Chandra ACIS-I particle background: an analytical model and its applications

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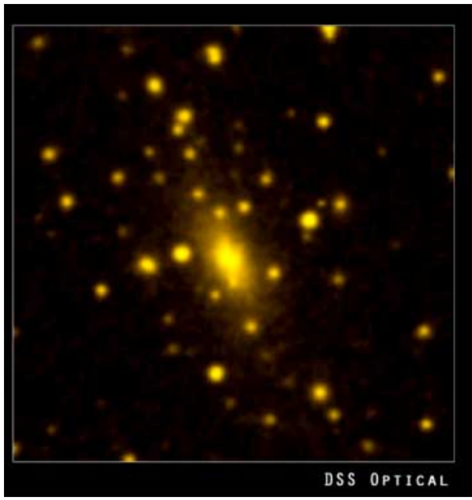
Done my Ph.D. and master thesis in Rome…

…at the university of Rome “Tor Vergata”

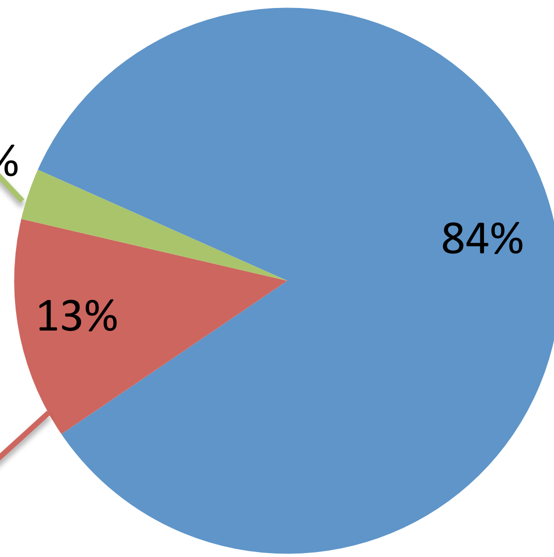
Contents:

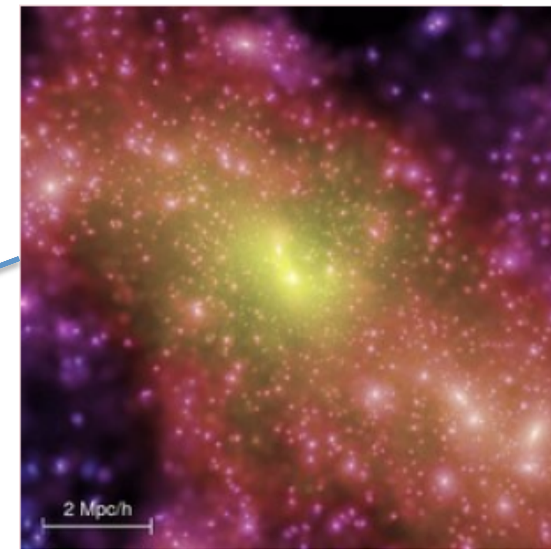
- Introduction
- Background subtraction
- Instrumental analytical model
- Chandra-XMM comparison
- Results and conclusions

Galaxy cluster introduction



Galaxies and stars





Dark matter

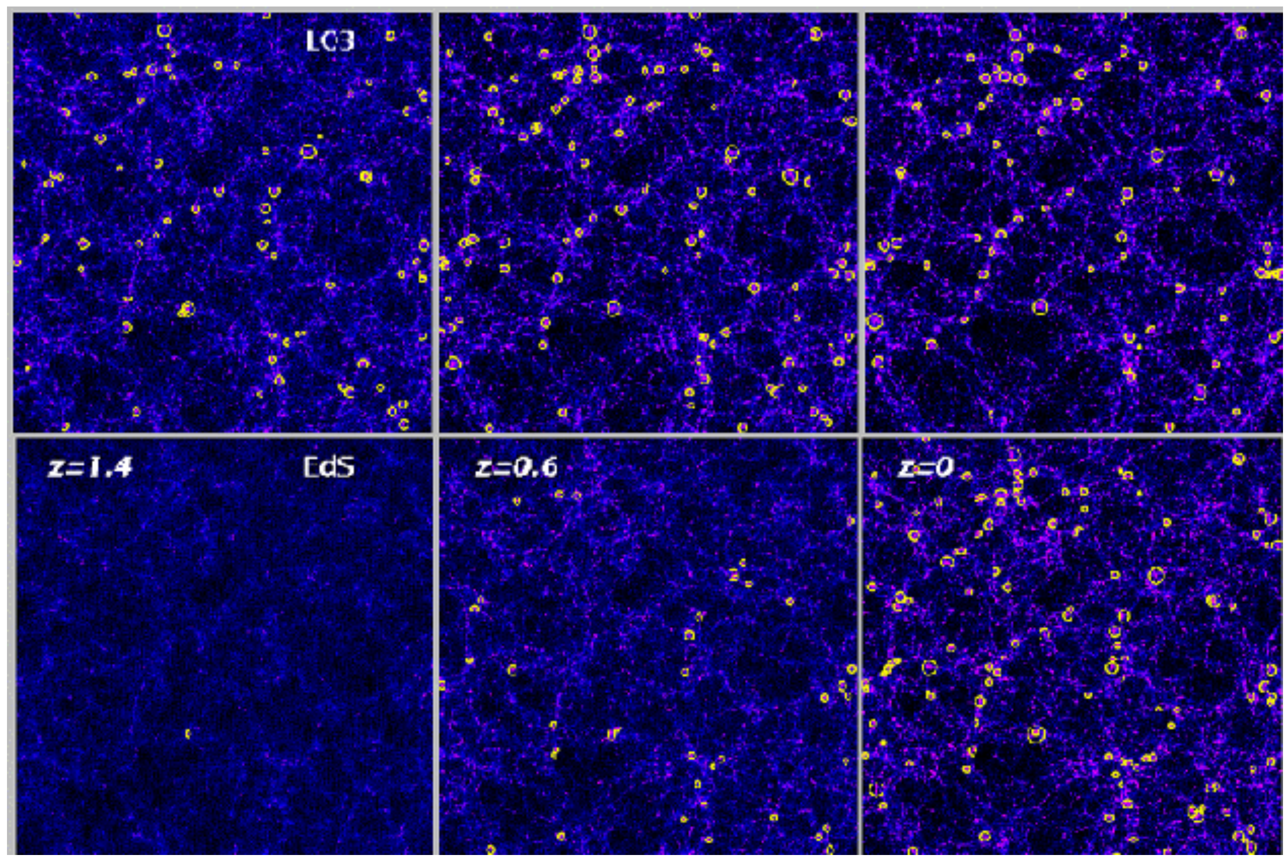
Hot (10^7-10^8 K) and rarified(10^{-2}-10^{-4} cm^{-3}) plasma known as IntraCluster Medium

Galaxy cluster as probes

We can use galaxy cluster to trace large structure formation. Cosmological models predict large scale distribution and growth of mass in function of redshift…

Λ=0,7
Flat universe

Λ=0
EdS universe



Borgani & Guzzo 2001

Galaxy cluster as probes

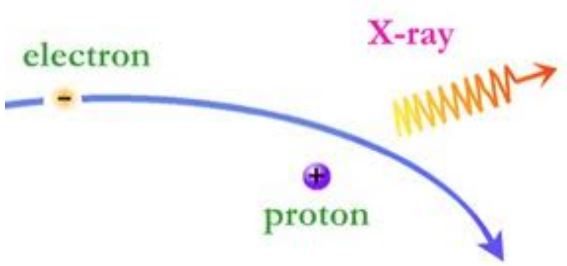
We can use galaxy cluster to trace large structure formation. Cosmological models predict large scale distribution and growth of mass in function of redshift…

To use galaxy clusters as cosmological probes we need to measure the **mass**

Borgani & Guzzo 2001

Galaxy cluster X-ray observations

Galaxy clusters emit in the X-ray for thermal Bremsstrahlung emission



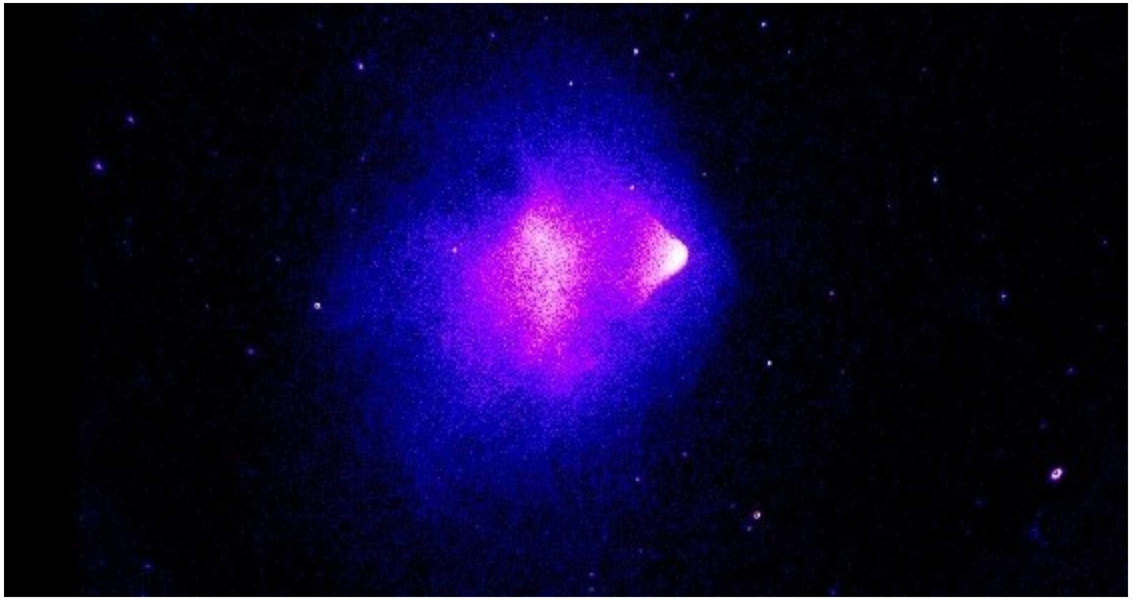
$$\frac{dW}{d\nu dV dt} \propto n_e^2 e^{-\frac{h\nu}{kT}}$$

Assuming hydrostatic equilbrium

$$M(r) = -\frac{kT\, r}{G\mu m_p}\left[\frac{d\log n_e}{d\log r} + \frac{d\log T}{d\log r}\right]$$

Caveat

Hydrostatic equilibrium does not hold for all systems...



Markevitch et al 2004

Mass determination
is a complex task, which
requires detailed study of
ICM physics...

