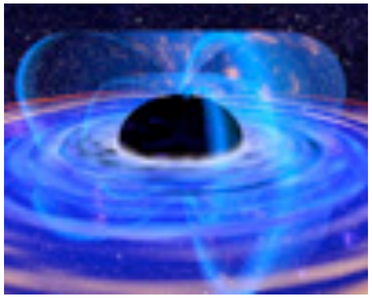
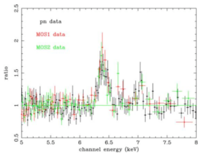


Statistics of relativistic broadened Fe K lines in AGN

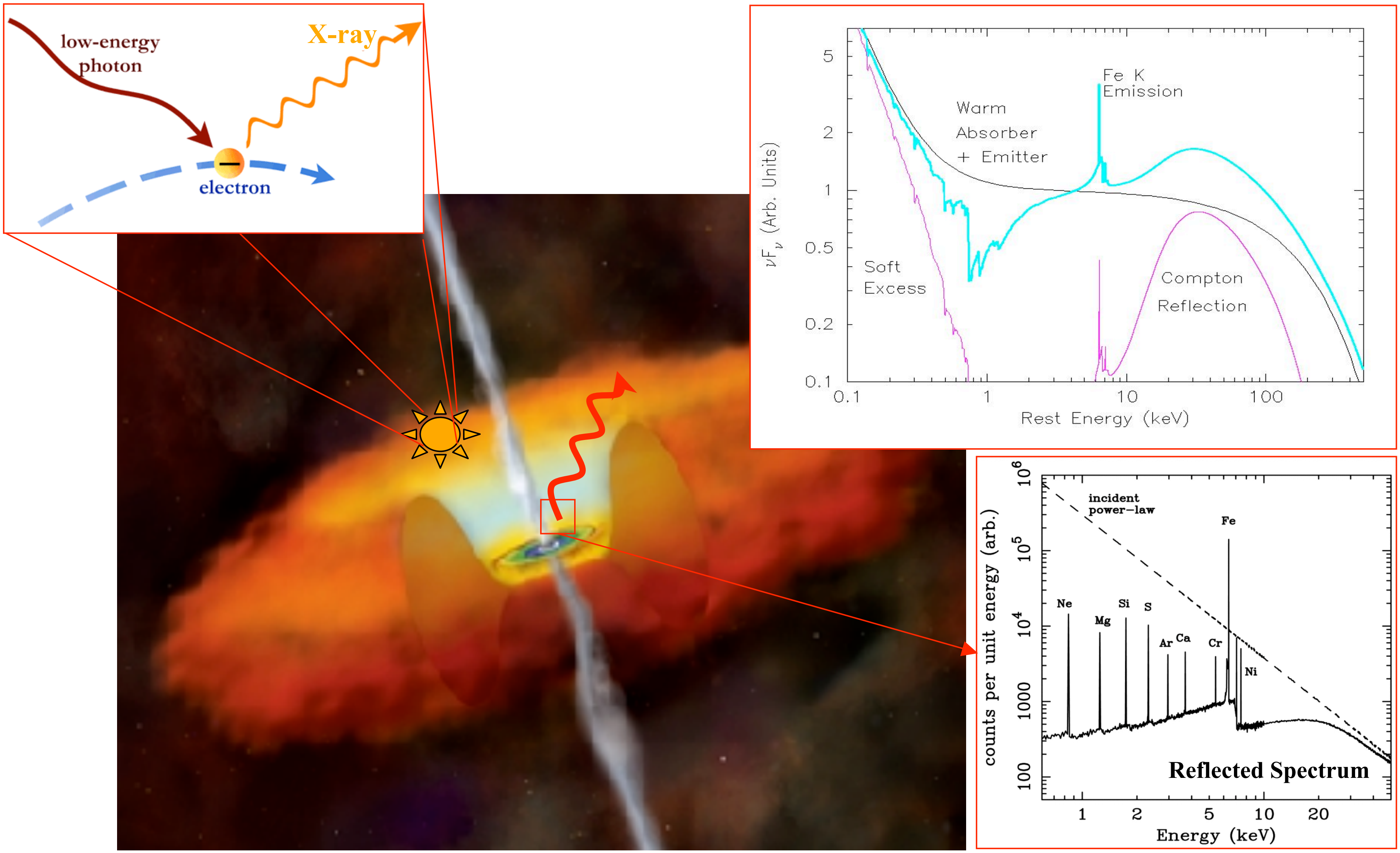
I. de la Calle, A. L. Longinotti, M. Guainazzi, S. Bianchi and M. Dovčiak

INSA
INGENIERIA Y SERVICIOS AEROESPACIALES, S.A.

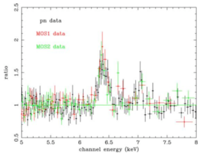


X-ray Emission in Active Galactic Nuclei

X-ray Spectrum



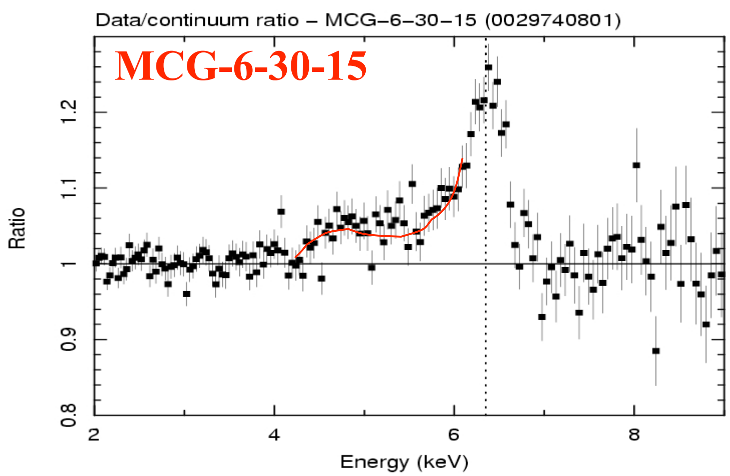
XMM-Newton: The Next Decade
June 4-6, 2007

