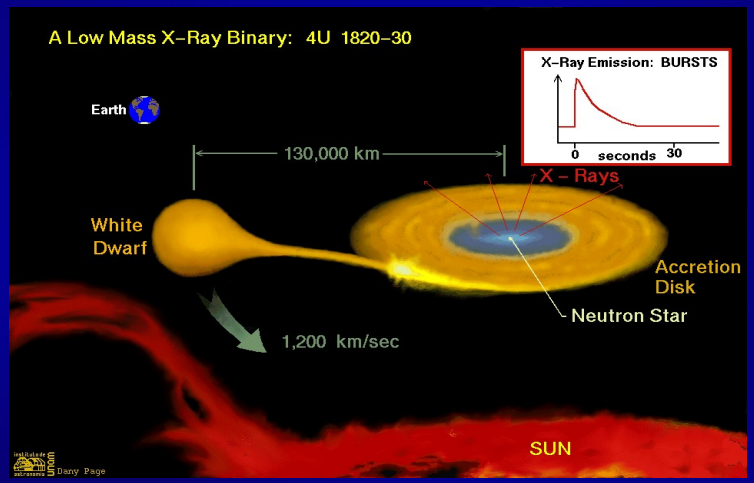
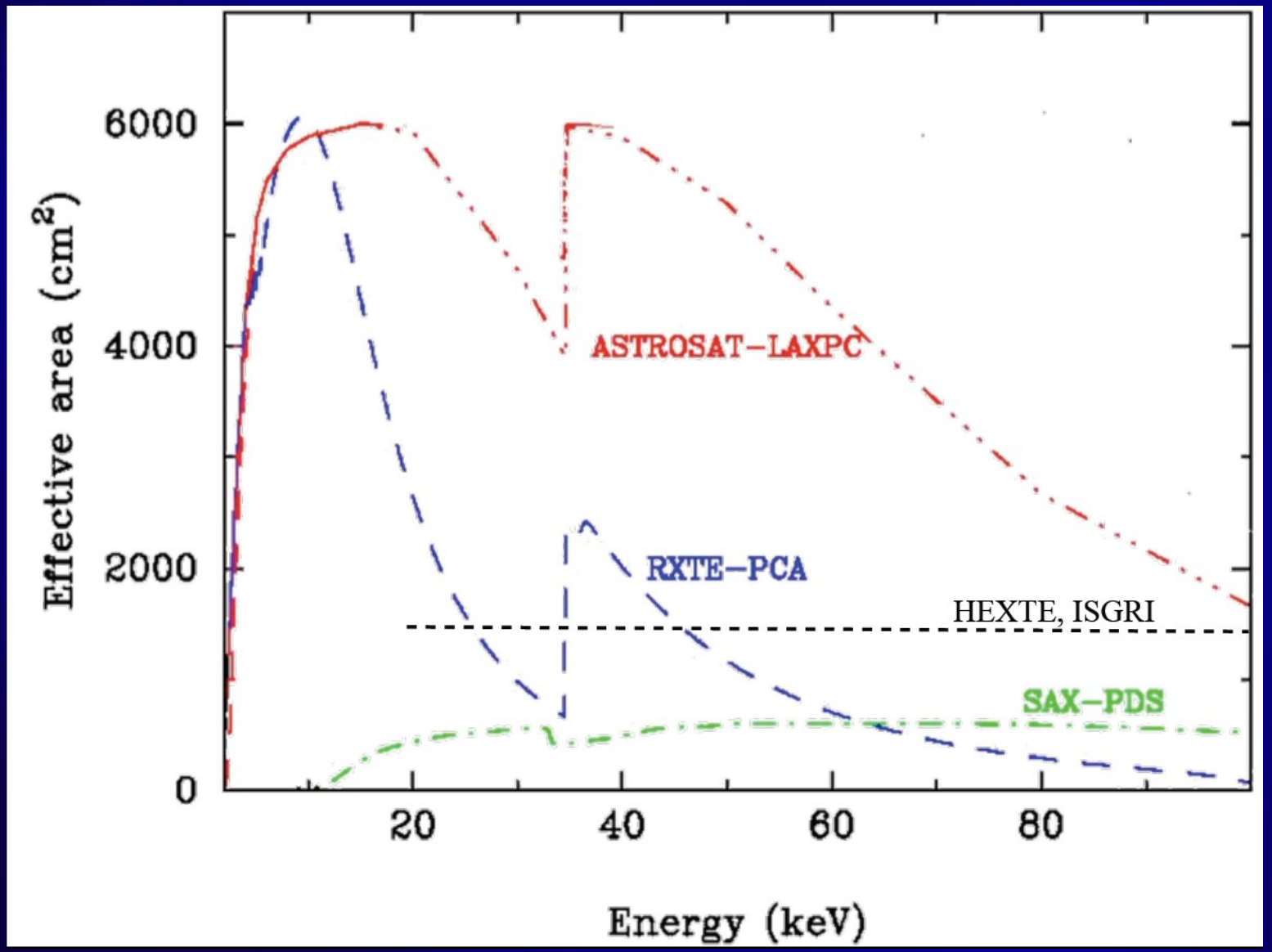
Timing properties of Neutron Star LMXBs



Diego Altamirano

UNIVERSITY OF AMSTERDAM

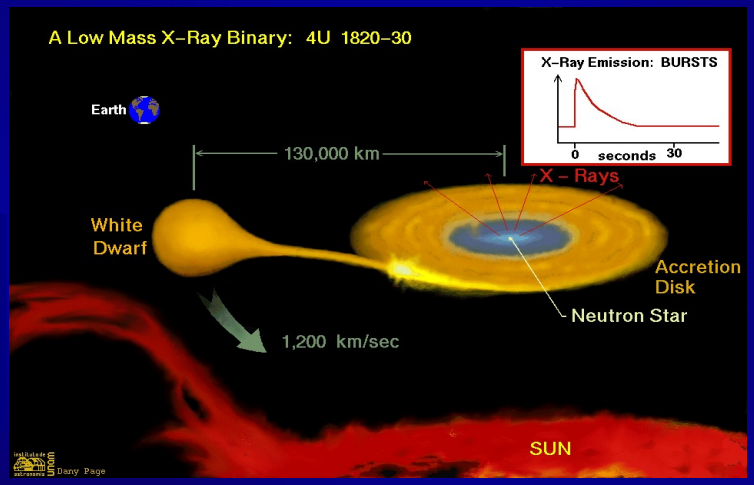

6000
4000
2000
0
Effective area (cm^2)
20
40
60
80
Energy (keV)
ASTROSAT−LAXPC
RXTE−PCA
HEXTE, ISGRI
SAX−PDS

We now know when/what to observe!

Accretion disk

Radio Jets

Spectral states



Thermonuclear Burning
(talk by S. Bhattacharyya)

Optical variability
(talk by P. Gandhi)

Spectral lines

Pulsar/non-pulsar Magnetic field
(talk by A. Patruno)

X-ray variability
(talk by van der Klis, Mendez, Belloni, this one)

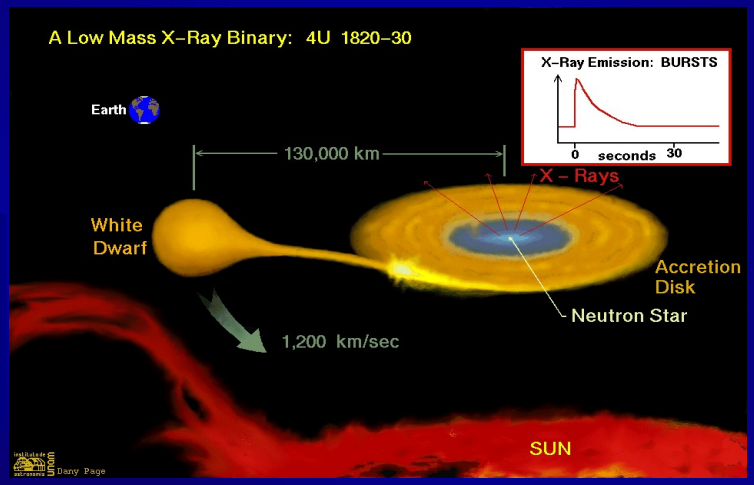
What follows is a brief summary of many years of work...

Accretion disk

Radio Jets

?

Spectral states



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?

Spectral lines

X-ray variability
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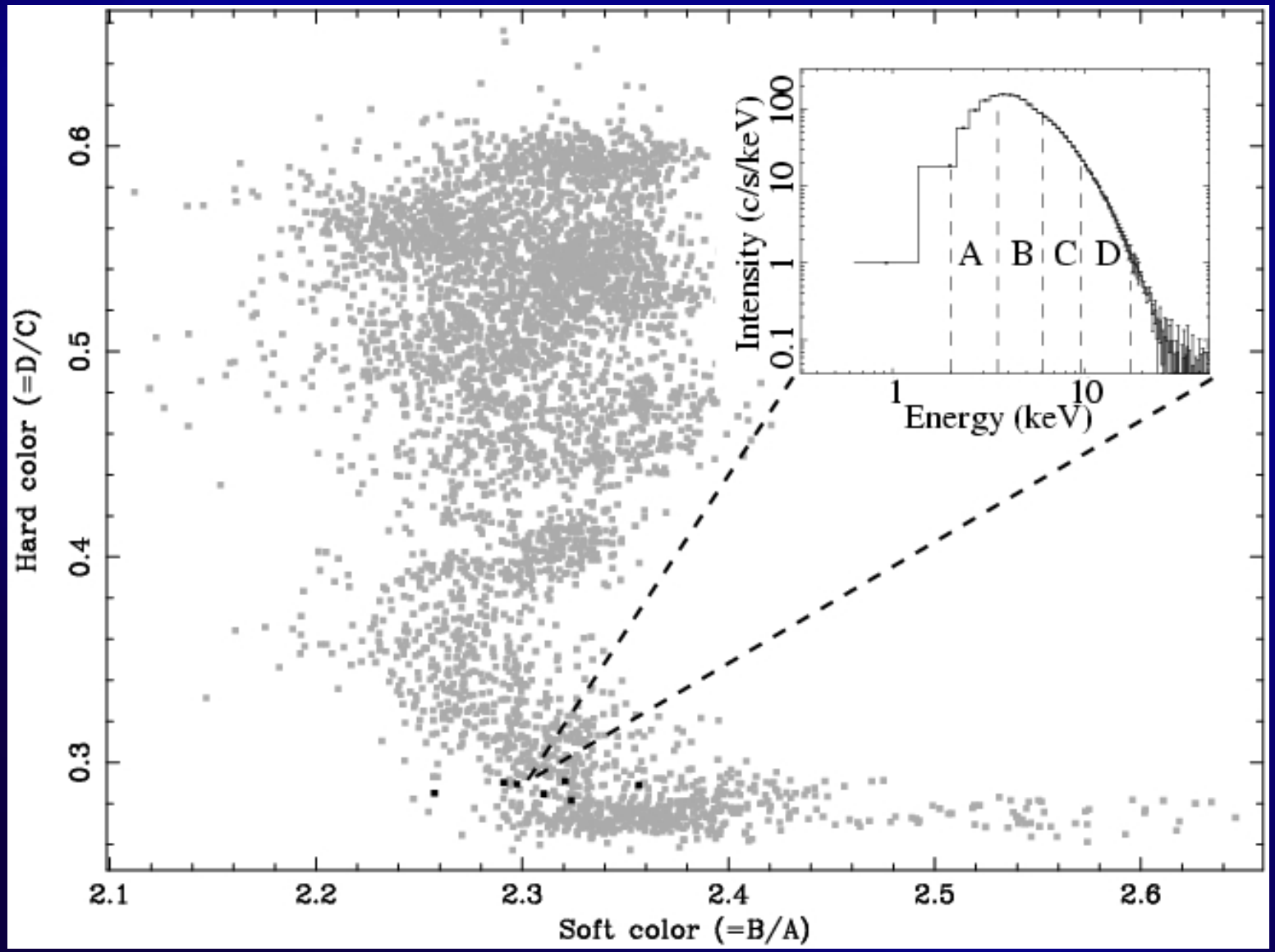
Pulsar/non-pulsar Magnetic field
(talk by A. Patruno)

Color Color Diagrams

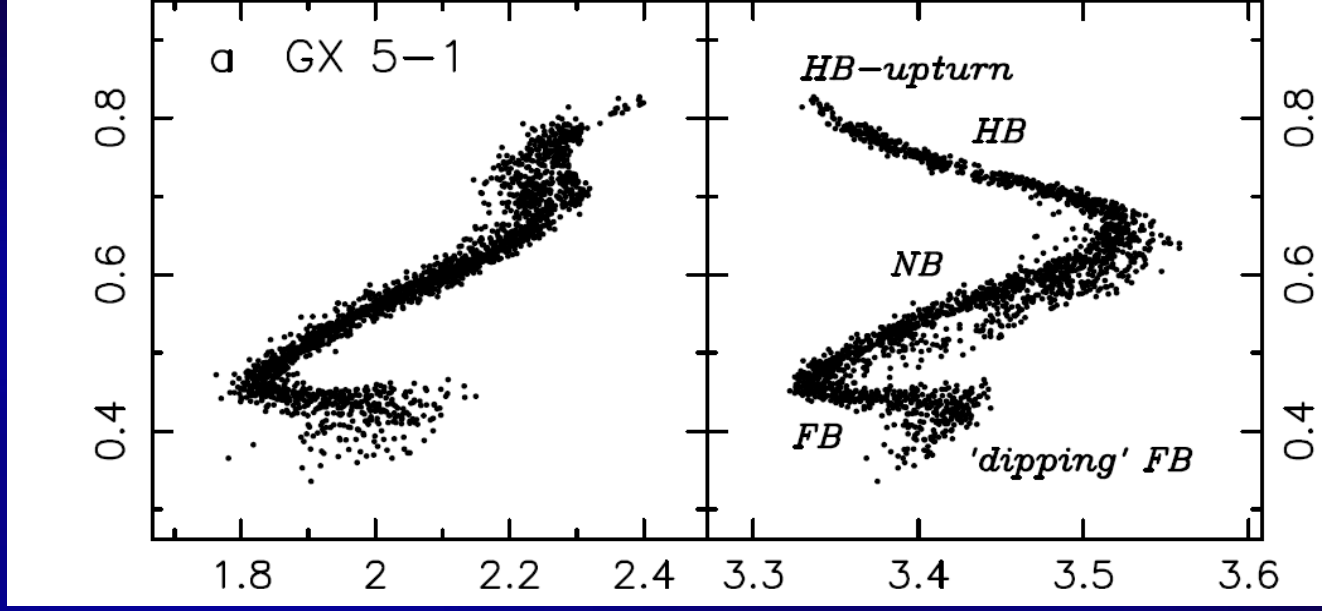
(or hardness-intensity diagrams)

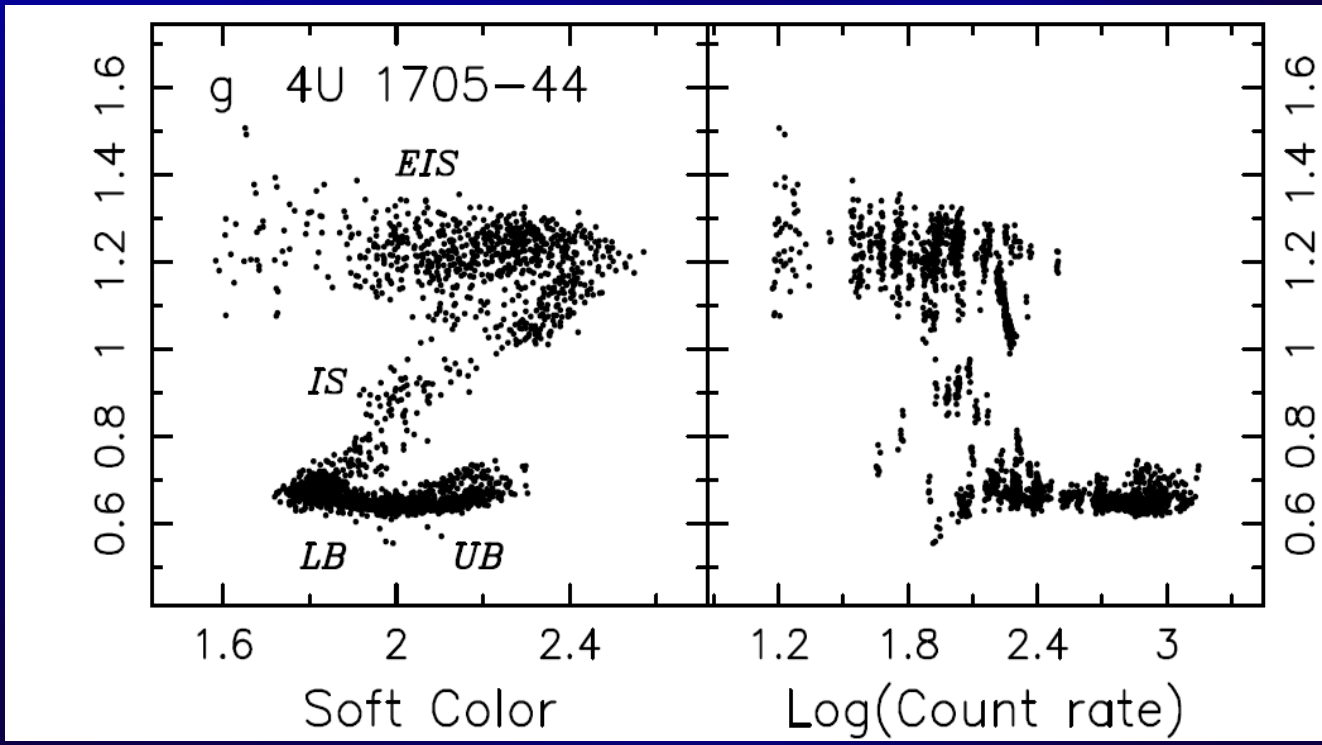


Z-source

Accretion rate

Atoll source





Actually...

