Future prospects for the detection and characterization of non-thermal emission in galaxy clusters

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Overview

- Critical assessment of the observational evidence gathered over the last decade
- Overview of future missions which will provide advancement in this field
- A few examples of expected measurements with Simbol-X
- General remarks on future studies of non-thermal emission

Non-Thermal processes

- Bulk of the emission is thermal, non-thermal mecahnisms are potentially very important, provide clues on the physical process presiding over the formation and evolution of clusters.

- In some objects, evidence of non-thermal processes has been known for quite some time. Radio observations indicate that merging clusters are often the site of cluster-wide synchrotron emission (radio haloes & relics).

B field

- B fields can be estimated through radio measurements (Faraday rotation, minimum energy)
- Alternativelly from combination of radio and X-ray measurements.
- The latter rely on the detection of non-thermal emission at X-ray wavelengths (hard tails) attributed to IC scattering of microwave background photons by relativistic electrons.
- If the emission is not detected the upper limit on the X-ray flux converts to a lower limit on the B field

Measurements

Object	BeppoSAX 10^{-12} erg cm^{-2}s^{-1} 20-80 keV band	RXTE 10^{-12} erg cm^{-2}s^{-1} 20-80 keV band
Coma	15±5	21±6
A2163	---	11^{+17}_{-9}
A2256	$8.9^{+4.0}_{-3.6}$	4.6±2.4
A2319	<23	14±3
A3667	<6.4	<4.0
A754	~2.0	---

