

The average hard X-ray spectrum of NLS1's (and of other classes of Seyferts)

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**Ricci et al. 2011,
A&A accepted**

Study of the average hard X-ray spectra of Seyfert galaxies through stacking analysis of INTEGRAL IBIS/ISGRI images

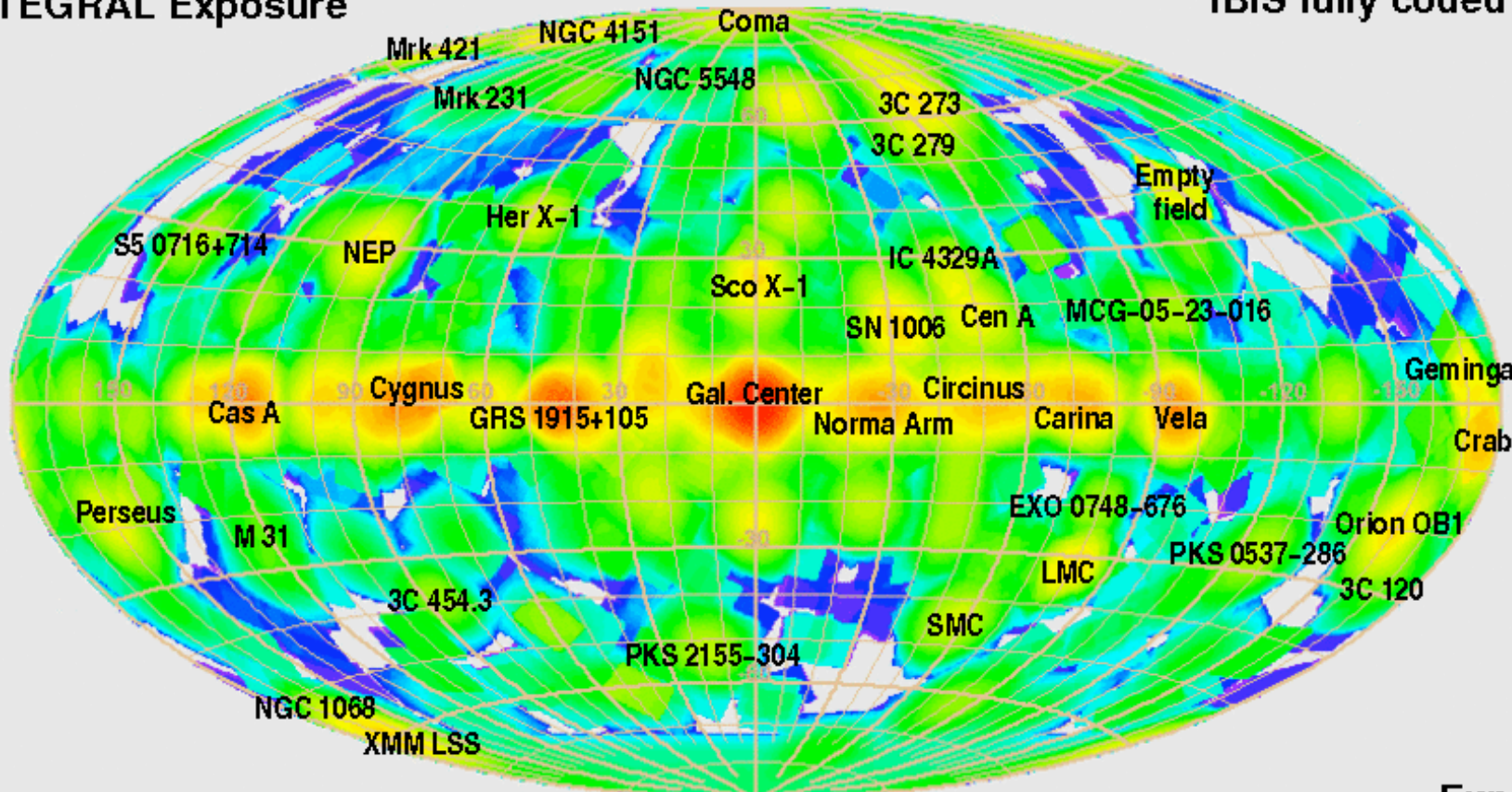
- INTEGRAL
- NLS1 in the hard X-rays
- The stacking analysis
- The average hard X-ray spectra of NLS1 and other classes of Seyfert galaxies
- Summary & Conclusions

- ESA mission launched on 2002, October 17
- Four instruments coaligned instruments and simultaneously working
- ~1000 sources detected
- Data received as Science Windows (Scw) ~ ½ hour

Credit: ISDC website

INTEGRAL Exposure

IBIS fully coded field of view



Revolutions 1 to 800

Exposure [sec]

Optically selected NLS1's

10-20% of Sy1's (Williams, Mathur & Pogge 2003)

Soft X-ray selected NLS1's

~50% (e.g. Grupe 2004)

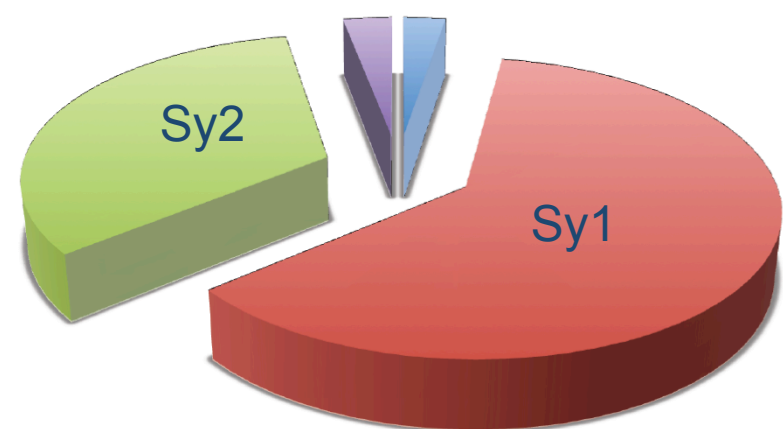
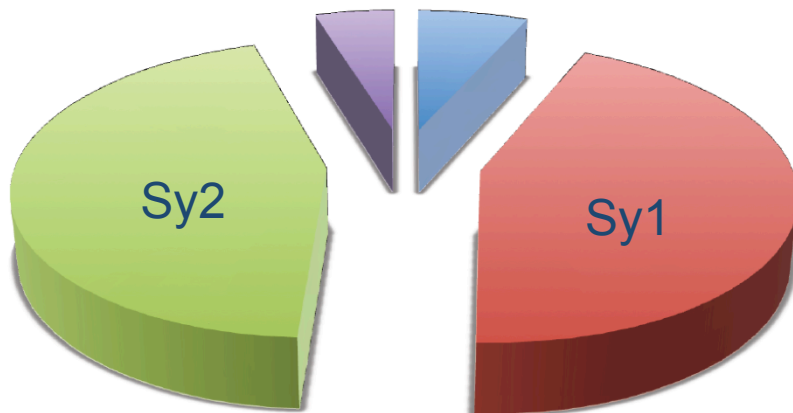
And in the hard X-rays?

