The Broadband Variability of the Black Hole Cygnus X-1

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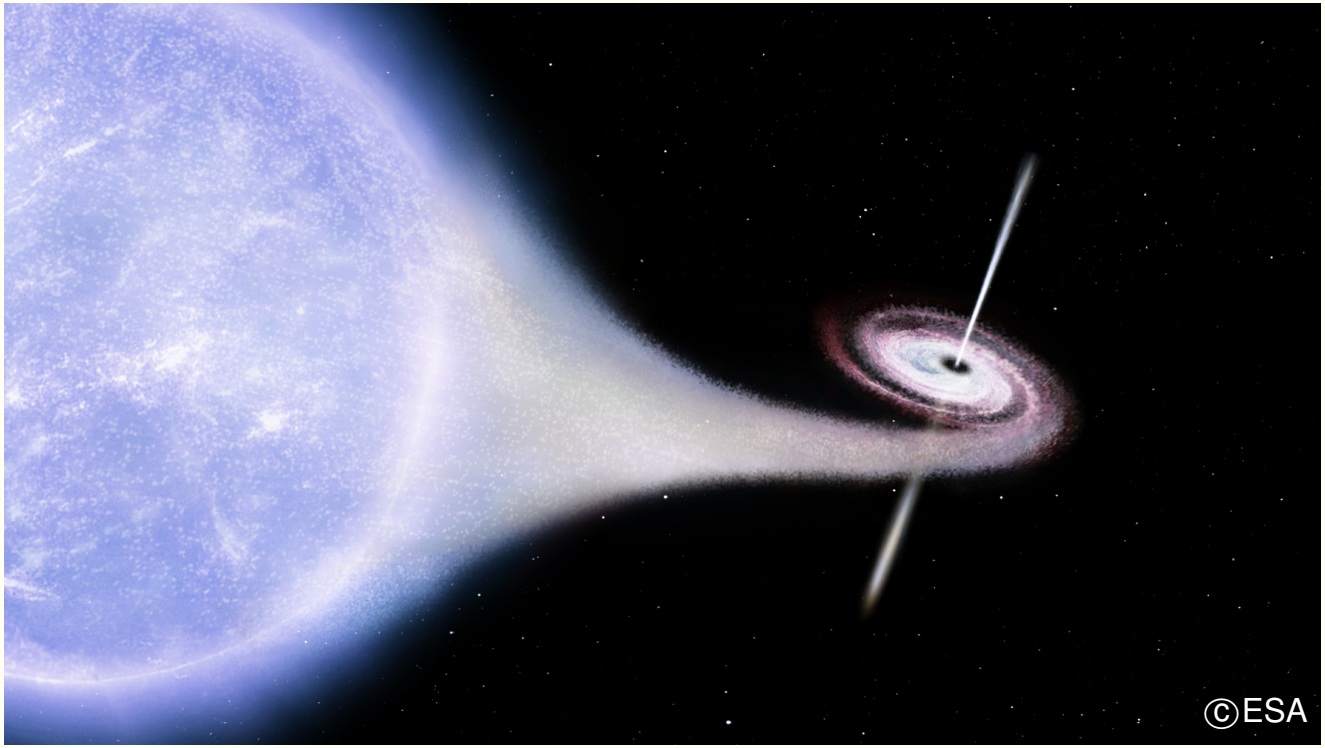
Cyg X-1 / HDE 226868 System



HMXB
(High Mass X-ray Binary)

companion:
HDE 226868,
O-type supergiant, close to filling its Roche lobe

- strong stellar winds $\Rightarrow$ accretion via focused wind
- orbital period $\sim$ 5.6 days; distance $\sim$ 2 kpc
- jets resolved in radio observations

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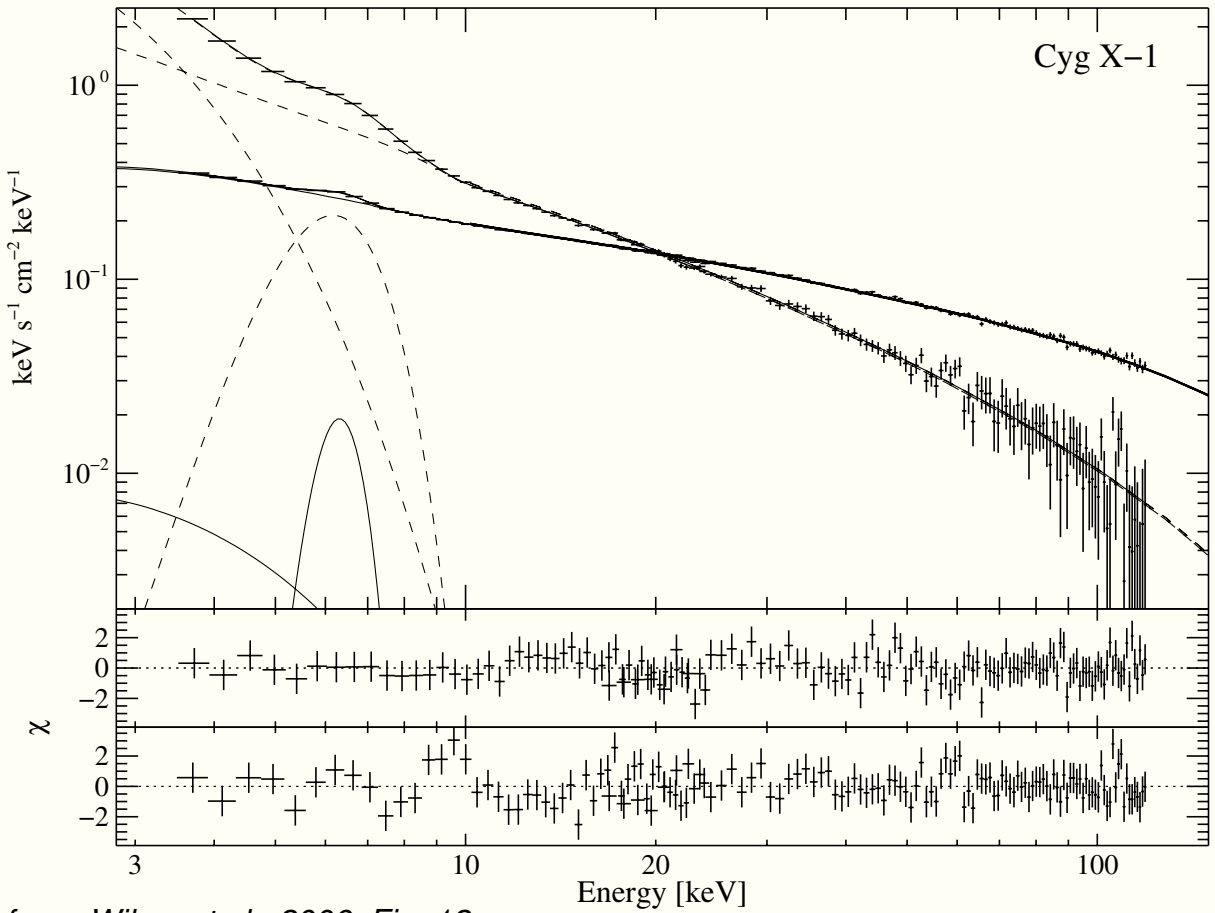
X-ray States of Cyg X-1



