

Turbulence measurements in clusters of galaxies with XMM-Newton

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and the CHEERS collaboration

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CHEmical Enrichment RGS Cluster Sample

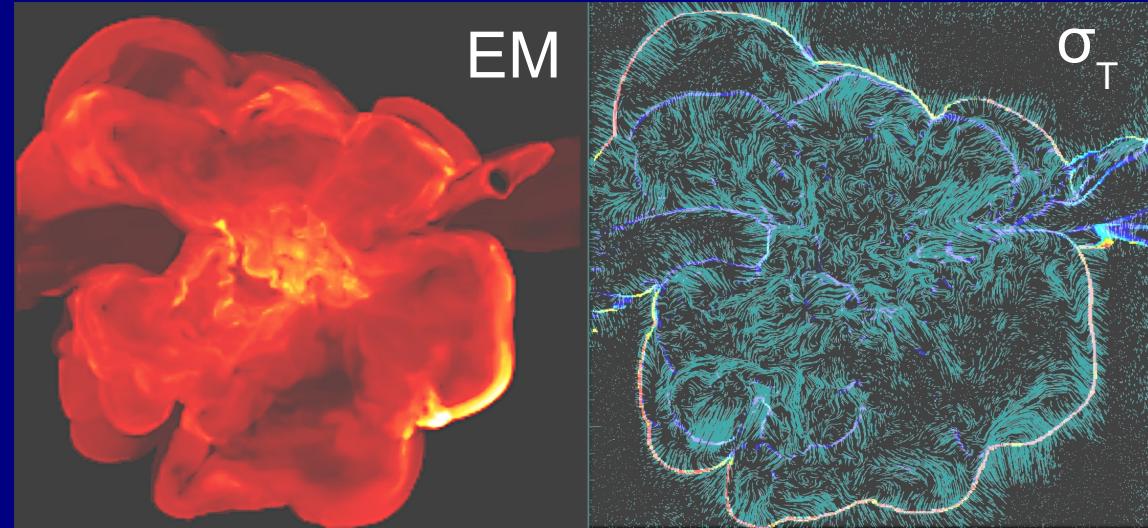
PI of the proposal: Jelle de Plaa



1.6 Ms new obs for 11 clusters (+18 in archive)

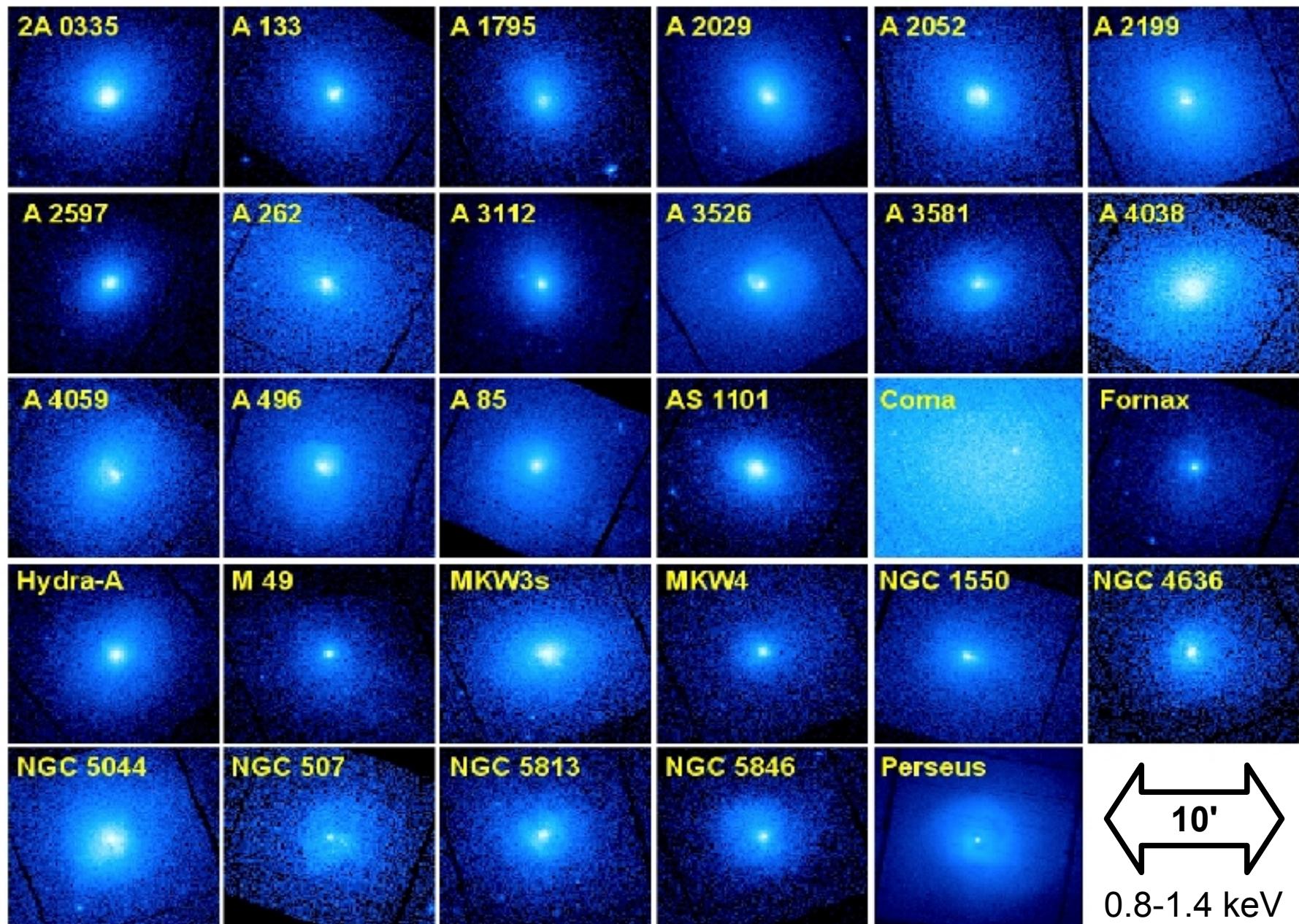
- SNIa / SNcc contribution in cluster cores
- Multiphaseness, Heating / cooling, Turbulence

