Long-term spectral study of Cygnus X-1 using INTEGRAL

Floriane Cangemi

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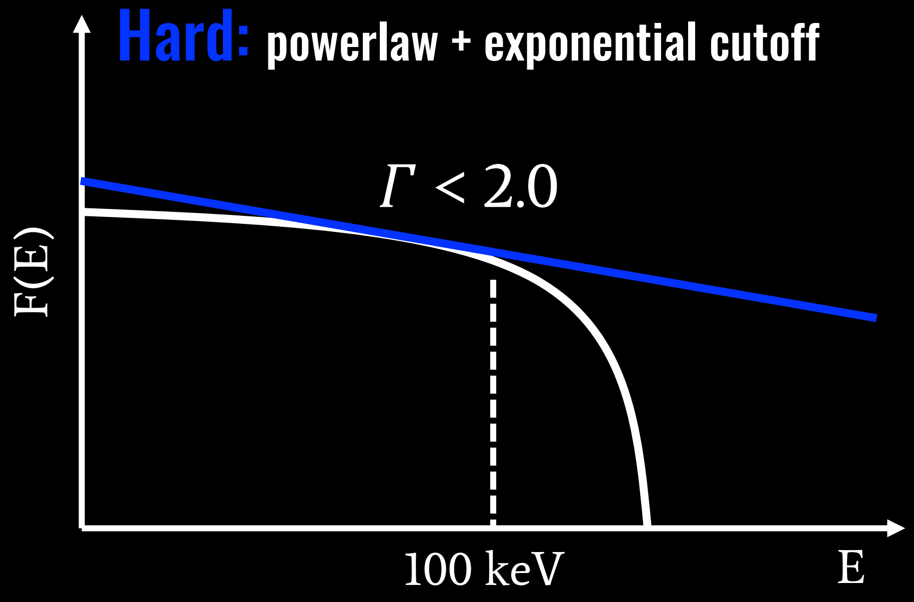
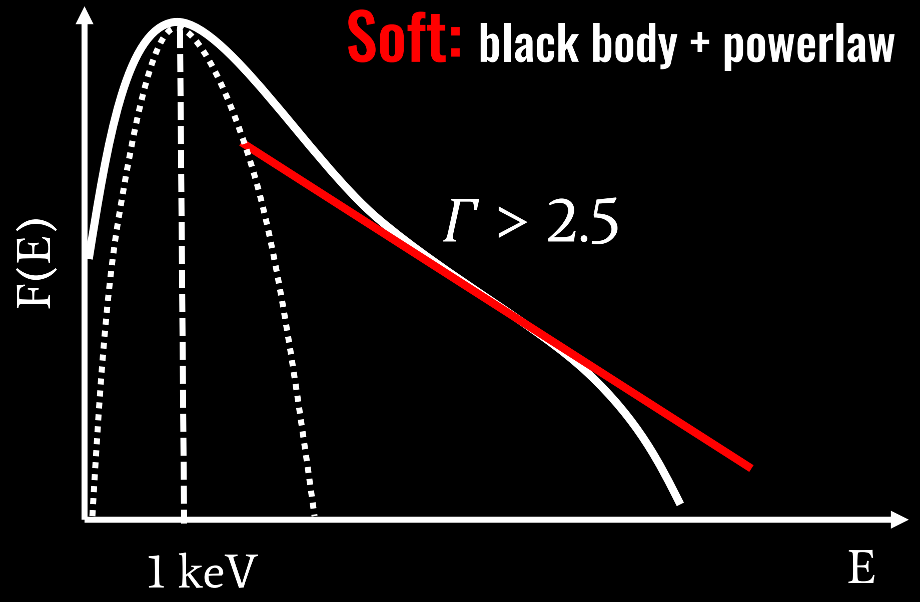
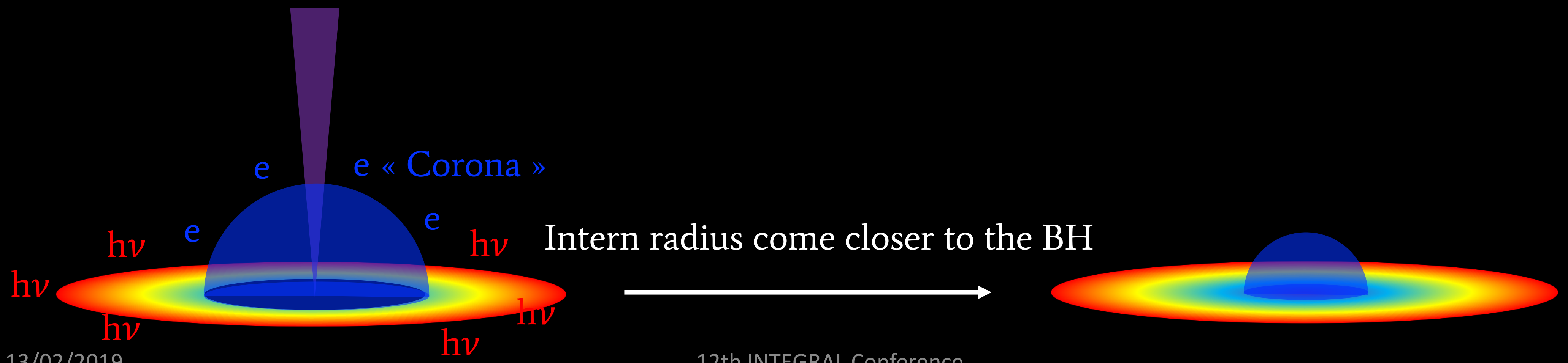
Black holes spectral states







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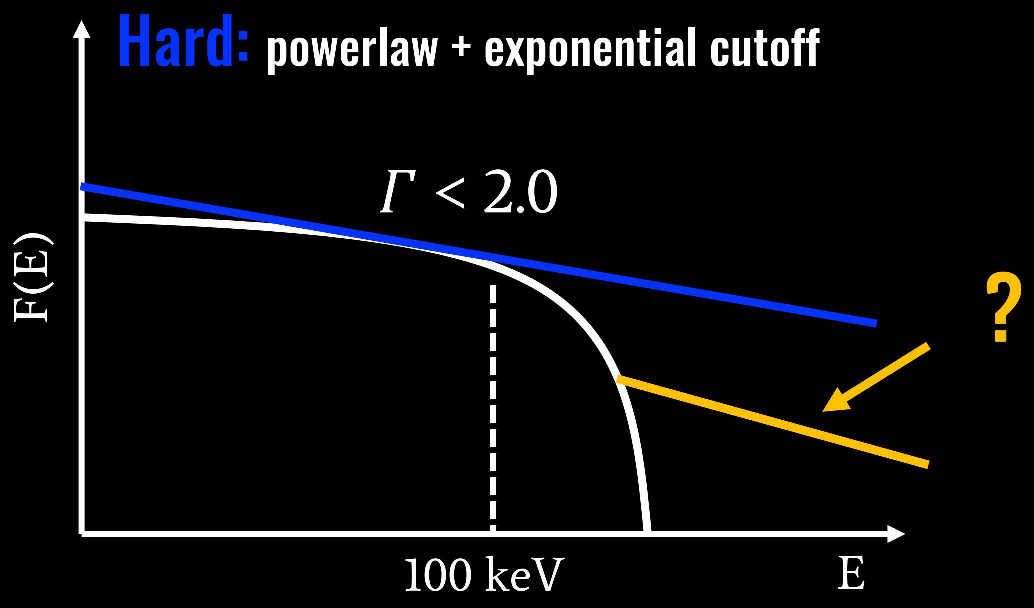
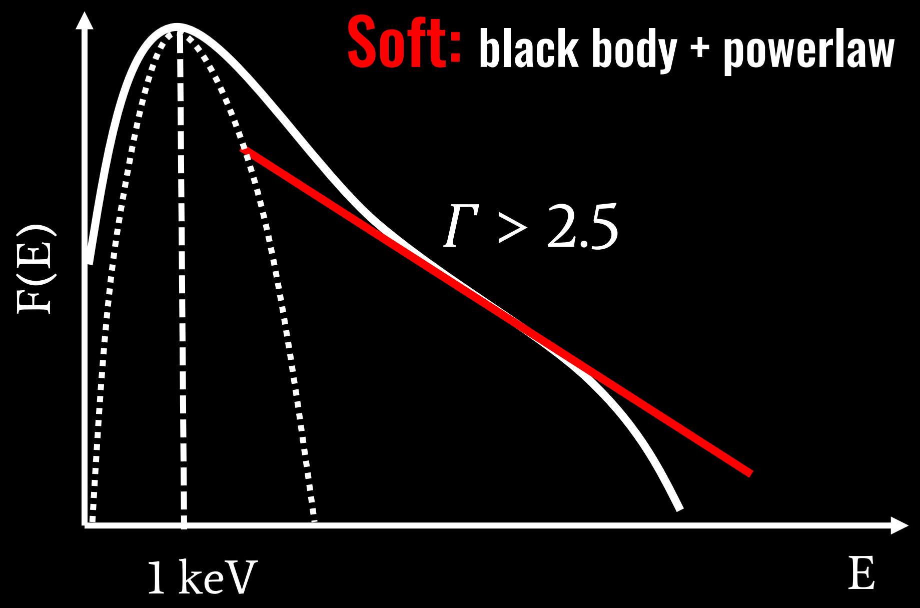
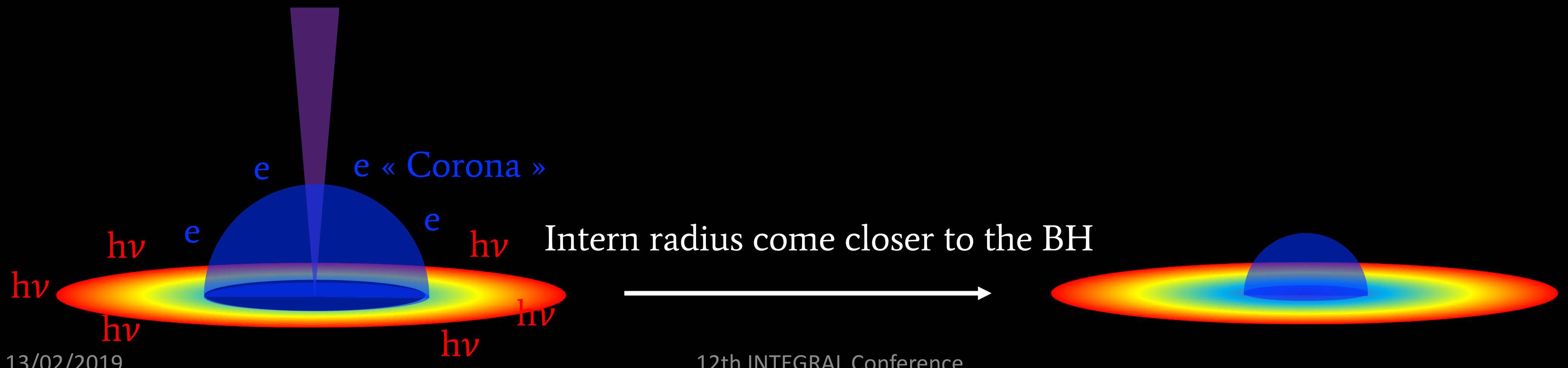
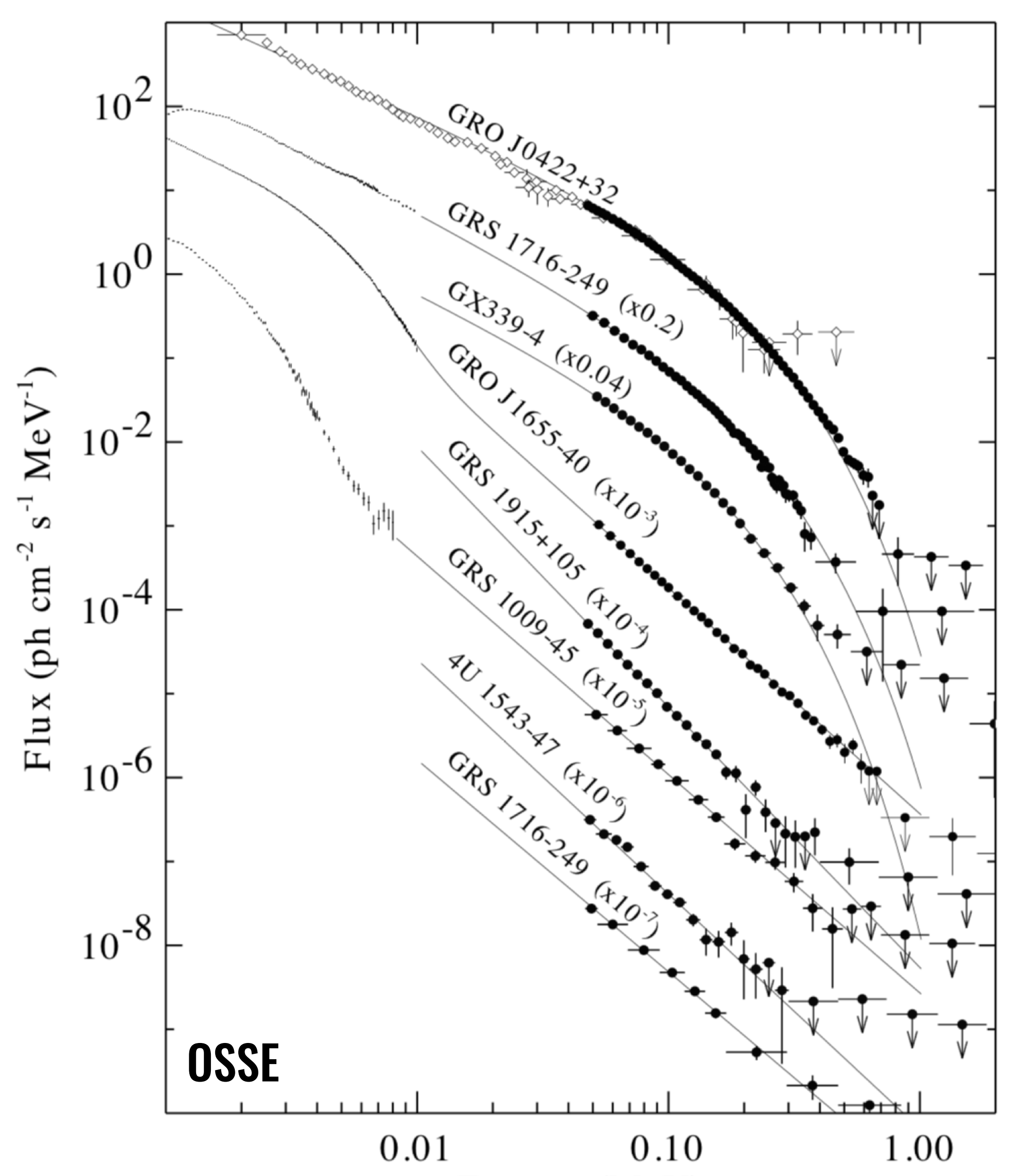






