Iron line emission in average X-ray spectra of Active Galaxies

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Iron line at high-z

High-z AGN in surveys fields (COSMOS, CDFS, etc.) are detected tipically with 50-1000 counts

same level of detailed study of Iron line as in local universe cannot be achieved on single objects with present instrumentation

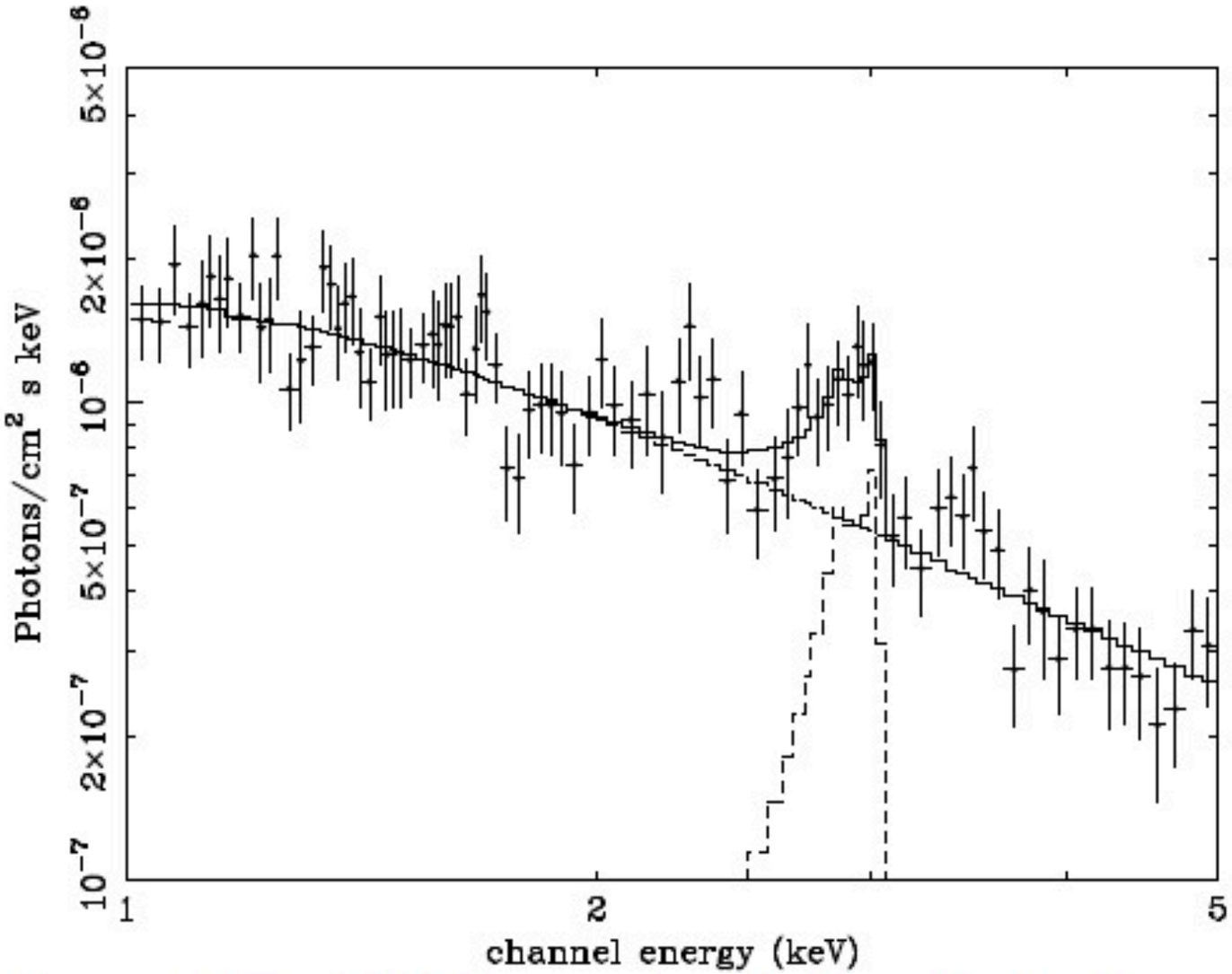


Figure 4. The unfolded spectrum fitted with an absorbed power law ($\Gamma \simeq 1.5$; $N_H \simeq 1.7 \times 10^{22}$ cm^{-2}) plus a relativistic disk line.

Comastri, MB & Civano 2004, MNRAS 351, L9

z=1.146

~2500 counts
2Ms observation

(CDFN)

Stacking!

- **Stacking = summing together emission from many sources.**
  loose info on the single sources, but gain on the ***average population***

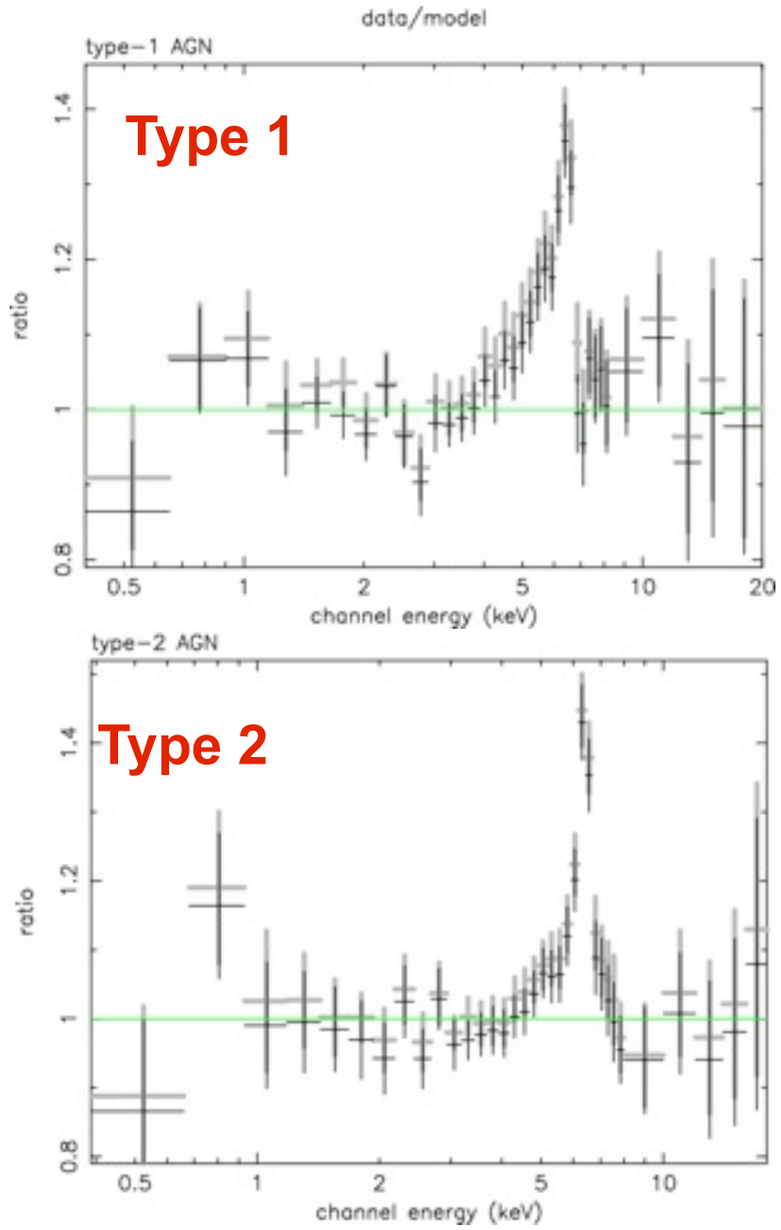
- Increase the exposure and statistics, push sensitivity *order of magnitudes* deeper than the nominal exposures (for samples of few hundreds of sources)

- ***Imaging*** stacking techniques routinely used at longer wavelengths -
  e.g. LABOCA/Herschel works (Lutz et al. 2010, Shao et al. 2010)

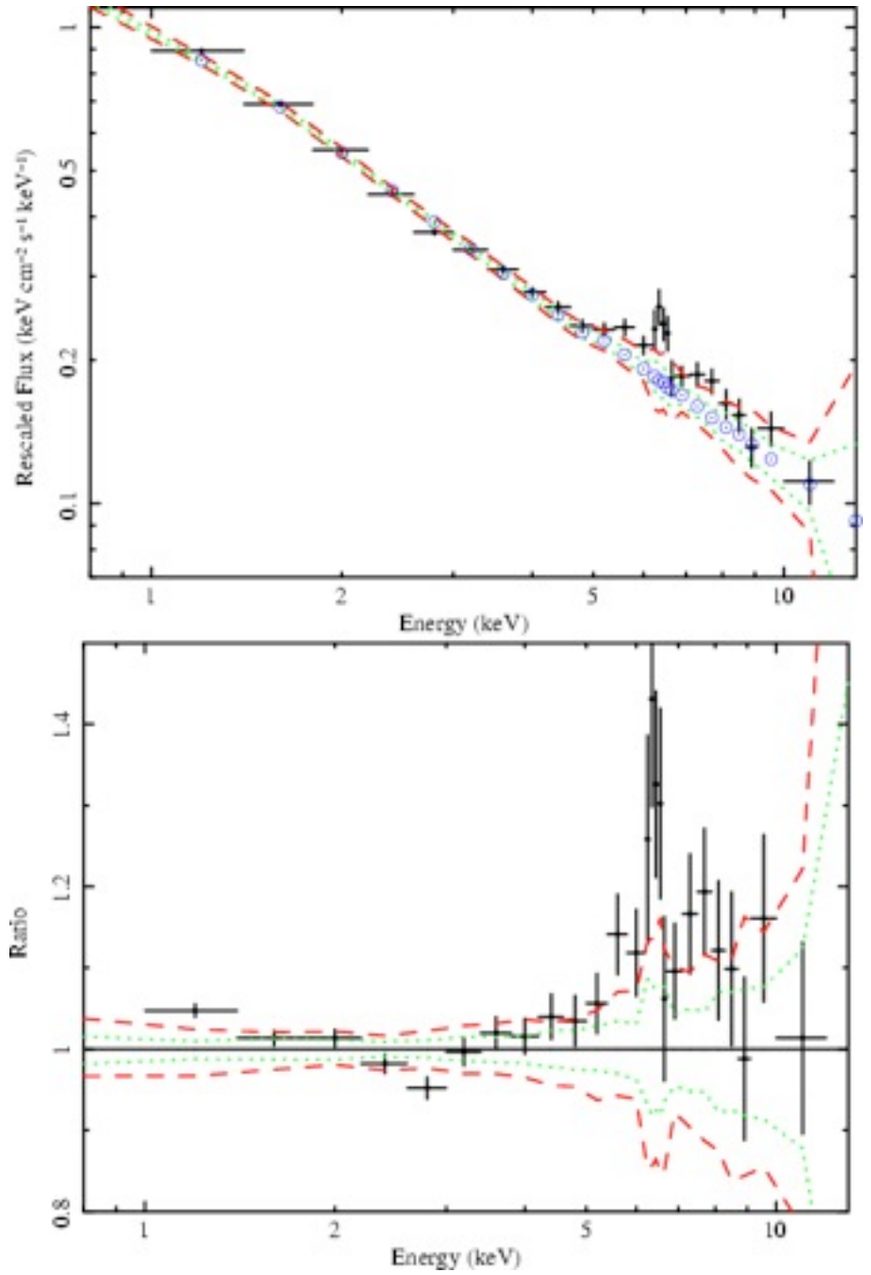
- ***Spectral*** stacking also very powerful -
  e.g. composite optical spectra from SDSS (Vanden Berk+2001)

- ***X-ray spectral*** **stacking** still “young” field - literature is relatively scarce

