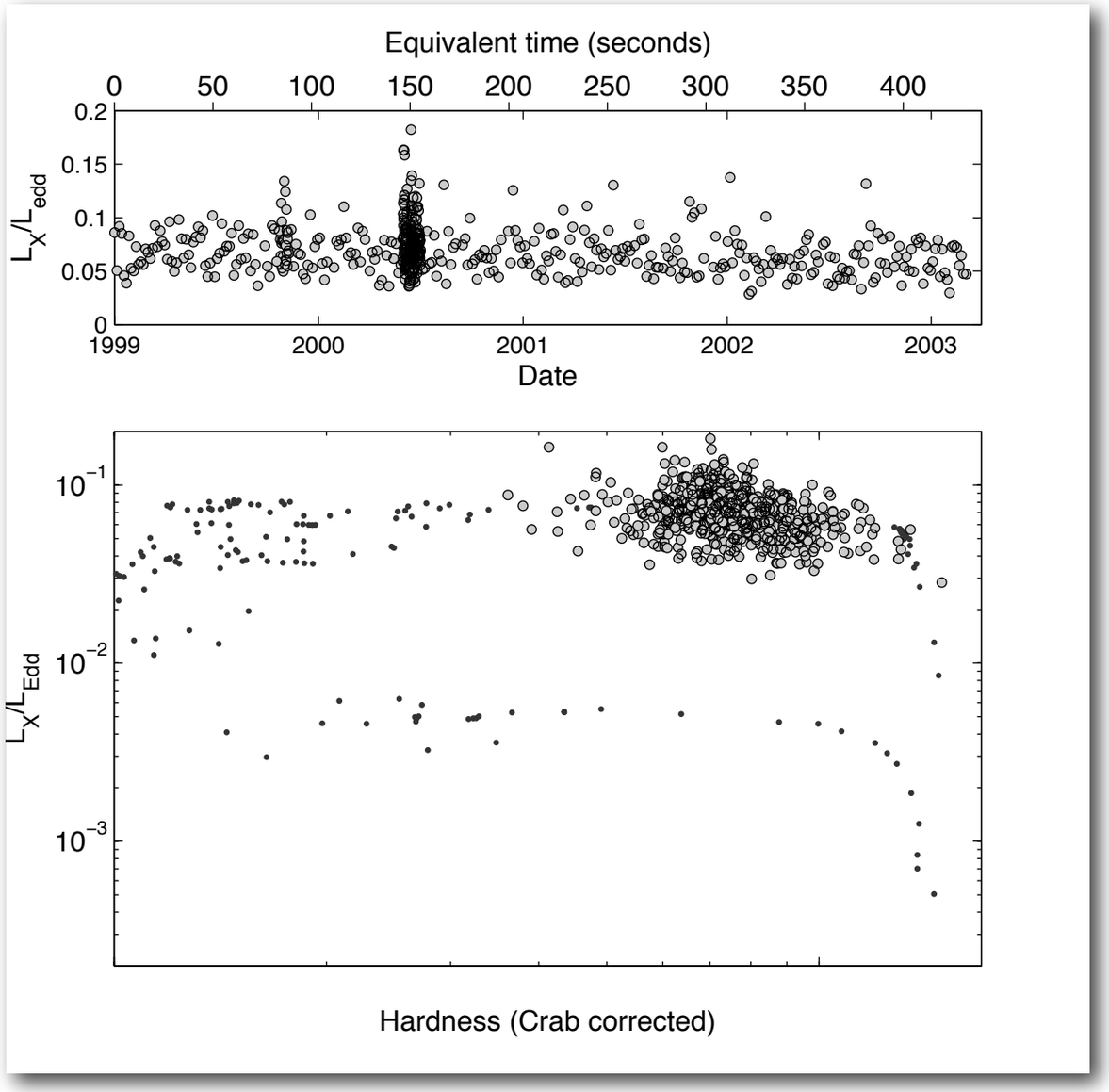
Cyg X-1



