Spectroscopy with Astro-H

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Instruments of Astro-H

- Four main instruments (some double)
- This talk: focus on SXS, assuming others will focus on other instruments
- Note: in many practical cases, data from more than one instrument can be used ➔ synergy between instruments

How to compare performance of different instruments?

Depends on scientific question:

- Strong versus weak lines
- Line detections, velocity shifts, line widths?

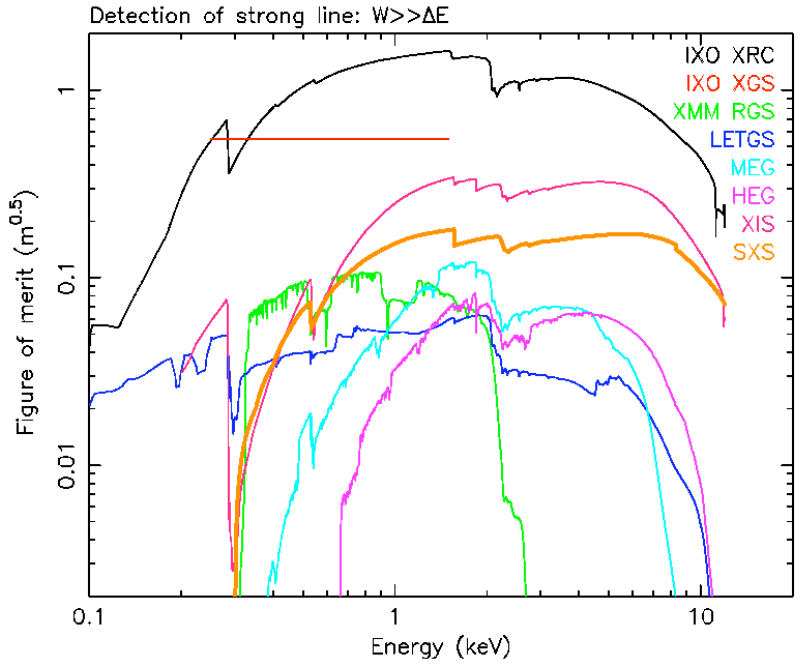
For all these, Figures of Merit (FOM) can be defined, proportional to S/N (“number of sigma’s”)

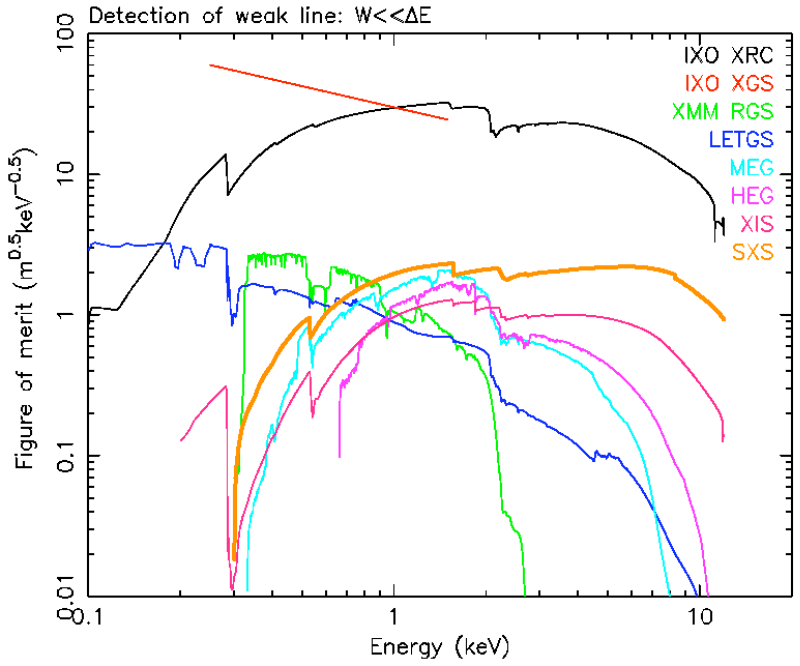
Present estimates extension of report I wrote for IXO (gratings versus TES array)

FOM: Line detection

Strong line: FOM~√A

Weak line: FOM~√(A/ΔE)





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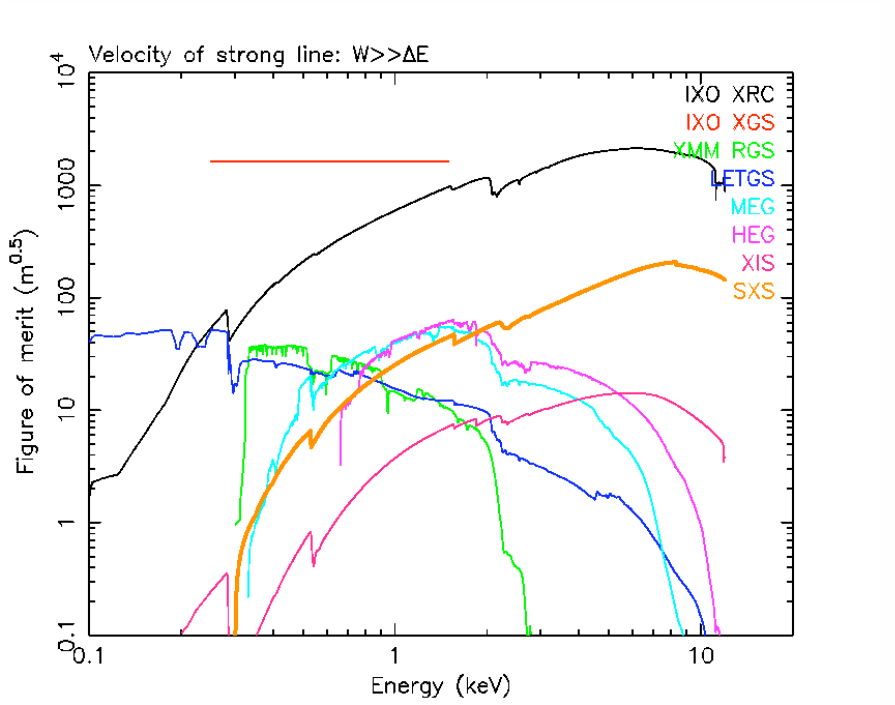
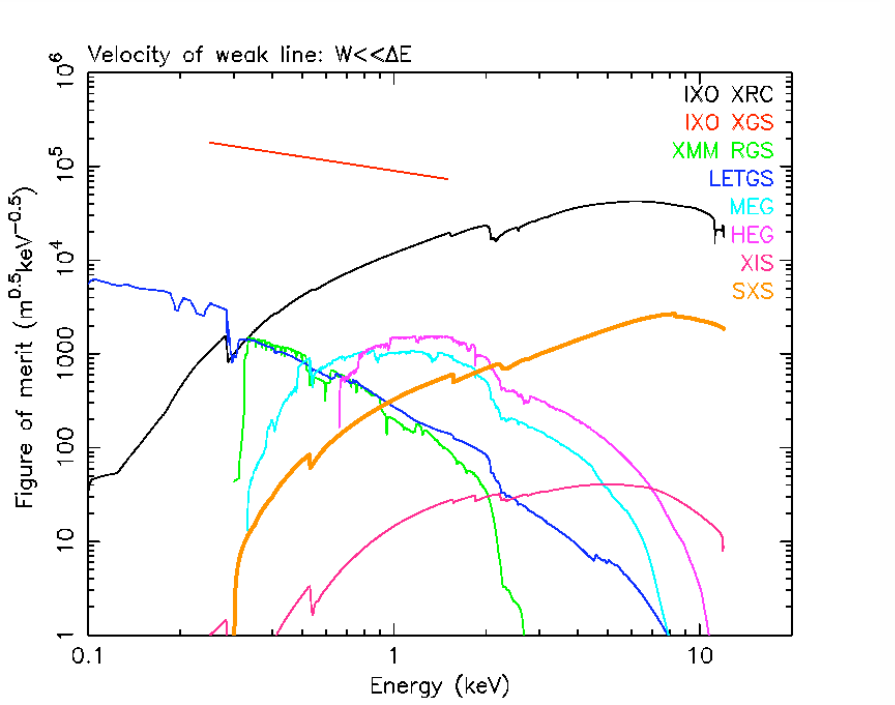
FOM: measuring velocity shifts