from: Wilms et al., 2006, Fig. 12

source always bright in X-rays
$\Rightarrow$ **persistent source**

two distinct regimes:

1. **low/hard state**
   lower flux at soft X-rays, higher flux at hard X-rays
2. **high/soft state**
   higher flux at soft X-rays, lower flux at hard X-rays

radio emission is correlated with X-rays

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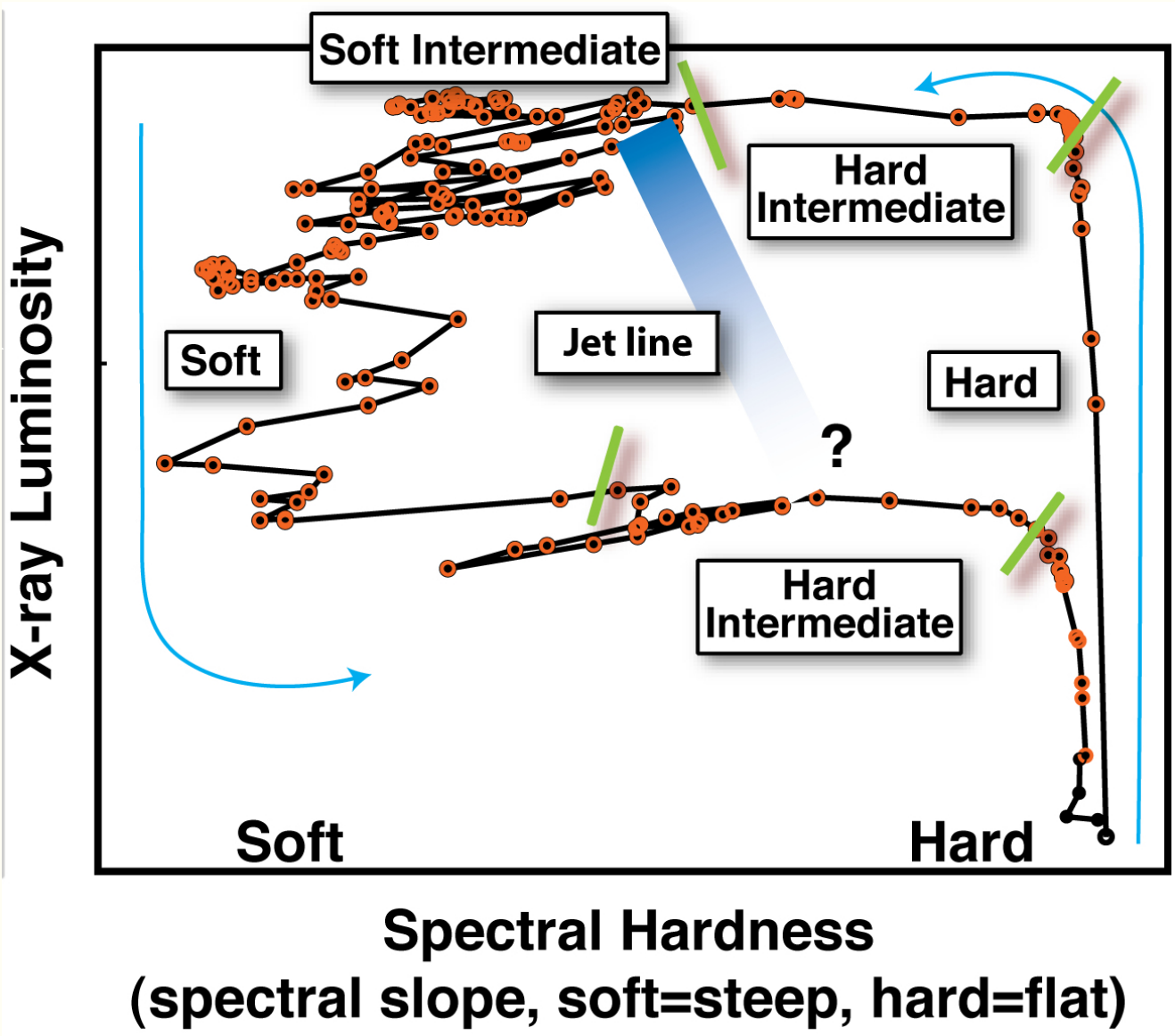
The q-Track