Broad component initial results

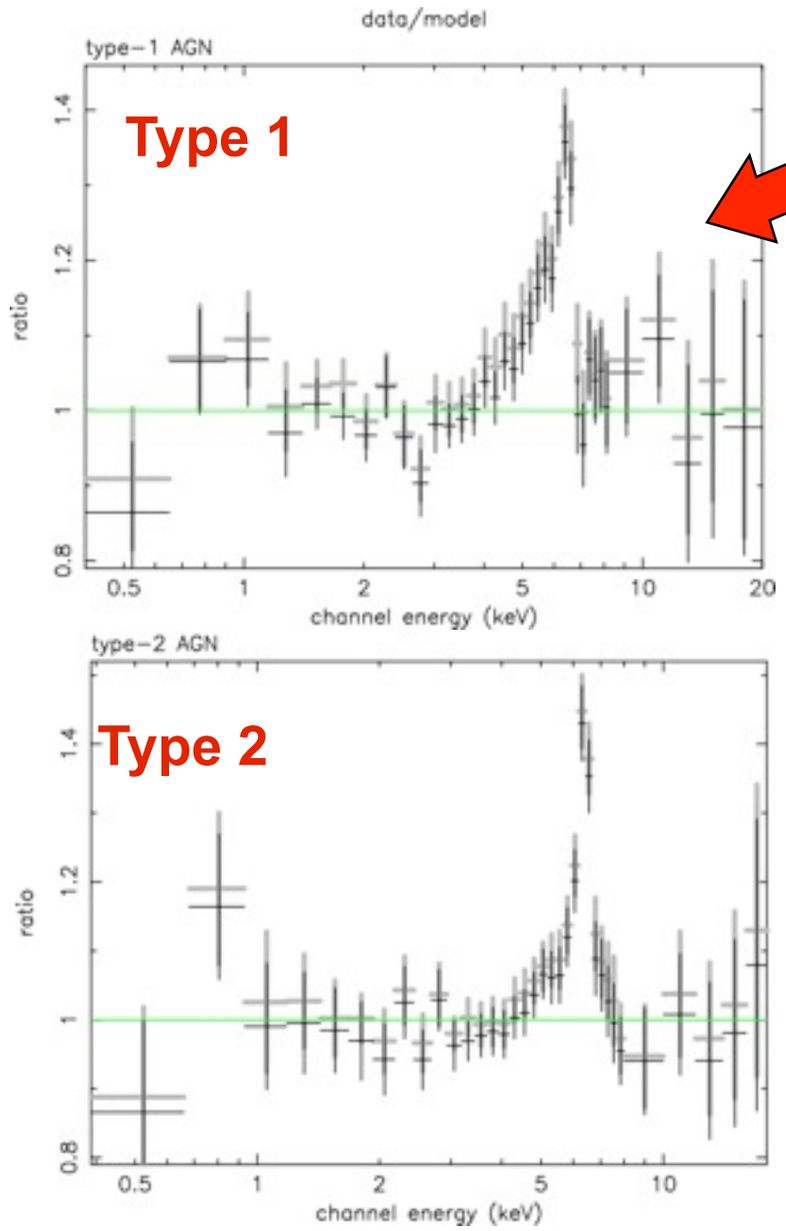


Streblyanska+2005



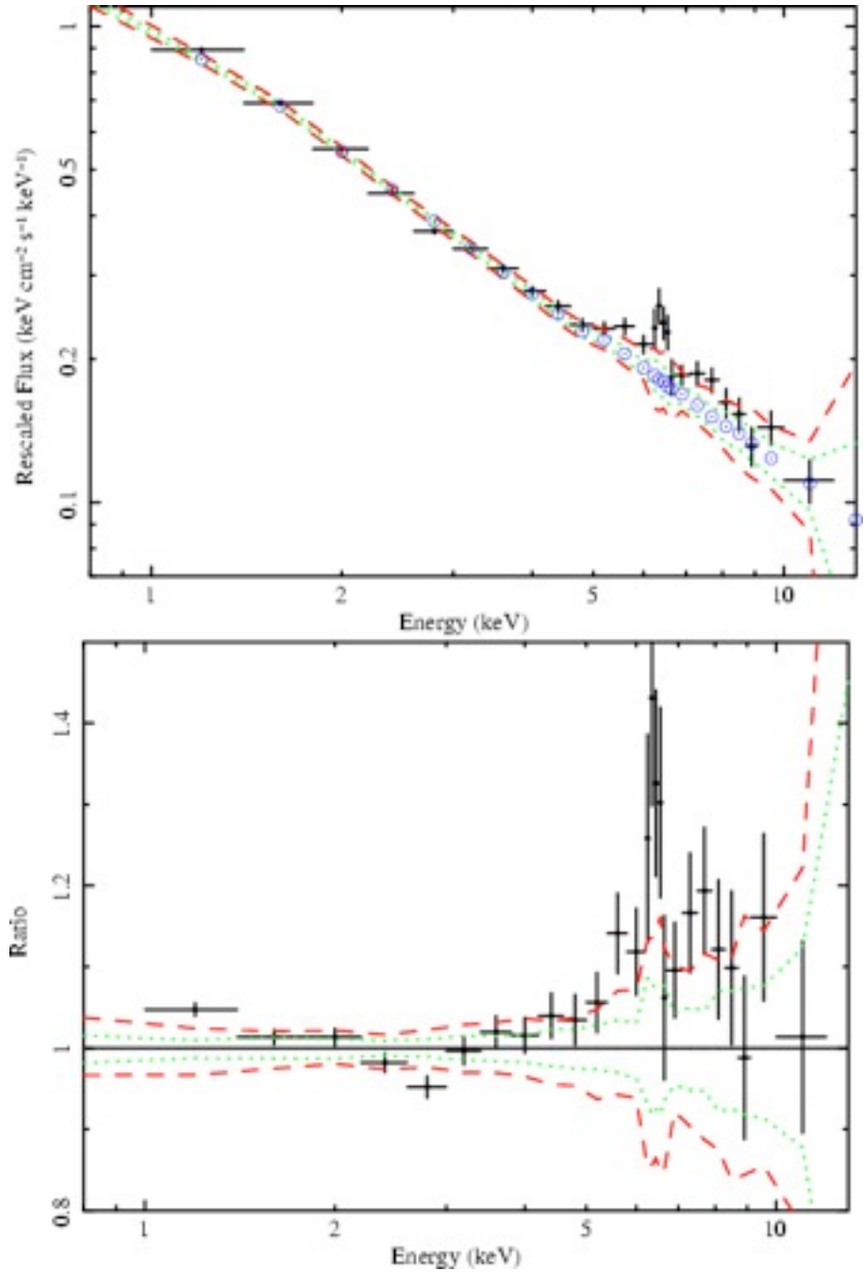
Corral+2008

Broad component initial results



Broad, relativistic line common in all AGN

EW ~ 300-400 eV (wide range of z)



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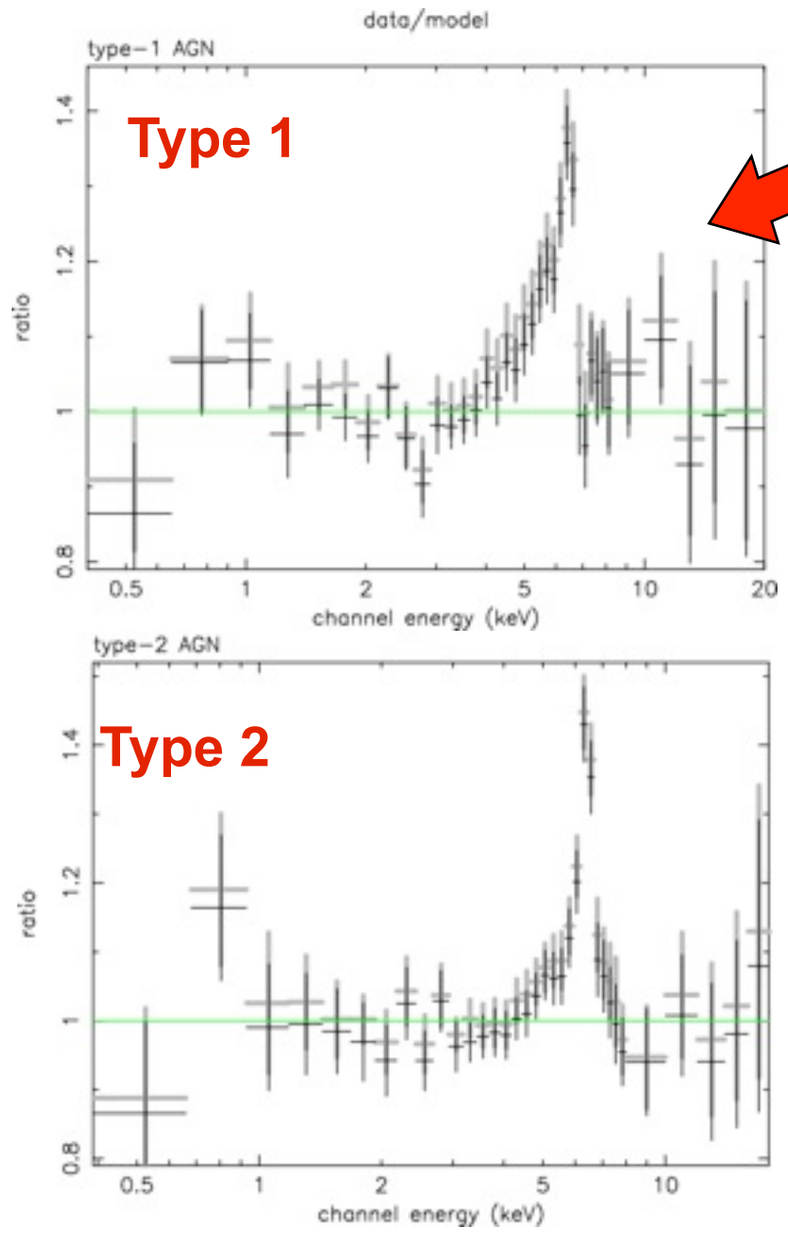
Broad component initial results



Streblyanska+2005

Broad, relativistic line common in all AGN

EW ~ 300-400 eV (wide range of z)

Iron line common in all AGN; broad component not significant

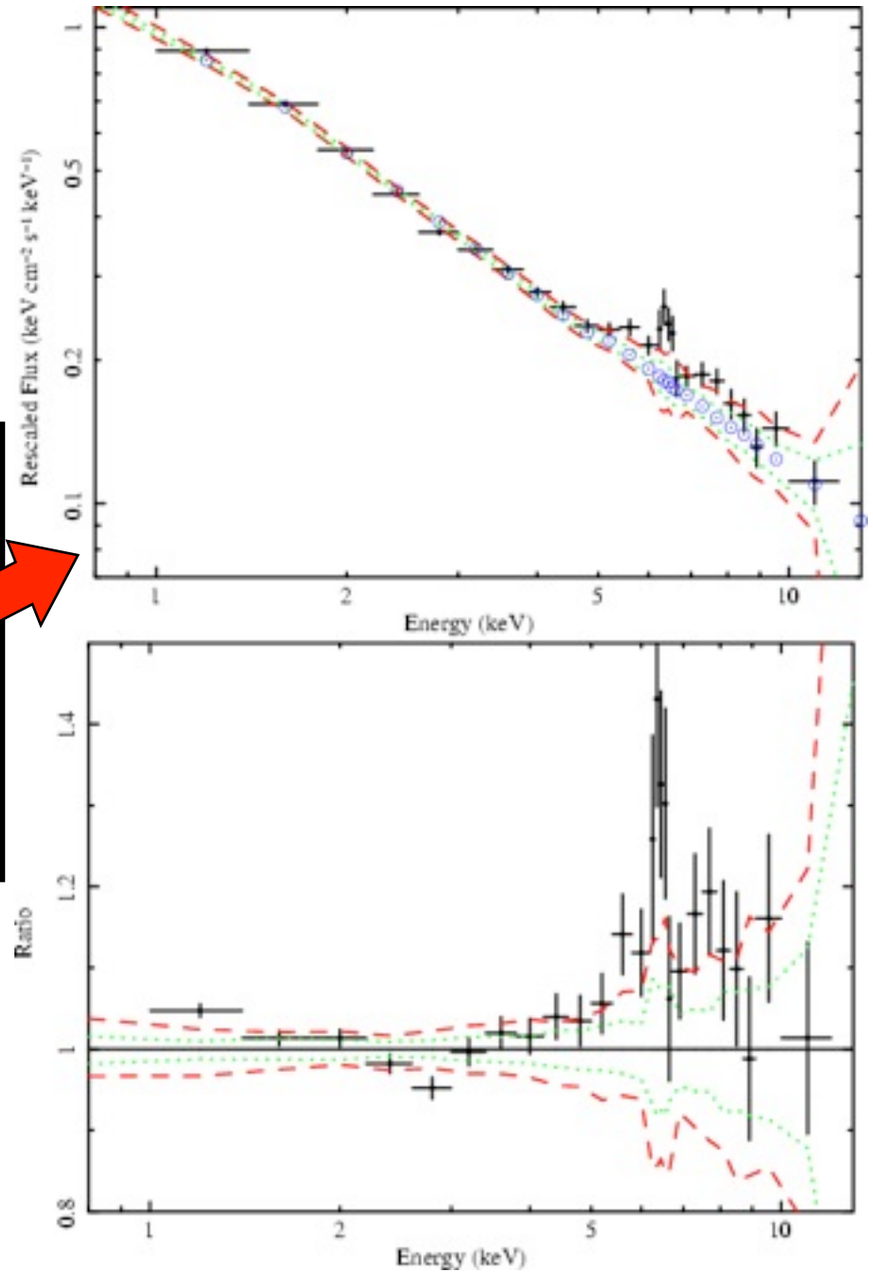
EW <400 eV (wide range of z)

see also:

Mao+2010:
BL ~ 400 eV but no relativistic

Iwasawa + 2012:
no significant detection of BL component

Falocco + 2012:
no evidence of a relativistic profile in any of the average stacked subsamples



Corral+2008

rest-frame method/procedure

(details... see extensive discussion in Chaudhary et al. 2012)

Extract individual spectra

First step: adaptive grouping (with grppha) the 2-10 keV (rest frame) range in predefined bins of equal width (0.25 keV and 0.1 keV)

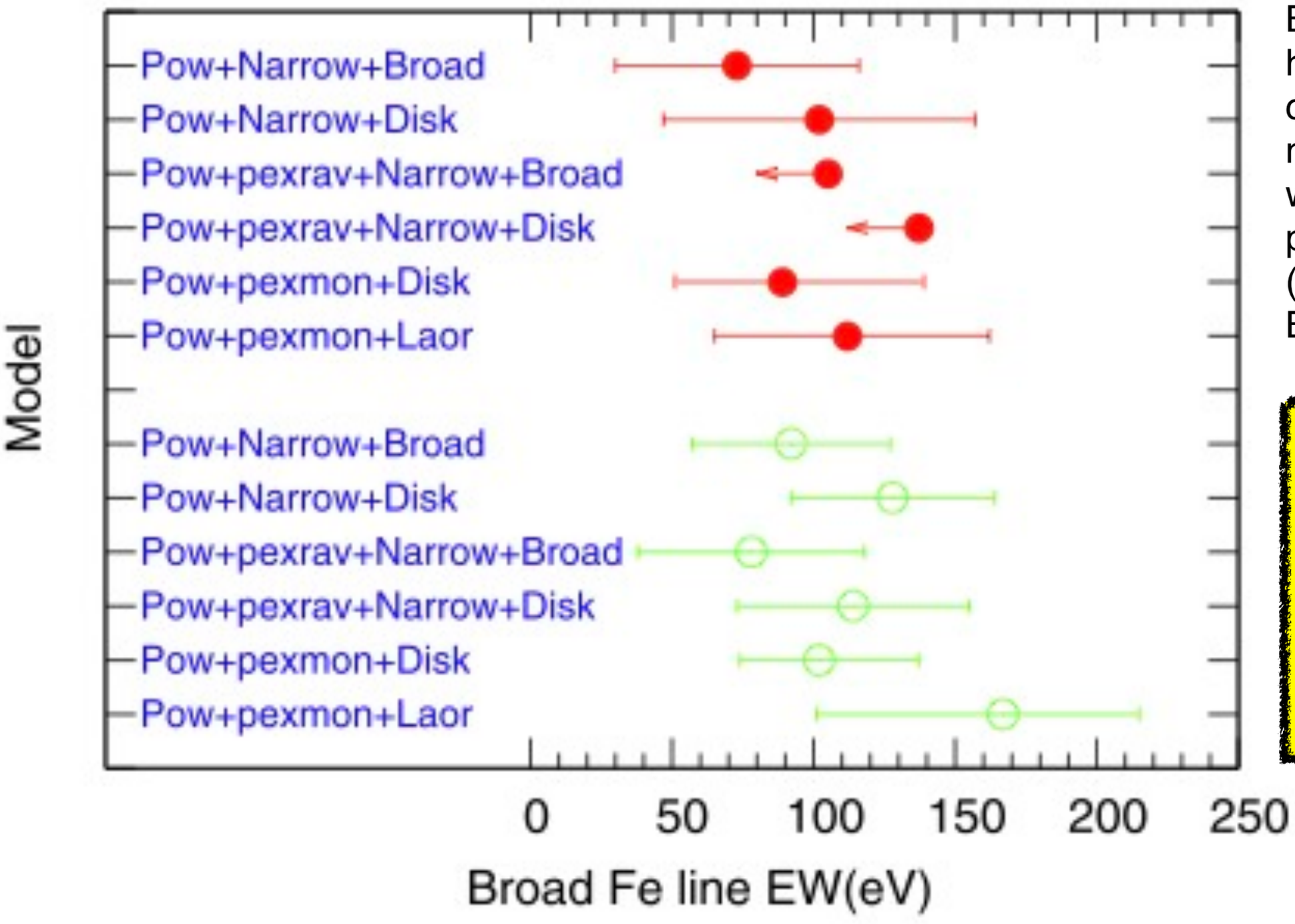
Second step: Each 2-10 keV rest frame, grouped spectrum is fit with C-statistic, and with an absorbed power-law (ignoring the 5.5-7 keV range); Ratios wrt best fit model are saved, as well as individual spectra

