Network meeting 2010 - Istanbul

Spectral Investigations of the Black Hole X-ray Binary XTE J1752-223

P2: Spectral Variability and Timing of X-ray Binaries

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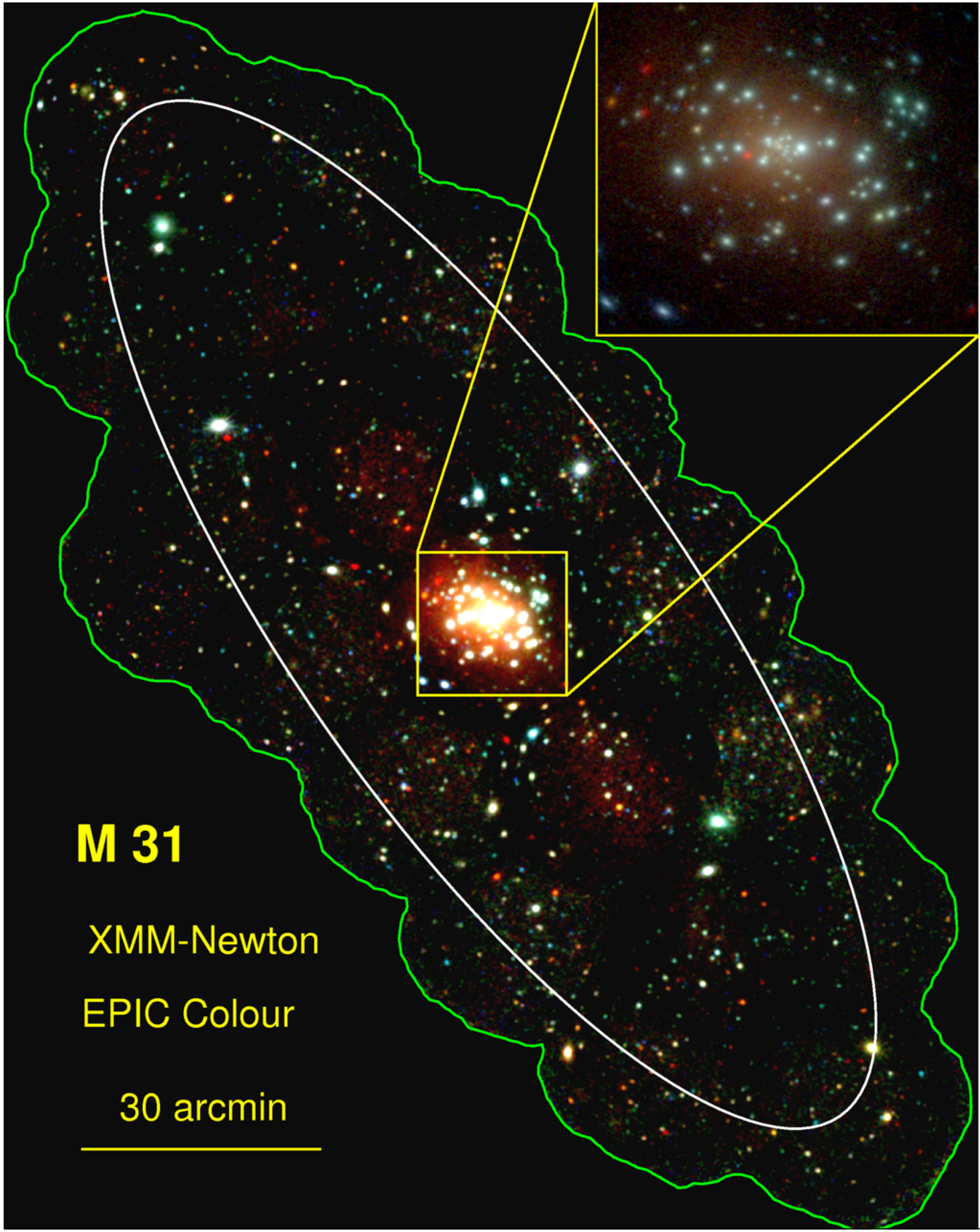
Holger Stiele

- I am from Munich
- studying Physics and Astrophysics at Ludwigs-Maximilians University in Munich
- Diploma thesis on „Clump formation in magnetically dominated molecular clouds“ at USM *(Supervisors: H. Lesch, F. Heitsch)*
- PhD project in the High Energy Group of MPE *(Supervisors: G. Hasinger, W. Pietsch)*



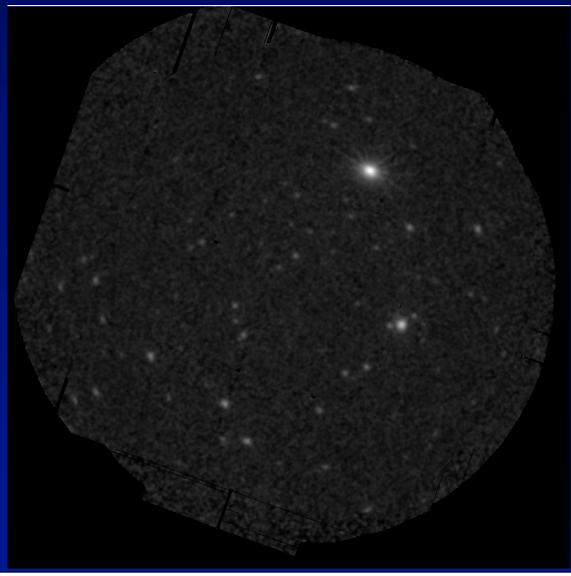
A deep XMM-Newton survey of M 31

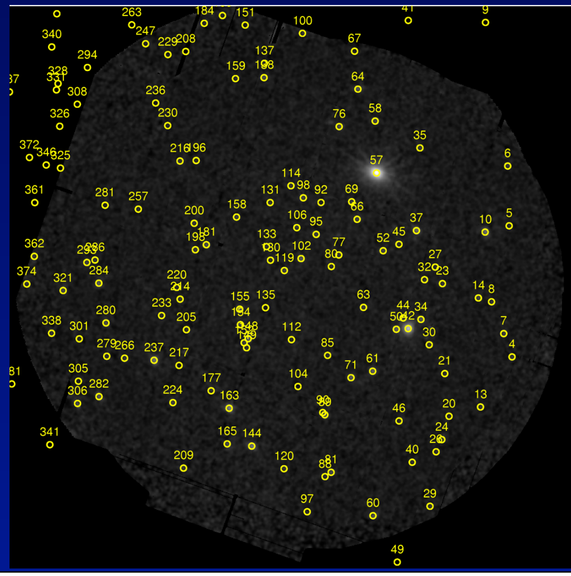
Why observe nearby galaxies?

- All sources at the „same“ distance
- Different source classes can be resolved
- Less interstellar absorption (eg. compared to Galactic centre)
- Better understanding of population of the Milky Way and more distant galaxies

Data analysis

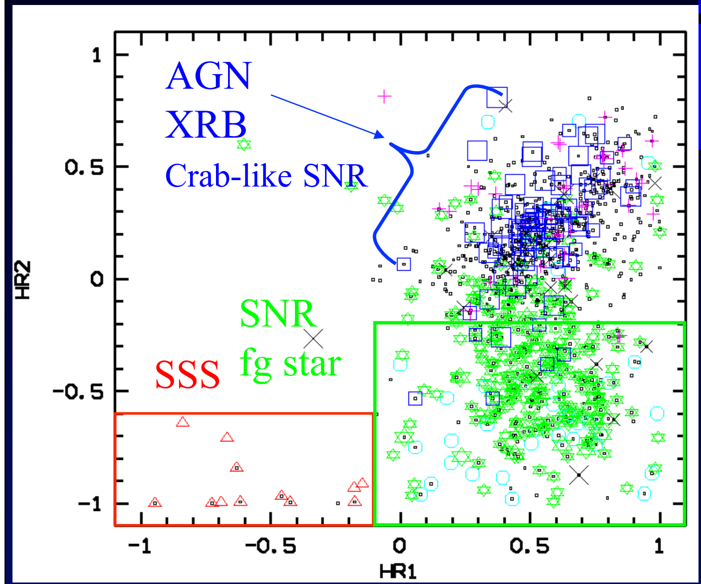
- X-ray imaging with XMM-Newton EPIC (CCD camera)
- Image creation (background images, exposure maps, vignetting) and source detection
- in total observations