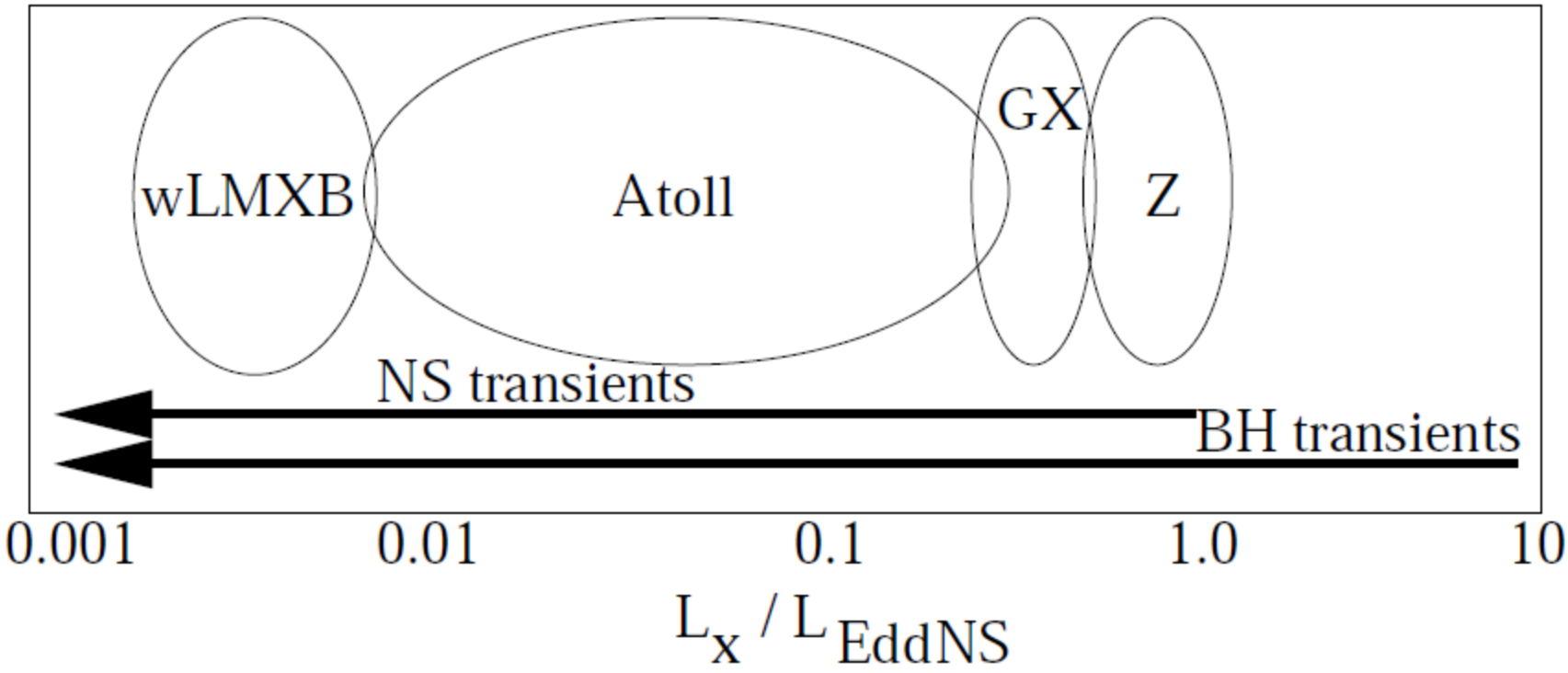
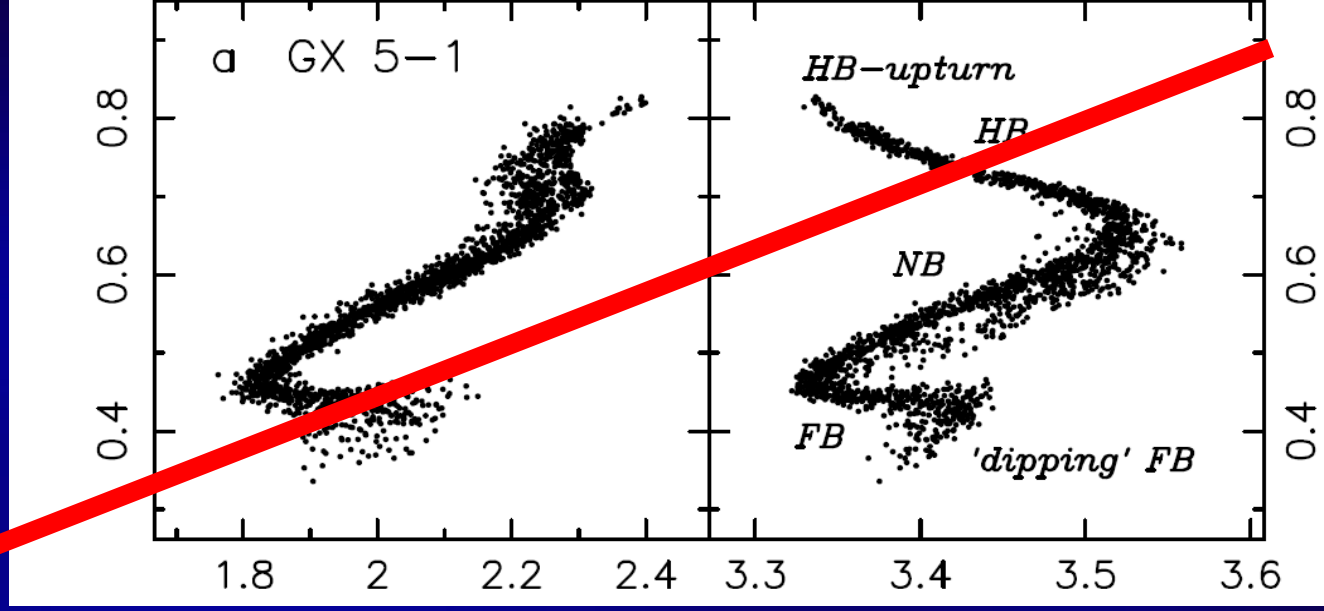


Fig. 2.1. Luminosities attained by Z sources, GX atoll sources, ordinary atoll sources and weak LMXBs, respectively, as well as by neutron-star and black-hole transients. The extent of the L_x overlaps between these source types is undecided in detail, but those shown here are likely.

van der Klis, 2006

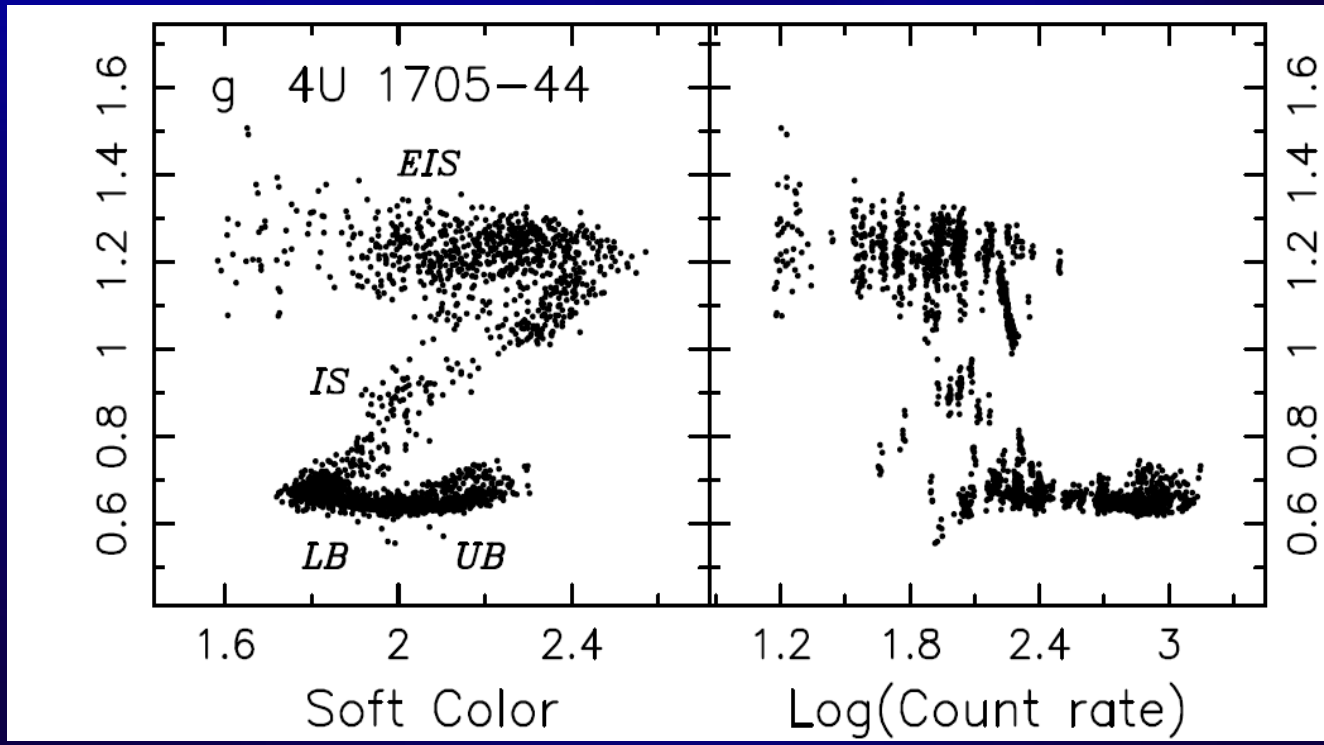
It would take to long to show you everything....
(and it would probably make it too complicated)

Z-source

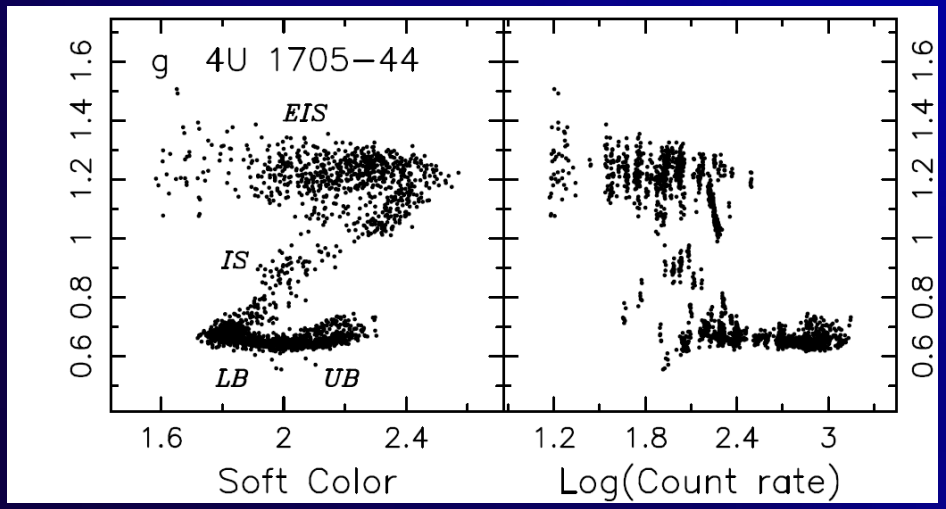


Accretion rate

Atoll source



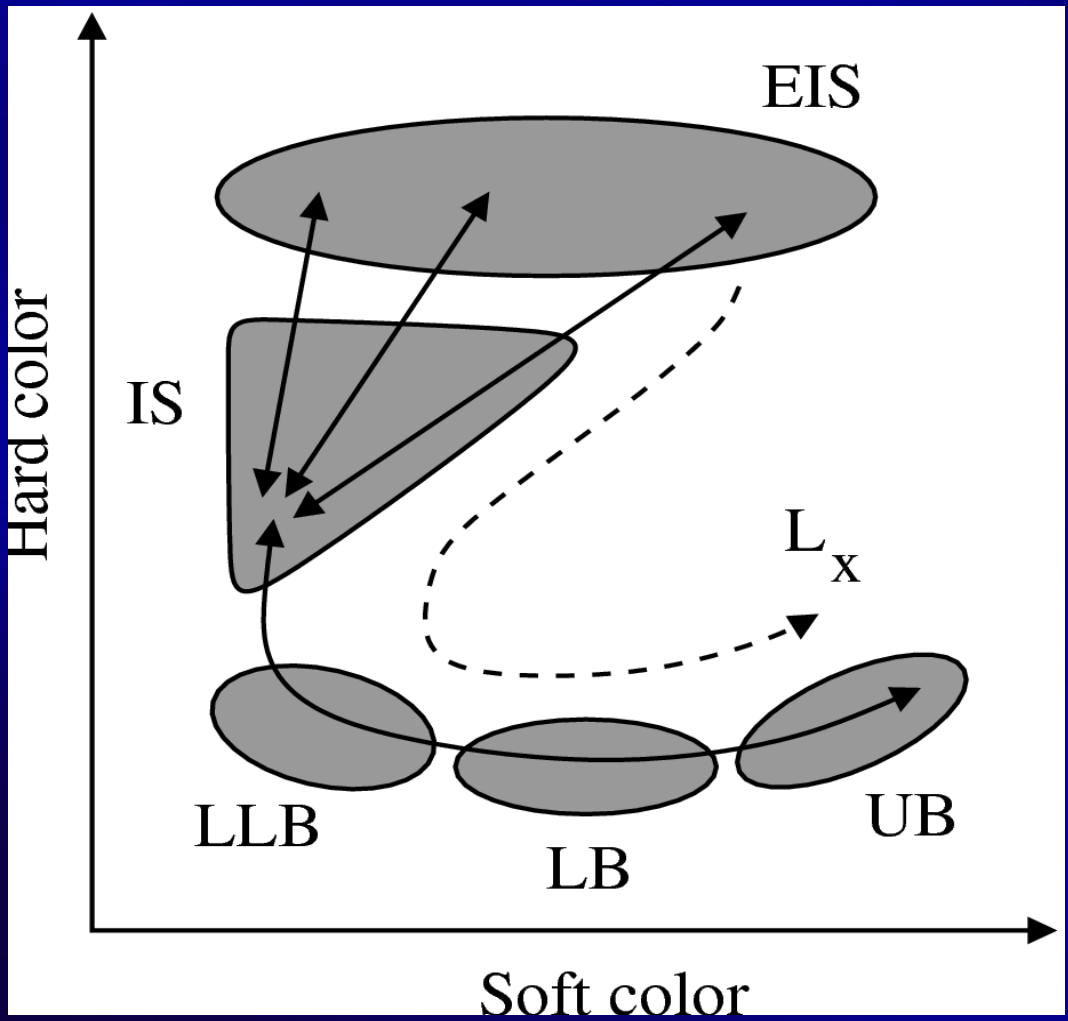
I will concentrate on Atoll sources

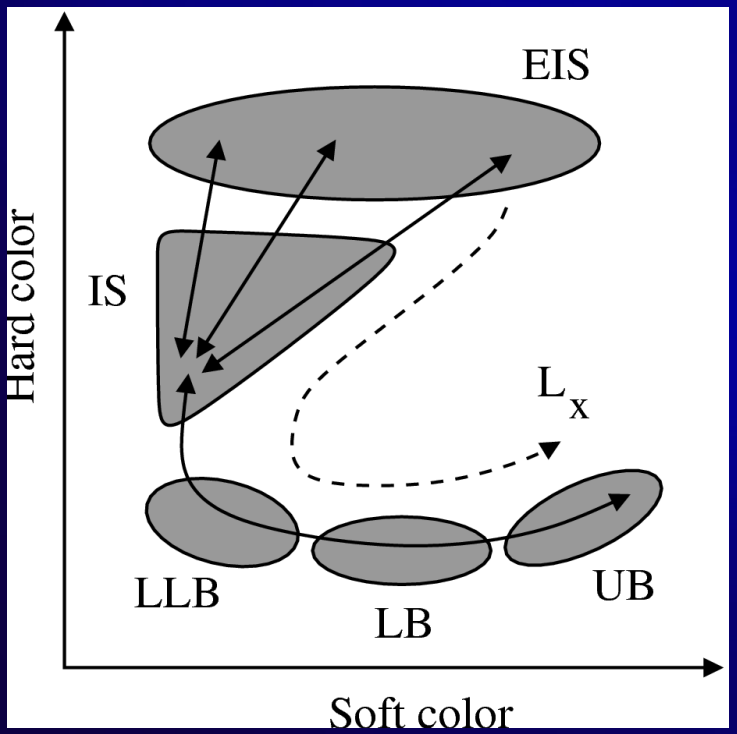


- Low luminosity (≤ 10% L_E)
- Majority of systems
- Transient and persistent
- Some of them are pulsars! (see talk by A. P)
- Show a whole range of thermonuclear burning regimes (see talk by S. B.)