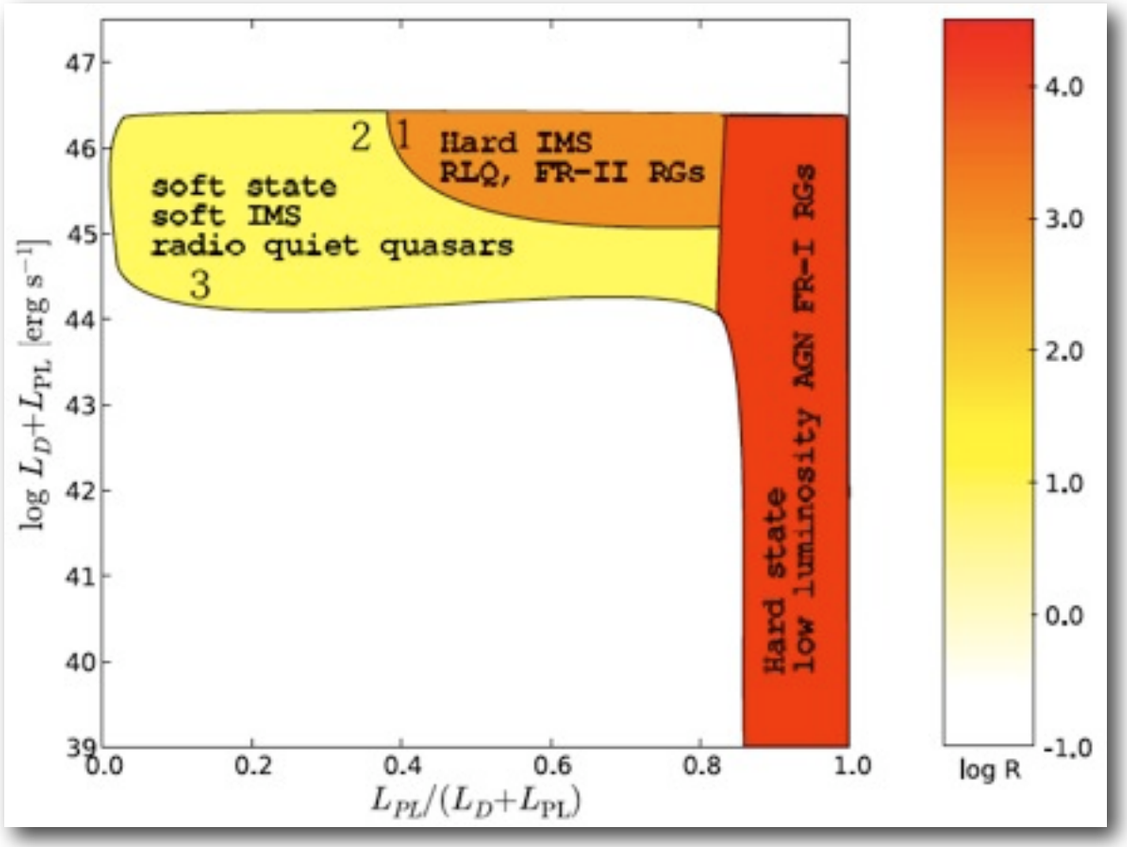
GRS 1915+105

TMB (2010)

