High energy astrophysics summer school

Urbino 28 July- 1August 2008

Neutron Star Low Mass X-ray Binaries (NSLMXBs) seen by INTEGRAL: high energy behaviour

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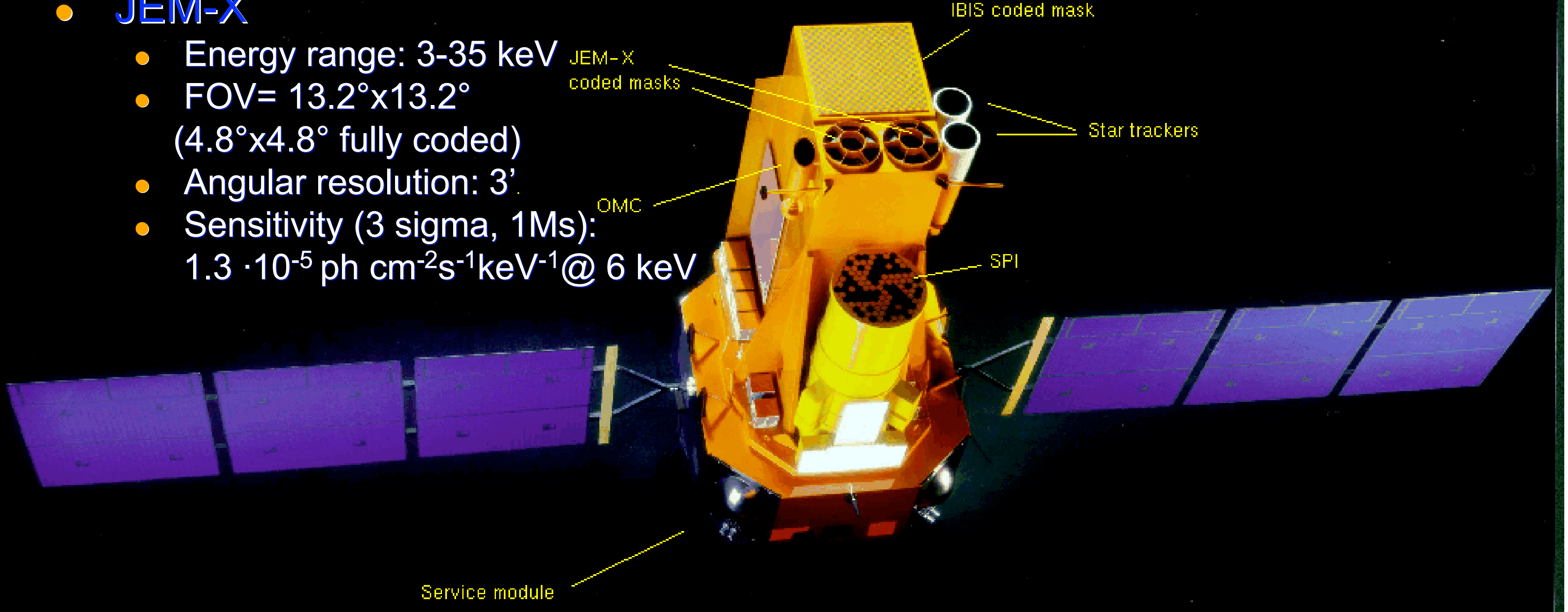
Outline

- The INTEGRAL Laboratory
  - The Galactic Survey
- Low Mass X-ray Binaries, Bursters and Atoll sources
  - Emission processes
  - INTEGRAL contribution on understanding NSLMXBs (>20 keV)
- LMXBs spectral variability study with INTEGRAL: some example
- Our Project: the source selected and aims.

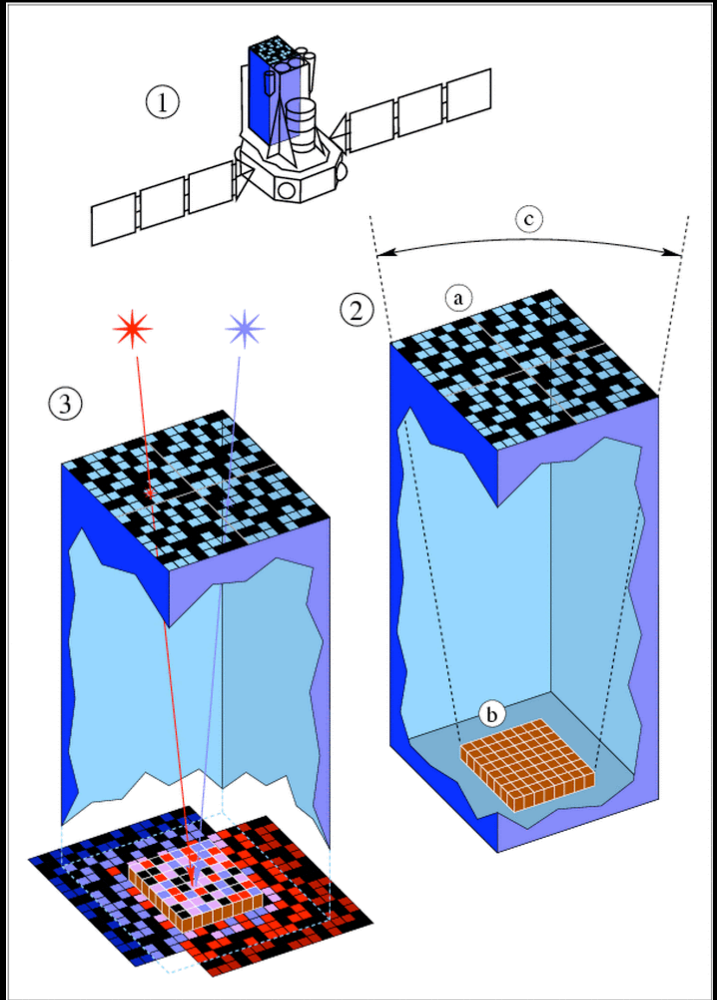
INTEGRAL

- INTEGRAL (INTErnational Gamma-Ray Laboratory): launched on October 17th 2002, elliptic orbit lasting about 3 days.
- IBIS (Imager on Board the INTEGRAL satellite)
  - Energy range: 15 keV - 10 MeV
  - FOV: 29°x29° (9°x9° fully coded)
  - Angular resolution: 12’
  - Sensitivity (3 sigma,1Ms): $2.3 \cdot 10^{-6}$ ph $cm^{-2}s^{-1}keV^{-1}$ @ 100 keV
- JEM-X
  - Energy range: 3-35 keV
  - FOV= 13.2°x13.2° (4.8°x4.8° fully coded)
  - Angular resolution: 3’
  - Sensitivity (3 sigma, 1Ms): $1.3 \cdot 10^{-5}$ ph $cm^{-2}s^{-1}keV^{-1}$ @ 6 keV



INTEGRAL

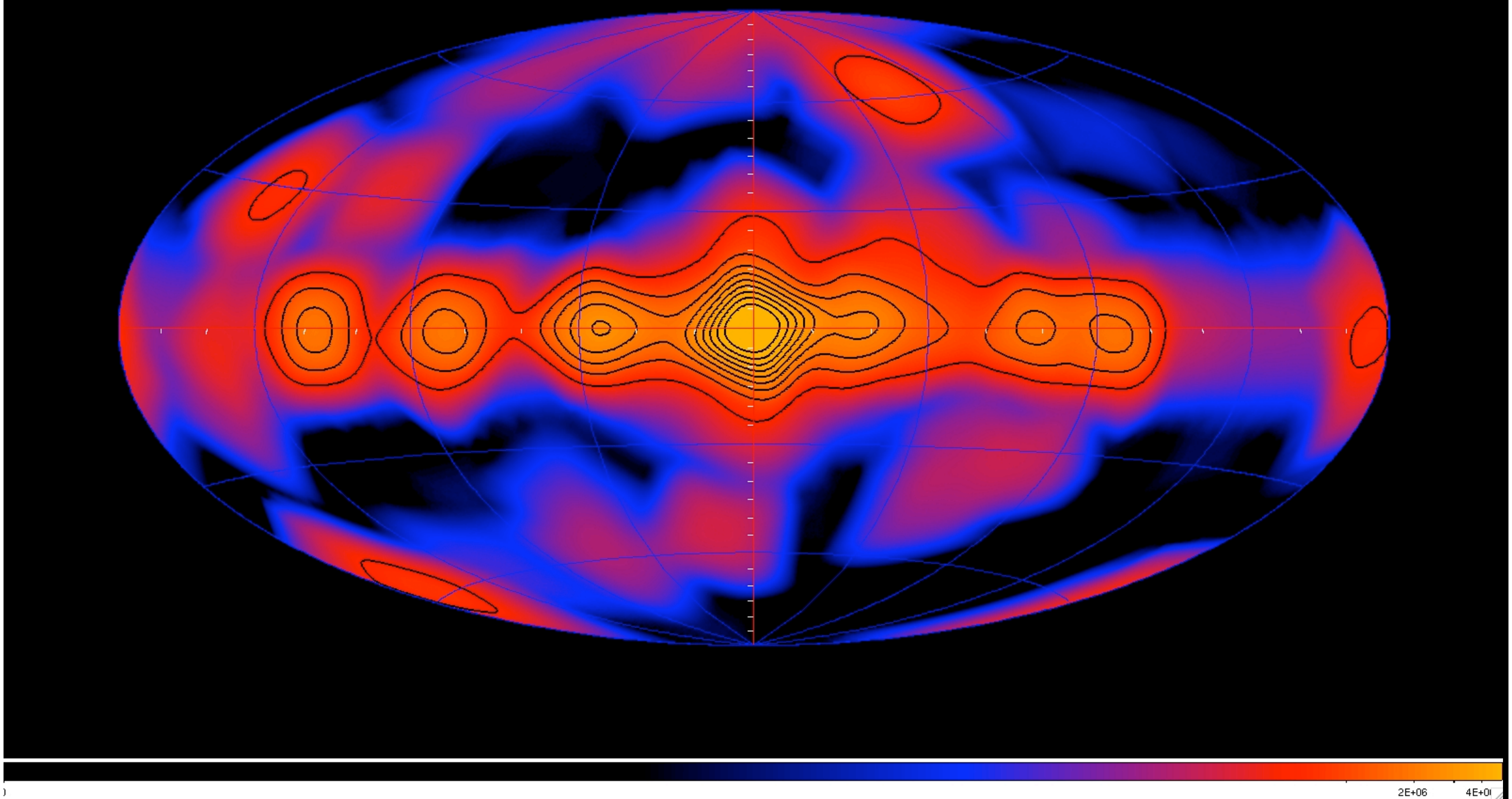
- Coded mask instruments: the signal must be decodified.
- All the sources of the Field Of View (FOV) must be identified.