Chandra & XMM-Newton

CHANDRA(NASA)

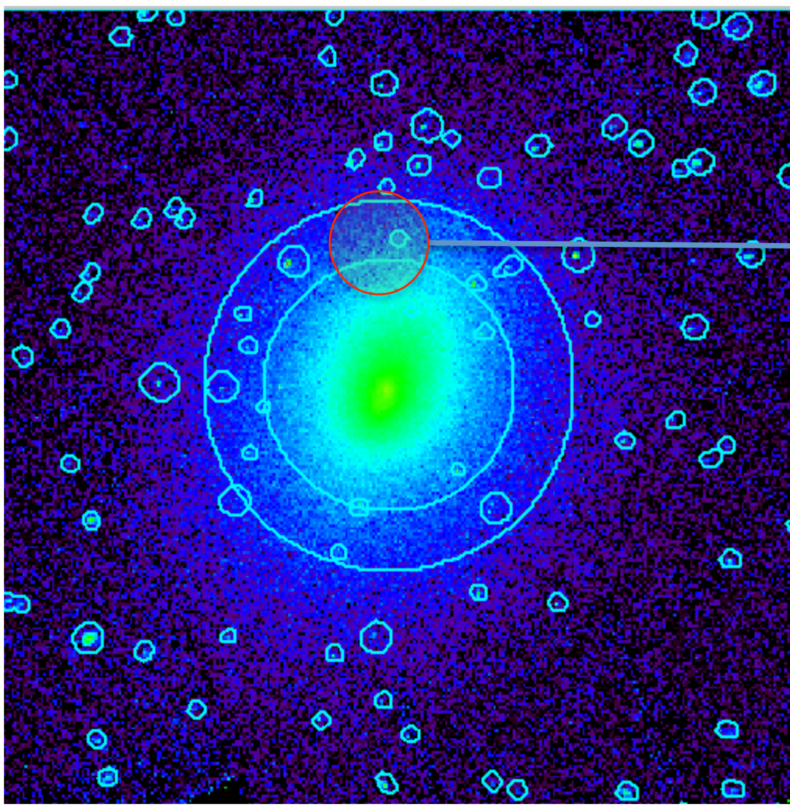
XMM-NEWTON(ESA)

- Angular resolution: ~ 0.5 arcsec
- Energy range: [0.5-9] Kev
- E/ΔE: ~ 40 @1 Kev
- Fov: ~ 16 arcmin

- Angular resolution: ~ 6 arcsec
- Energy range: [0.3-10] Kev
- E/ΔE: ~ 40@1 Kev
- Fov: ~ 30 arcmin

Background model: why?

Measures in the galaxy clusters are still difficult because of the low surface brightness



$$\epsilon(\nu) \propto n_e^2$$

$$n_e \sim 10^{-2} cm^{-3}$$

Background model: why?

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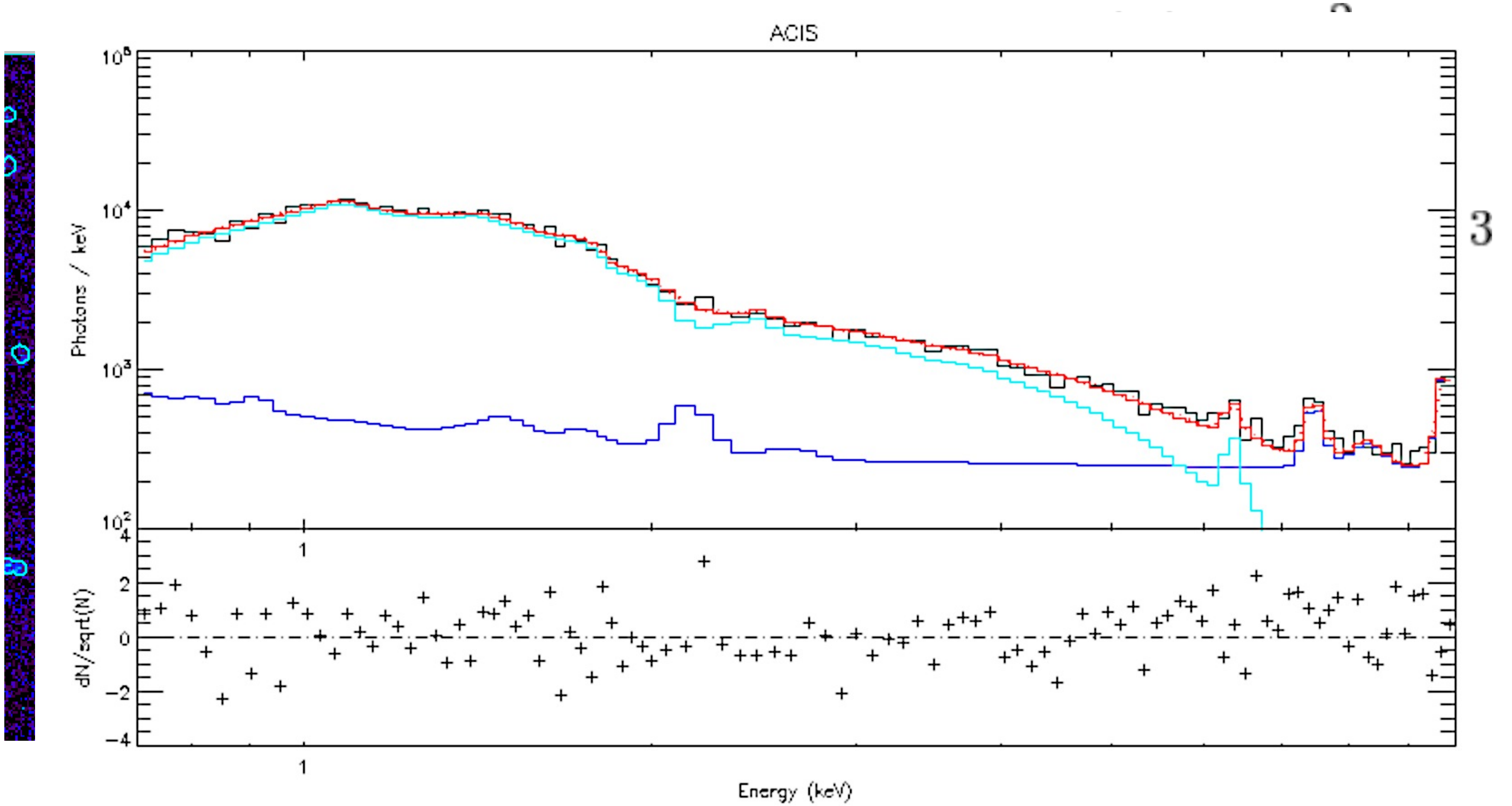

Background model: why?

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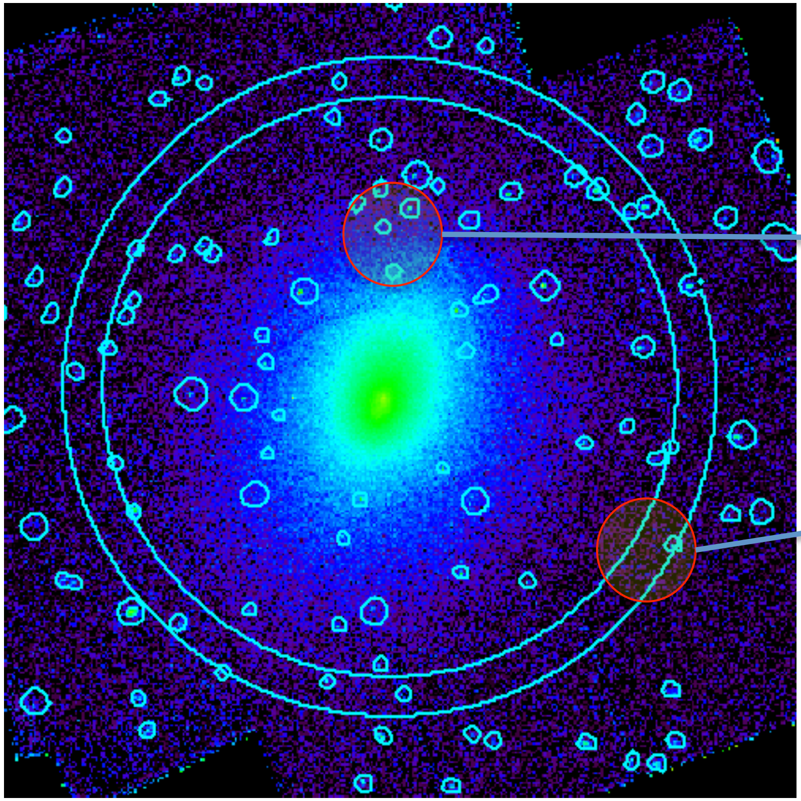
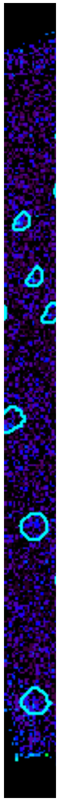


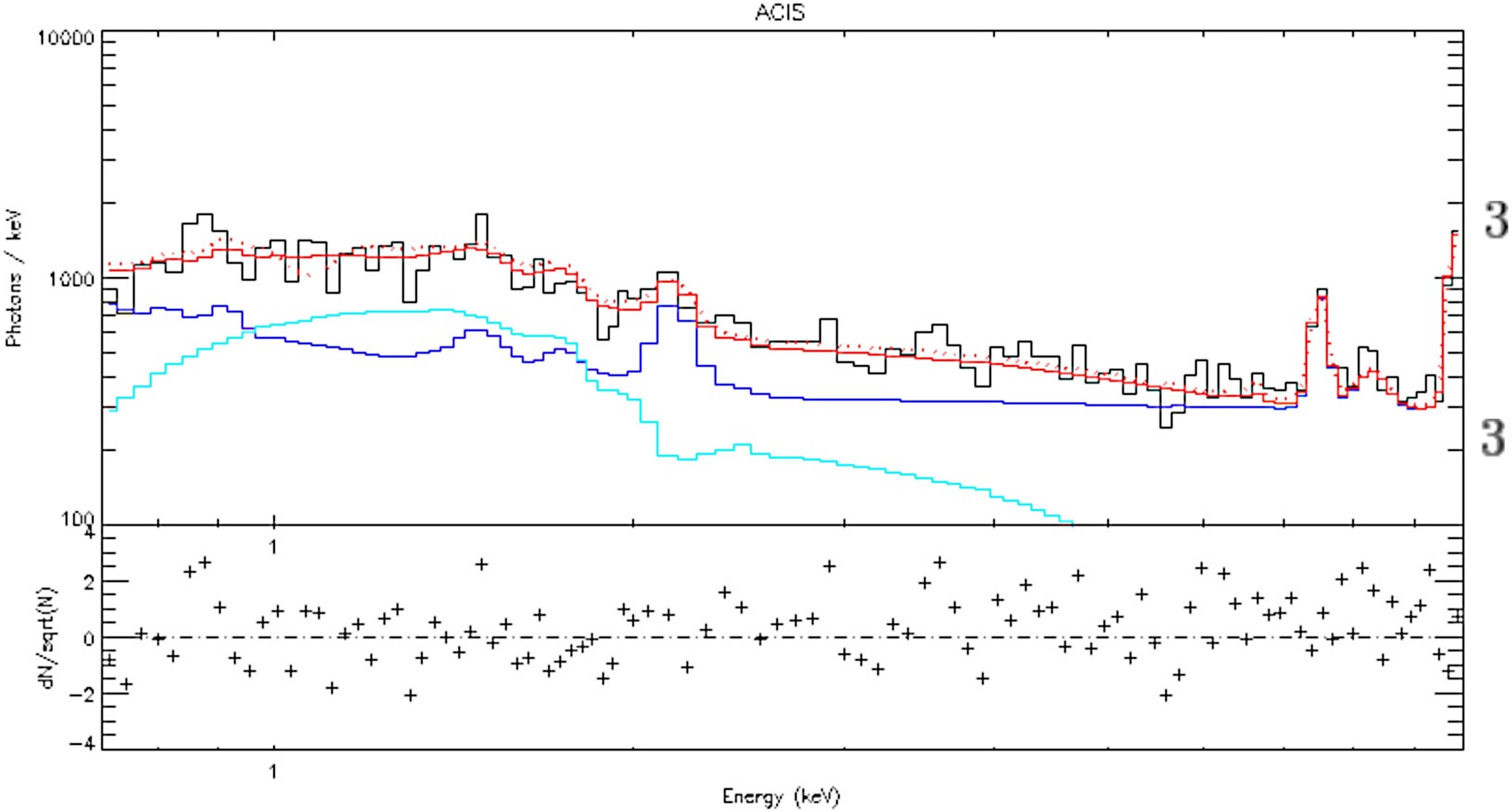
$$n_e \sim 10^{-2} cm^{-3}$$

$$n_e \sim 10^{-4} cm^{-3}$$

Background model: why?