Other sources - other time scales



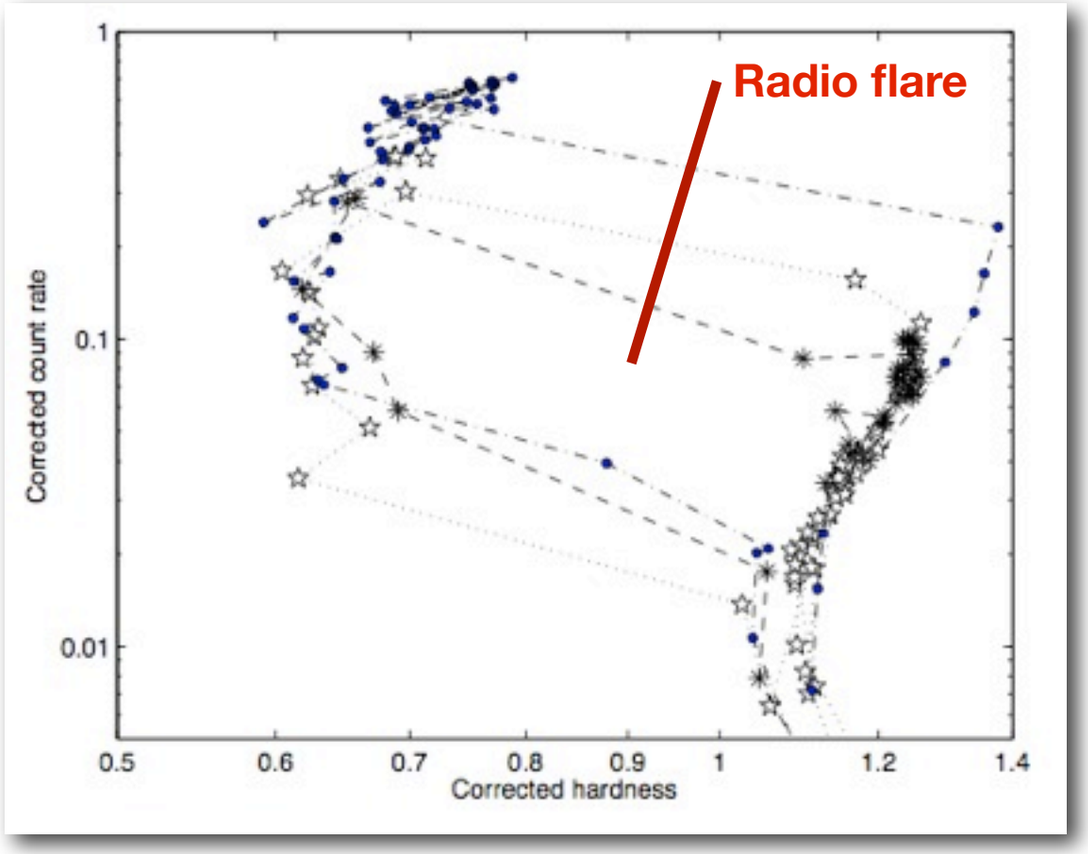
TMB (2010)



Körding et al. (2006)