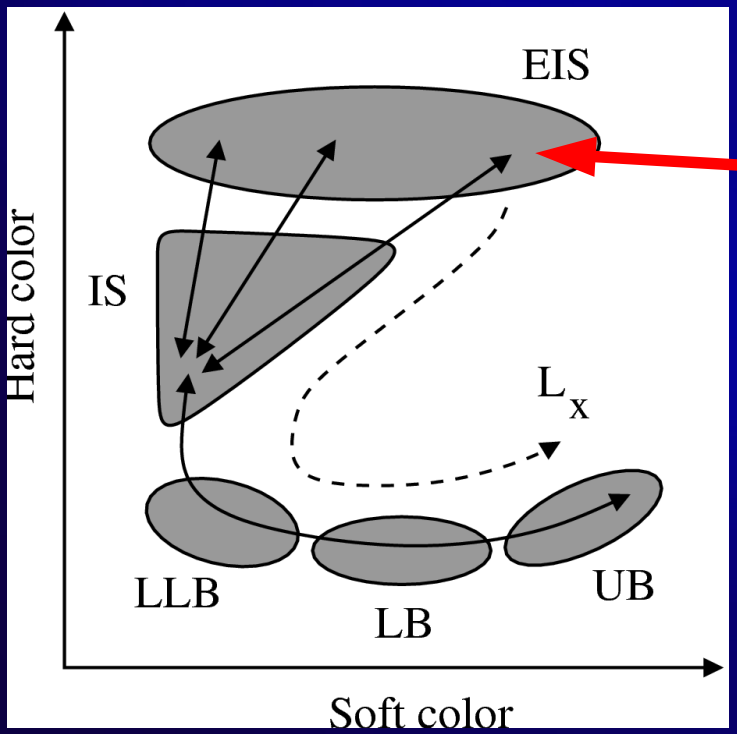
See also talks by M. Mendez and F. Ozel

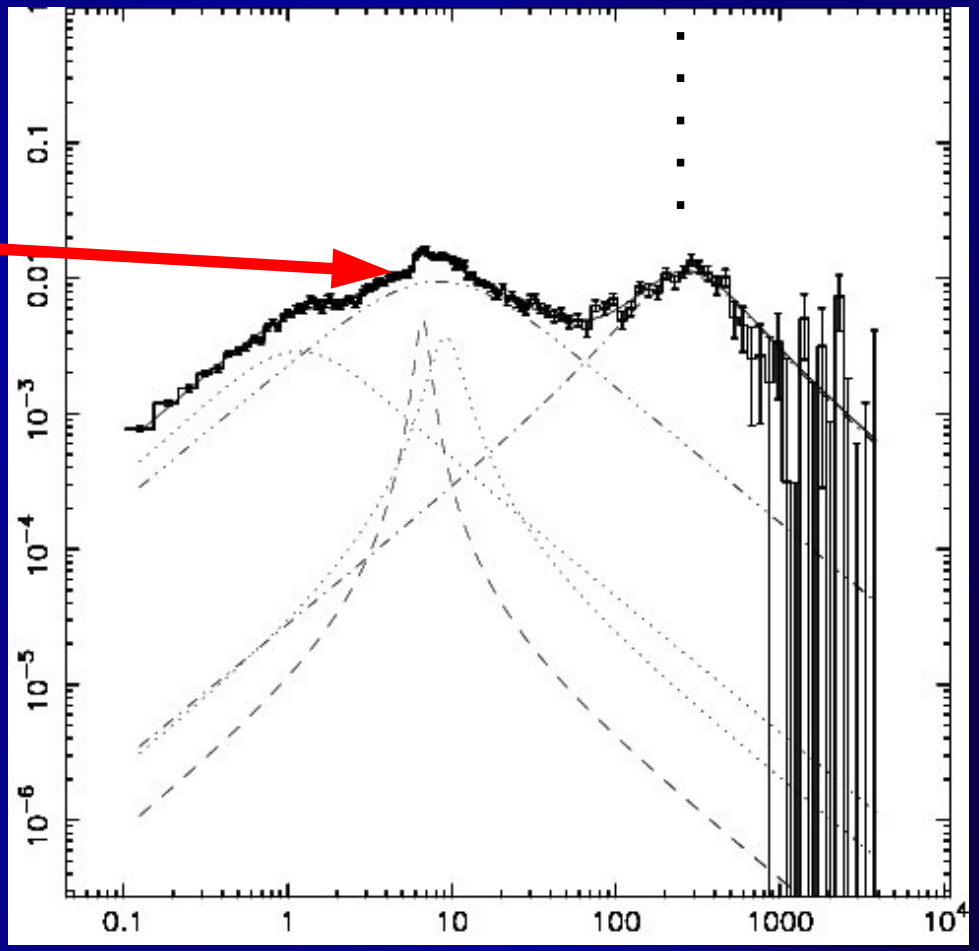
Is there any relation between spectral states and X-ray variability?