INTEGRAL

- From October 2002 to today:
  - Revolution #705
  - About 60000 pointings (ScWs) lasting 2000-3600 seconds each.
- At IASF-Rome more than 4 tera byte of data
- Third IBIS Galactic Survey (first 3.5 years) (Bird et al. 2007): about 460 sources!
  - 21% transient, 79% persistent: for the persistent sources we can use the mosaic of all observations! For the transient sources we must do a more detailed pointing study.

Sky coverage



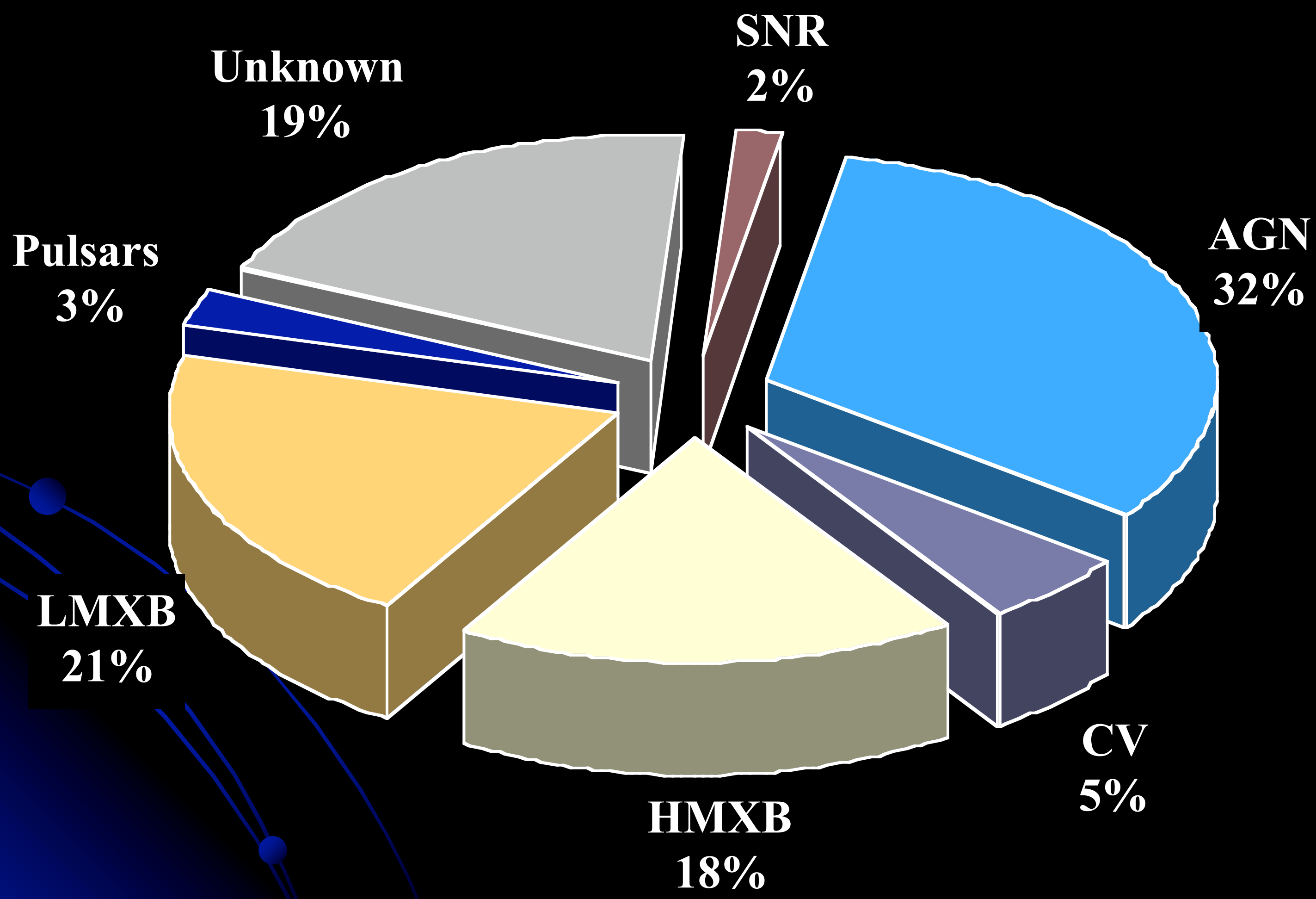
All-sky galactic projection - contours at 500ks intervals