Measures in the galaxy clusters are still difficult because of the low surface brightness





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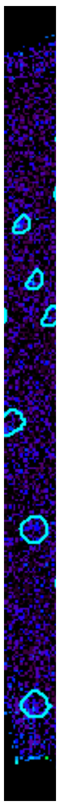
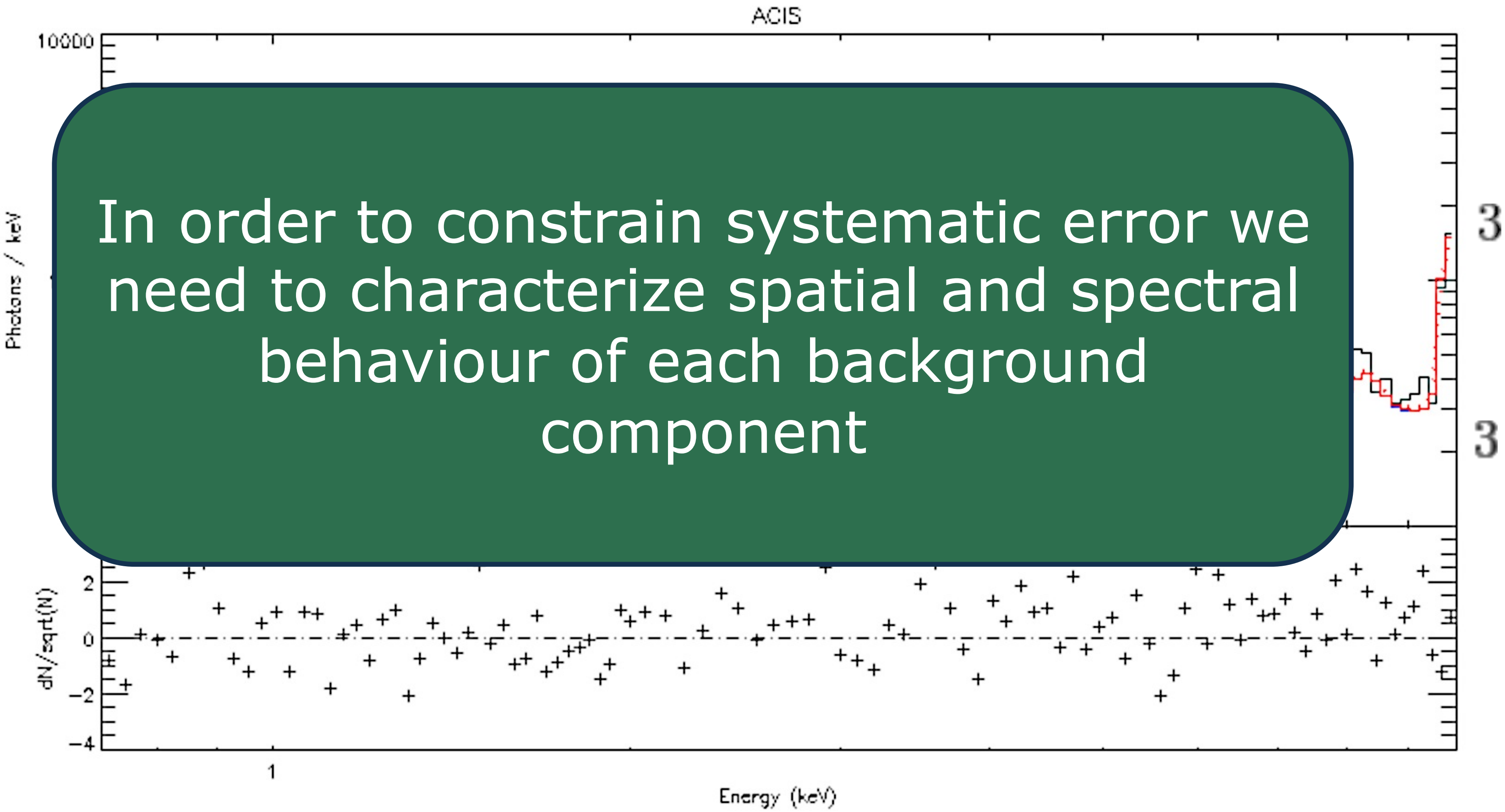




In order to constrain systematic error we need to characterize spatial and spectral behaviour of each background component

X-ray background

X-ray background is due to *sky* and *instrumental* components:

-Local Hot Bubble and Trans absorption emission (e.g. Kuntz & Snowden 2000) modelled with two absorbed thermal emission

T=0.24 keV T=0.14 keV

-Unresolved X ray point sources modelled with an absorbed power law (e.g. Lumb et al. 2002)

γ=1,42

-Emission from telescope itself hit by high energetic particles(e.g. Hickox and Markevitch 2006)

-Particle revealed by the detectors as photons

X-ray background

X-ray background is due to *sky* and *instrumental* components:

-Local Hot Bubble and Trans absorption emission (e.g. Kuntz & Snowden 2000) modelled with two absorbe

T=0.2

-Unresol modelle law (e.g

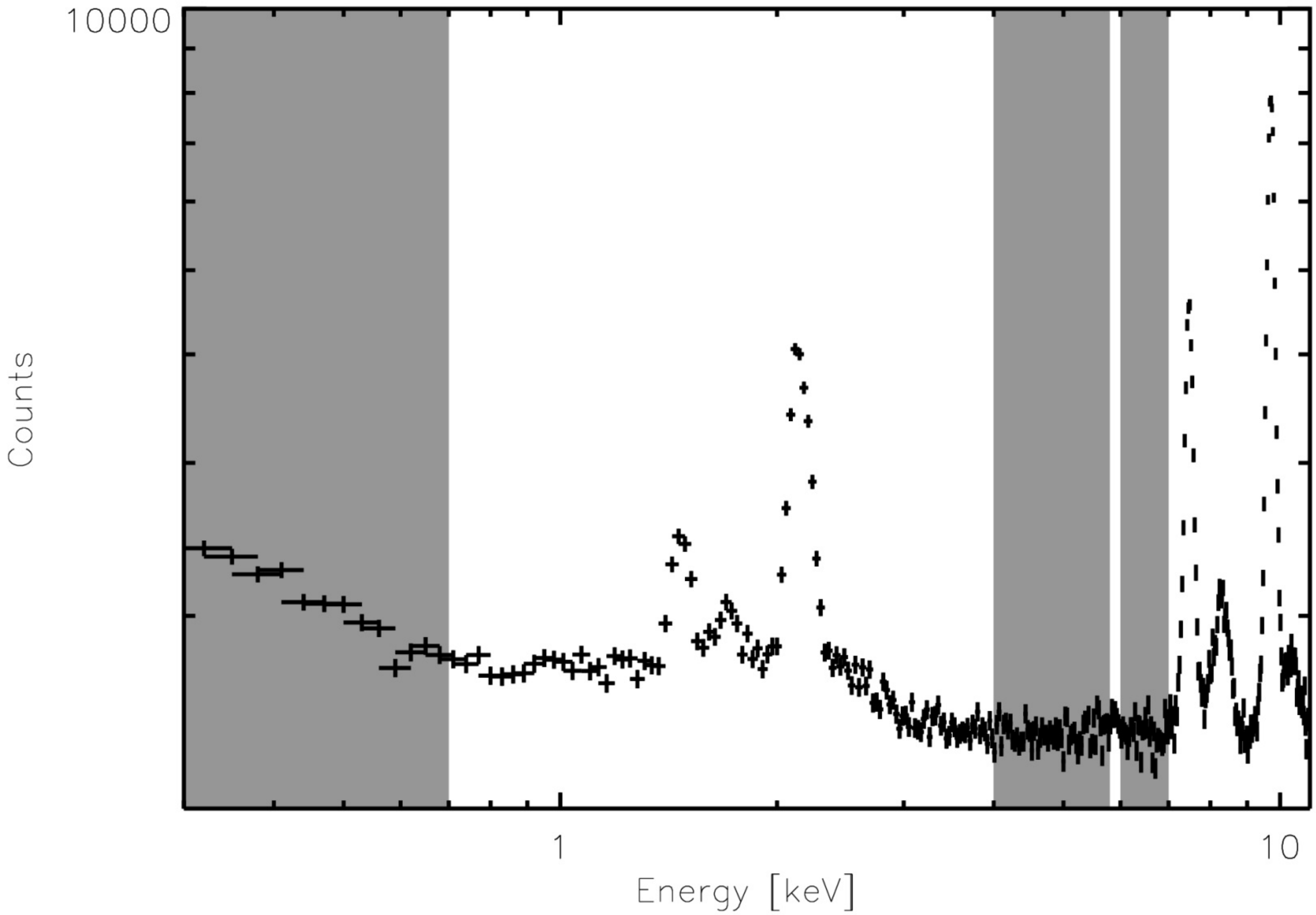
γ=1,42

-Emission from telescope itself

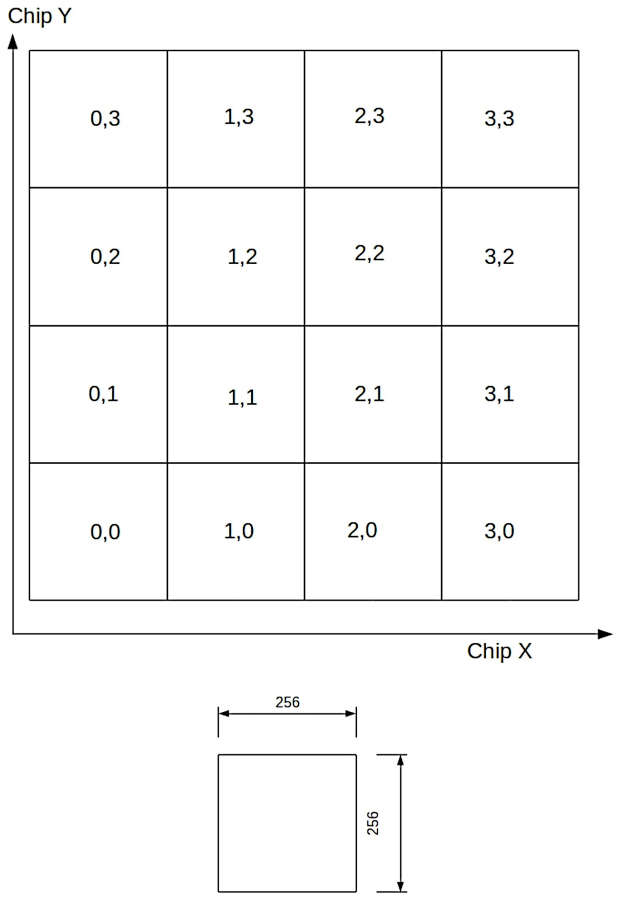
XMM instrumental background has been already studied, Kuntz and Snowden 2008, so I focus on the ACIS-I detectors