Strong line: FOM~$\sqrt{(A\,E^2/\Delta E^2)}$

Weak line: FOM~$\sqrt{(A\,E^2/\Delta E^3)}$





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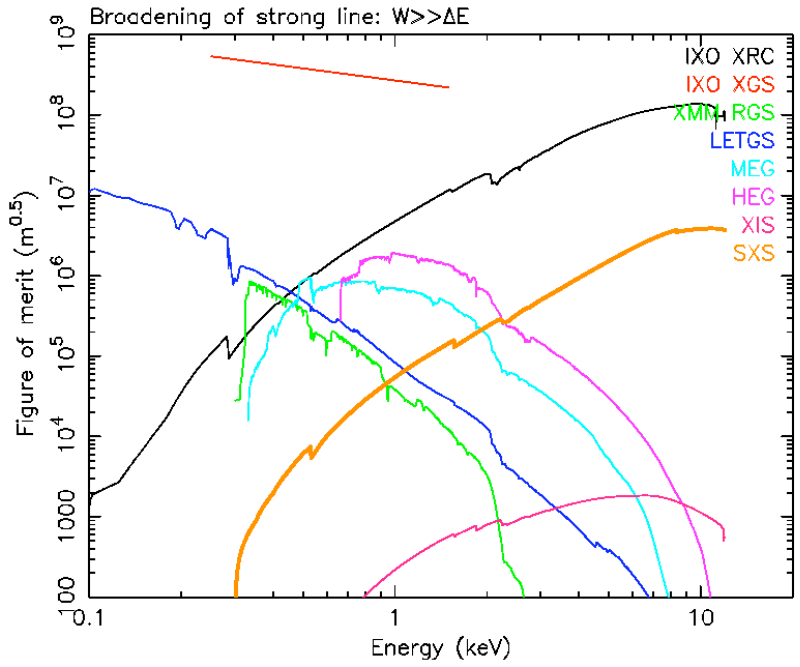
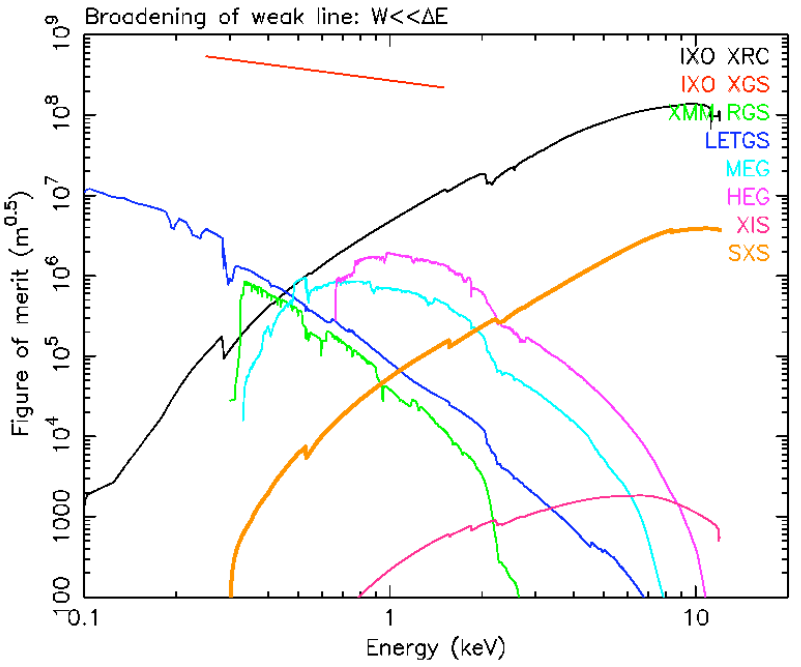
FOM: measuring line broadening

Strong line: FOM~√(A $E^4/\Delta E^4$)



Weak line: FOM~√(A $E^4/\Delta E^5$)