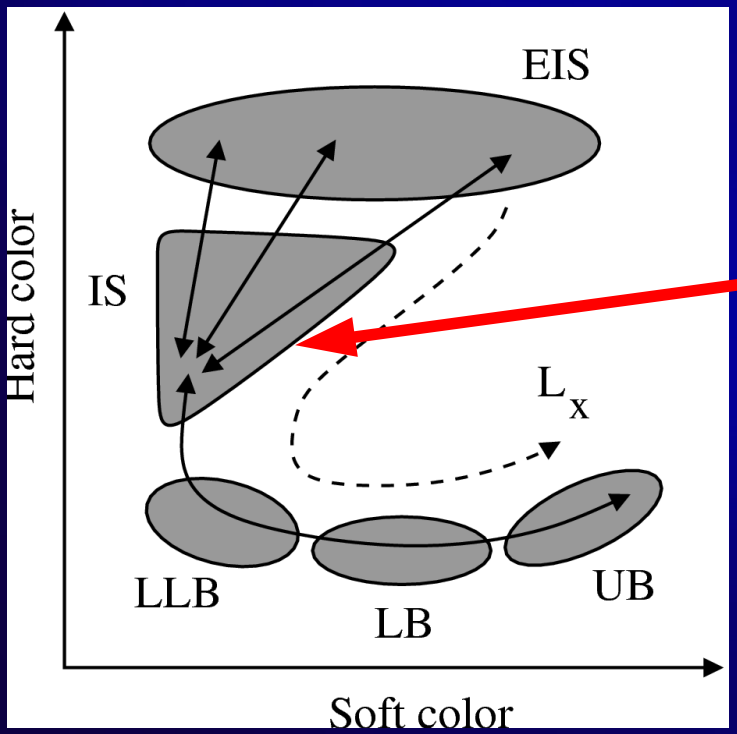

EIS
IS
Hard color
L_x
LLB
LB
UB
Soft color

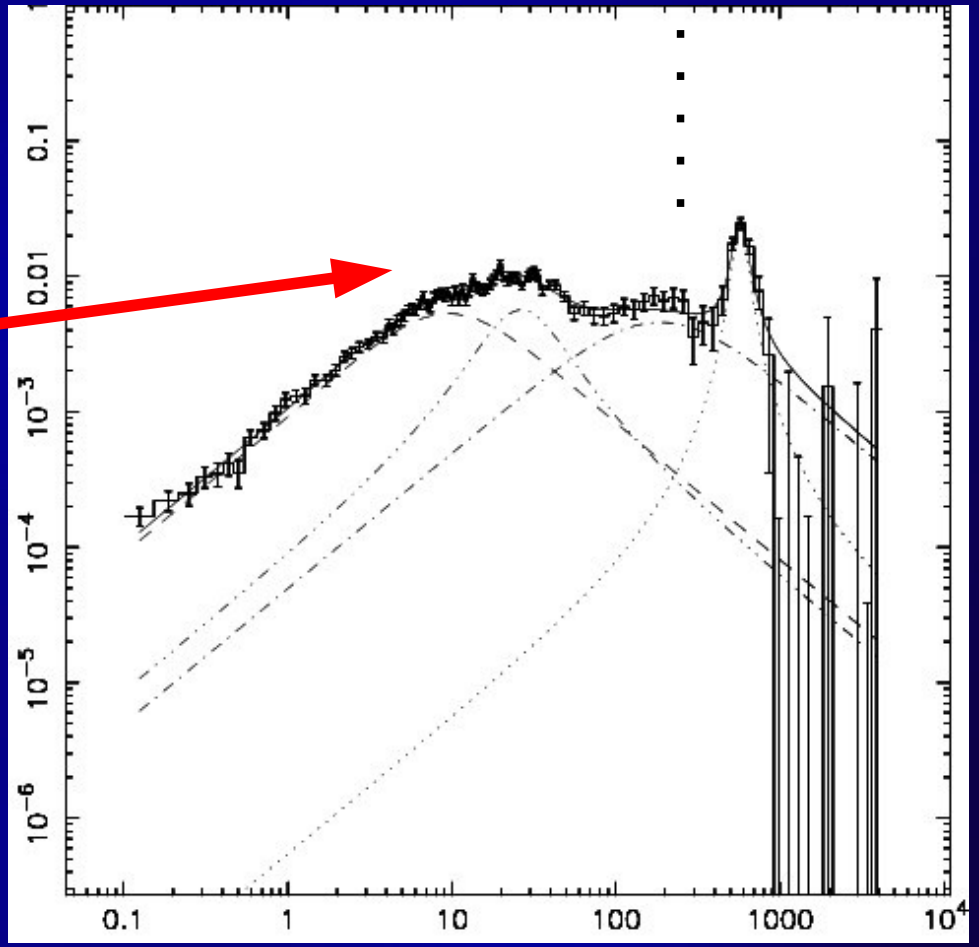
Extreme Island State



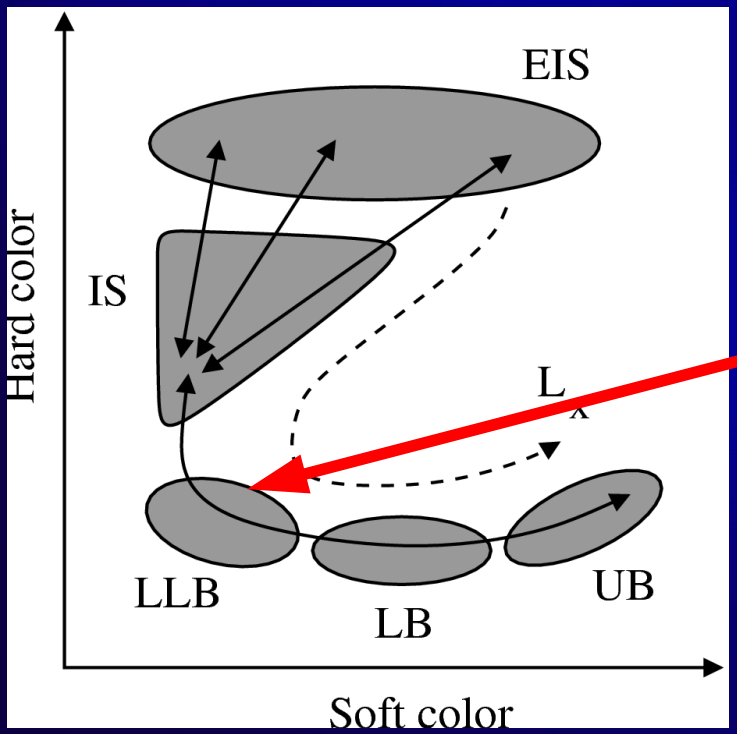


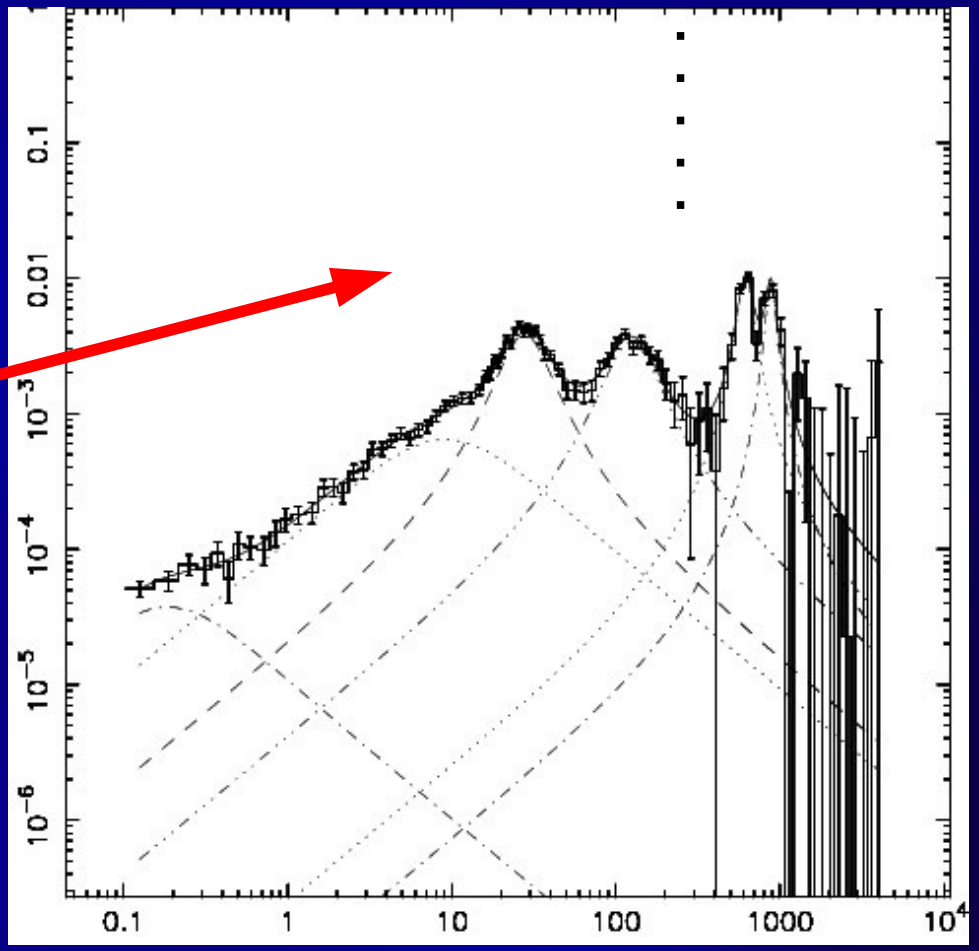
Island State



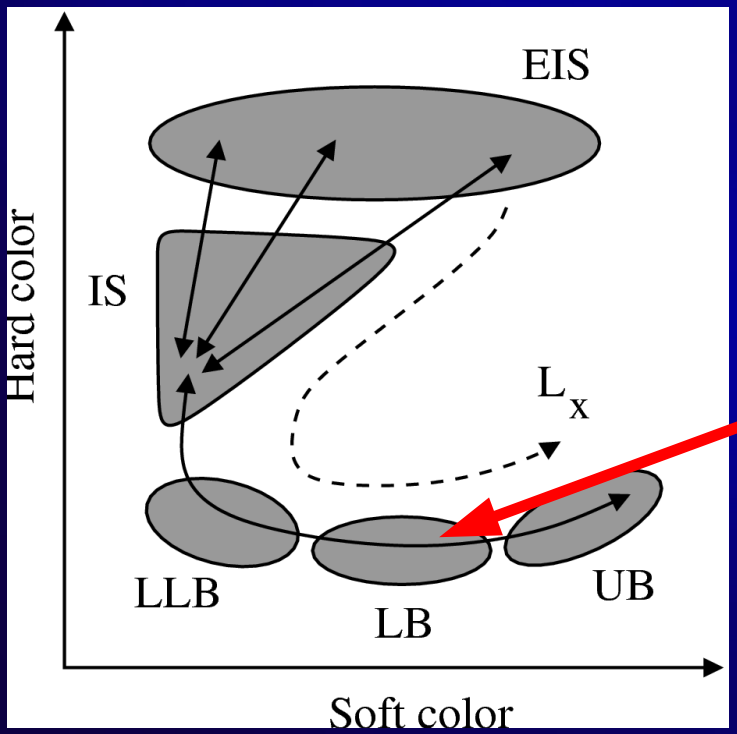


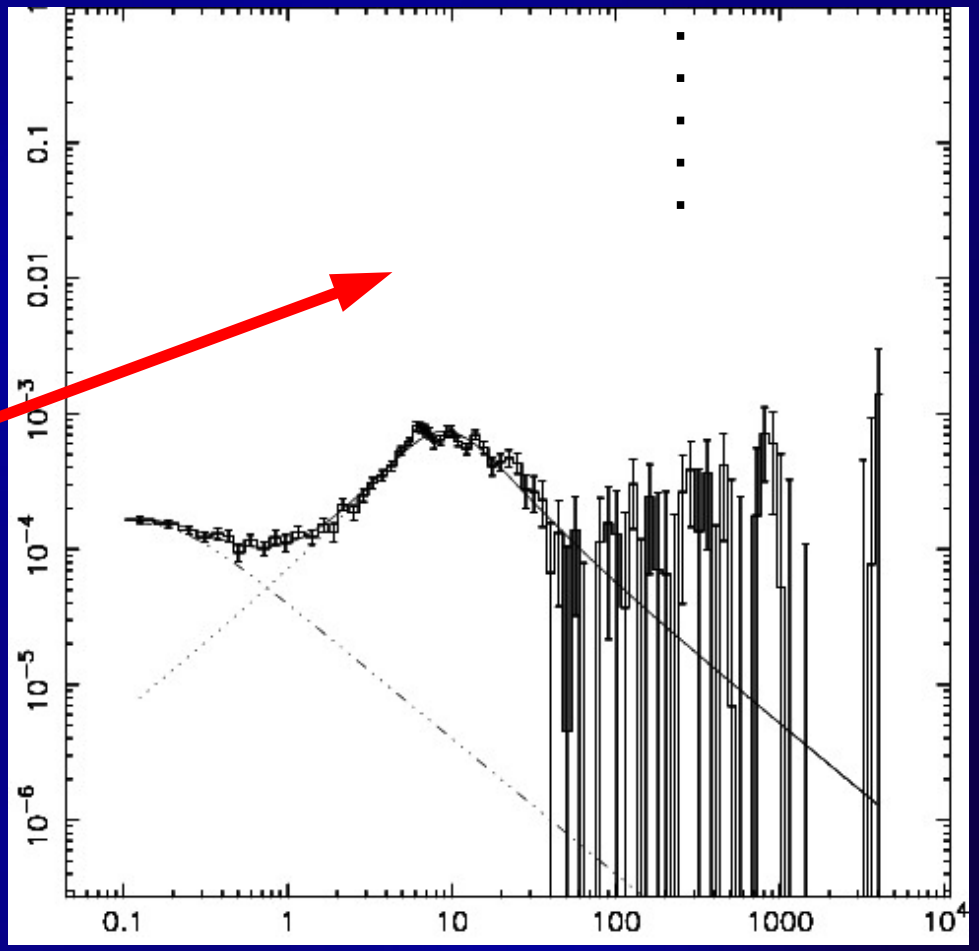
Lower Left Banana



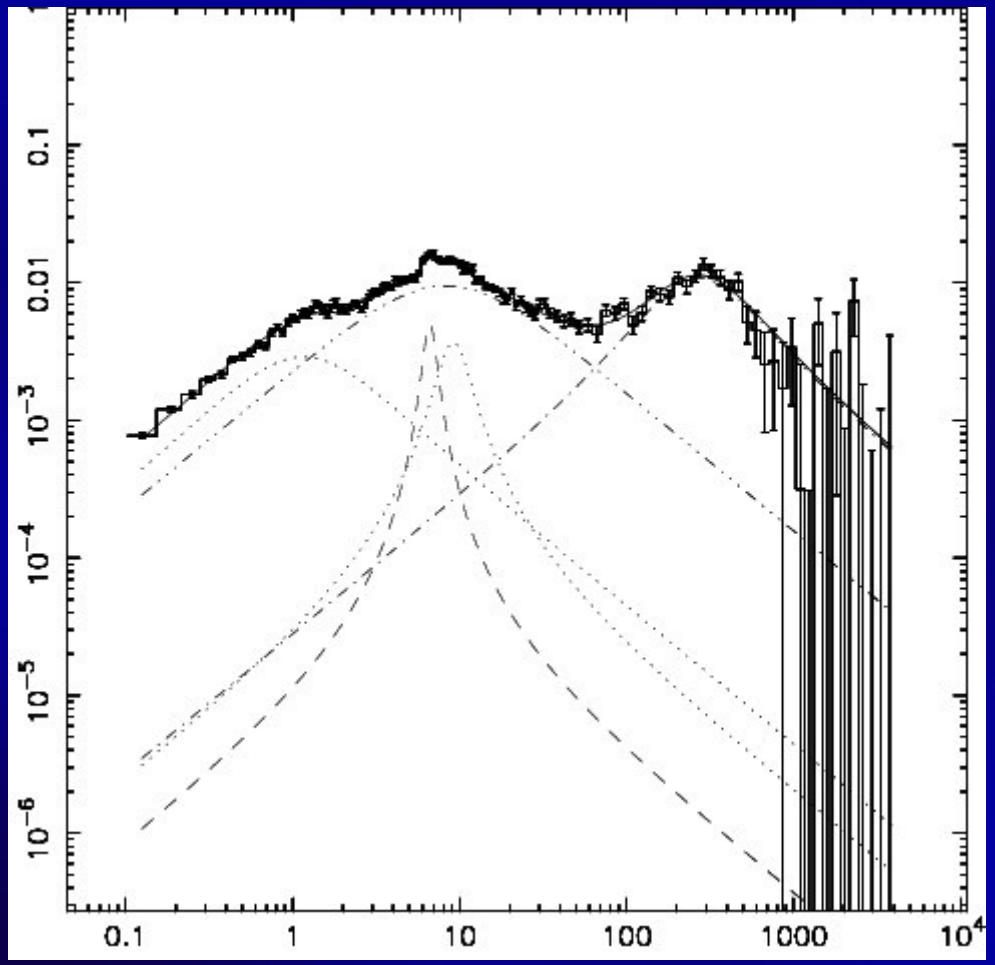


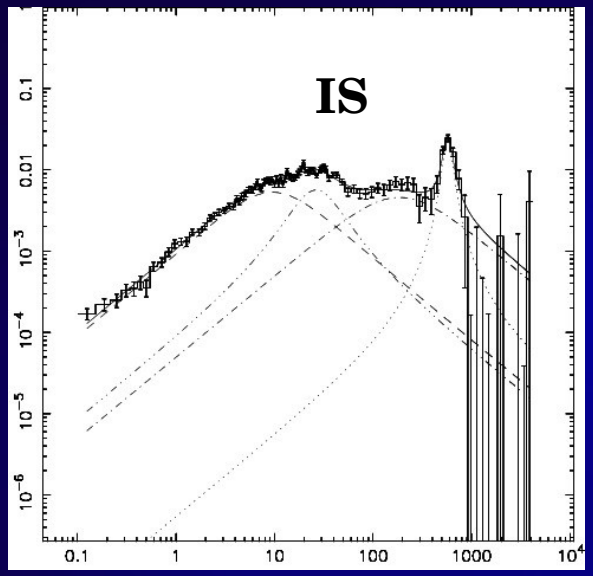
Lower Banana

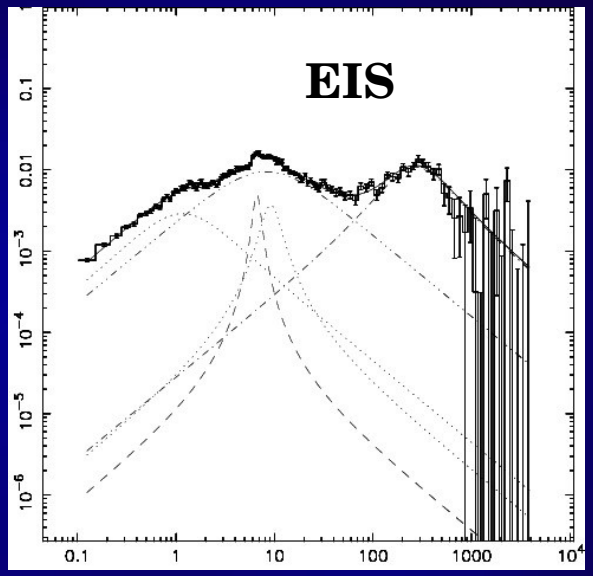


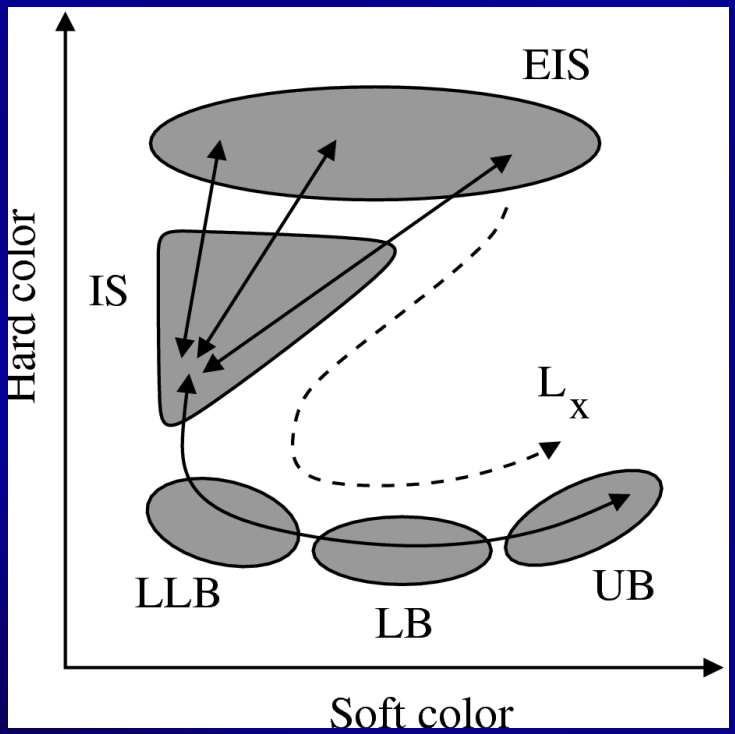


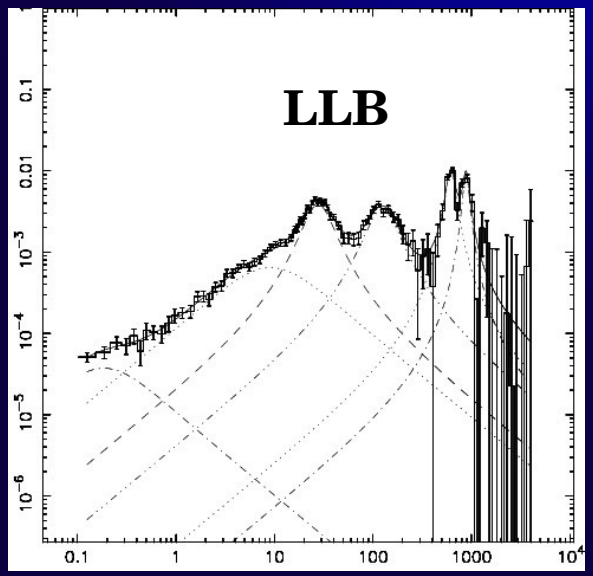
Power spectra

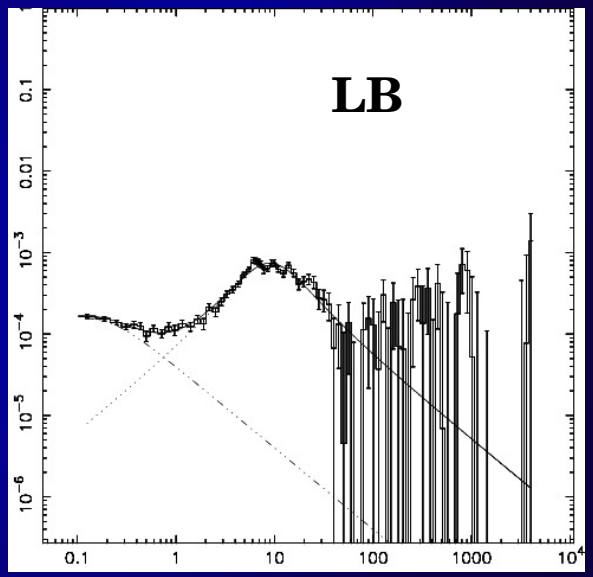






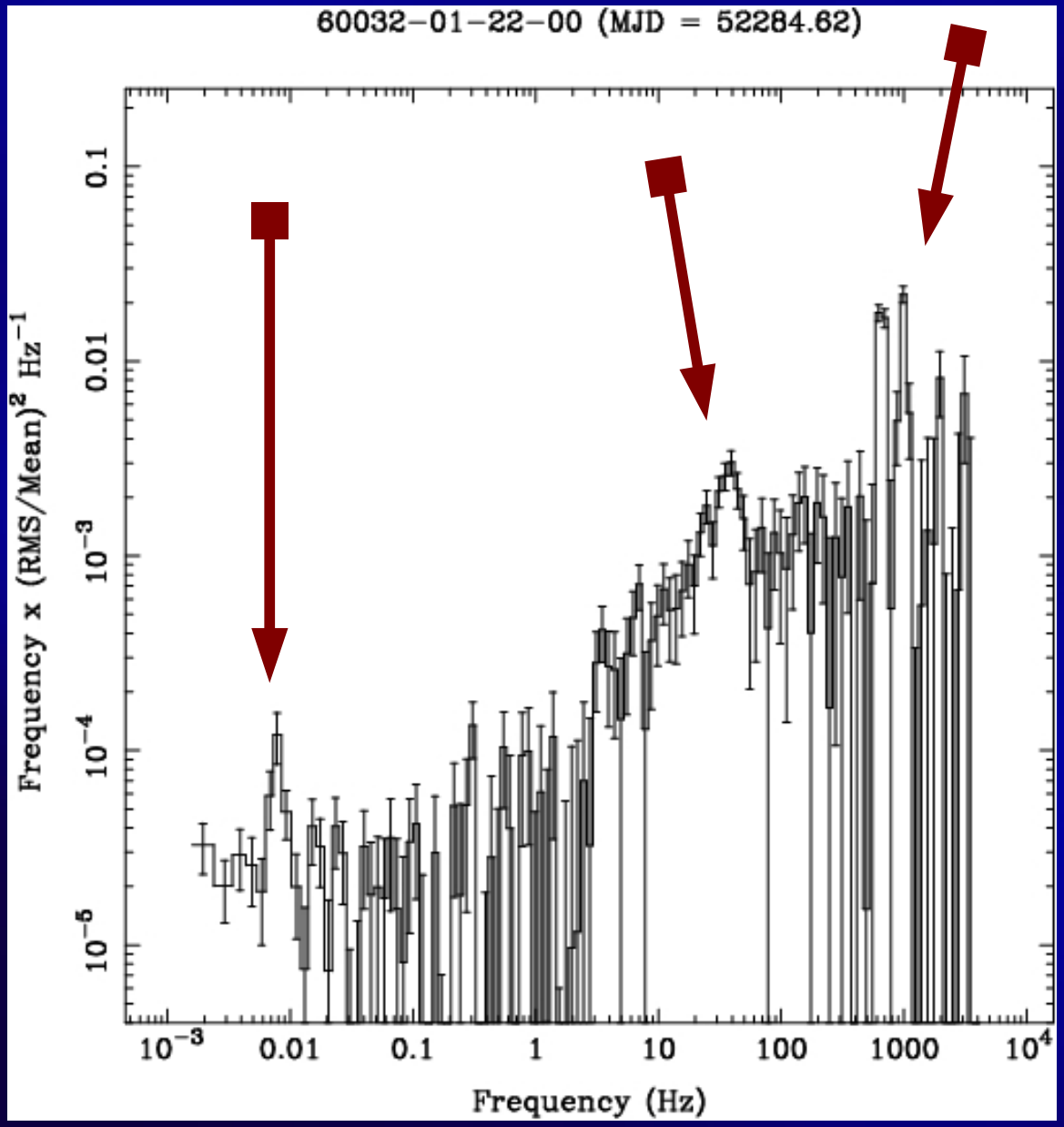






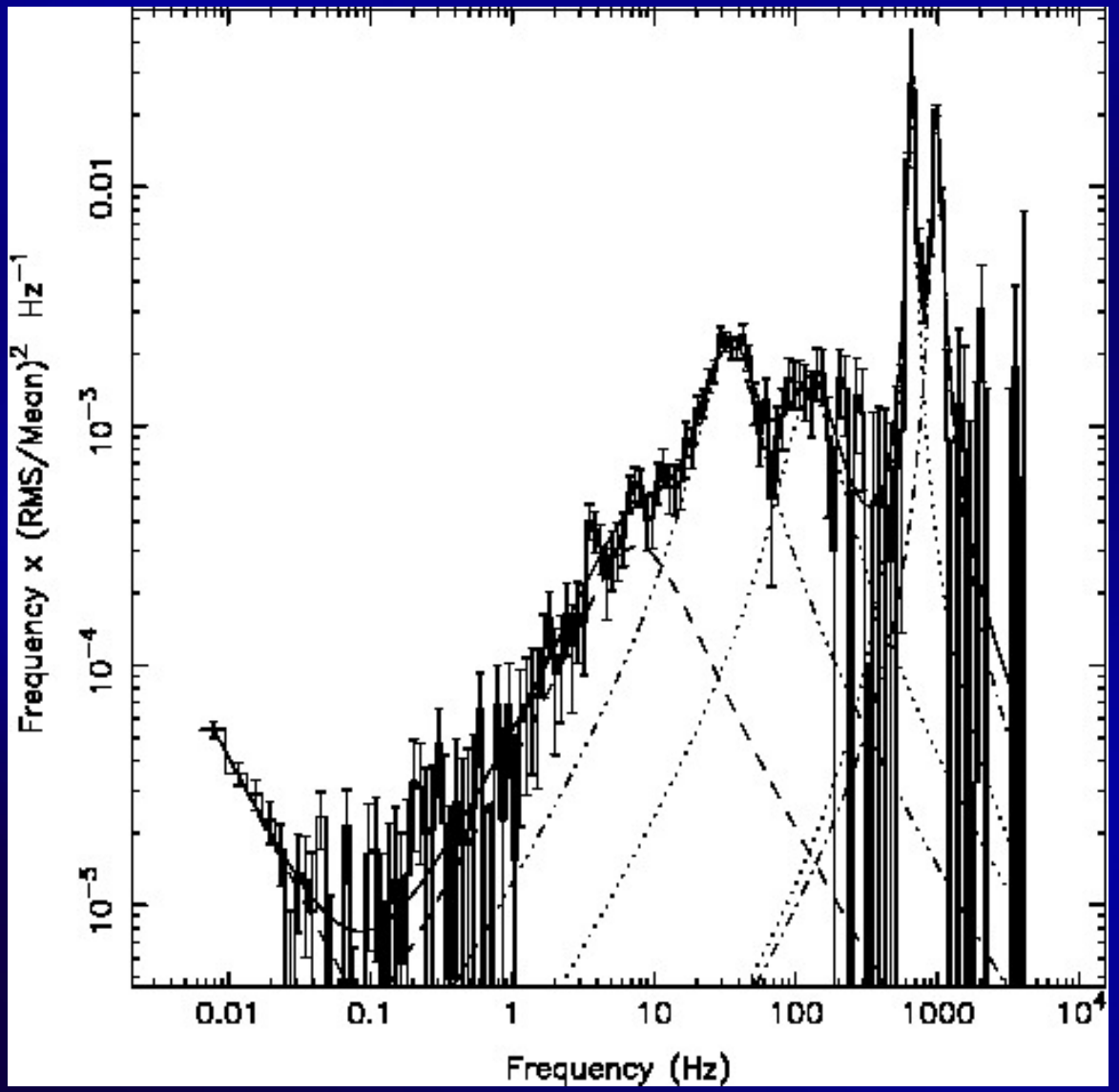
"All" NS sources appear show this same correspondence

Power spectra (1/3)



Ideally we would like a physical model...