same kind of behaviour for different accreting objects

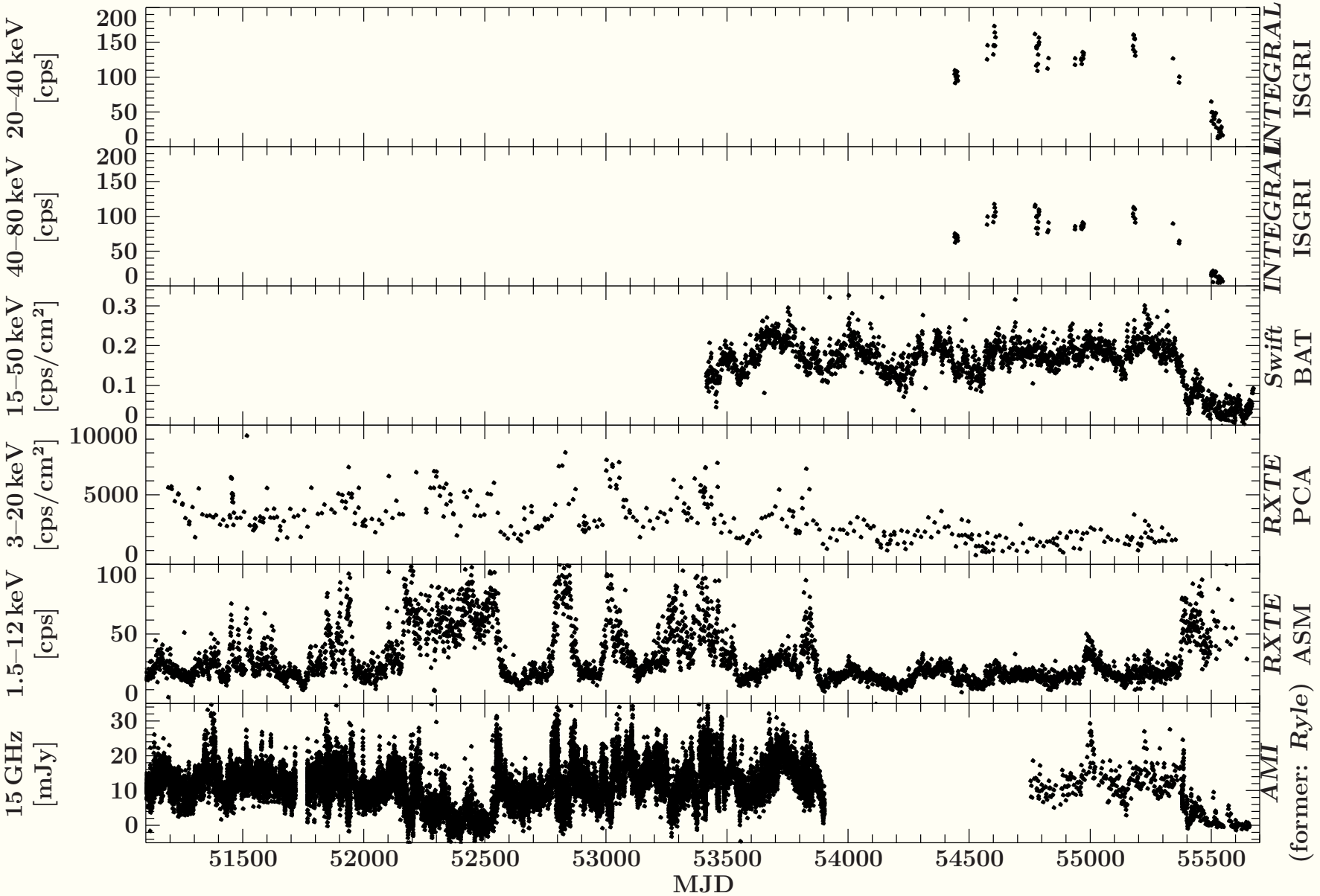
$\Rightarrow$

one unified scheme for state transitions: **q-Track**

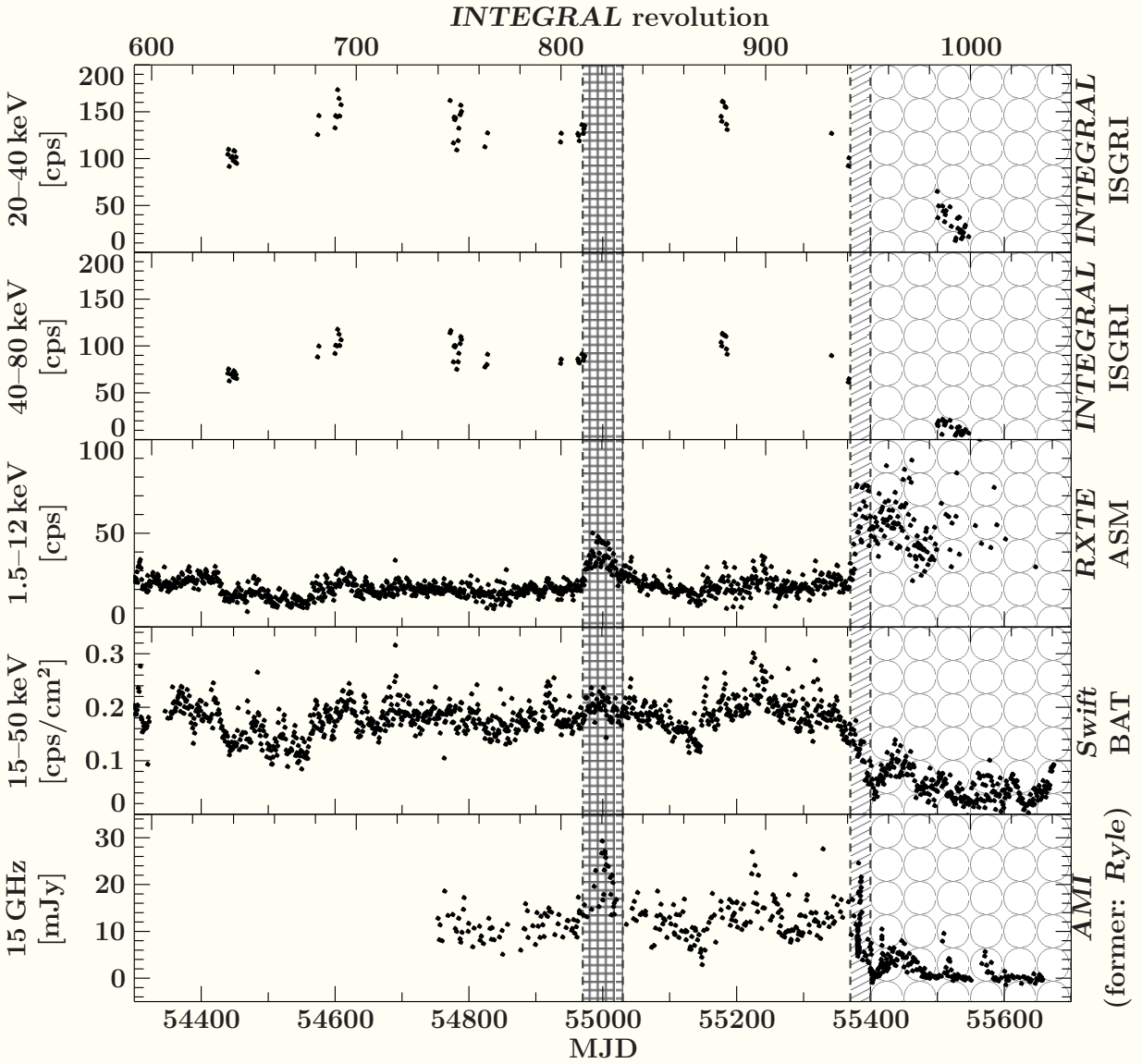


Credit: International Space Science Institute (ISSI), `http://www.sternwarte.uni-erlangen.de/proaccretion/`

Long-Term Behaviour of Cyg X-1