Turbulence: Science context

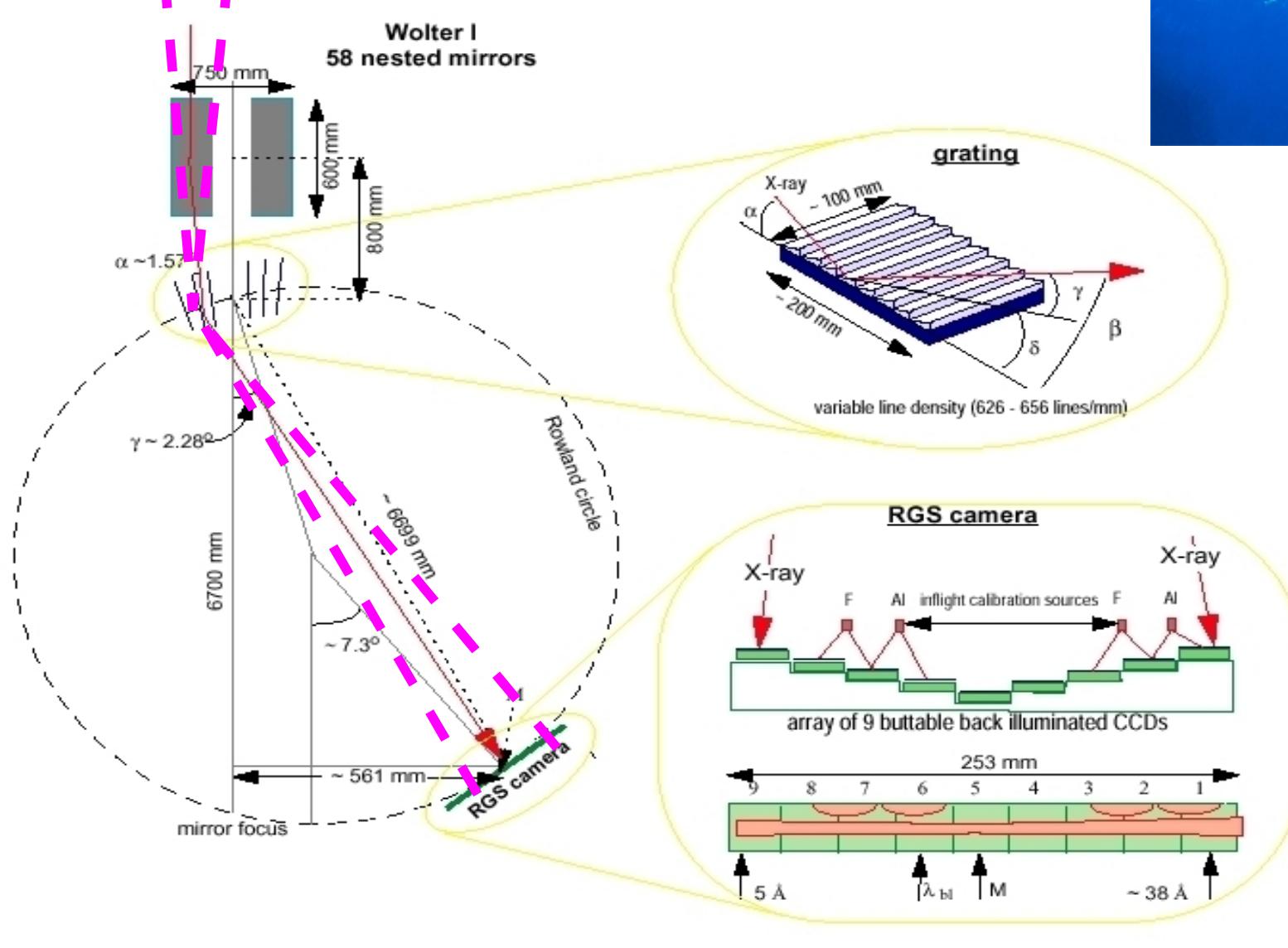


- AGN feedback simulations: $v_{\text{ICM}} \sim 100 \text{s km s}^{-1}$
- Merging & sloshing also produce turbulence
- Turbulence may drive heating and prevent cooling

CHEERS Clusters as seen by MOS 1



XMM-Newton Reflection Grating Spectrometer (RGS)

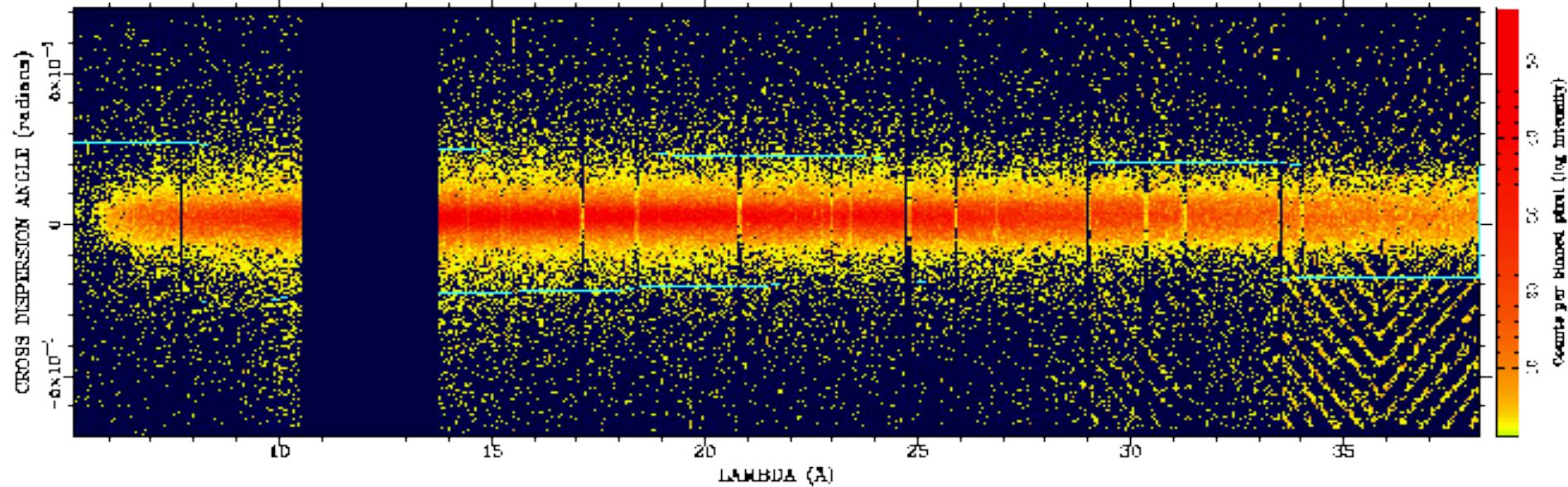


Line widths
depend on the
source size

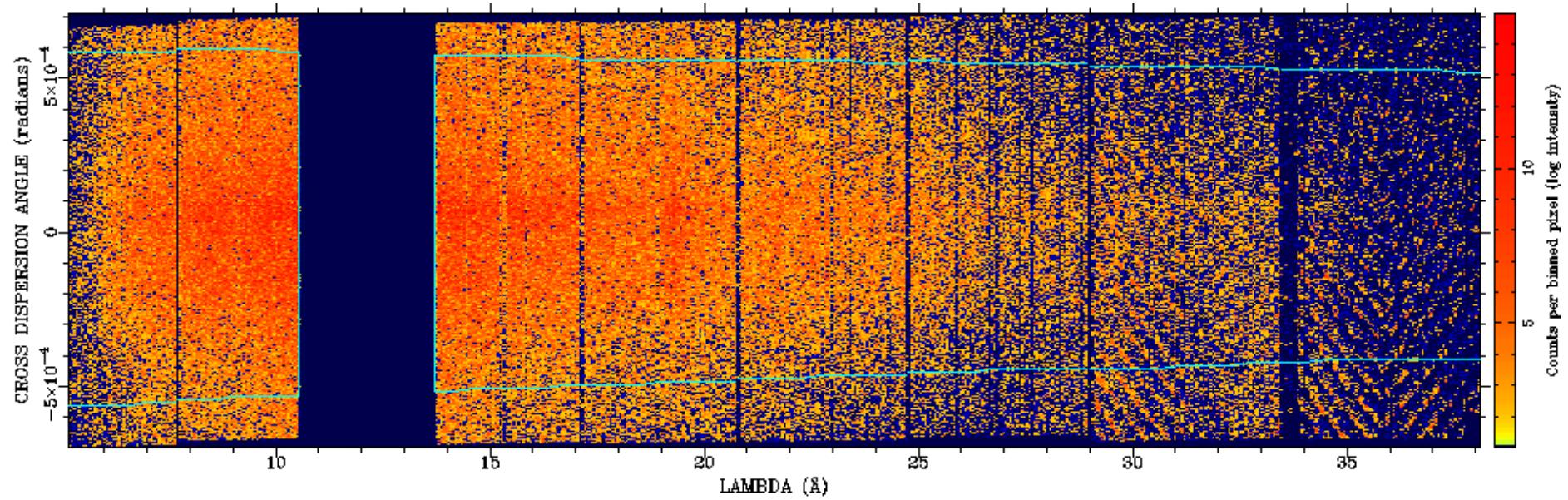
$$\Delta\lambda = 0.1387 \text{ \AA} \Delta\theta$$