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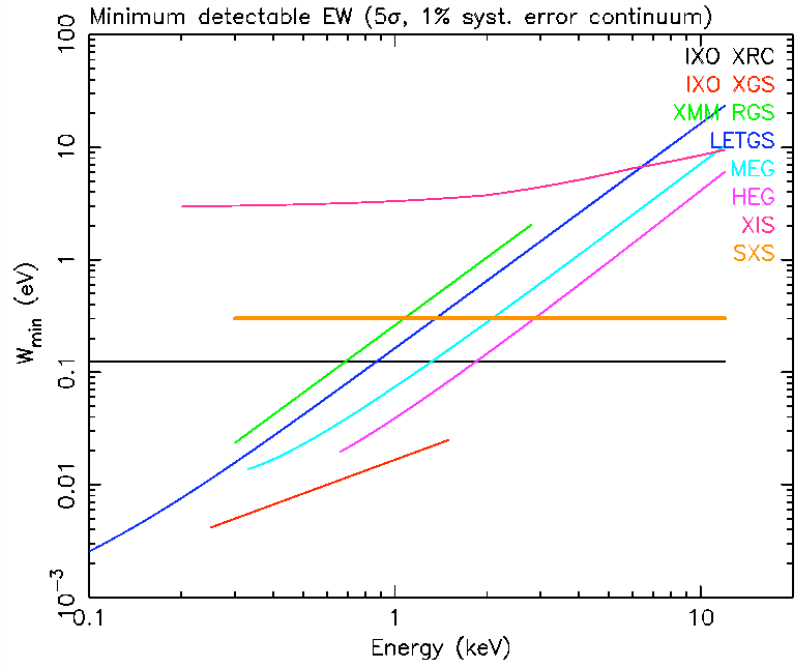
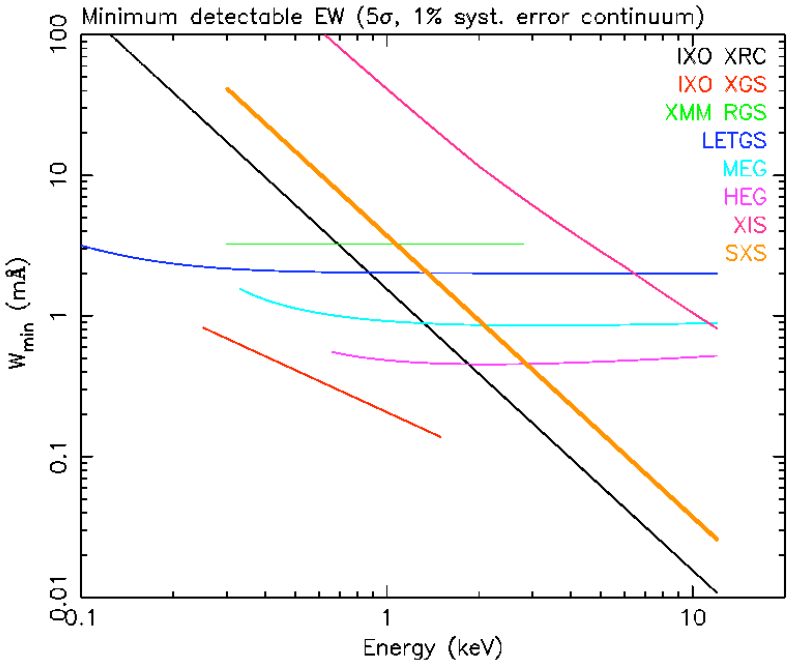
Minimum detectable equivalent width





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Low energy efficiency & spectral resolution

Test files:

- default filter versus thin filter
- 7 eV versus 4 eV resolution

What would be most important to optimise?

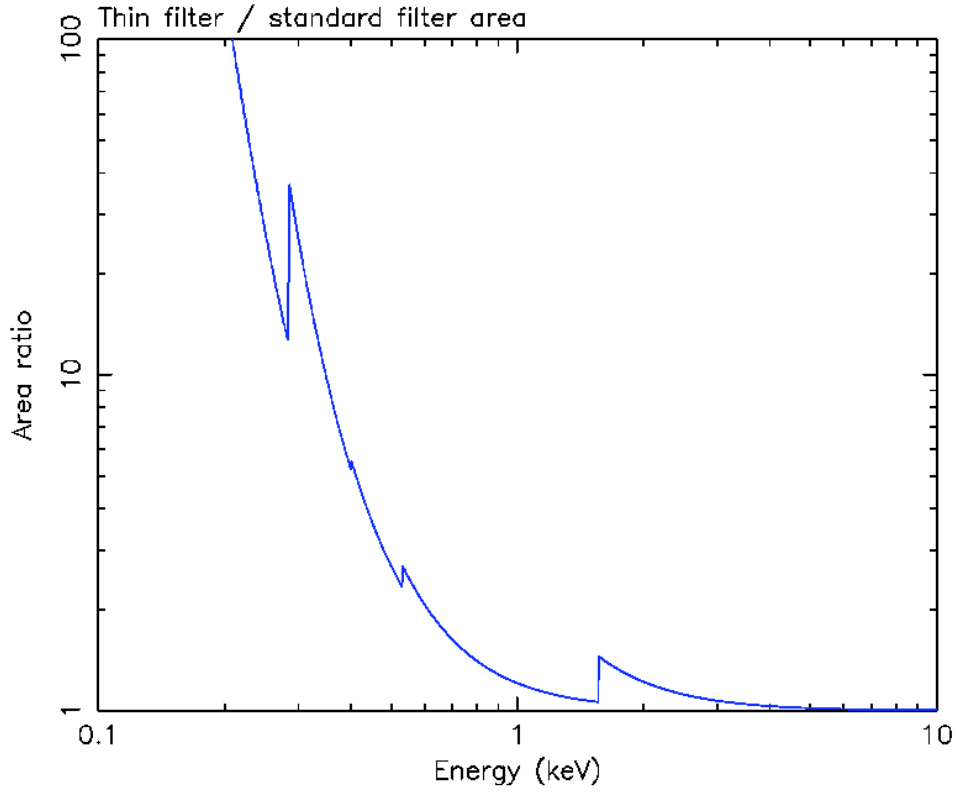
Optimalisation

Thin filter improvement:

- 2.7 @ N VII Lyα
- 1.8 @ O VIII Lyα

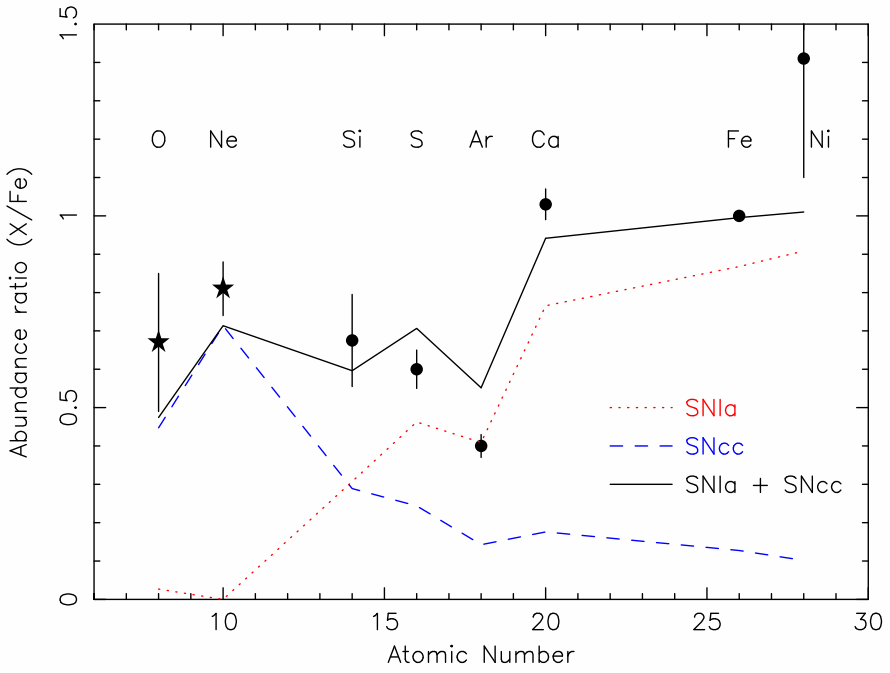
Resolution improvement 7->4 eV: 1.75

➔ impact similar for weak line detection, but for dynamics ΔE most important



The origin of the elements

- Clusters can be used to unravel chemical history of the Universe
- Decomposition into SN types
- Feedback on SN models