Third step: Ratios are summed and averaged; Spectra are divided for the effective area, normalized to the 3-5 keV continuum and then summed and averaged (Iwasawa method)

Fourth step: Ratios are reconverted in flux space by multiplying for E^{-Gamma}, then fit to determine spectral parameters

broad component: 2XMM results

Chaudhary, MB et al. 2012, A&A, 537, 6

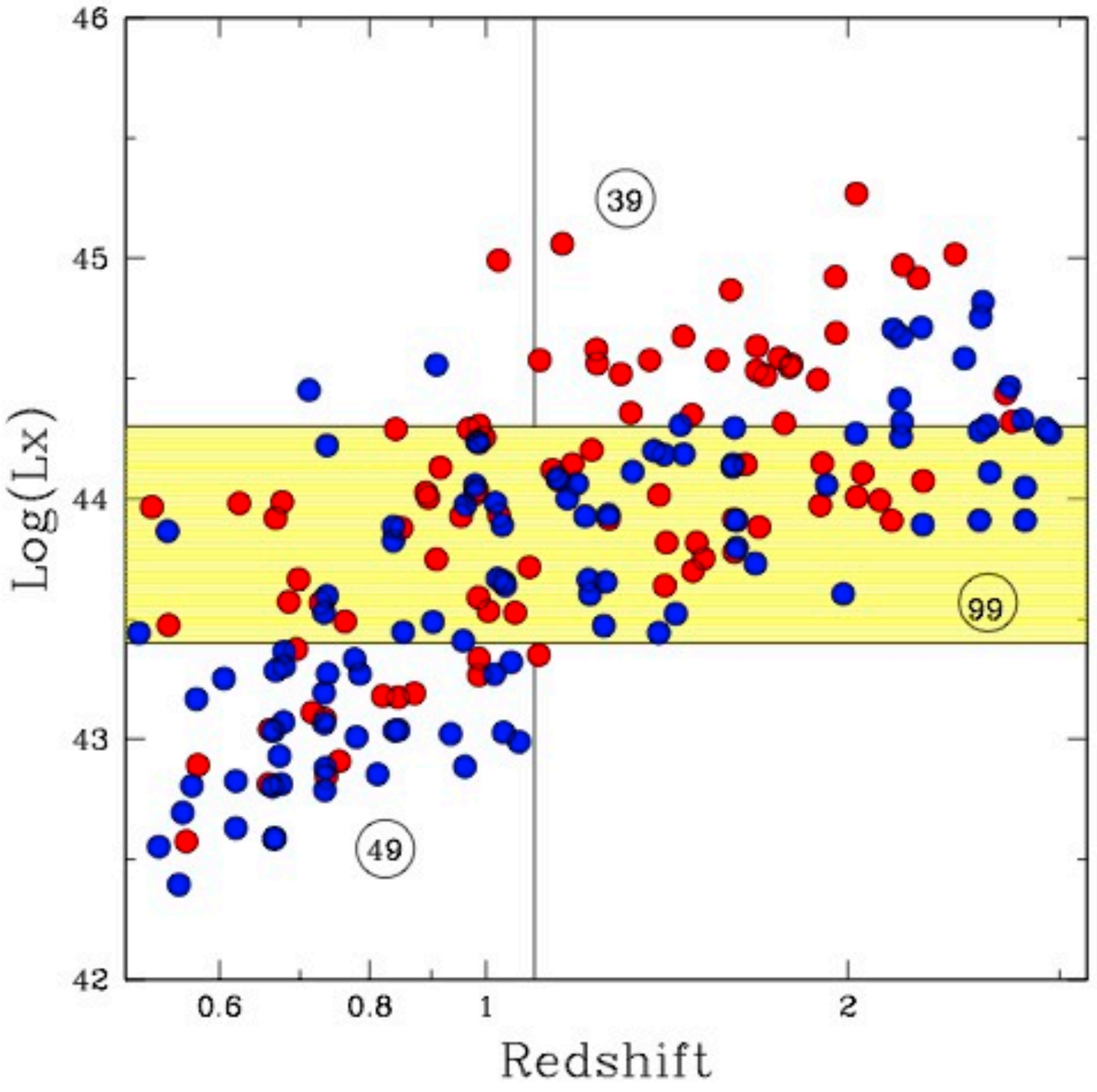


Broad line parameters: highly sensitive to continuum and stacking method but consistent with theoretical predictions (George+Fabian 1991, Ballantyne 2010)

EW for the broad component ***never exceeds 200 eV*** in all the models investigated

Chandra stacking

Brusa et al. in prep



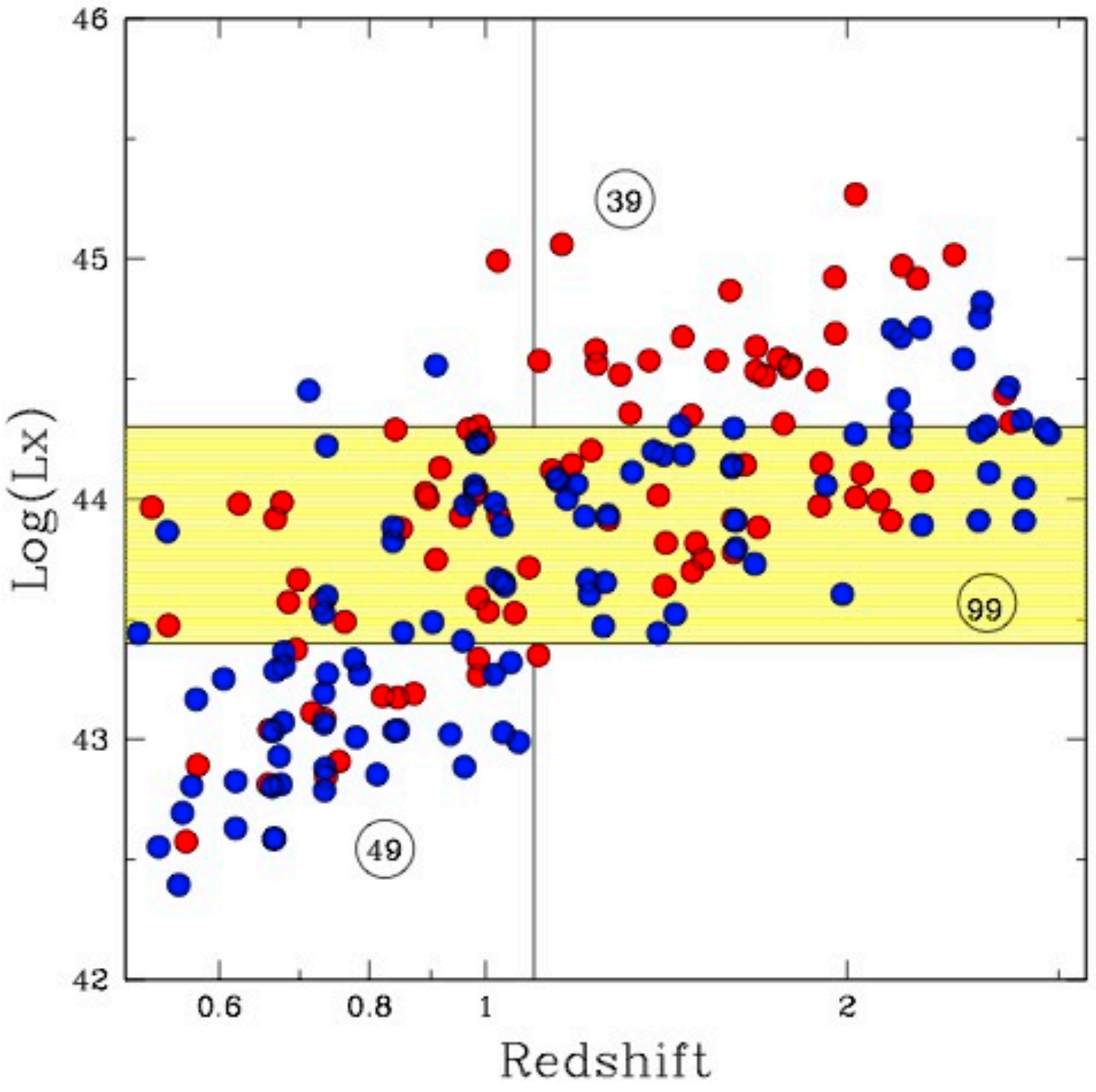
- stacking of Chandra Deep Fields (CDFS, E-CDFS, CDFN) + C-COSMOS + AEGIS

- same method of Chaudhary et al. 2012

- **192** sources with >500 counts, z=0.5-3, NH<23

Chandra stacking

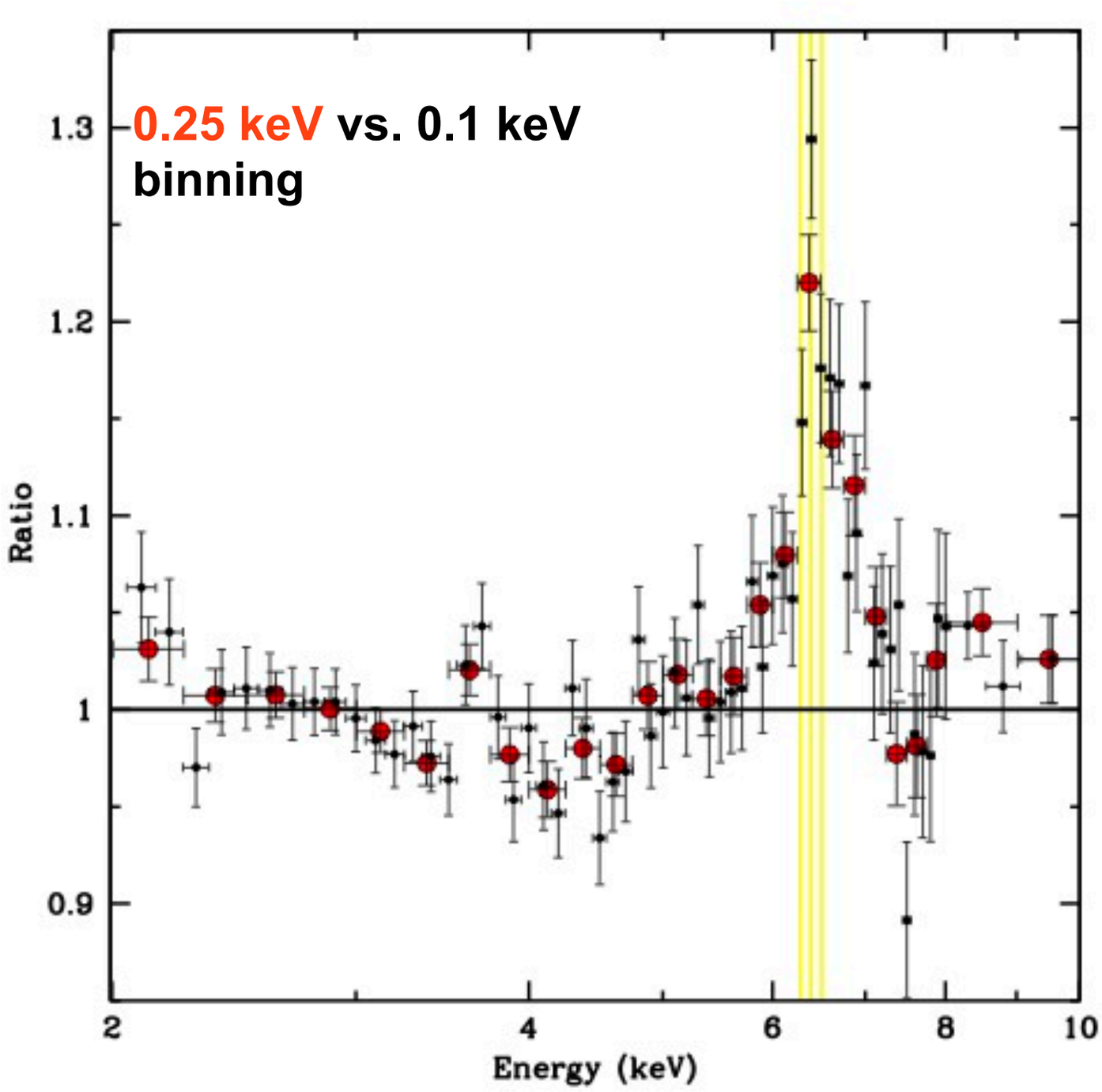
Brusa et al. in prep



- 101 sources from “deep” fields (>1 Ms exposure)
- 91 sources from “shallow” fields (150-800 ks expo)
- All but AEGIS: complete multiwavelength follow-up, very good photometric redshifts, SFR and stellar mass estimates from SED fitting