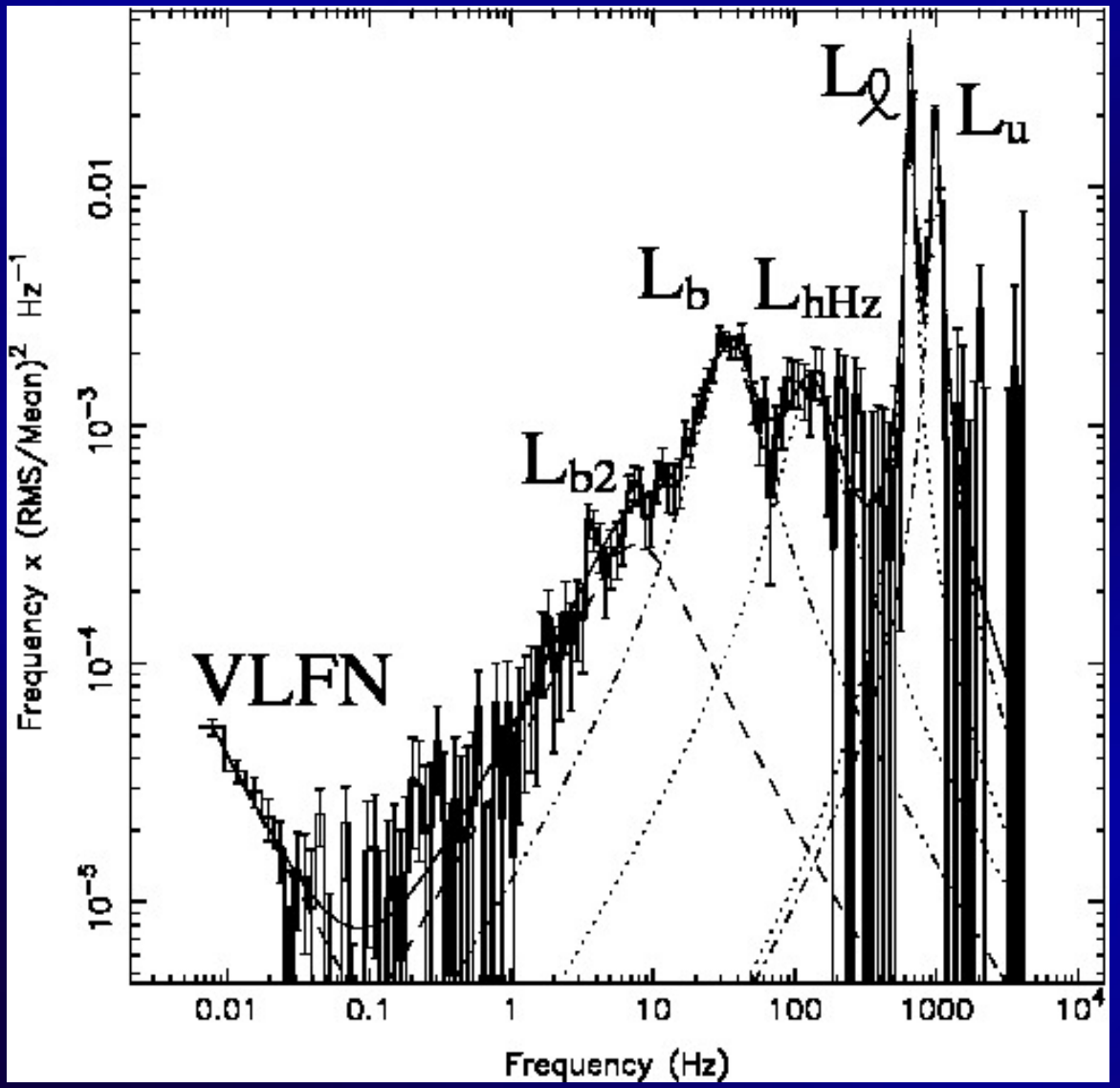
Power spectra (2/3)



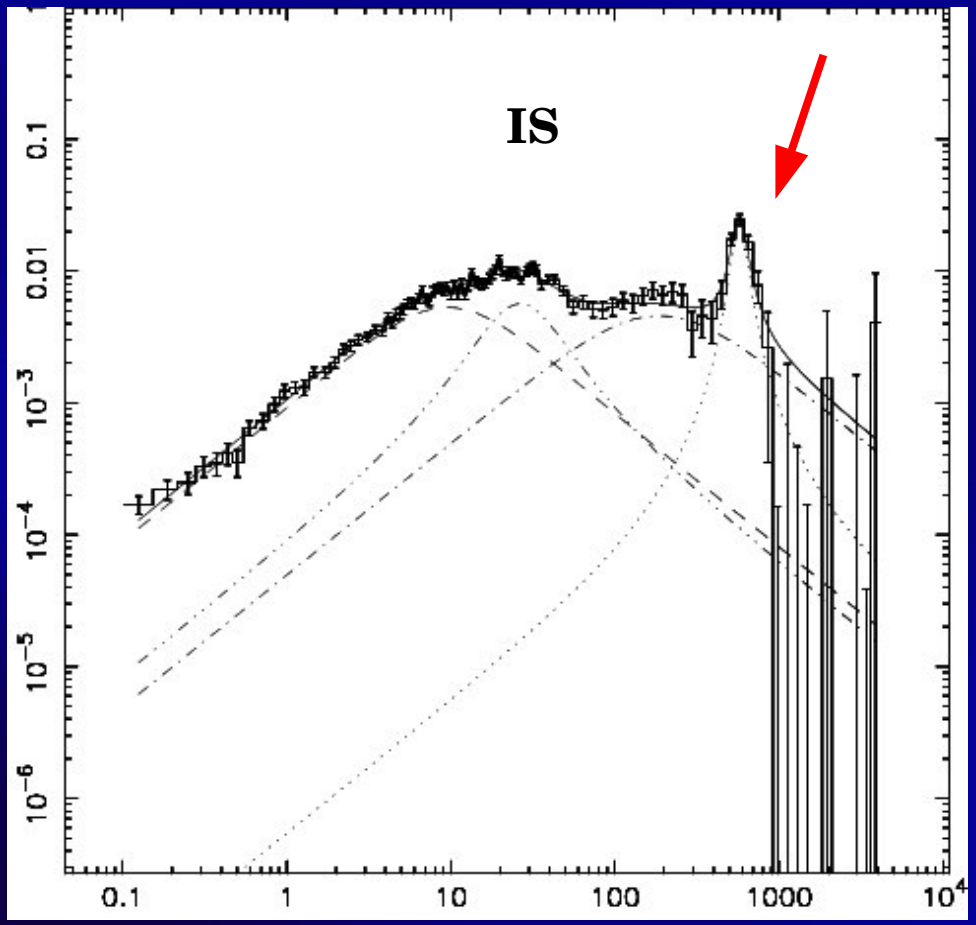
When we study many PDS
we find features that appear again and again....

so in an effort to understand what is going on....

Power spectra (3/3)



Do the different components evolve?



Only by having continuous observations we might be able...

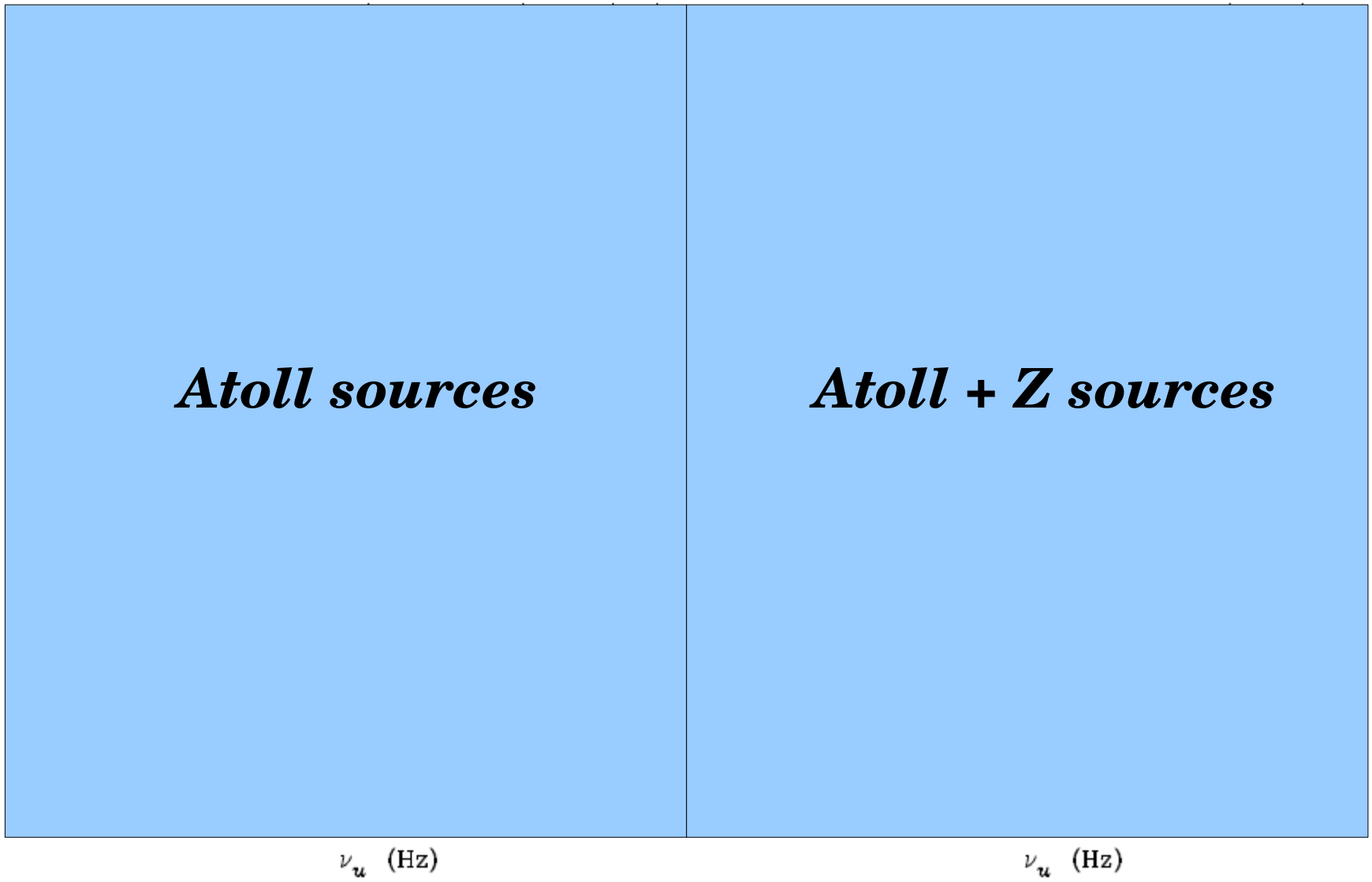
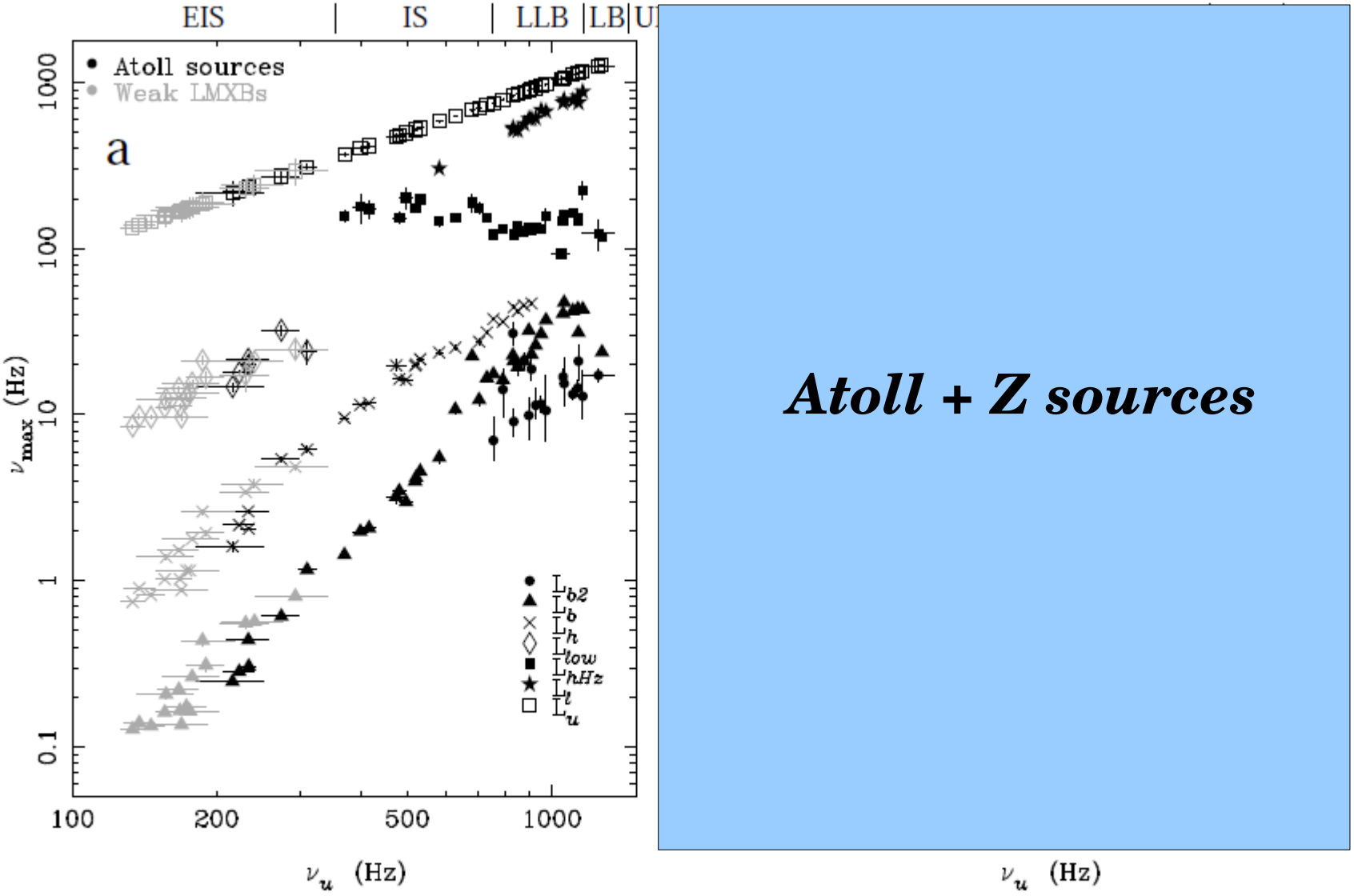


Fig. 2.9. Frequency correlations. *(a)* Atoll sources and weak LMXBs, *(b)* Z sources compared with these objects. The characteristic frequencies (ν_{max}, §2.2) of the components are plotted as indicated; approximate source state ranges are indicated at the top.