History of the high energy tail



Grove et al. (1998)

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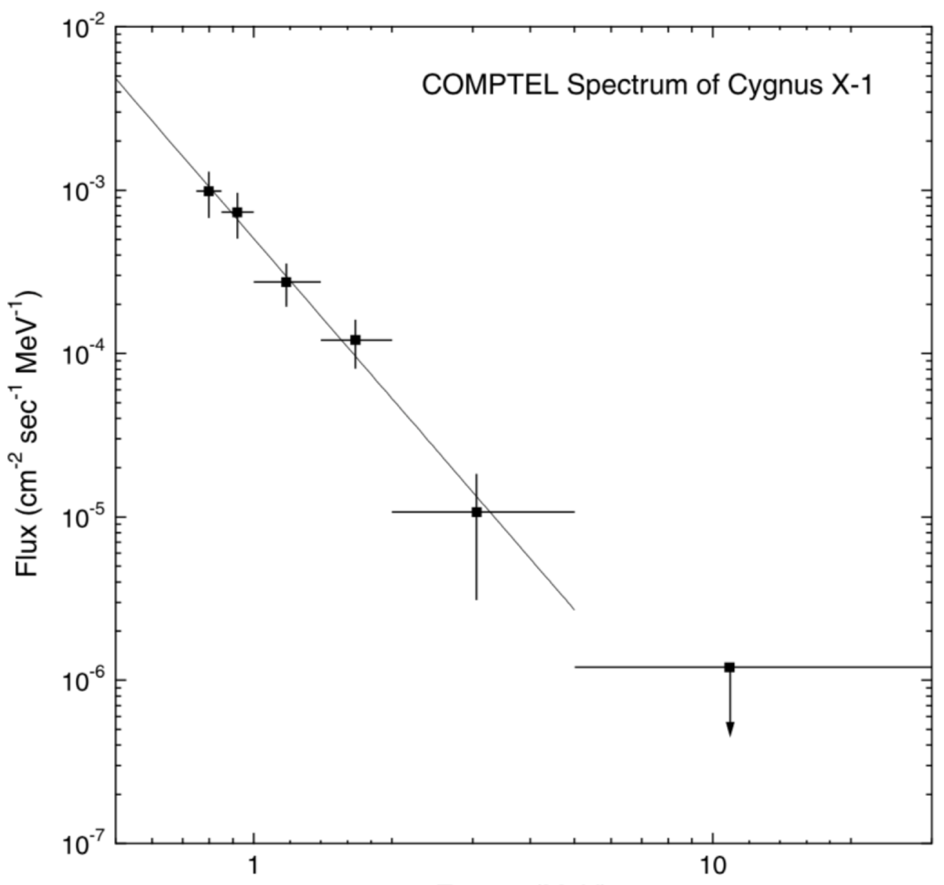

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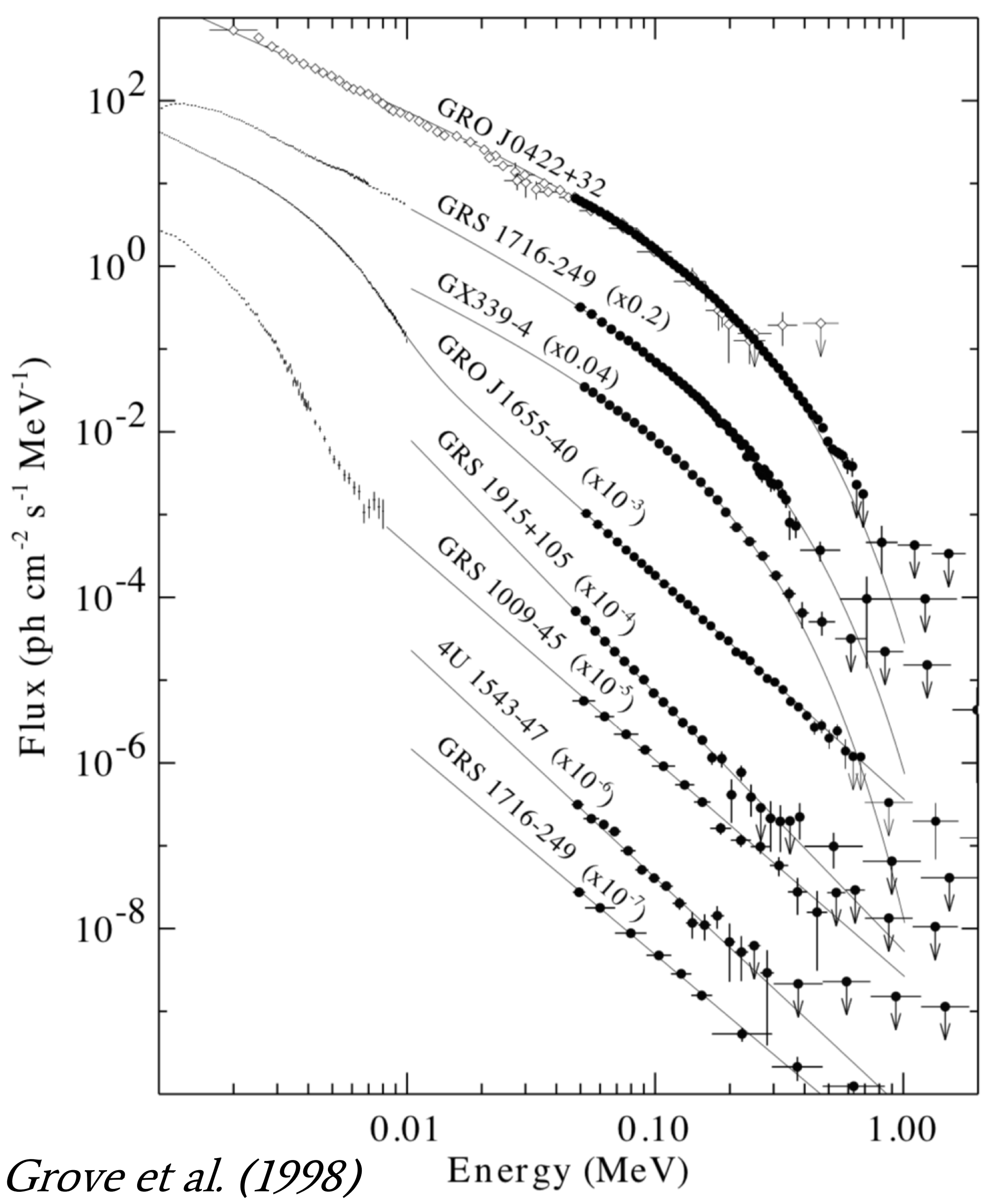

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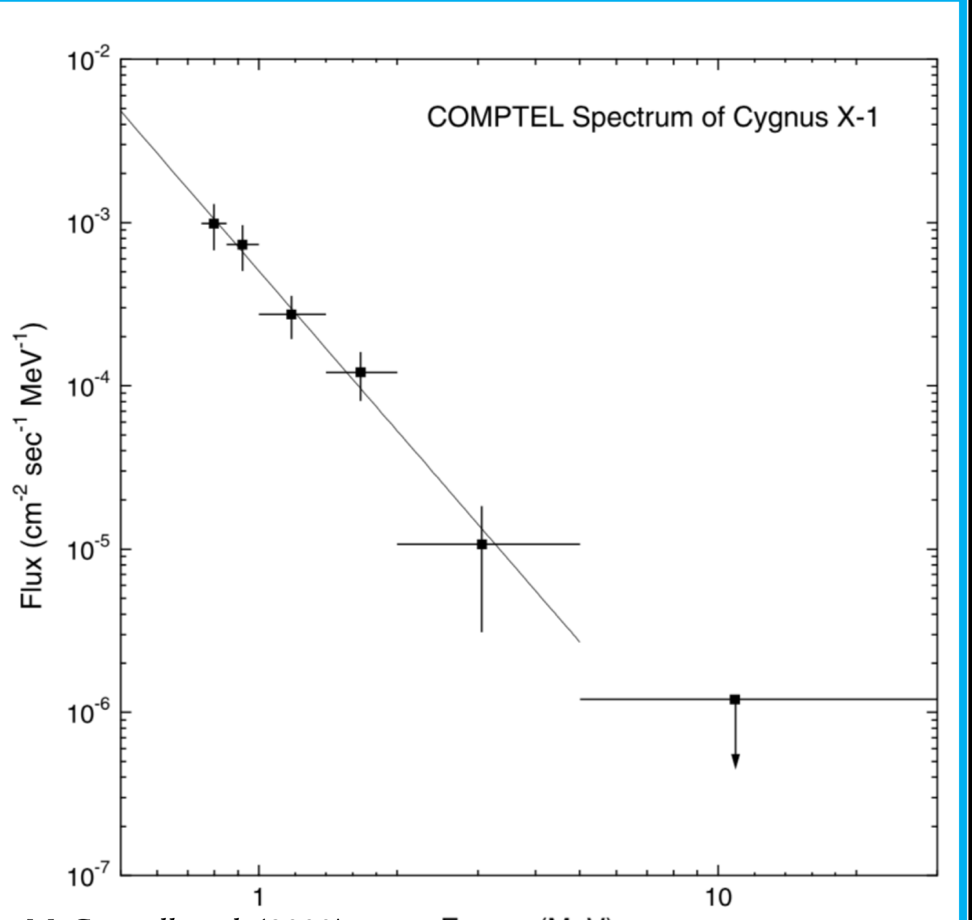