Chandra stacking

Brusa et al. in prep

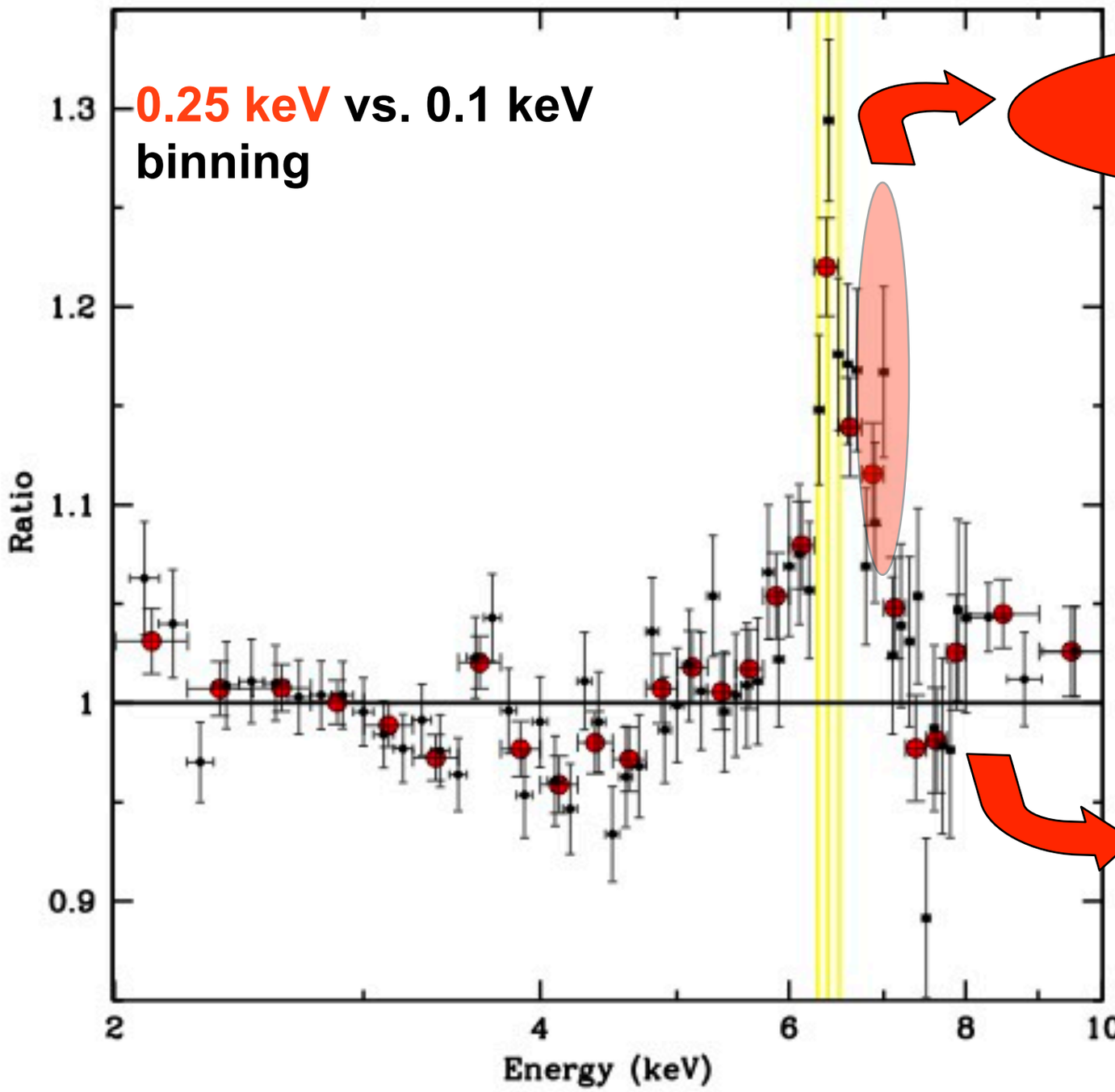


- Total of **~300.000** counts (highest number of counts ever achieved in a stacked spectrum)

N.B: Statistical errors already of the order of the absolute calibration of the instrument

Chandra stacking

Brusa et al. in prep

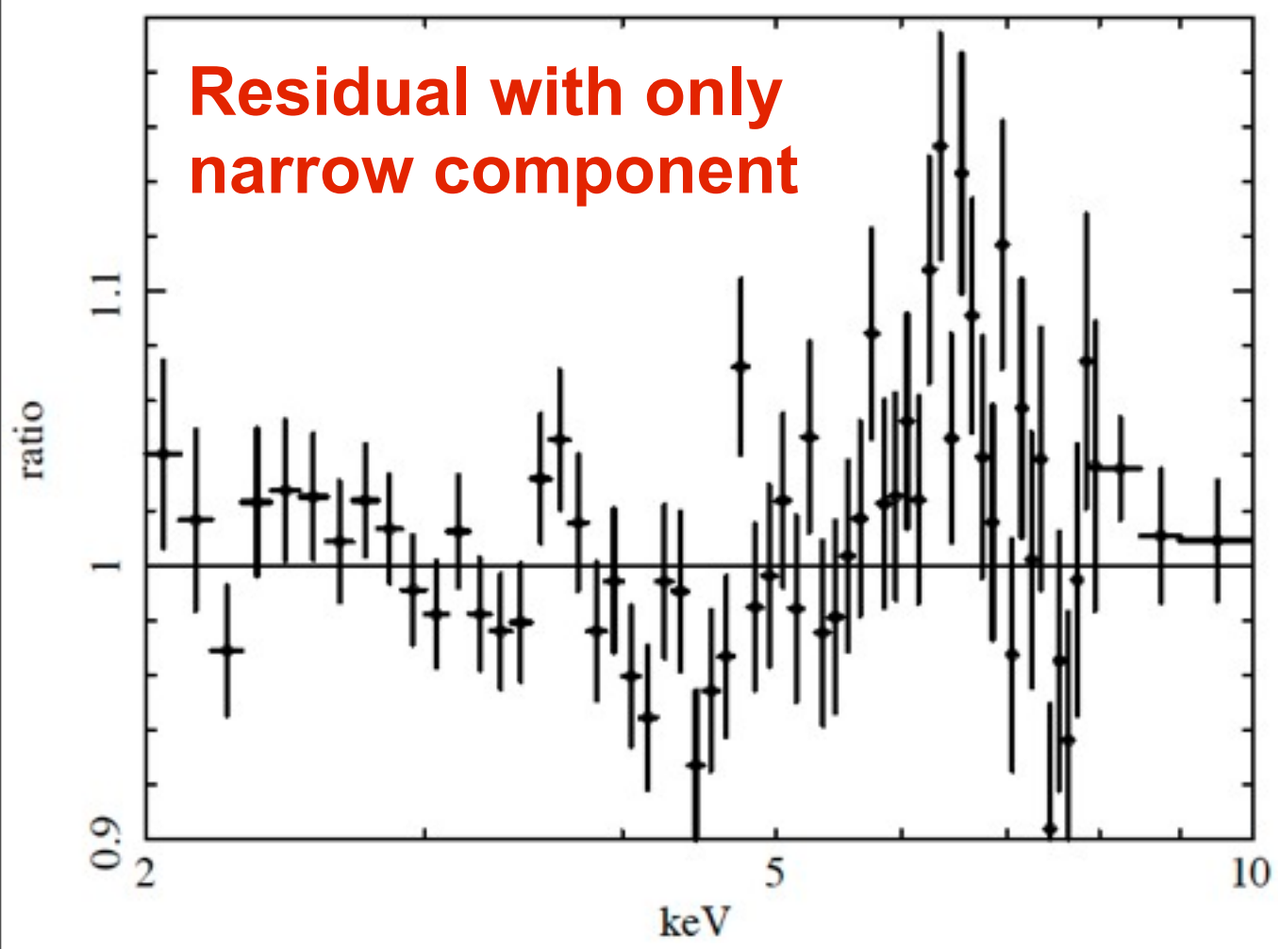


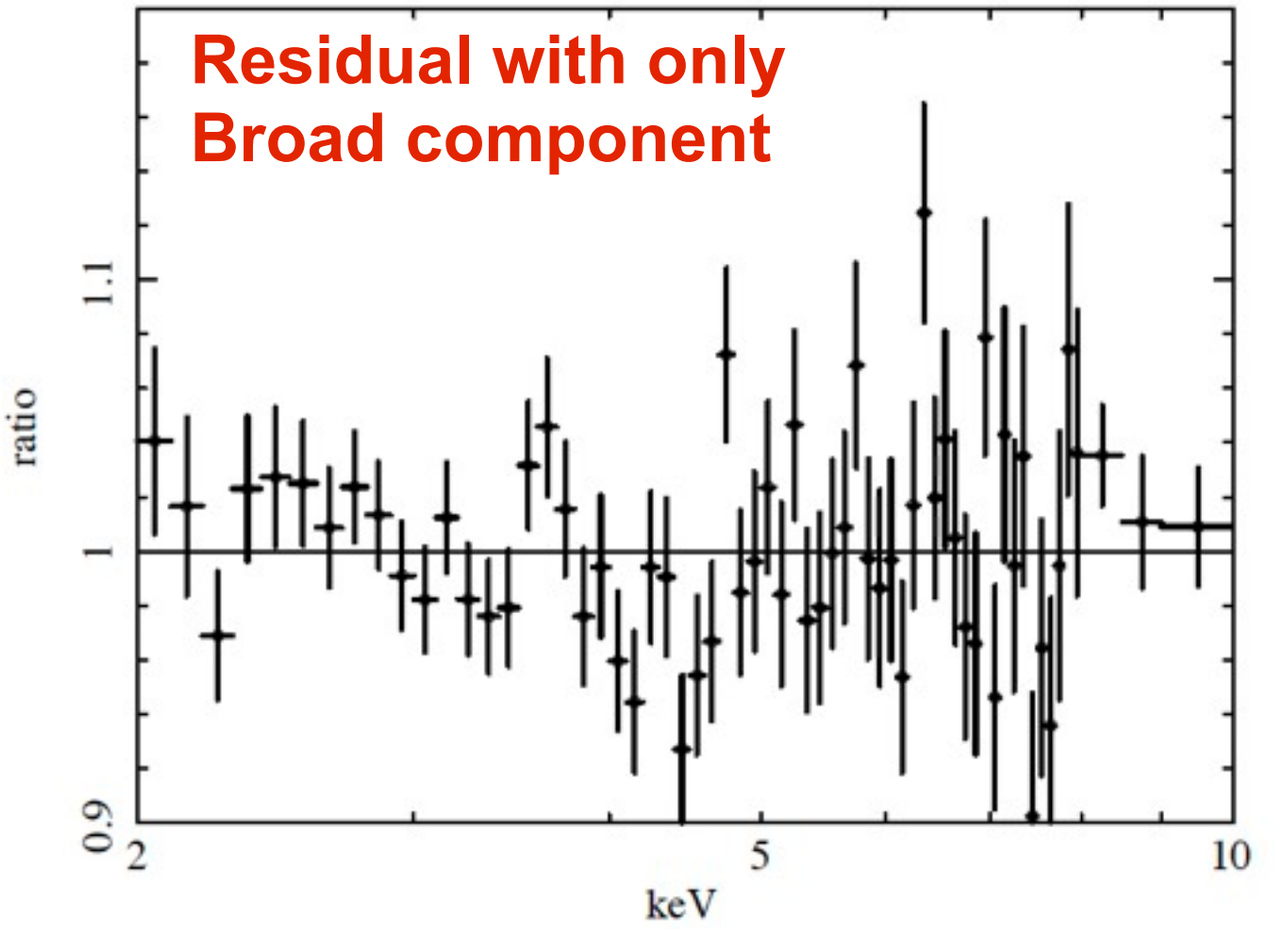
finer binning
6.97 keV line ?

- Total of **~300.000** counts (highest number of counts ever achieved in a stacked spectrum)

reflection component
+ 7keV edge

N.B: Statistical errors already of the order of the absolute calibration of the instrument