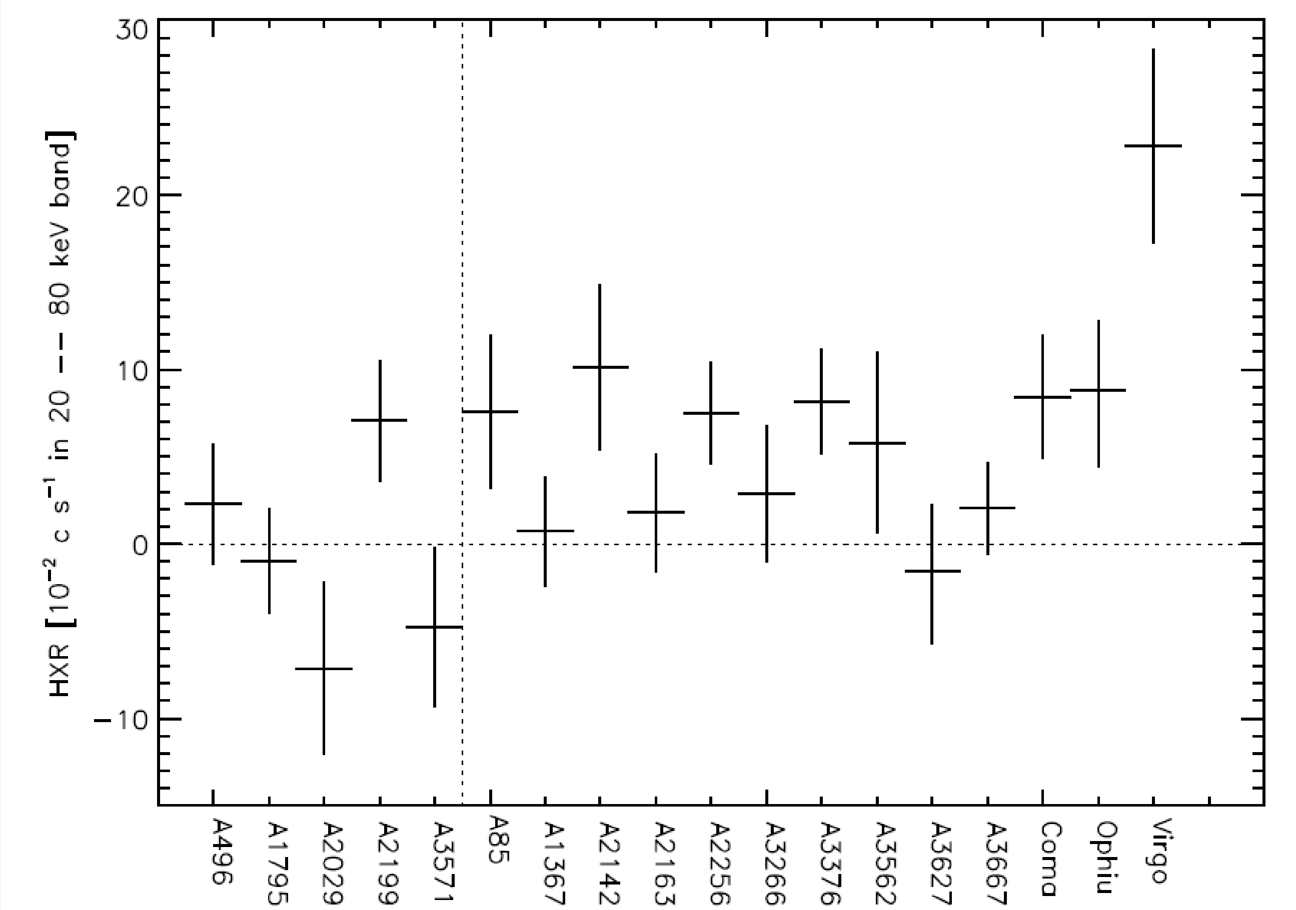
uncertainties are 90% confidence

Fusco-Femiano+

Rephaeli & Gruber

Measurements

BeppoSAX Sample (Nevalainen+04)



"Detection at 2 sigma level for 50% of the objects"

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Strongest hard tail detection on Coma

Rossetti+SM 04,07 challenged BeppoSAX result

Rossetti+SM find upper limit of~8x10^{-12}erg cm^{-2}s^{-1}

Coma with Integral

No hard tail detected, UL consistent with BSAX and RXTE detections and of-course BSAX UL (Lutovinov+08,Eckart+06).

- In 2001 before INTEGRAL's launch Goldoni+ claimed "IBIS is fully able to detect and separate the two components of the emission."
- The sensitivity reached by INTEGRAL/IBIS is not as good as the expected one.

Coma with Integral

Solid estimate of the background is important when trying to assess the capabilities of future missions

- In 2001 before INTEGRAL's launch Goldoni+ claimed "IBIS is fully able to detect and separate the two components of the emission."
- The sensitivity reached by INTEGRAL/IBIS is not as good as the expected one.

Suzaku

A3376 upper limit (Kawano+08)