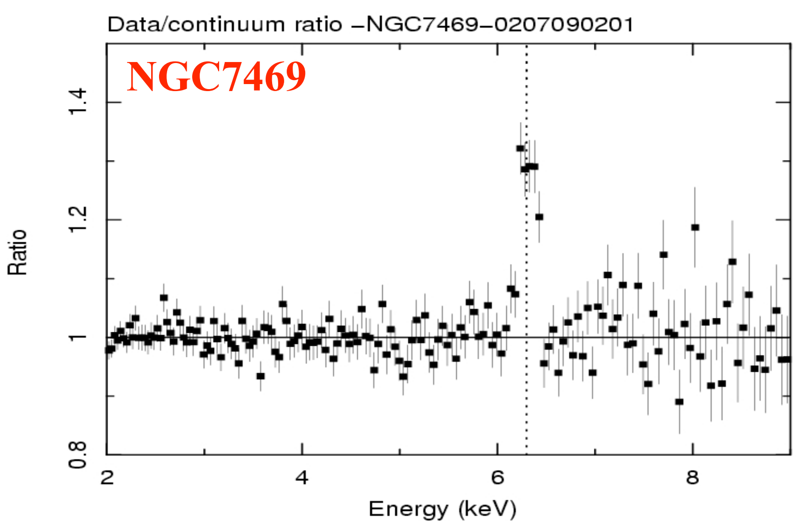


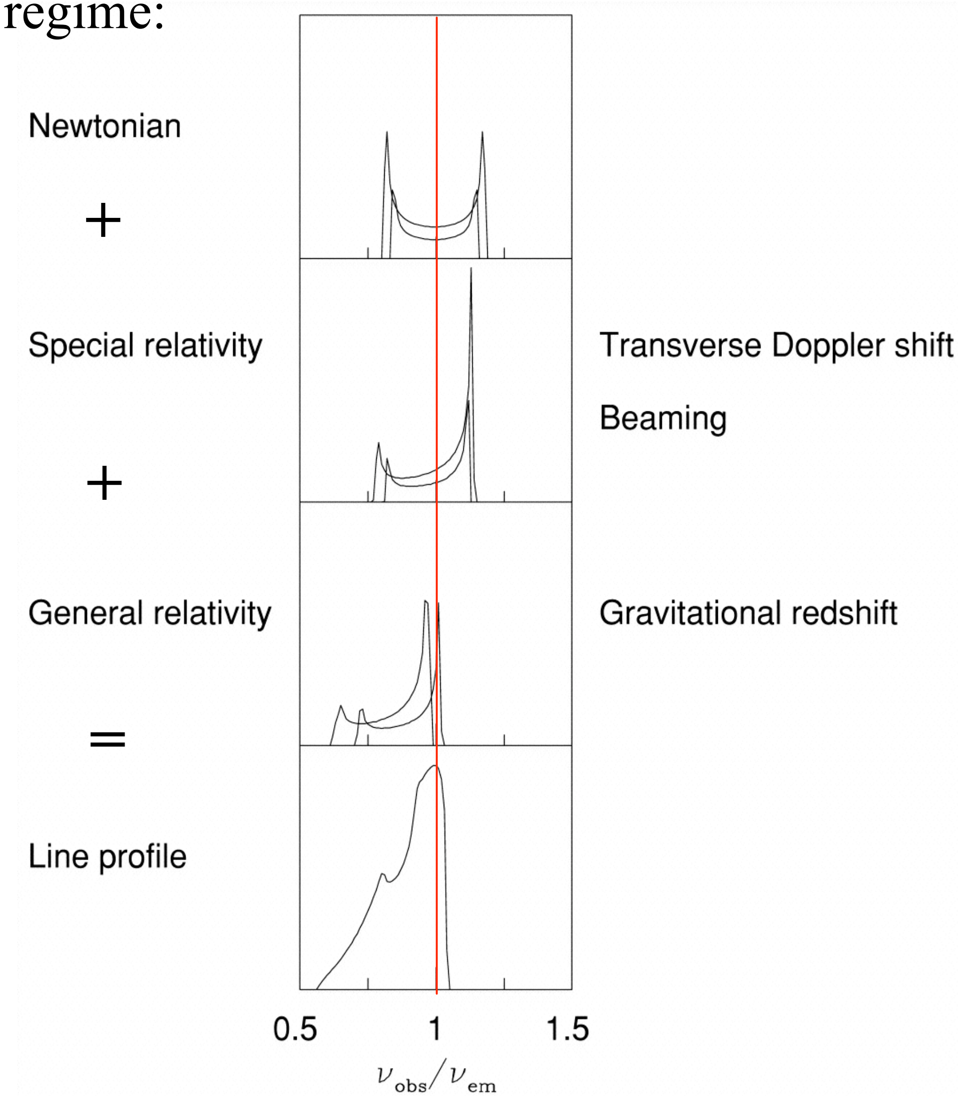
Broad Iron Lines

Disk Dynamics

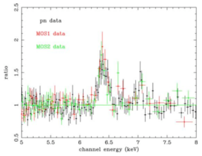
Line emission under a strong gravitational regime:







Fabian et al. 2000



What can we learn ?

Relativistic Fe Line

The broad Fe lines carry information about strong gravity, so they can be used as a diagnostics of the innermost regions of AGN:

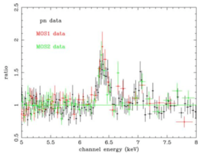
Central supermassive black hole => potential to measure black hole spin and mass

Accretion disc => the shape of the line carries information on the dynamics of the accretion disk: diagnostic of accretion disc structure, like extension and ionisation state *e.g. Guainazzi et al. 2006*

Fraction of **AGN** with relativistically broadened lines is still largely unknown

How often relativistic broadening appears in AGN spectra?

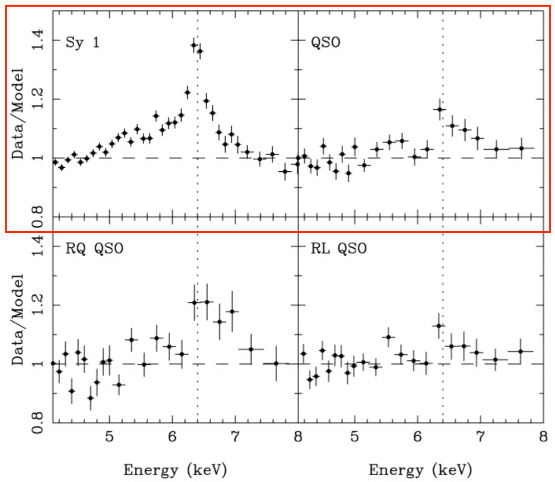
Relativistic Line Profile Studies



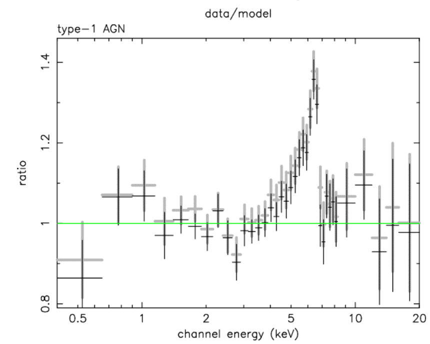
Relativistic Fe Line

Sample Studies:

1) ASCA data
39 AGN
(Sy1 & QSO)
Nandra+ 97

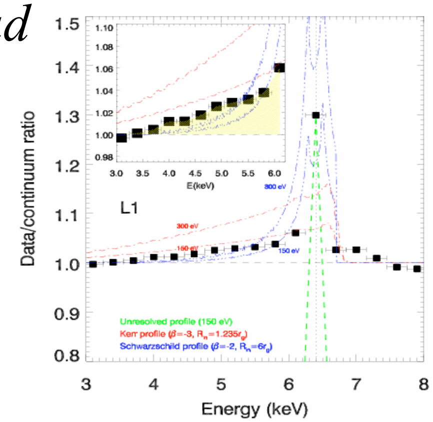


2) XMM-Newton data 104 AGN (Lockman Hole, faint sources: F=10^{-15}-10^{-13} ergs/s/cm^2): EW~500 eV
Streblyanska+ 05

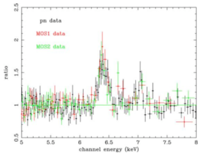


3) XMM-Newton data 38 AGN (PG QSO): **3** significant broad line detections Jimenez-Bailon+ 05

5) XMM-Newton data
102 AGN (QSO, Sy1, Sy2)
≈25% *show broad K_α profiles (50% of well exposed sub-sample)*
Guainazzi+ 06



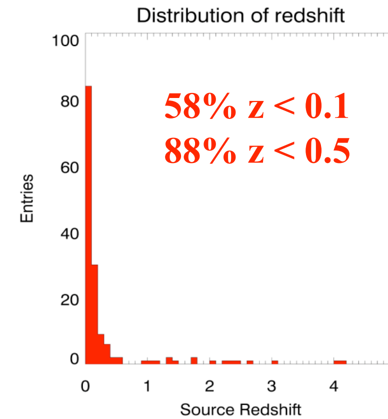
4) XMM-Newton data
30 AGN (Bright Sy1)
≈73% *show broad K_α profiles*
Nandra+ 06

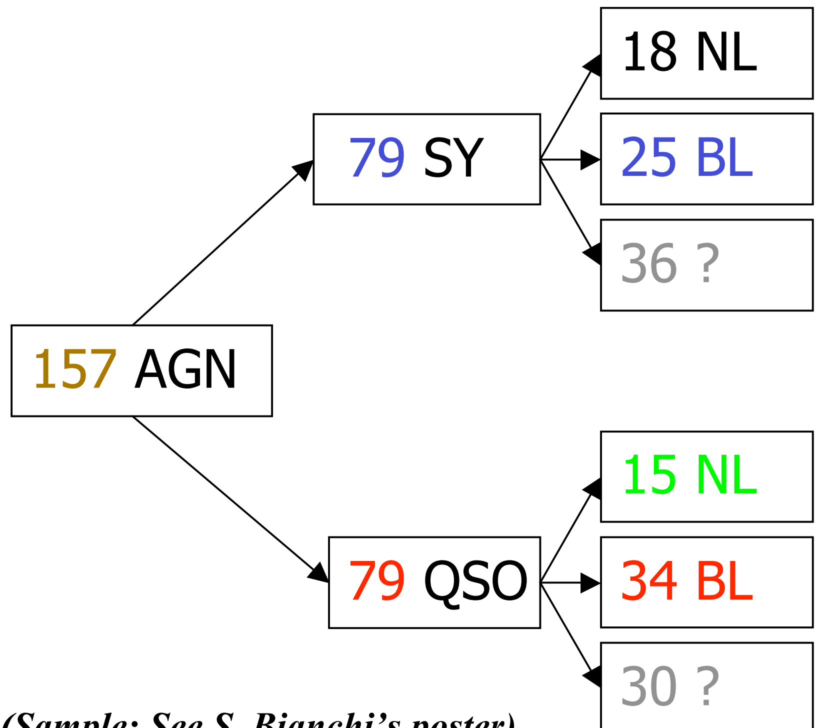


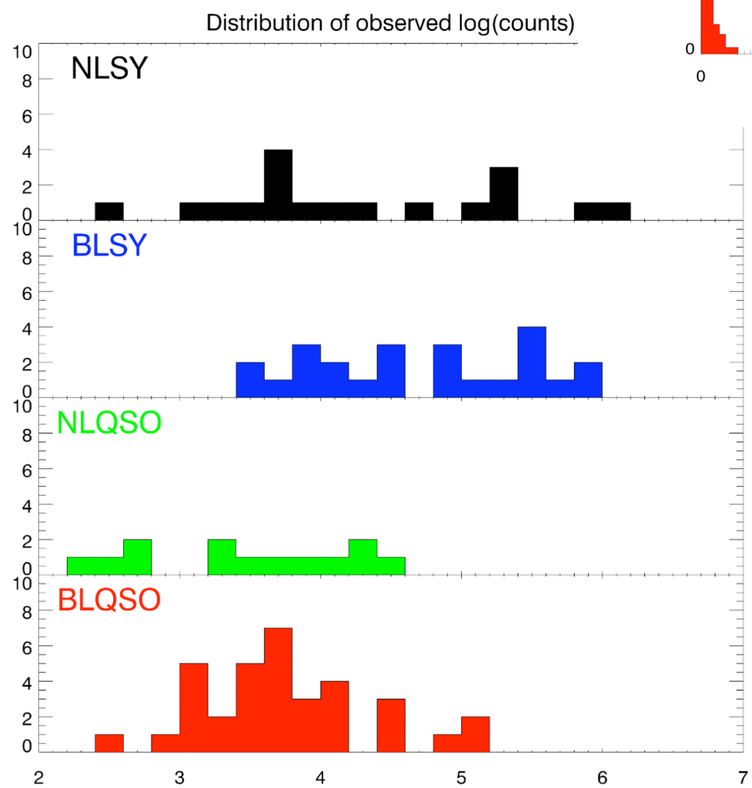
The Sample

157 type 1 AGN

Intrinsic column density: $N_h < \sim 3\times10^{22}\ \mathrm{cm}^{-2}$

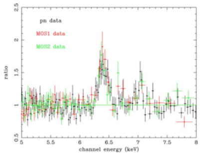






(Sample: See S. Bianchi's poster)

~65 % of sources
H_β available



Analysis

Observations

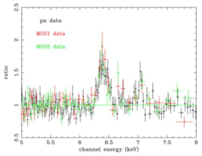
- 221 XMM-Newton target observations, corresponding to 157 different sources obtained as pointed observations by XMM-Newton (*public up to March 2007*)
- Exposure times range from 0.9ksec and 398ksec.

Analysis

- Homogeneous analysis of all sources with latest SAS version and calibration files.
- Multiple observations of the same source have been combined (21 sources).
- Only EPIC-pn data has been considered.