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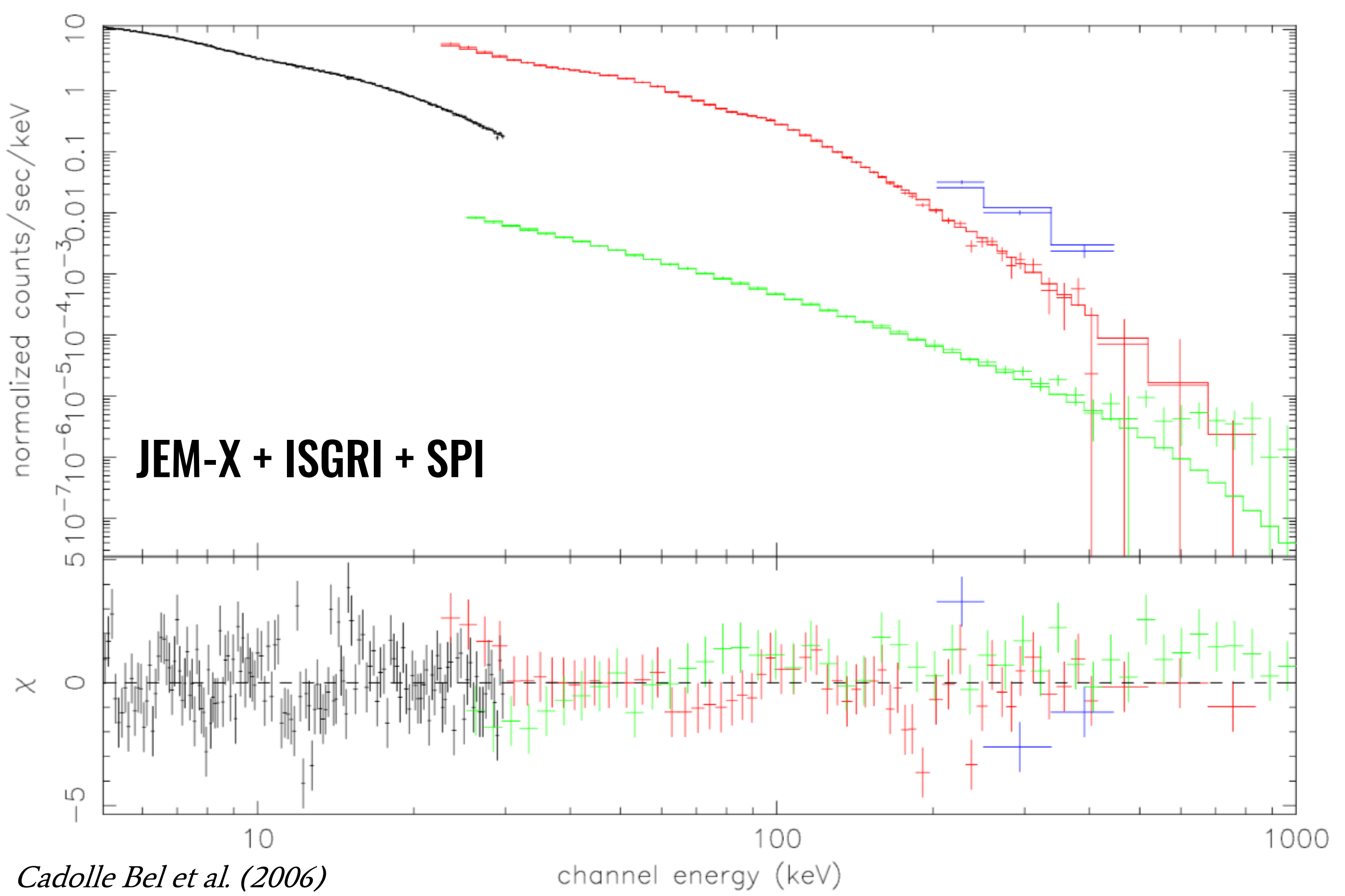

Cadolle Bel et al. (2006)

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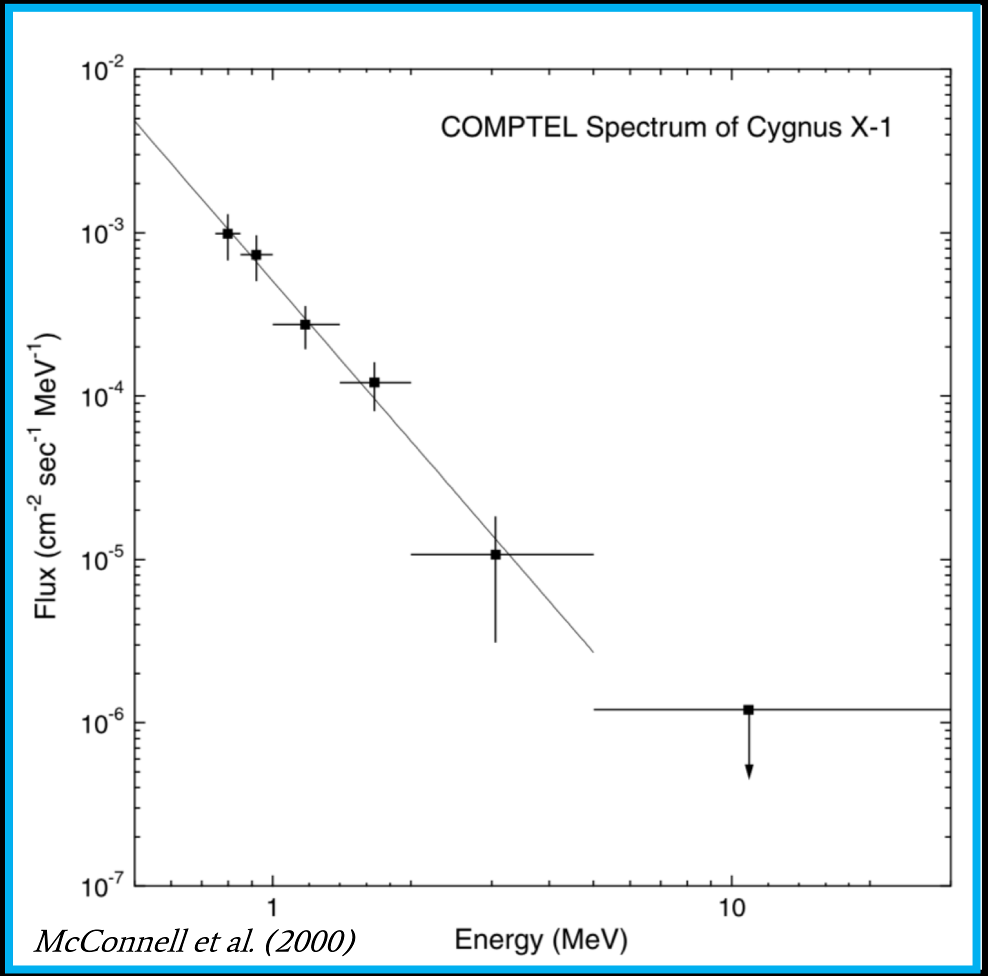

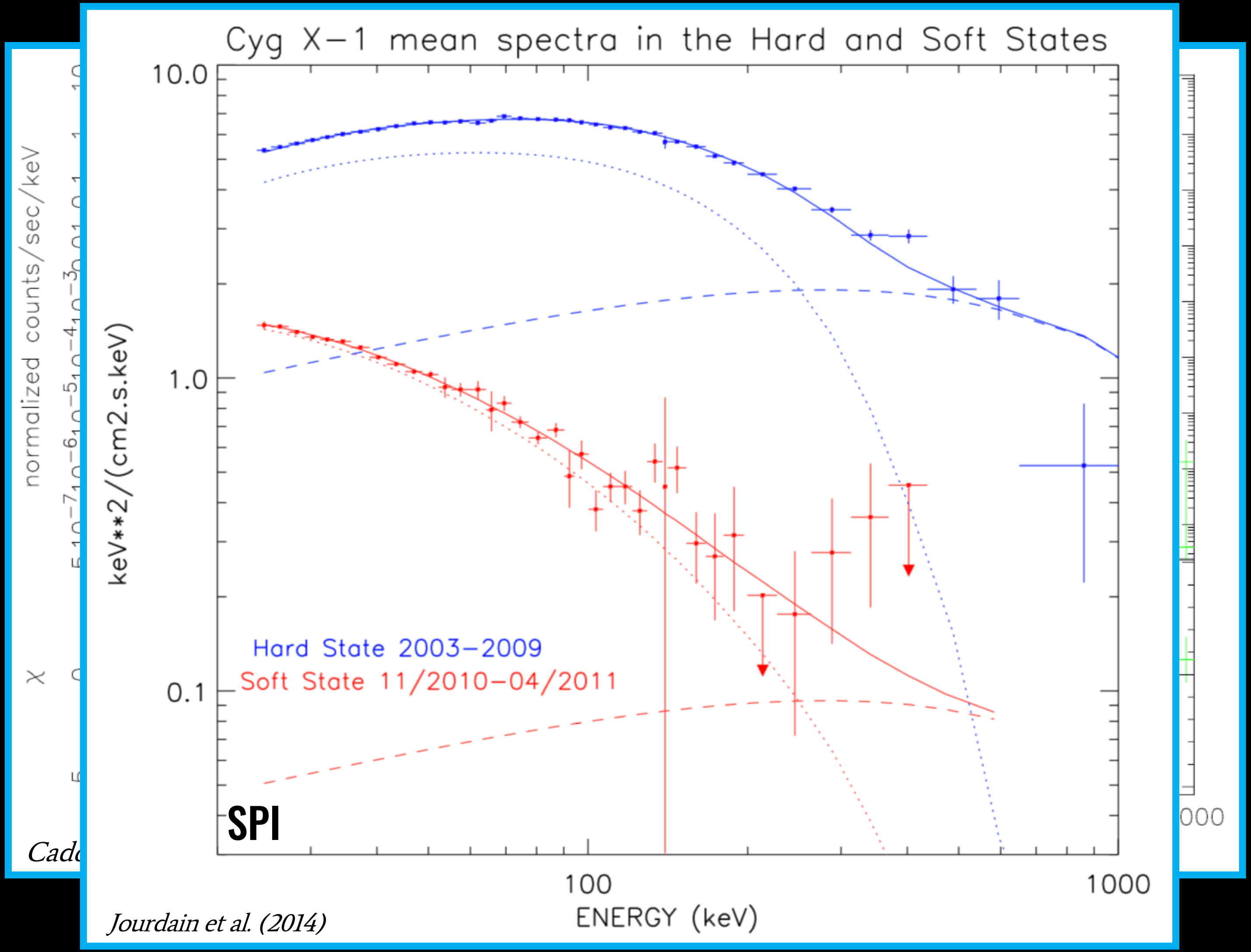

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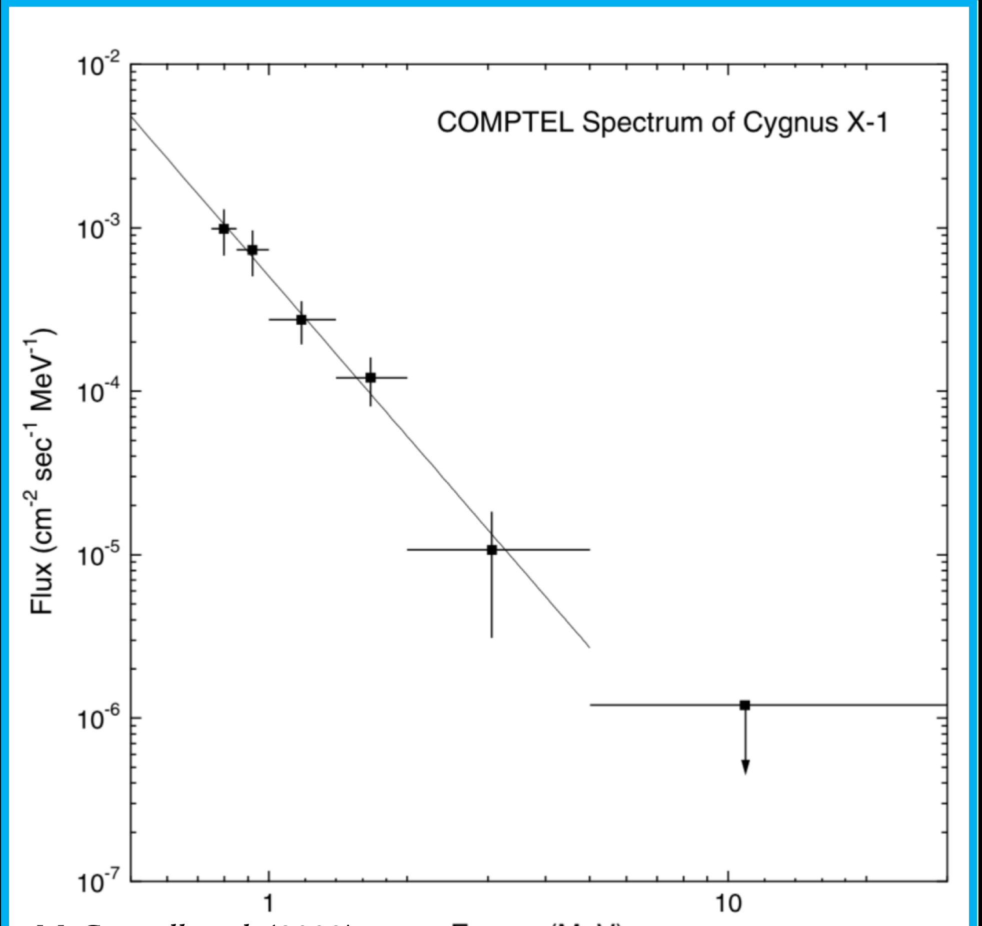