Methods

Hardness ratios



$$EHRi = 2\frac{\sqrt{(B_{i+1}EB_i)^2 + (B_iEB_{i+1})^2}}{(B_{i+1}+B_i)^2}$$

$$HRi = \frac{B_{i+1} - B_i}{B_{i+1} + B_i}$$

B1: 0.2-0.5 keV
B2: 0.5-1.0 keV
B3: 1.0-2.0 keV
B4: 2.0-4.5 keV
B5: 4.5- 12 keV

□ XRB ✡ fg star
△ SSS + AGN
⬢ SNR × Gal/GlC

Time variability

- Long-term variability
- Time scales of month to years
- SNRs show **no** time variability
- Variability of XRBs much stronger than that of AGNs
- 6 „new“ XRB candidates in central area of M 31

Stiele et al. 2008, A&A

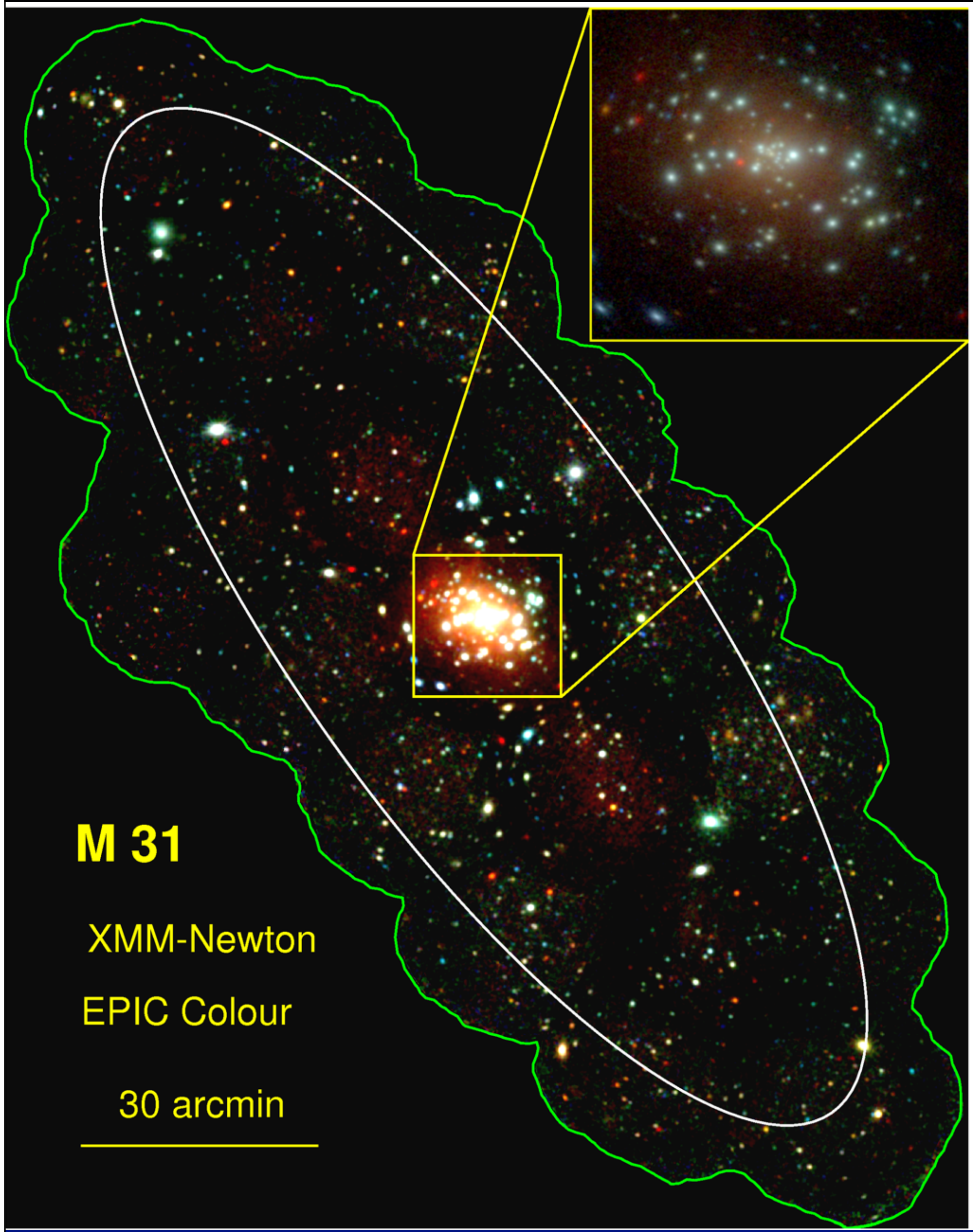
Extent

- Supernova remnants (with Chandra) Kong et al. 2002
- Hot gas (HII regions, superbubbles) Chu & Mac Low 1990
- Galaxy clusters eg. Kotov et al. 2006

Cross Correlations

- With catalogues from other wavelenths (optical, infra red, radio)
- Optical images ➔ distinguish foreground stars from supernova remnants
  ➔ identify optical novae
- AGN classification supported by radio counterparts and optical spectra

Image



- of Deep survey ("outer ring") and archival ("major axis") data (see Pietsch et al. 2005)
- Fields with high background repeated
- Optical extent indicated by D_{25} ellipse
- 0.2 – 1 keV
  1 – 2 keV
  2 – 12 keV

  Stiele et al. 2010, submitted
- SSSs; fgstars + SNRs; hard (AGN,XRBs,Crab like SNR)

In total 1948 X-ray sources

Extended sources mostly background galaxy clusters

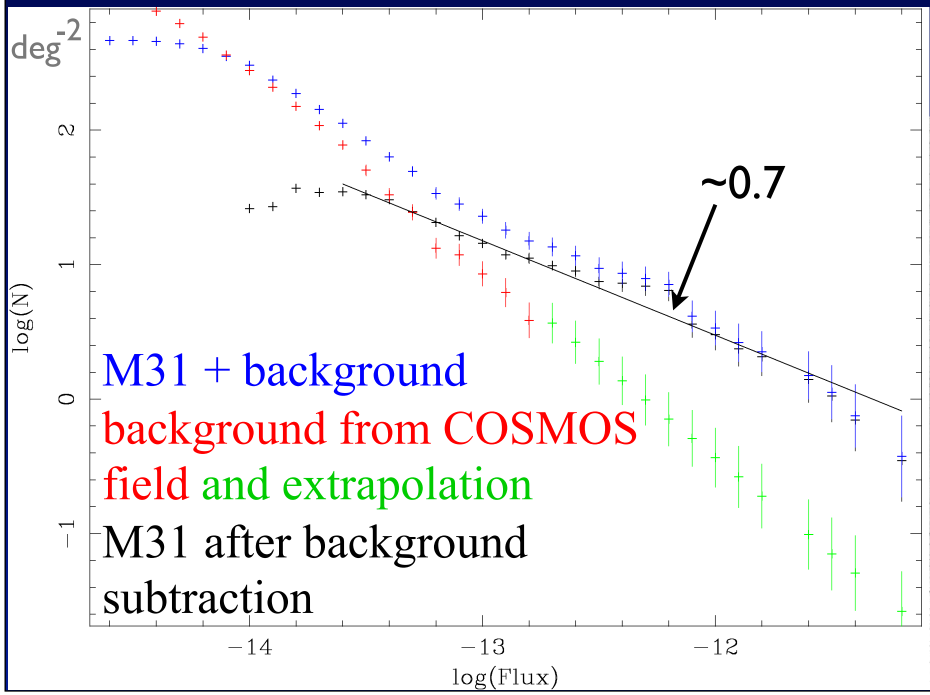
log N - log S relation

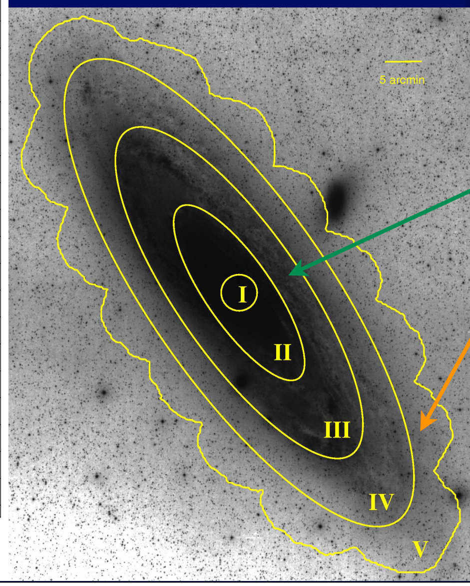
- 1287 sources can be only classified as „hard“