INTEGRAL IBIS/ISGRI (17-80 keV)

Swift/BAT (14-195 keV, Cusumano et al. 2010)

LINERS NLS1

LINERS NLS1



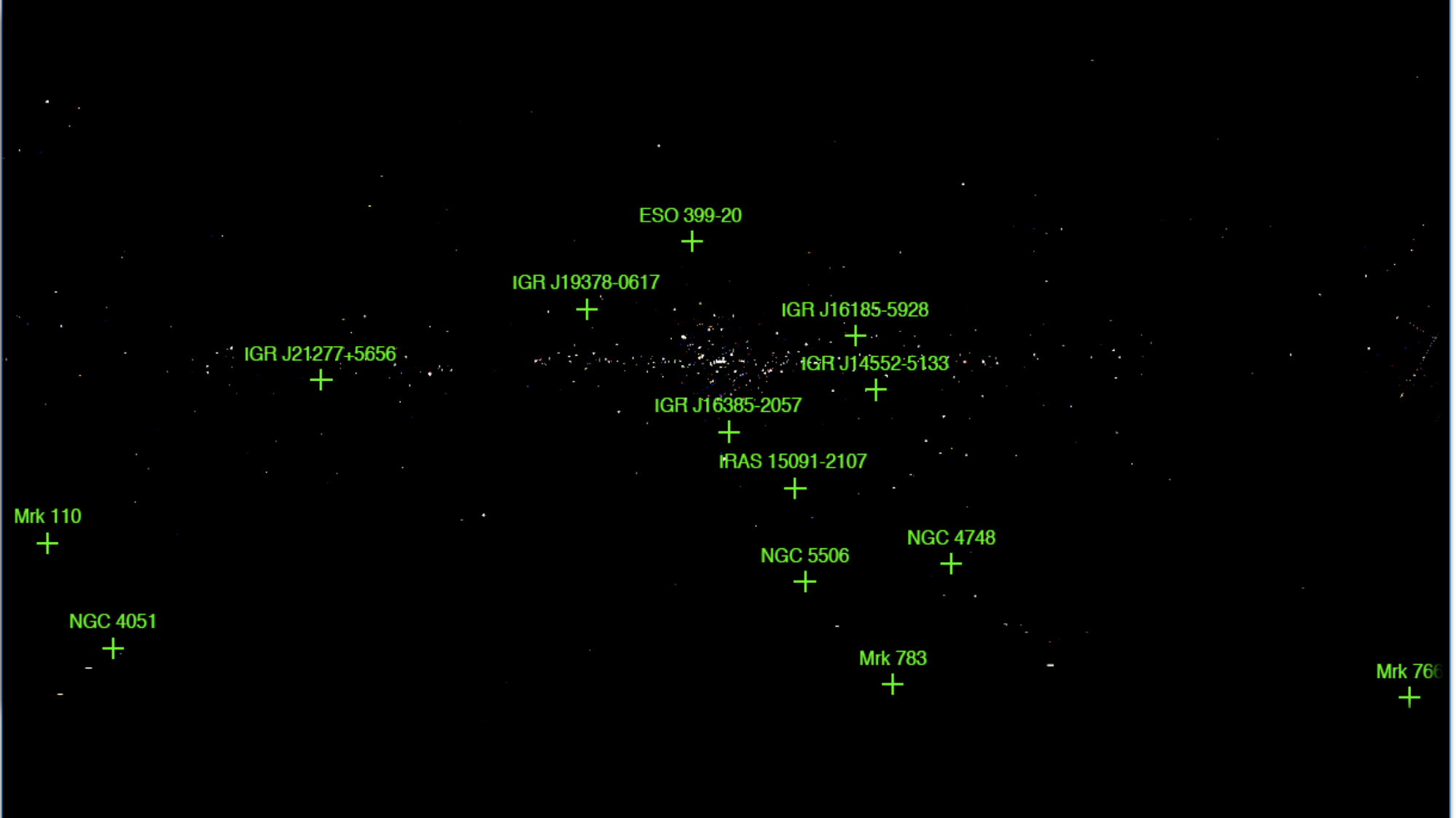
~200 Seyfert galaxies

~500 Seyfert galaxies

92 Sy1's → **15% NLS1** (14)

307 Sy1's → **4% NLS1** (13)

14 Narrow line Seyfert 1's detected by INTEGRAL



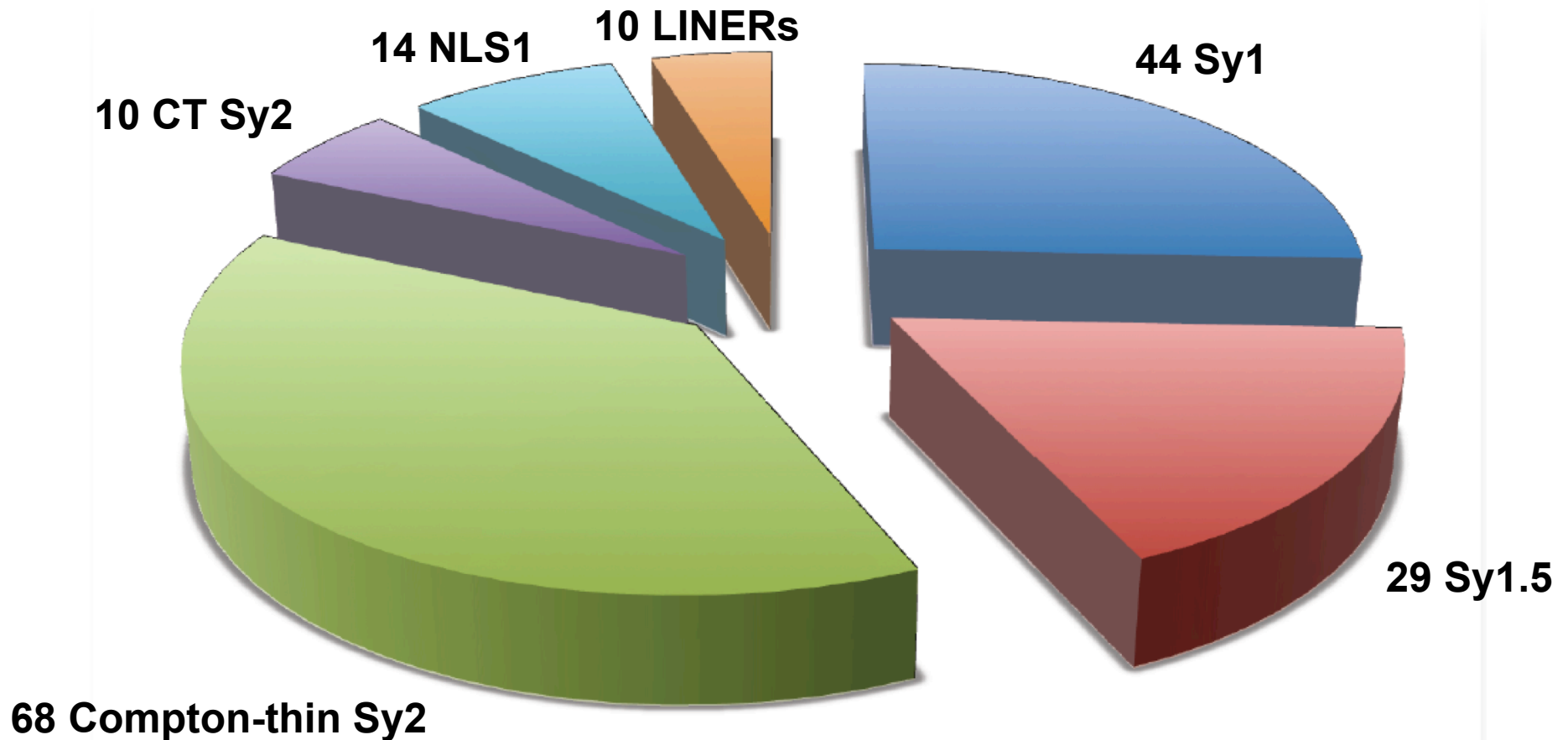
Stacking of all the images of each source of different classes of Seyferts