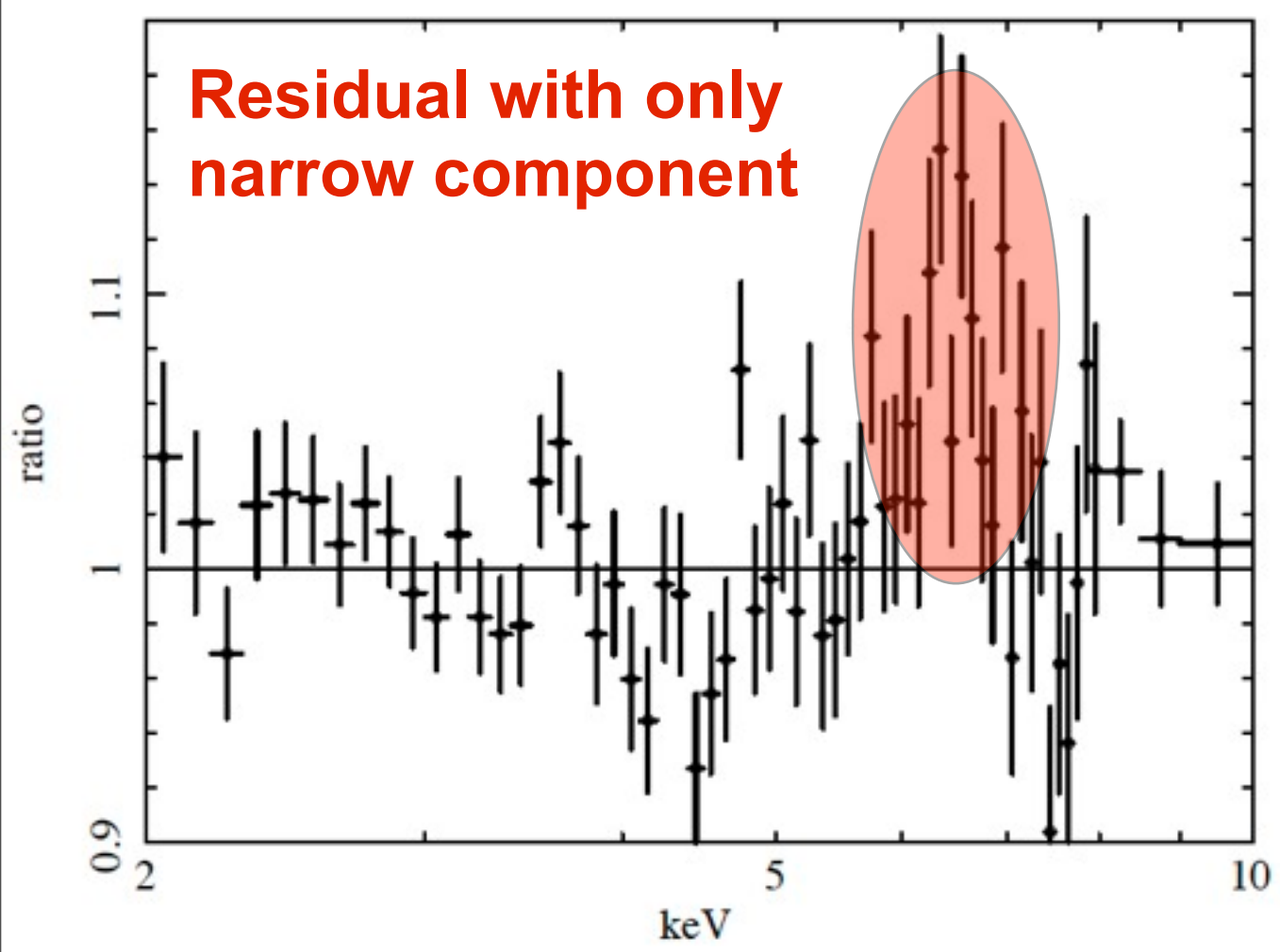
192 source spectrum

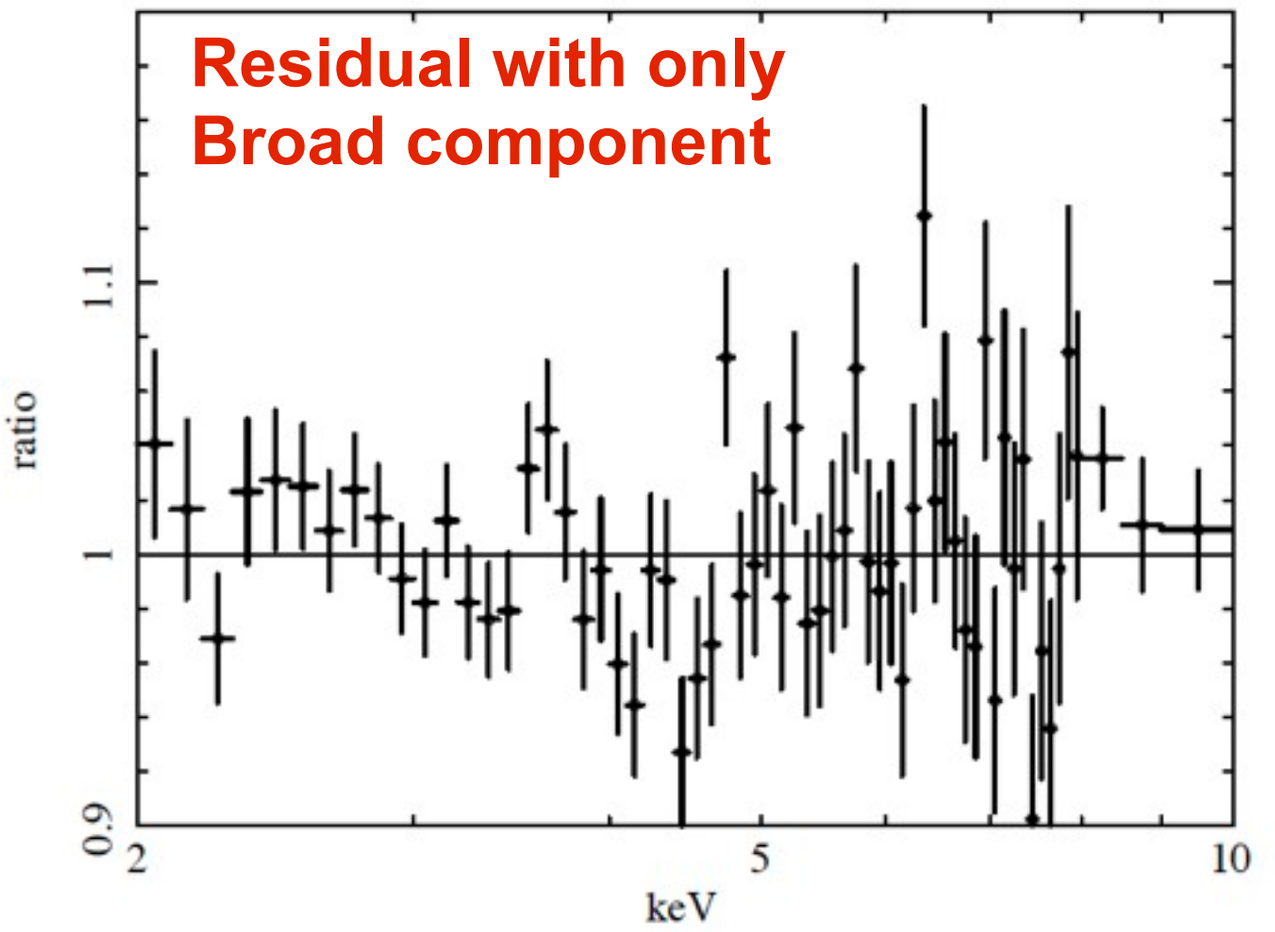
PL+pexrav+Gauss(N)+Gauss(B)

[all other complex models need to be explored]

EW(N) ~ 30 eV

EW(B) ~100 eV





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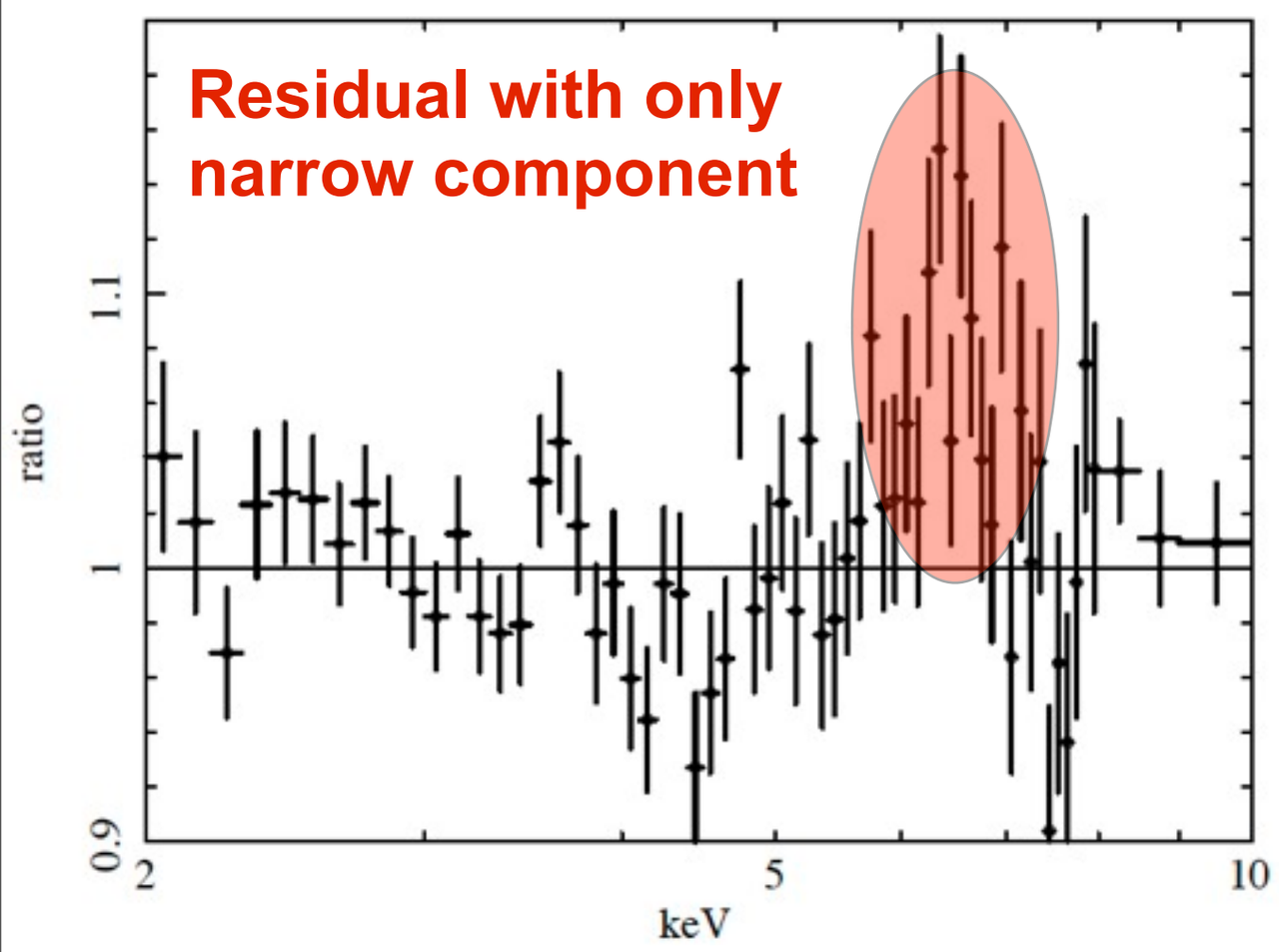