Spectral Analysis

- *Pre-analysis cut*: only source spectra with good statistics are fitted (>17 d.o.f).
- Spectra rebinned with 25 background subtracted cts/channel, and > 3 bins.
- Fit done in the 2 – 10 keV rest frame.
- The same model has been uniformly applied to the whole sample.



The Model

Analysis

$$e^{-\sigma_{ph} N_H} \times A(\Gamma, T, \xi) \times N \, [\, E^{-\Gamma} + C(\Gamma, E_c, \phi) + \sum_{i=1}^{5} G_i + R(\phi, \beta, a)$$

$A(\Gamma, T, \xi)$: ionized absorber

$C(\Gamma, E_c, \phi)$: Compton-reflection by a **neutral slab**

$R(\phi, \beta, a)$: full relativistic treatment of the accretion disk emission around a Kerr black hole

(Kyrline, Dovčiak+ 04)

G_i : Gaussian profiles for emission lines:

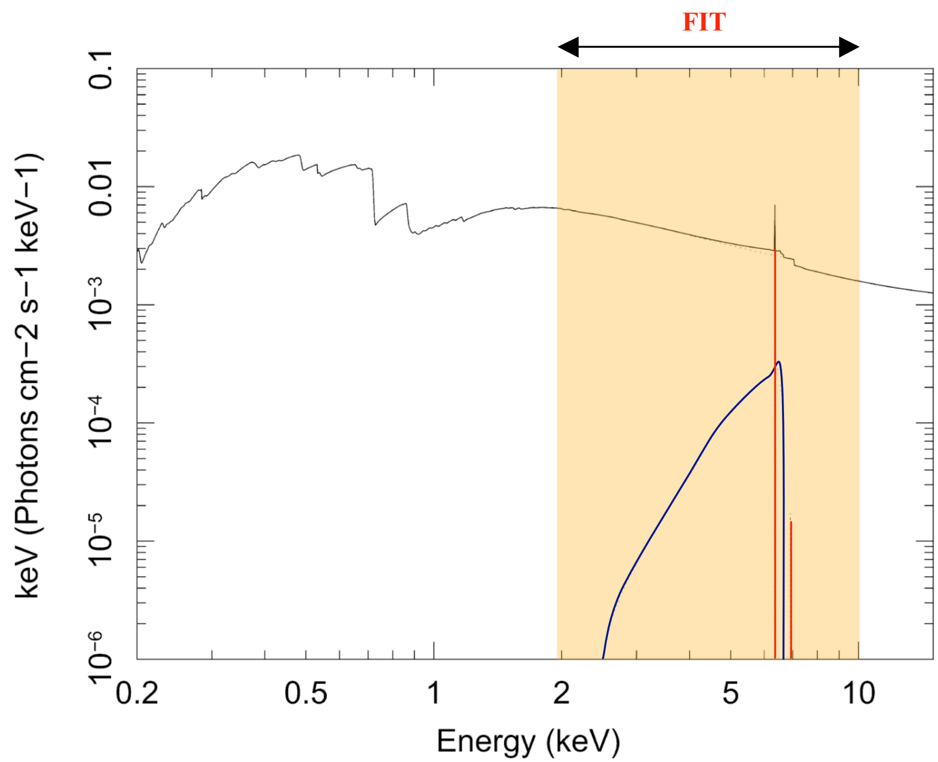
6.4 keV � Fe I K_α

6.7 keV � Fe XXV

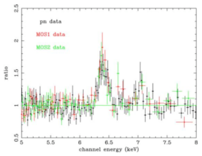
6.96 keV � Fe XXVI

7.06 keV � Fe I K_β

6.3 keV � CS



Guainazzi+ 06



Results

- Individual Source Detections

- Stacked Spectra of non-detections
  - No evidence for large EW
  - No significant dependence with Luminosity

(Anna Lia Longinotti's poster)

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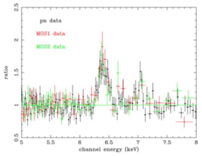
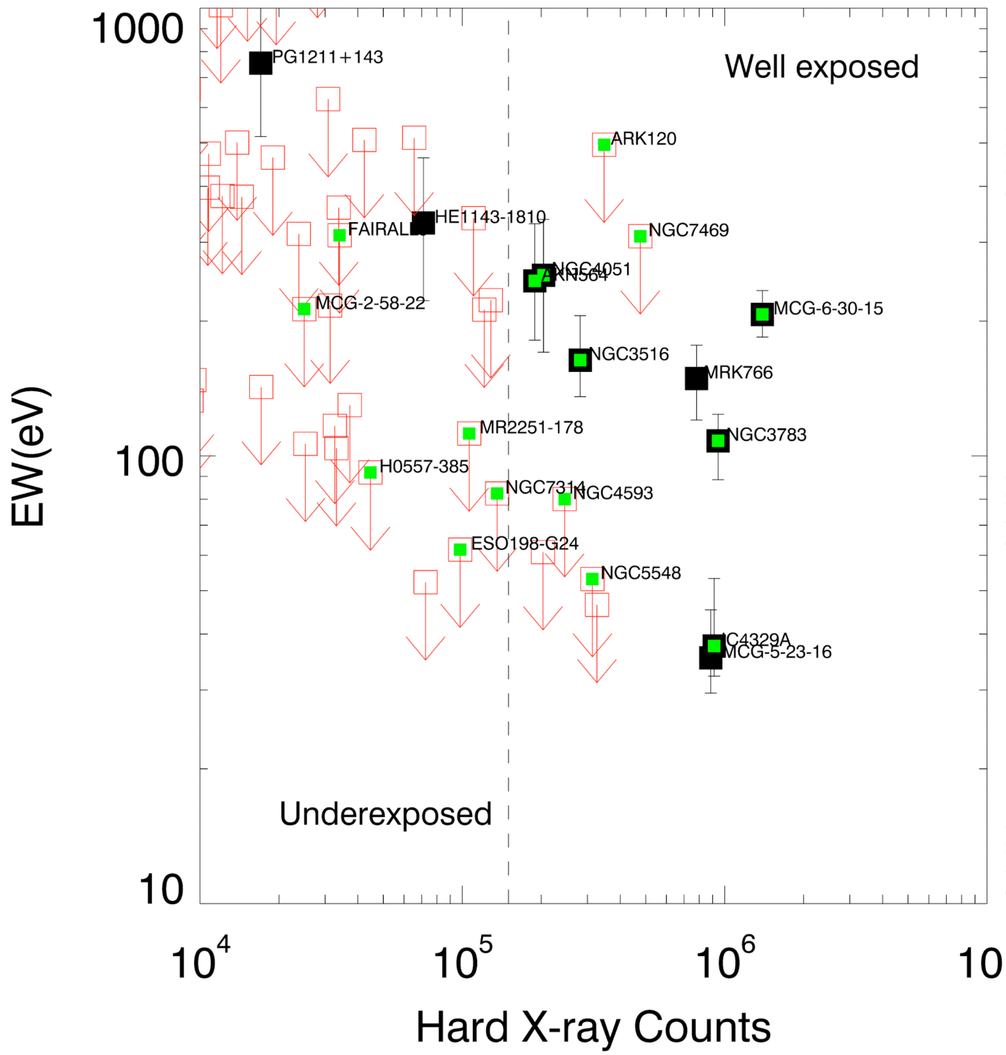
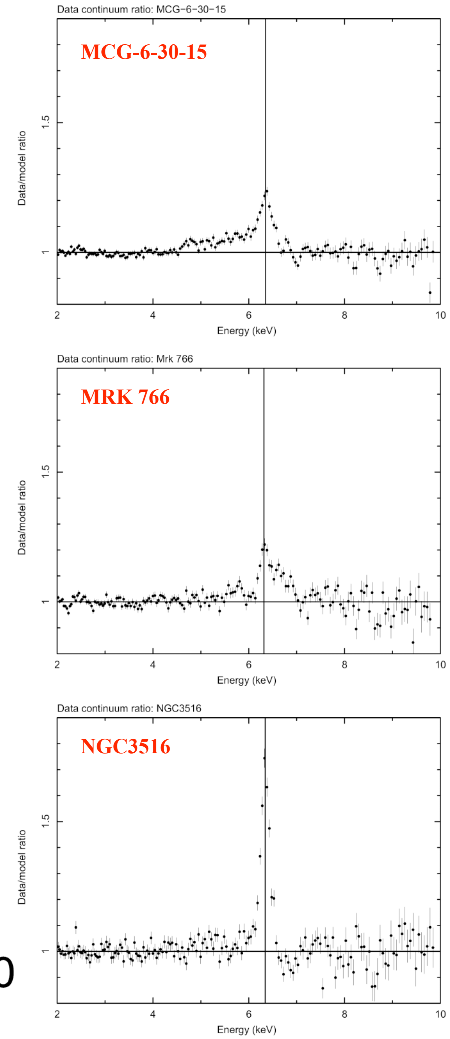