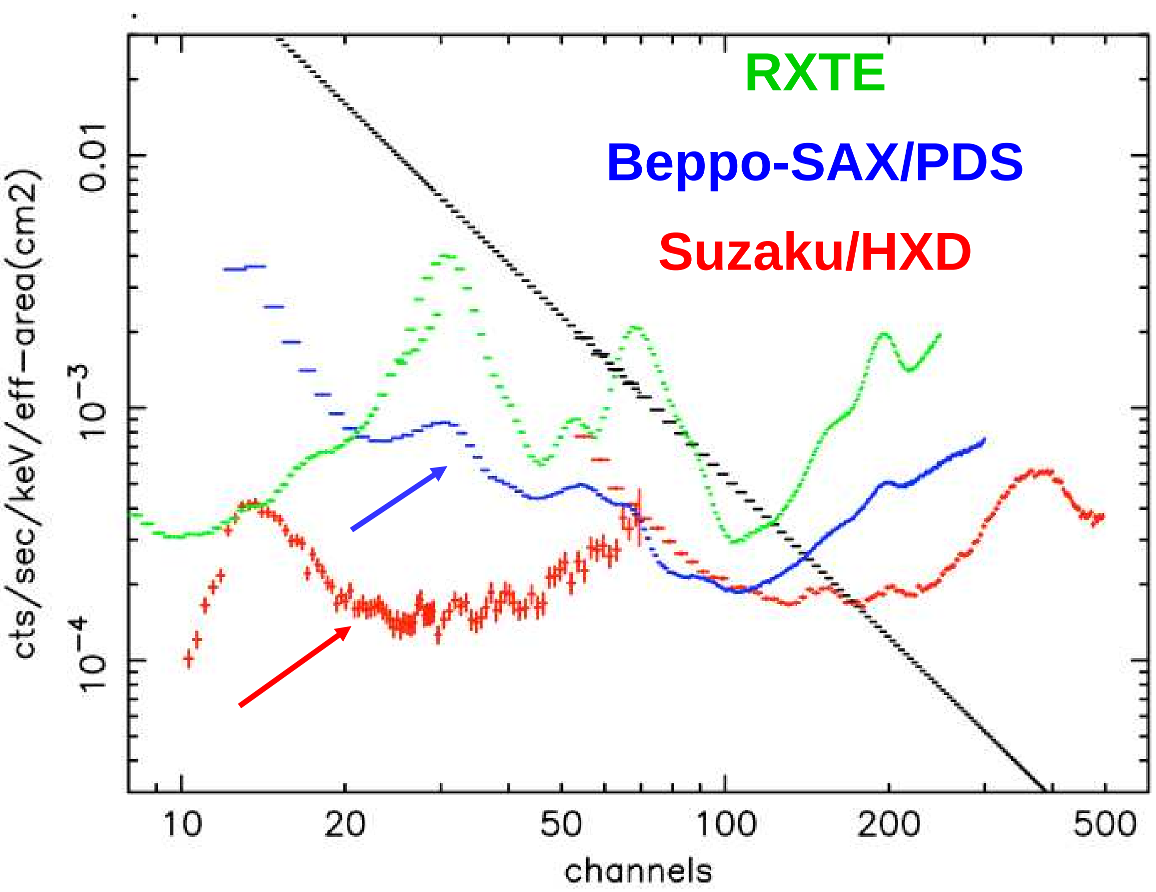
A3667 upper limit (Sarazin)

Coma upper limit (Sarazin) consistent with BSAX UL

Suzaku

Suzaku/HXD sensitivity comparable to Beppo-SAX/PDS altough the bkg/EffArea ratio is 4-5 times smaller?

PDS twin rocking collimators allowed a simultaneous measure of source and bkg.