Cat 1

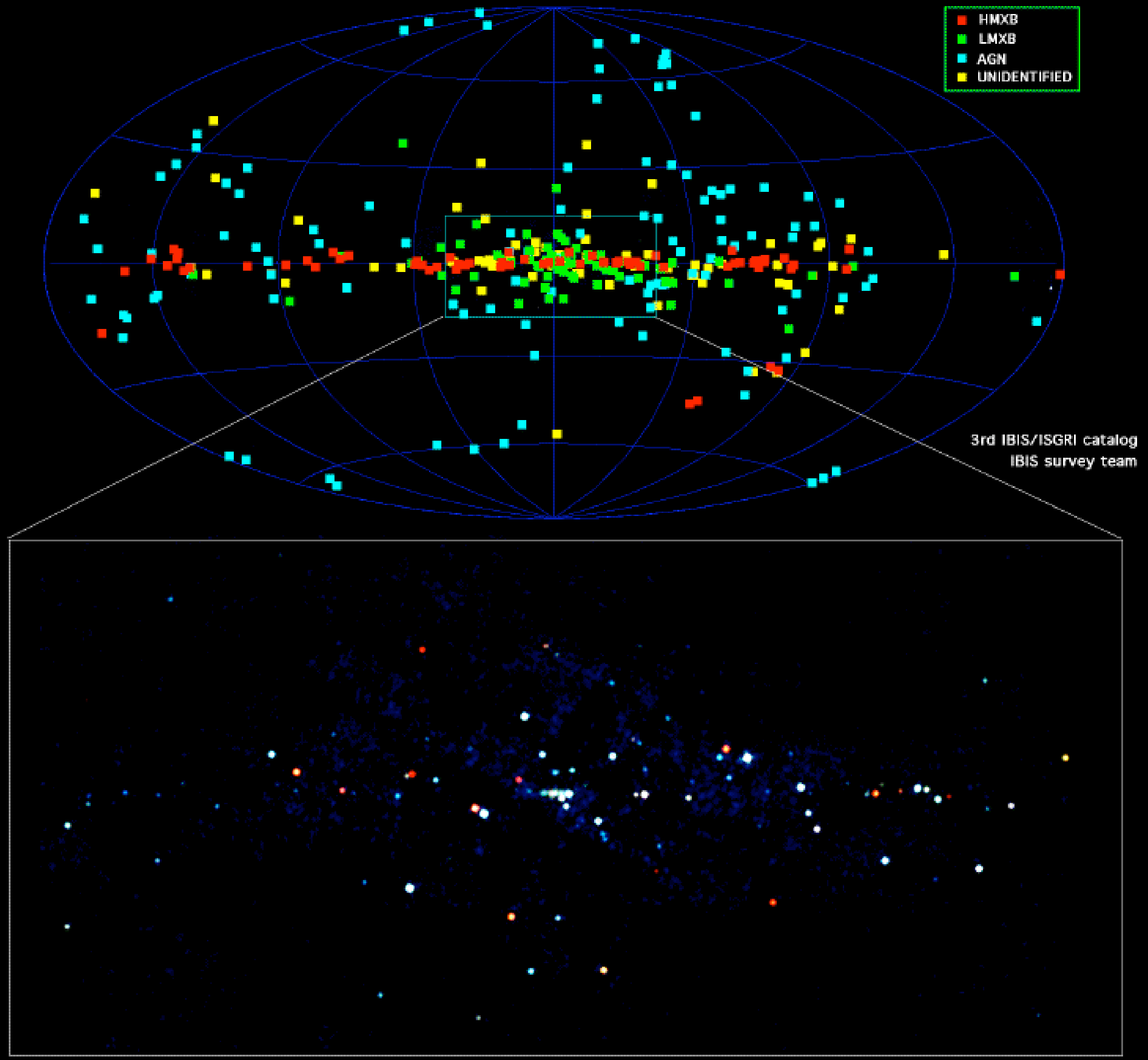
Cat 2

Cat 3

Sources population

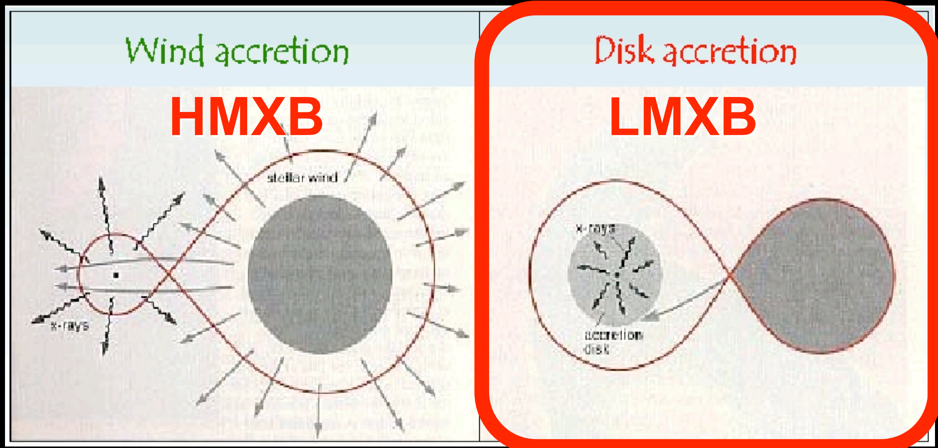


Sources distribution



The Low Mass X-ray Binaries

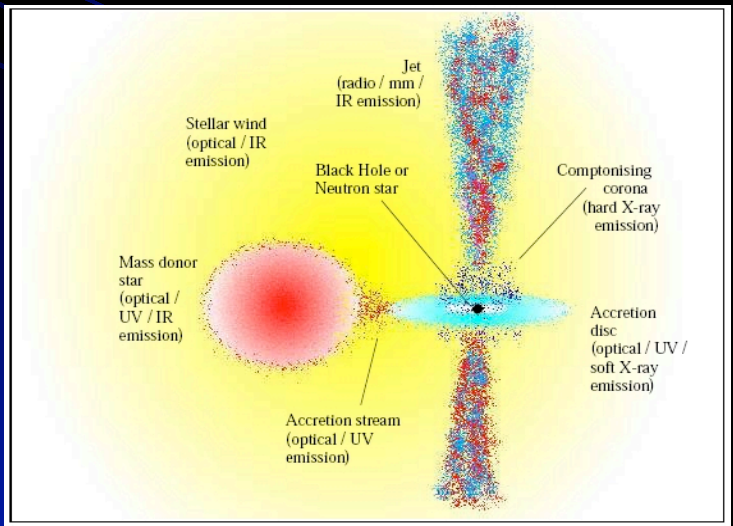
X-ray Binaries: systems composed by a normal star and a compact star (BH, NS and WD). X-ray emission at $L_X \sim 10^{37}$ erg s^{-1} due to mass tranfer phenomena.



- **Accretion by Roche Lobe overflow**
- **Companion star:**
  - **Late type (> A), pop II**
  - **mass M<2M_**
- **L_X/L_{ott}~100-1000**
- **Orbital Period ~ 10 m-10 d**
- **Rare eclipses and X pulsation**

→ old systems→ located in the Galactic Bulge

Emission processes:



- Accretion disk → black body (thermal)
- Corona → Comptonization
- Reflection → reflected emission by the accretion disk
- Jet ? → non-thermal emission (synchrotron emission)

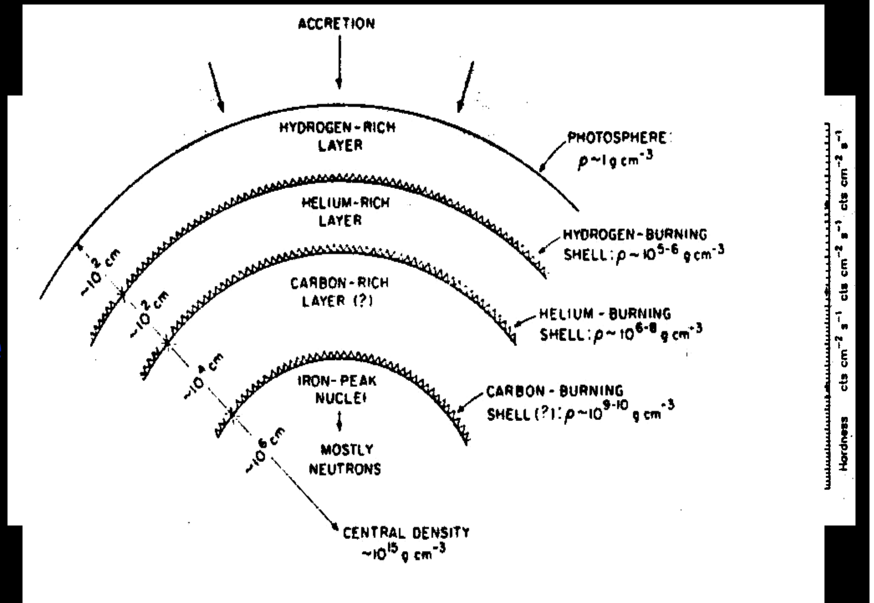
Burster and Atoll sources

Type-1 X-ray bursts sources:

-Recurrent X-ray peak emission
(range E=0.1-40 keV) with E ~10^{39} erg
- Fast rise (~ 1 s) and exponential decay
- Cooling black body spectra during the decay

<u>Thermonuclear flash</u> on the NS surface

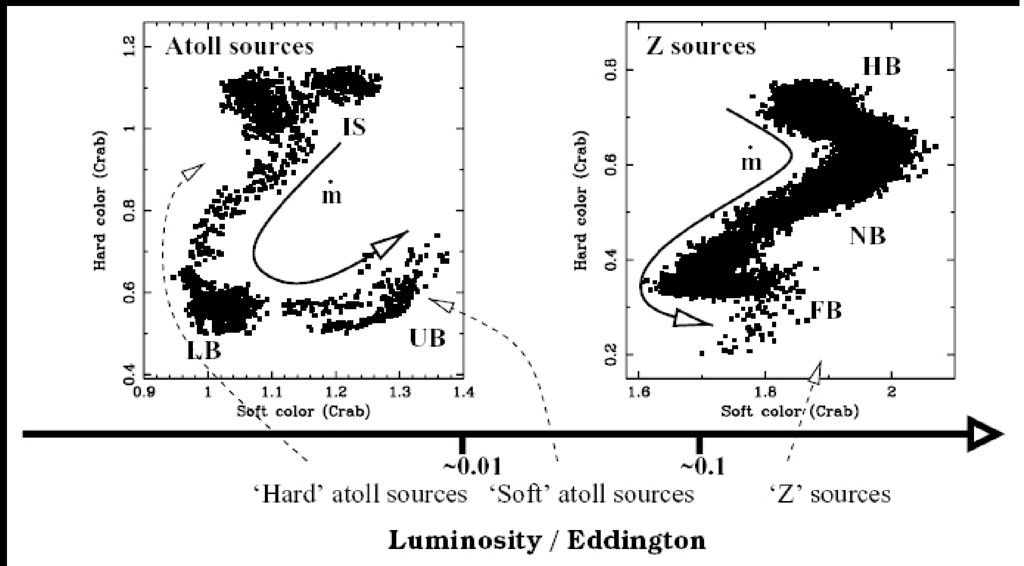
→The compact objects are NEUTRON STARs



Atoll sources:

- "Atoll" track in the Color-Color Diagram (CCD)
- Different spectral and timing properties in the different branches of the CCD