- **Broad energy band (17-250 keV)**
- **Extremely long exposures (up to ~44 Ms)**
- **Geometry of the images modified to have consistent PSFs**
- **Improved software (OSA9)**

30 sources removed

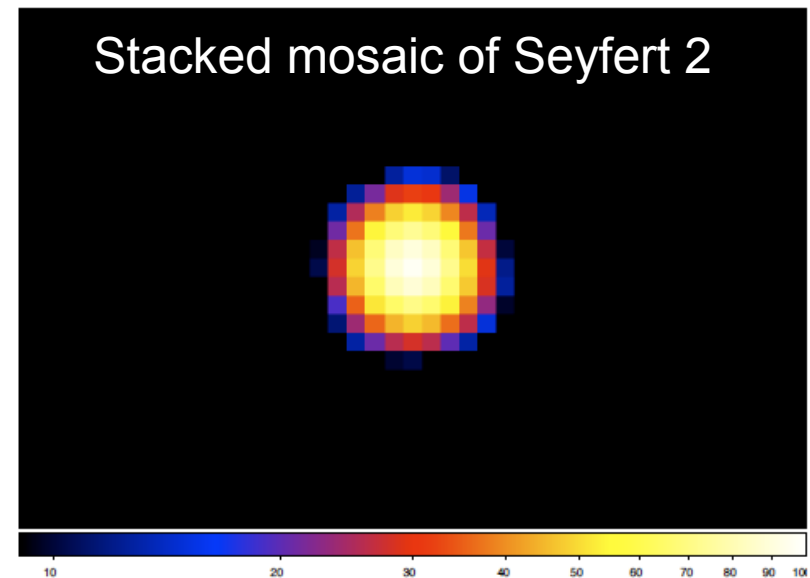
- Too close (< 0.4 degrees) to bright sources or to other sources of the sample
- Classification unclear (Variations Compton-thick/Compton-thin)
- Too bright ($> 50\sigma$ in the 17-80 keV band)
- $z > 0.2$

Final sample: 165 Seyfert galaxies detected by INTEGRAL IBIS/ISGRI



Stacked mosaics using all the available Scws

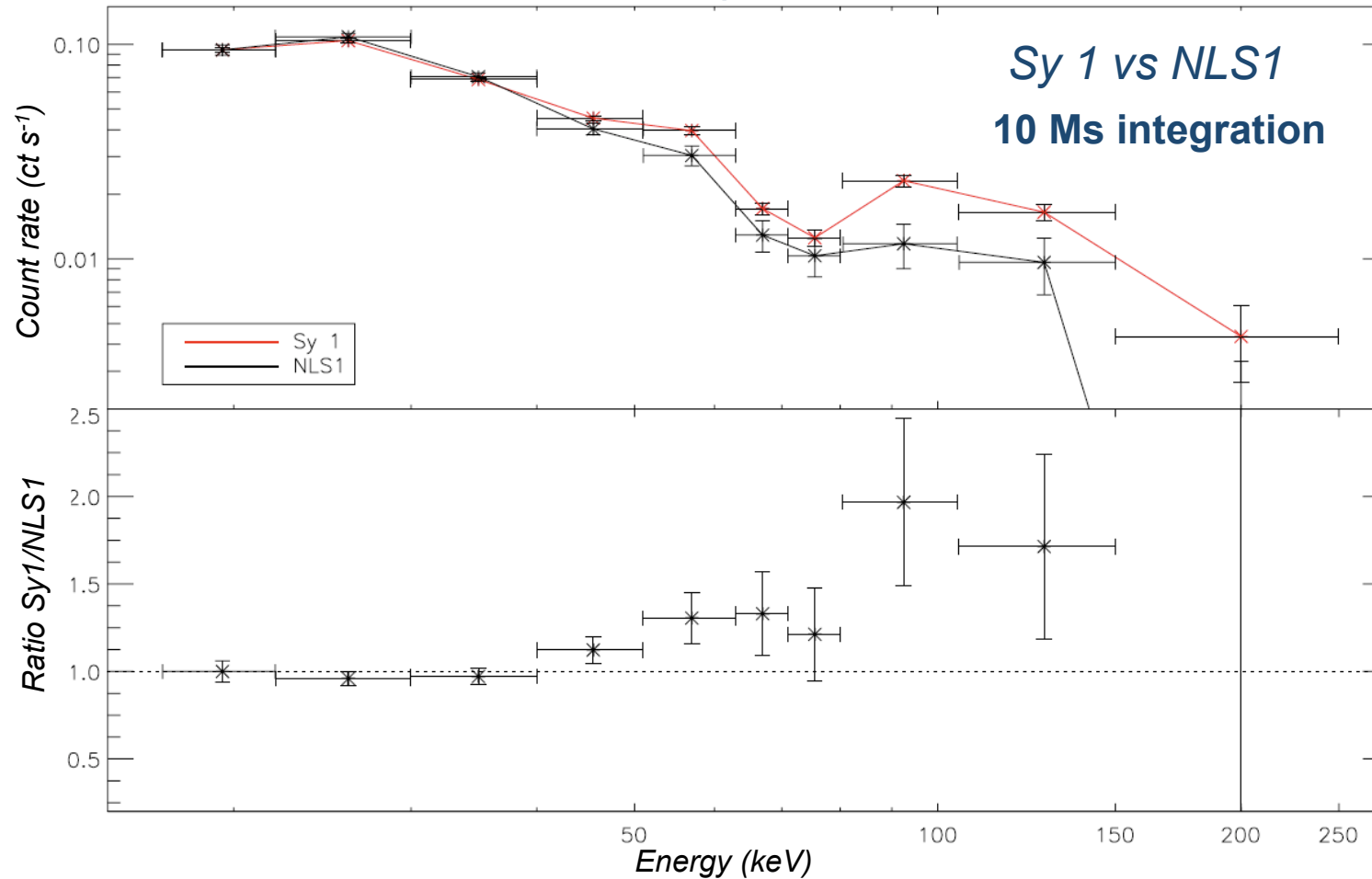
Sample	Srcs	Exp. [Ms]	Det. Significance [σ]
Seyfert 1	44	37.6	91.1
Seyfert 1.5	29	13.2	59.1
Seyfert 2	68	44.0	102.8
CT Seyfert 2	10	4.7	32.9
NLS1	14	10.1	44.3