The Cyg X-1 Key Programme



the Cyg X-1 Key Programme covers:

- a long, exceptionally hard state
- a radio flare
- a soft state transition
- a long soft state

$\Rightarrow$ analysis of parameter ranges for different states

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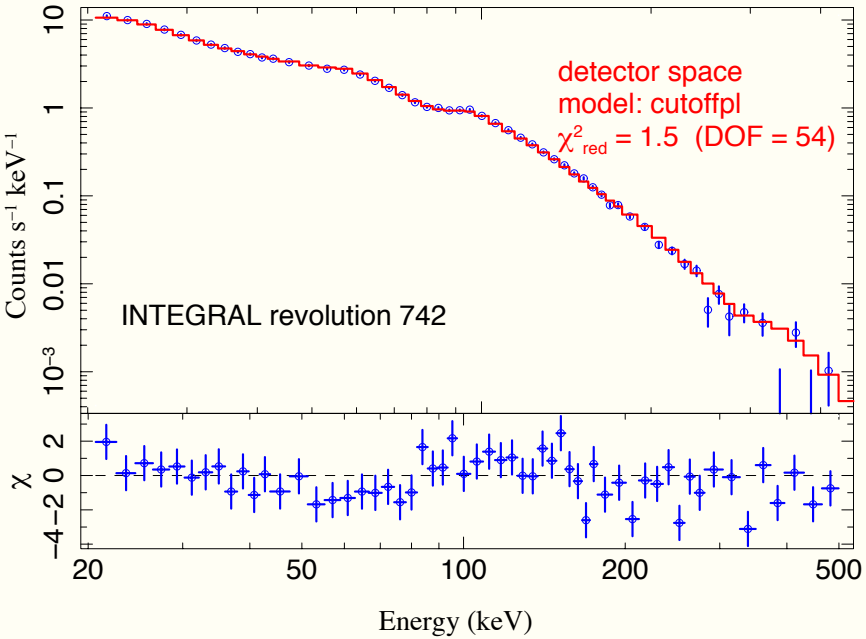
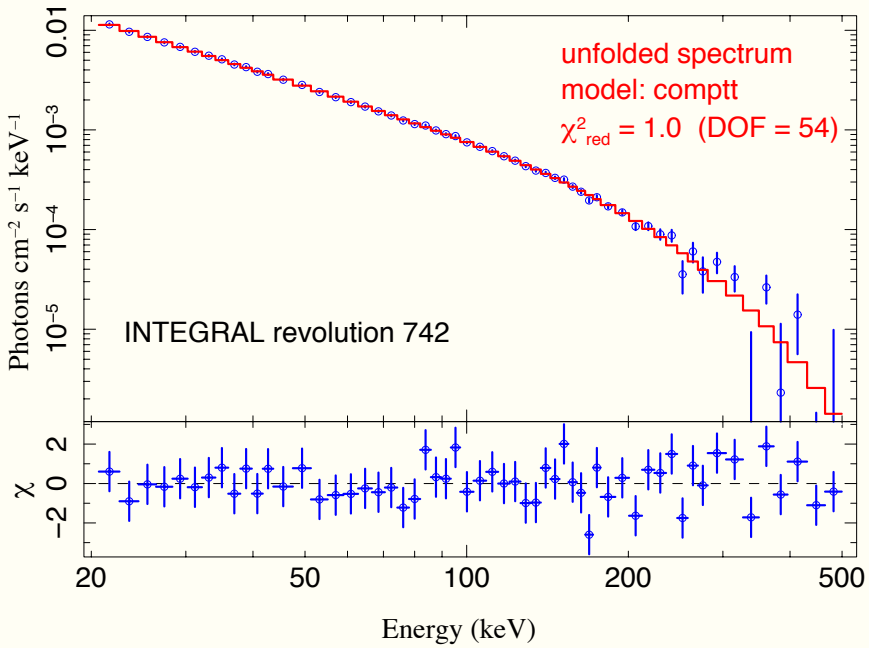
Spectral Modelling