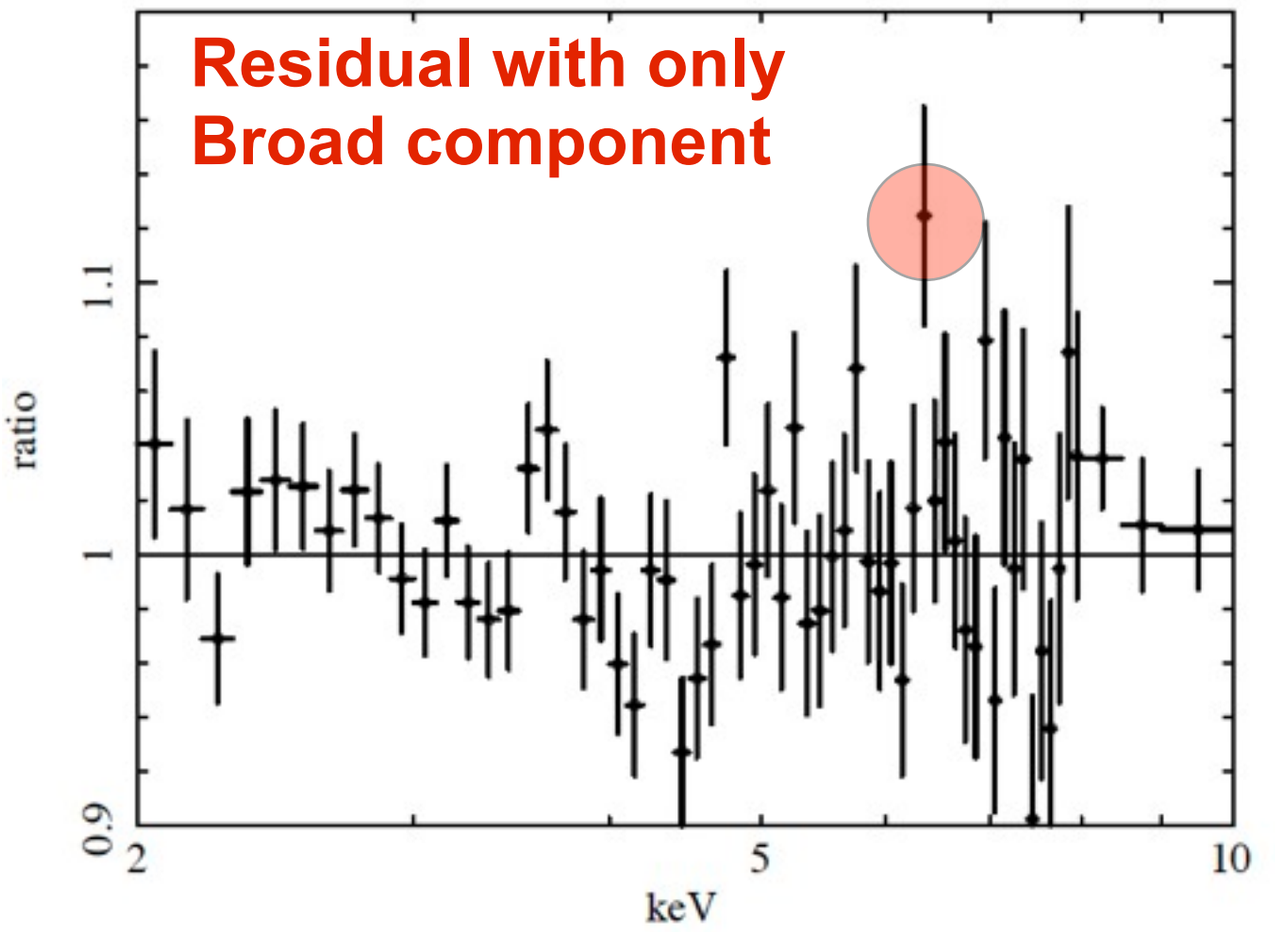

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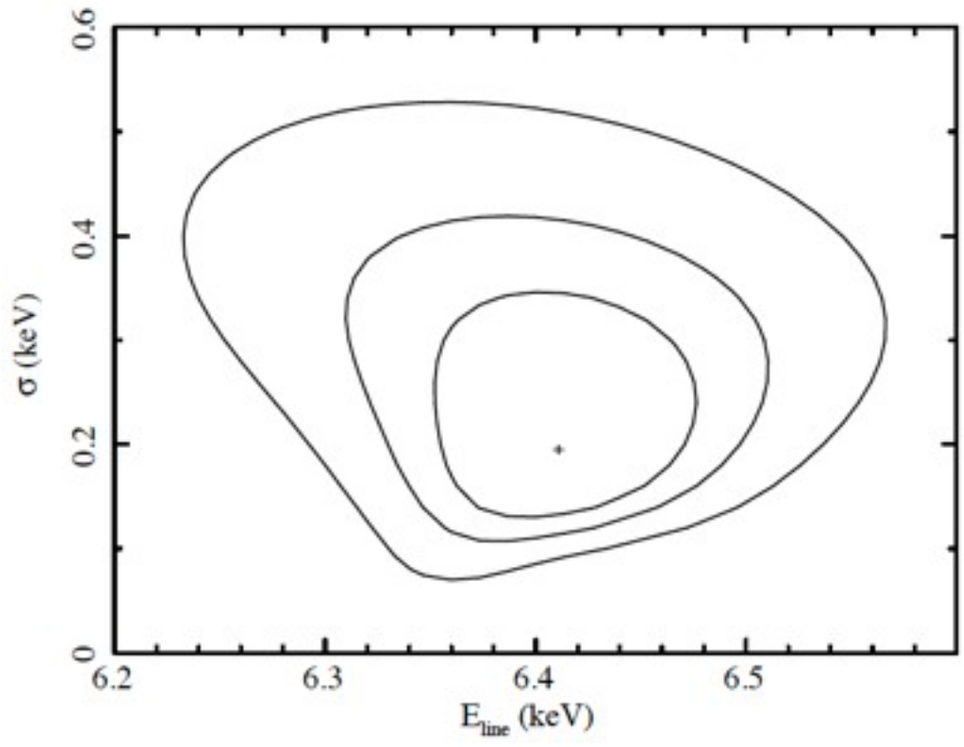
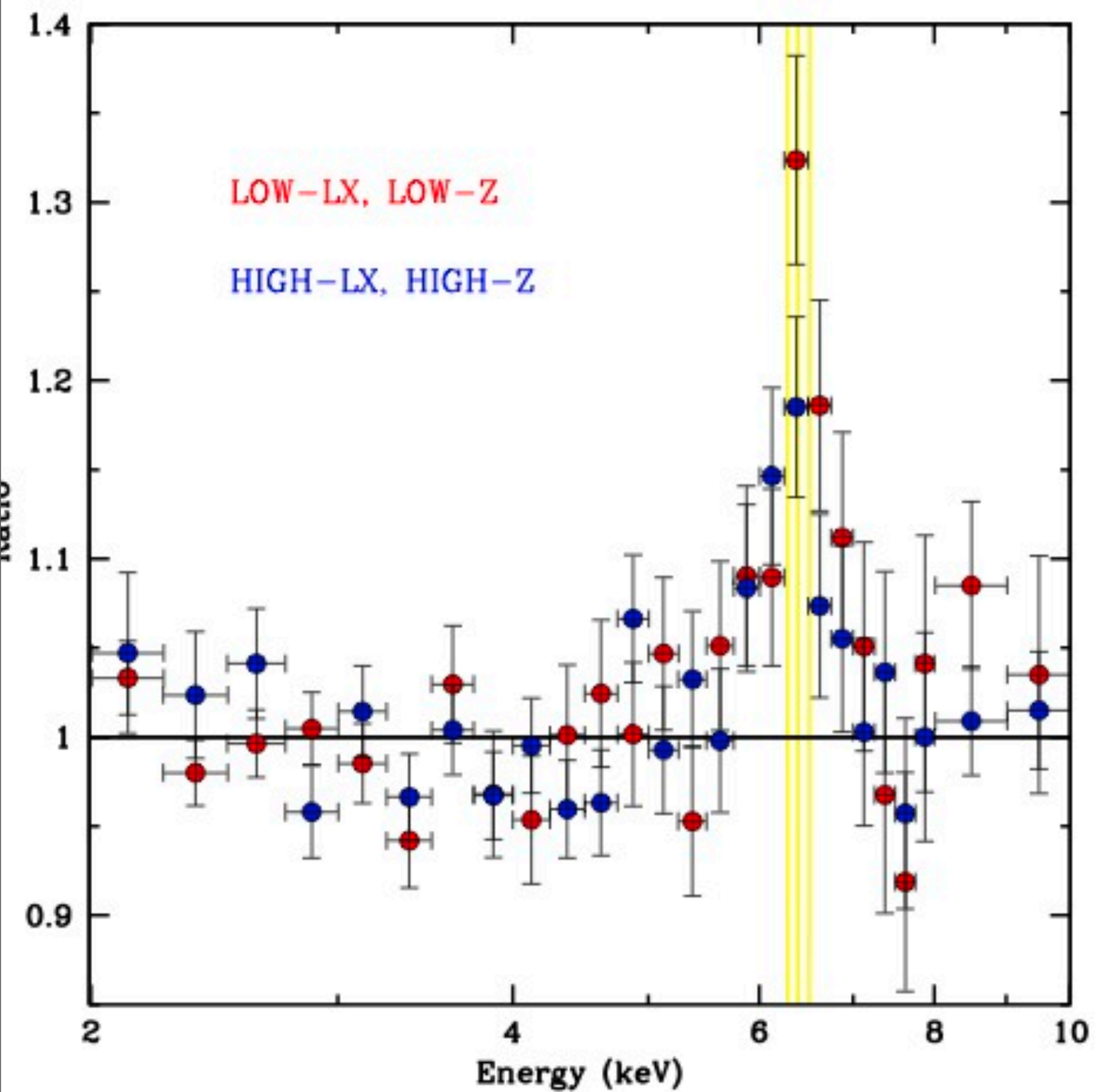
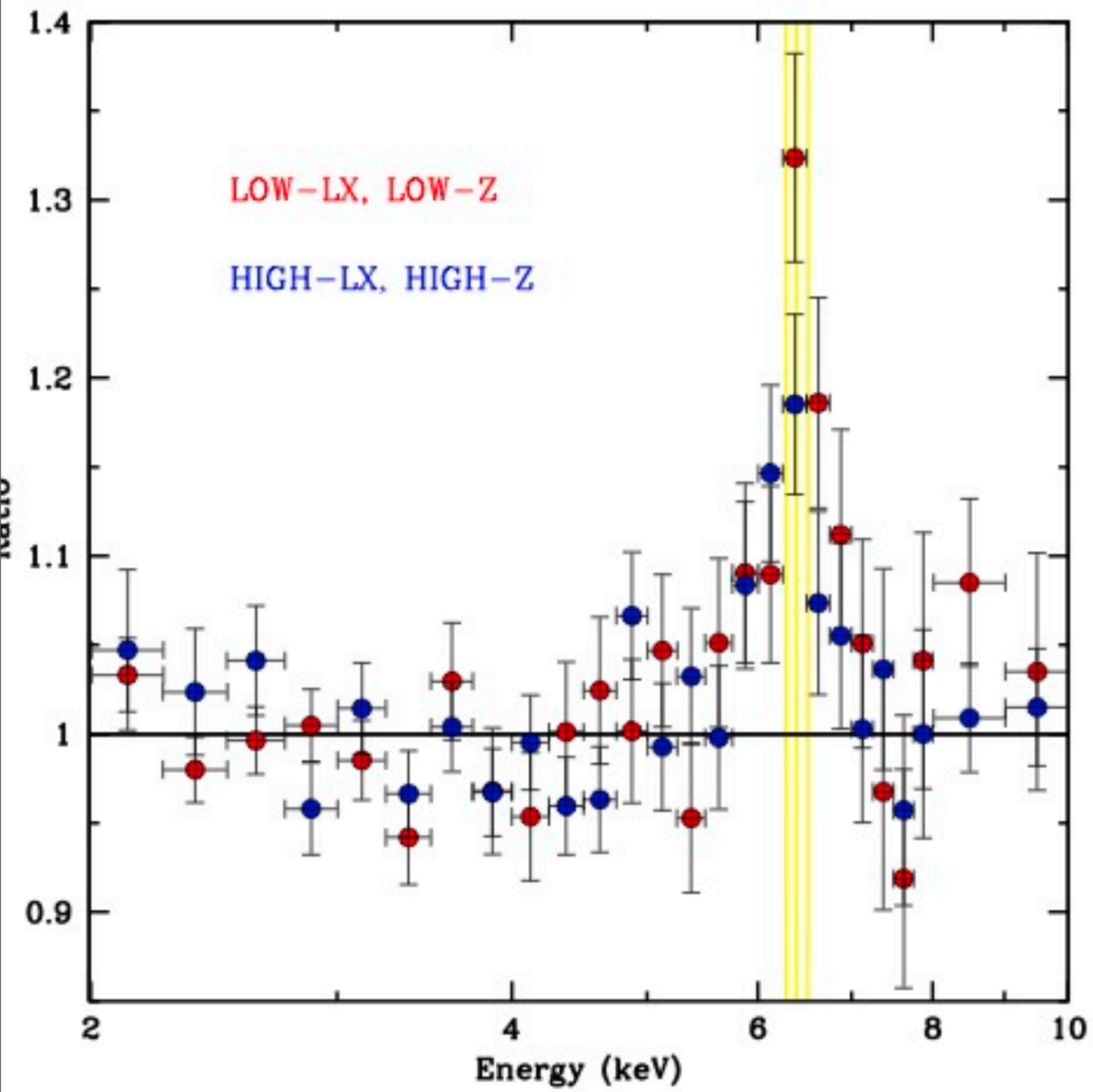


Chandra stacking



Low-LX:
reflection and edge more prominent
EW(N) ~ 30 eV
EW(B)~130 sigma=0.4

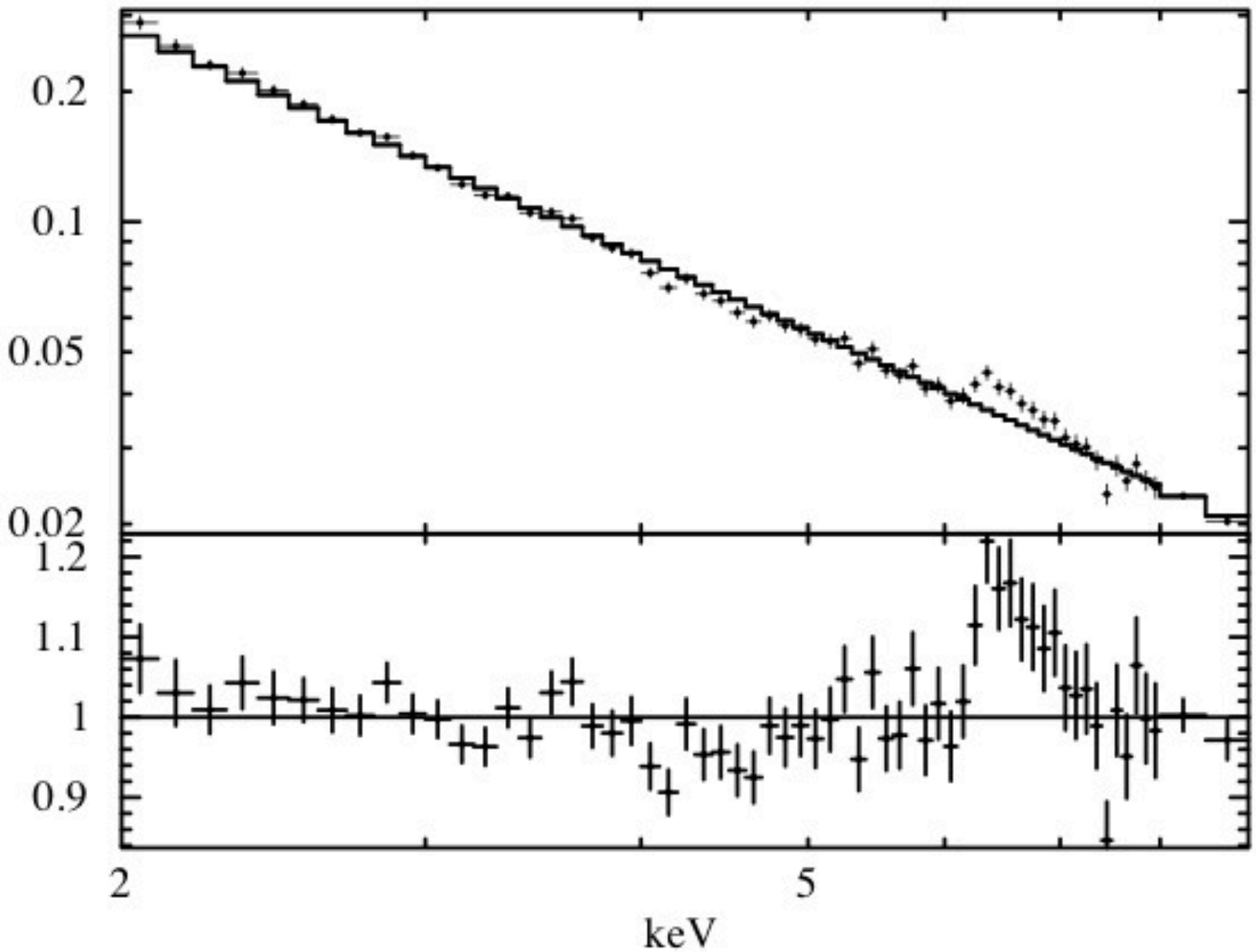
Chandra stacking



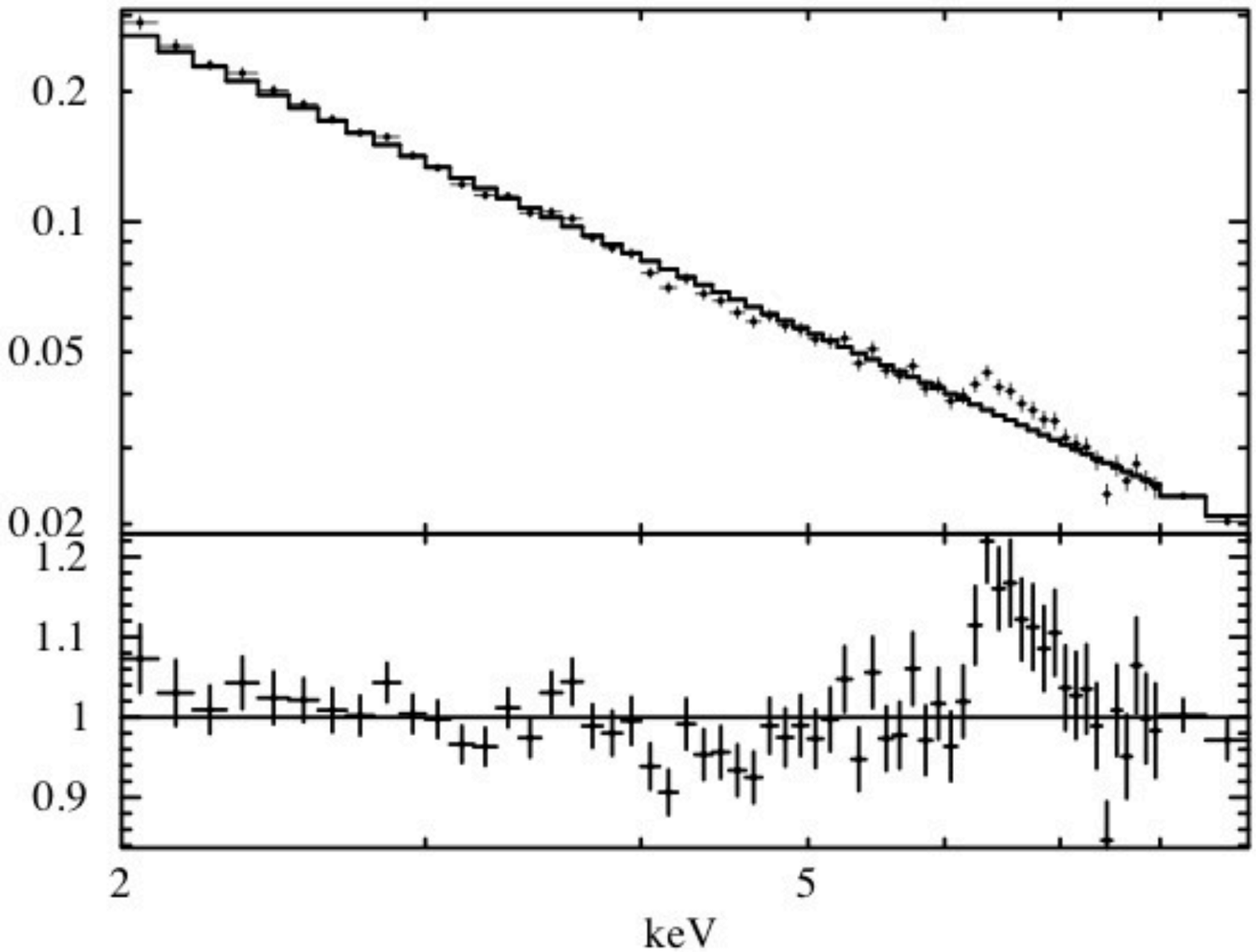
Low-LX:
reflection and edge more prominent
EW(N) ~ 30 eV
EW(B)~130 sigma=0.4