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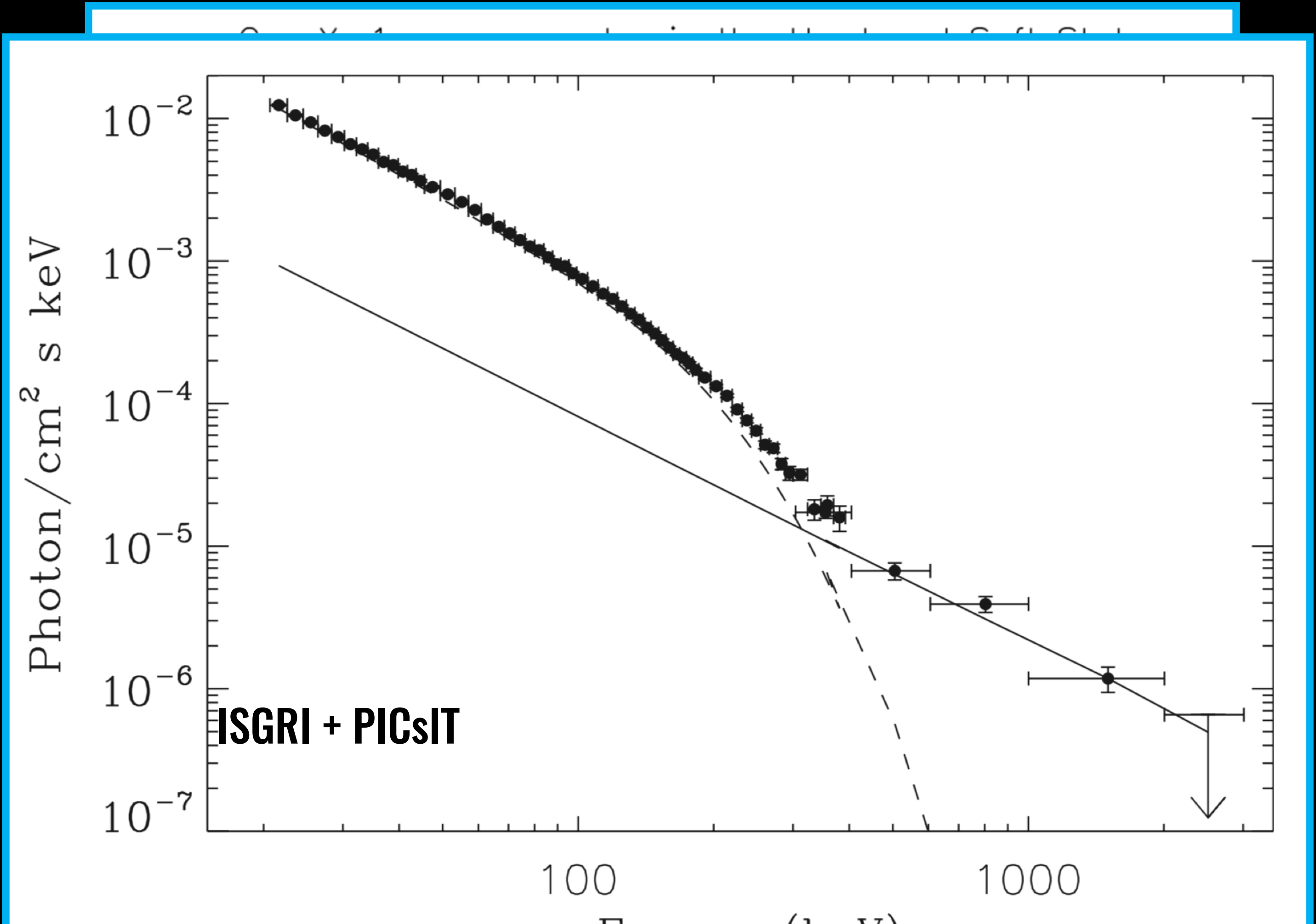
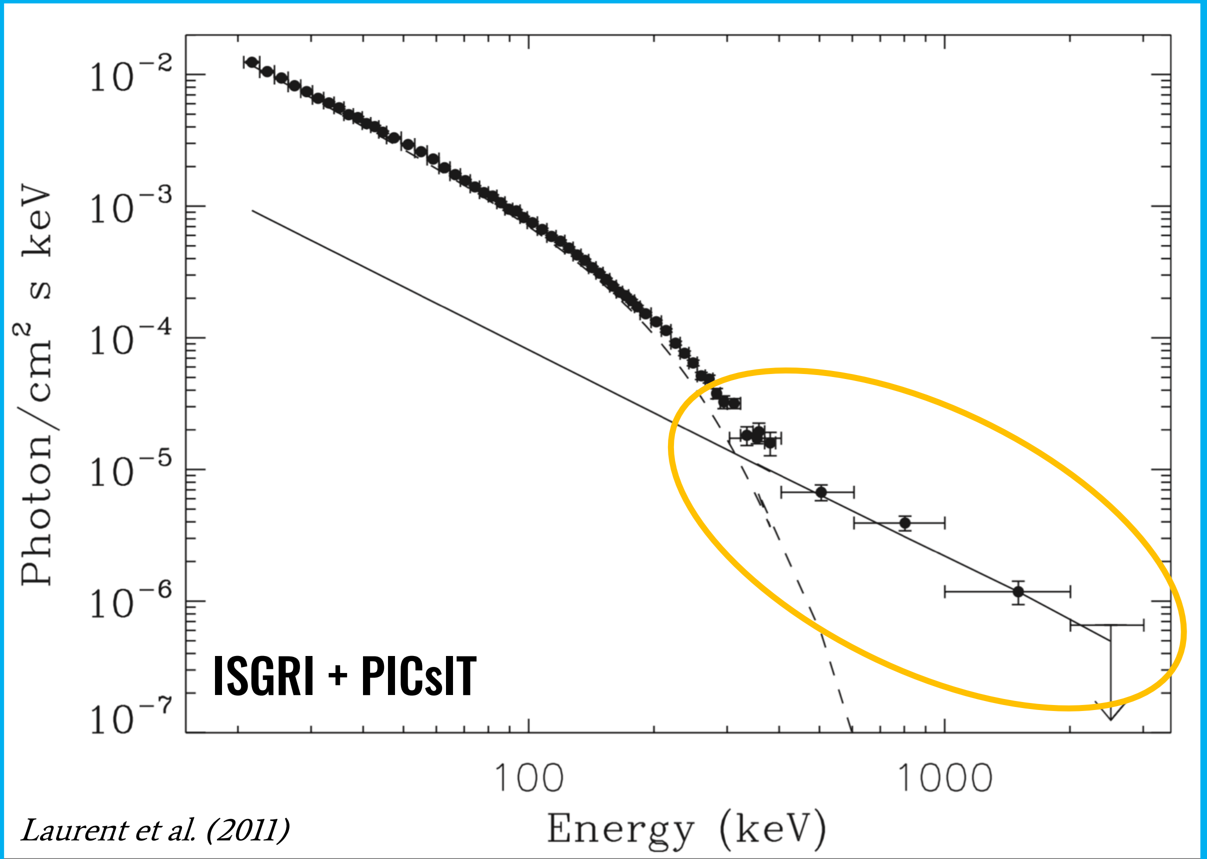


Laurent et al. (2011)

Previous work

2003 - December 2009



Laurent et al. (2011)

Previous work

State-resolved

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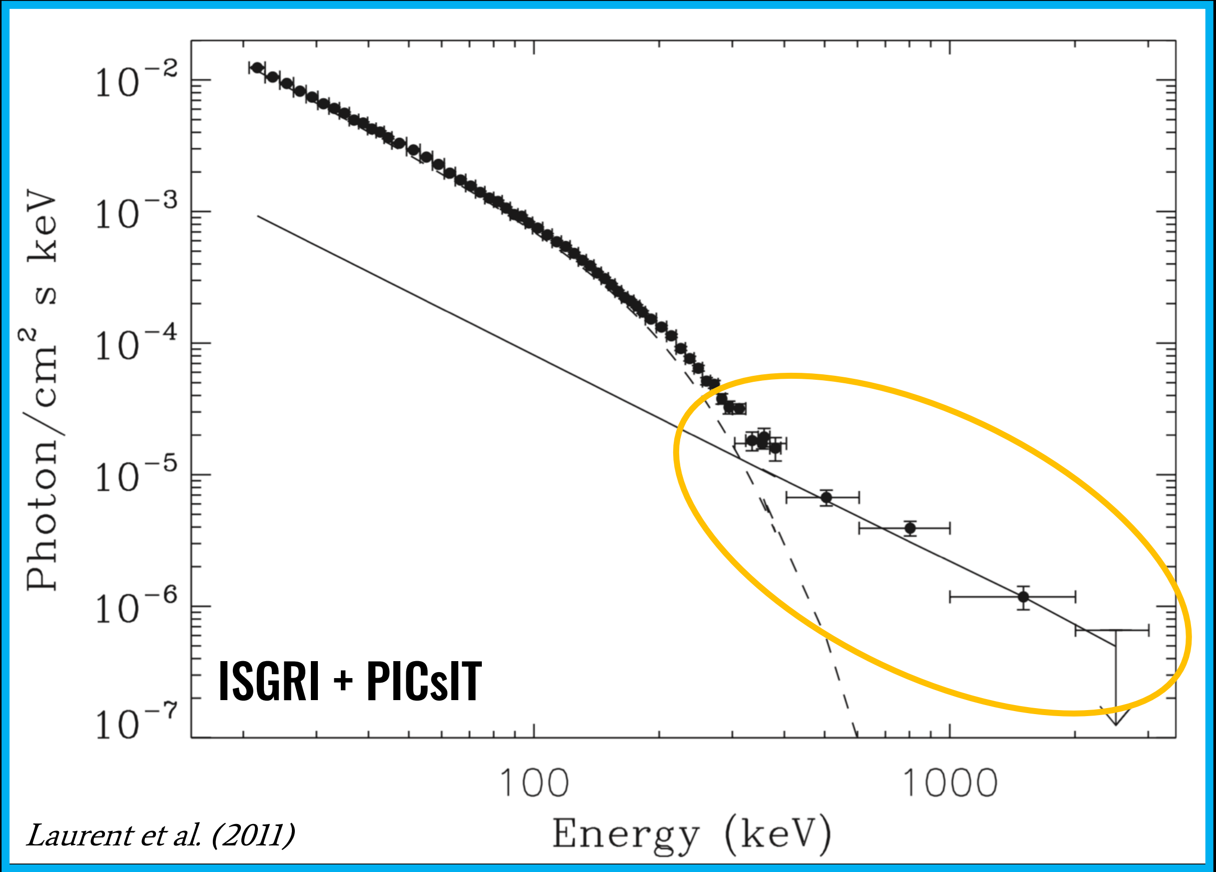
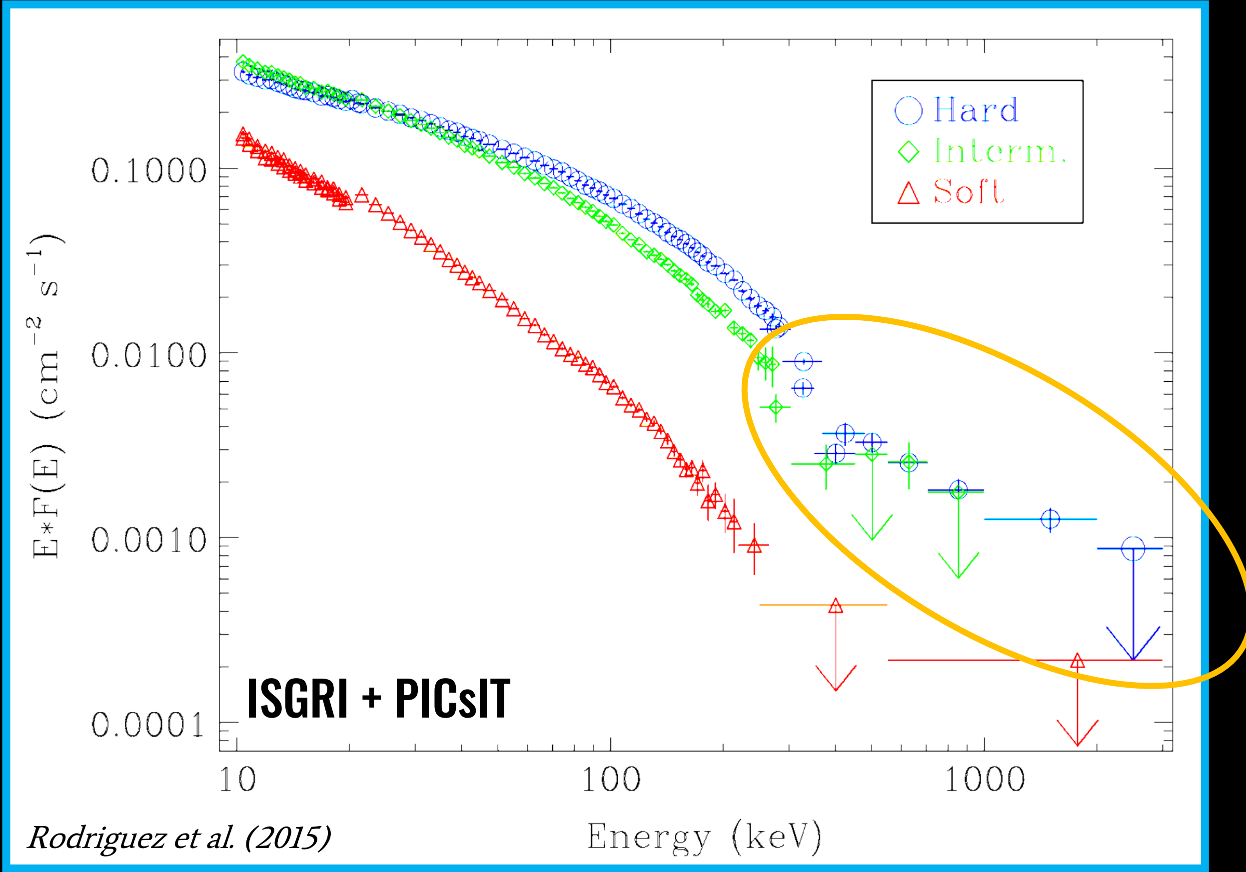
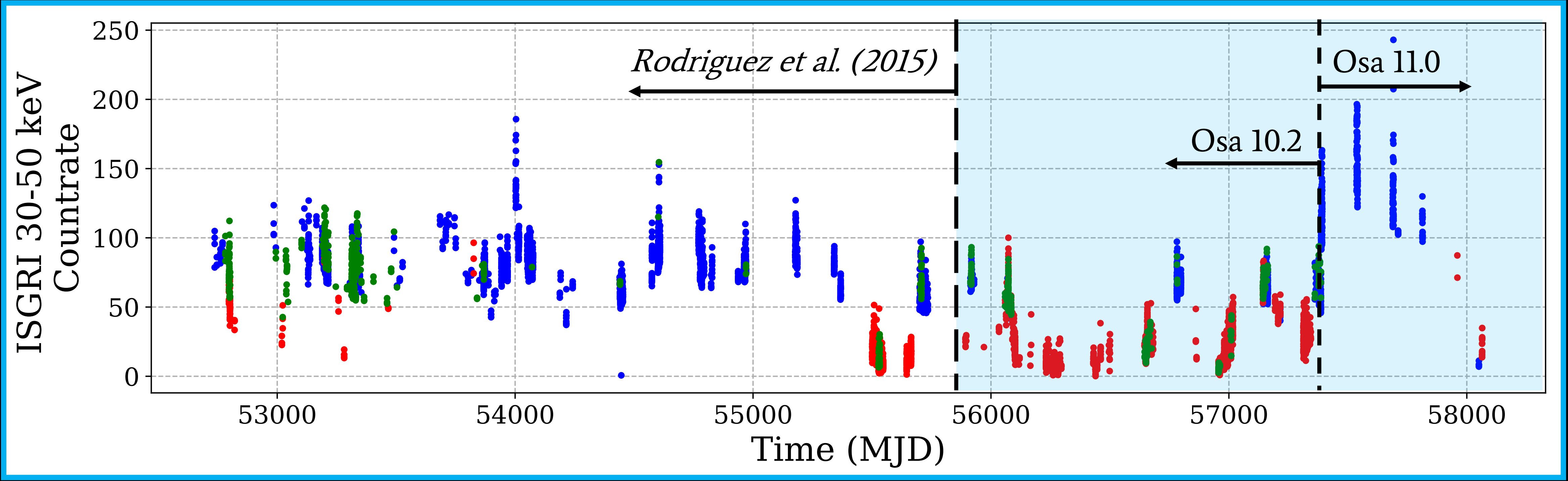
2003 - December 2012