two basic spectral models employed to describe the ISGRI data:





- cutoff power law
- purely empirical model

- simple Comptonization model (`comptt`)

$\Rightarrow$ both generally describe data equally well

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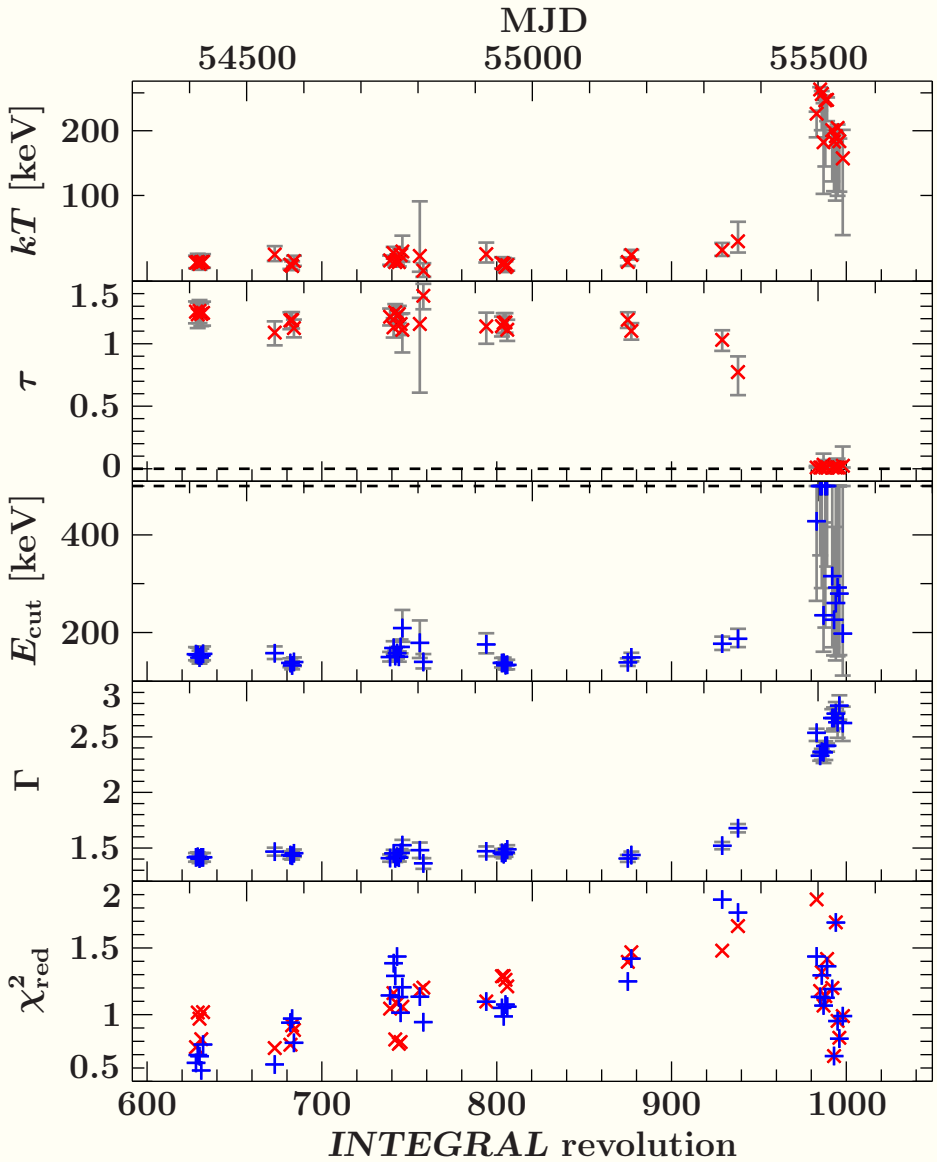
Spectral Parameters