Stacked mosaics → average spectra

Model-independent spectral analysis:

Ratios of normalized spectra of different classes



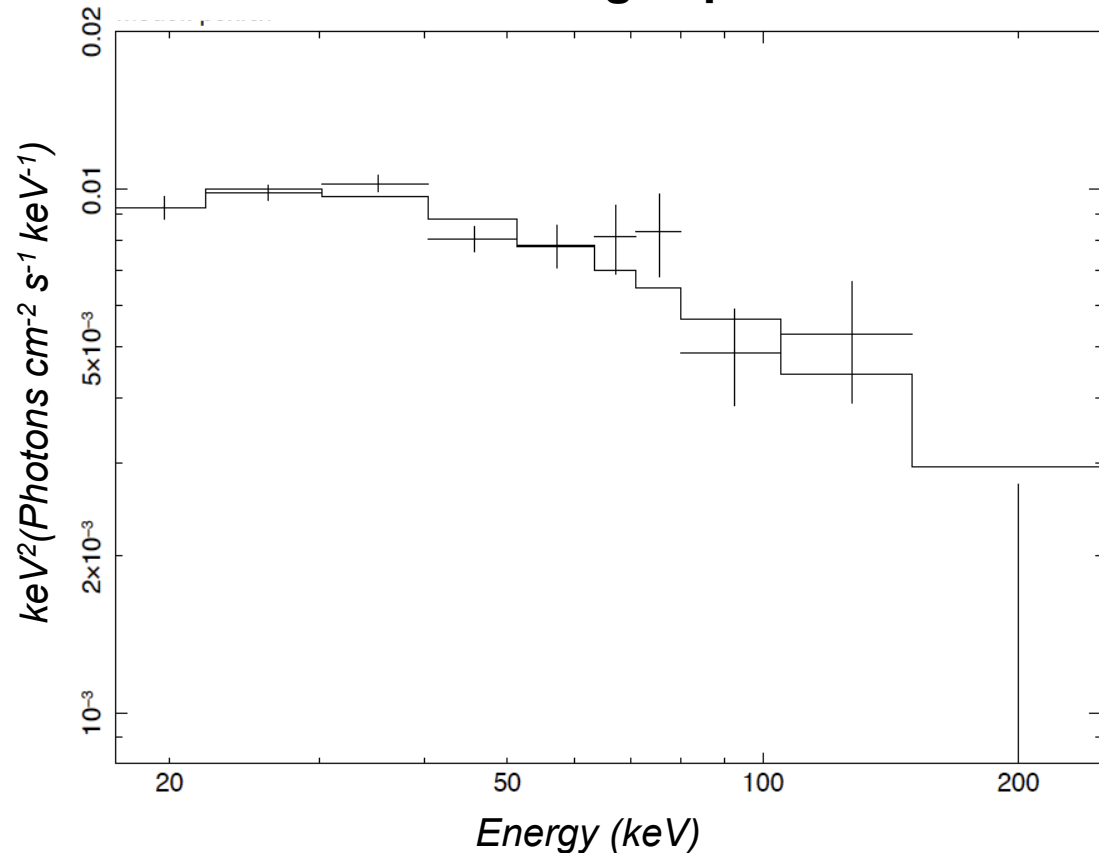
Average hard X-ray spectrum steeper than that of Sy1's

Model-dependent spectral analysis:

cutoff power law continuum model + reflection from neutral matter

NLS1's average spectrum

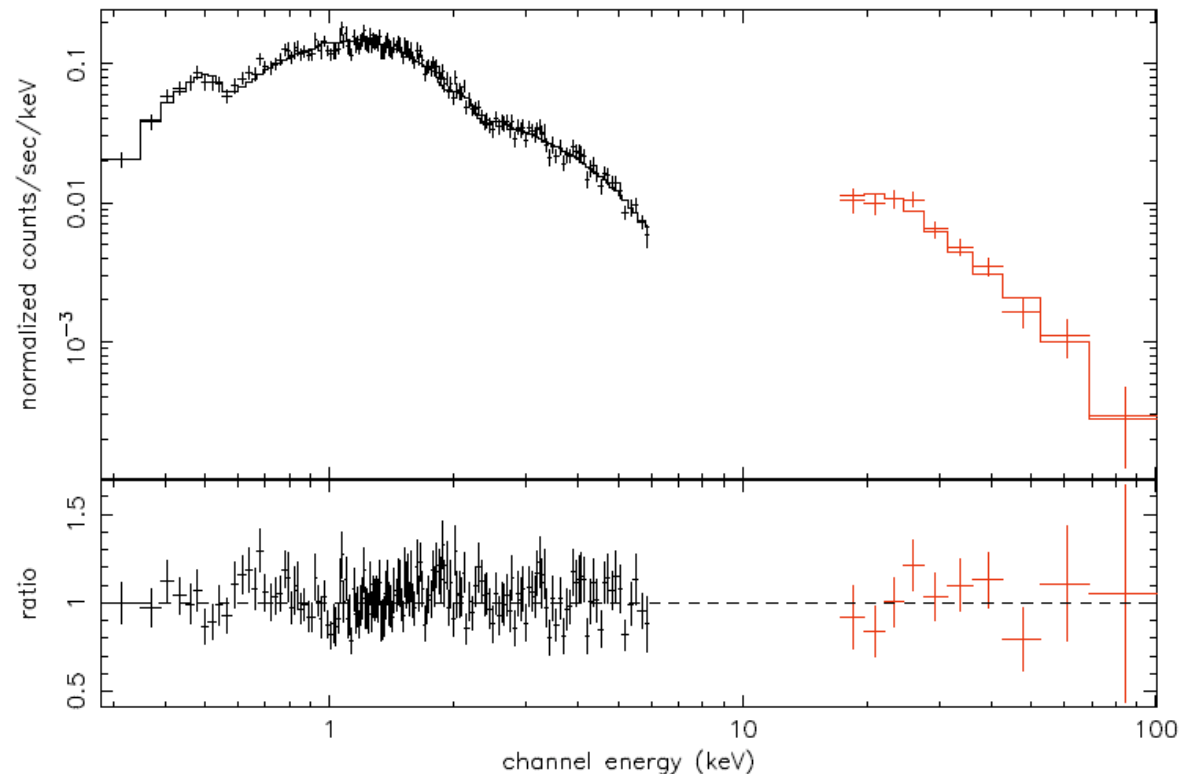
NLS1	Sy1
$\Gamma = 2.2^{+0.2}_{-0.7}$	$\Gamma = 1.8^{+0.1}_{-0.1}$
$E_c \geq 53 \text{ keV}$	$E_c \geq 200 \text{ keV}$
$R = \text{NC}$	$R \leq 0.4$