RGS 1 image: X-dsp vs λ

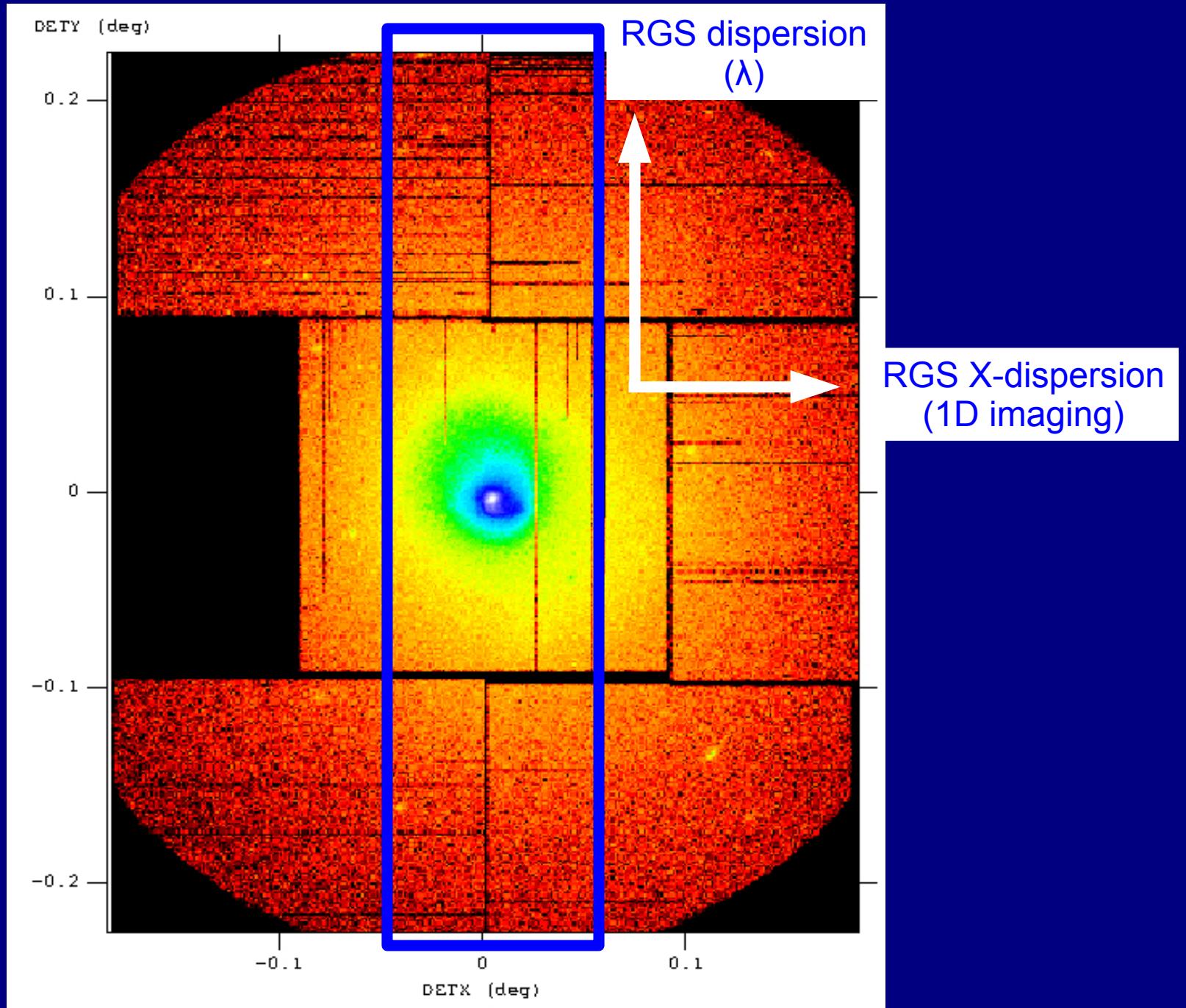
Point-like source



Extended source

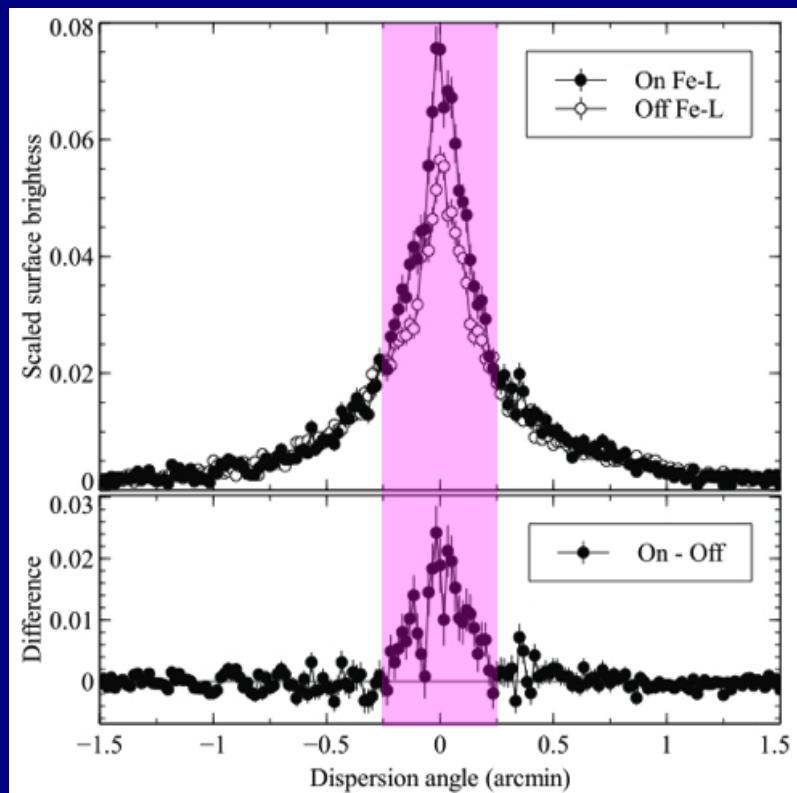


MOS 1 vs RGS : spatial broadening correction

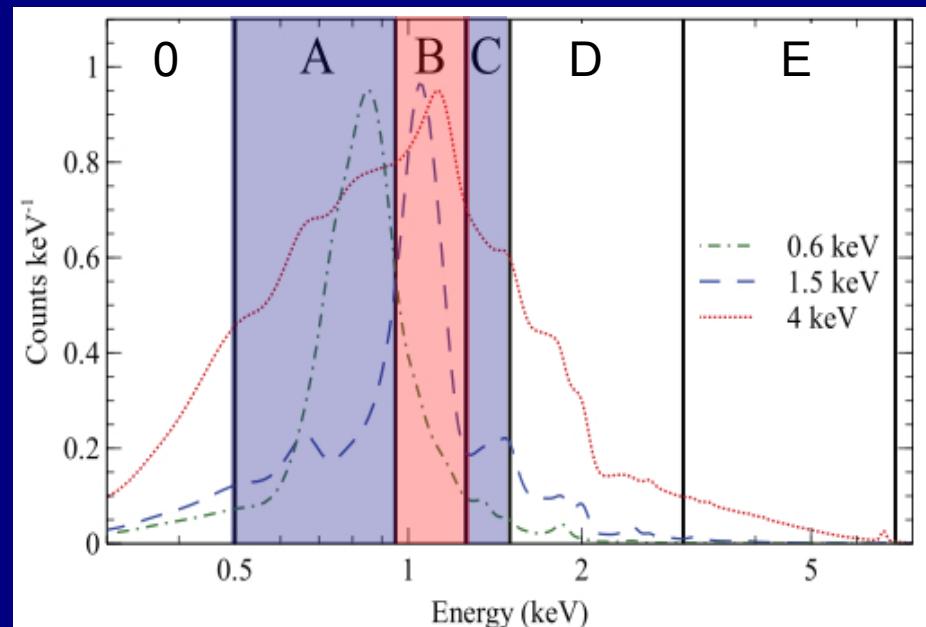


Continuum-subtraction method

SPECTRA



IMAGES



The continuum
affects the line wings!