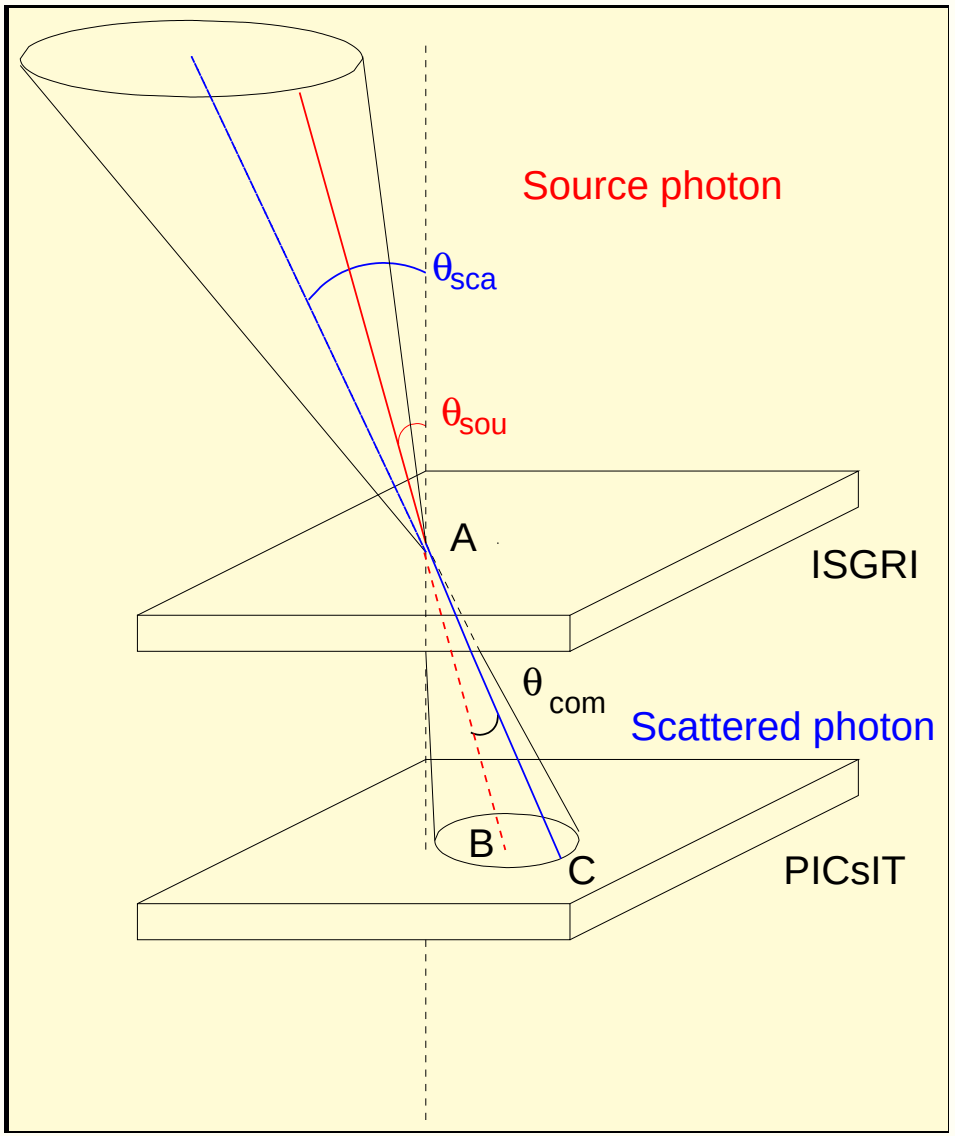
growing $\chi^2_{\rm red}$ due to calibration uncertainities $\Rightarrow$ awaiting new OSA version

results:

- clearly defined parameter ranges for states
- no notable spectral changes in the 20–500 keV range during the radio flare ($\sim$ revolution 800)
- clearly changing parameters already during the very start of the transition to the soft state in summer 2010



Compton Mode of *INTEGRAL*/IBIS



after: Forot et al., 2007, Fig. 1

Compton mode of IBIS: Compton scattering in ISGRI layer, absorption in PICsIT layer detection of both events allows to:

- reconstruct the position to 12' precision
- measure the **Compton scattering angle**
- **measure polarization**