HXD relies on a background model based on bkg measures which are not simultaneous with sou measures.



Suzaku

Keeping your background low is important.
Knowing to a high precision the intensity and shape of your background is also very important.

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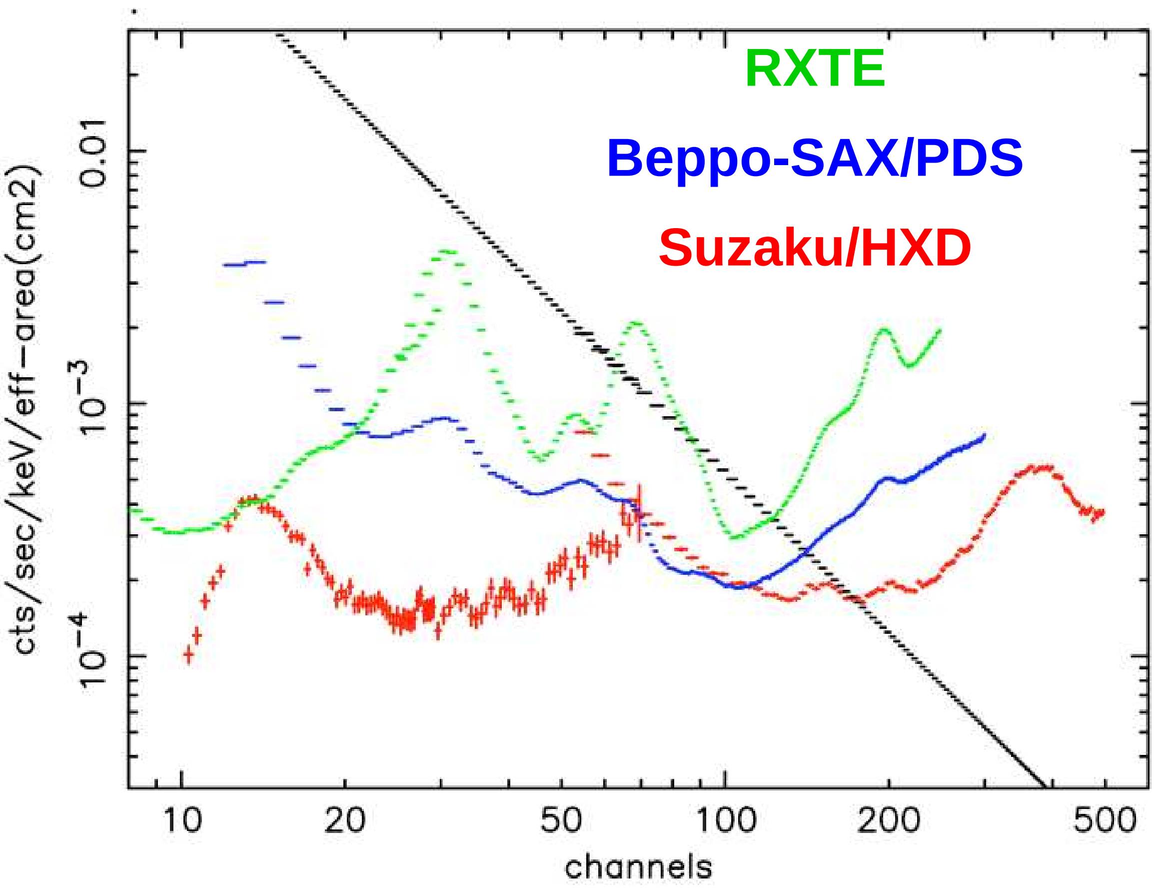