van der Klis 2006



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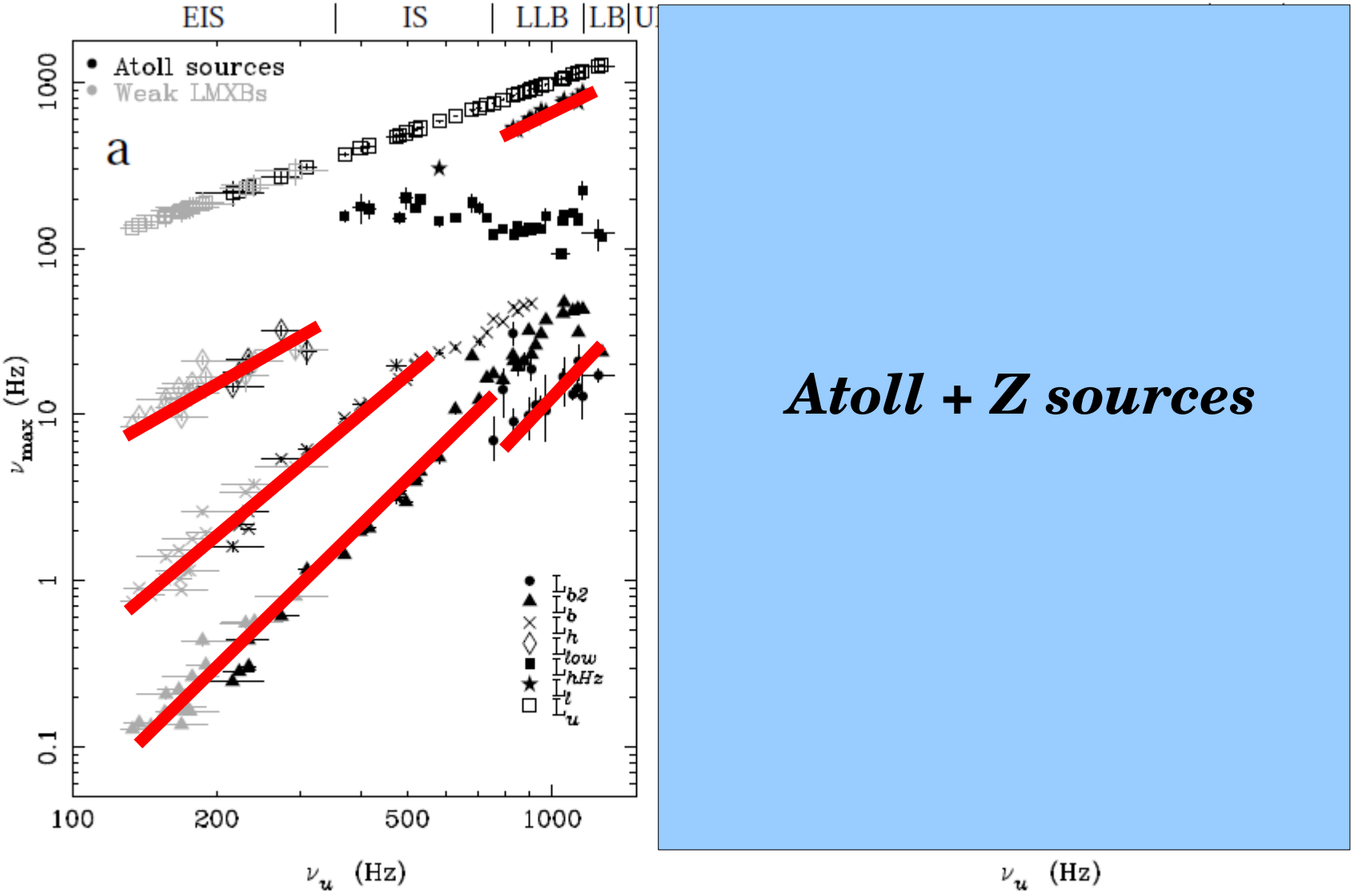

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van der Klis 2006

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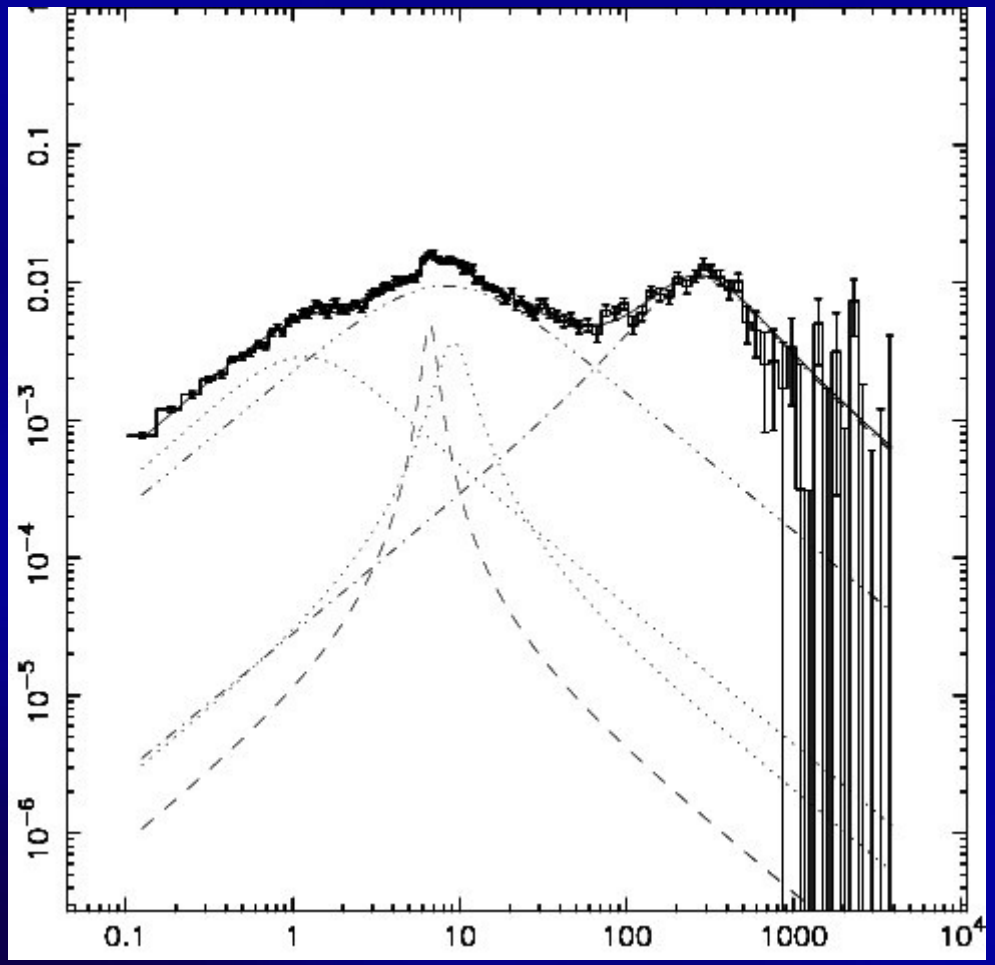

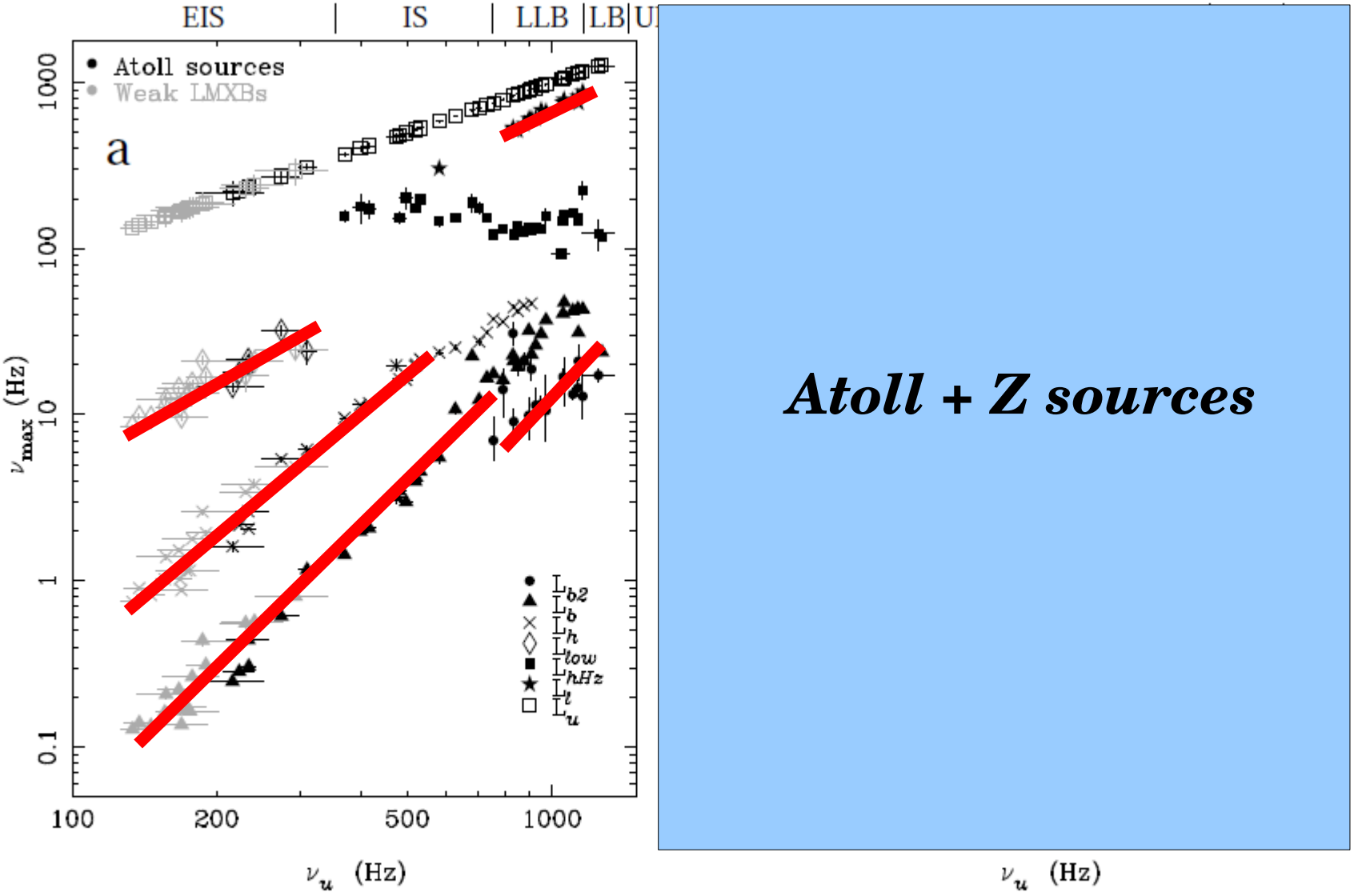

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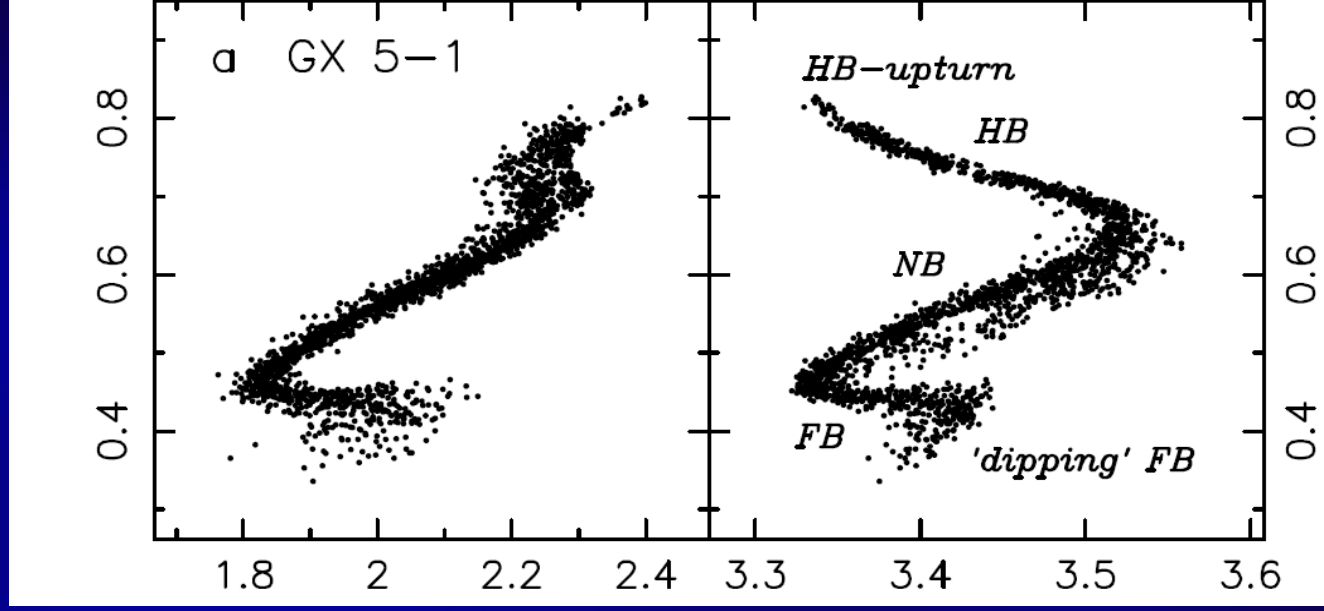
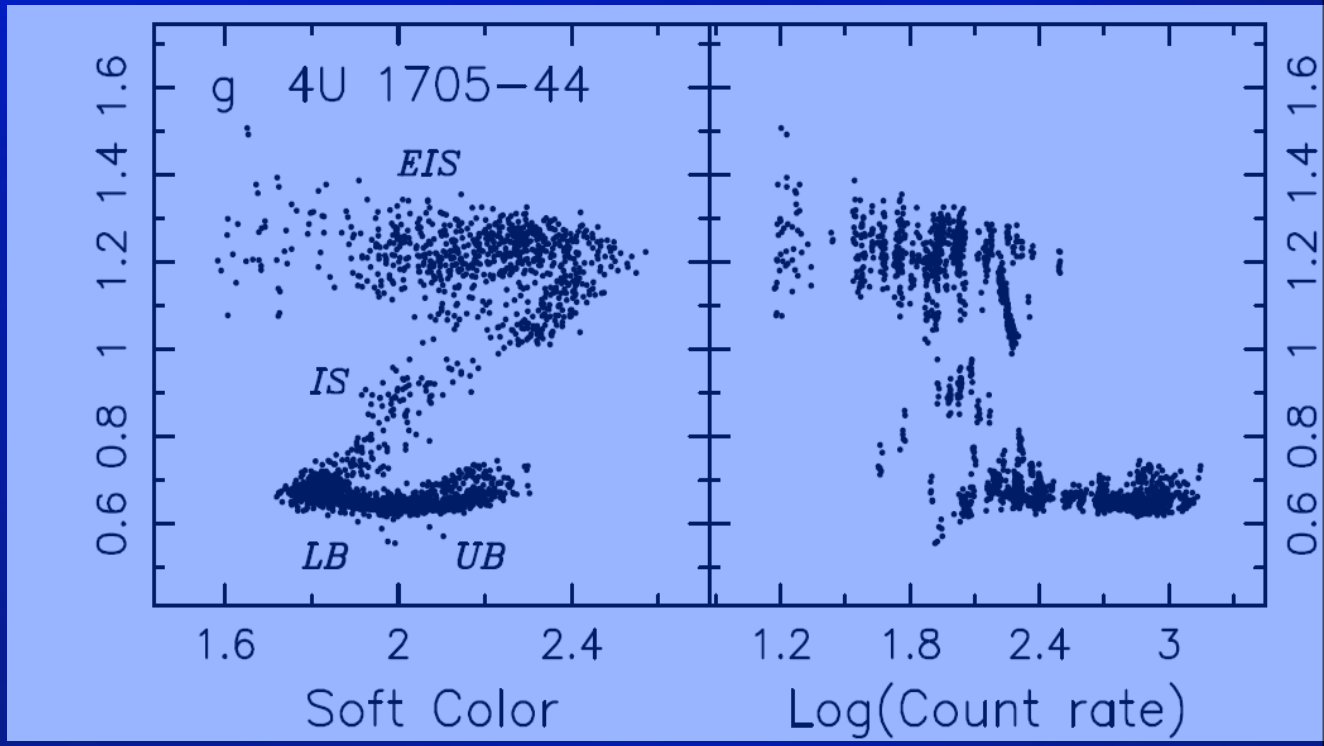
van der Klis 2006

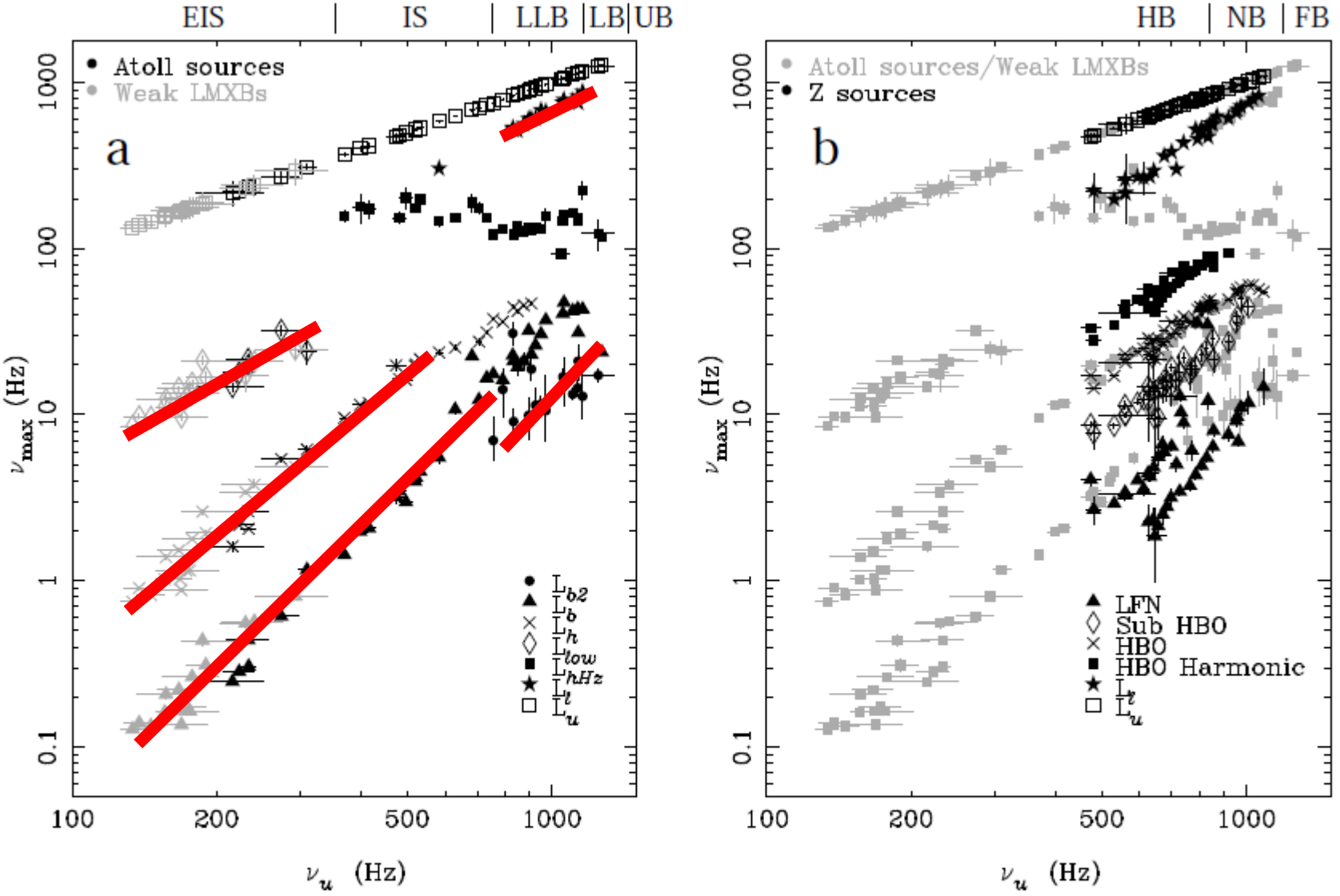
Z-source



Accretion rate

Atoll source





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van der Klis 2006

Atoll vs Z sources?