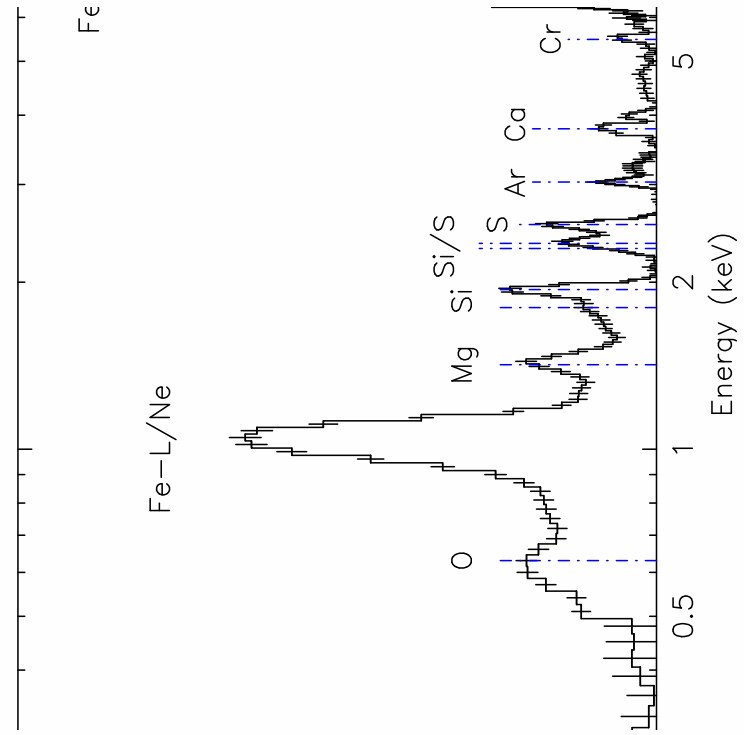


De Plaa et al. 2007

Rare elements as seen by EPIC

(Werner et al. 2006)

- Current best case: deep XMM-Newton observation of one of brightest clusters
- First evidence of traces of Cr (0.5±0.2 Solar)

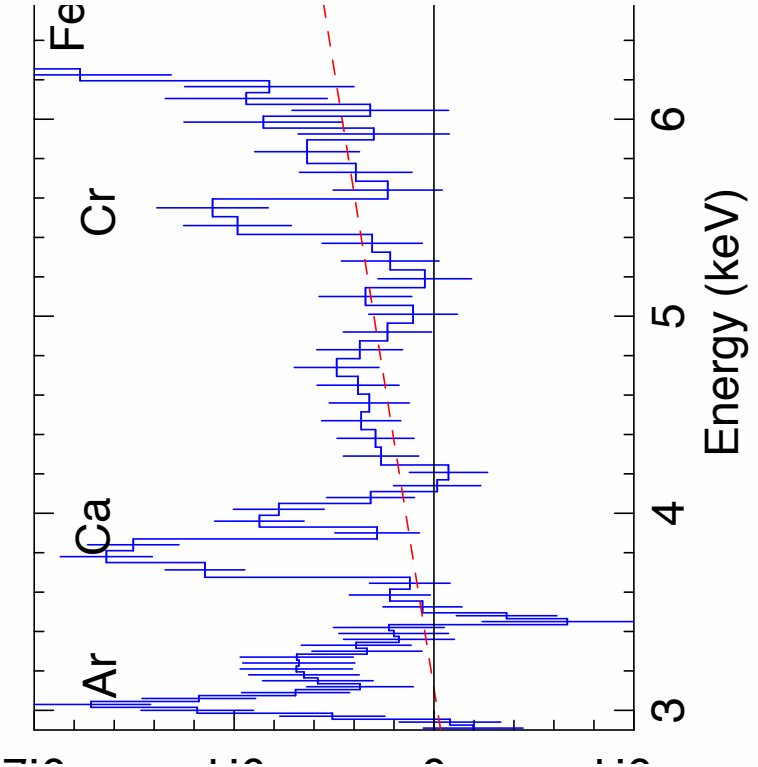


2A 0335+096, Werner et al. 2005

But: take care of bias…

(Werner et al. 2006)

- Some features subtle
- Example: 2A0335+096, 130 ks XMM-Newton
- To determine Cr abundance (0.5±0.2 solar) needs carefull analysis local continuum



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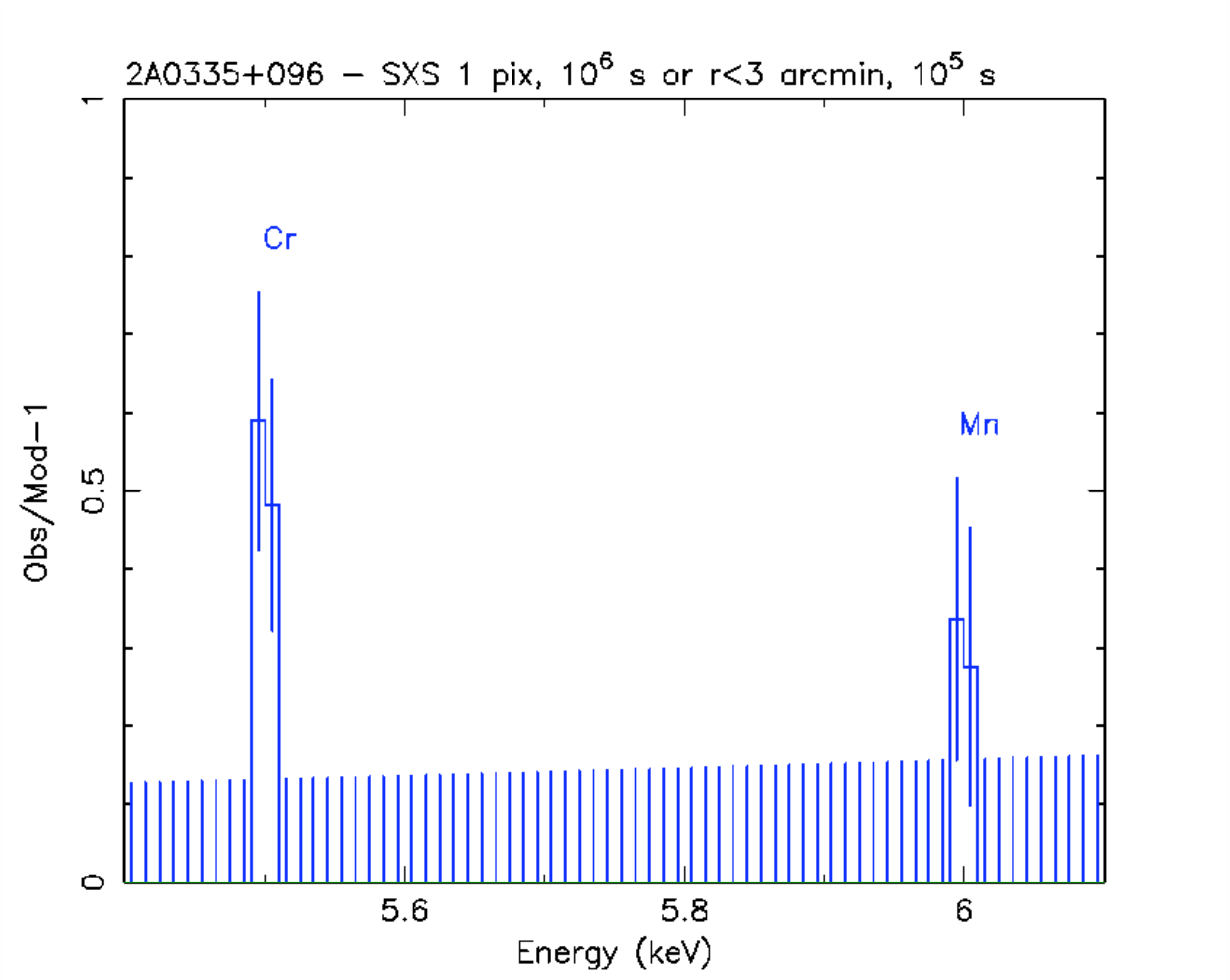
And this is how SXS sees it…