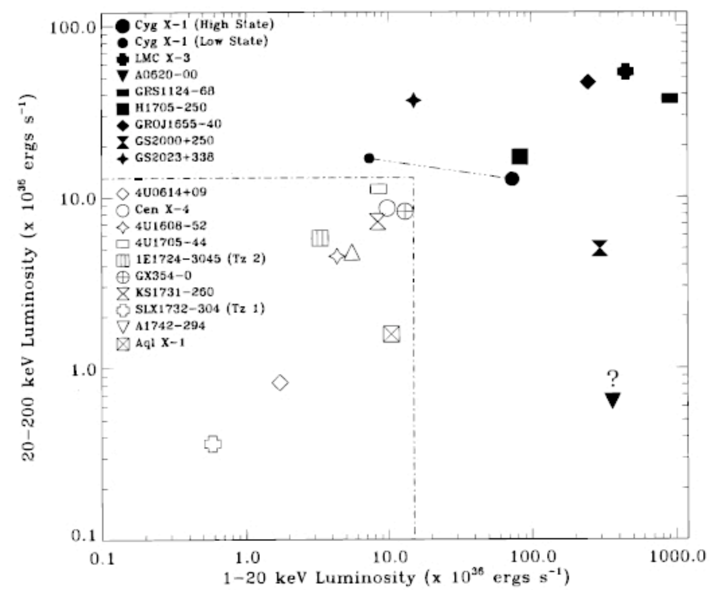
→Sources with spectral state variations



Why the high energy

- Open questions in the physics of NS LMXBs, Atoll:
  - Thermal high energy emission:
    - Are the bursters lower luminous than Black Hole Binaries? (Bursters Box?)
    - Have the Bursters different spectral state parameters respect to the Black Hole Binaries?
  - Non-thermal emission: what is the origin of the hard power law tails?
  - Does Radio-X ray connection exist also for Atoll as for BH and Z sources?
- Accretion processes physics
- Differences and similarities with BHCs and AGNs.

Barret et al. 1996, 2000



; and NSBs. Filled
he dot-dashed line

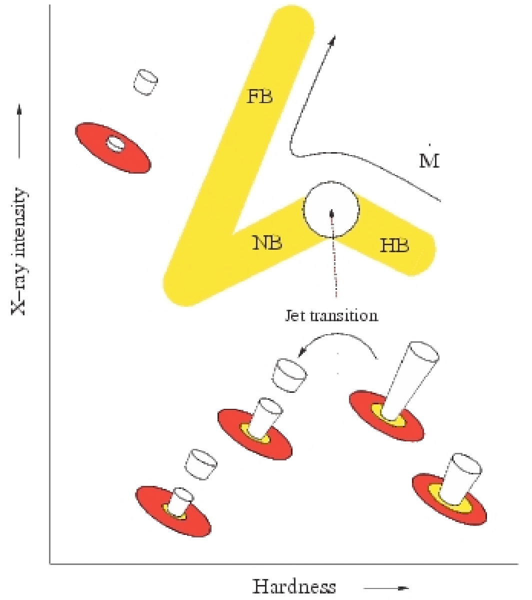
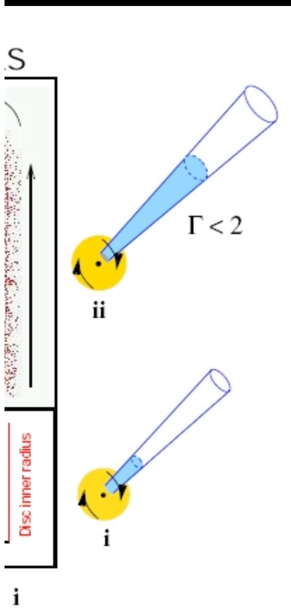


Figure 6. Sketch of the disc–jet coupling in Z-type sources, which we believe to be the NS equivalents of the BH GRS 1915+105, constantly accreting at approximately Eddington rates and producing powerful jets associated with rapid state transitions. See Section 4.5 for a discussion.

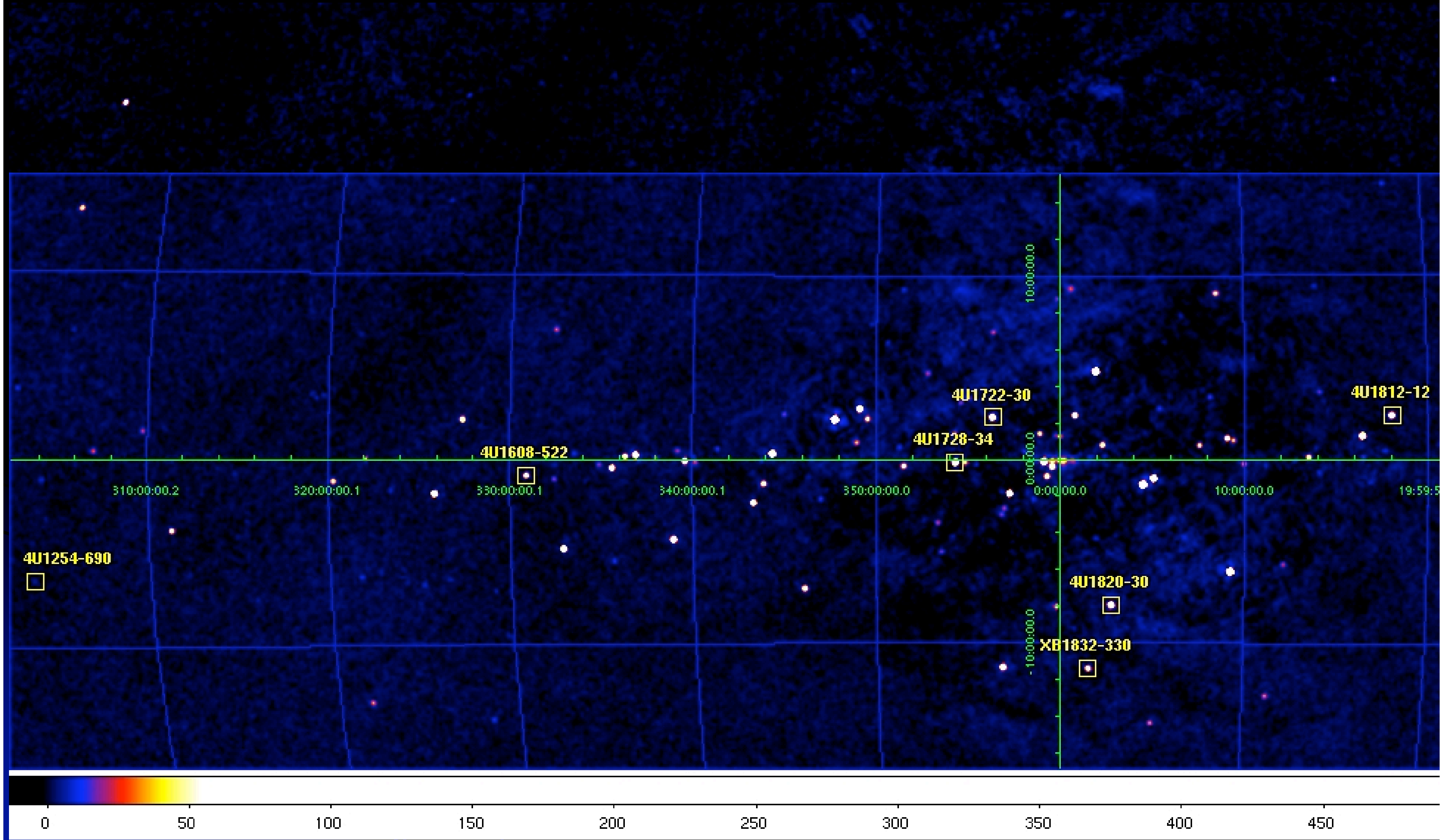


Migliari et al 2006

Fender, Belloni, Gallo 2004

NSLMXBs observed by INTEGRAL: some example

IBIS/INTEGRAL "mosaic" image (20-100 keV)