Average IBIS/ISGRI+ Swift/XRT spectrum

Malizia et al. (2008)

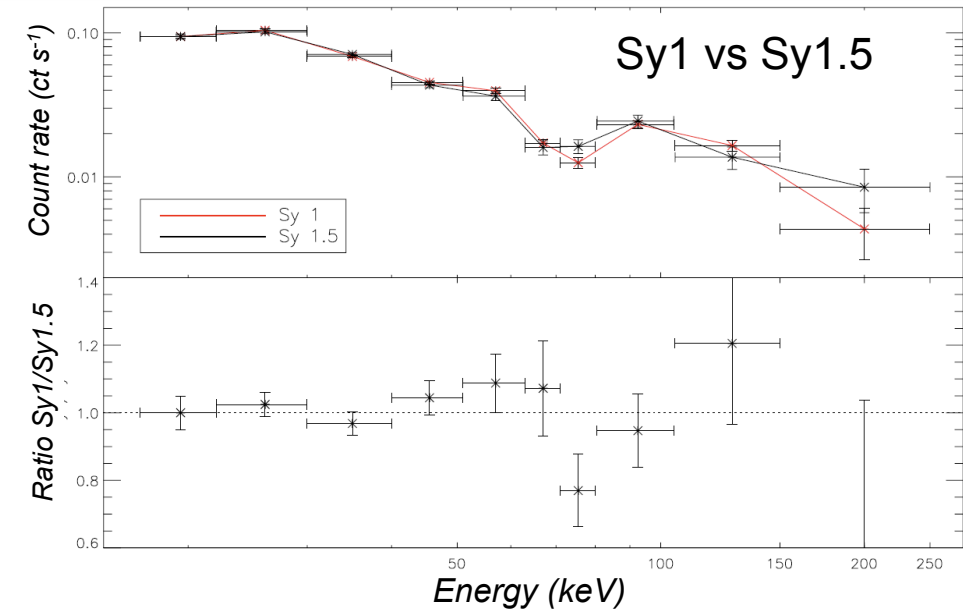
- Average spectrum steeper than classical Seyfert 1's ($\Gamma=2.6\pm0.3$)
- $E_C \approx 60$ keV
- Reflection component $R \leq 0.8$



→ Next talk: Francesca Panessa

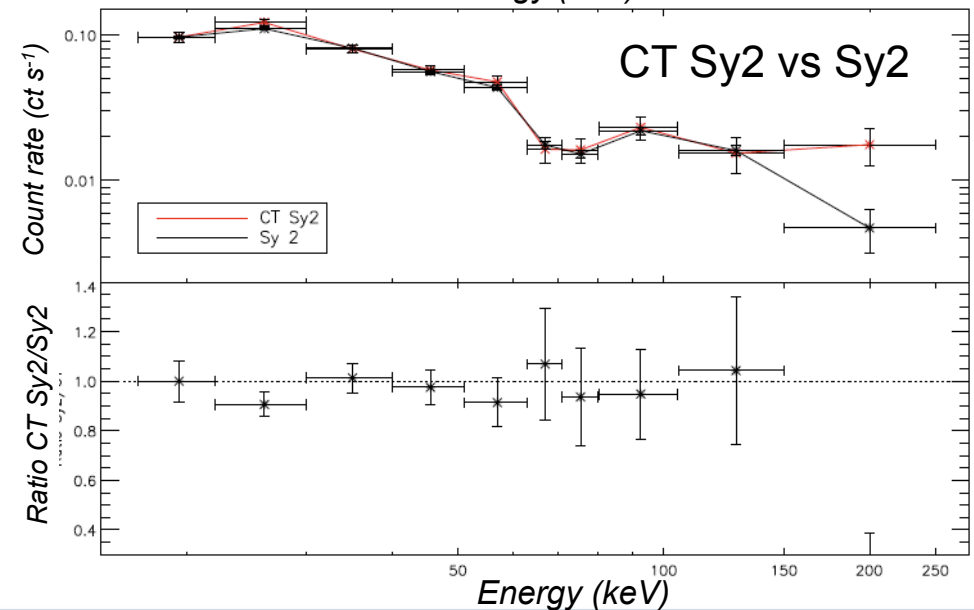
Seyfert 1's and Seyfert 1.5's:

- Consistent average hard X-ray emission \rightarrow as expected from the Unified model

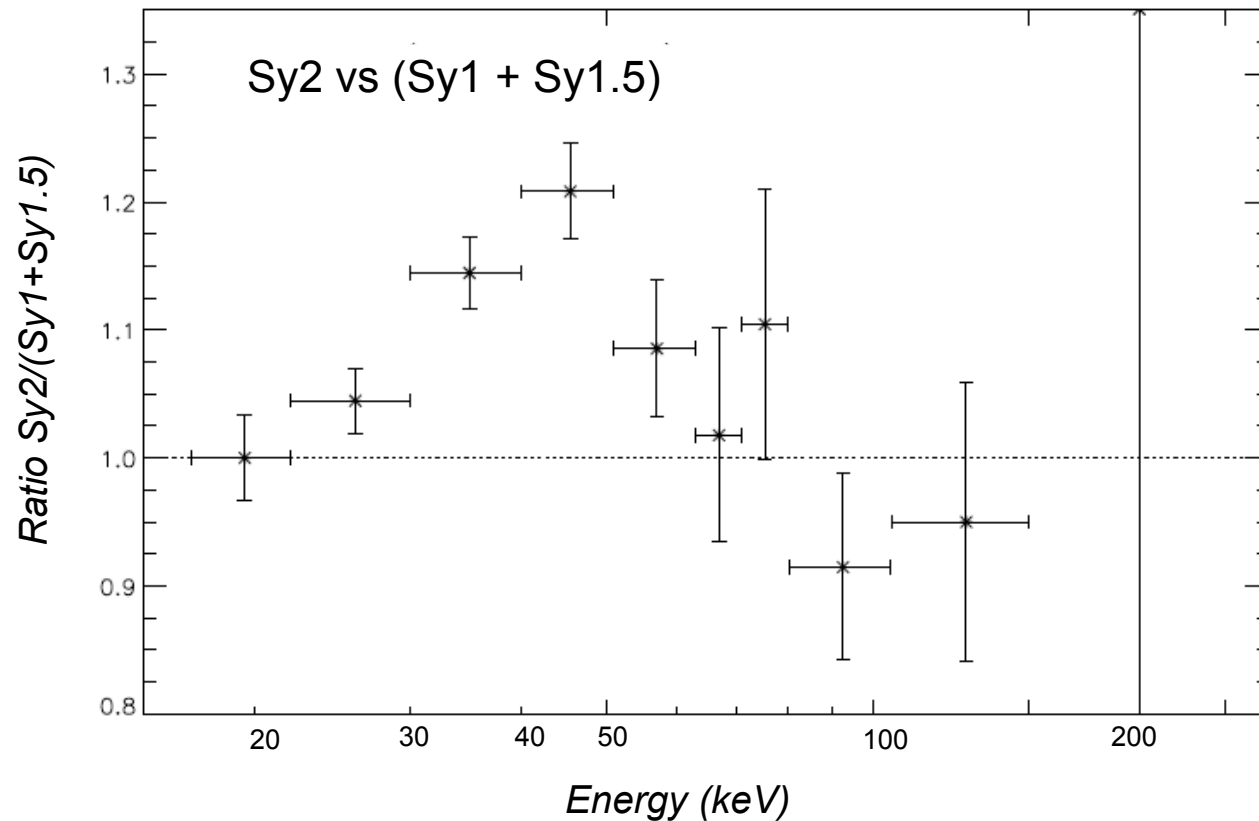


Compton-thin and Compton-thick Seyfert 2's:

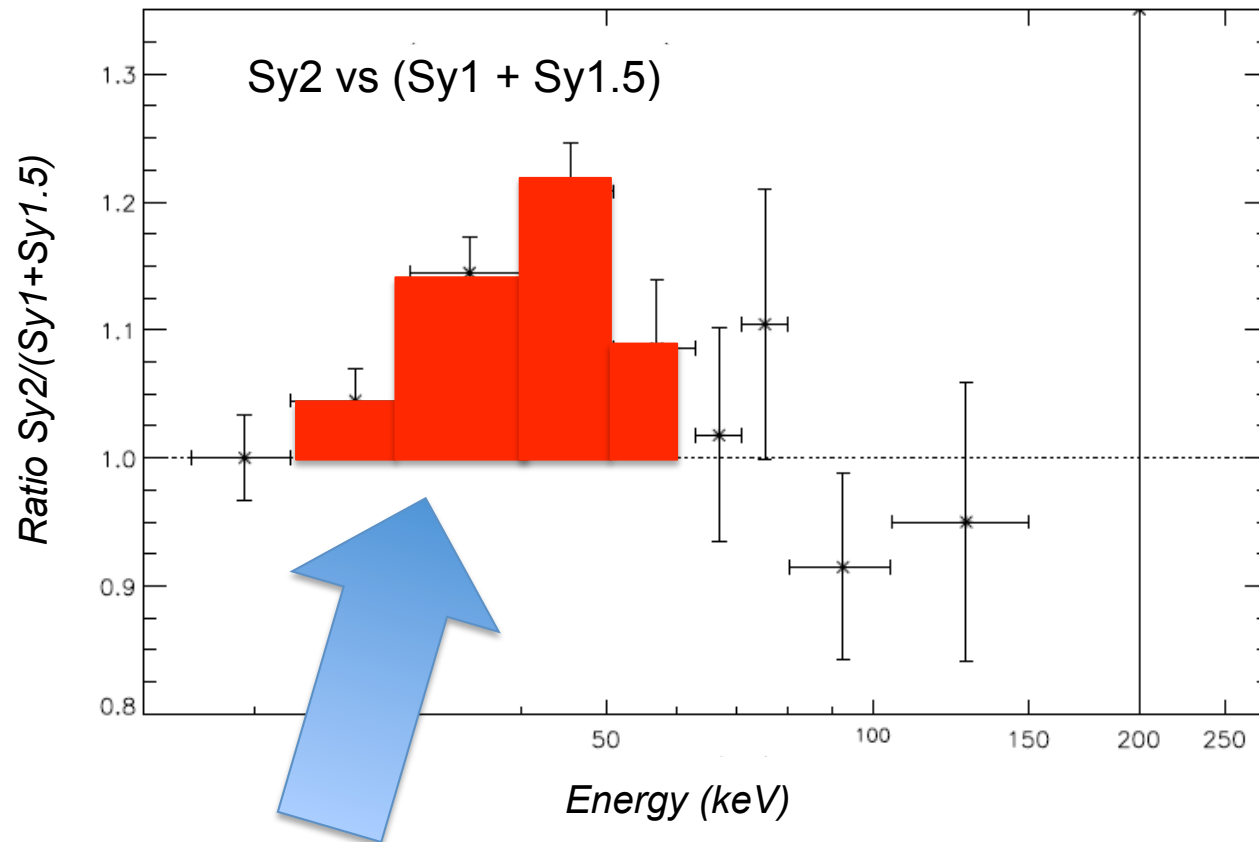
- No trace of more curvature (i.e. more reflection) in the spectrum of CT Sy2's.



Differences between the average hard X-ray spectrum of Sy2's and those of Sy1's and Sy 1.5's?



Differences between the average hard X-ray spectrum of Sy2's and those of Sy1's and Sy 1.5'2s?