- Z are brighter than Atoll sources... and they show different (although similar) characteristics.
- so.. why are they different?
  - magnetic field?
  - spin frequency?
  - viewing angle?
  - So on ...

Atoll vs Z sources?

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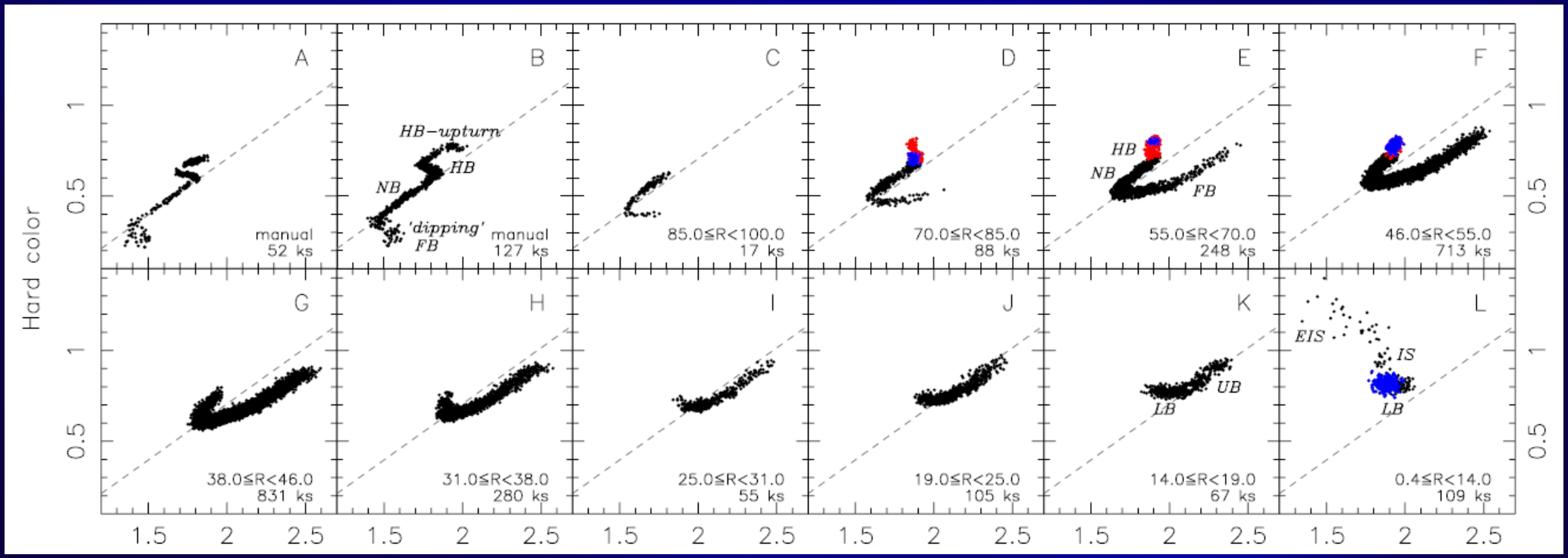
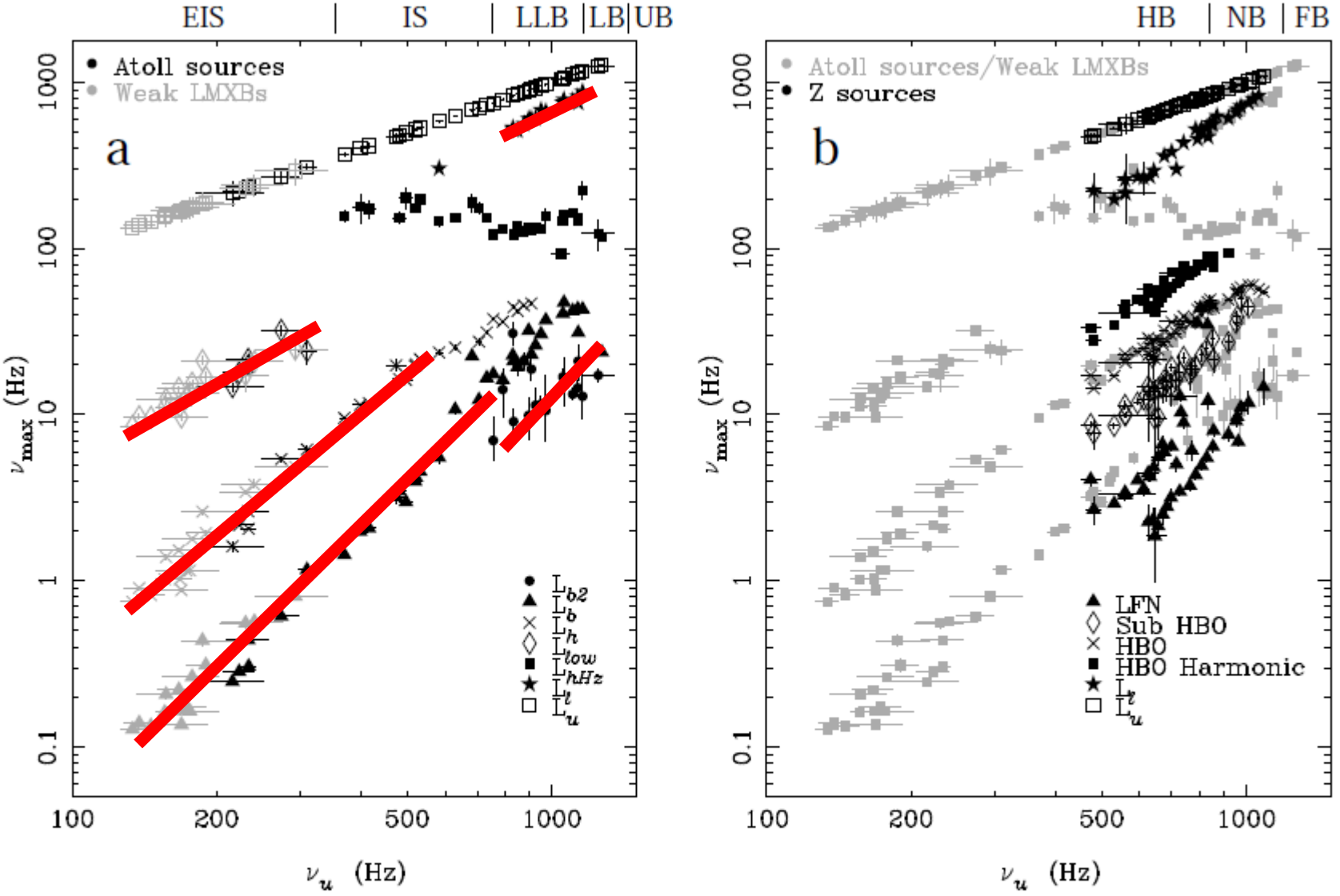
- so.. why are they different?
  - magnetic field?
  - spin frequency?
  - viewing angle?
  - So on ...

After more than 20 years we now know that a given source can behave like both!

Atoll vs Z sources?



XTE J1701-462, see Homan et al. 2010



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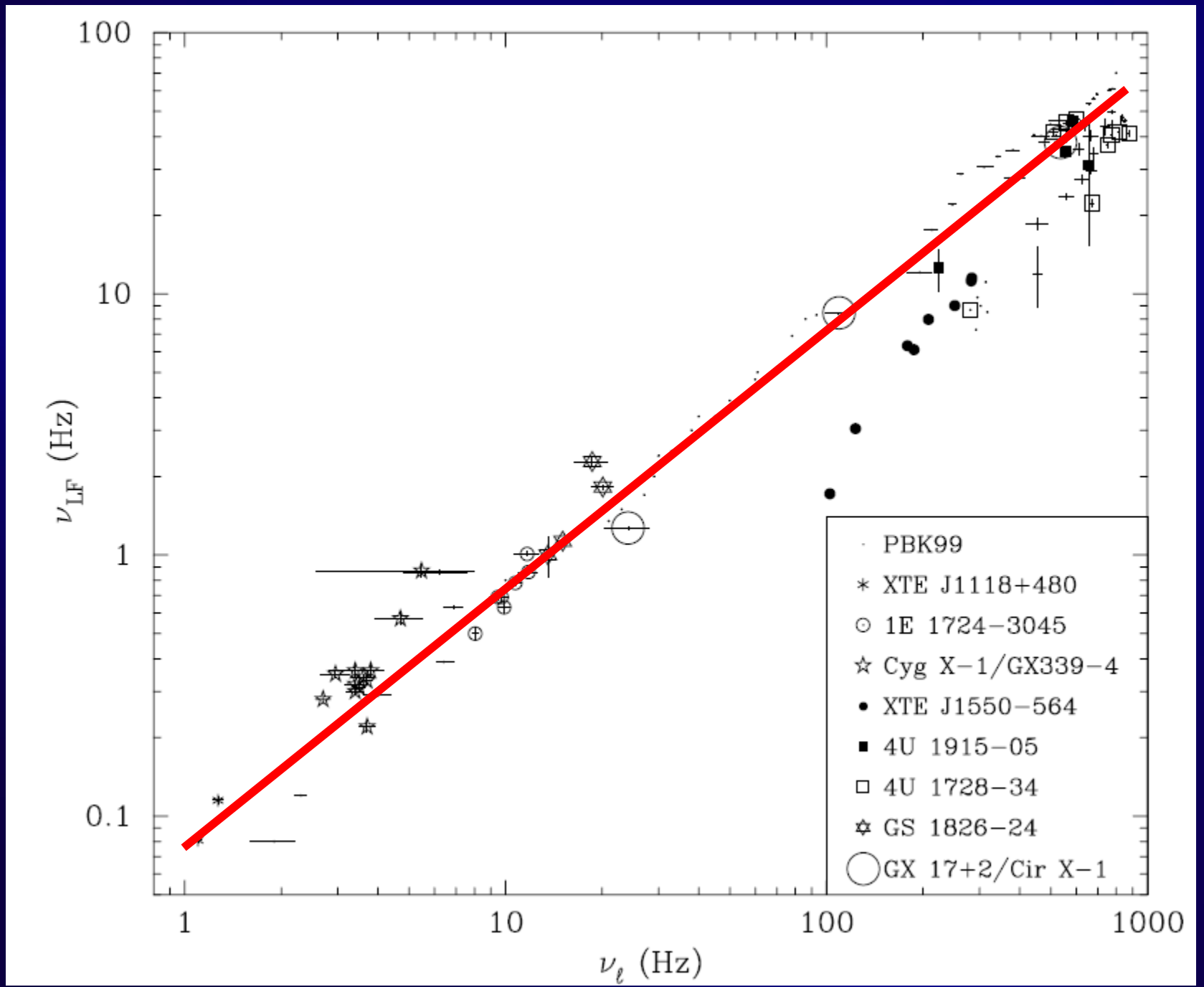
van der Klis 2006

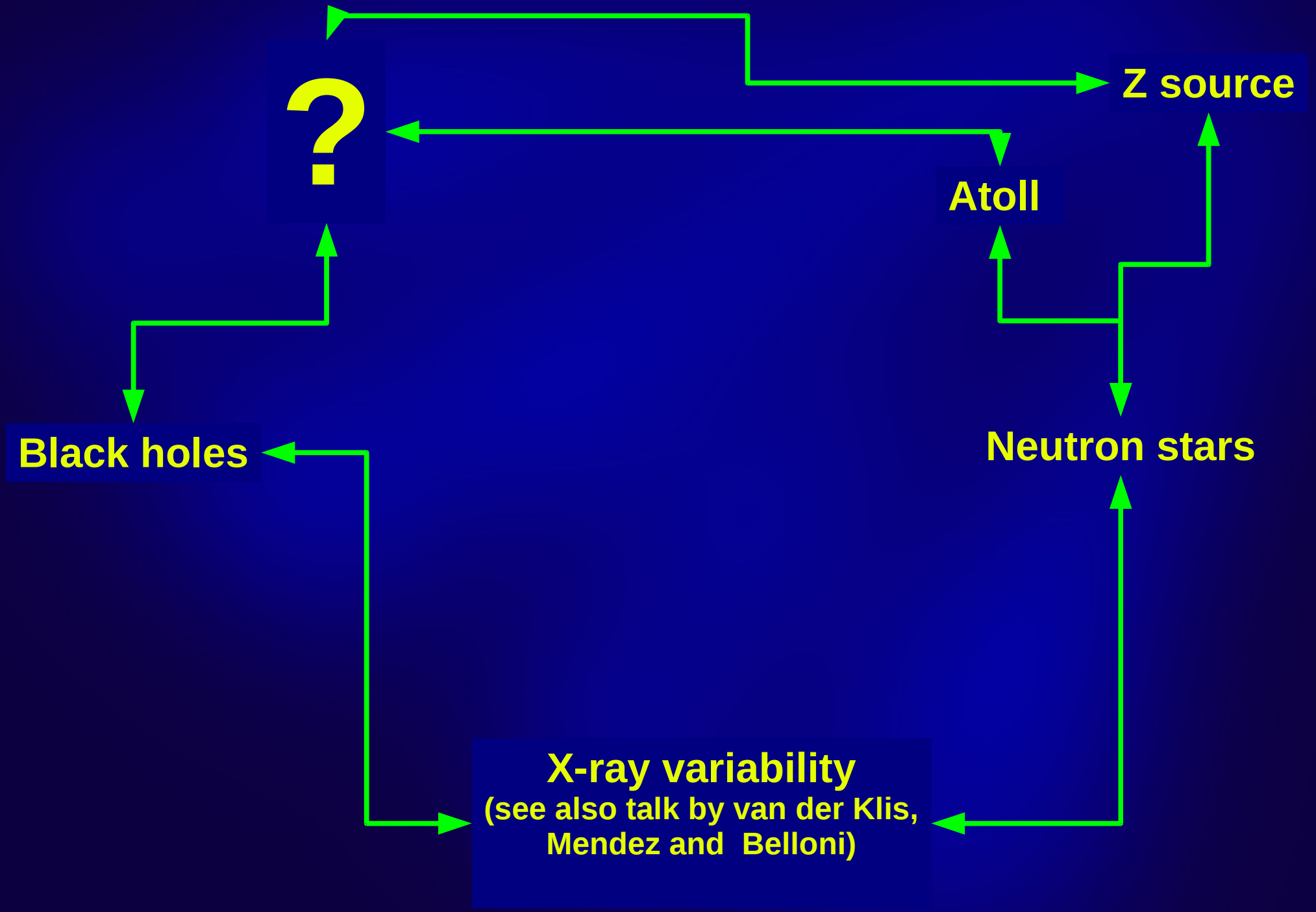
We can go a step further and compare with BHs...