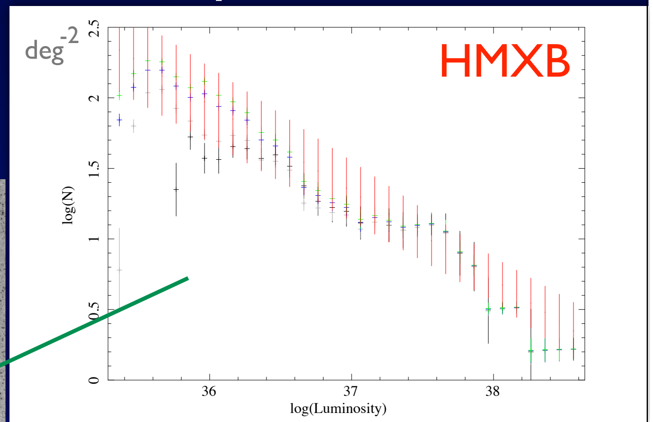
➡ catalogue of sources detected in the 2-10 keV range (reduce effects of absorption)

➡ logN-logS relation: #sources above certain flux/surveyed volume ← limiting flux

- estimate number of background sources from deep fields ➜ relation for sources in M 31





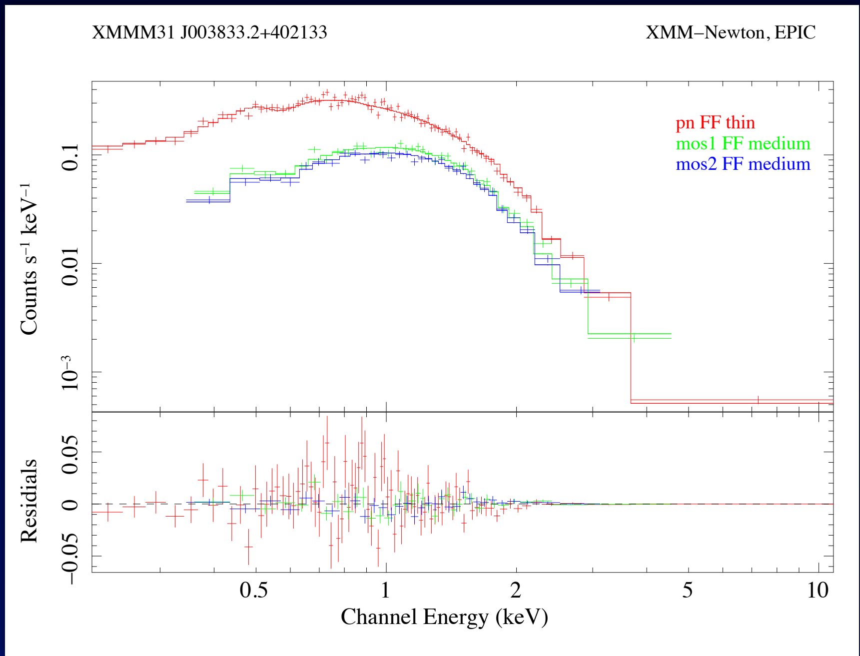


still ~ 13 srcs/deg^{-2} of M 31

Stiele et al. 2010, in prep.

X-ray spectra

- e.g. a bright transient source in M 31



fitted in Xspec with an absorbed power law:

$N_H = (1.68 + 0.42 - 0.48) \times 10^{21}$ cm^{-2}

$k_B T_{in} = 0.462 \pm 0.013$ keV

$\Gamma = 2.55 + 0.33 - 1.05$

No short-term variability and absence of optical/UV counterpart → BH LMXB candidate in steep-power law state

Stiele et al. 2010, submitted

Istituto Nazionale di Astrofisica

Osservatorio Astronomico di Brera

Merate

The Project

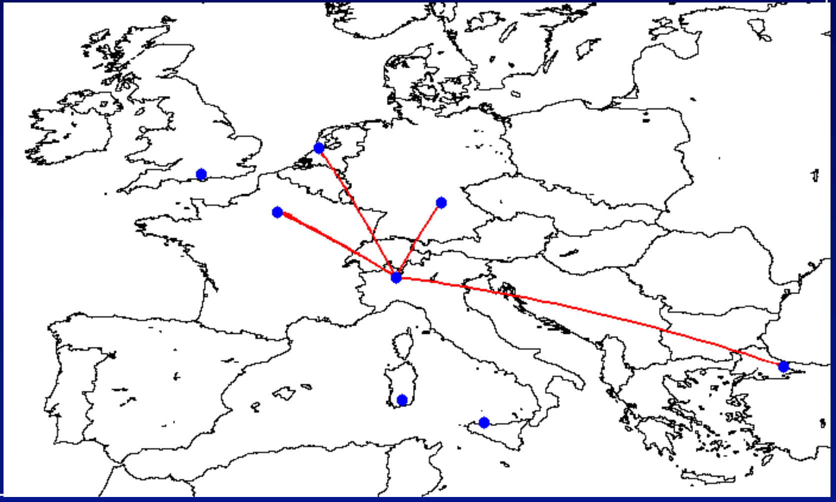
P2: Spectral Variability and Timing of X-ray Binaries

with

T. Belloni, T. Muñoz-Darias (Postdoc), S. Motta (PhD student), D. Carbone (undergraduate student)

Related nodes:

Amsterdam, Sabanci, CEA Saclay, FAU Erlangen-Nürnberg



The Goals

- How are spectral and time variabilities connected with the BHs physics?
- What are the physical conditions of the plasma in the accretion disk around the compact object (especially during fast state transitions)?
- Investigation of high-frequency oscillations to study strong gravity effects

Structure

- full timing analysis of (fast) variability properties; variability ⇔ states (transitions)

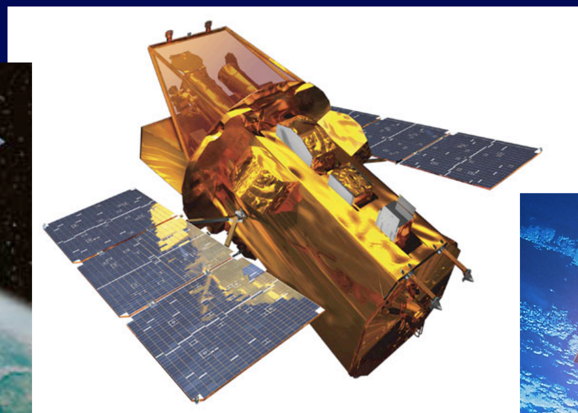
  ➫ Teo's talk

- thorough, complete, and homogeneous spectral analysis
- spectral components during different states
- spectral components during state transitions
- What happens at energies > 20 keV?

Satellites

- Archival (huge) and new RXTE observations (proposals for AO 15)
- Accepted proposals for INTEGRAL
- Proposals for *Swift*, XMM-Newton, ...



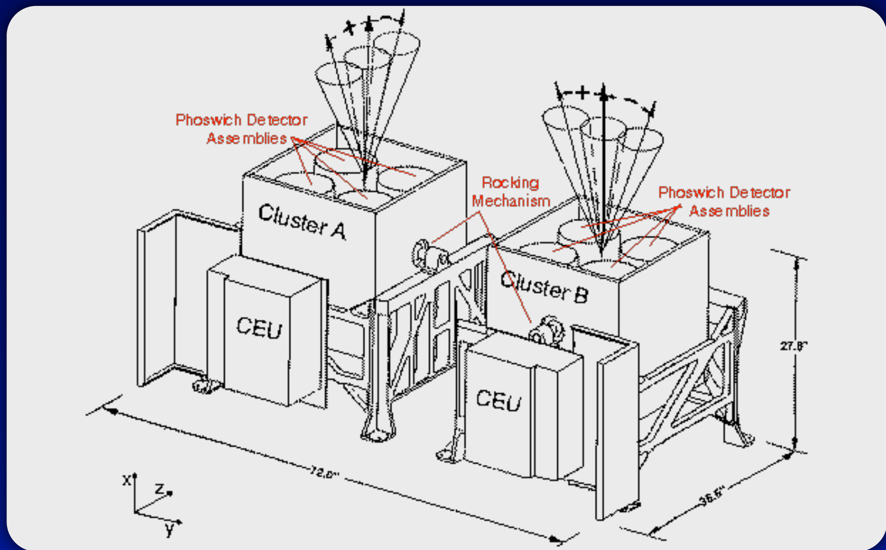



Rossi X-ray timing explorer

- Launched 30 Dez. 1995
- Data from two instruments:
  - PCA (proportional counter array; 2-60 keV)
  - HEXTE (phoswitch scintillation detector; 15-250 keV)

Clusters stopped rocking:

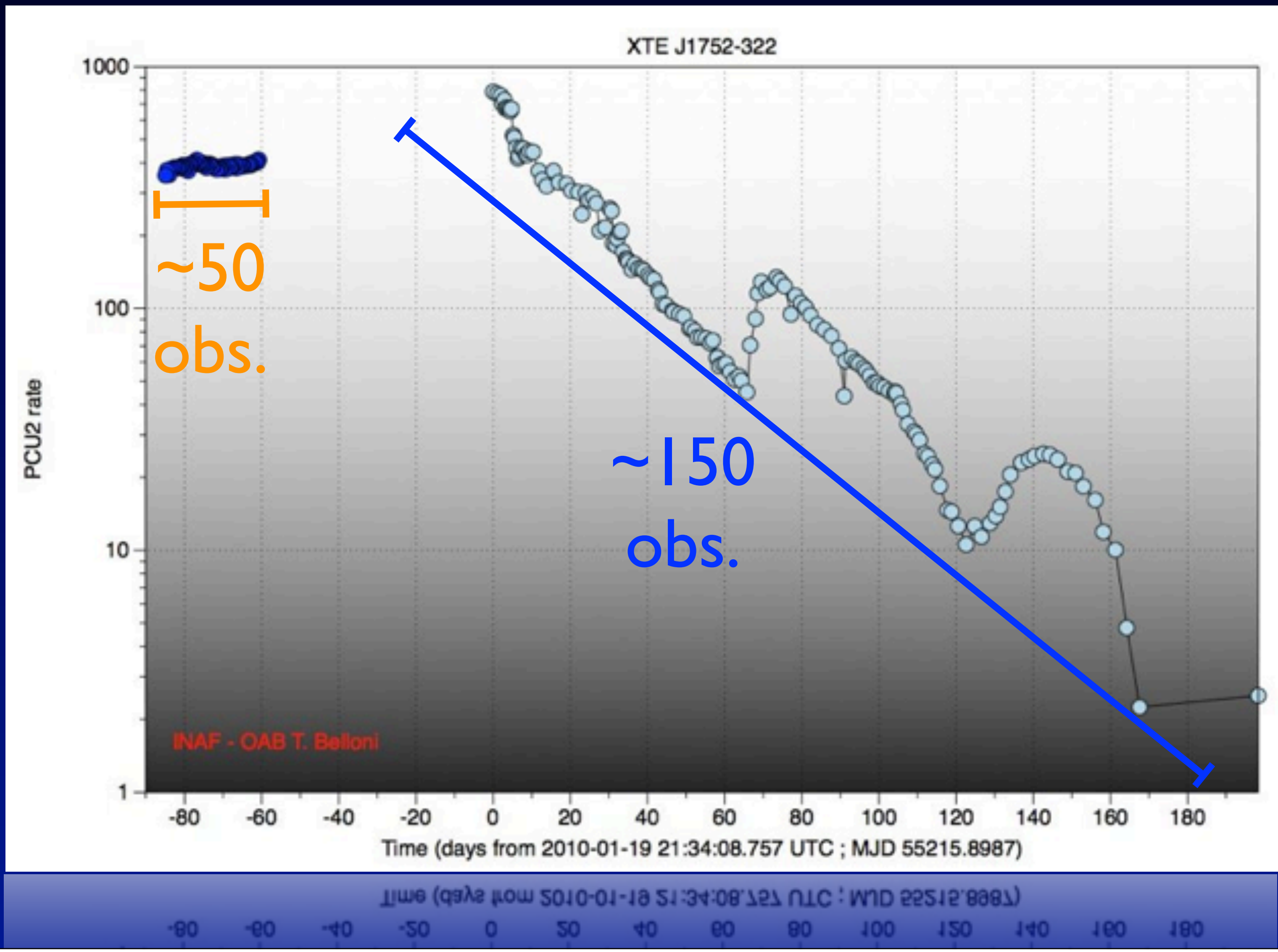
Cluster A → on source (20. Oct. 2006)
Cluster B → off source (14 Dez. 2009)



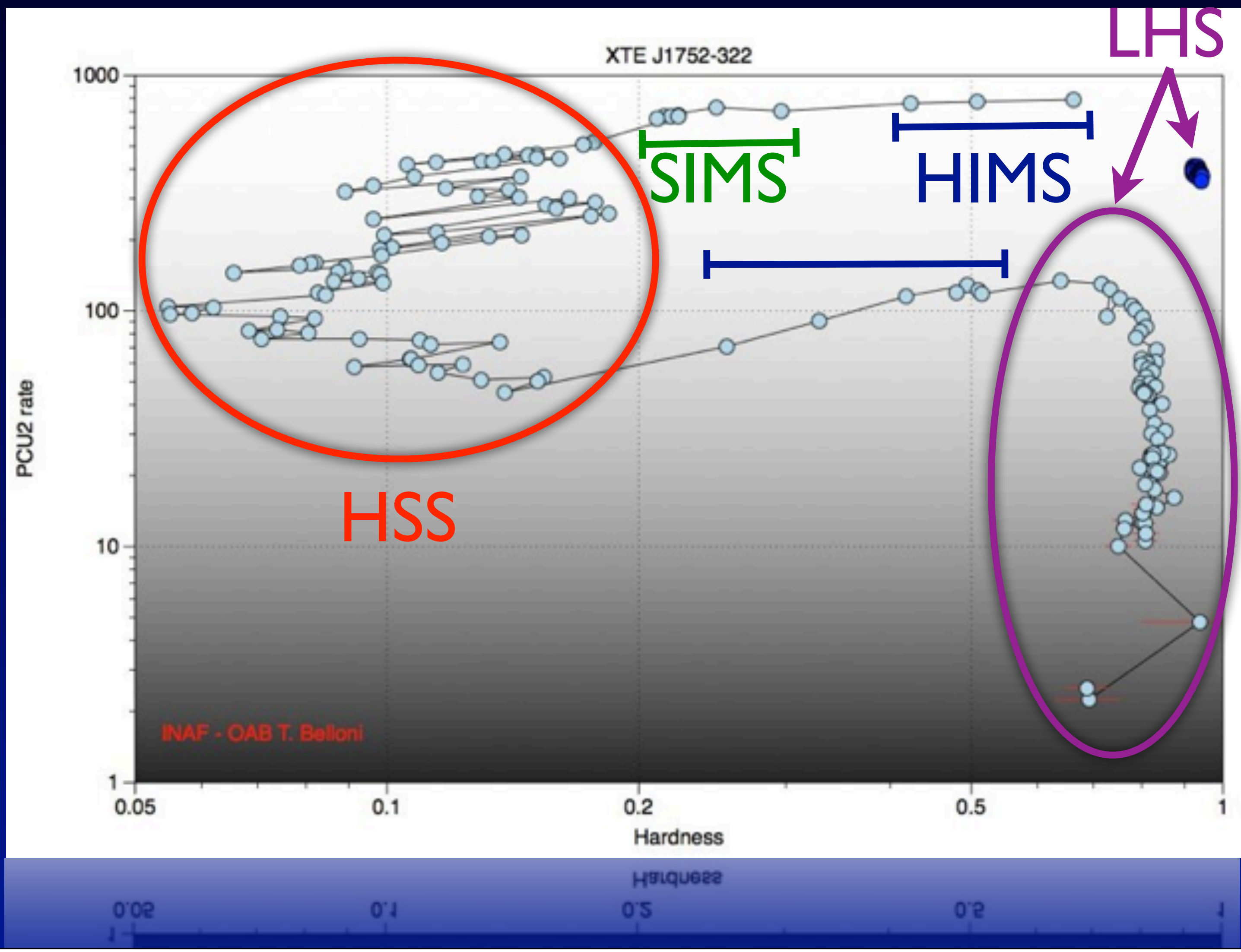
First source: XTE J1752-223

- discovered by RXTE on 23. Oct. 2009 (Markwardt et al. 2009)
- not known before → new transient source
- showed complete outburst

XTE J1752-223
Light curve



XTE J1752-223
Hardness intensity diagram



RXTE data

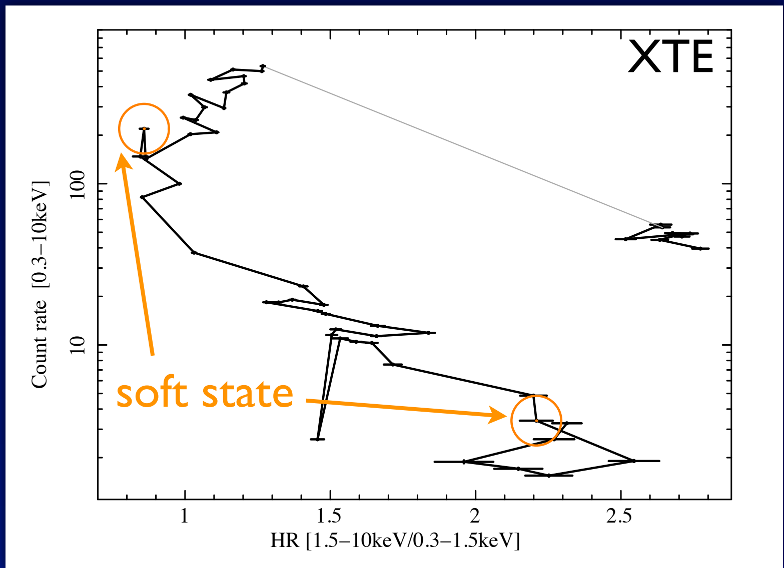
- Muñoz-Darias et al. 2010 (MNRAS 404, L94)
  - ★ 2-day long RXTE observation + simultaneous *Swift* data (during hard state)
  - ★ stable spectral and timing properties
  - ★ spectral properties:
  - ★ fractional rms ~ 48%