BAT/Swift

Ajello+

"Using XMM, Swift/XRT and BAT data, we are able to put limits on the Inverse Compton emission mechanisms which are in disagreement with most of the previously claimed detection of non-thermal components"

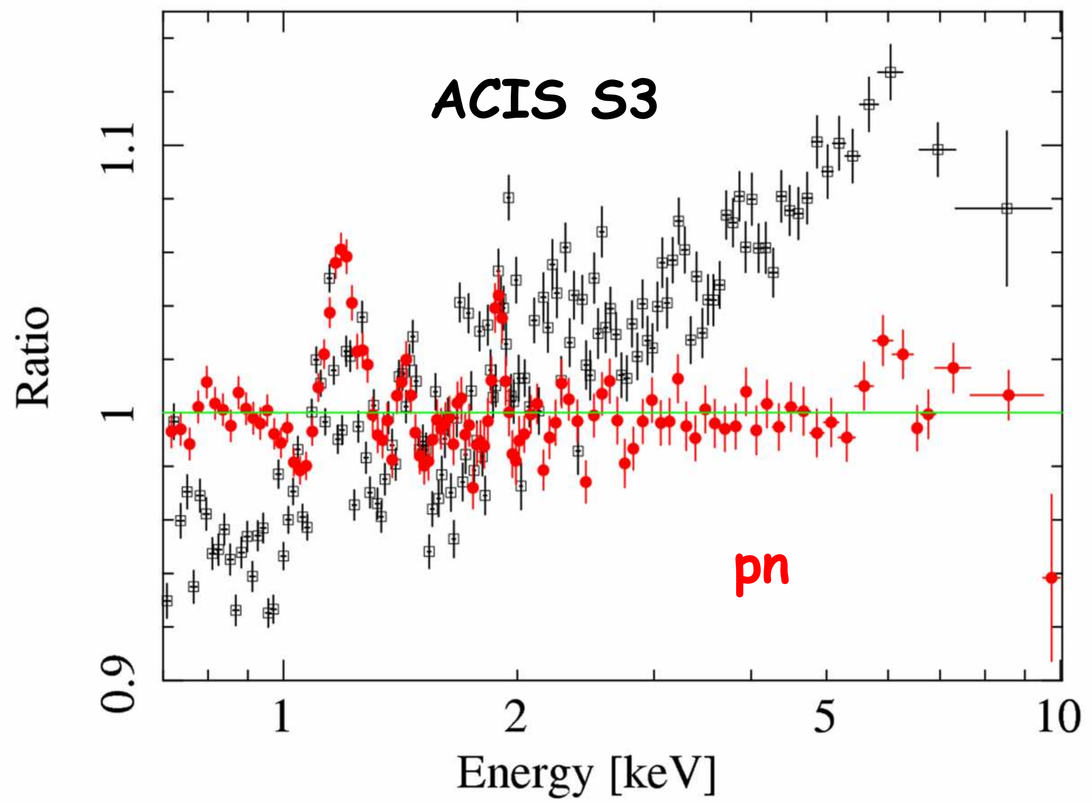
Chandra & XMM-Newton

- Perseus hosts a mini radio halo
- Detection of non-thermal emission from Chandra data (Sanders & Fabian 05,07).
- Analysis of EPIC data using new calibrations and detailed treatment of bkg and systematics finds no evidence of non-thermal emission (SM & Gastaldello sub.)

Perseus

The difference btwn Chandra and EPIC measures is due to a cross calibration issue between EPIC and ACIS

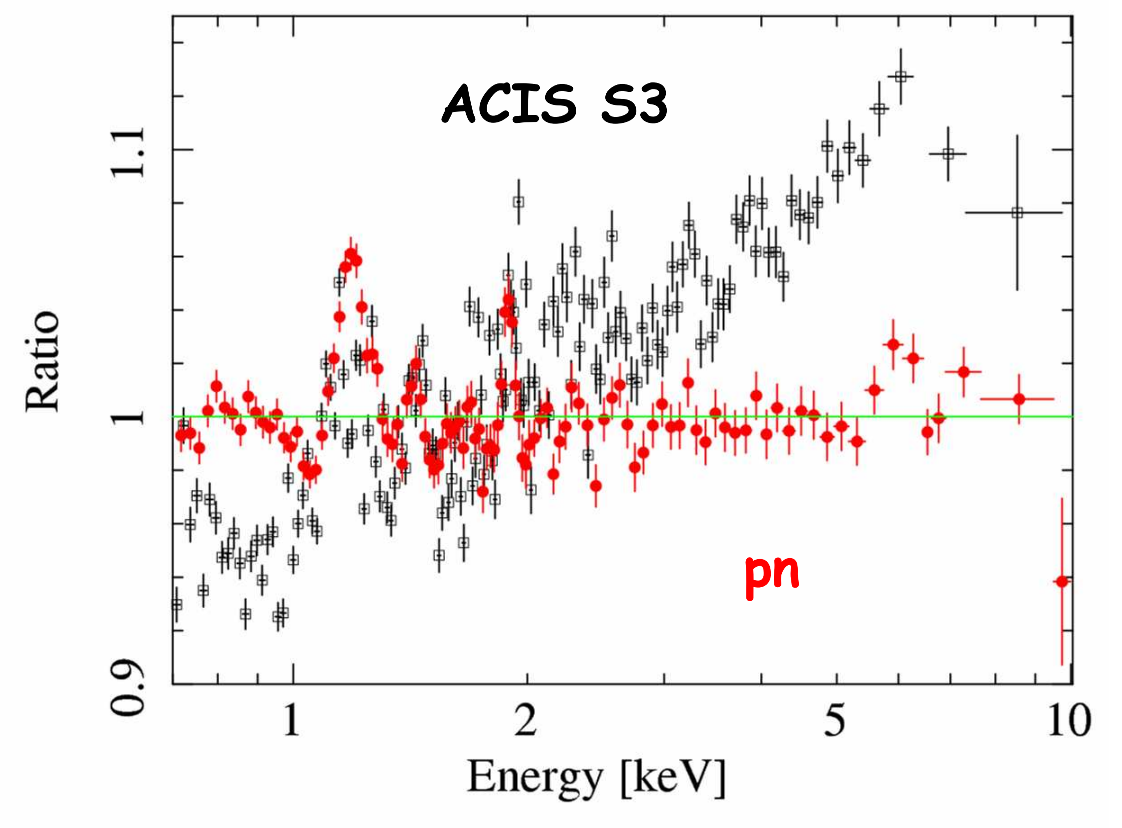
Caused by a problem in the calibration of the Chandra high energy effective areas recently identified by Chandra calibrators (David+07)



Perseus

A high quality calibration of the instrumentation is very important

Caused by a problem in the calibration of the Chandra high energy effective areas recently identified by Chandra calibrators (David+07)



Detections vs UL

Non-thermal emission results are "controversial"

The way forward

Best experiement to study diffuse hard X-ray emission would of-course be a Wide Field Hard X-ray Imager.