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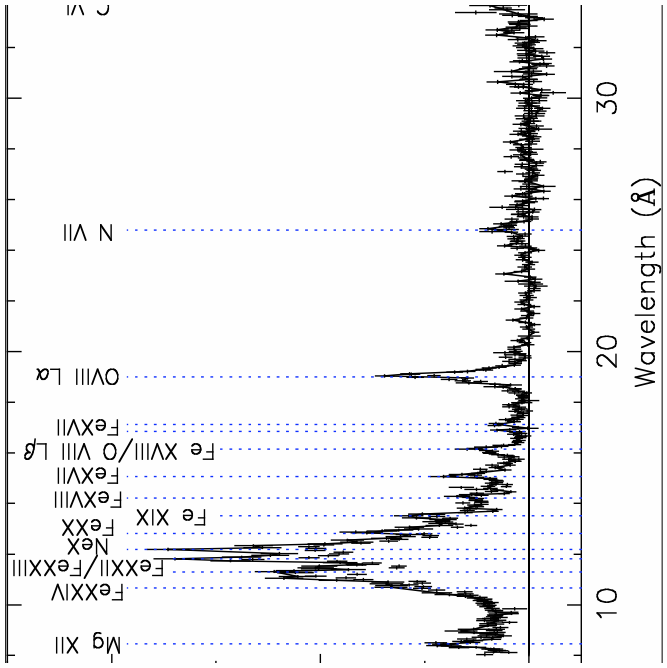
PM: CNO

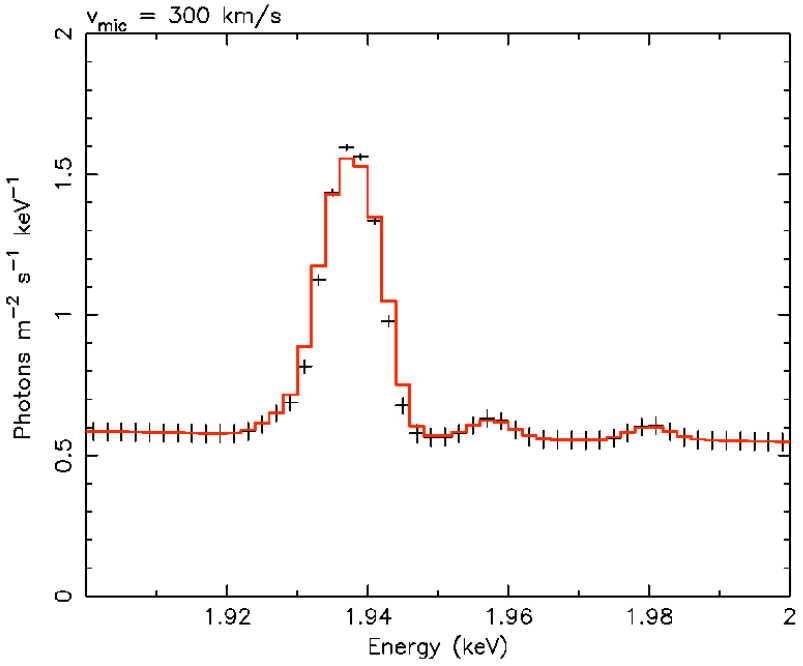
- Also for CNO abundances SXS very important: up to now, only RGS can measure C & N abundance, but only in compact (cooling) clusters



M87, RGS, Werner et al. 2006

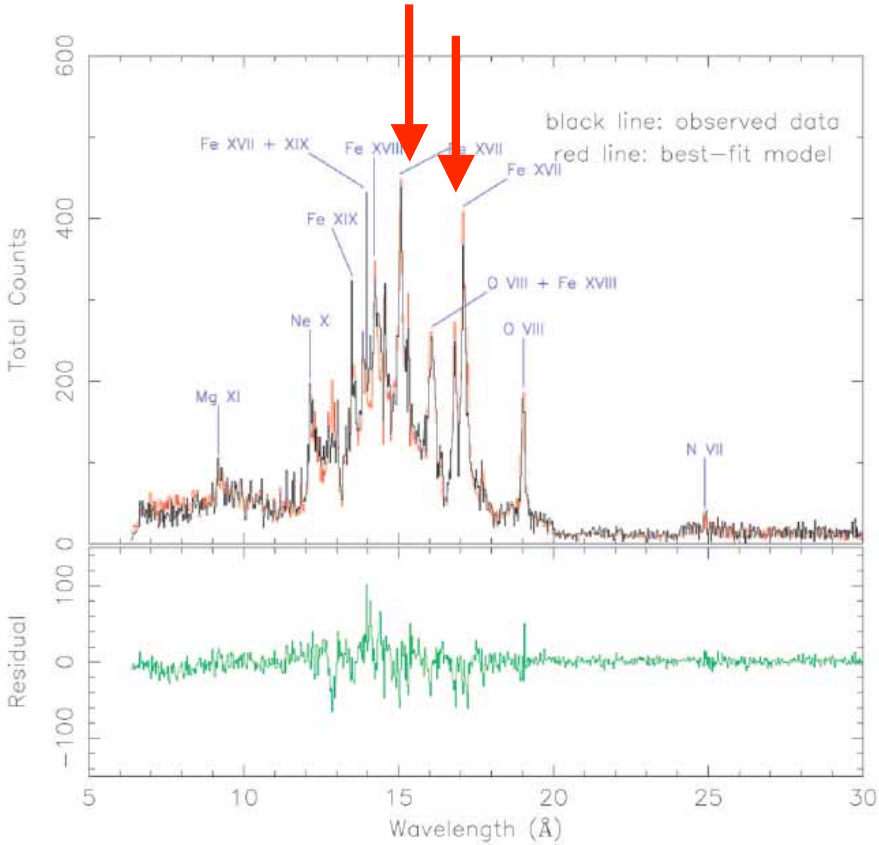
Turbulence easy to measure…

- Example: 2A0335+096 (as before), 100 ks core
- Data: no broadening
- Model: 300 km/s
- Example here for Si XIV, much better of course for Fe
- But: need to pay attention to calibration!