Belloni et al. 2002

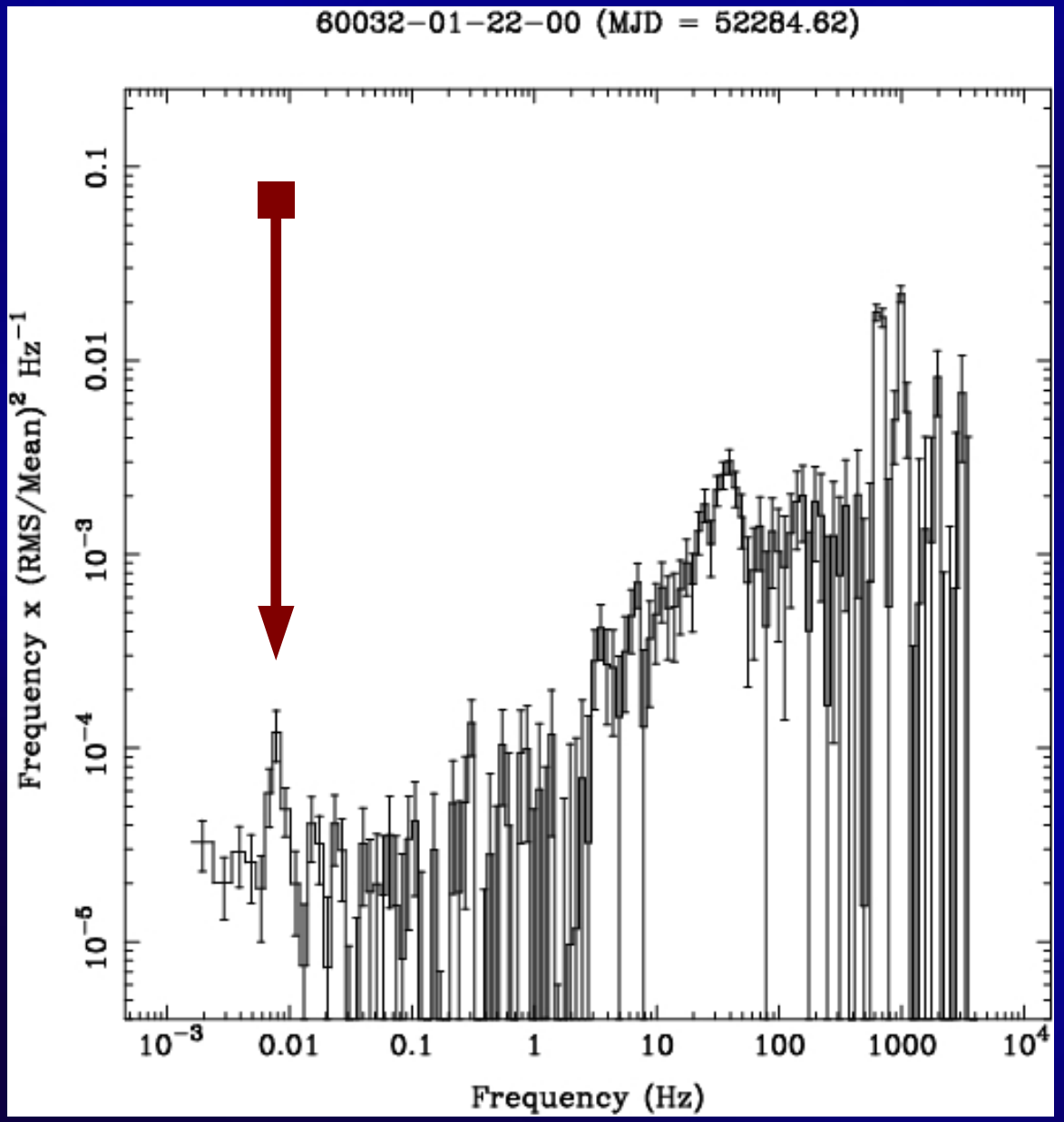
Which are the implications of these correlations?

- Physically similar phenomena cause these ν–ν correlations within one source, and between sources....
- The “same” phenomena produces frequencies which can be:
  - Orders of magnitude different in frequency
  - Can be the same between NS and BHs (even may be white dwarf systems!)
    - Spin, surface, magnetic field independent?

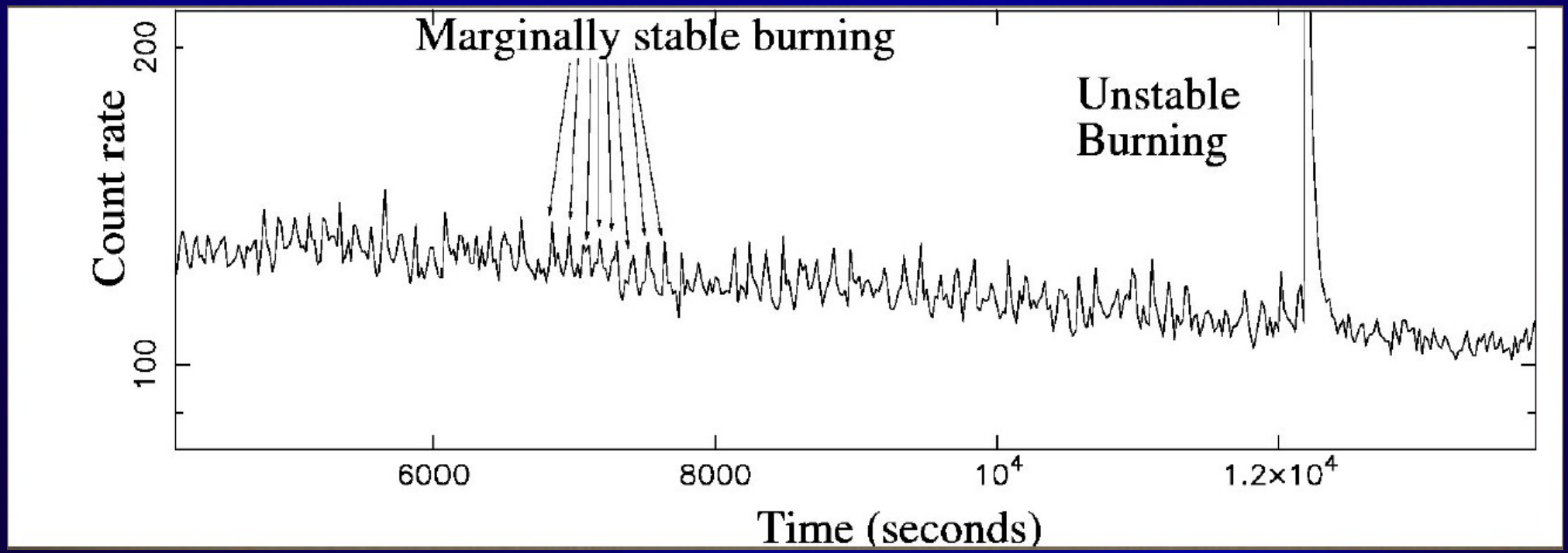

?
Z source
Atoll
Black holes
Neutron stars
X-ray variability
(see also talk by van der Klis, Mendez and Belloni)

Not everything we see in NS originates in the accretion disk ...

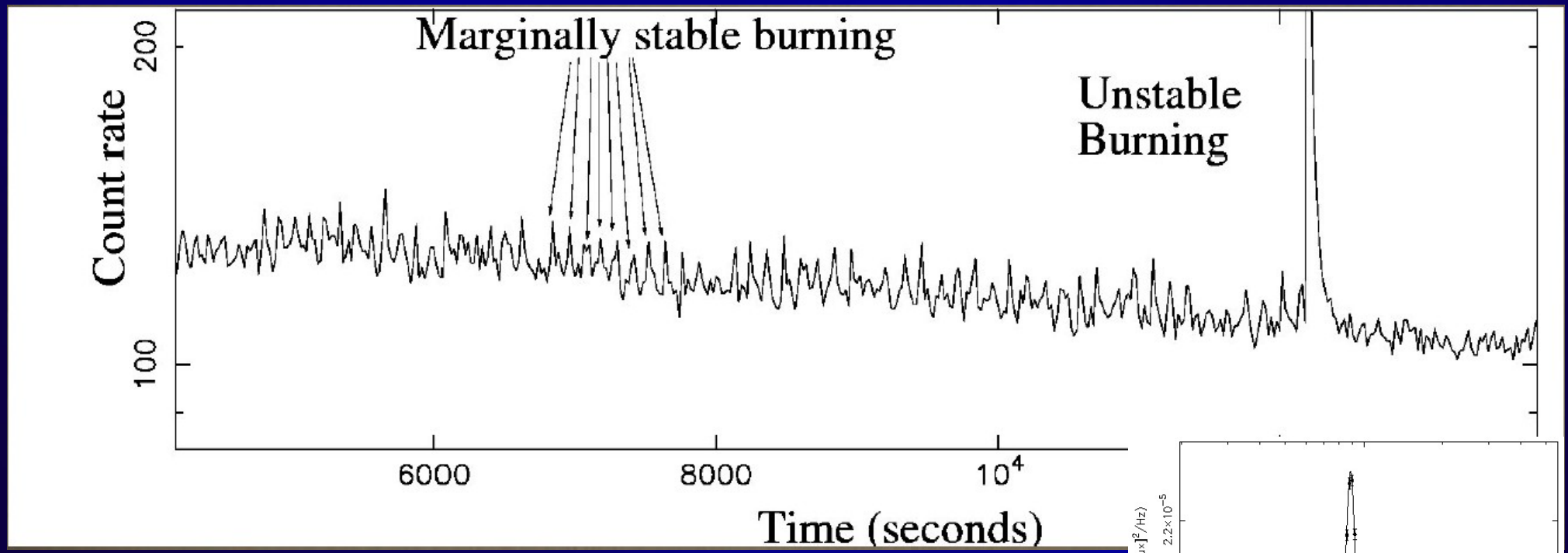
Marginally stable burning and accretion disk physics....



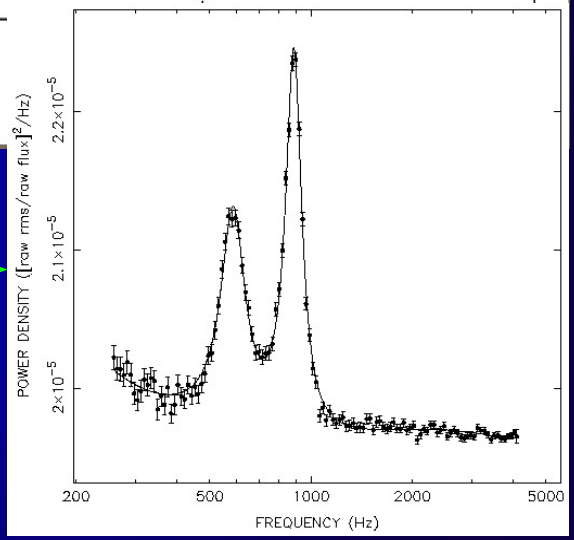
Marginally stable burning and accretion disk physics....



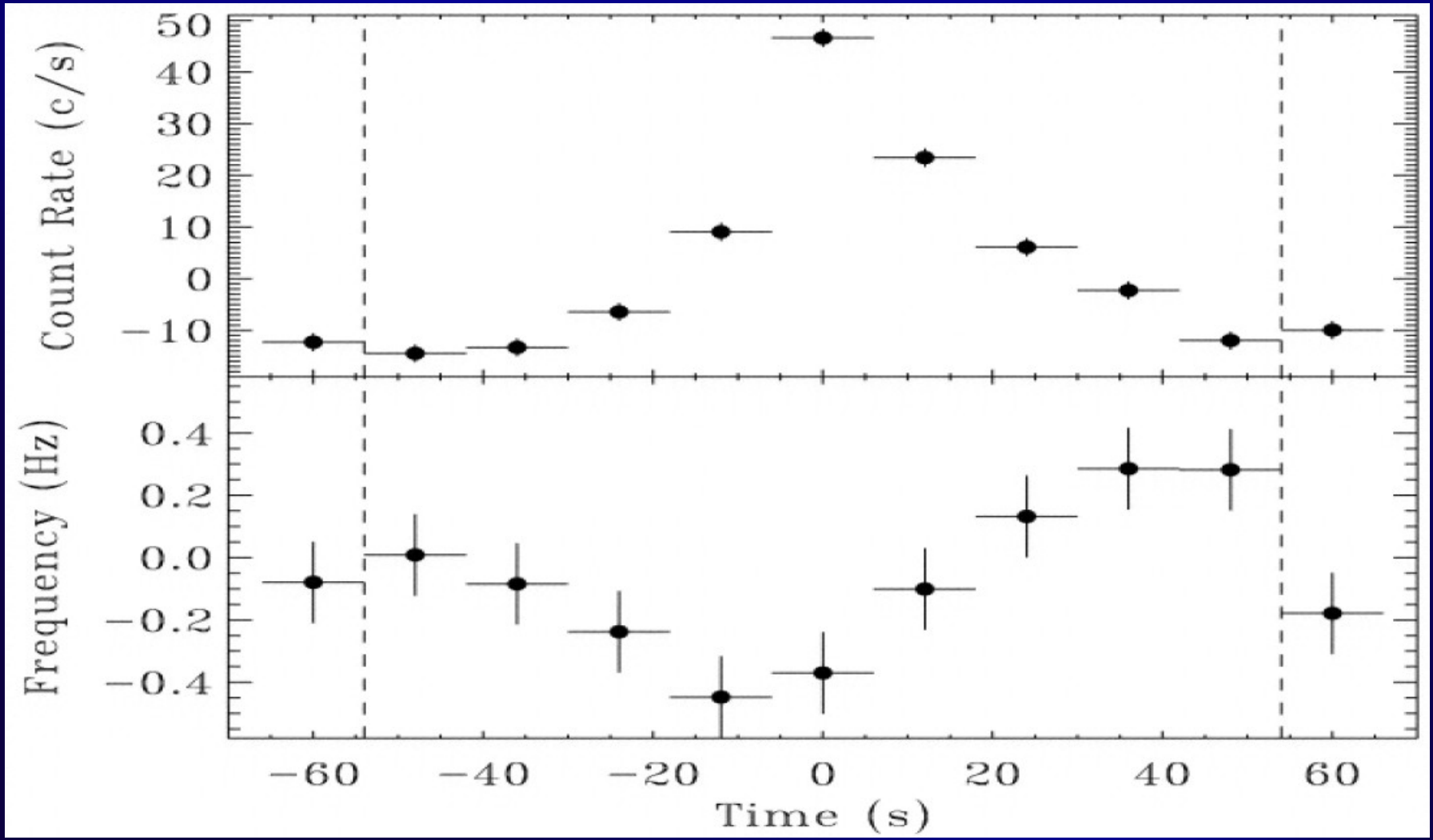
Studying the interaction with the accretion disk...



Keplerian (?)!



Marginally stable burning and accretion disk physics....



Yu and van der Klis 2002

Accretion disk

Radio Jets

Spectral states

Thermonuclear Burning
(talk by S. Bhattacharyya)

Optical variability
(talk by P. Gandhi)

Spectral lines

X-ray variability

Pulsar/non-pulsar Magnetic field
(talk by A. Patruno)

Accretion disk

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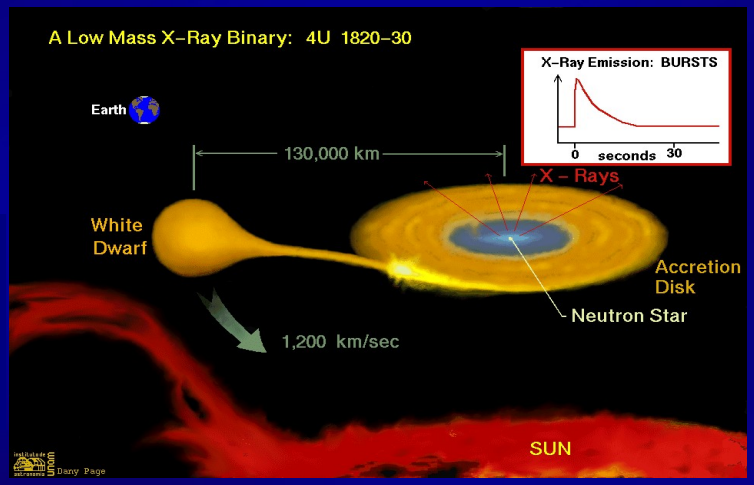

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(talk by S. Bhattacharyya)

Optical variability
(talk by P. Gandhi)

Spectral lines

X-ray variability

Pulsar/non-pulsar Magnetic field
(talk by A. Patruno)

So I showed you that...

(1) Power spectral features appear to evolve, (apparently) similarly in different type of systems: this points to a physical mechanism in common!

(2) The study of the interactions between different processes can tell us a lot about these systems...

(3) and this is only the tip of the iceberg ....

And I refer to this

"rich legacy of knowledge"

when we say

"We now know when/what to observe with ASTROSAT!"

Personal suggestion on strategy?

- Observations
  - e.g. during the state transitions: a key to understand these systems!
    - What happens with the PDS components? Are they evolving as suggested by the data?
    - What happens with the nuclear burning (see talk by S. B.)
    - What happens with the disk? Jets ejection?
    - Can we understand the interconnection between all what we see?.... Unified picture?

Personal suggestion on strategy?

- Observations
  - of new transients!
    - New pulsars? (see talk by A. P.)
    - Atoll – to – Z – to Atoll transitions!
    - What is the roll of B and accretion rate?
  - All under a multi-wavelength campaign!

FIN