Unfortunatelly the construction of such an experiement is beyond current technological capabilites. We have to fall back on telscopes affording smaller FOV.

Hard X-ray focusing mission for 2012-2015

	HPD	FOV FWHM	Foc Length m	Aeff cm2@30keV
NuStar	40"	15'	10	300
NeXT	30"	12'	12	300
Simbol-X	20"	12'	20	300

Major limitation is FOV

Requirements

NeXT, NEW and Simbol-X similar properties in principle should have similar sensitivities

Not necessarily true

- Background intensity
- Background characterization
- Instrument calibration

↓

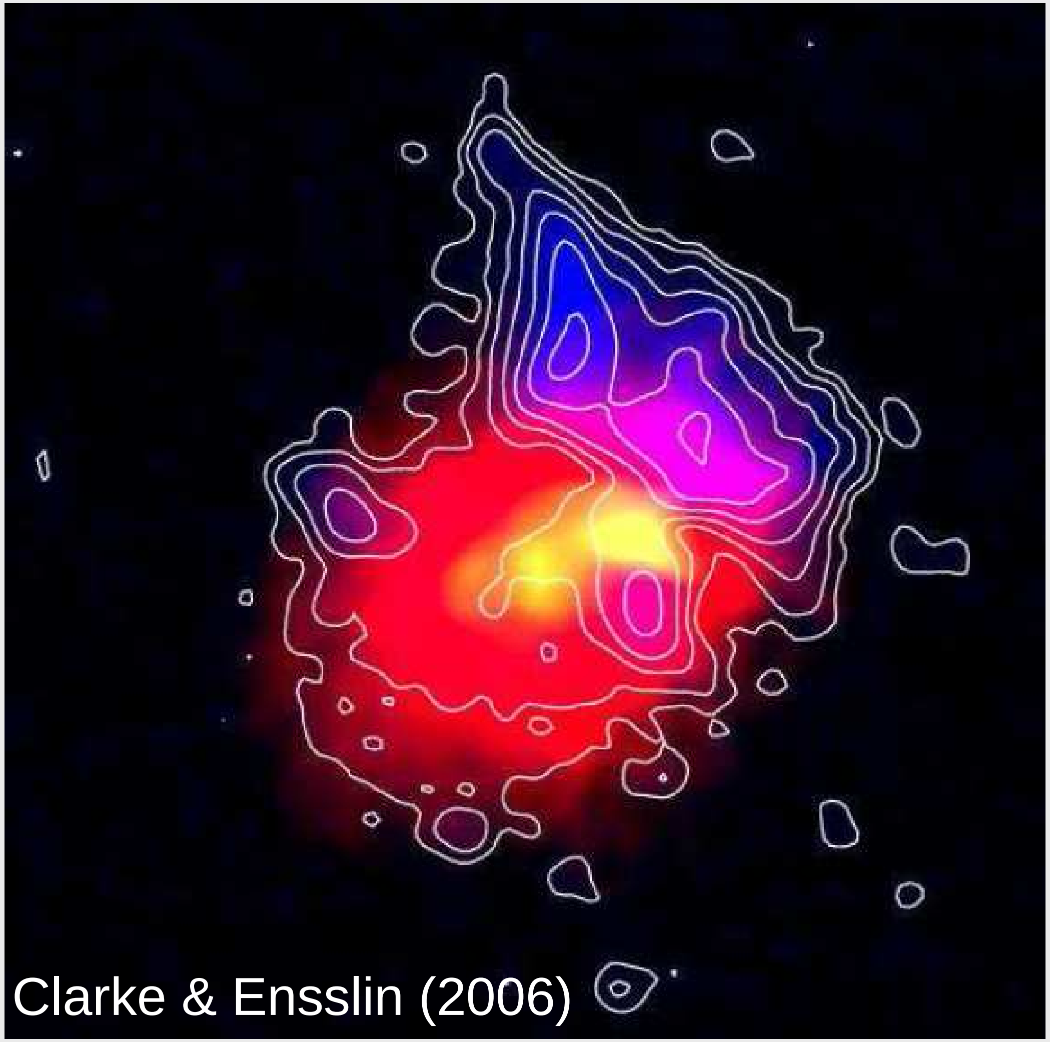
Understand and control systematic errors