Spectral parameter	Value
Absorption (10^{22} atoms cm^{-2})	$0.72^{+0.01}_{-0.04}$
T_{in} (keV)	0.313 ± 0.007
Diskbb norm.	$(1.027 \pm 0.001) \times 10^6$
Γ_1	1.471 ± 0.008
E_{break} (keV)	10.2 ± 0.4
Γ_2	1.24 ± 0.01
PL norm. (photons keV^{-1} cm^{-2} s^{-1})	$44.7^{+0.5}_{-0.6}$
High-energy cut-off (keV)	133^{+6}_{-5}

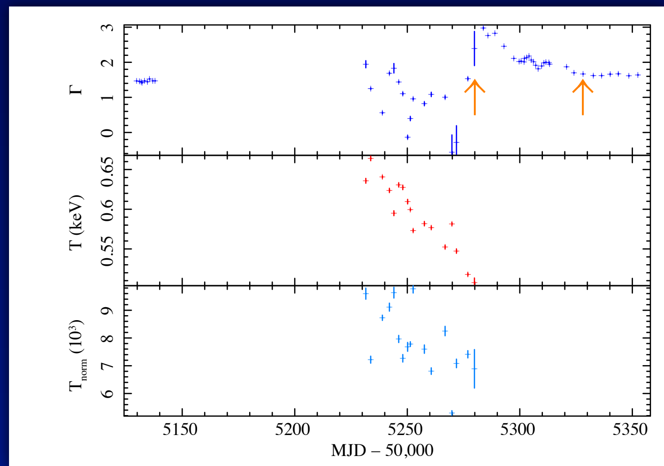
  - ★ power density spectrum: high-frequency component and 2 weak quasi-periodic oscillation-like features
  - ★ Timelag between soft and hard X-rays: $\Delta t \propto \nu^{-0.7}$
  - ★ properties similar to those of Cyg X-1
- Shaposhnikov et al. 2010 (arXiv1008.0597)
  - ★ whole outburst, but only PCA data

Swift data

- Curran et al. 2010 (arXiv1007.5430)
  - ★ *Swift*-UVOT data confirm optical counterpart, which displays variability in soft state
  - ★ Hardness-intensity diagrams and spectral investigations based on XRT and BAT data
  - ★ rms of ~53.9% in hard state and < 12% in soft state



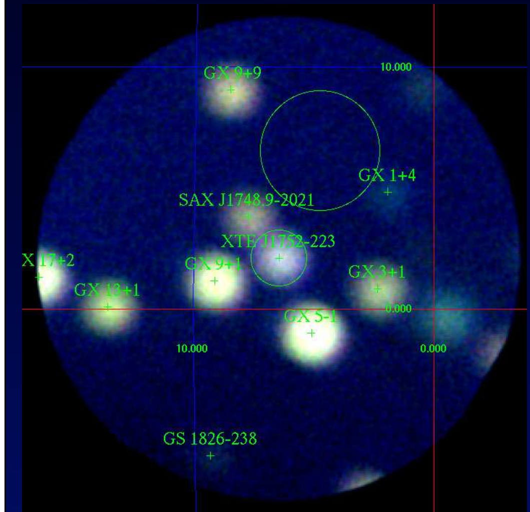
TBabs * (powerlaw + diskbb)