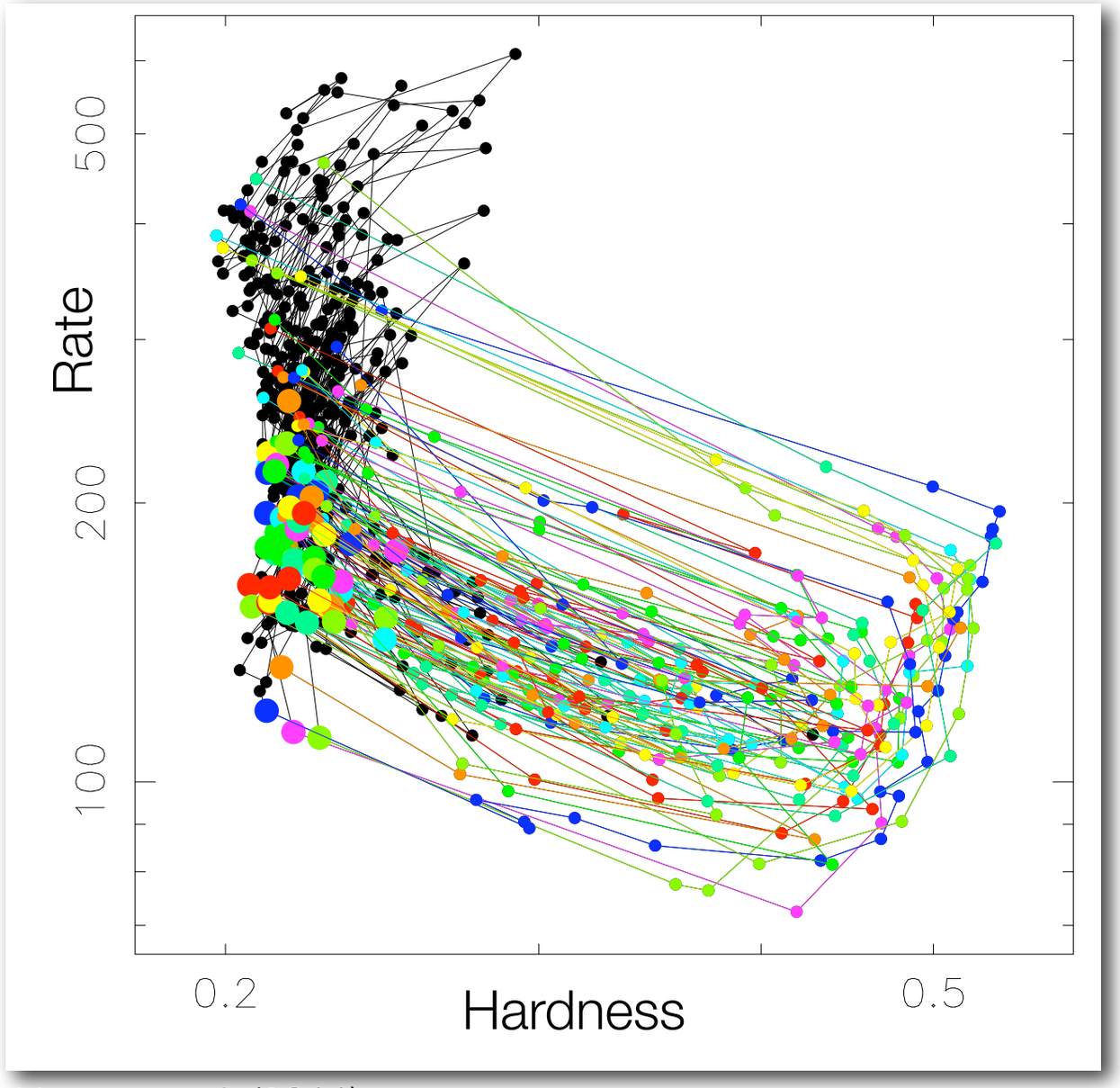
Ark 564

Neutron-star X-ray binaries



TMB (2010)