Fe lines: B-(A+C) / B-D / B-E

O VIII: A-C / A-D / A-E

Sanders & Fabian 2010-2013:
upper limits + some values 150-550 km s^{-1}

Spectral analysis

Extraction:

1) 3.4' and 0.8' spectra
& BKG templates

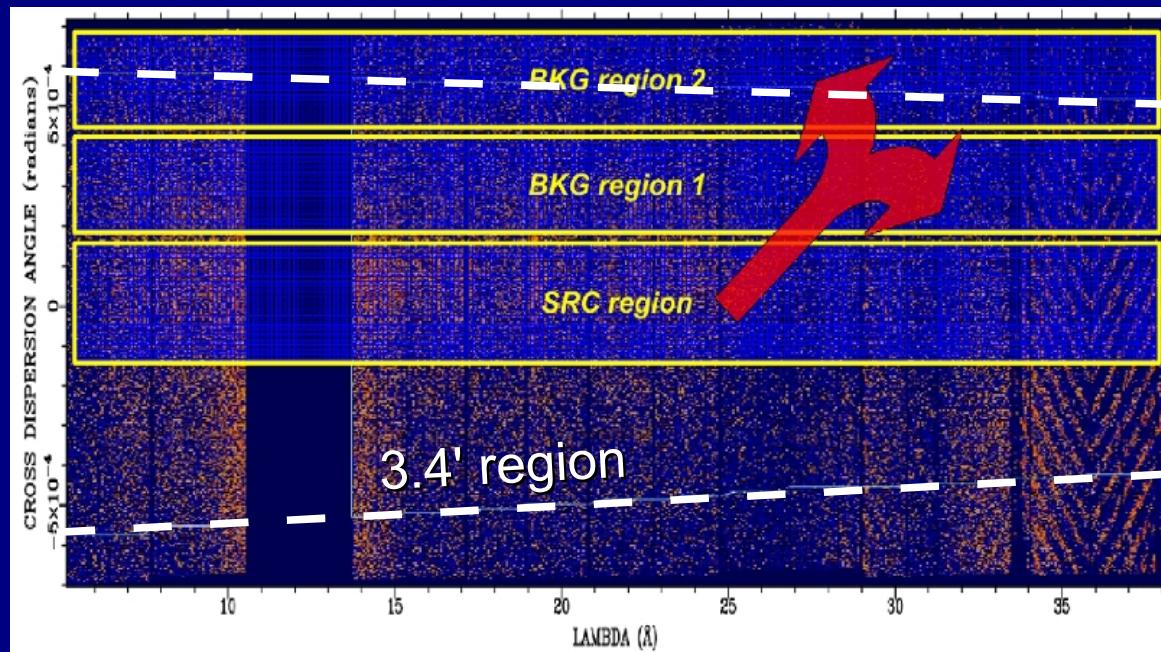
2) 0.8' Continuum-subtracted spectra
& BKG from adjacent bands

Modeling:

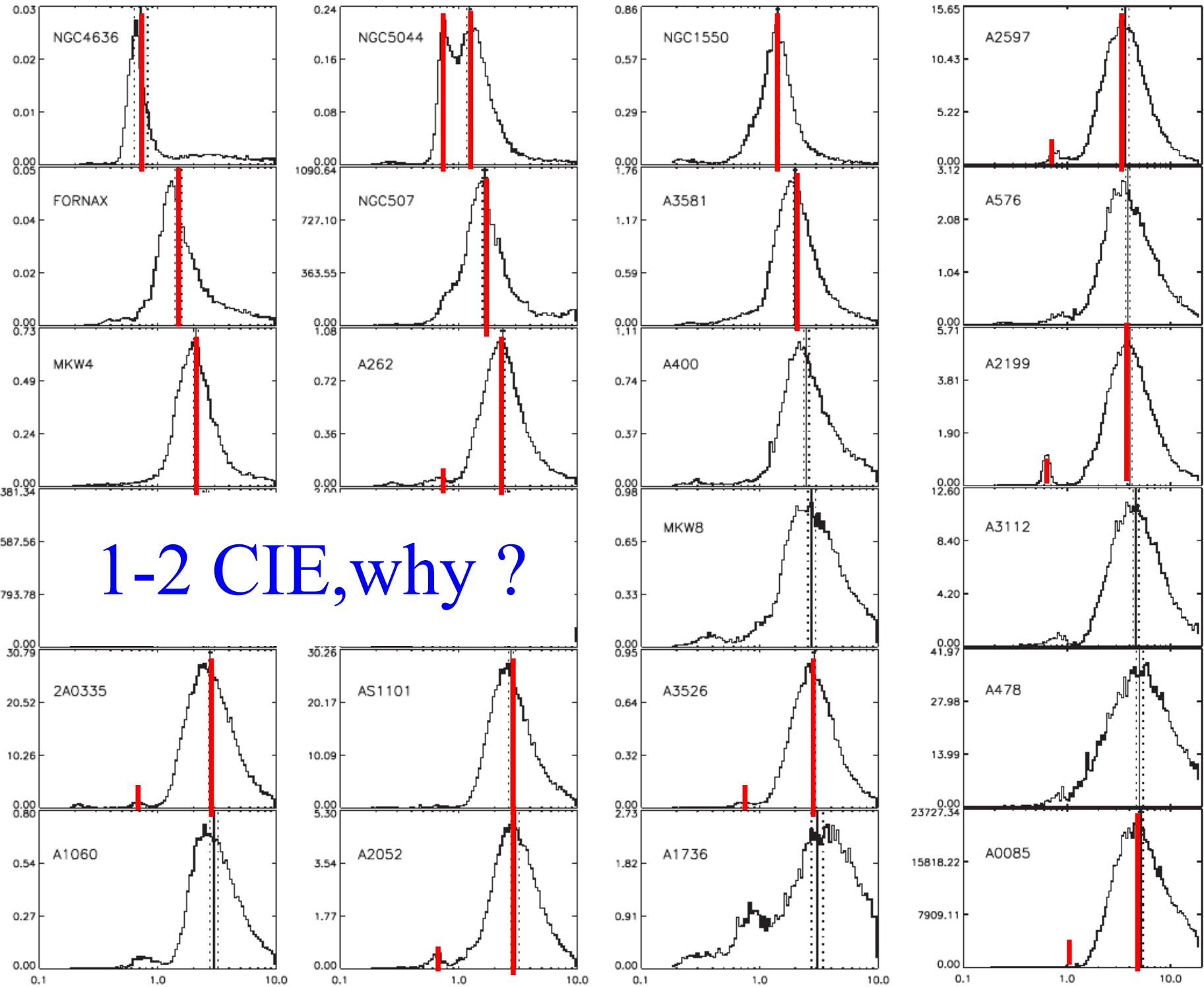
→ 1-2 CIE components

N, O, Ne, Mg, Fe

→ 7-28 Å (0.44-1.77 keV), C-Statistics

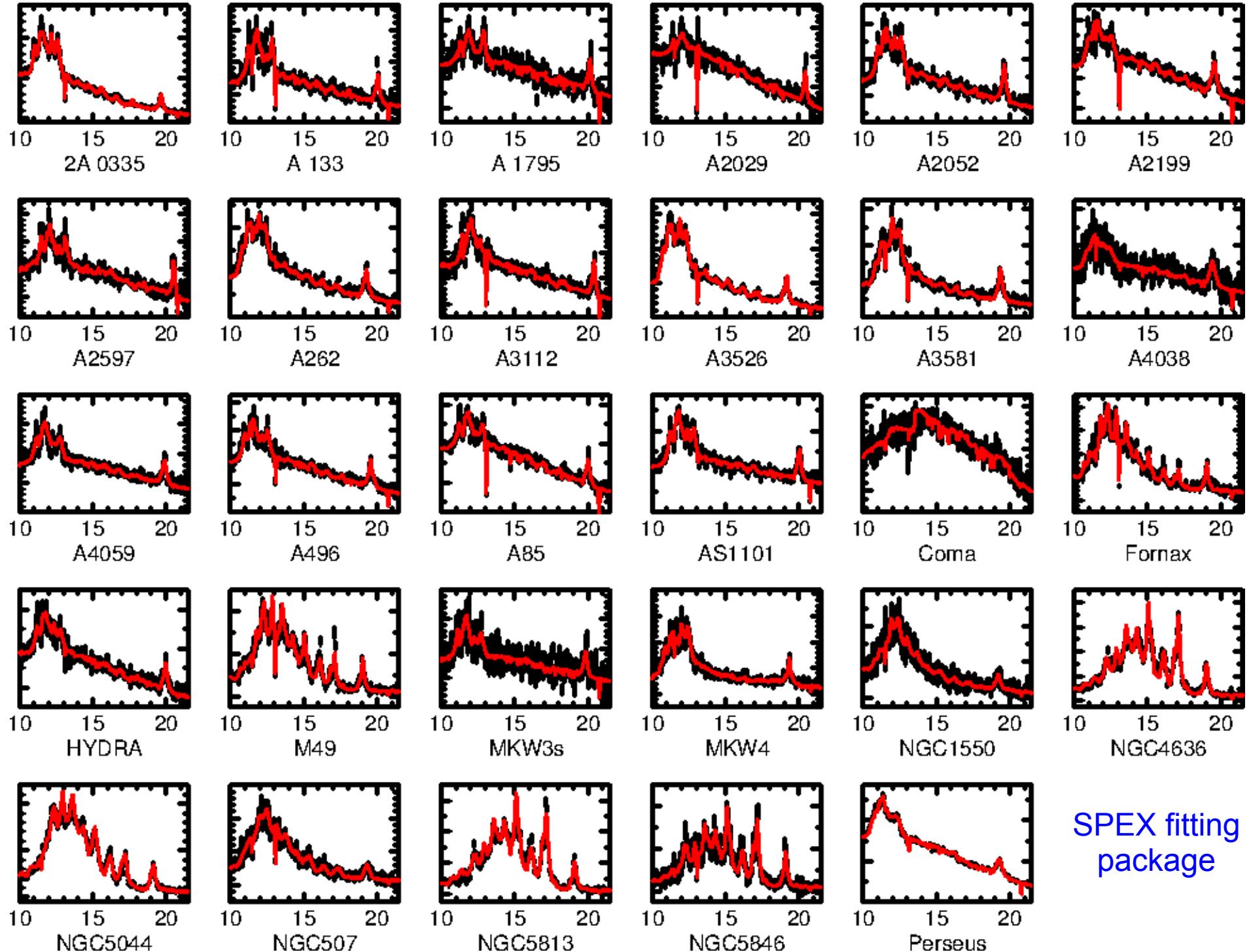


Emission Measure (10^{65} cm^{-3})



1-2 CIE, why ?