$N_H = 0.513 \pm 0.003 \times 10^{22} cm^{-2}$

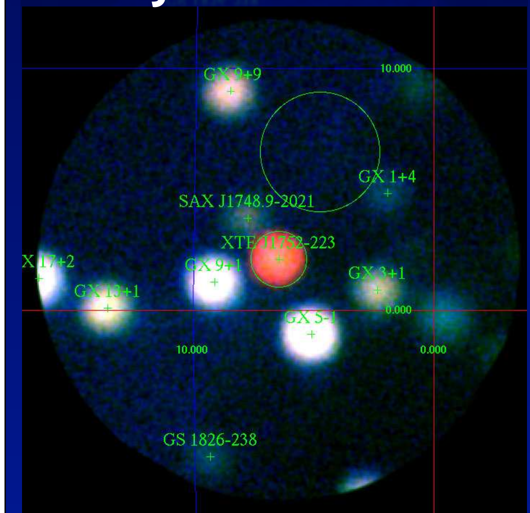
MAXI GSC data

20 Dez - 19 Jan

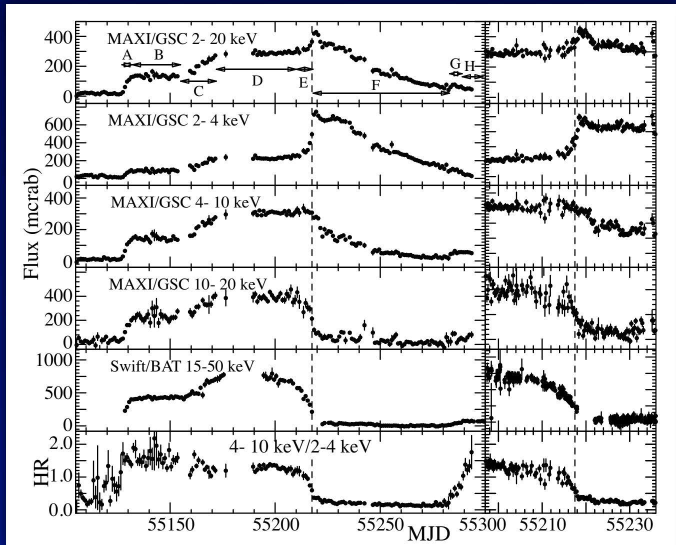


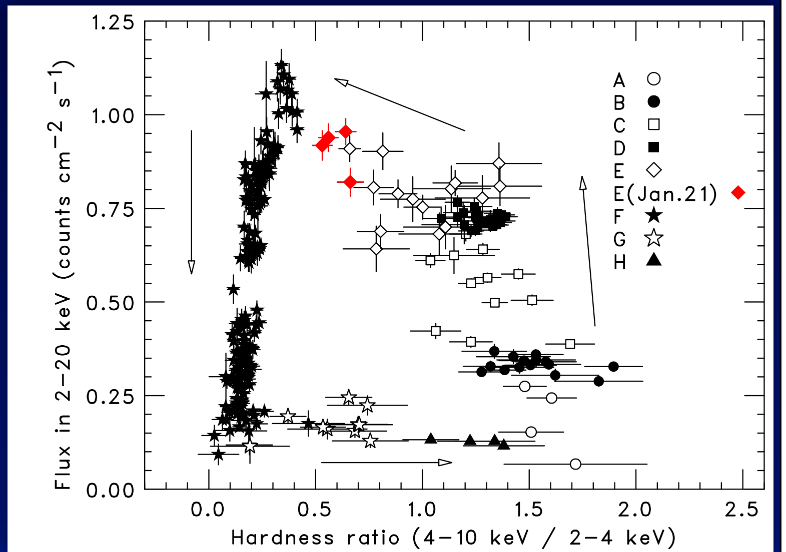
2 - 4 keV
4 - 10 keV
10 - 20 keV

20 Jan - 28 Feb



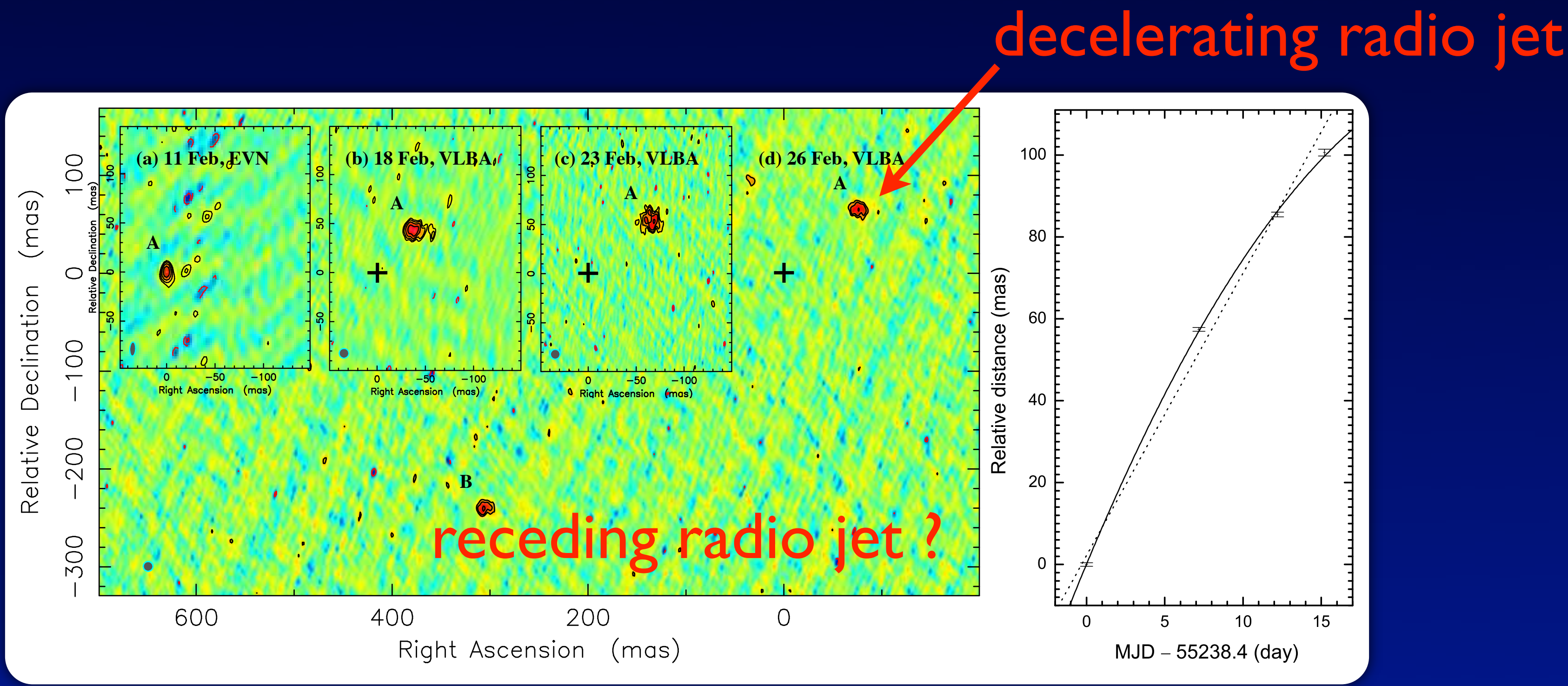
- Nakahira et al. 2010 (arXiv1007.0801)
  - ★ Gas Slit Camera (2-20 keV) on-board the Monitor of All-sky X-ray Image on the International Space Station
  - ★ Hardness-intensity diagram and lightcurves





Radio data

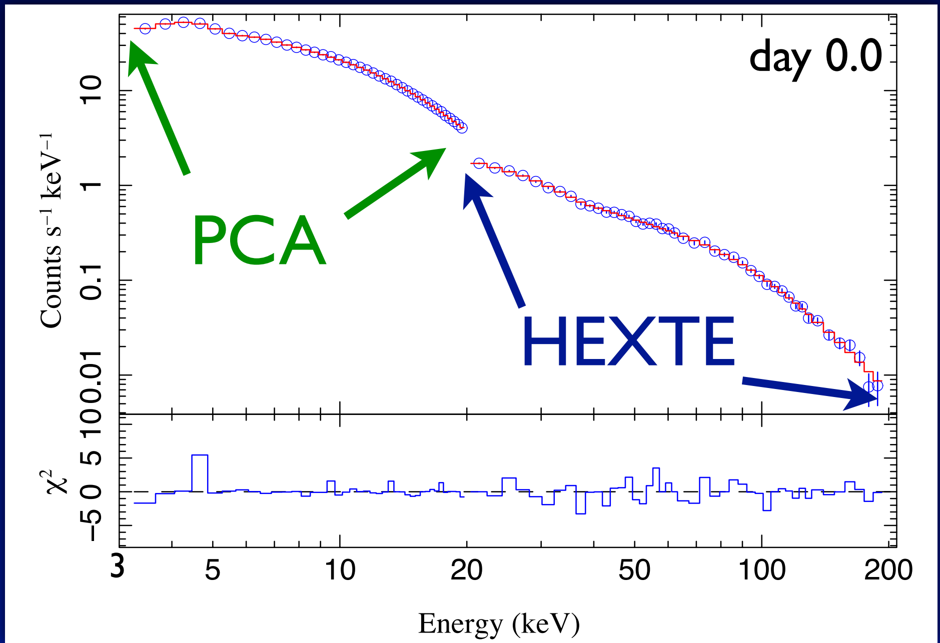
- Yang et al. 2010 (arXiv 1009.1367)
  - ★ European VLBI Network and Very Long Baseline Array observations

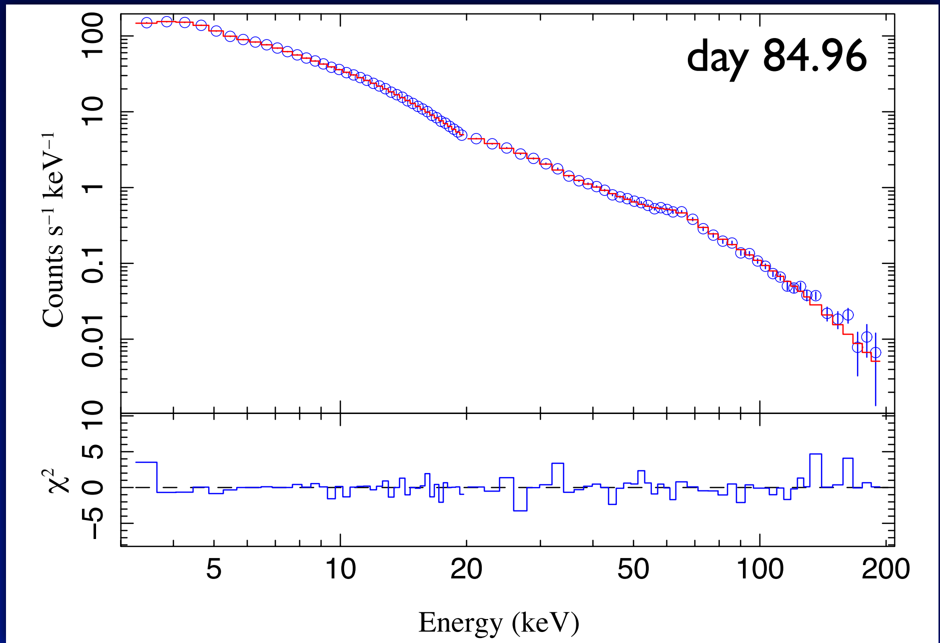


Spectral fitting

Work in progress

- Developed isis procedure to fit spectra interatively
- Simple models (absorbed powerlaw or diskbb) do not give acceptable fits
- Two more advanced models





The first model

TBabs*highecut*const*(bmc+gaussian)

(Shaposhnikov et al. 2010)