Detections

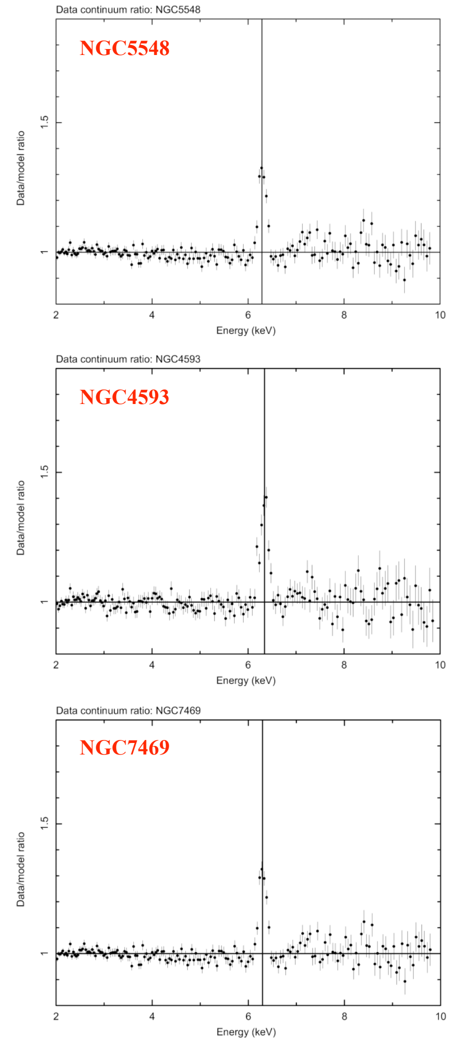
Results

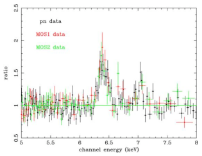


>3σ Detections



Upper Limits





Detections

Results

SOURCE NAME	TYPE	Cts (2-10 keV)	L_X (*)	EW (eV)	σ
MCG-6-30-15	NLSY	13.92e+05	0.57	207.0	9.1
IZW1	NLQ	0.39e+05	4.76	1452.1	6.9
IC4329A	BLSY	9.12e+05	5.66	37.6	6.9
MCG-5-23-16	NCSY	8.85e+05	1.42	35.4	6.0
NGC3516	BLSY	2.81e+05	0.37	163.6	5.8
NGC3783	BLSY	9.44e+05	1.15	108.0	5.5
MRK766	NLSY	7.81e+05	0.62	148.8	5.2
AKN564	NLSY	1.90e+05	2.41	246.0	3.8
NGC4579	NCSY	0.08e+05	0.03	5557.6	3.4
PG1211+143	NLQ	0.17e+05	4.86	754.1	3.2
NGC4051	NLSY	2.04e+05	0.03	253.2	3.0
HE1143-1810	BLSY	0.71e+05	6.98	331.3	3.0

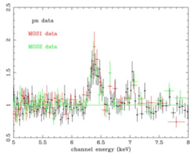
TYPE: 10 Sy / 2 QSO

LUMINOSITY:

L1 5 (~ 16%)
L2 5 (~ 13%)
L3 2 (~ 6%)
L4 0

L1	31 $L_X < 1$
L2	39 $1 \leq L_X < 5$
L3	33 $5 \leq L_X < 15$
L4	46 $L_X \geq 15$