Long-term study



- 15 years of *INTEGRAL* data, 6 years of new data since *Rodriguez et al. (2015)*
- Classification after V. Grinberg method (*Grinberg et al. (2013)*) -> model-independant method
- Recently in the soft state -> more data in the soft state -> more physical constraints
- Stack data for each state -> better statistics than previous work especially in the soft state

Spectral analysis - Results

Broad band spectral study

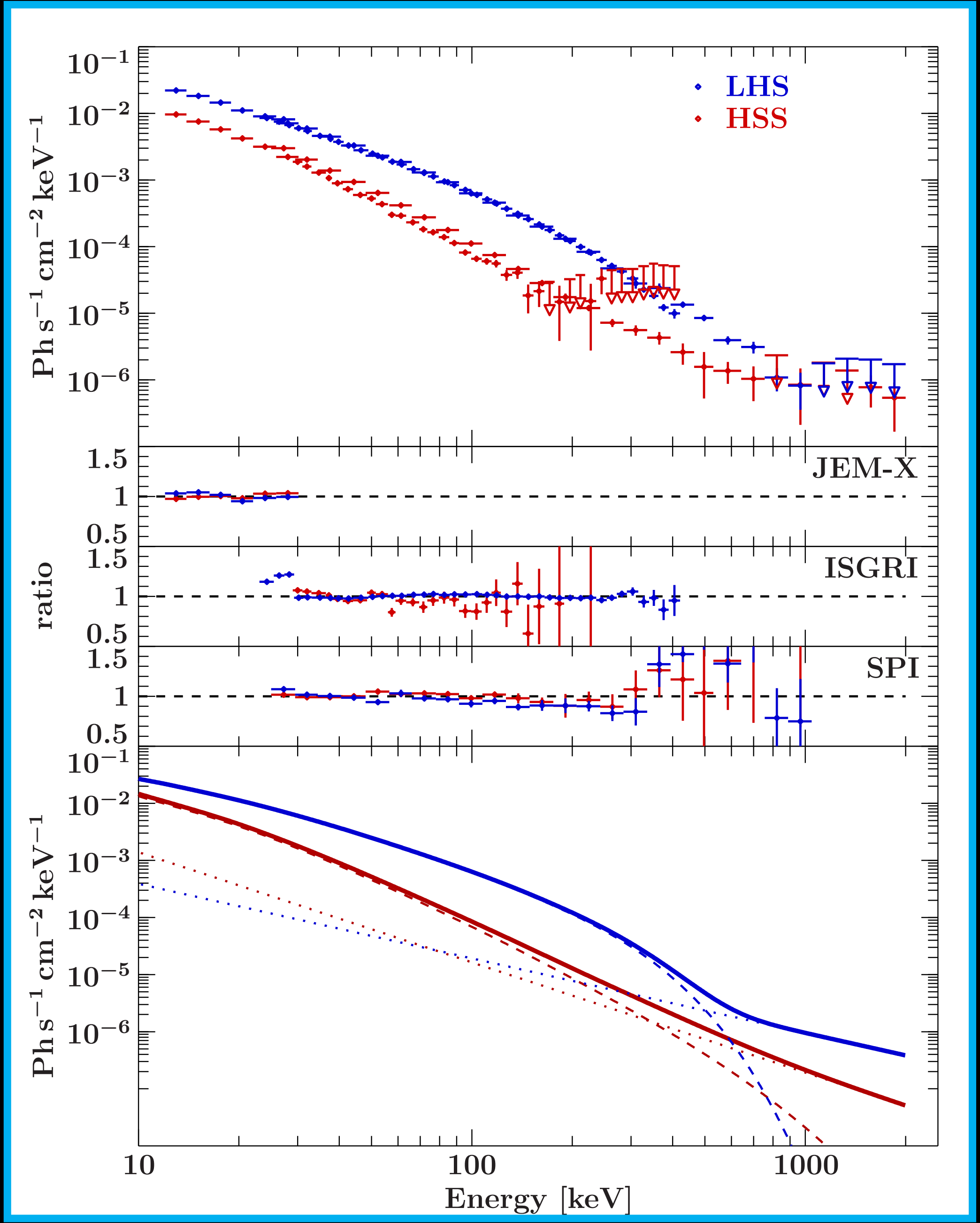
- Using JEM-X, ISGRI and SPI

Results

⟶ Basic approach:

- **Hard state**: reflected Comptonisation + powerlaw tail
- **Soft state**: reflected Componisation + powerlaw tail

	kT (keV)	Γ (powerlaw)	Flux 400 -1000 keV (ergs/cm2/s)
Hard	$63.4^{+1.6}_{-1.7}$	$1.31^{+0.25}_{-0.41}$	$2.1.\,10^{-9}$
Soft	318^{+14}_{-137}	$1.93^{+0.39}_{-0.71}$	$6.6.\,10^{-10}$



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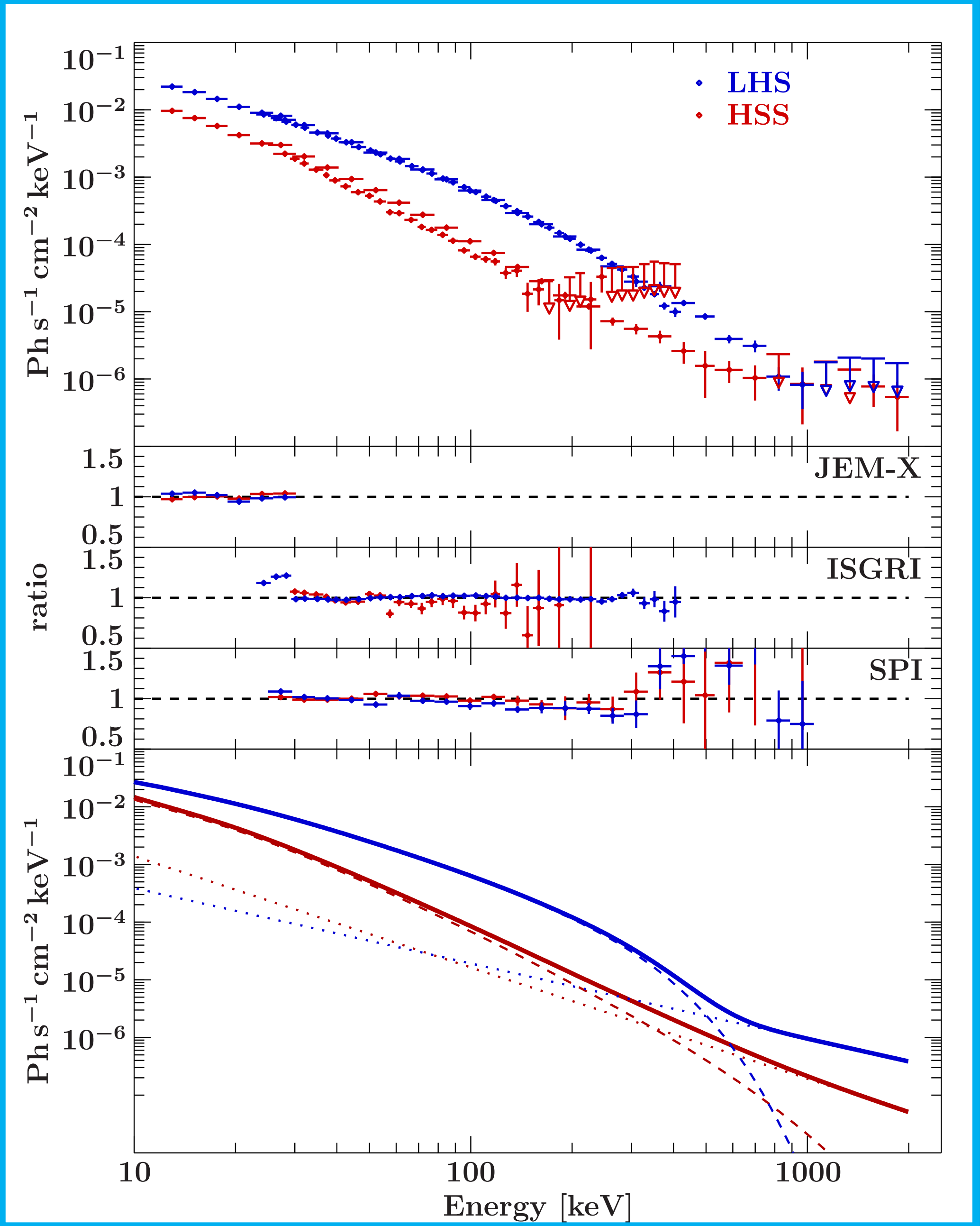

Polarisation with the Compton mode – Preliminary results

Rodriguez et al. (2015)

- Polarised hard tail in the hard state with PA = 40° ± 14° and PF = 75% ± 32%
- Not enough exposure in the soft state

⟶ Synchrotron radiation from the jets?