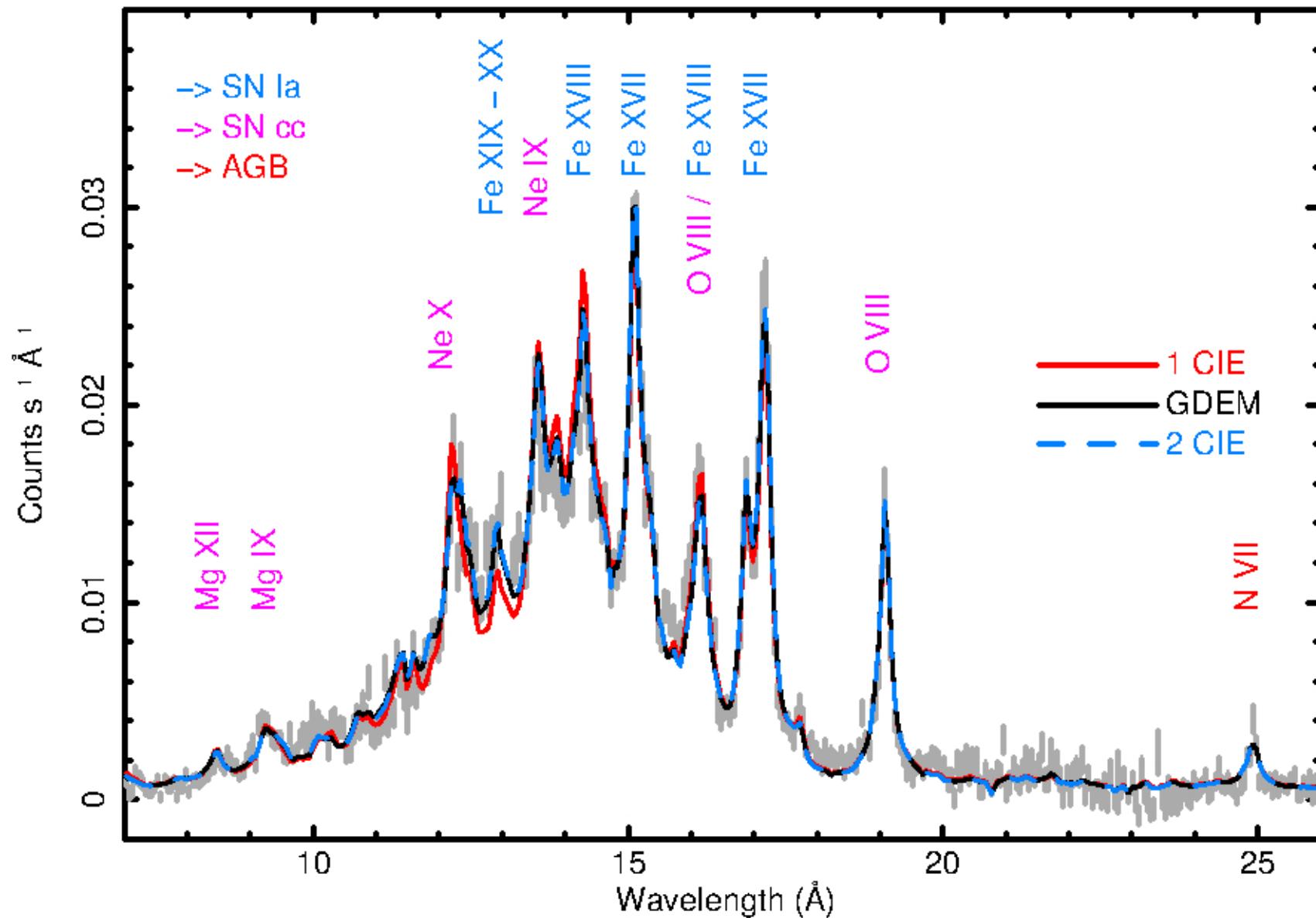
Stacked RGS spectra



SPEX fitting
package

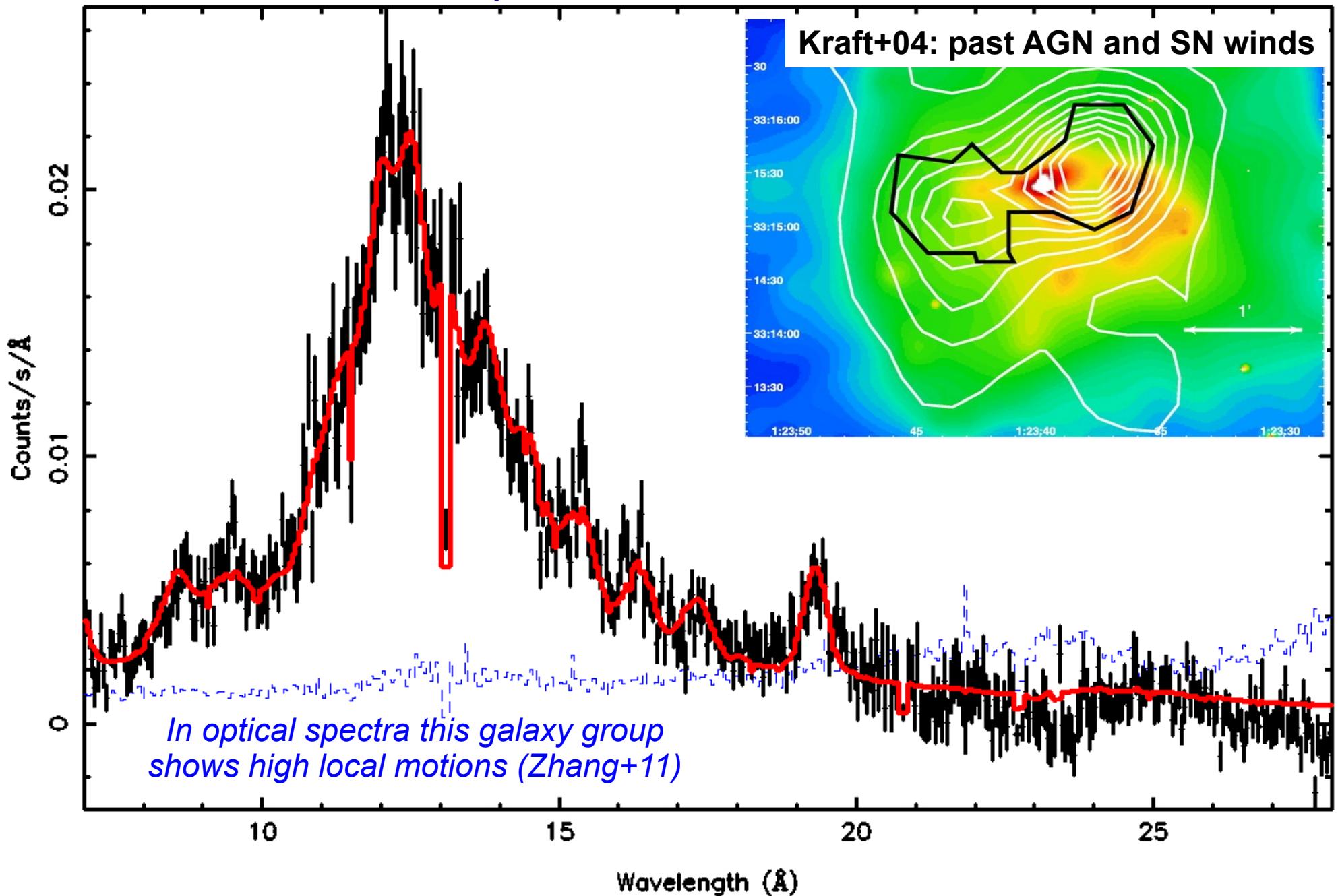
NGC 5846

$\sigma_v < 100 \text{ km s}^{-1}$