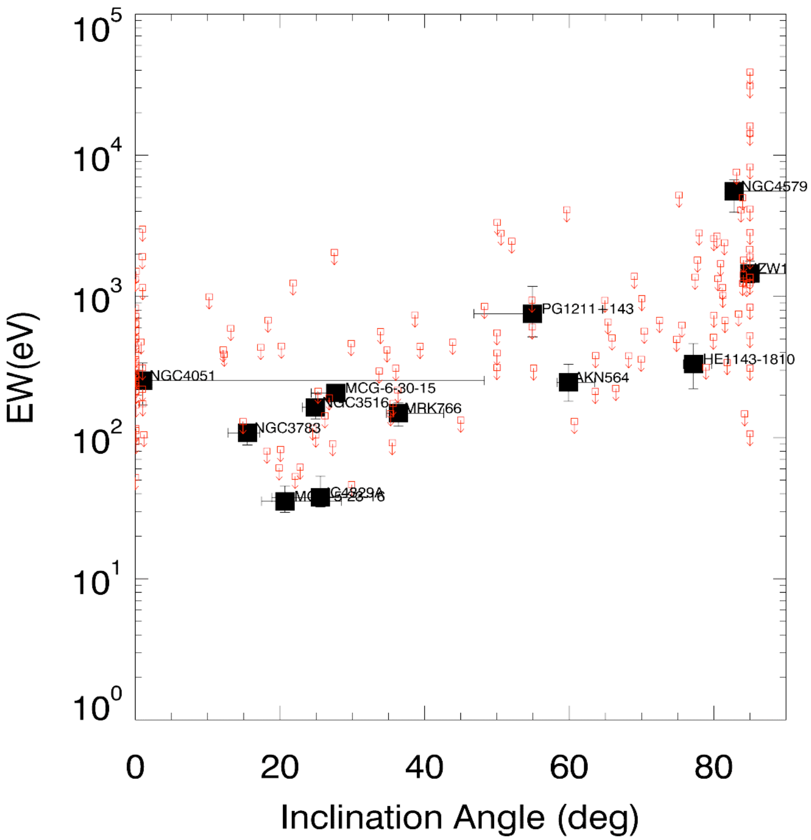
(*) L_x in 10^{43} erg s^{-1} (2 – 10 keV)



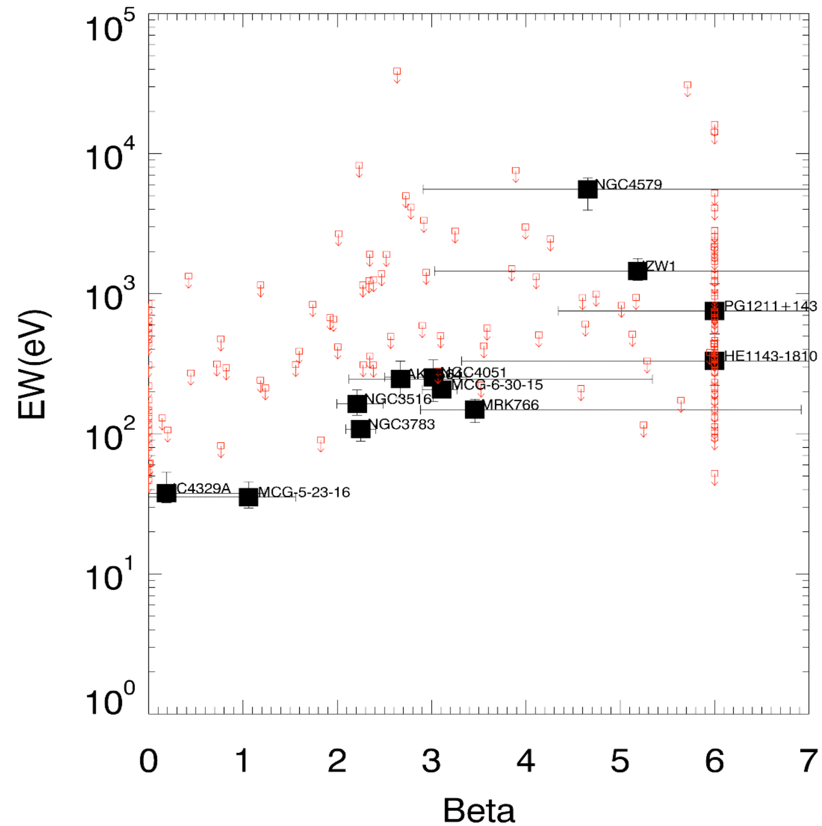
Detections

Results

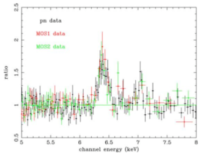
EW vs Luminosity, Inclination Angle and power-law index of emissivity



Consistent with Standard Model of AGN (ϕ~30°)



Consistent with standard Sakura-Sunyaev accretion disk (q≈3)

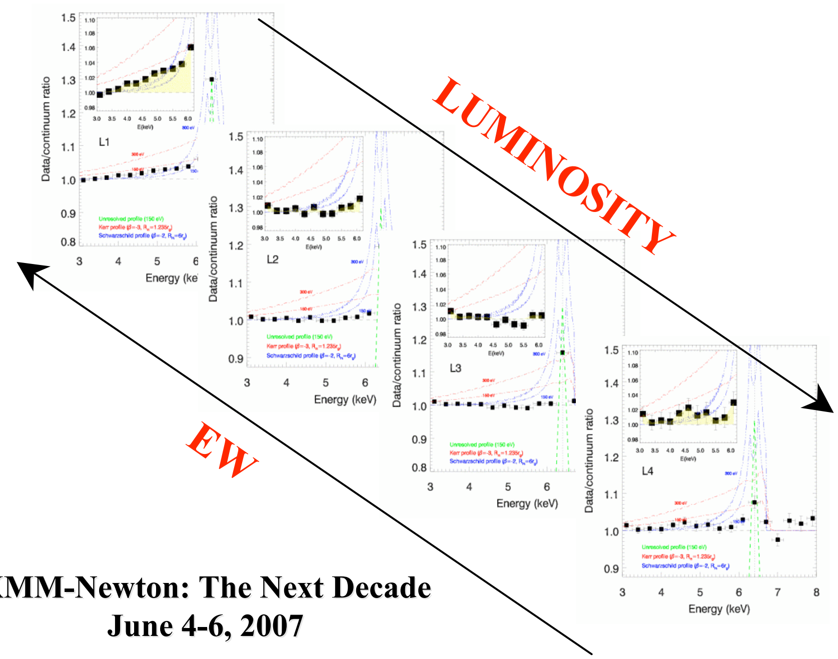


Conclusions

Guainazzi+ 06

Relativistic broadened Fe K_α lines:

- are present in 25% of the sample, ~50% of well exposed sample
- are significantly more common in low luminosity AGN



This Work

Relativistic broadened Fe K_α lines:

- **are present in 8% of the sample, ~57% of well exposed sample**
- **no significant difference between different luminosity classes, but our stacked spectra are not dominated by well exposed sources (*see Anna Lia Longinotti's poster*)**
- **EW < 400 eV**
- **disk parameters are consistent with expectations ($\phi \sim 30°$, $\beta \sim 3$)**