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- Polarisation detected in the hard state with

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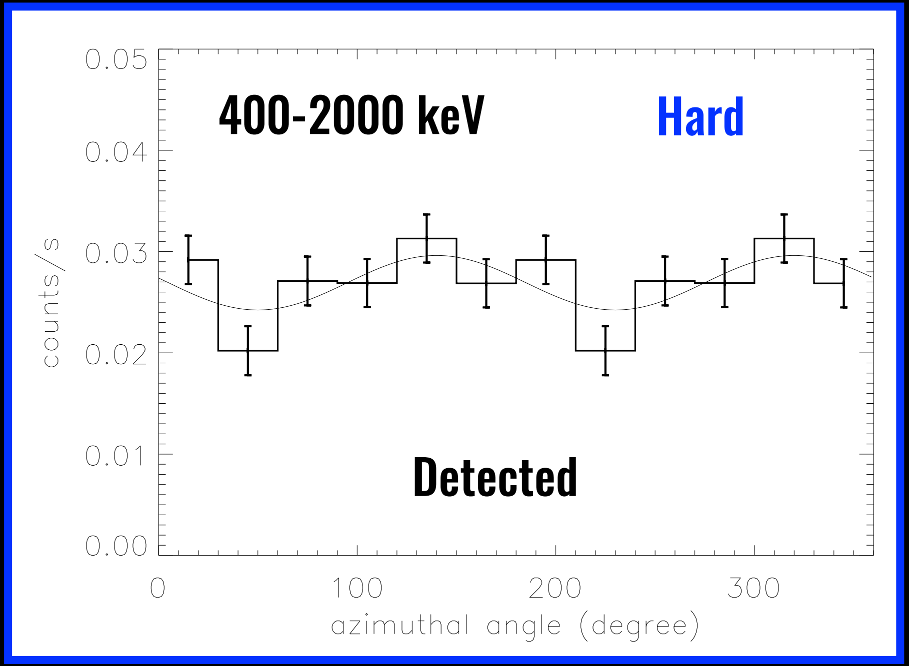

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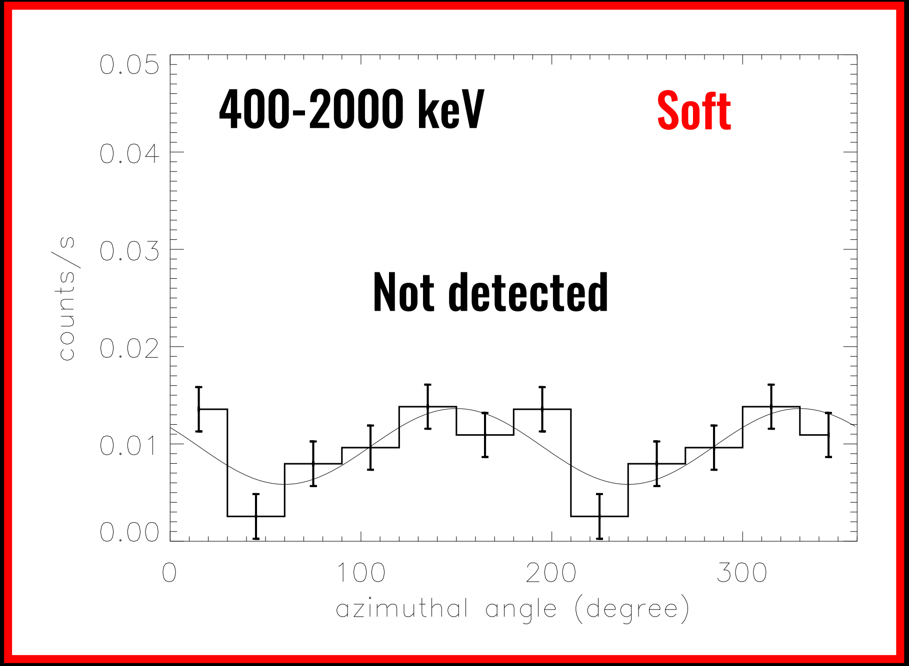
  Upper limit: PF = 51%



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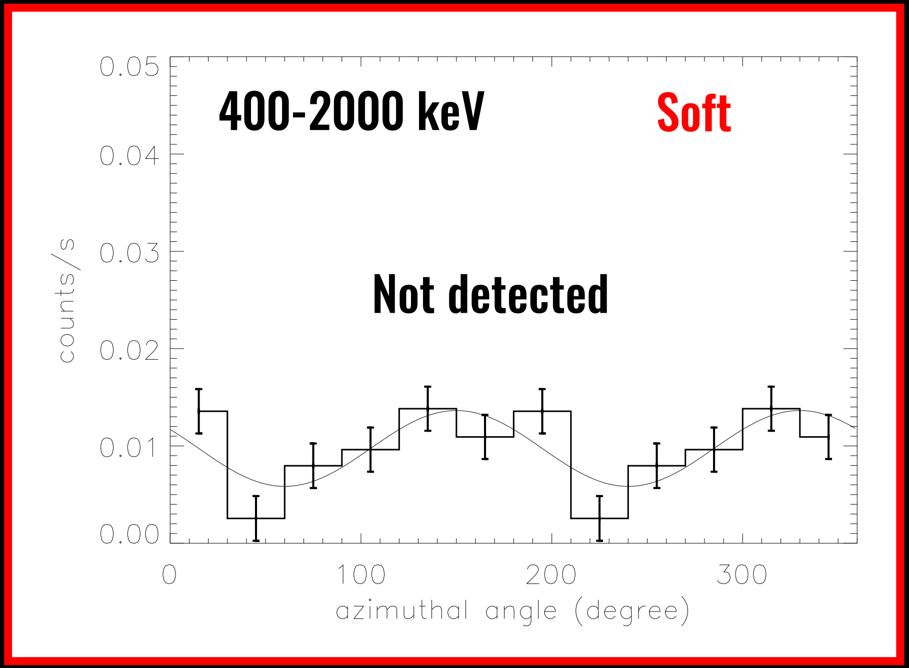
Jourdain et al. (2012)

PA = 40° ± 3° and PF > 75 % above 400 keV with SPI



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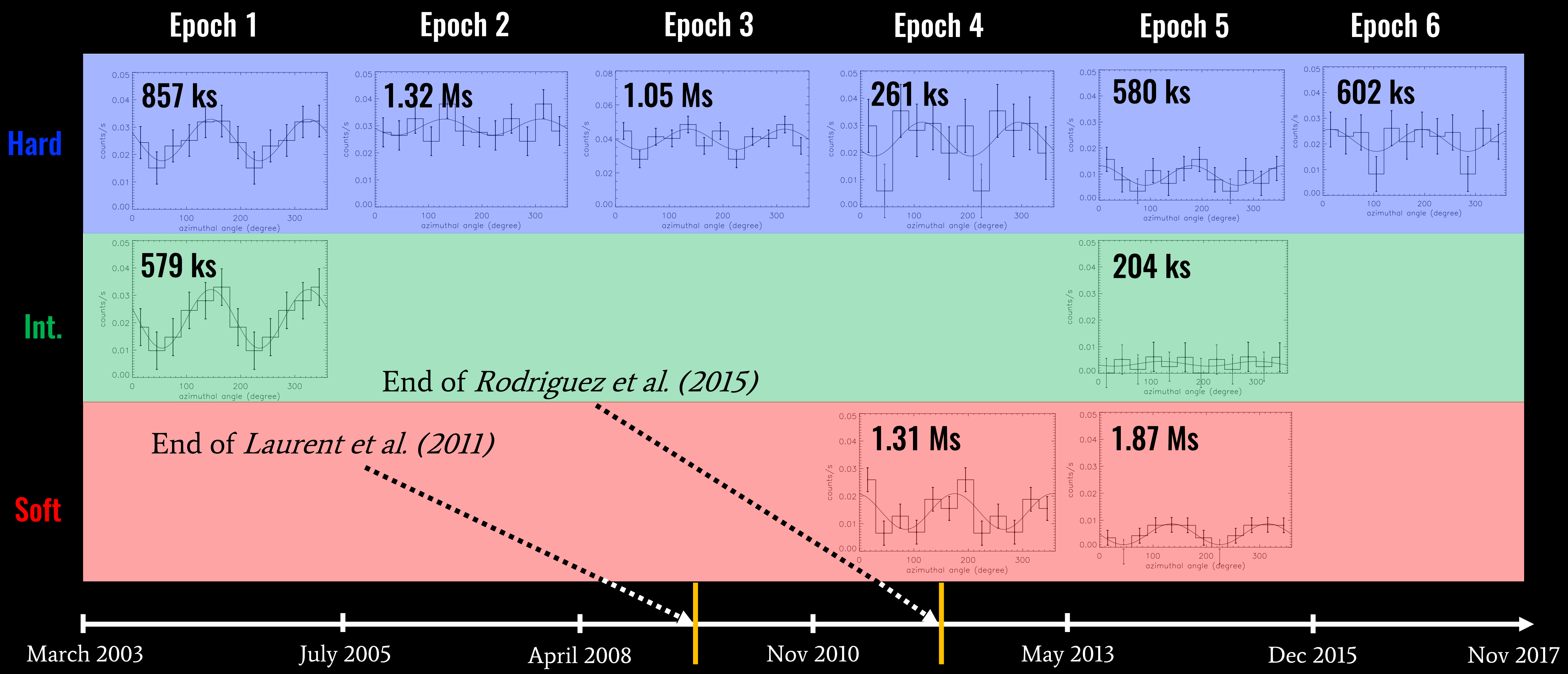

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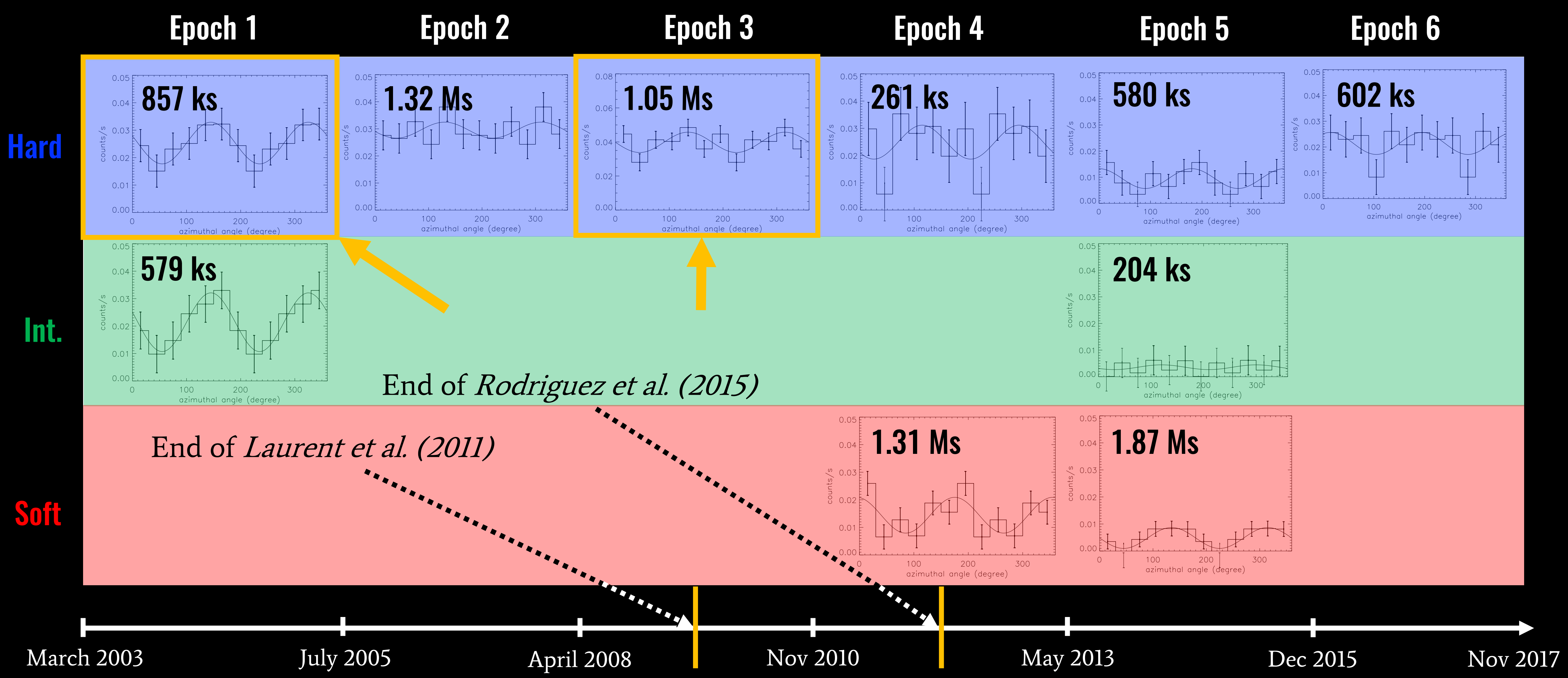

Conclusion and discussion

This study

- Broad band spectral analysis for both states, hard and soft
- Detection of a powerlaw tail at high energy in the hard state and ALSO in the soft state
- Polarisation of the high energy tail in the hard state, never detected in the soft state

Origin of the high powerlaw tail?