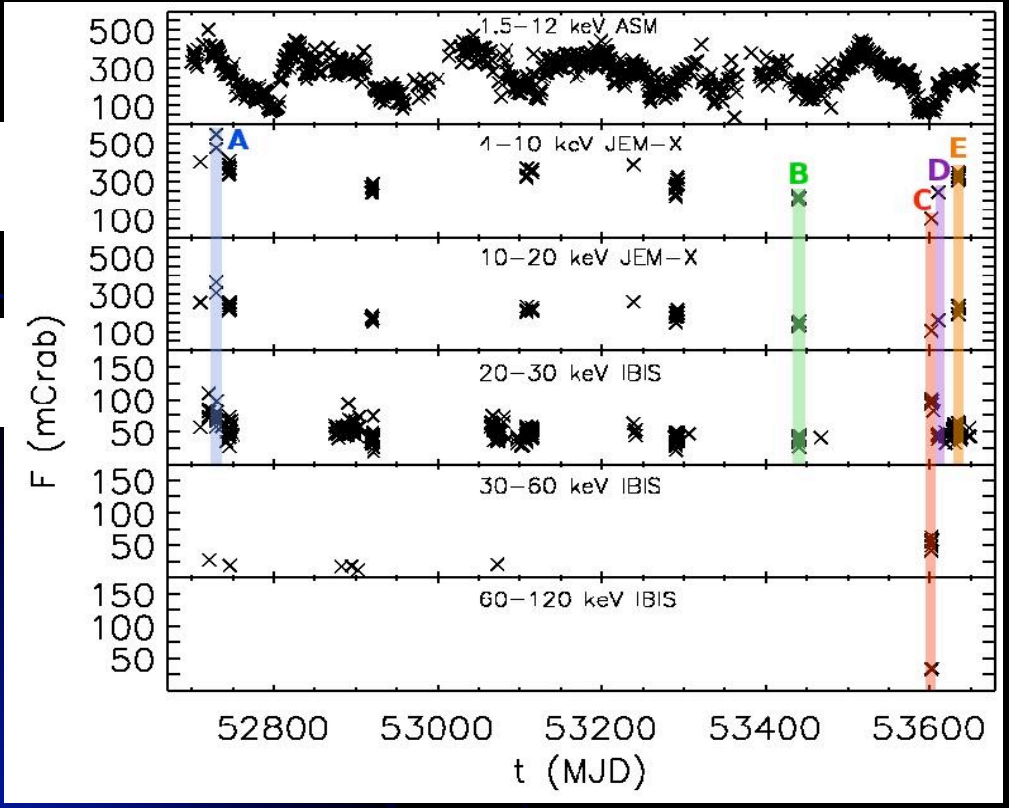
4U 1820-30

- Ultracompact sistem, P=685 s
- In the Globular Cluster NGC 6624.

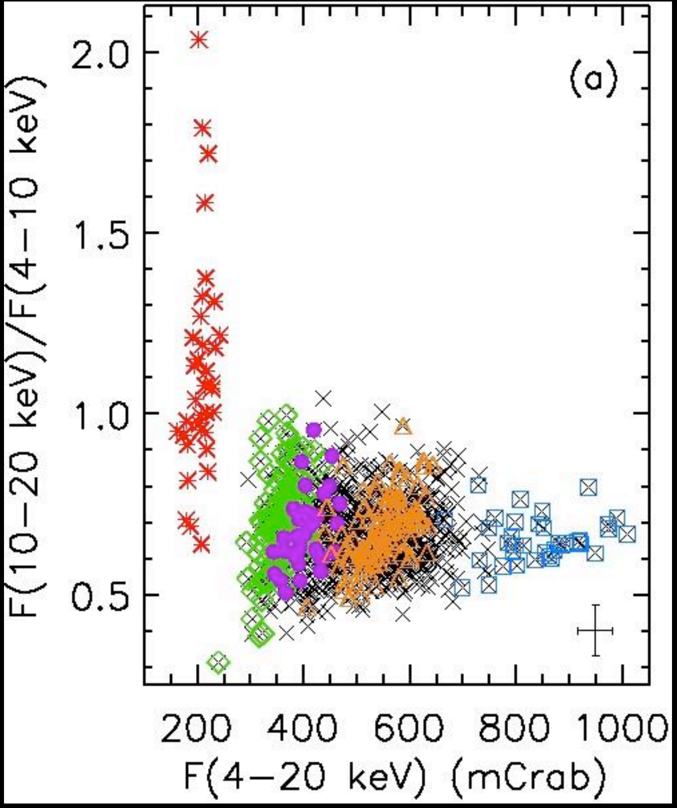
- **Ligth curves** ASM, JEM-X and IBIS: March 2003 - October 2005
- Period A: max Flux in the 4-10 keV band, ~ 530 mCrab; period C min Flux in the 4-10 keV band, ~ 100 mCrab

4-10 keV

20-30 keV



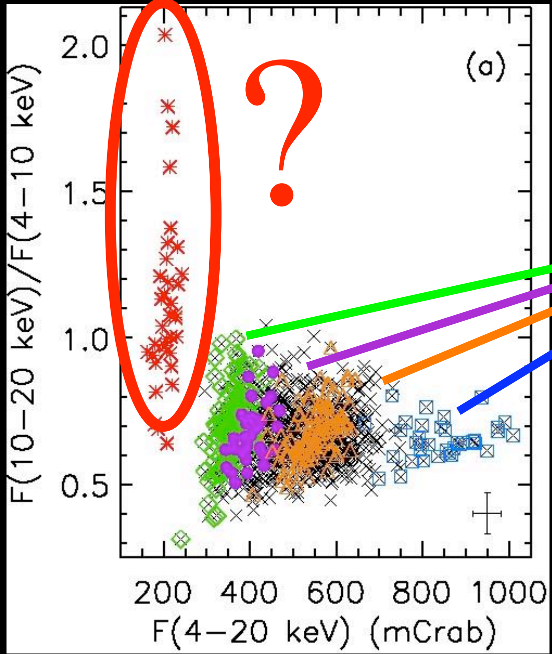
- **Hard color- Intensity diagram:**
  JEM-X (4-10 and 10-20 keV)

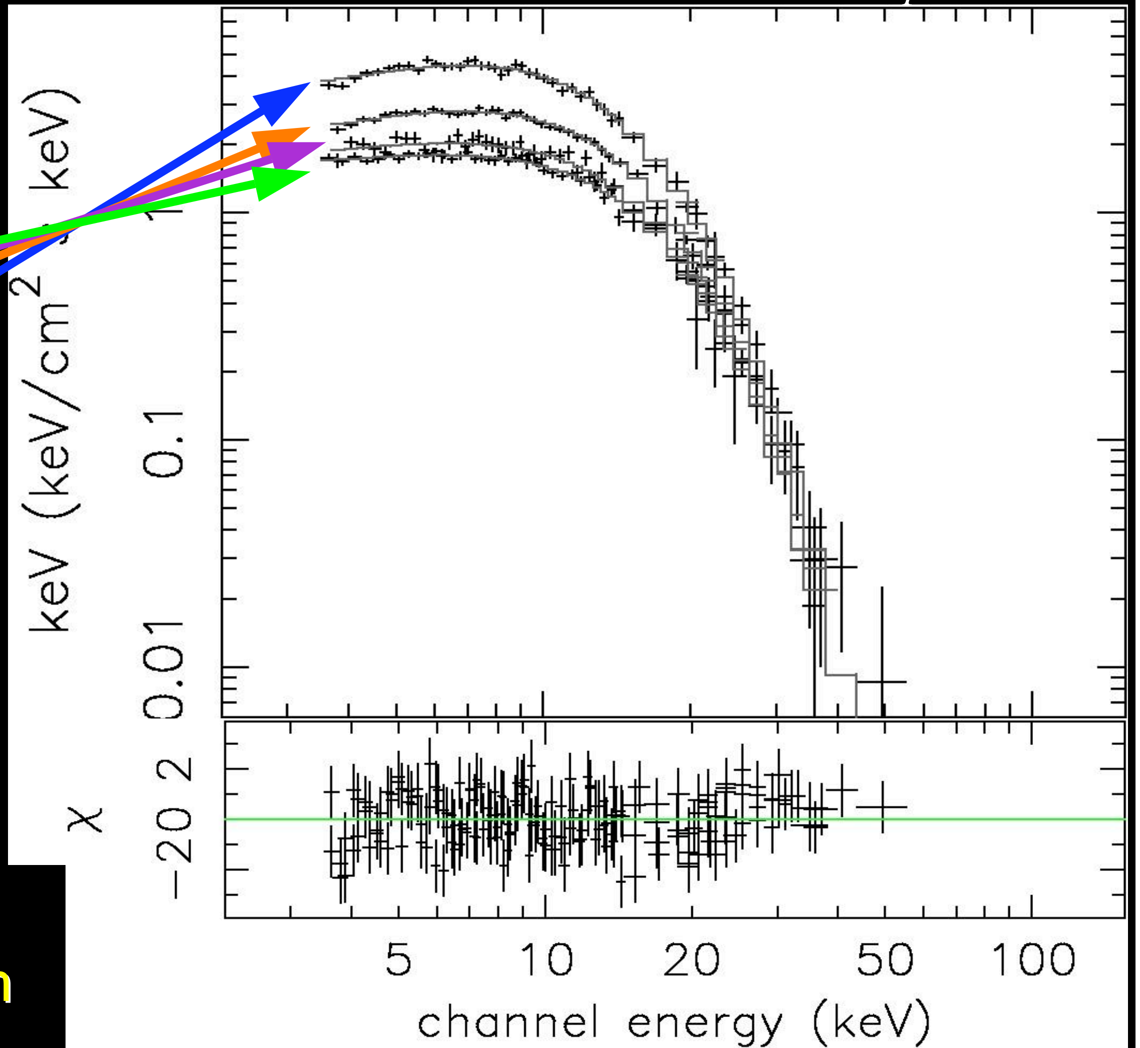


Tarana et al. ApJ 2007

Soft states

Tarana et al. ApJ 2007





All the Soft spectra are modelled with **Comptonization model**: CompTT (Titarchuk 1994) with kT_e ~2-3 keV, optical depth ~6-7 and kT_0~0.2-0.4 keV.