Resonance scattering

- Alternative to measure turbulence
- Fe XVII 15.02 to 17.05/17.10 ratio sensitive to res. scat. (τ depends on turbulence)
- Currently only RGS can do it (see also Werner et al. 2009)
- SXS can map it



Xu et al. 2002, NGC 4636

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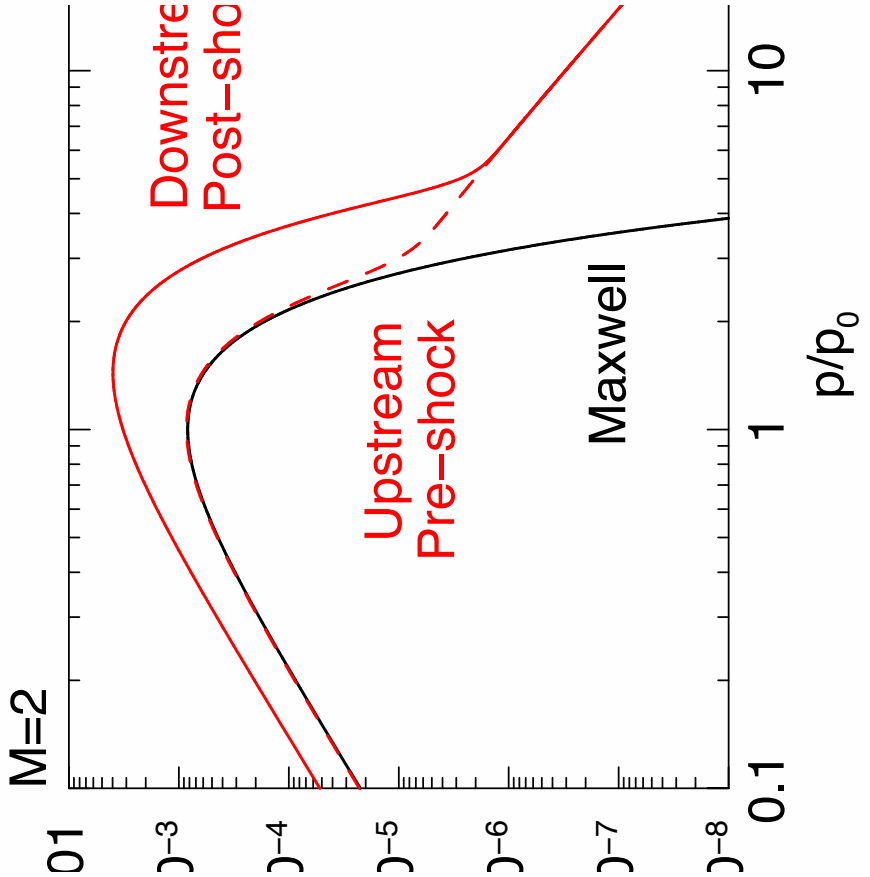
Detecting non-thermal electrons

- Particle acceleration in many sources (shocks, flares, etc)
- How to detect non-thermal tails?



shock in hot cluster (Kaastra, Bykov & Werner, in prep)

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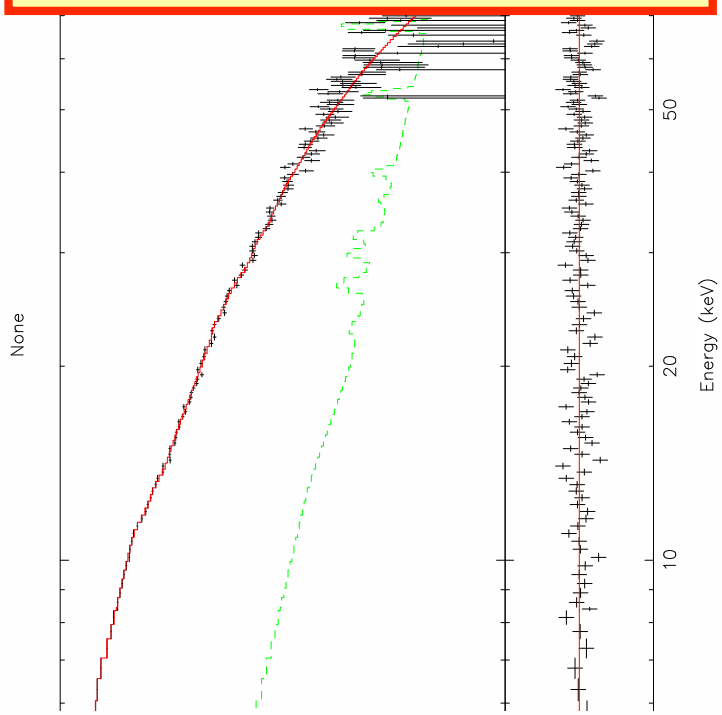
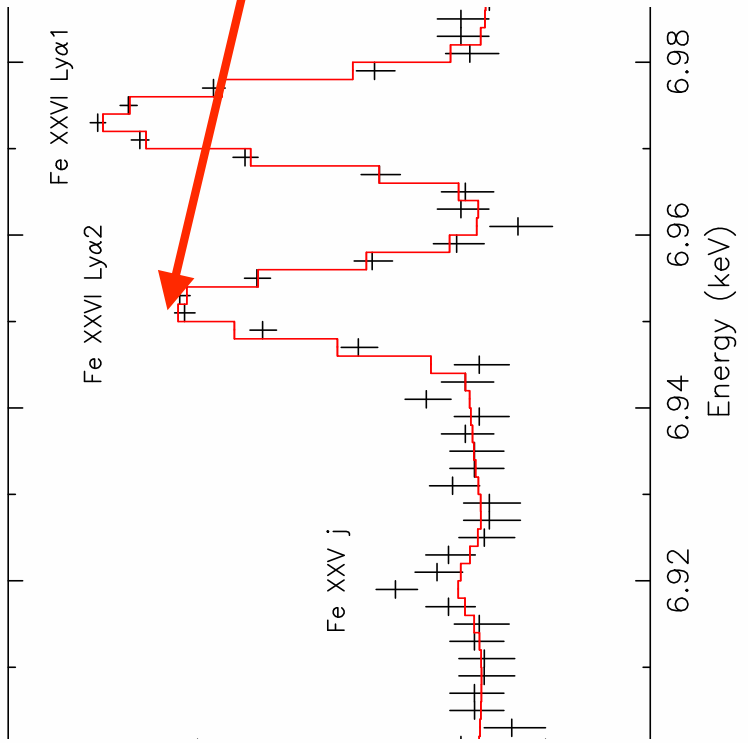
HXI and SXS

Fit with thermal plasma only already acceptable



Satellite lines provide the answer!