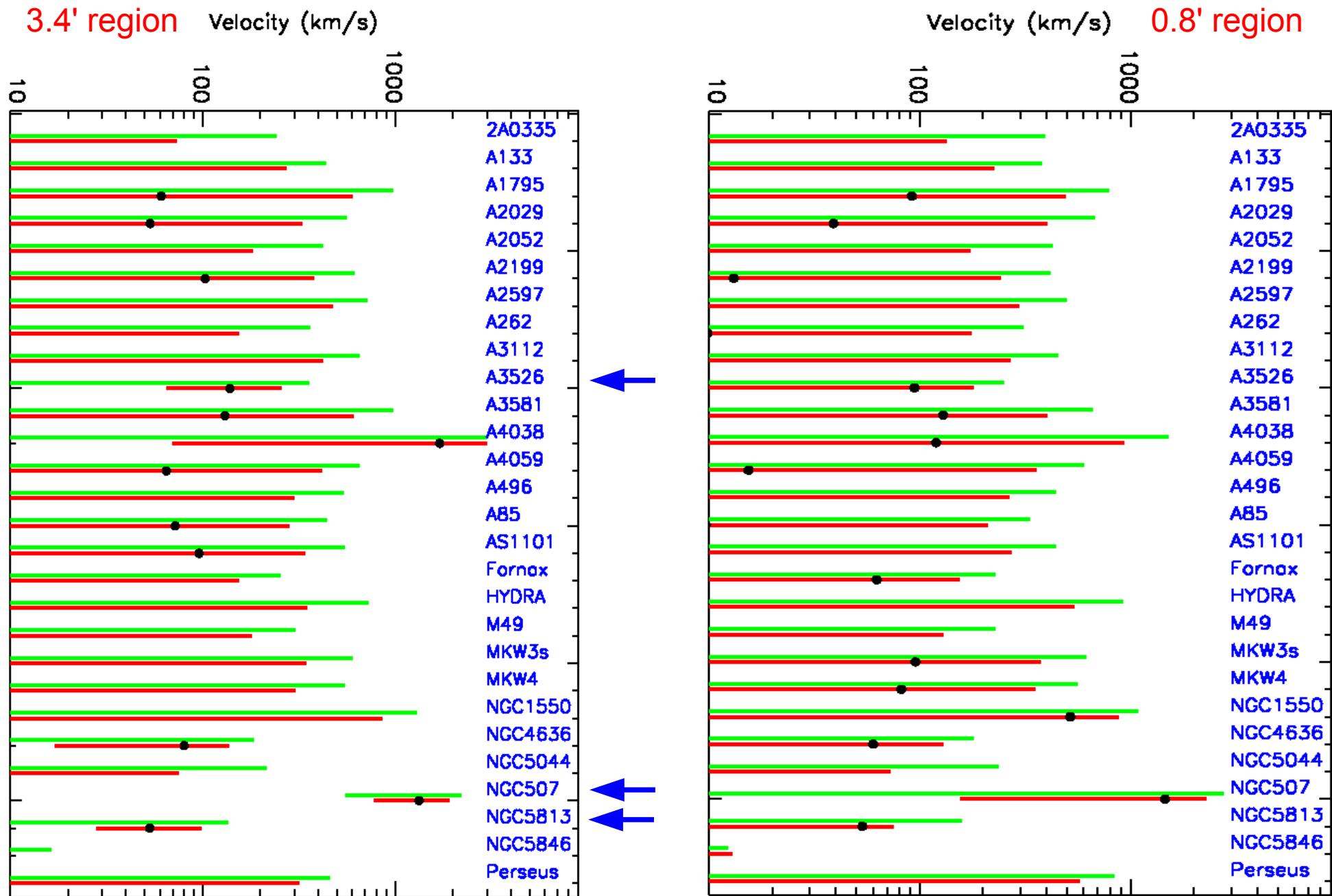
NGC 507

$\sigma_v \sim 1000 \text{ km s}^{-1}$

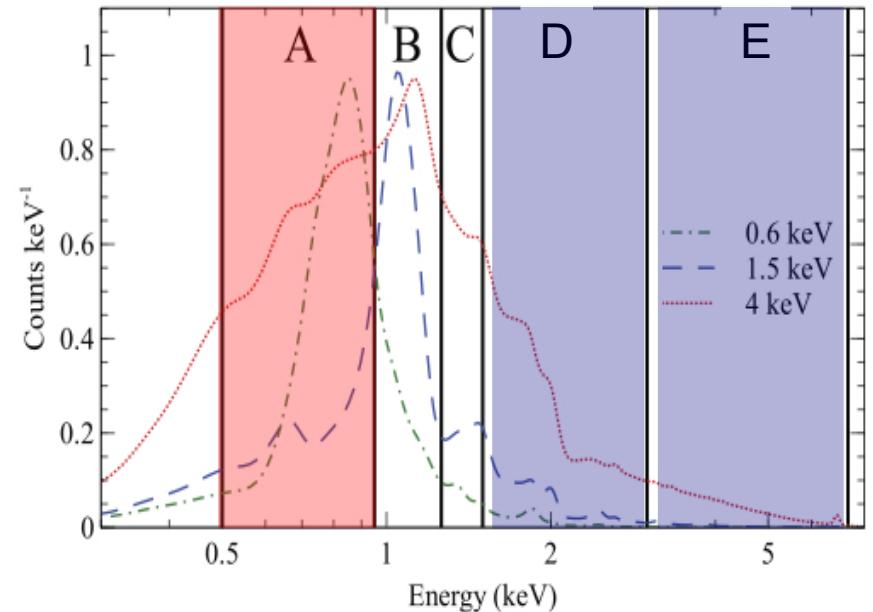
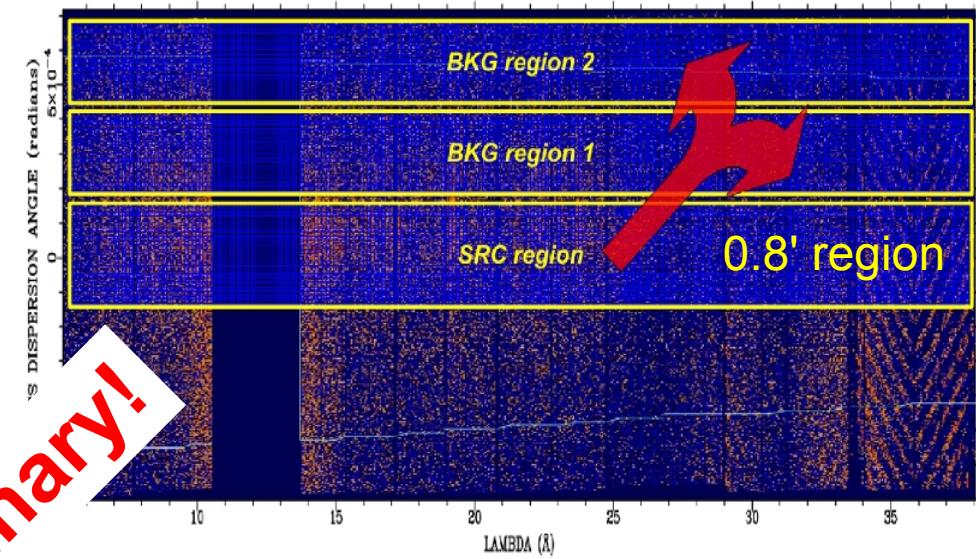


Velocity estimates (1-2 σ)