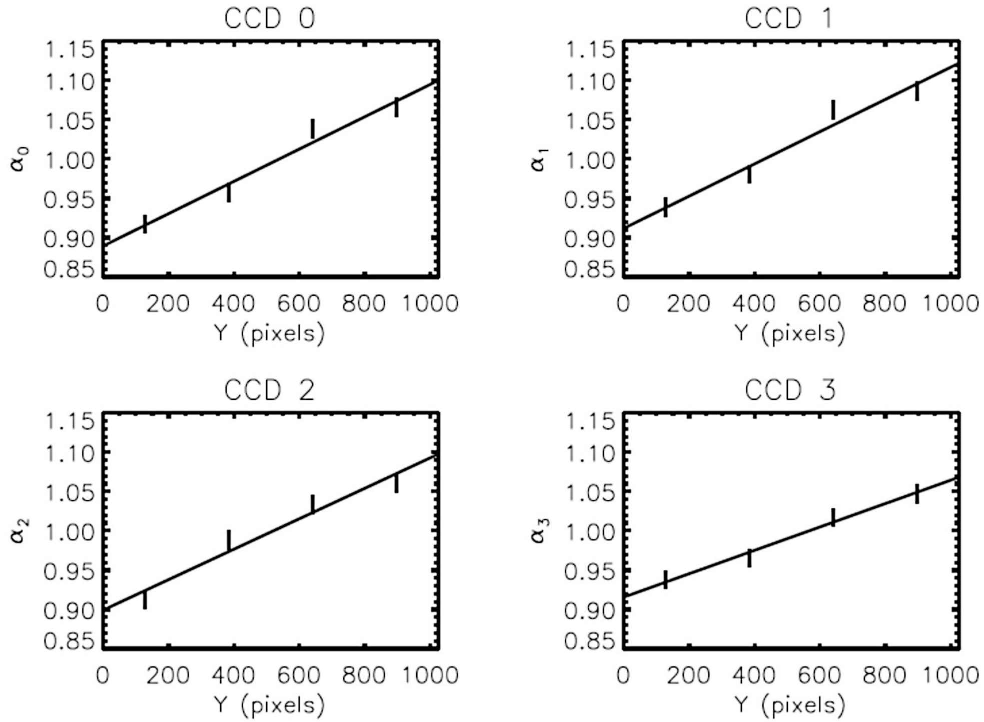
Particle background spectrum

We extract the spectrum from the four chips of ACIS-I and we find a continumm plus some emission lines

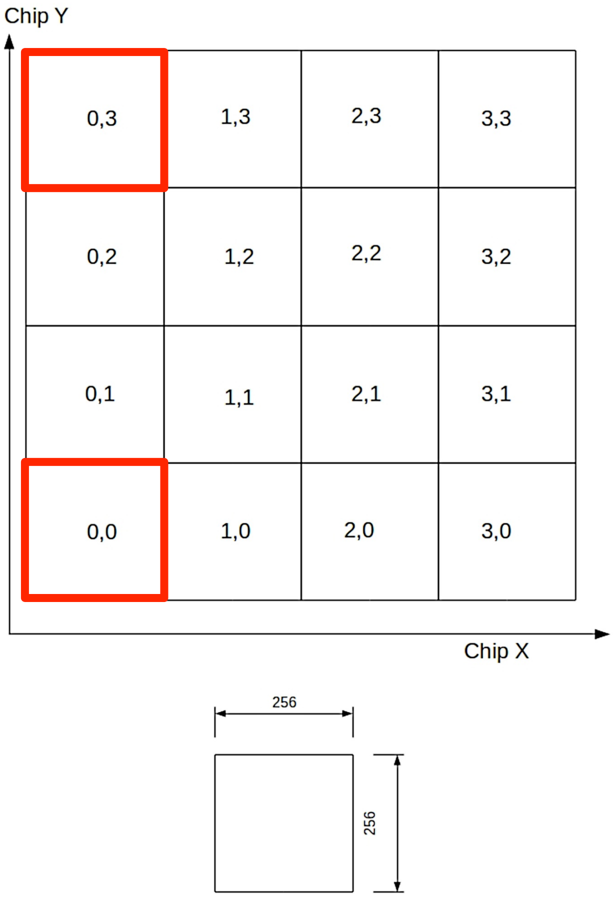


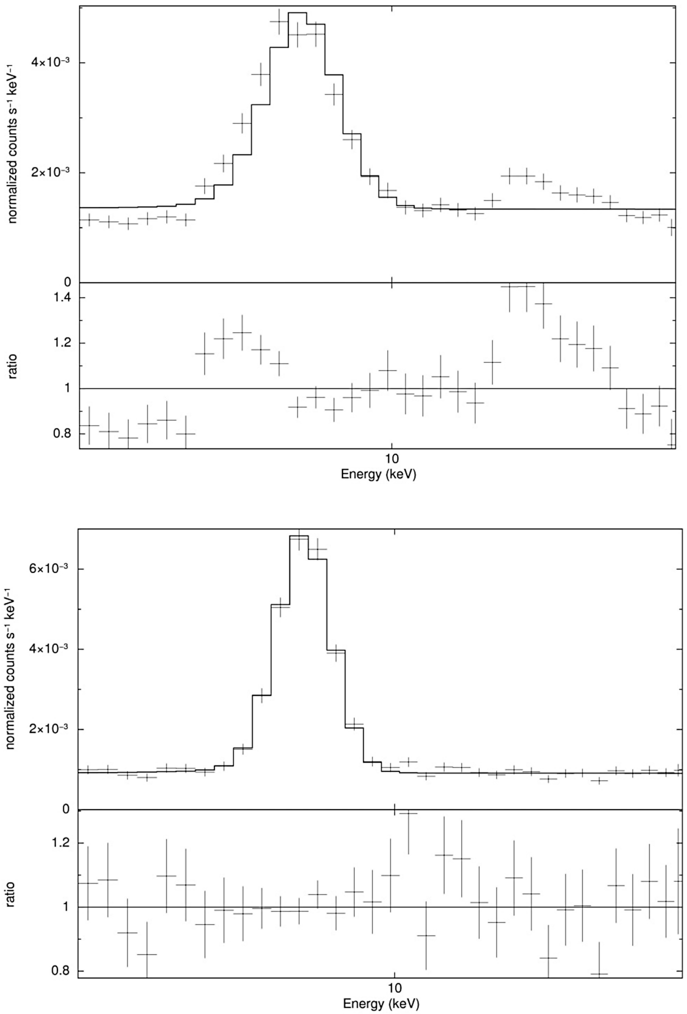
Particle background analysis





Particle background analysis





The analytical model

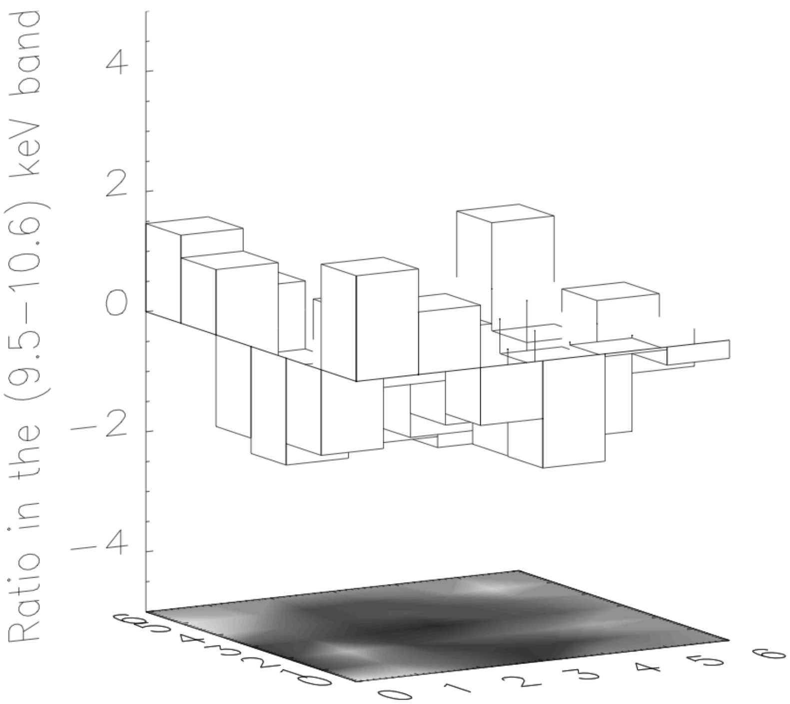
We model the particle background emission using two terms, one for the continuum and one for the lines:

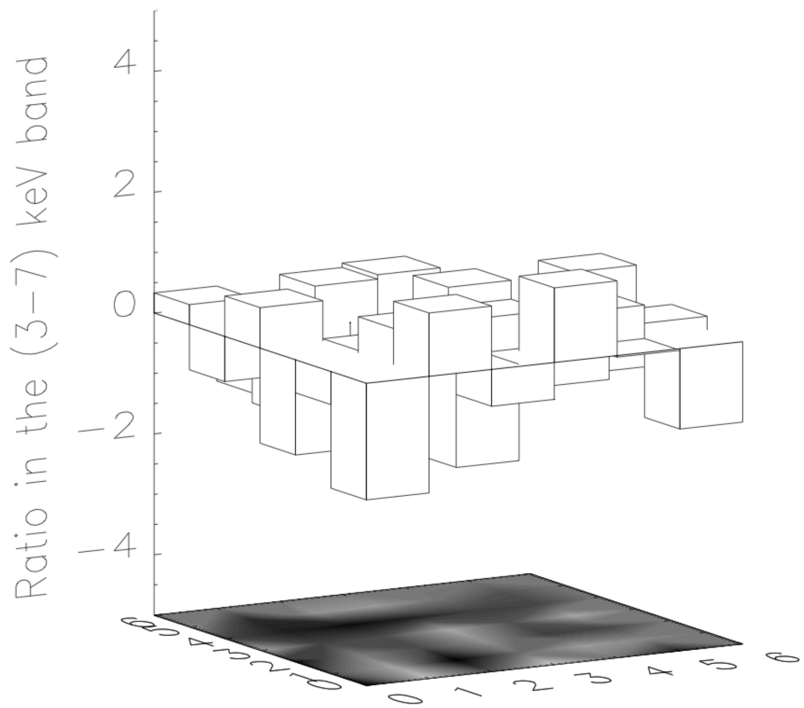
$$F_i(E,y) = \underbrace{C_i(E,y)}_{\text{Continuum term}} + \underbrace{L_i(E,y)}_{\text{Lines term}}$$

$$C_i(E,y) = \alpha_i(y)\left(K_1 \mathrm{e}^{-A_1 E} + K_2 E^{-A_2}\right)$$

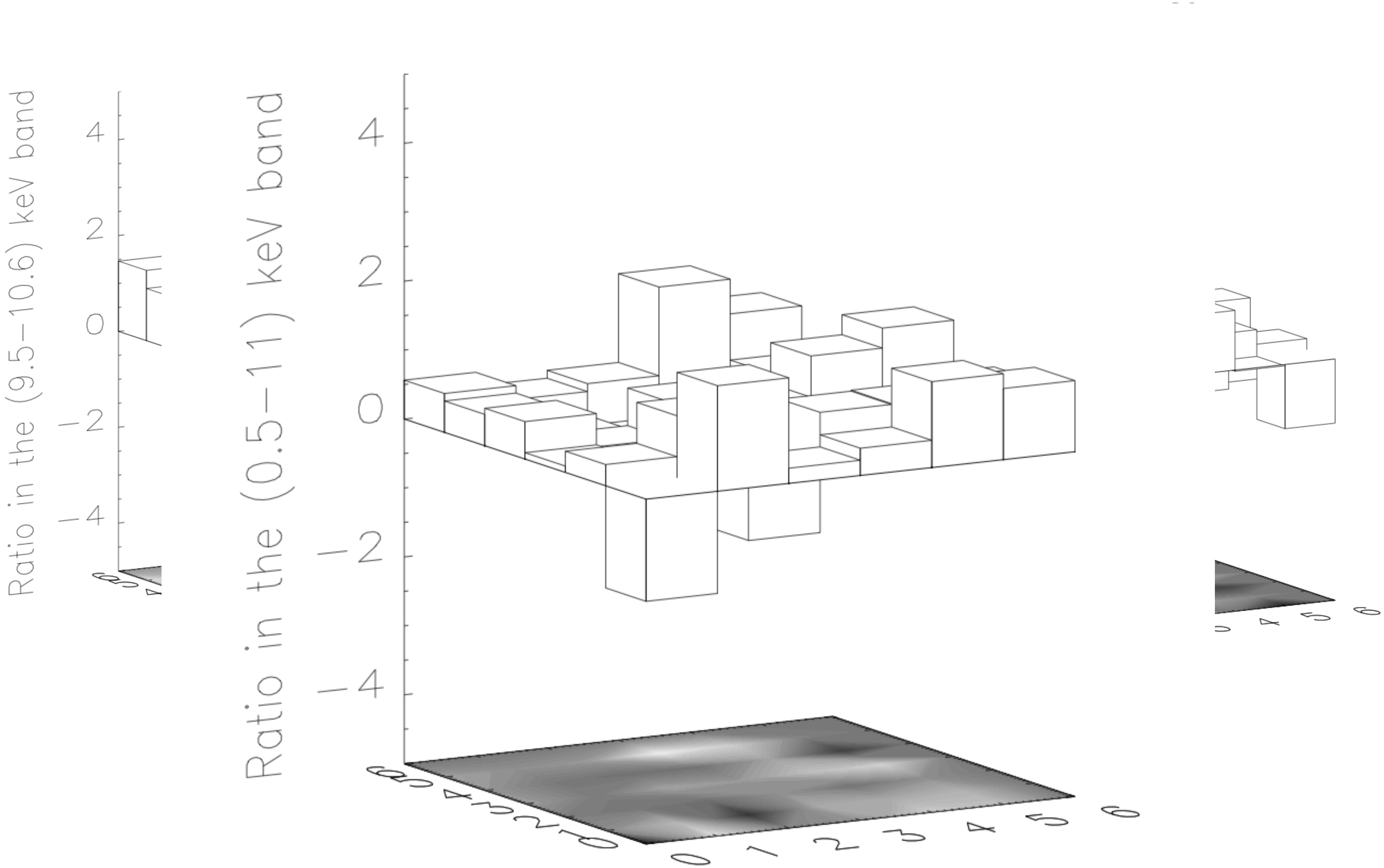
$$L_i(E,y) = D(E) + \sum_{l=1}^{3} S_{i,l}(E,y)$$

Flux prediction test





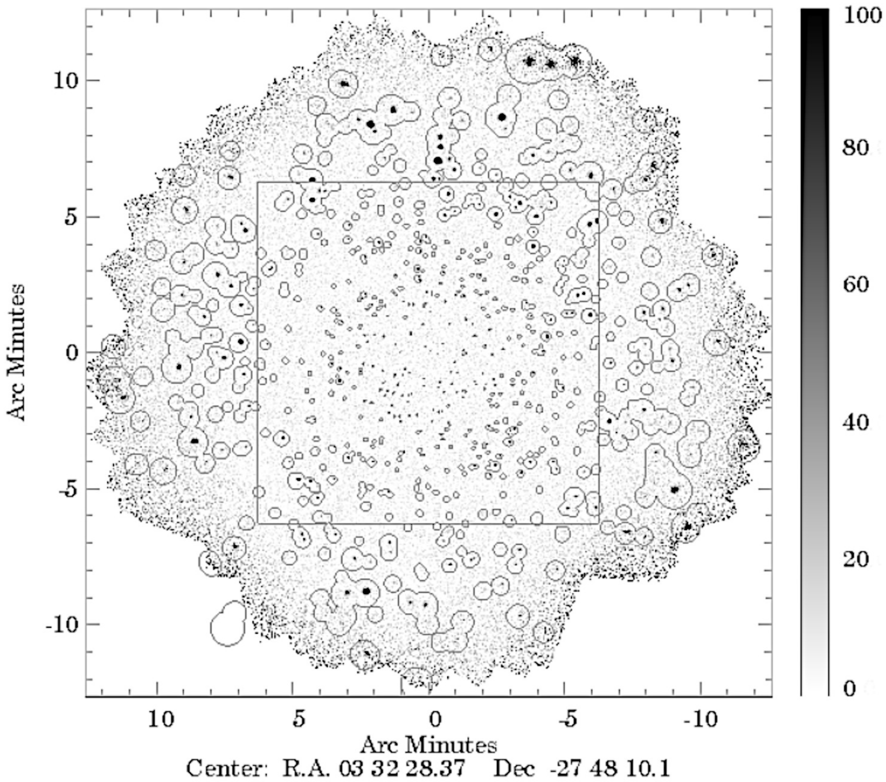
Flux prediction test



What is new?

-We produced a new background models for Chandra observations made by ACIS-I in very faint mode(Bartalucci et al 2014). These models predict the spatial variation of the background to better than 2% on the continuum and 5% on lines.

Unresolved flux measurement



We performed a flux measure of the unresolved CXB in the 5x5 arcmin square obtaining

$$[1-2]\ \mathrm{keV}$$

$$(0.97 \pm 0.03) \times 10^{-12} cm^{-2} s^{-1} deg^{-2} erg$$

$$[2-8]\ \mathrm{keV}$$

$$(4.14 \pm 0.01) \times 10^{-12} cm^{-2} s^{-1} deg^{-2} erg$$

Bartalucci et al. 2014

Fully consistent with previous measures e.g.

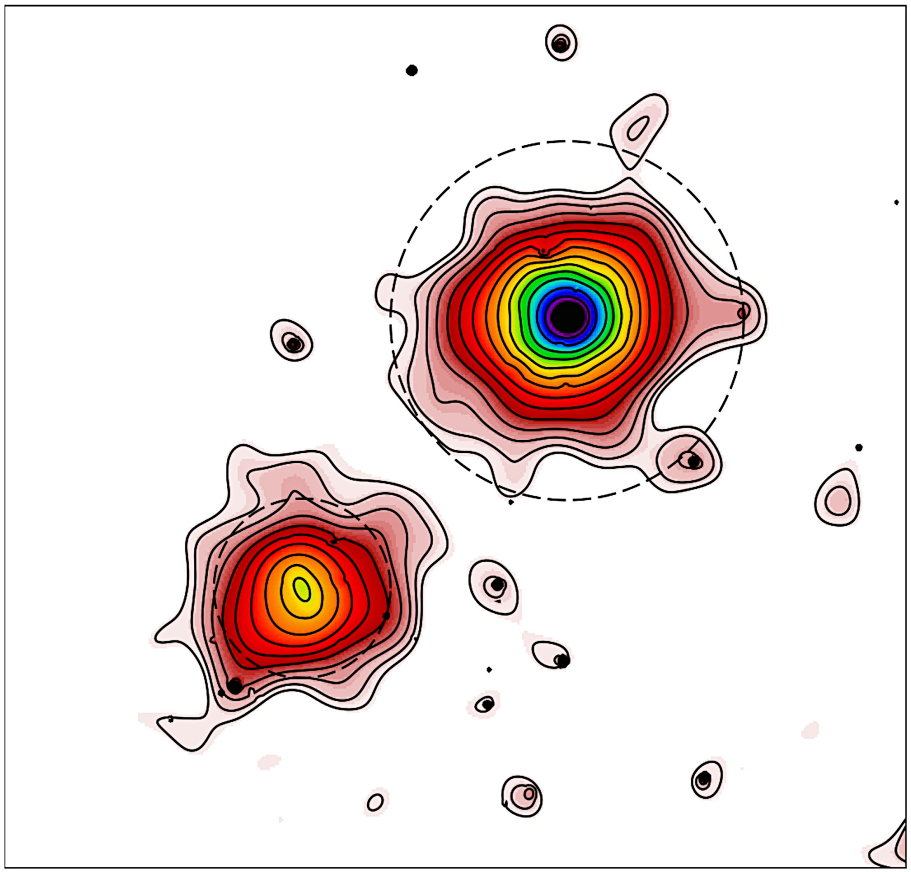
$$[1-2]\ \mathrm{keV}$$

$$(1.04 \pm 0.14) \times 10^{-12} cm^{-2} s^{-1} deg^{-2} erg$$

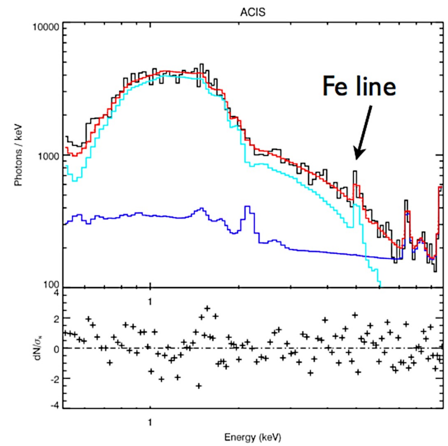
Hickox and Markevitch 2006

Redshift determination

The determination of each component of the spectrum allowed us to measure the redshift of a new detected cluster