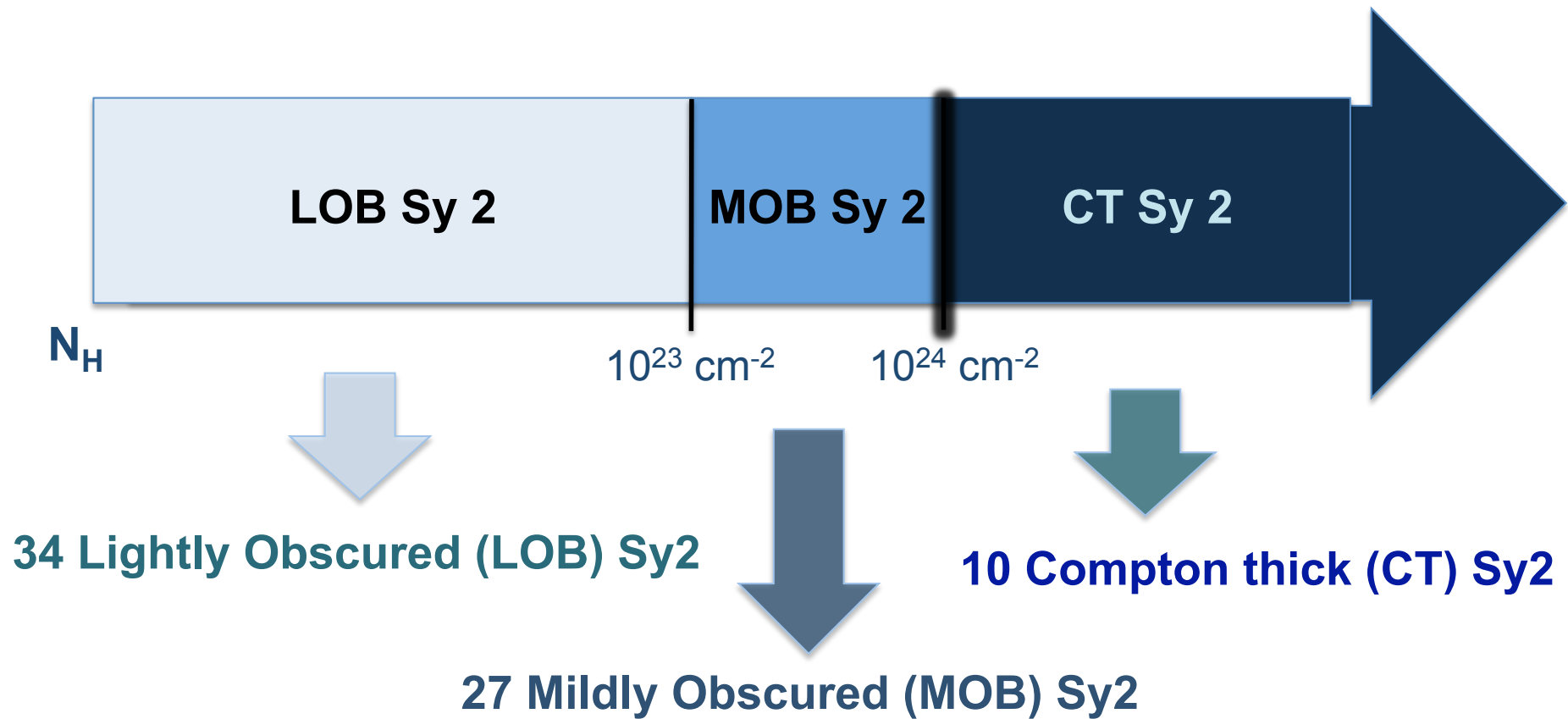


The average hard X-ray spectrum of Sy2's shows an excess over that of Sy1's and Sy1.5's in the 20-60 keV band

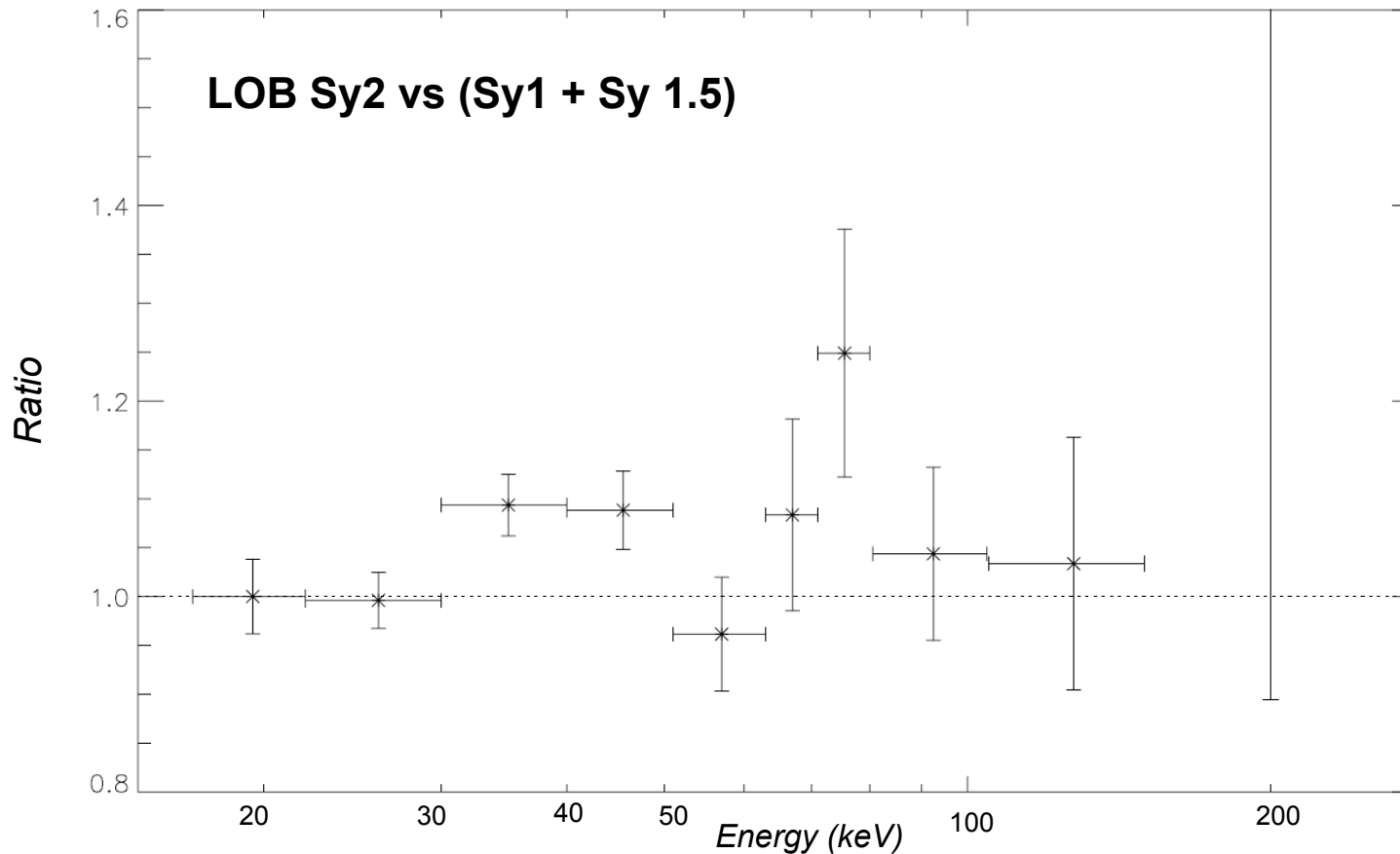
Could absorption still play a role?



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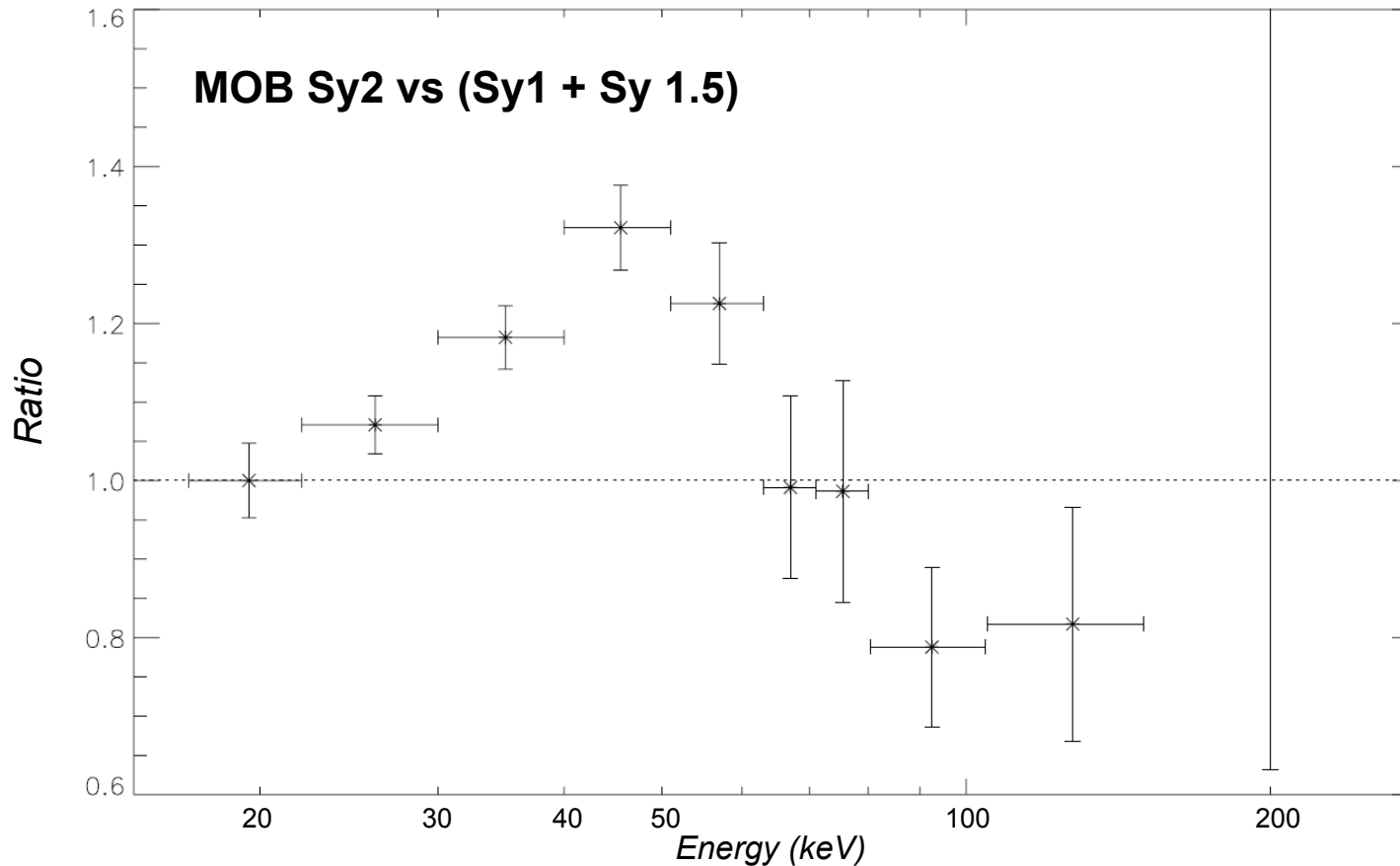