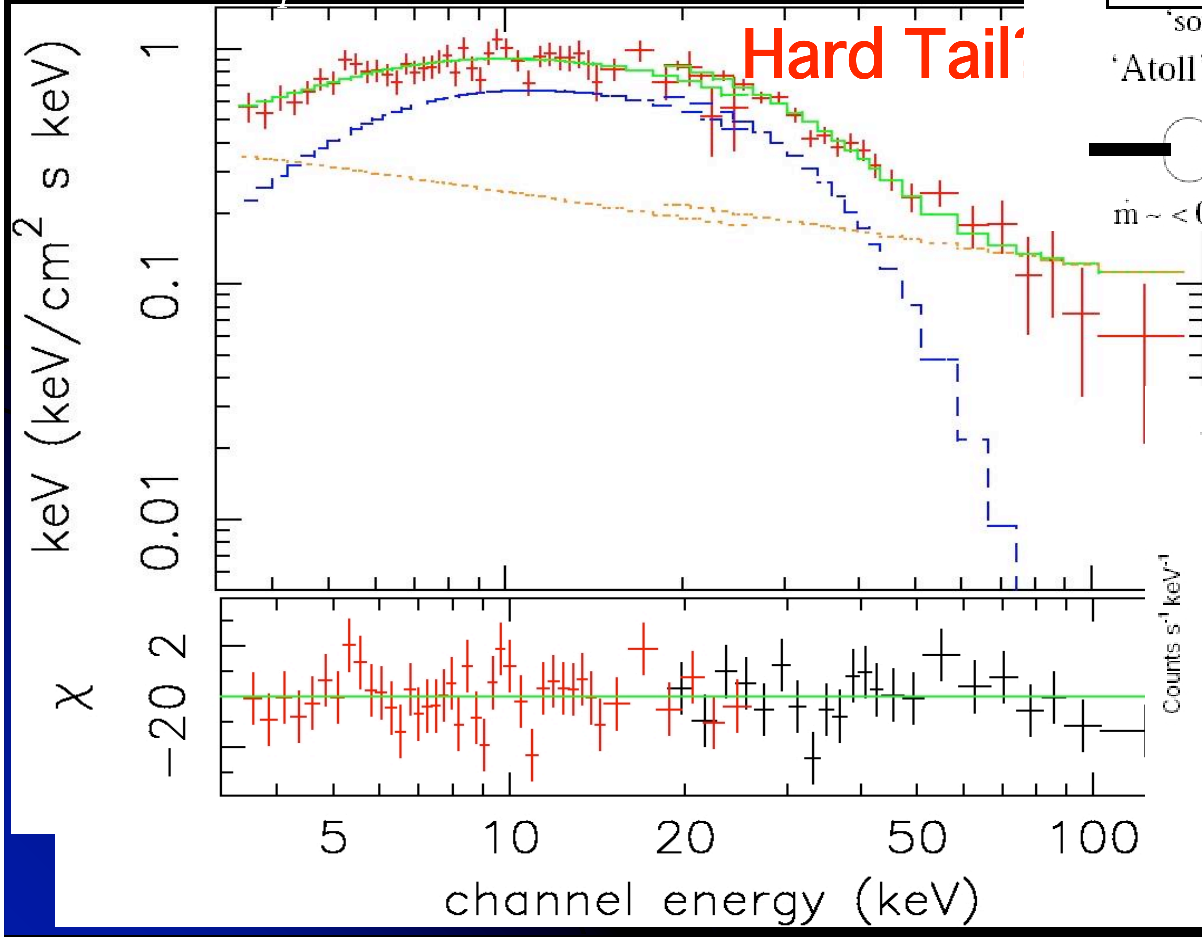
Maximum bolometric Luminosity 7.7 _10^{37}erg s^{-1} (assuming d=5.8 kpc)

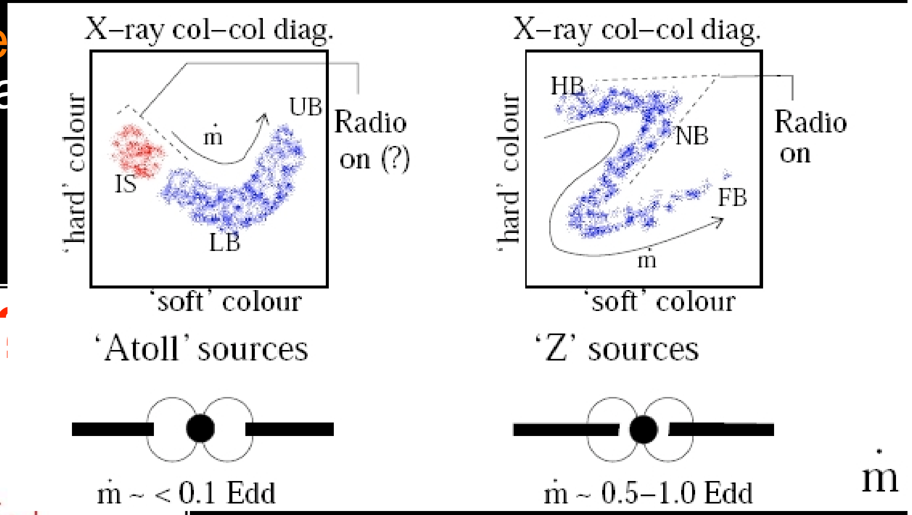
Hard State

Spectral model **CompTT+ power law**:

- Electron temperature, kT_e = 6 ke
  photons, kT_0 1.5 keV and corona
- Power law with photon index, _

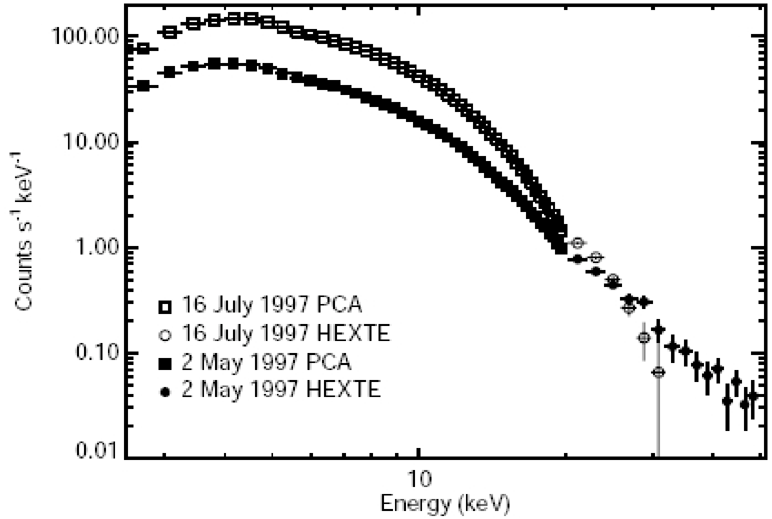
Tarana et al. ApJ 2007





Fender 2000

Bloser et al 2000

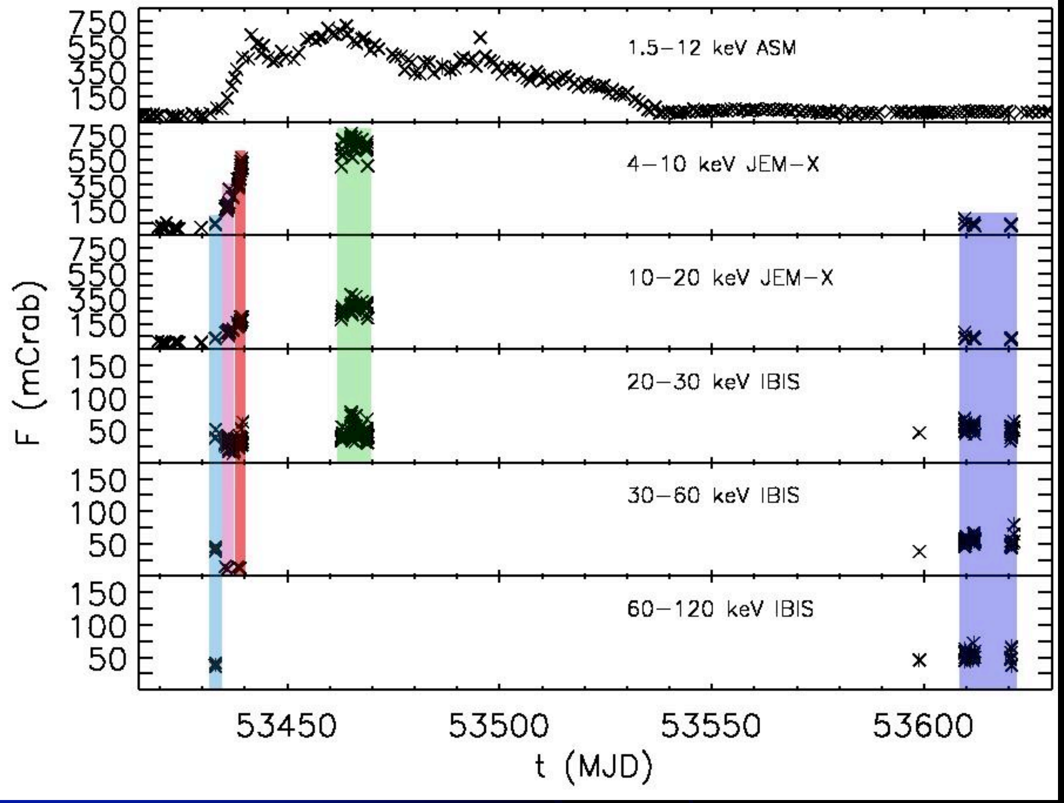


4U 1608-522

Transient source

- Observation period February 2004 – September 2006
- Outburst: February – June 2005