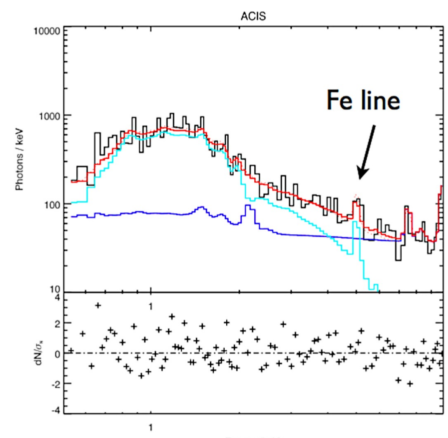


Macario et al. 2014



MACSJ0520.7-1328

$$z = 0.336^{+0.004}_{-0.002}$$

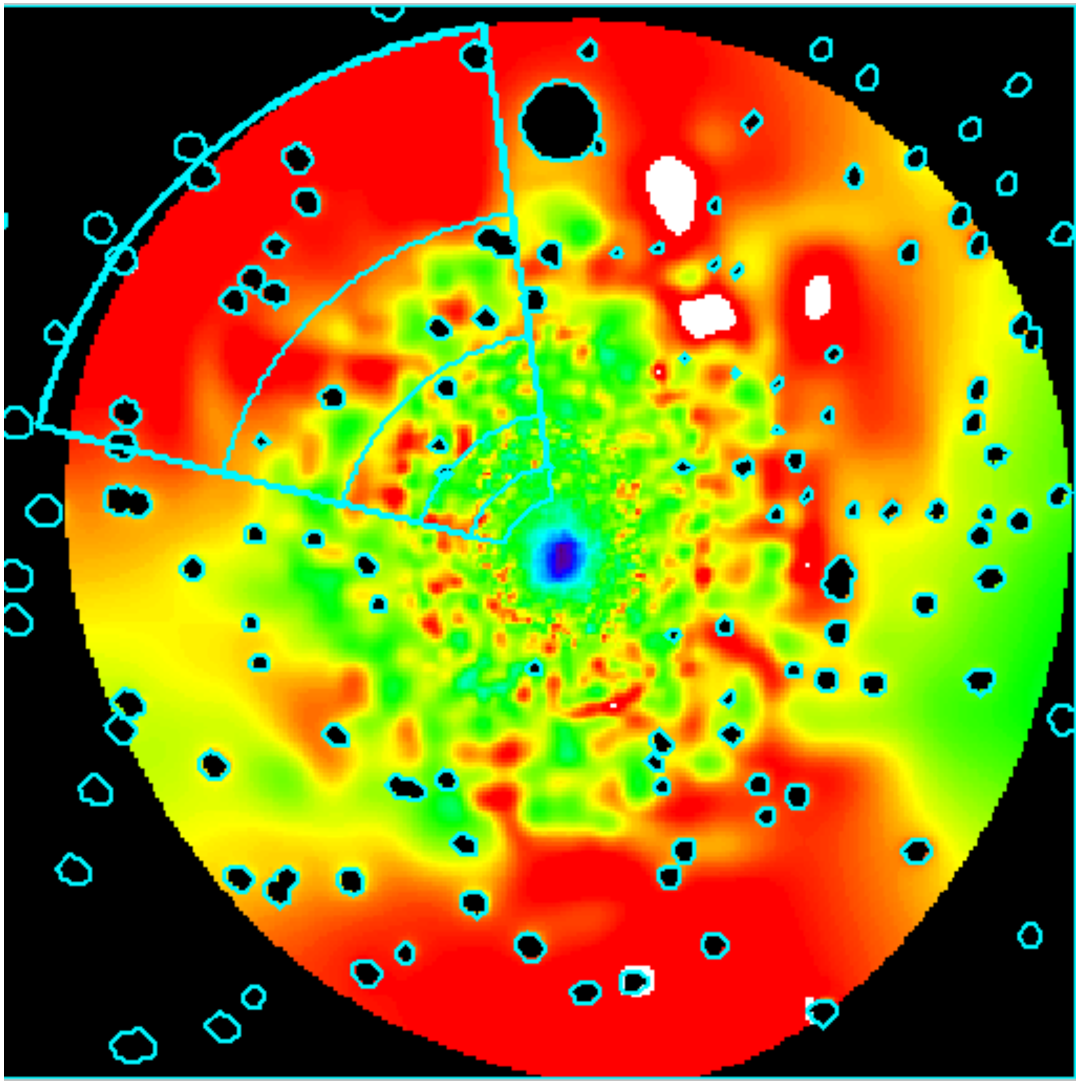


WGA 0521

$$z = 0.34^{+0.01}_{-0.02}$$

Temperature maps

Abell 1795



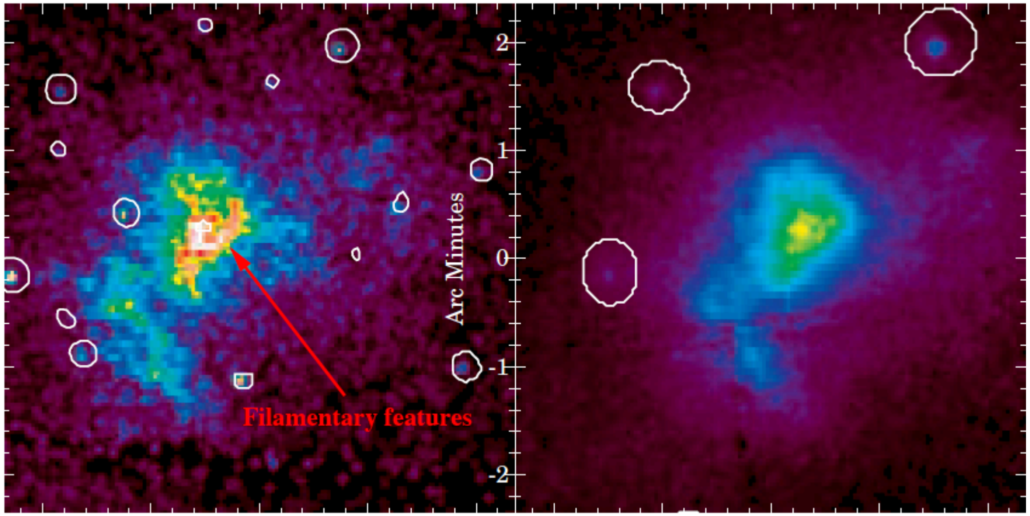
Another application is in the production of temperature maps.

E.g.: in this case we can study the dynamical state of the cluster and if the H.E. holds

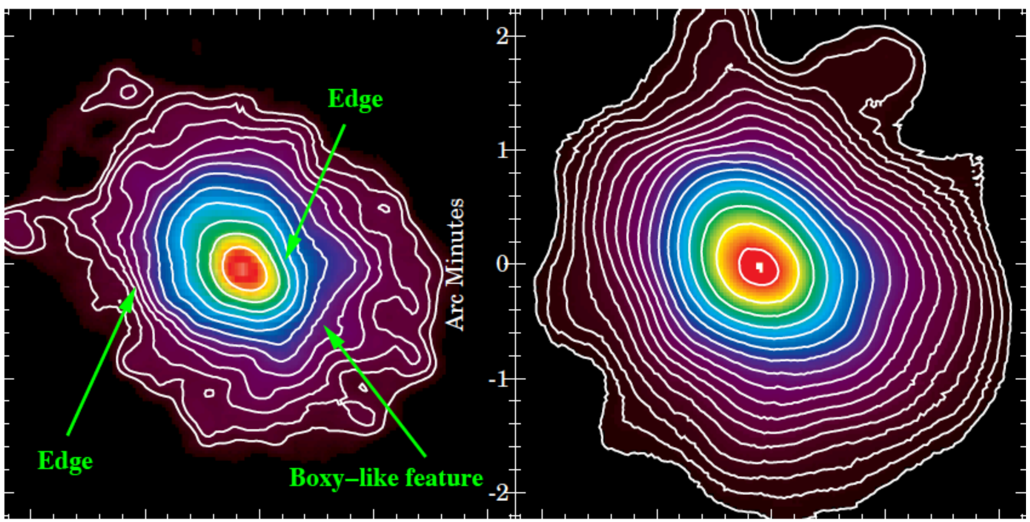
Temperature map algorithm: Bourdin & Mazzotta 2008

Chandra & XMM: why?