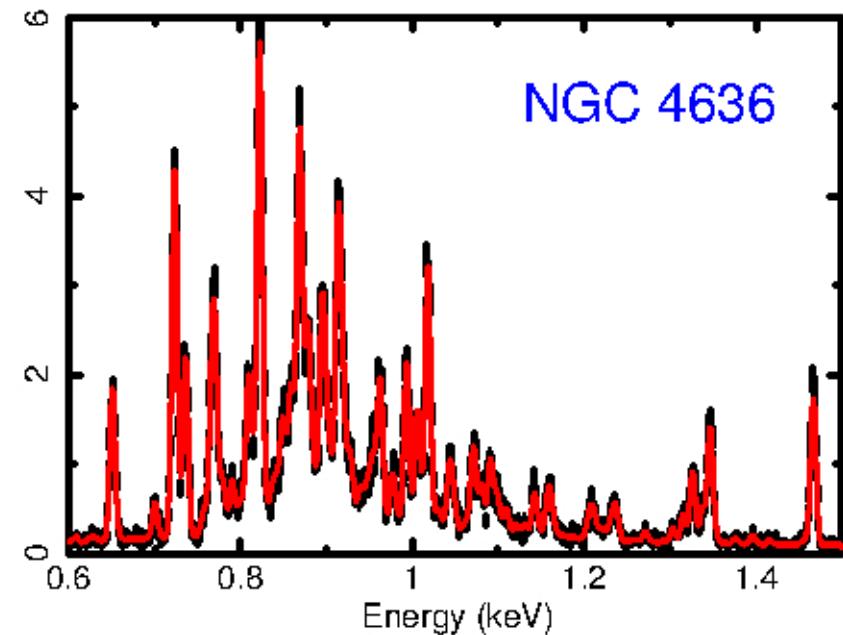
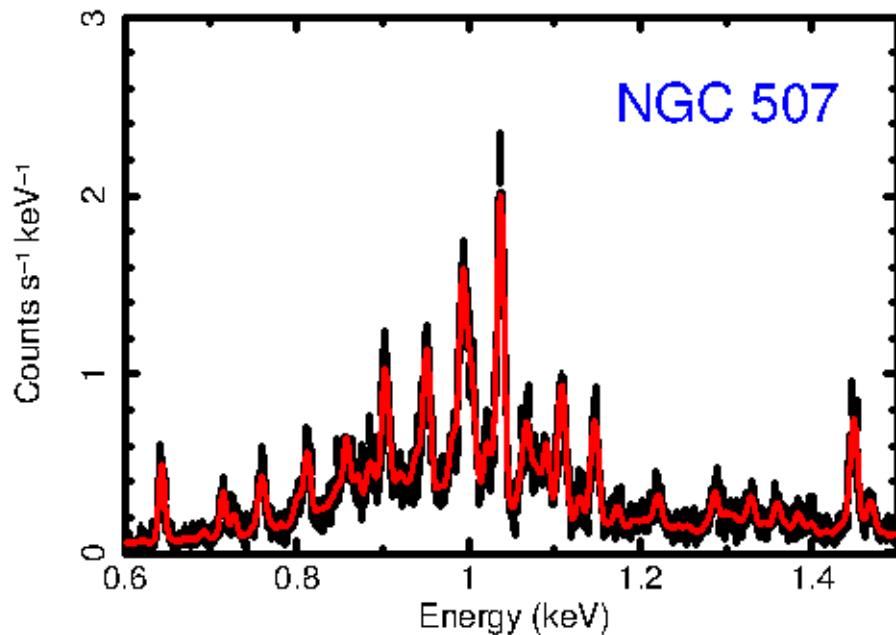
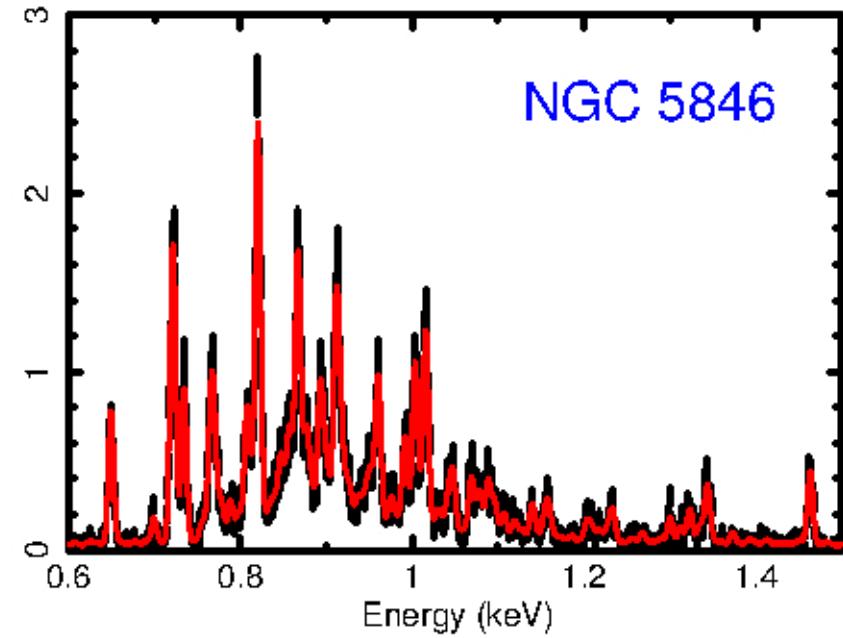
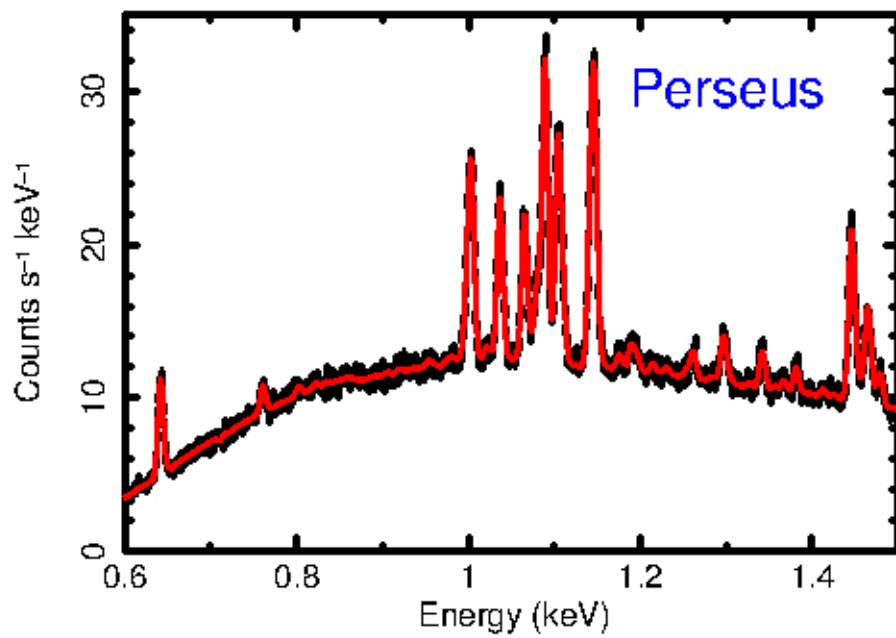
BKG from tamplate



Continuum-subtraction: O VIII lines



Astro-H 100ks simulations



Conclusion / Future

- It is possible to measure turbulence in clusters
 - Continuum affects line wings...
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- σ_v -limits agree with Werner+09, de Plaa+12, Sanders+13
 - Velocity broadening indicates also bulk motions
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- Next: Fe XVII 15-17Å line ratio / Fe K shifts
 - ASTRO-H will revolutionize the V_T measurements