High-LX:
lower intensity in the 6.4 keV peak
EW(N) <30 eV
EW(B) ~130 eV (6.25 keV)
no excess at >8 keV

Chandra stacking



Chandra stacking



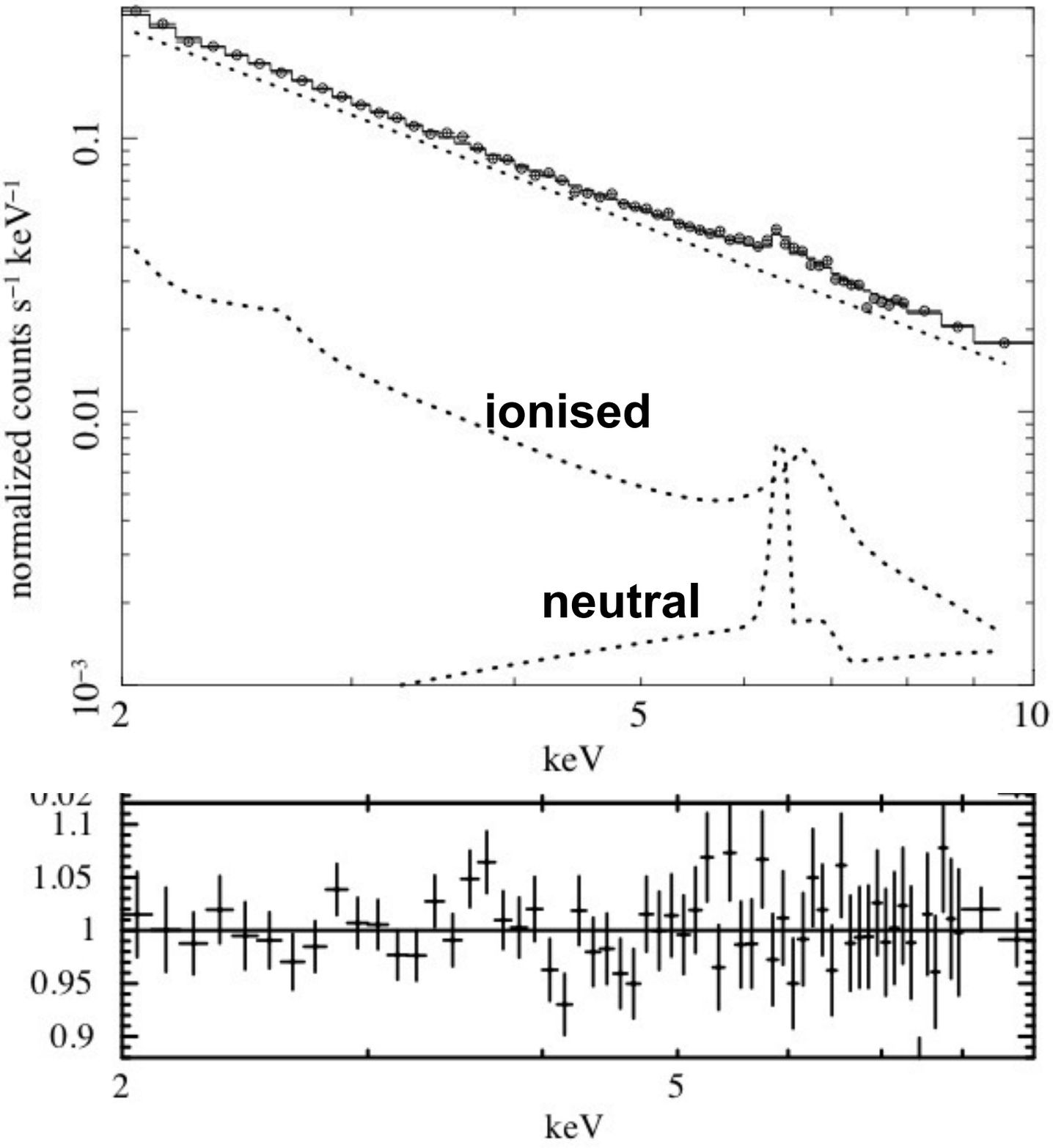
99 sources at log(Lx)~44

simple power-law fit:

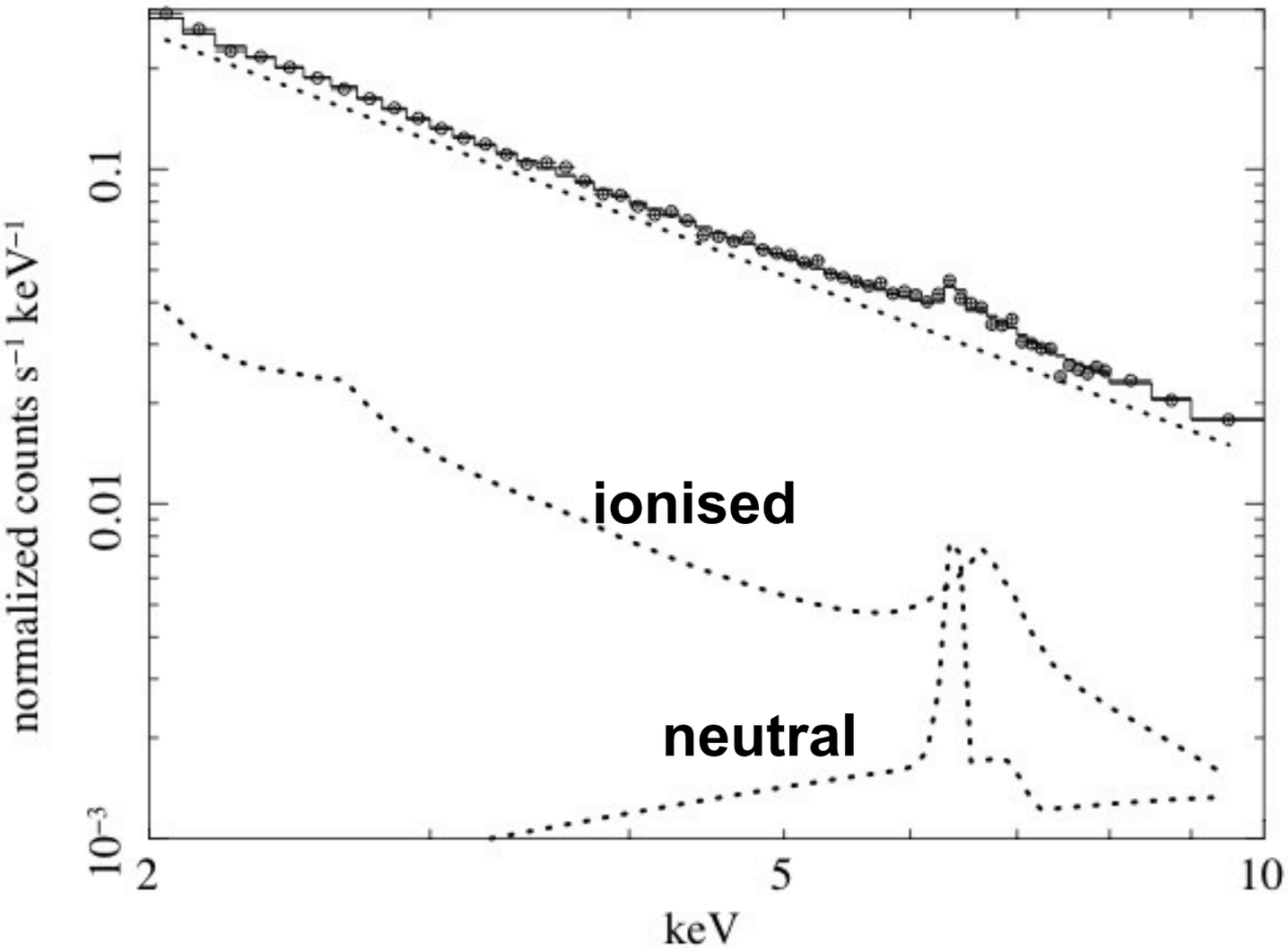
Iron line skewed to the BLUE

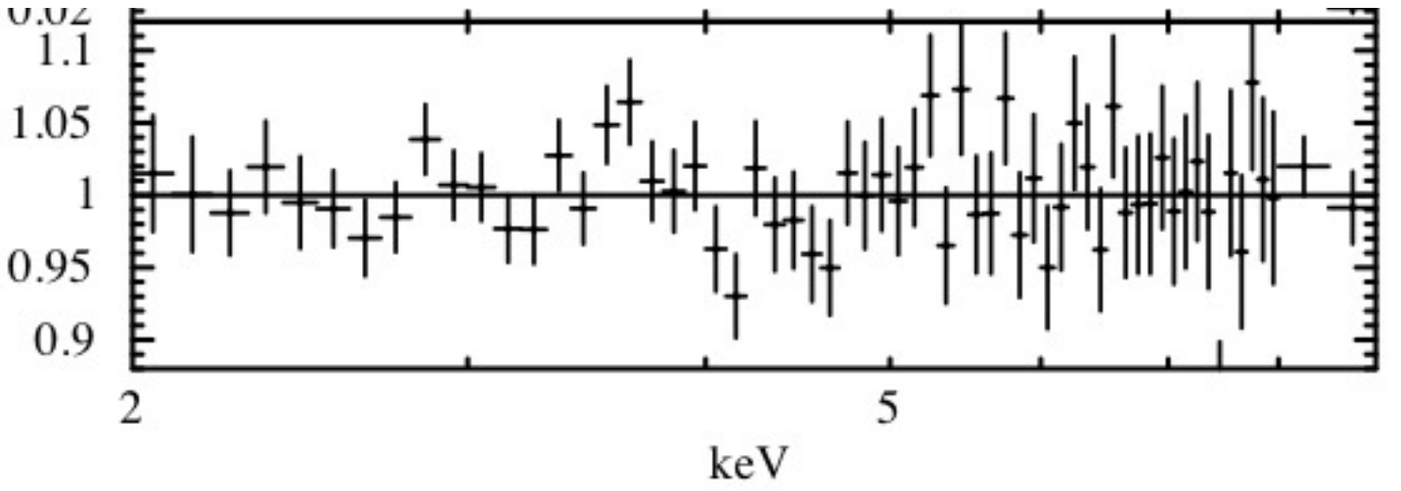
noisy/scattered continuum

Chandra stacking



Chandra stacking





99 sources at log(Lx)~44

Two reflectors fit:

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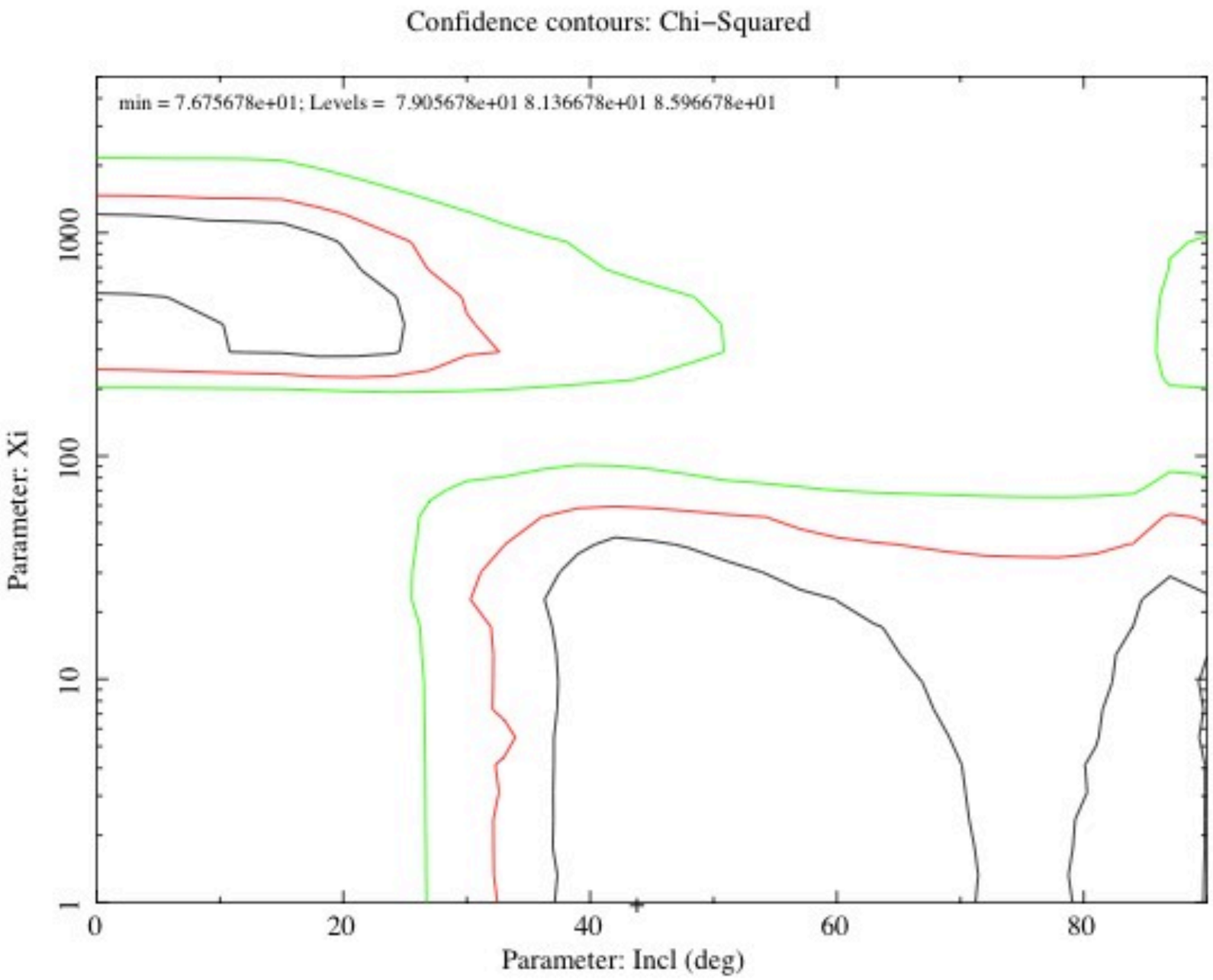
po+reflionx+reflionx