CHANDRA *XMM-NEWTON*

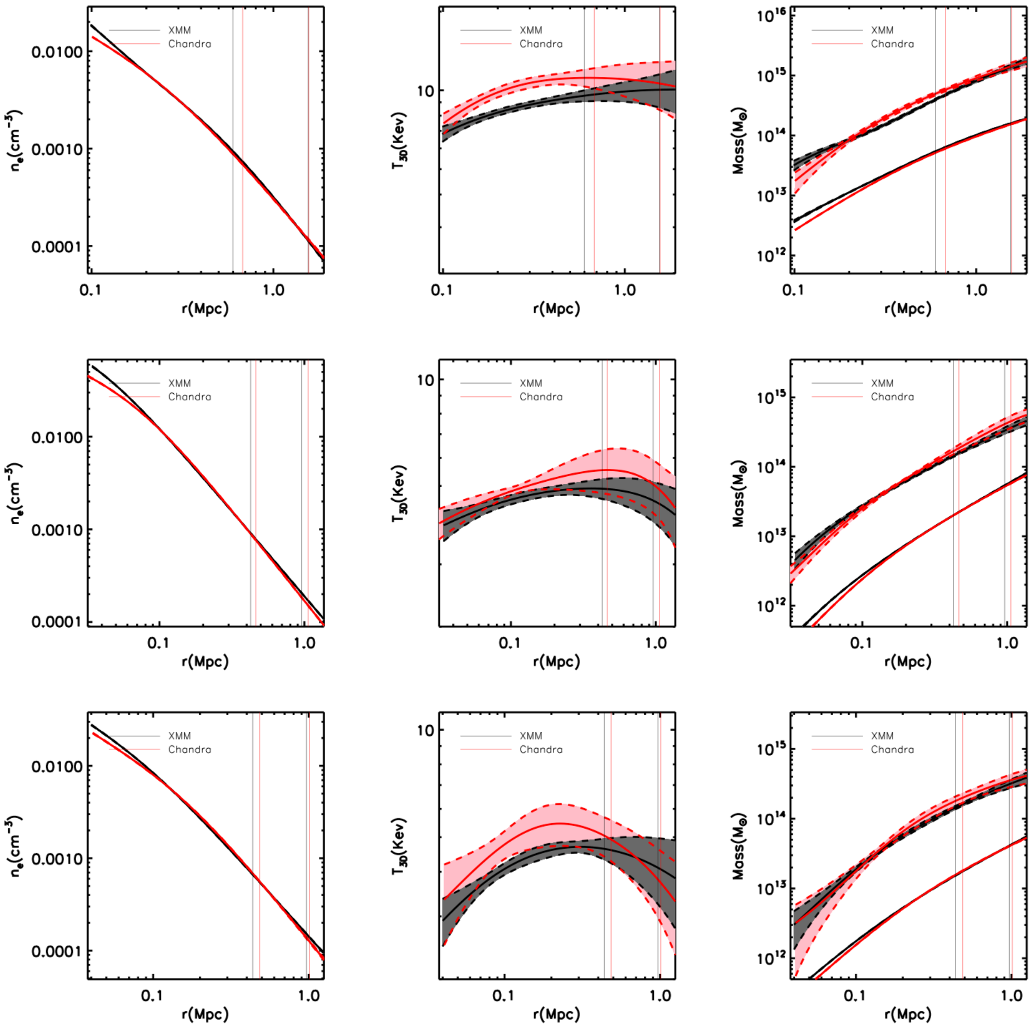


MACS J0717.5+3745
Z = 0.55



Cl0016+16
Z = 0.55

Chandra & XMM comparison



Martino et al. 2014

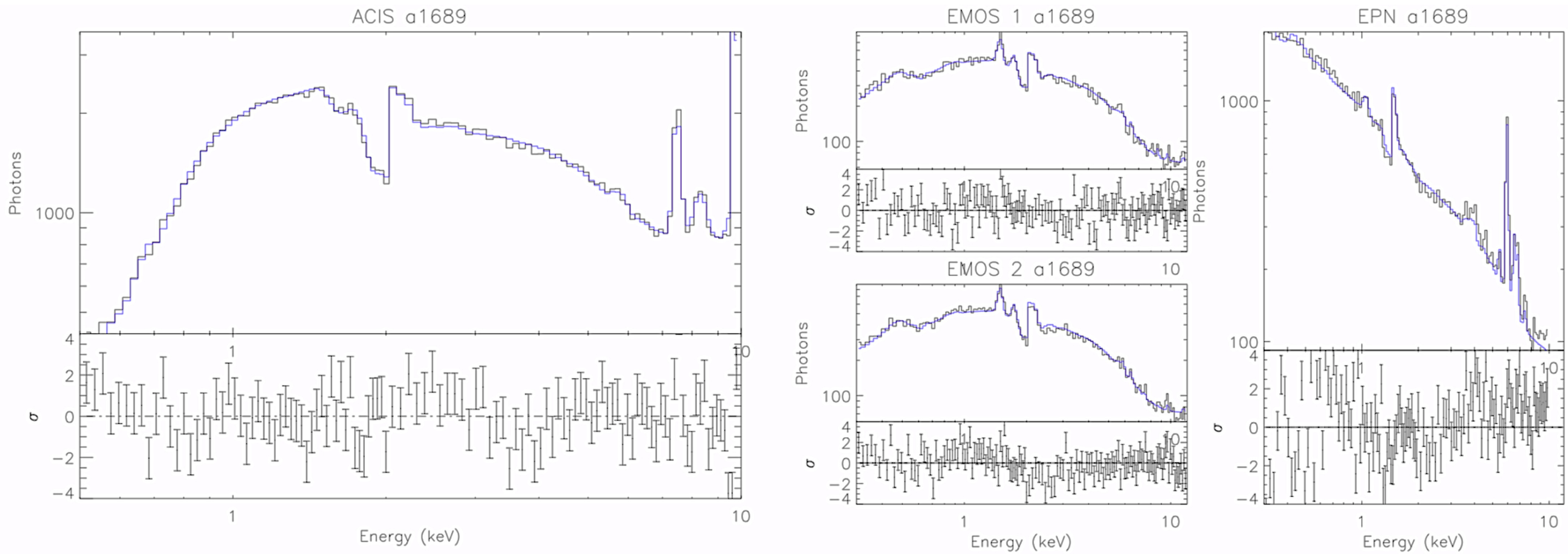
We used the same analysis technique to analyse a sample of clusters

We find that the fluxes measured by the two instruments are in agreement within the statistical errors

We find that temperture of Chandra is sistematically 10-15% greater than XMM

Chandra and XMM comparison

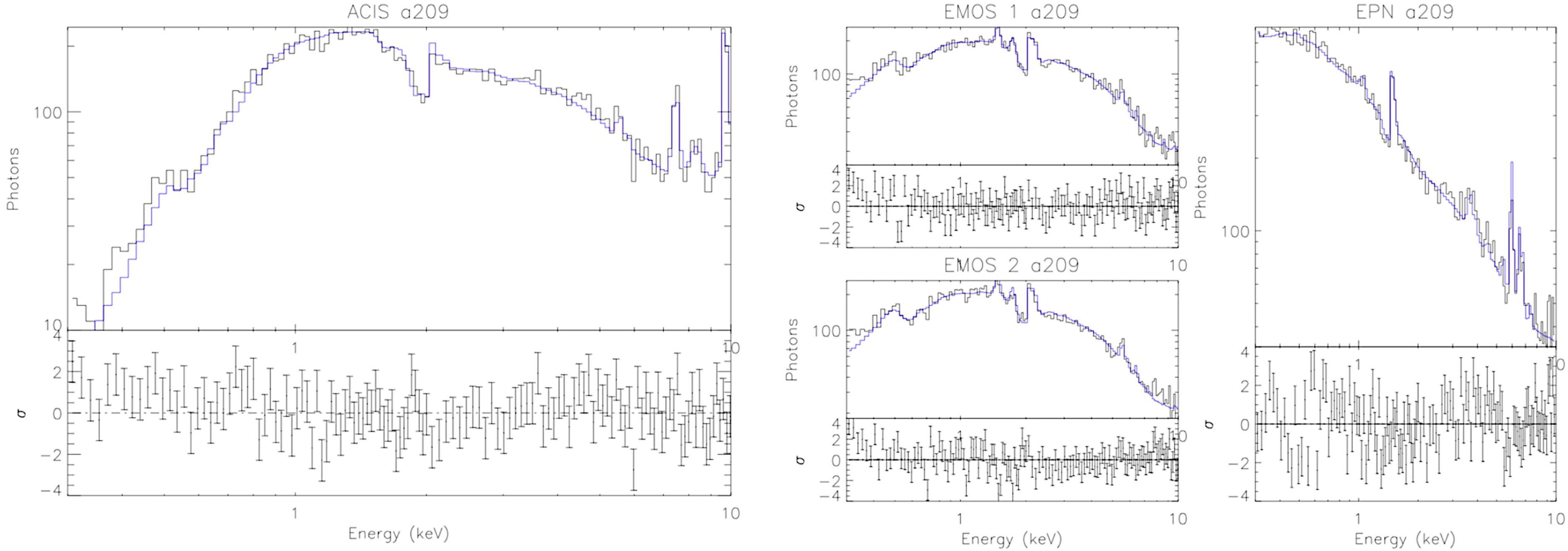
We compare the best fit spectrum from Chandra using XMM
We obtain three different cases:
a) We see a good agreement between ACIS and EPIC



Martino et al. 2014

Chandra and XMM comparison

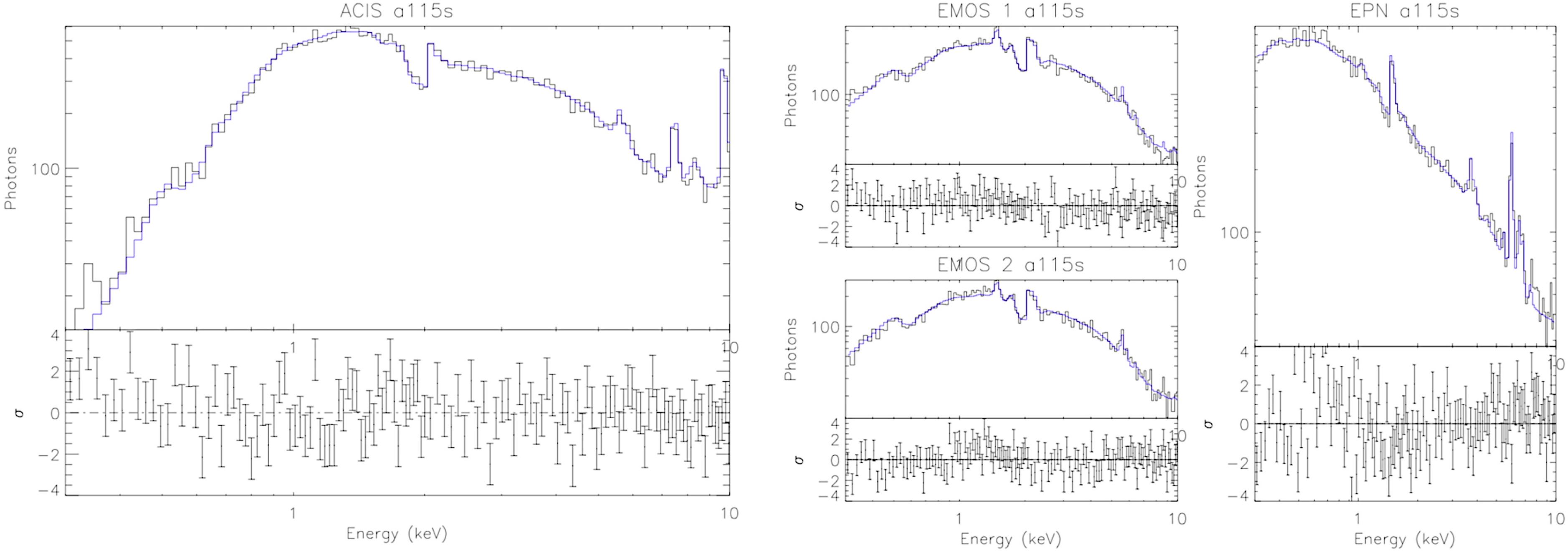
We compare the best fit spectrum from Chandra using XMM
We obtain three different cases:
b) good agreement between ACIS and two EPIC camera



Martino et al. 2014

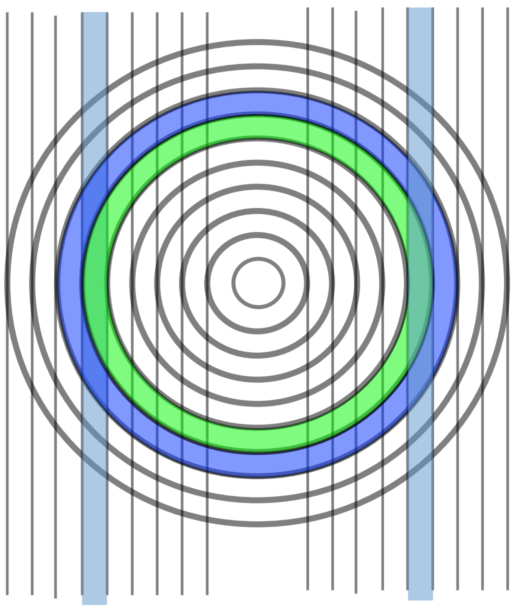
Chandra and XMM comparison

We compare the best fit spectrum from Chandra using XMM
We obtain three different cases:
c) bad agreement between ACIS and EPIC