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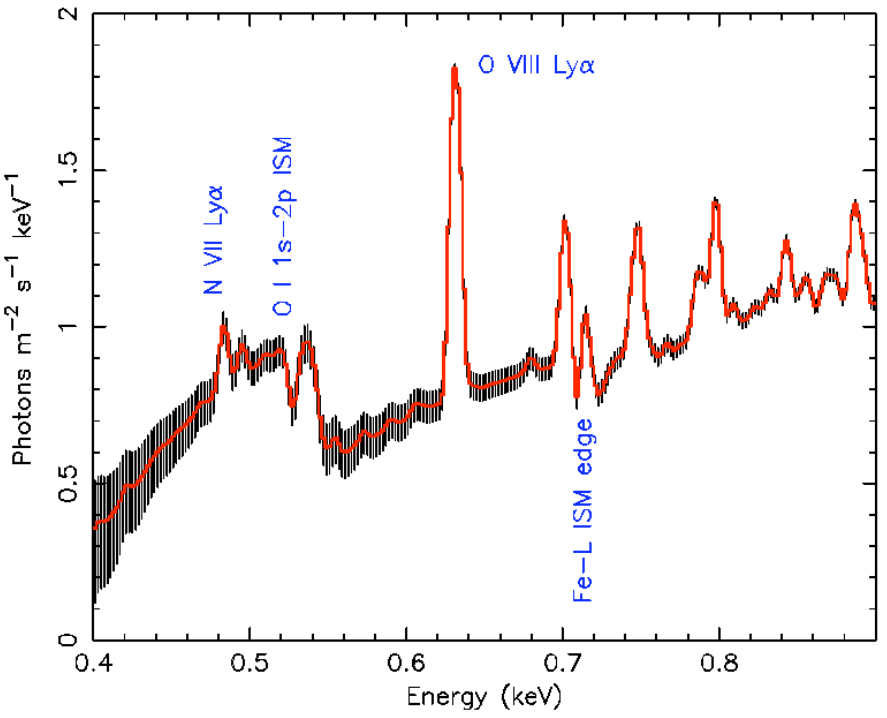
Constraining the ISM through absorption

- Example: same spectrum of 2A0335+096
- See interstellar O I edge and O I 1s-2p line; also Fe-L edge
- ➔ even clusters can be used as backlights!



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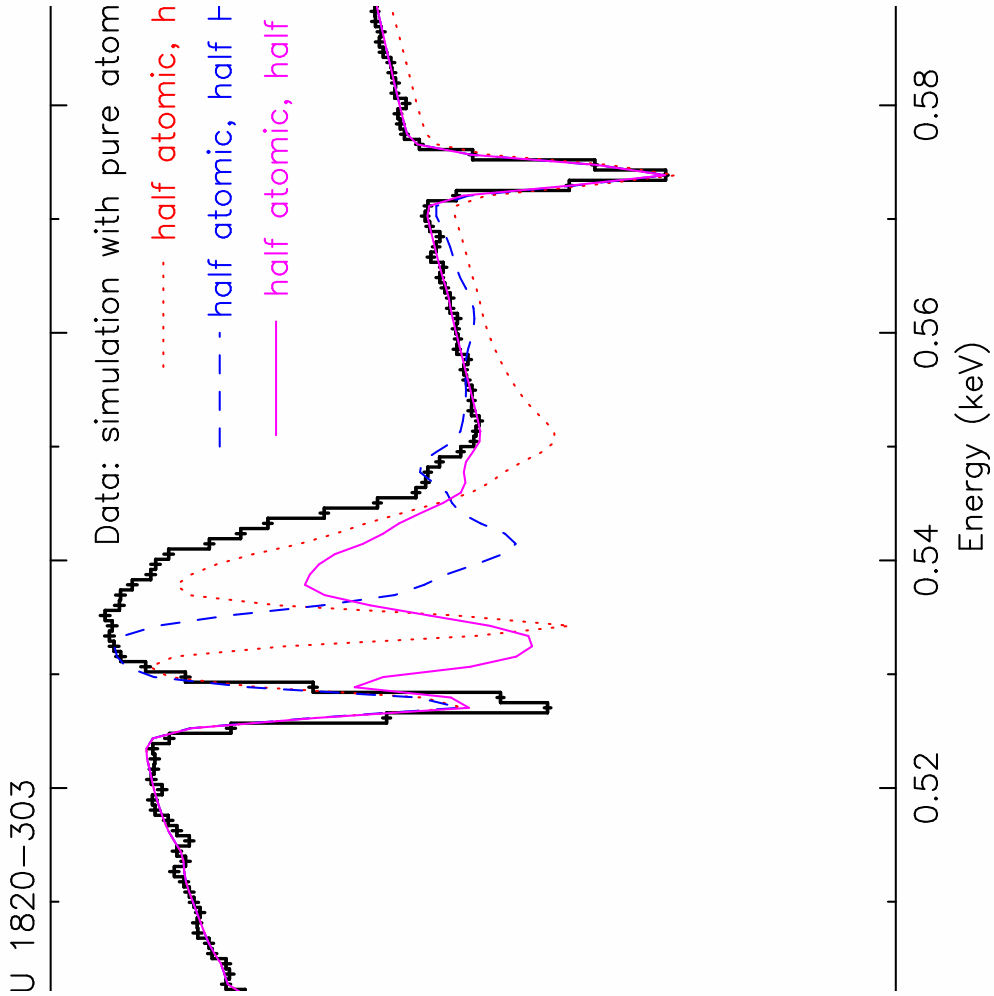
(true) chemistry of the ISM



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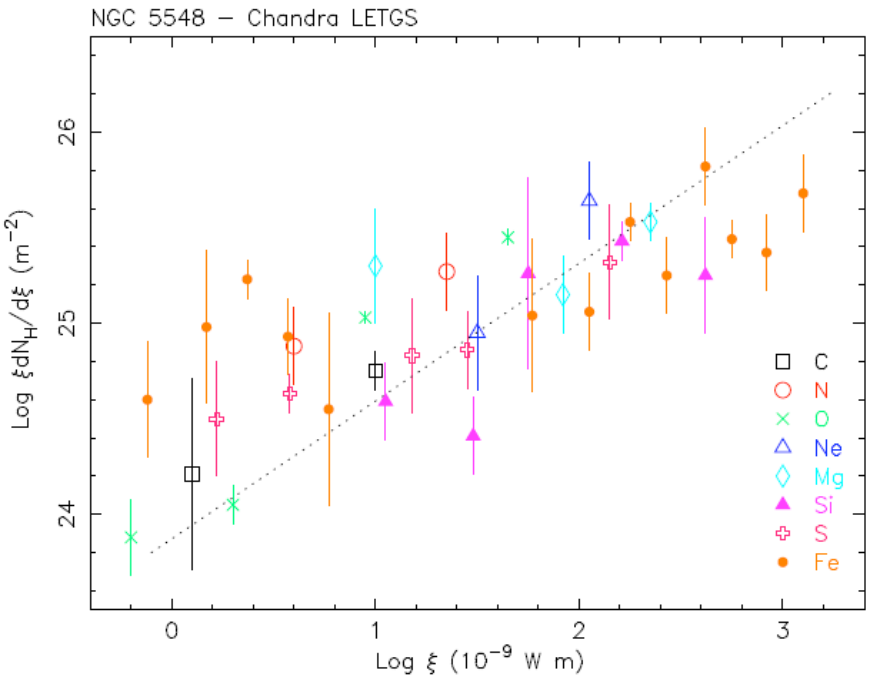
Warm absorbers