Photon index in both states are compatible ⟶ 1) Physical mecanism is the same in both states:

- From the corona:
  - Thermal/non thermal comptonisation: *Romero et al. (2014)* predicted PF = 54% in states where there are no jets
- From the jets:
  - Synchrotron emission (*Laurent et al. (2011), Zdziarski et al. (2012), Rodriguez et al. (2015)*), what about the soft state ? ⟶ Dark jets (*Drappeau et al. (2017)*) but we could not see synchrotron emission

2) Physical mecanism is not the same in both states ⟶ synchrotron emission in the hard state and another mecanism in the soft state

Perspectives

- Do a spectral analysis with more physical models as eqpair, belm…
- Consolidate the polarisation results
- Evolution of the polarisation? Idea: discrete ejections can modify the magnetic field configuration and so disrupt polarisation
- Confrontation to radio data (AMI data)

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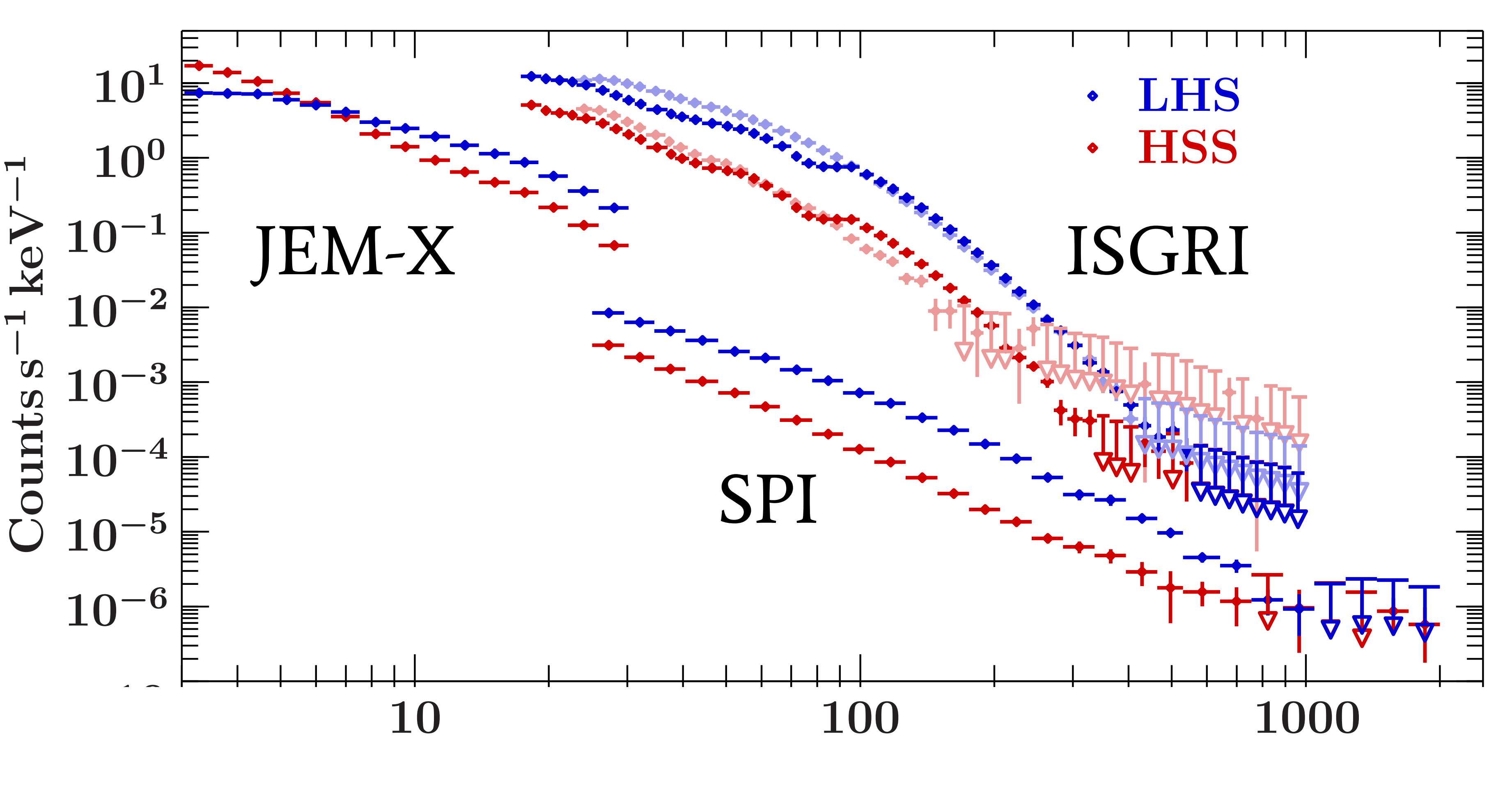
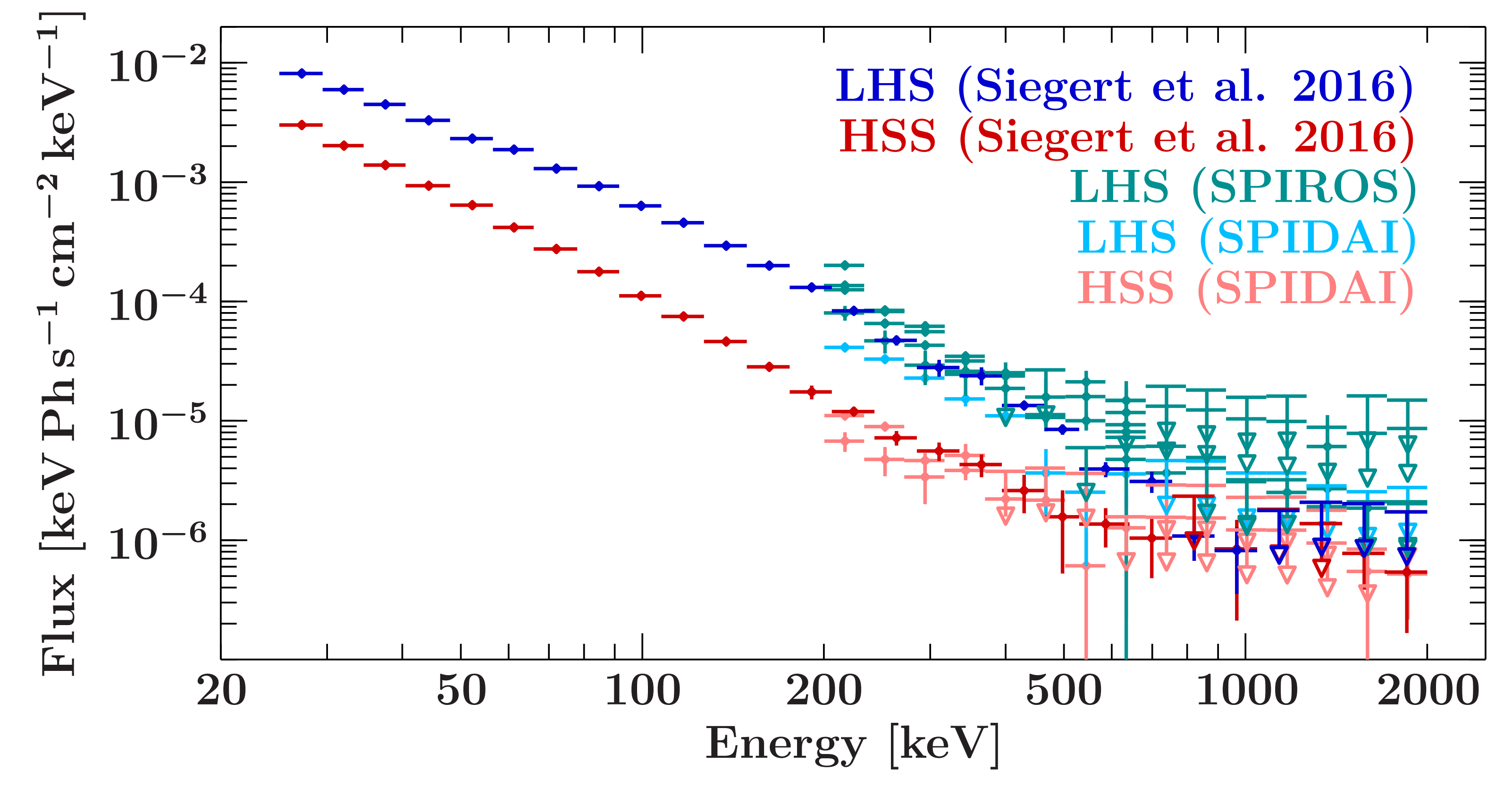
Thank you for your attention…

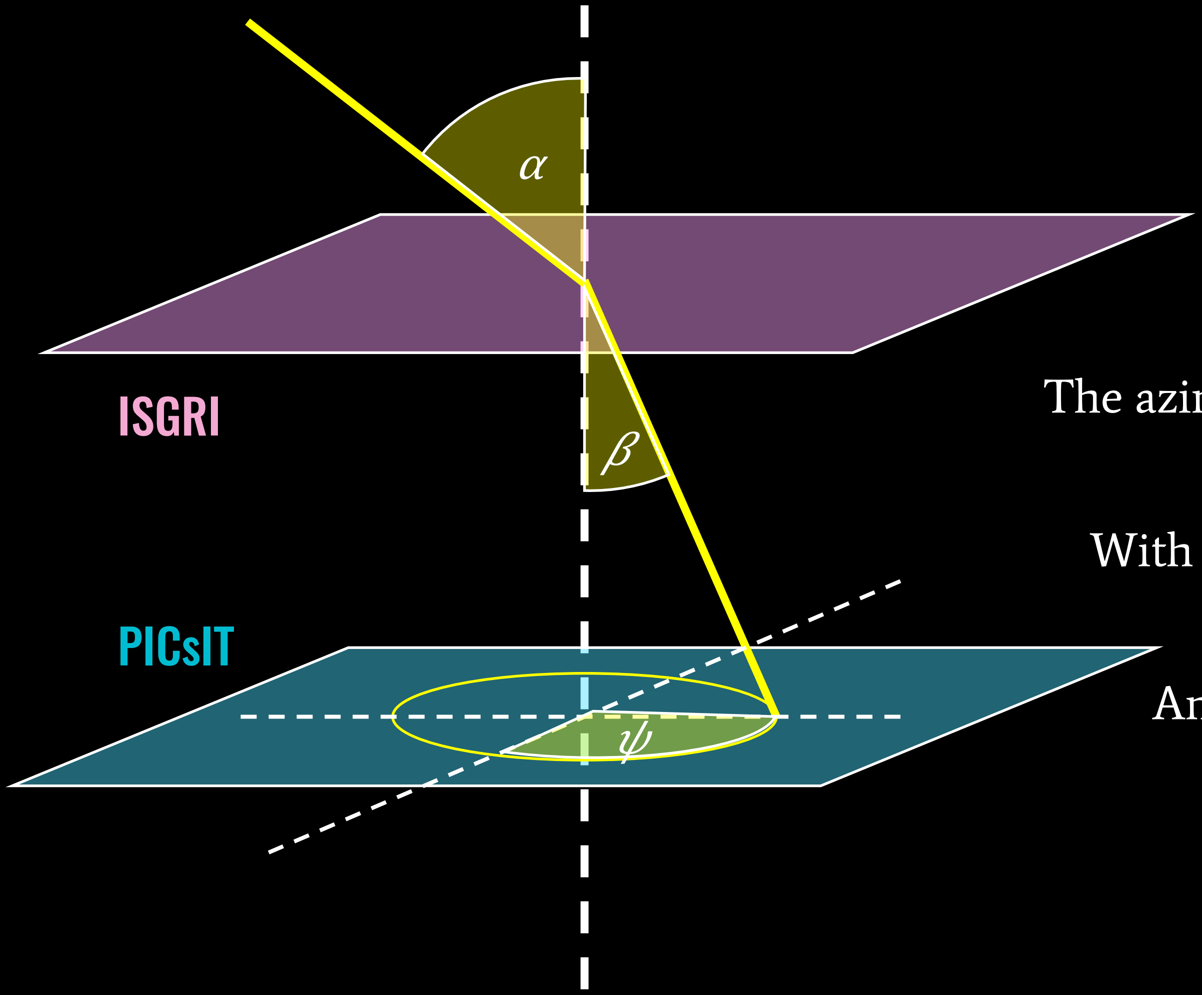
Spectral analysis – Unfolded spectrum

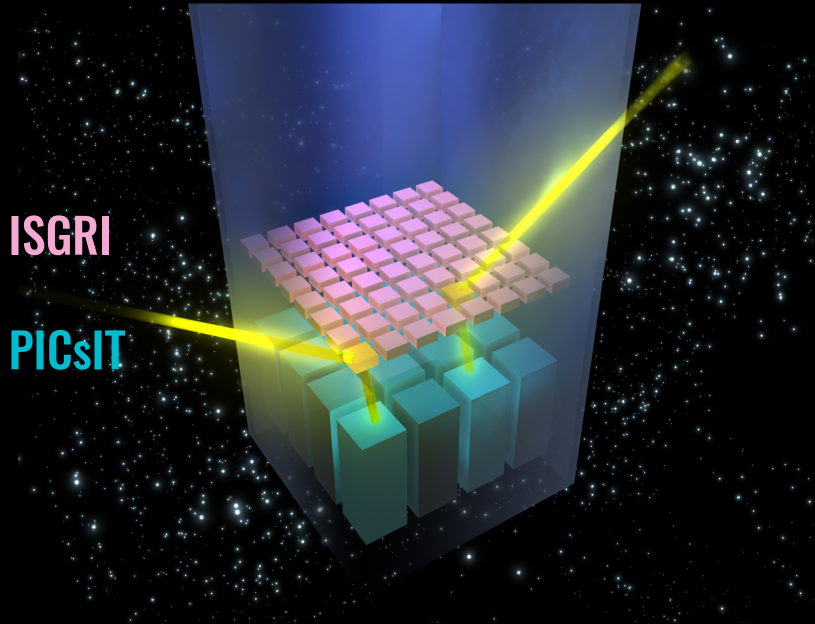


Spectral analysis – SPI



Mesure of polarisation



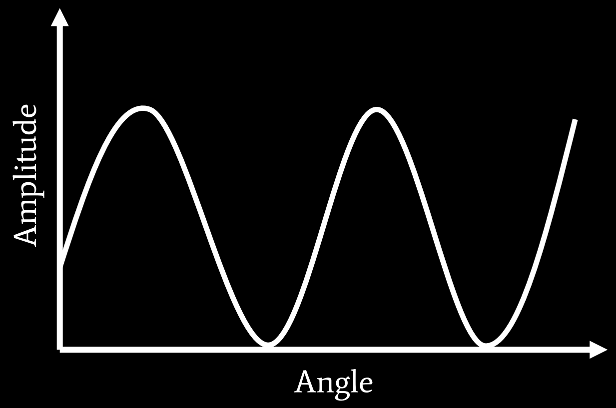


The azimuthal profile follows: $\boxed{N(\psi) = S[1 + a_0 \cos(2\psi - 2\psi_0)]}$