Martino et al. 2014

Deprojection technique

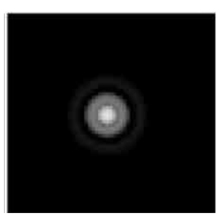


To get gas density profiles we fit a parametric model, projected and convolved with the PSF to the surface brightness

$$n_p n_e(r) \equiv \frac{n_0^2 (r/r_c)^{-\alpha}}{[1+(\frac{r}{r_c})^2]^{3\beta-\alpha/2}} + \frac{n_{02}^2}{[1+(\frac{r}{r_{c2}})^2]^{3\beta_2}}$$

Vikhlinin et al 2006
Ettori & Balestra 2009

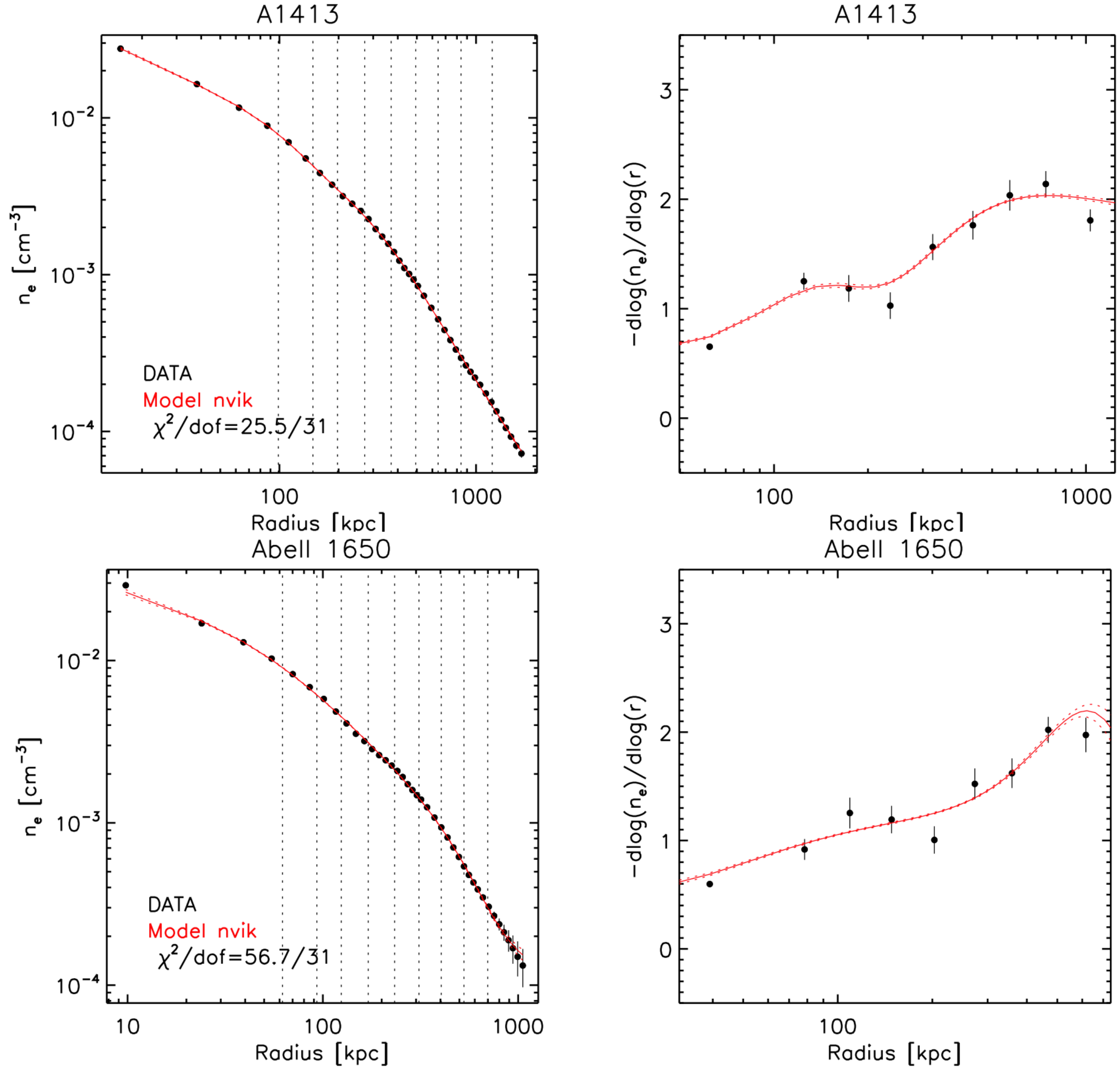
Projection



PSF

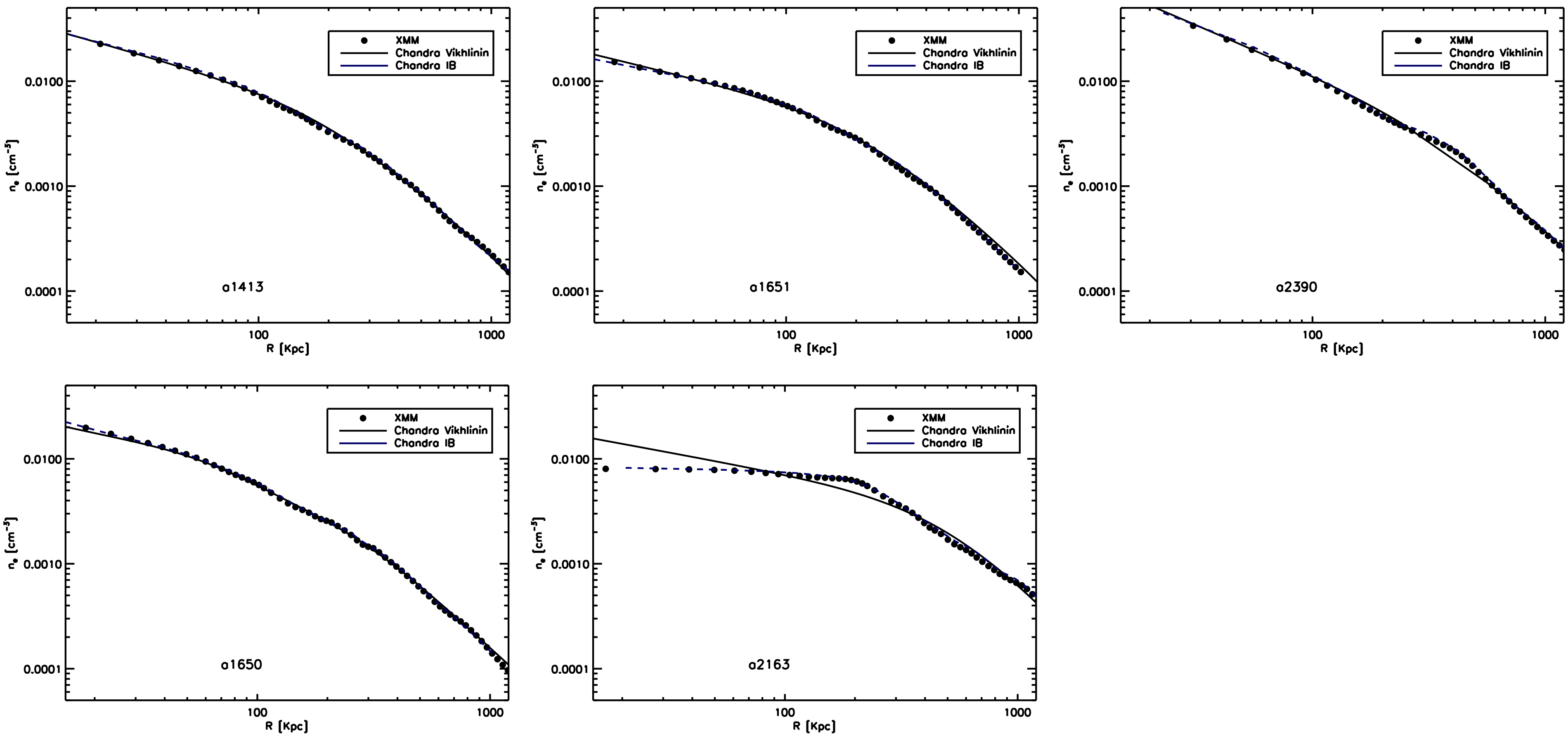
In our case we want to invert Chandra surface brightness profiles to get directly the gas density.
Similarly to the XMM procedure described in, e.g., Democles et al 2014

Result so far:density



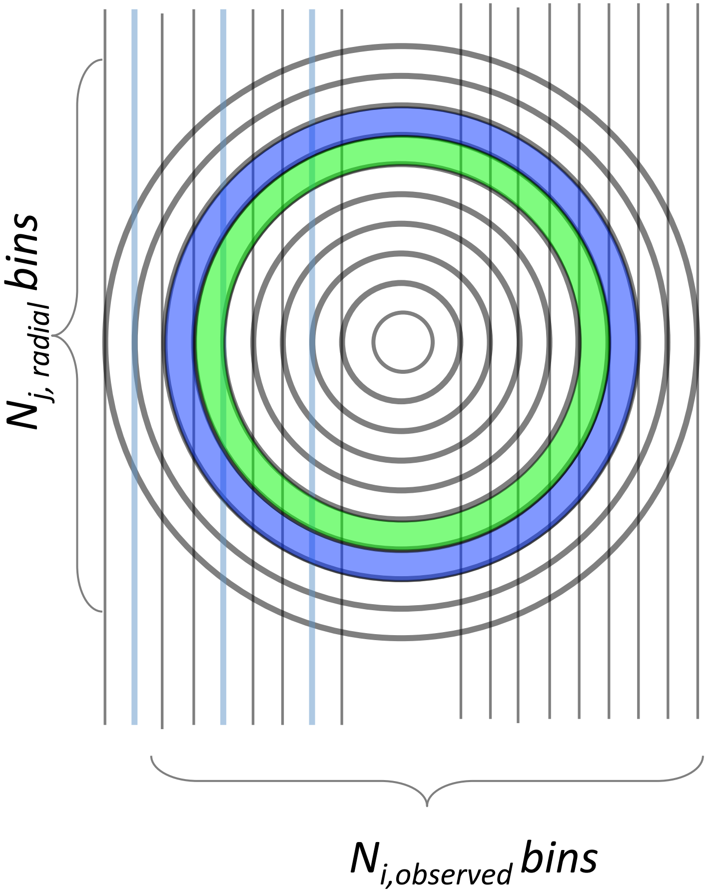
<u>Caveat</u>:
The derivative of the density is computed in the temperature profile bins

Results so far:density



Still working on...

For the temperature we can not do the same thing



Credit: Monique Arnaud
Journée IRFU Energie Noire

The observed emission is due to the superimposition of different radius at different temperatures

$$S_i = \sum_j em(j,i) T_j$$

Not linear!

We need to be accurate with calibration corrections!

Thank you!