Reduced $X^2 = 1.04$

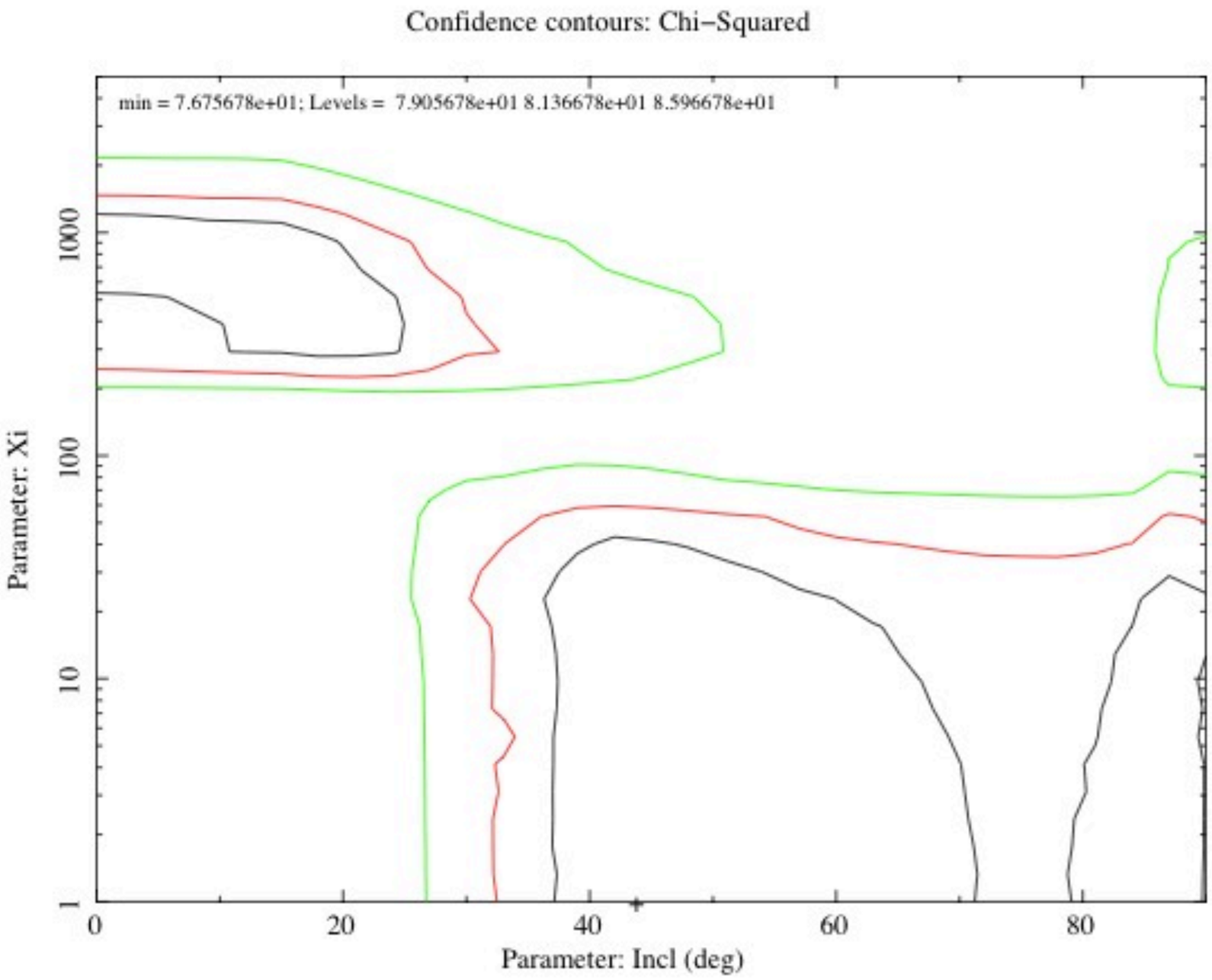
Xi = 885 +/- 250

Ionised reflector needed to model at best the continuum at 2-5 keV

Ionisation vs. Inclination



Ionisation vs. Inclination



Two reflectors fit:

---

po+reflionx+kdblur*reflionx

parameters not constrained (degenerate)

Next

- draft circulated to “original” co-authors + new C-COSMOS/ AEGIS; just ask if you are interested/want to contribute

- Intro+sample selection+method: “almost final”;

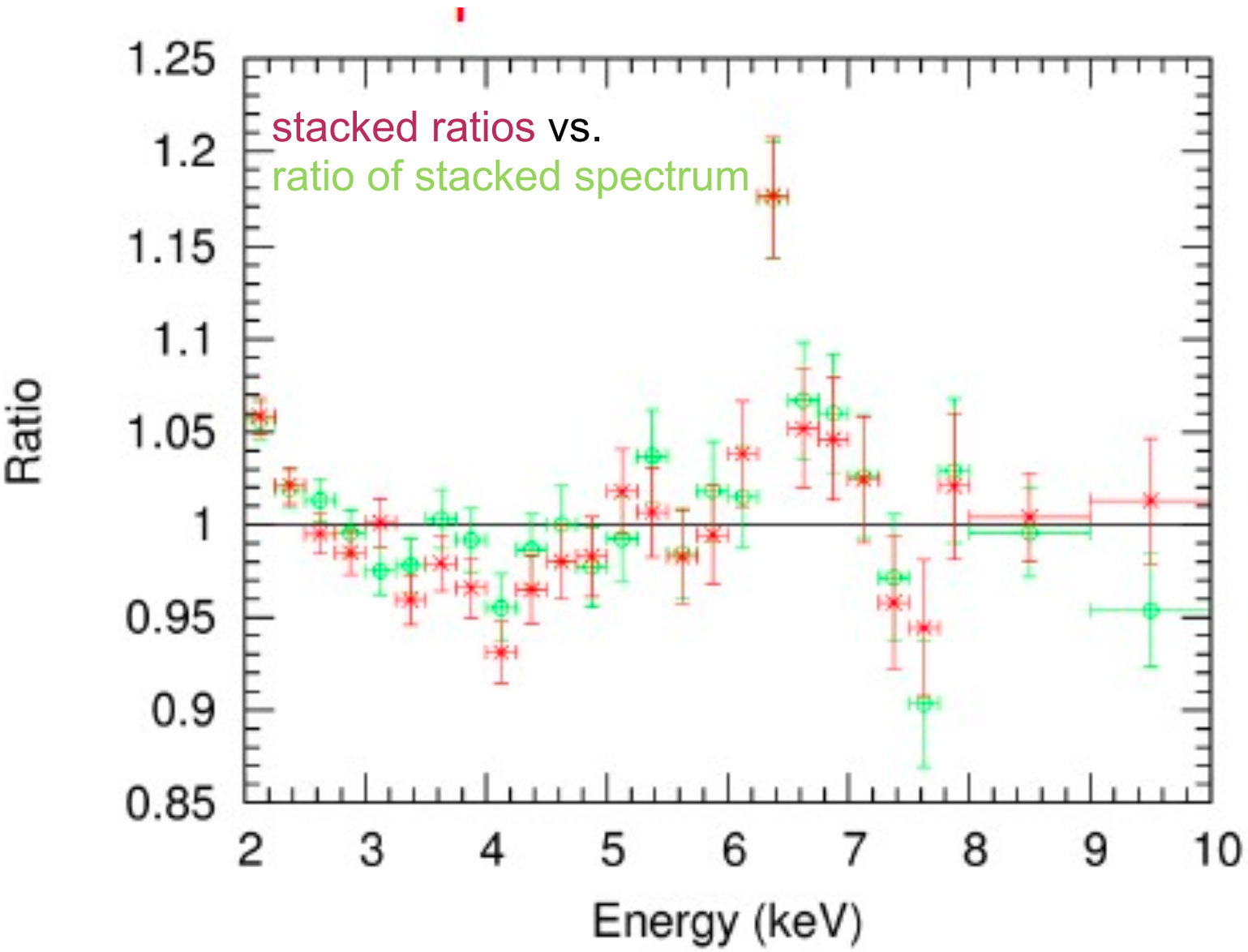
- Fit and discussions sections to be written; stacked spectra to be constructed (and fit) for subsamples of masses, SFR, L/Ledd

- goal is to work on the fit and writing in next month, recirculate it and submit the paper by end of July...

backup slides

2XMM sources stacking

248 sources with >1000 counts from XMM archive (Chaudhary, MB et al. 2012)

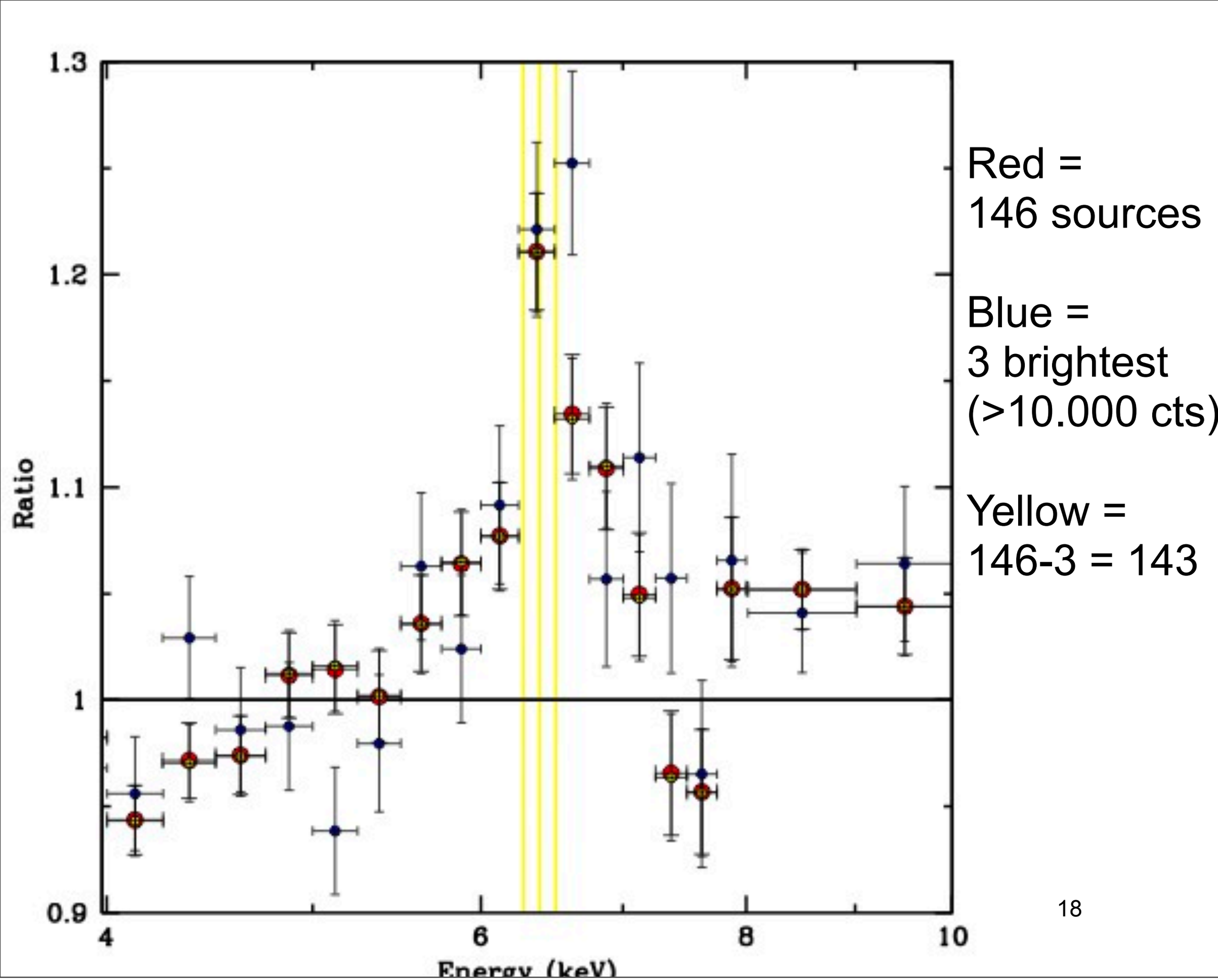


red = sum (average) of ratios of single power-law fit to 248 XMM spectra

green = ratios of the sum (average) of 248 red-shifted XMM spectra, fitted with a single power-law

Residual at position of Iron Kalpha line (6.4 keV) clearly present

Results tested against simulations of stacked samples of similar number of sources w/o line



Red =
146 sources

Blue =
3 brightest
(>10.000 cts)

Yellow =
146-3 = 143