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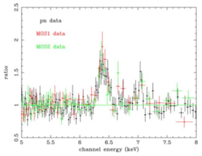
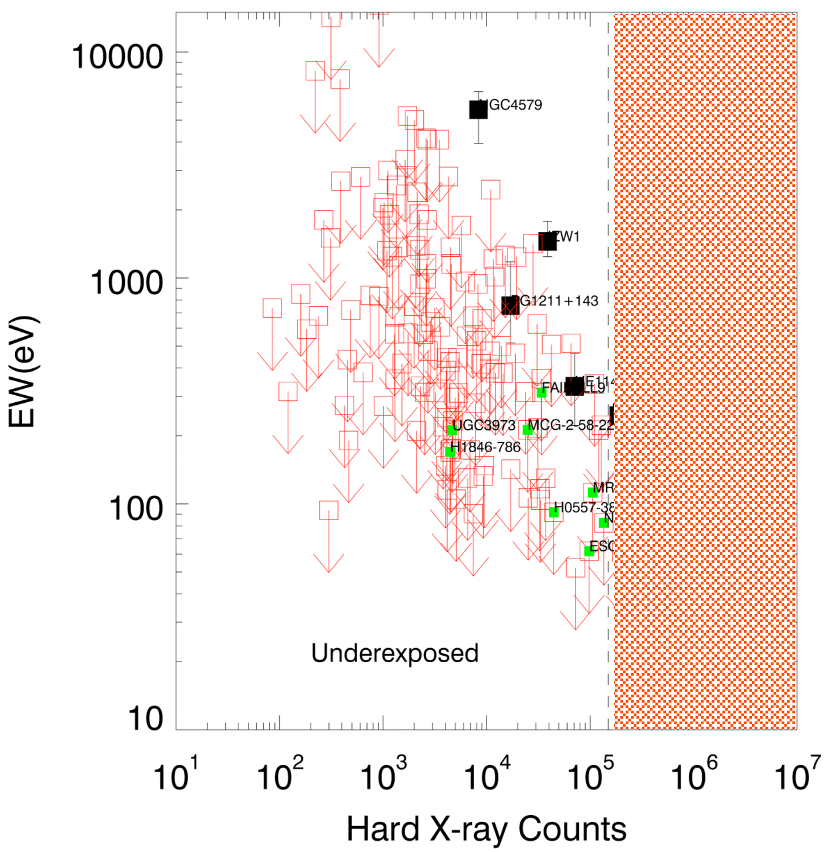


Future Work

Summary



Sources with enough statistics

$\geq 1.5\times10^5$ counts in the 2-10 keV band

By the end AO6:

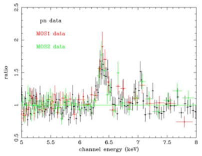
10 X-ray unabsorbed AGN to complete the XMM-Newton coverage of an XSS flux limited sample.

Model

- Ionized reflection, more complex warm absorber

Physics

- Correlation of the EW with accretion rate and BH mass



Spectral Stacking

Analysis

To overcome the statistical limitation in the detectability of a broadened K_{α} profile on individual sources, the individual source spectrum can be stacked.

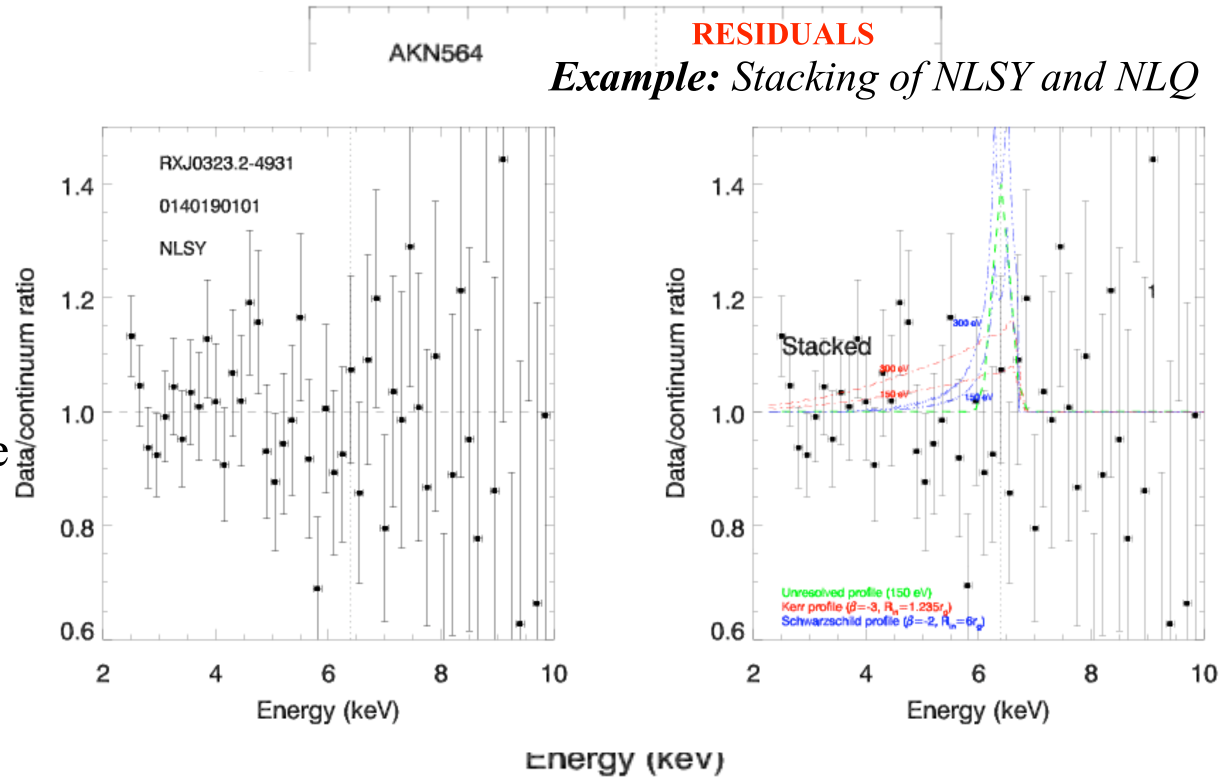
Stacked Spectrum

- Residuals with respect to the continuum in the 2 – 10 keV energy range
- Residuals binned over 150 eV bins
- *Loop* over sources stacking the residuals by working out the weighted mean in each energy bin.