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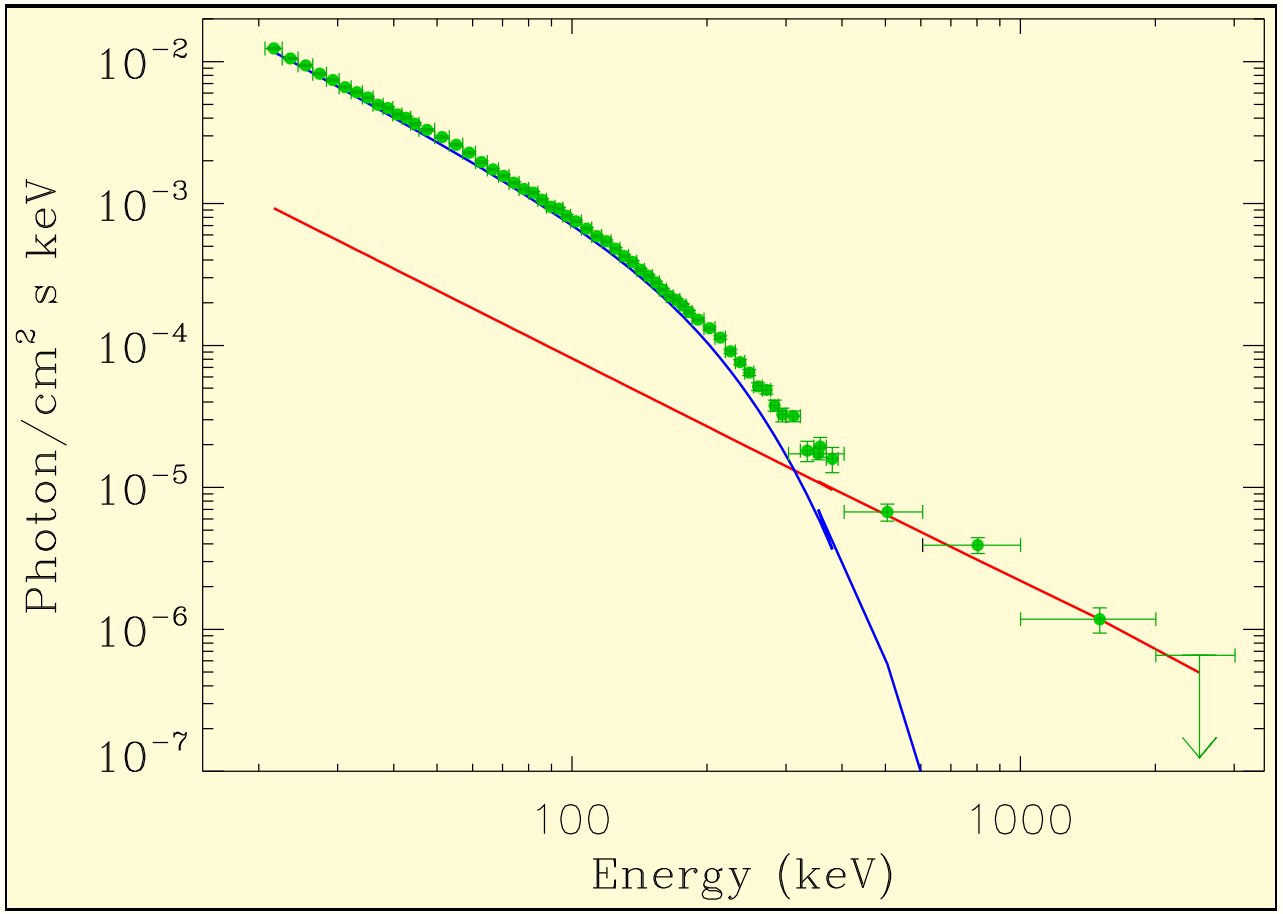
Spectral Shape

P. Laurent et al., 2011, Science 332, 438

INTEGRAL monitoring of Cyg X-1: $\sim$ 5Ms of data between 2003 and 2009

two spectral components:



- $\lesssim$ 400 keV: curved component $\Rightarrow$ Comptonization/reflection
- $\gtrsim$ 400 keV: nonthermal component, hard tail