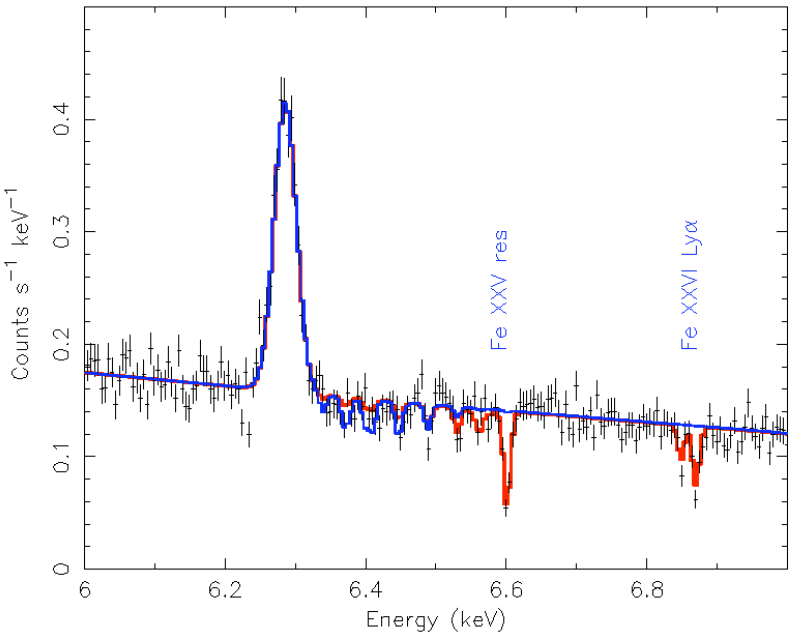
- Discussion about differential absorption model: continuous, discrete, intermediate …
- Important to know high-ξ cut-off (if any)



Steenbrugge et al. 2005

Constraining the most highly ionised gas

- Model: power-law distribution $dN_H/d\xi$, cut-off @ log ξ = 5
- Data: idem but cut-off @ log ξ = 3
- Would be great to have at least RGS and/or Chandra still up, for simultaneous observations



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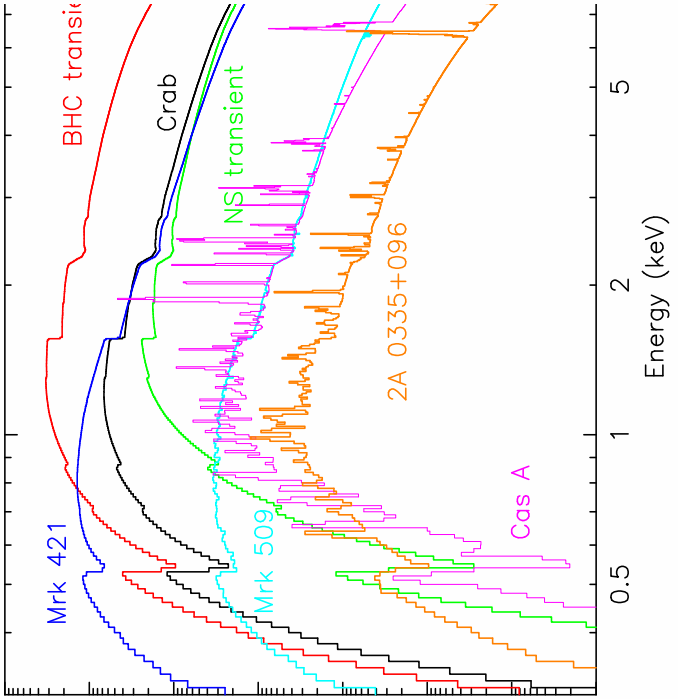
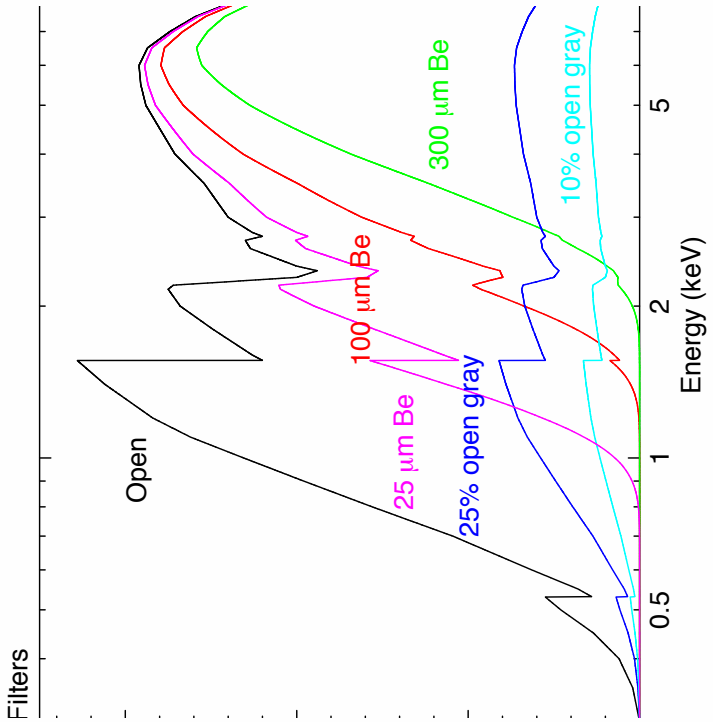
Pile-up reduction





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Need for filter wheels

CR (c/s)	Open all	Open good	100µm Be	10%gray
Crab pix	113	1.0	8.0	7.0
BH trans	698	0.0	0.002	3.8
NS trans	53	5.8	8.8	4.2
Mrk 421	179	0.1	8.7	8.5
Mrk 509	4.4	3.7	0.7	0.4
Cas A pix	4.9	4.0	1.2	0.5
2A0335	0.5	0.5	0.08	0.05

Final remarks

- For bright sources, when good spatial resolution not needed, SXS can do almost same as IXO TES, at expense of ~5-10 x longer exposure
- General advise (based on RGS GT): better fewer sources with better statistics (= longer exposures)

Meeting announcement

High-resolution X-ray spectroscopy: past, present and future

15-17 March 2010

Utrecht, Netherlands

www.sron.nl/xray2010