We re-ran the stacking dividing Sy2's in LOB and MOB
34 LOB Sy2's , ~23 Ms cumulative exposure



LOB Seyfert 2's have an average spectrum similar to Sy1's and Sy1.5's

We re-ran the stacking dividing Sy2's in LOB and MOB
27 MOB Sy2's , ~14 Ms cumulative exposure



Most of the curvature seen in Sy2's comes from MOB Syfert 2's

$R > 1 \rightarrow$ transmission efficiency
 $\approx 1/R$ (Ueda et al. 2007)

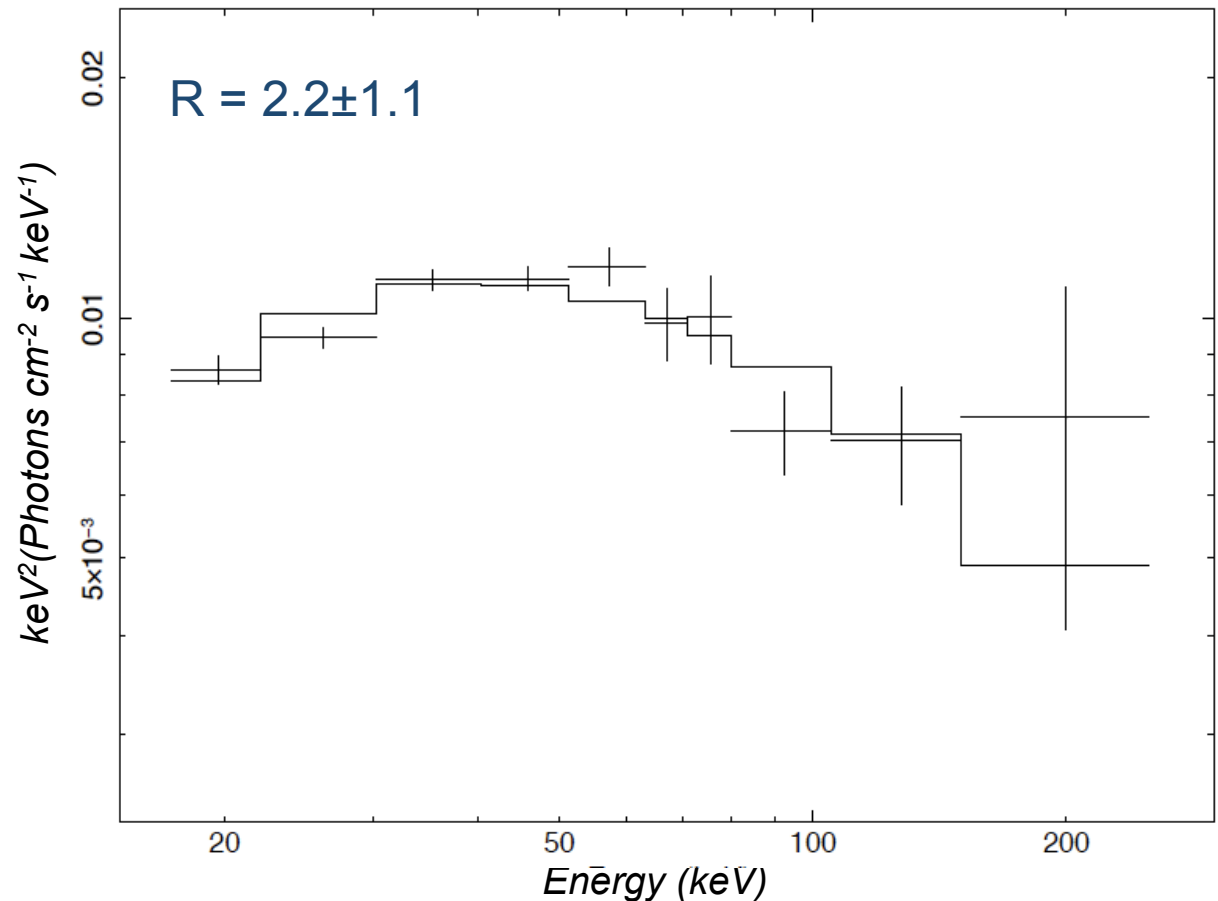
A clumpy torus?

(e.g. Nenkova et al. 2002)

*Continuum dampened and
 enhanced reflection
 component*

\rightarrow Clumpy torus consistent
 with IR observations
 (e.g. Mor et al. 2009)

MOB Sy2's average spectrum



Soft X-ray study ($K\alpha$ line) of all the objects of our sample ongoing!

- INTEGRAL detected 14 NLS1's above 20 keV, ~15% of Sy1's, consistent with optical observations
- Average hard X-ray spectrum of NLS1's steeper than Sy1's and Sy1.5's
- Average spectrum of Sy1's and Sy1.5's consistent, as predicted by the zero-th order Unified Model
- Average hard X-ray spectrum of Seyfert 2's shows more reflection wrt Sy1's & Sy1.5's
 - Most of this reflection comes from MOB ($10^{23} \leq N_H \leq 10^{24} \text{cm}^{-2}$) Sy2's
 - Is this due to a clumpy torus?
- Study of the $K\alpha$ line (Ricci et al. in prep.)