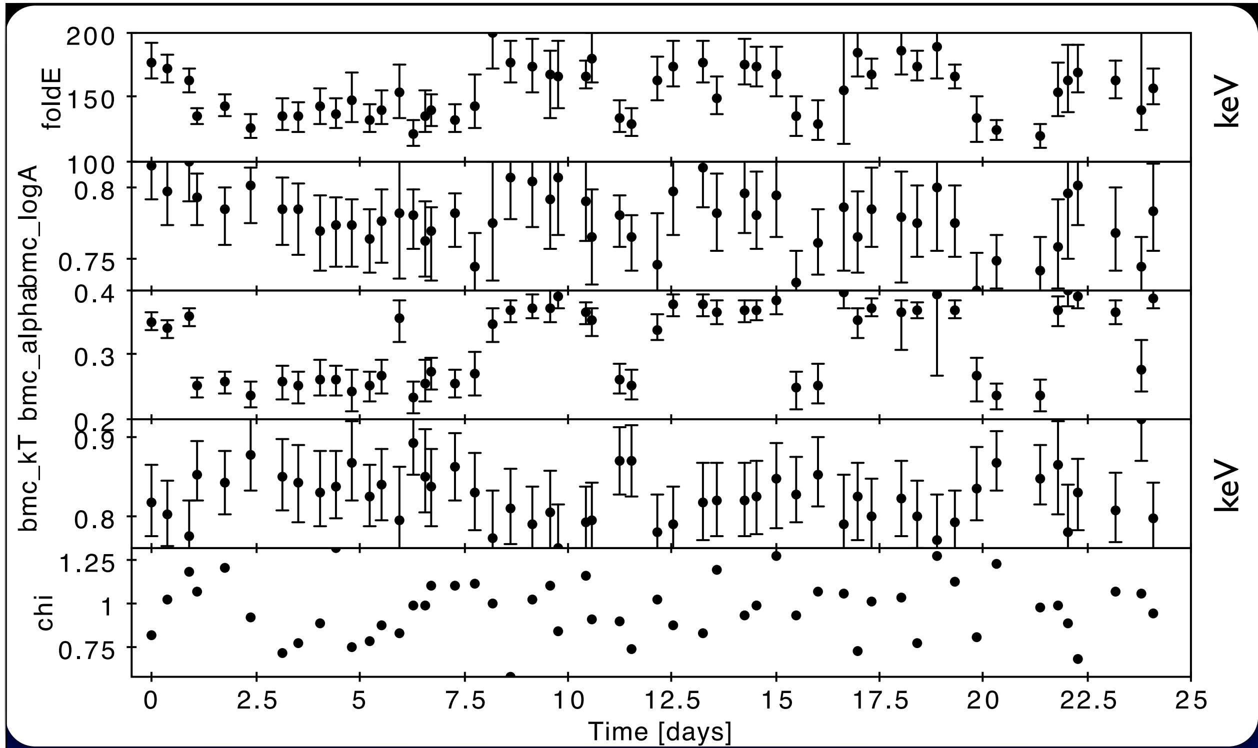
- absorption fixed to $N_H = 0.46\times10^{22}\ \mathrm{cm}^{-2}$
- gaussian: iron line at 6.4 keV (fixed)
- Comptonisation model (not just adding power law and thermal source):
  - ★ black body temperature
  - ★ spectral index
  - ★ illumination parameter (fractional illumination)

The second model

TBabs*highecut*const*(bknpower+diskbb+gaussian)

(Muñoz-Darias et al. 2010)

- absorption fixed to $N_H = 0.72 \times 10^{22}\ cm^{-2}$
- gaussian: iron line at 6.4 keV (fixed)
- Disk black body and broken power law:
  - ★ black body temperature (at inner disc radius)
  - ★ spectral index 1 ($E < E_{break}$)
  - ★ break energy
  - ★ spectral index 2 ($E > E_{break}$)



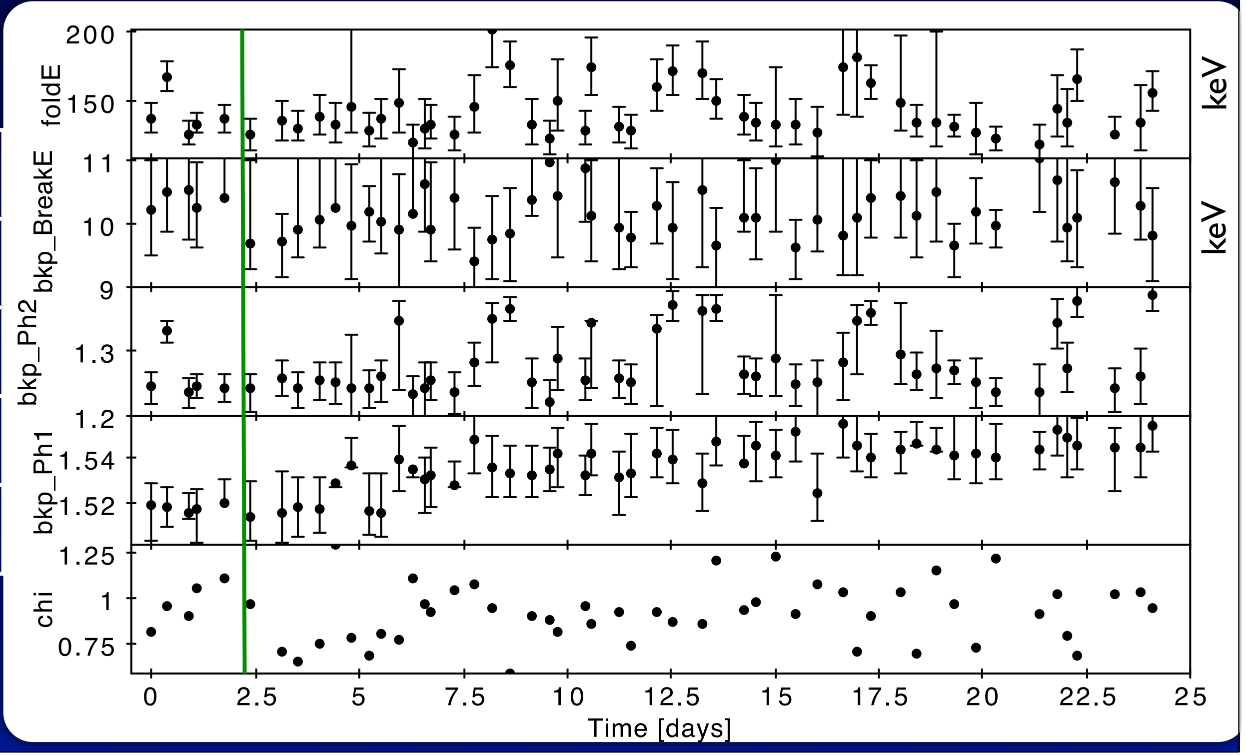
Work in progress

BMC

Low hard state

bknp+dbb

	My fits	Muñoz-Darias
Ph1	1.517 ± 0.002	1.471 ± 0.008
Ph2	1.26 ± 0.04	1.24 ± 0.01
BreakE	10.4 ± 0.1	10.2 ± 0.4
foldE	140 ± 14	133 + 6 - 5