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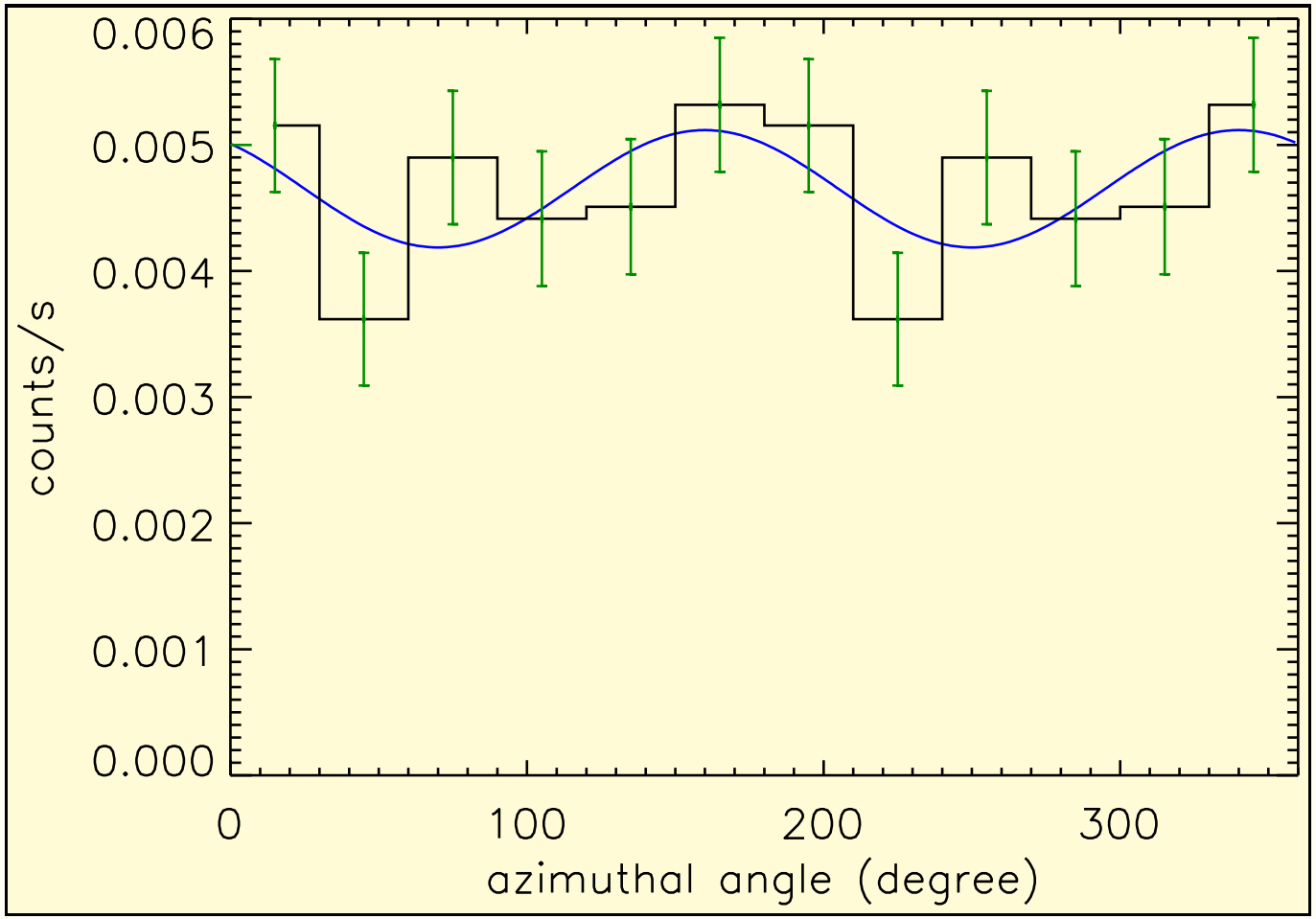
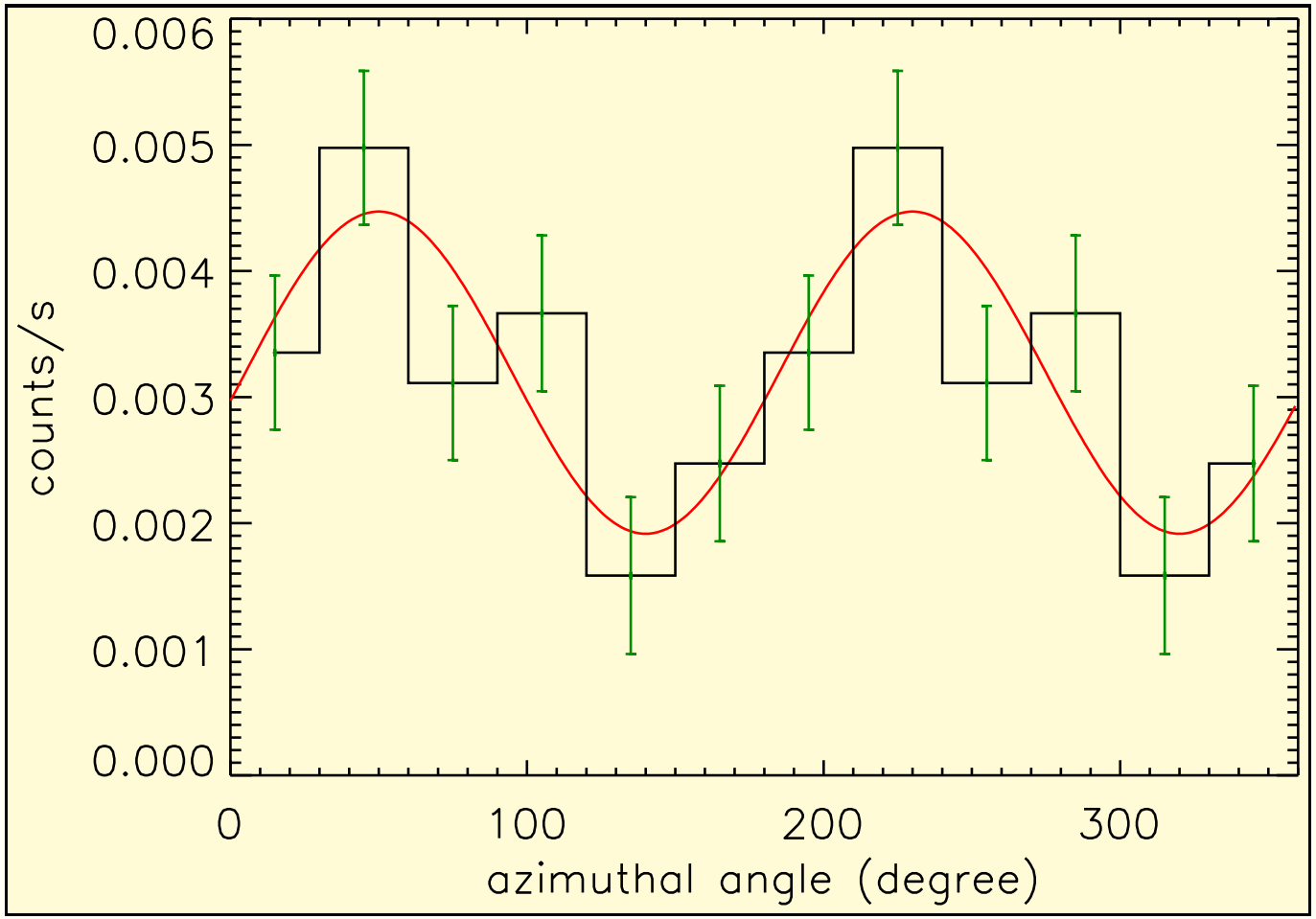
Polarization of Comptonization/Reflection Component



Compton mode for < 400 keV data:
polarization $< 20\%$ (90% conf.)

Polarization of Nonthermal Hard Tail Component



Compton mode for 400–2000 keV data:
polarization 67±30%

Summary & Outlook

Summary:

- good coverage of different source states with *INTEGRAL* Key Programme: hard state, radio flaring episode, state transition, soft state
- spectral analysis confirms expected behaviour, with the exception of the peculiar radio flaring episode
- Cyg X-1 is, after Crab, the second galactic source for which polarization has been measured in X-rays $\Rightarrow$ support for the notion that Gamma-rays are produced in jets

Outlook:

- broadband coverage of the Key Programme with JEM-X & SPI
- analysis of simultaneous *RXTE* observations
- polarization measurements for different source states

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