Aql X-1

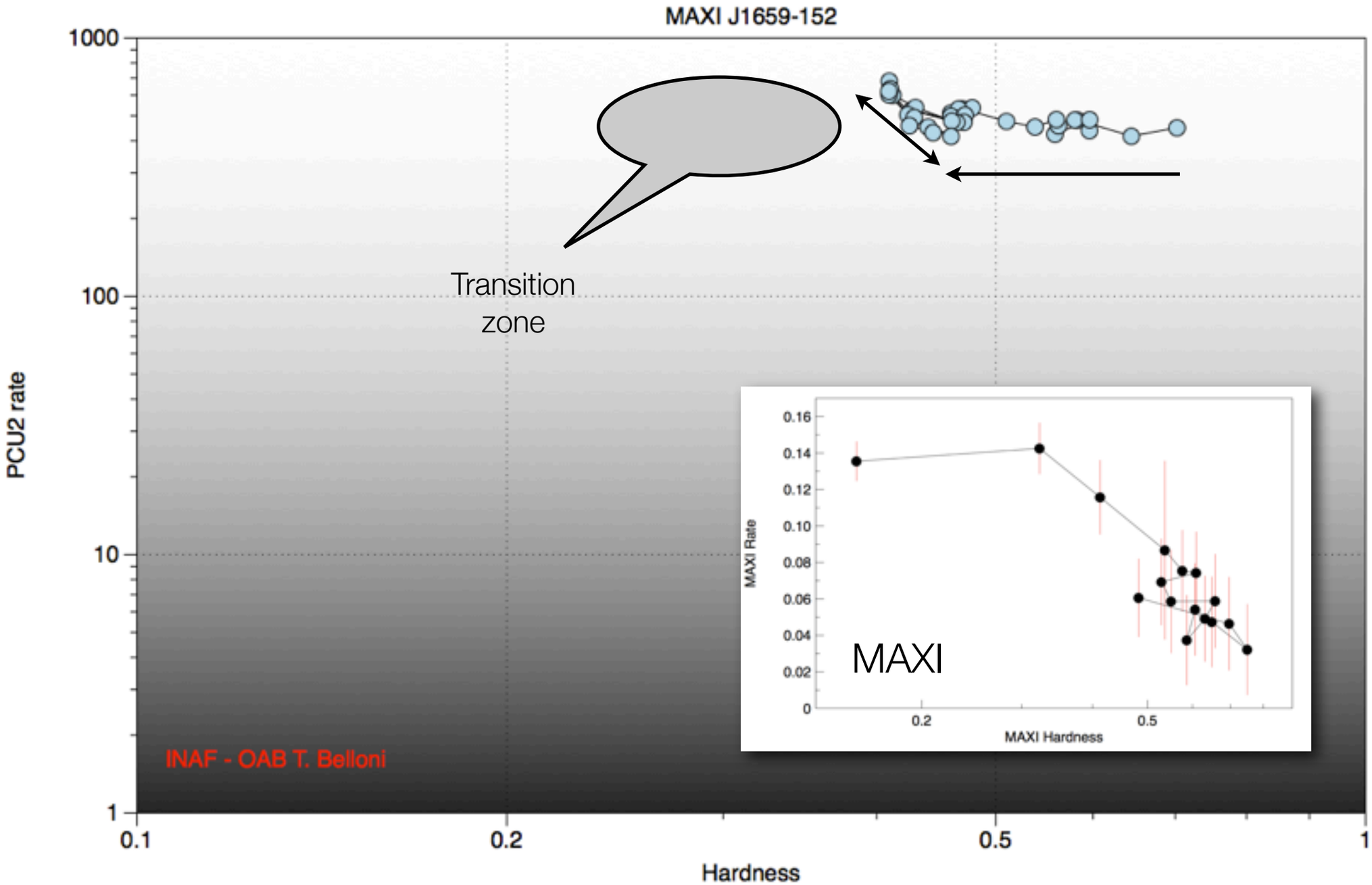


Homan et al. (2011)

4U 1636-53

New systems

- The recent transient MAXI J1659-152 as of today

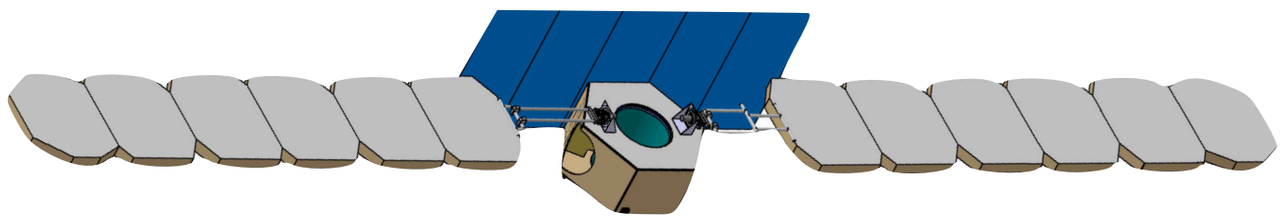


Conclusions

- We now have a very clear picture of how X-ray transients evolve
- This leads to a strong state classification based on transitions
- Never mix apples and pears. There is very little space to play here
- The radio/X-ray connection works with these states
- Timing is paramount, although we do not really know what it is (yet)
- The near future is ASTROSAT (launch early 2012)
- The far future could be

Conclusions

- We now have a very clear picture of how X-ray transients evolve
- This leads to a strong state classification based on transitions
- Never mix apples and pears. There is very little space to play here
- The radio/X-ray connection works with these states
- Timing is paramount, although we do not really know what it is (yet)
- The near future is ASTROSAT (launch early 2012)
- The far future could be



LOFT