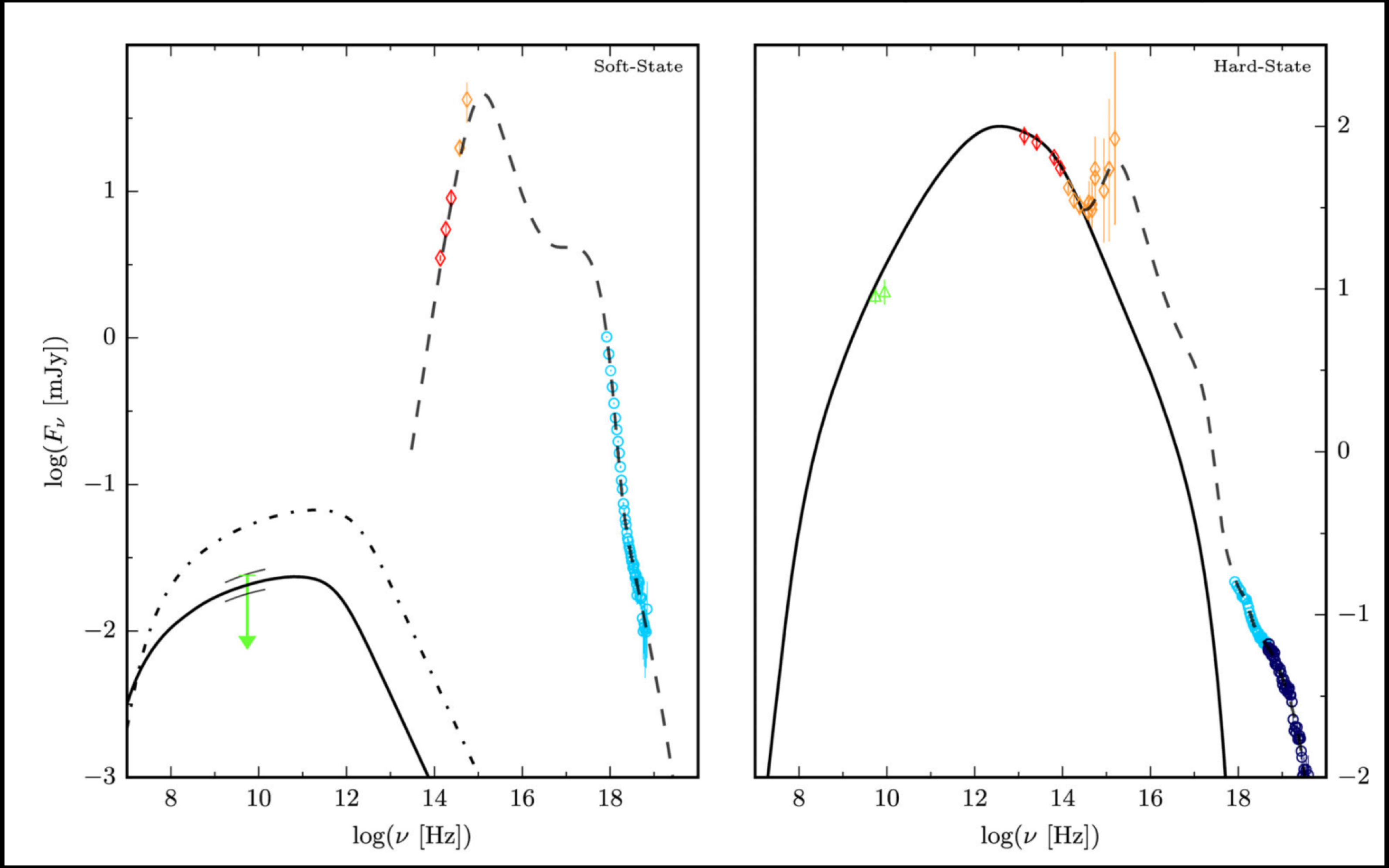
With Polarisation Fraction: $\boxed{PF = {}^{a_0}/_{a_{100}}}$

And Polarisation Angle:

$\boxed{PA = \psi_0 - {}^{\pi}/_{2}}$



Dark Jets



Spectral analysis - Parameters

Soft comptonisation			Hard comptonisation			Reflection	Power law	Disc
kT (keV)	τ	T_0 (keV)	kT (keV)	τ	T_0 (keV)	$^{\Omega}/_{2}$	Γ	kT_{disc}(keV)
4.4 ± 0.8	$3.7^{+3.9}_{-0.7}$	$0.018^{+0.983}_{-0.008}$	58^{+6}_{-5}	1.42 ± 0.12	$1.2^{+0.5}_{-0.7}$	$2.3^{+0.6}_{-0.5}$	$2.01^{+0.07}_{-0.211}$	-
-	-	-	330^{+7}_{-162}	$0.01^{+0.04}_{-0.00}$	$0.32^{+0.12}_{-0.16}$	$1.04^{+0.21}_{-0.19}$	$0.59^{+1.37}_{-0.09}$	1.03 ± 0.05

Spectral analysis - Results

Broad band spectral study

- Using JEM-X, ISGRI and SPI

Results

- Hard state: combination of a soft and hard thermal reflected comptonisation + powerlaw tail to describe the high energy tail
- Soft state: reflected componisation + disc + powerlaw tail

Soft comptonisation		Hard comptonisation		Reflect	Power law	Disc
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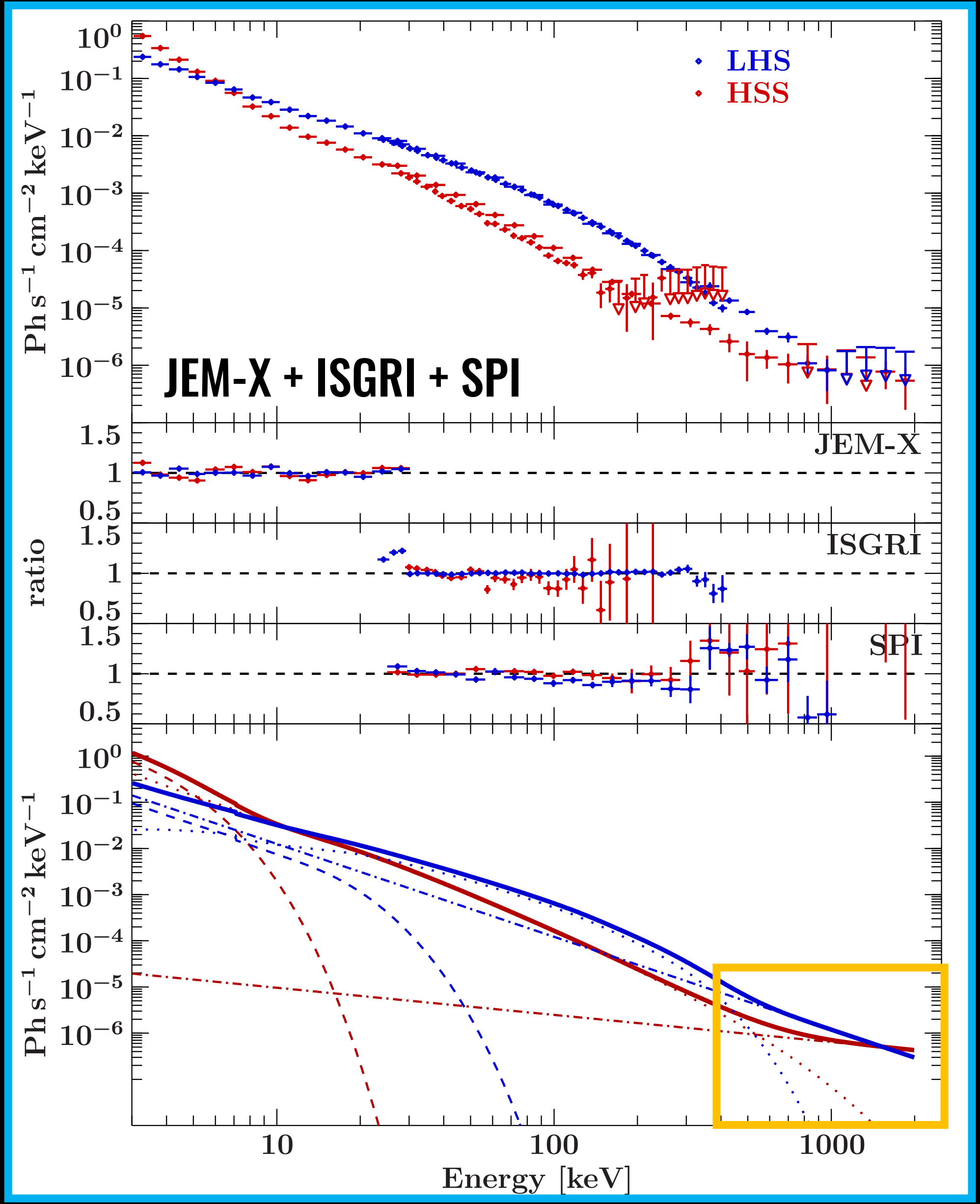
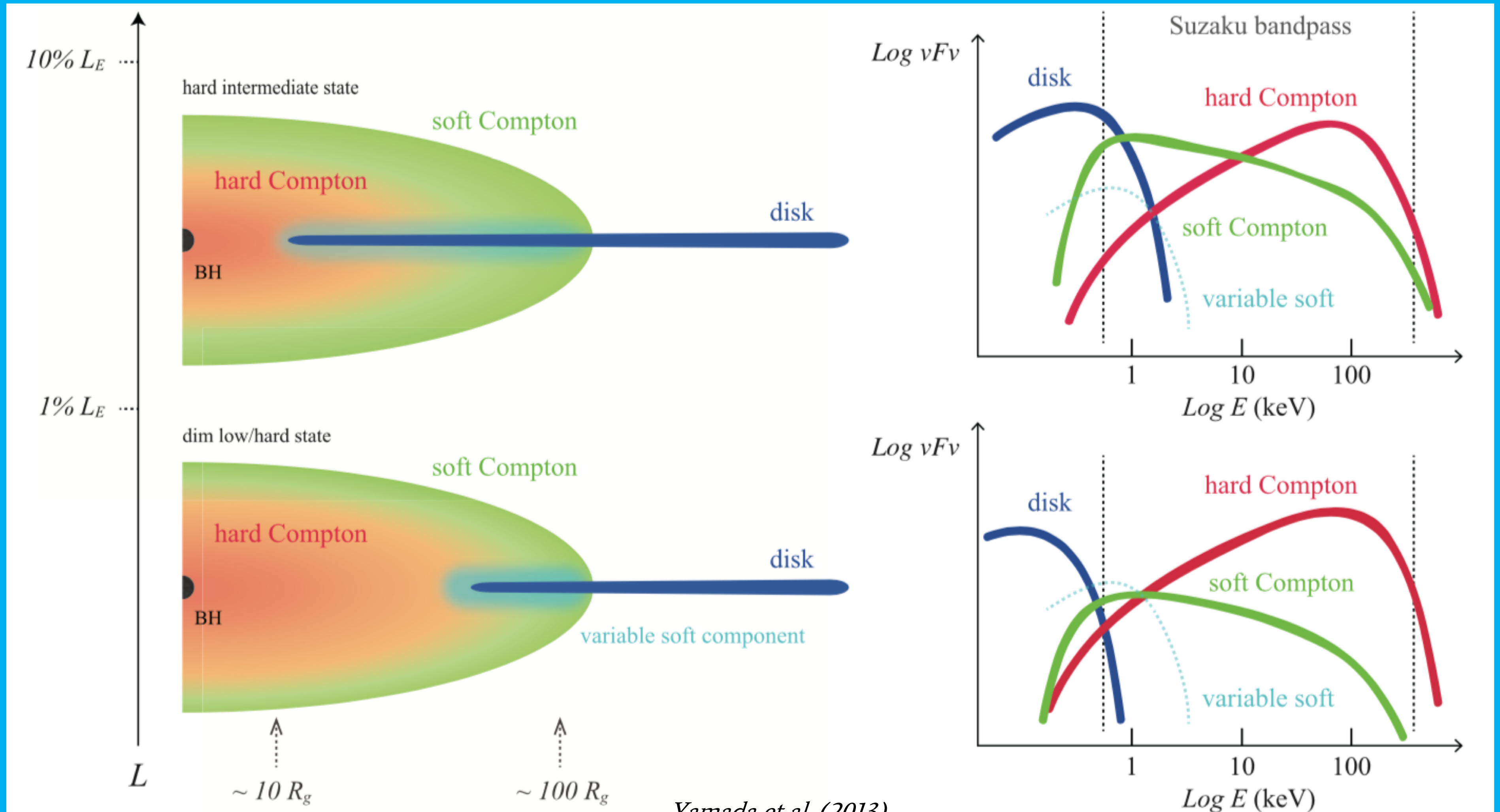


Two comptonisation components



Yamada et al. (2013)