Tarana et al. ApJ accepted



- IBIS and JEM-X:

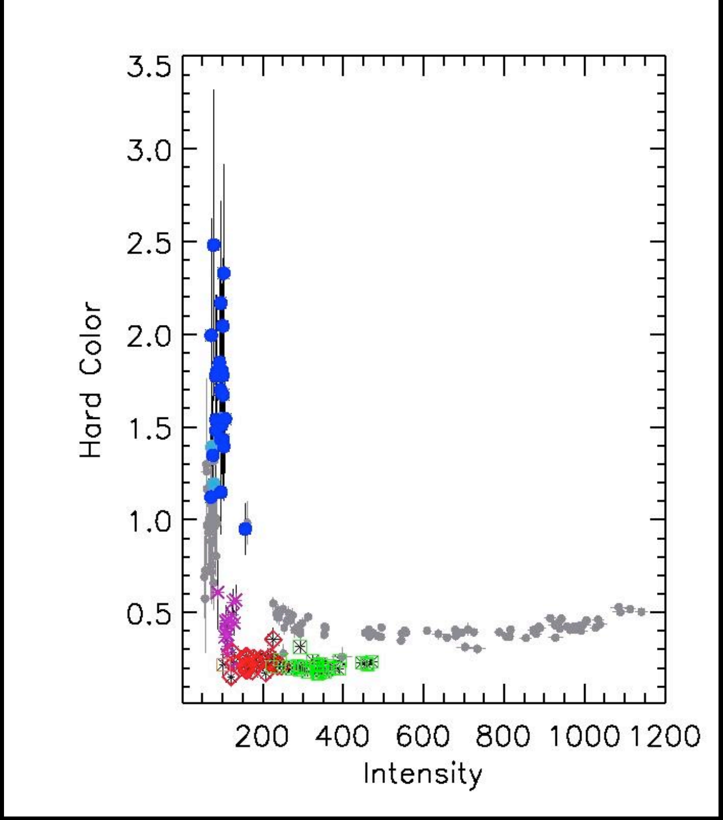
I= (10-20 keV)+(20-30 keV)

Hard Color= (20-30 keV/10-20 keV)

- JEM-X:

I= (4-10 keV)+(10-20 keV)

Hard Color=(10-20 keV/ 4-10 keV)

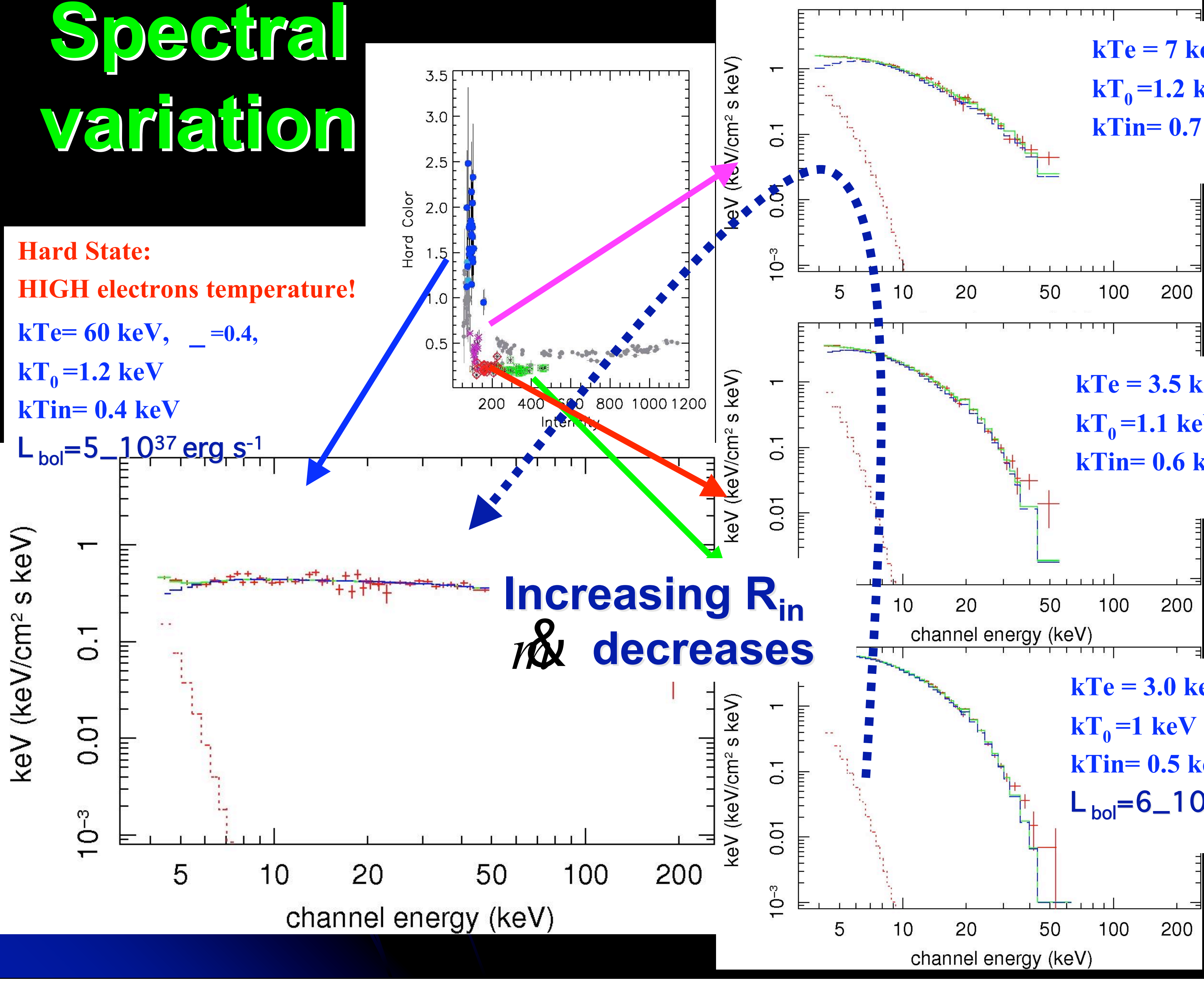


Spectral variation

Tarana et al. ApJ accepted

Hard State:
HIGH electrons temperature!