(See A. L. Longinotti's poster)

RESIDUALS

Example: *Stacking of NLSY and NLQ*



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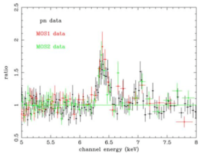
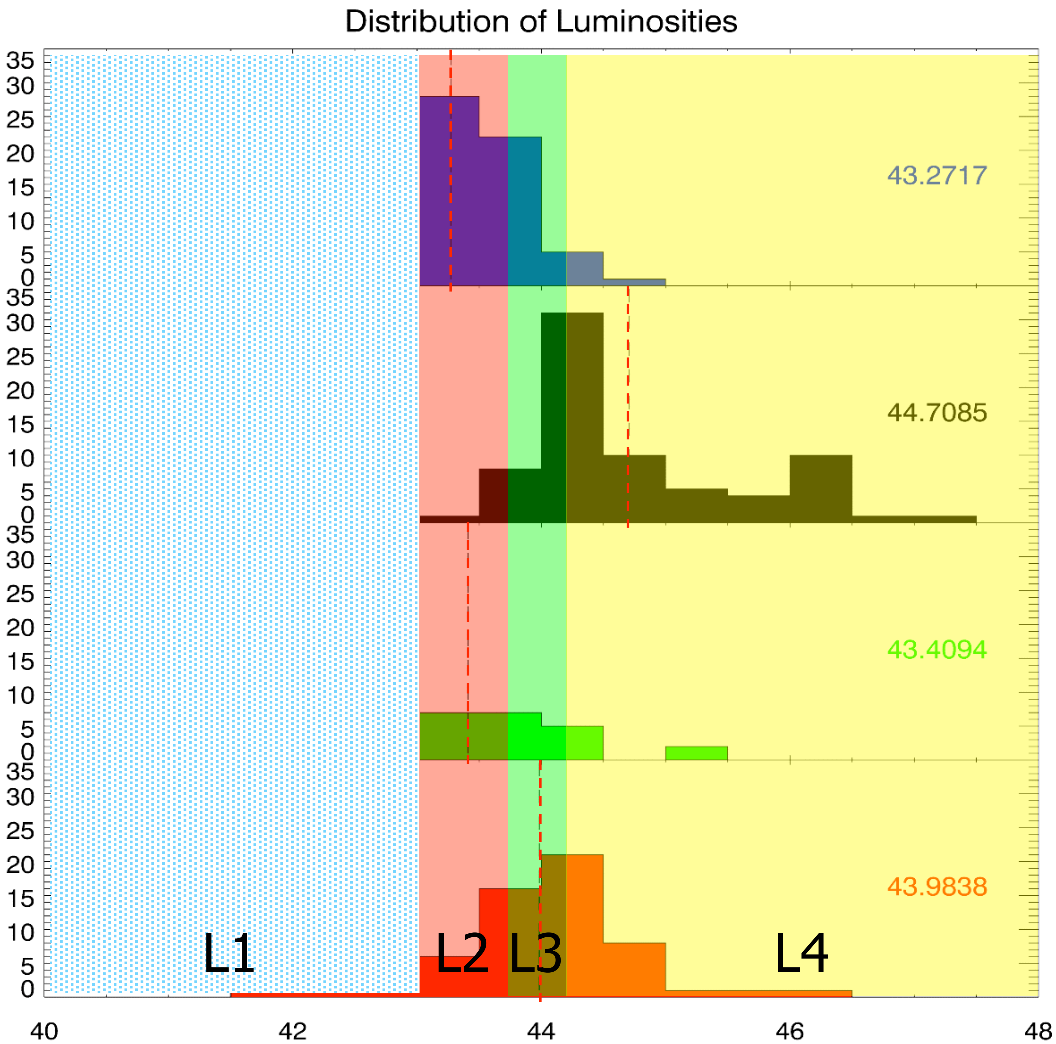


Luminosity Distribution



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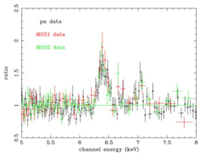
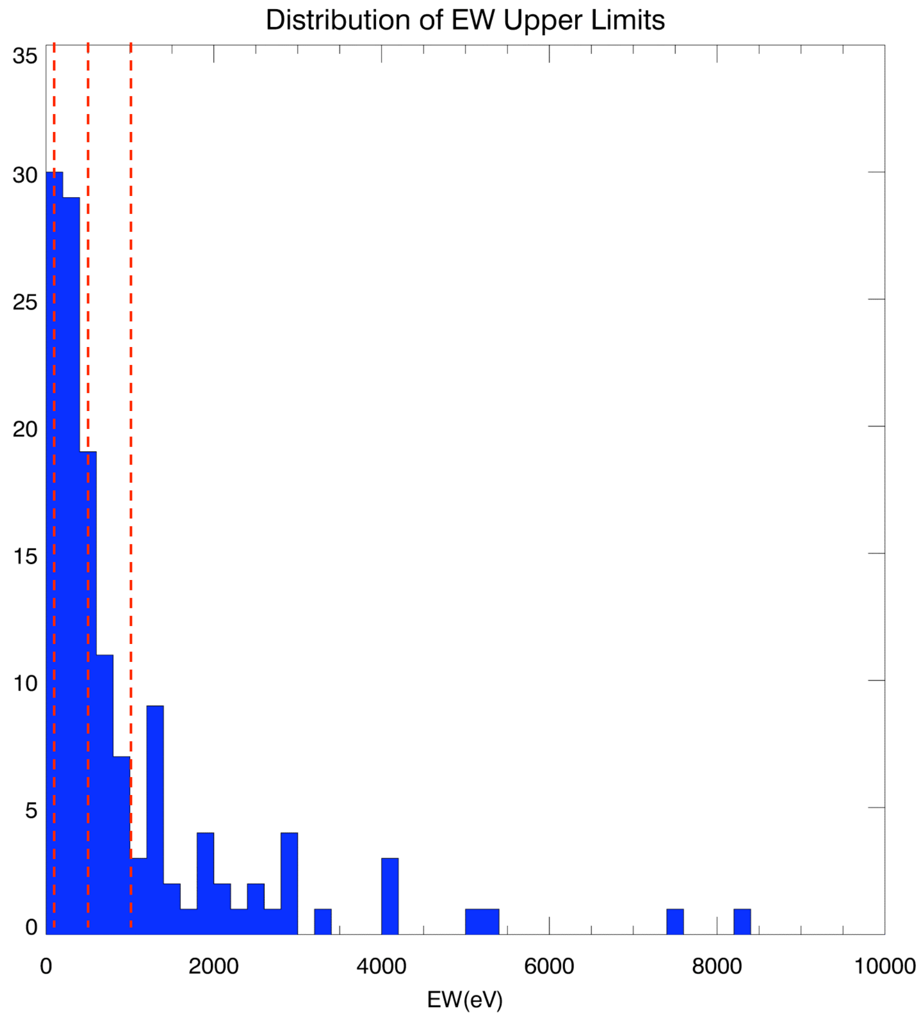
L_x in 10^{43} erg s^{-1} (2 – 10 keV)



Upper Limits

Results



Summary of Upper Limits

$EW_{UL}^{90C.L.} < 1000$ eV ~ 70%

$EW_{UL}^{90C.L.} < 500$ eV ~ 50%

$EW_{UL}^{90C.L.} < 100$ eV ~ 10%