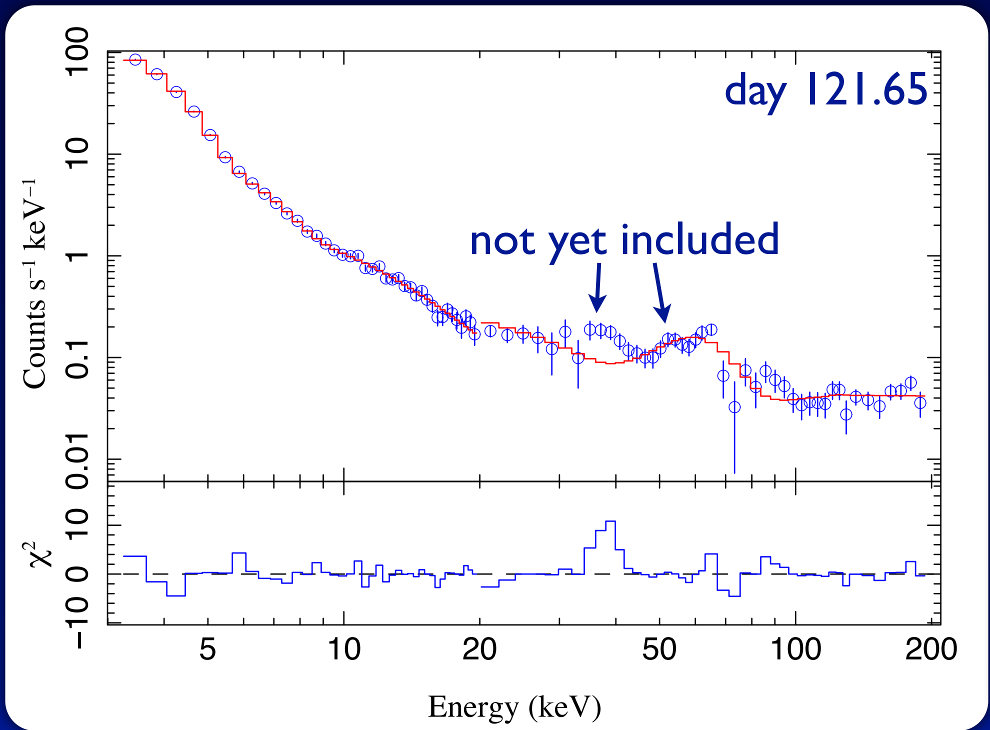
HEXTE spectral features

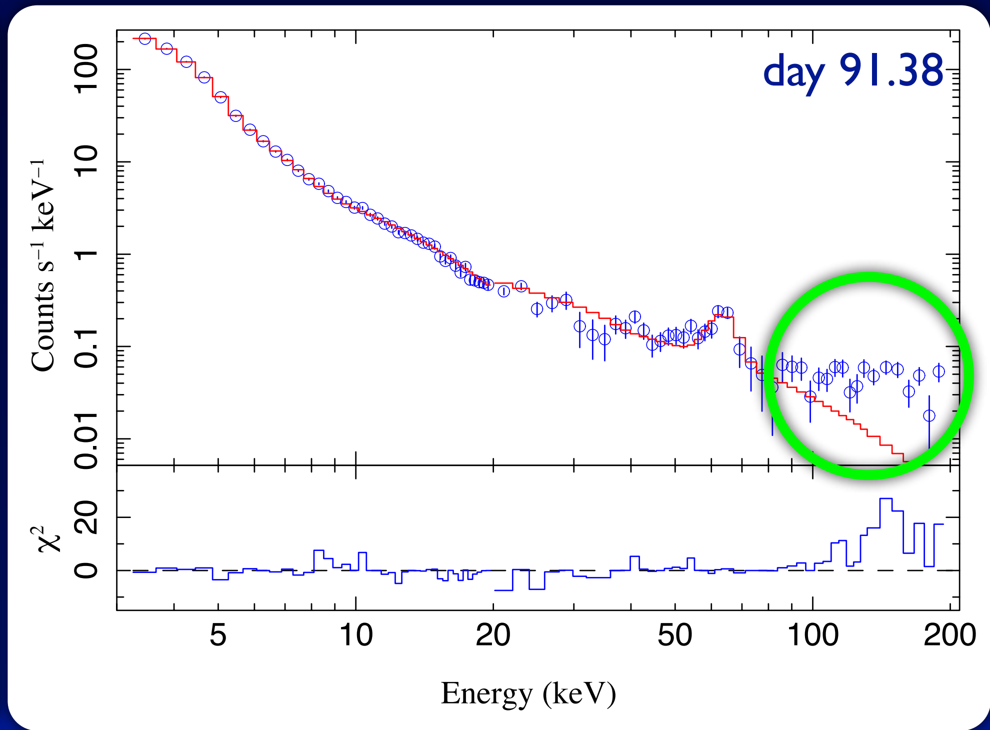
Work in progress

- (spectrum of source + background from cluster A) - (background spectrum from cluster B) ⇒

  residual features at ~40, ~53, and ~ 63 keV

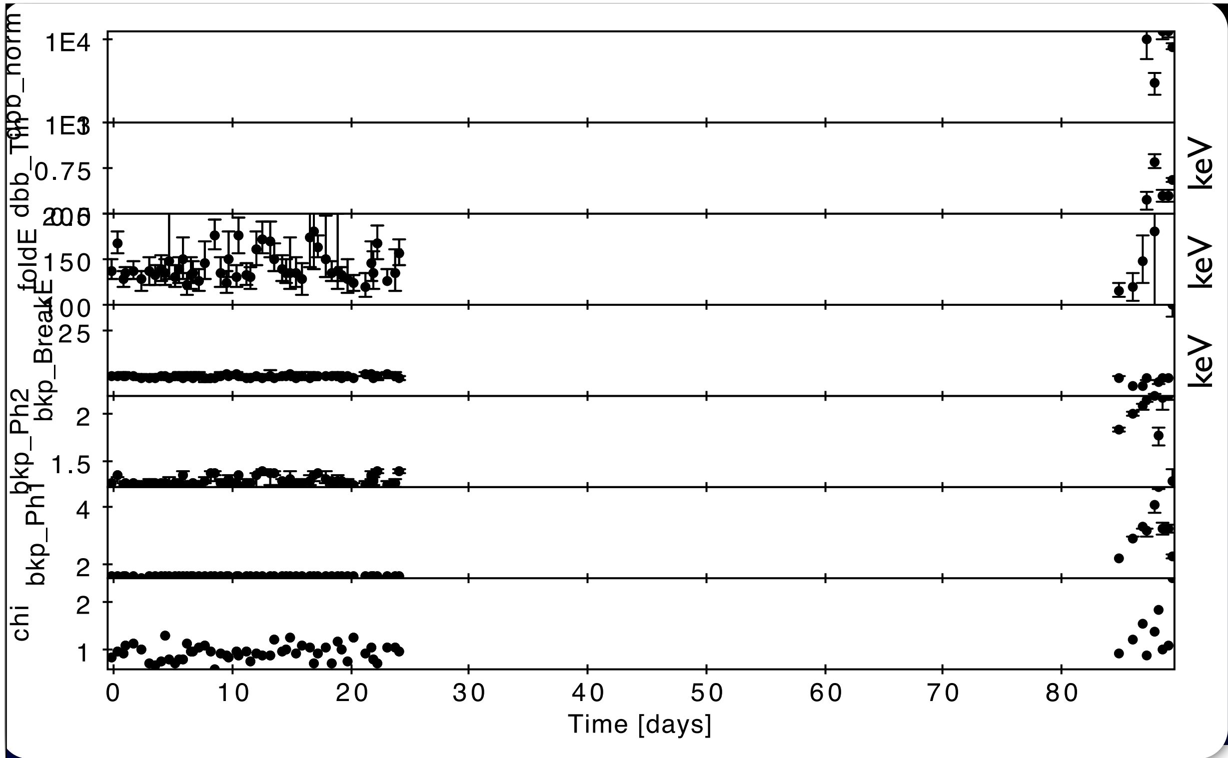
- additional gaussian to fit residual feature at ~ 63 keV (visible in (almost) all observations)



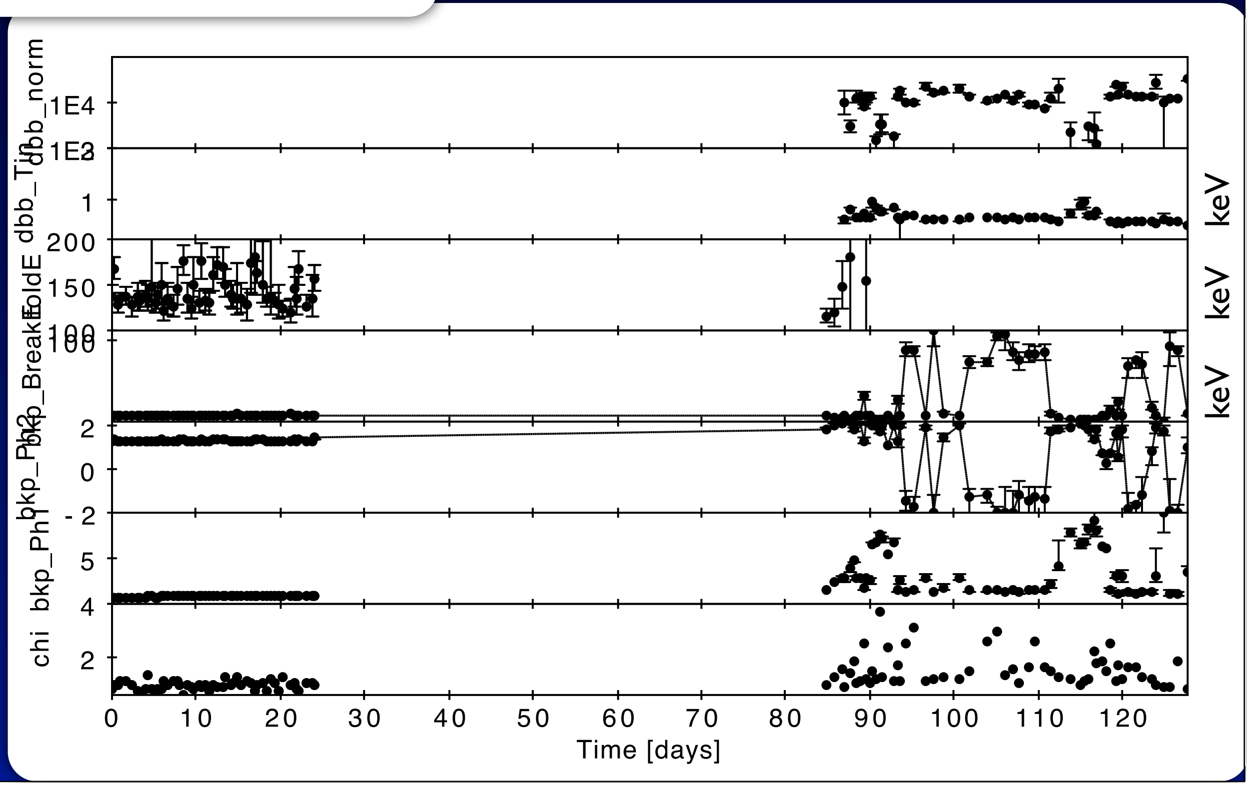


LHS - HSS

Work in progress



bknp+dbb



A lot of work to do ...

- improve spectral fits (HEXTE feature!!!)
- add *Swift* data (lower energies)
- timing ⇔ spectra (time resolved spectra)
- ...