kTe= 60 keV, _ =0.4,
kT_0=1.2 keV
kTin= 0.4 keV
L_{bol}=5_10^{37} erg s^{-1}

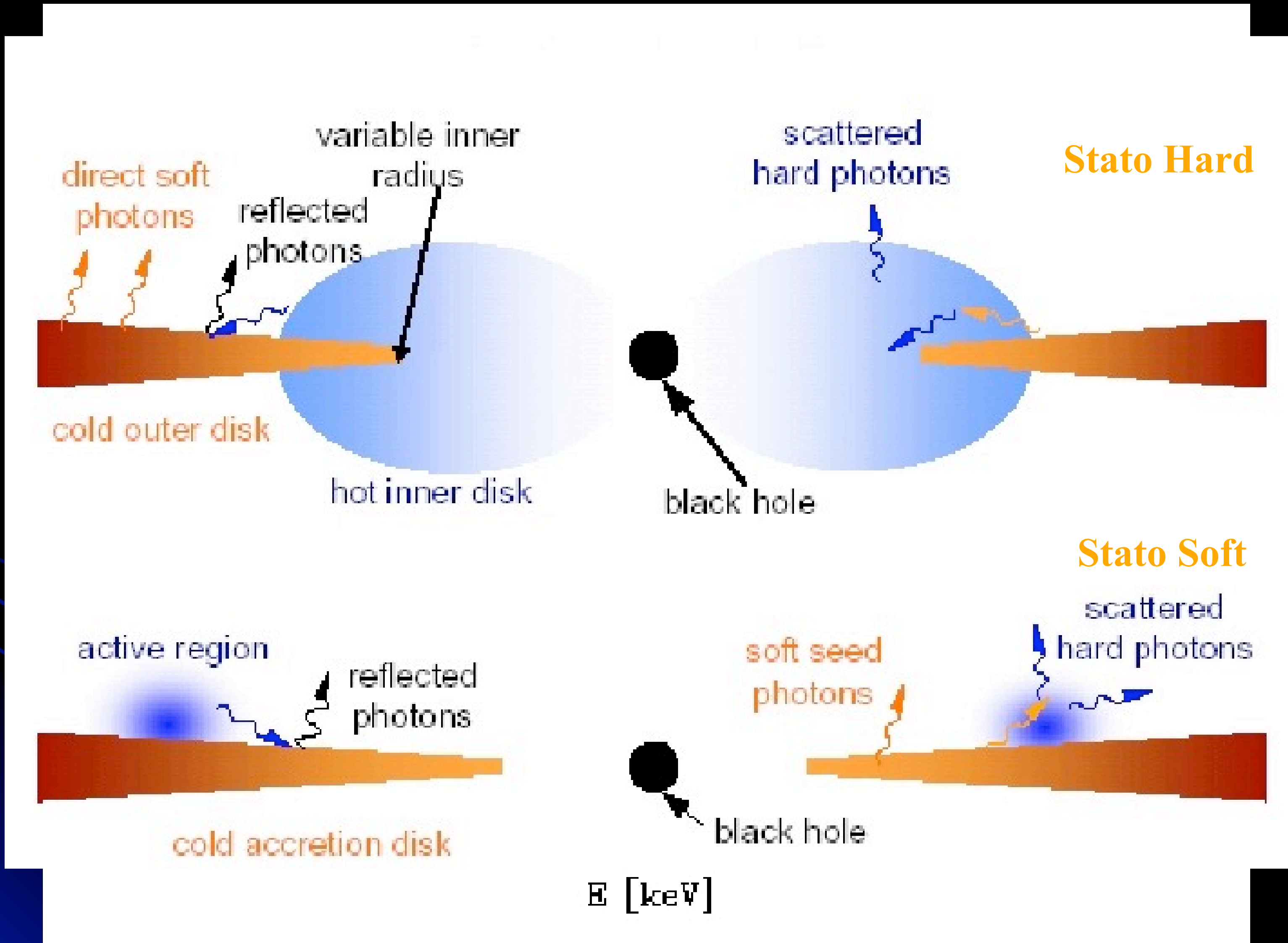


kTe = 7 keV, _ = 1.7
kT_0=1.2 keV
kTin= 0.7 keV

kTe = 3.5 keV,_ = 3.4
kT_0=1.1 keV
kTin= 0.6 keV

kTe = 3.0 keV, _ = 4.1
kT_0=1 keV
kTin= 0.5 keV
L_{bol}=6_10^{37} erg s^{-1}

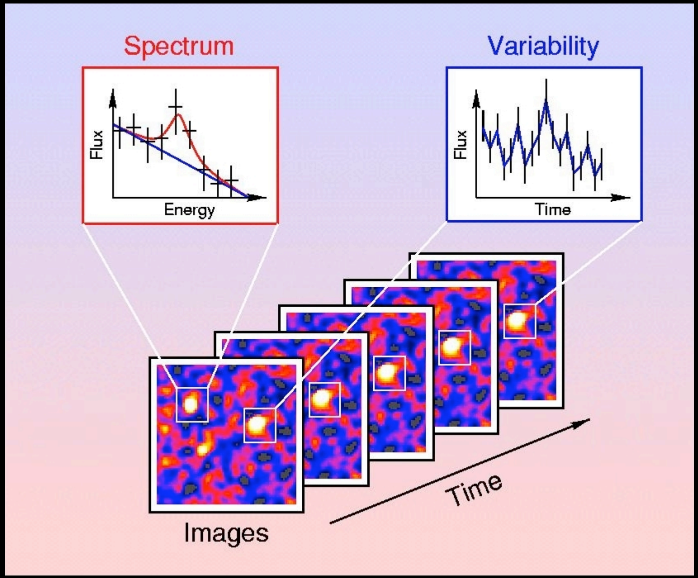
Increasing R_{in} & n decreases



Zdziarski 2000

Our project

- INTEGRAL data analisys of the transient source 4U 1722-30:
  - Temporal analysis: ligth curves
  - Photometric analysis: Color-Intensity diagrams
  - Spectral analysis: detailed wide band spectra

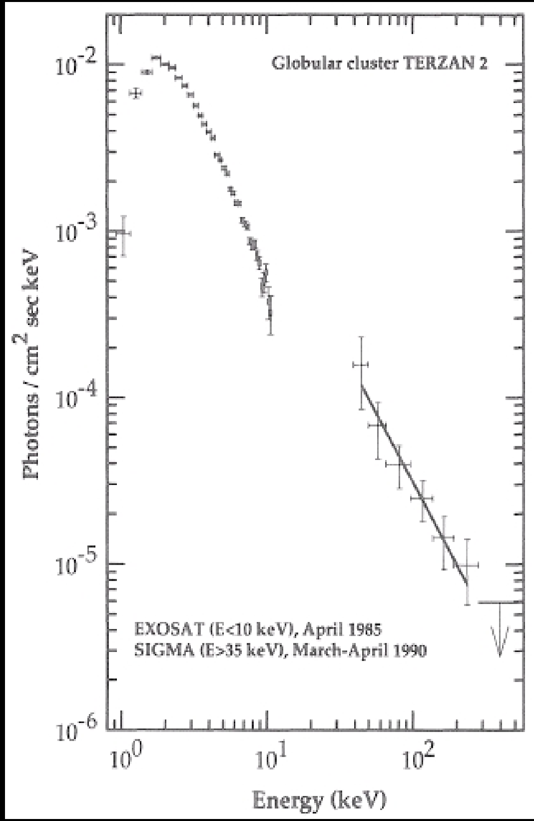


- Here only few month of observation (180 ScWs, August-October 2005) because of limited resources to be allowed (time and disk space)

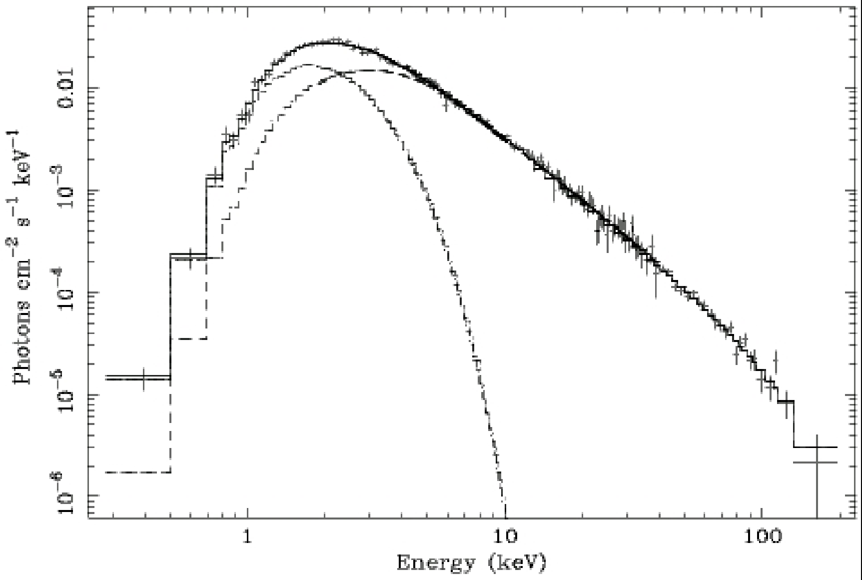
4U 1722-30

(alias GRS 1724-30, 1E 1724-3045)

- Located in the Globular Cluster Terzan 2
- Transient source
- Type 1 X-ray bursts source (Grindlay et al. 1980)
- ASCA, EXOSAT, ROSAT 1-20 keV observation: power law with photon index 2-2.4.
- High energy observations:
  - SIGMA/GRANAT (>40 keV): first detection of hard emission
  - BeppoSAX (0.1-100 keV): kT_0~ 1keV, kT_e~30 keV and τ~ 3; plus blackbody with kT_{bb}~ 0.6 keV



Barret et al 1991



Guainazzi et al 1998

Aim of the project

- Spectral parameter changes: what is the temperature of the Comptonised corona?

- How does the Soft component change during the spectral evolution?

- Does the R_{in} of the accretion disk change?

- Is there any non-thermal emission component in the Hard and Soft state?

Conclusions

- We aim to study the high energy behaviour of the NSLMXB 4U 1722-30
- INTEGRAL is the right laboratory to perform the study of the spectra at >20 keV:
  - IBIS is very efficient at ~ 60 keV where we expect differences in kT_e of BHCs vs NSs
  - Better angular and spectral resolution compared to Swift and other working satellites
  - Constant monitoring of the sky.