An example A2256

- z = 0.058
- Radio halo + relic

  substatial sub-structure
- Major merger
- B field ~ 3-9 μG from

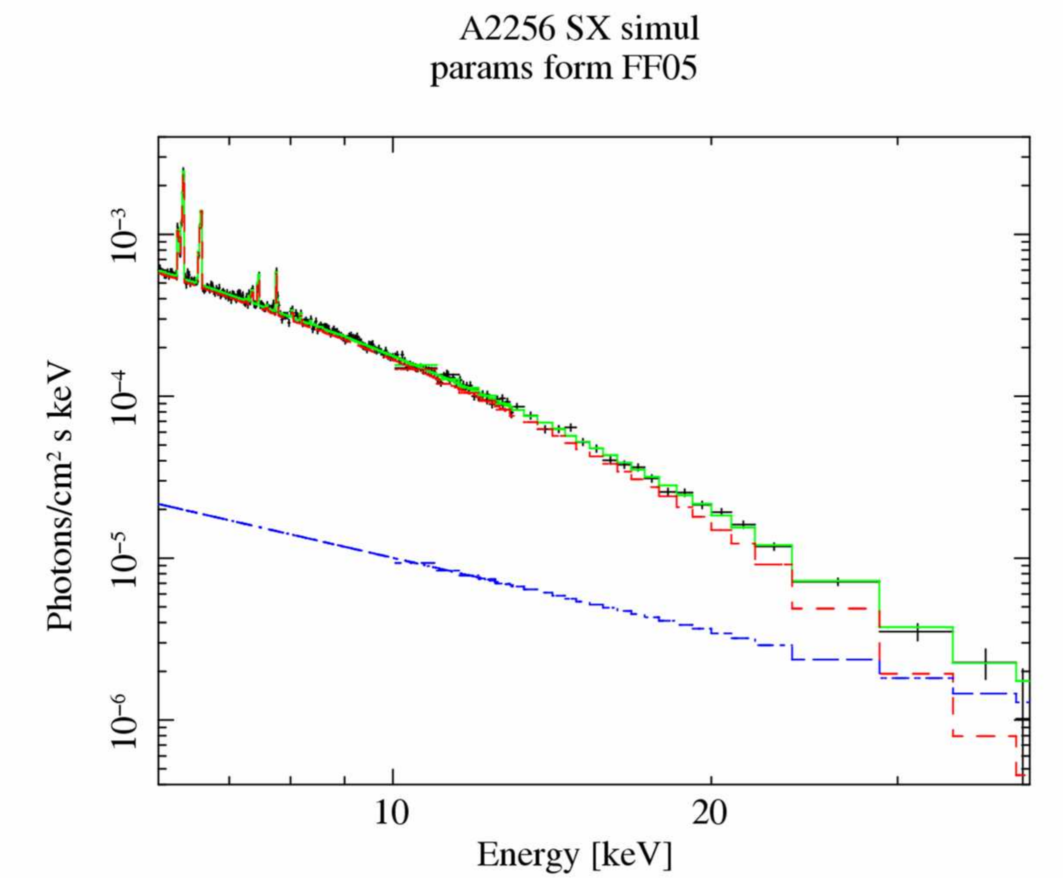
  equipartition arguments



An example A2256

- Simulation carried out assuming hard tail flux from Fusco-Femiano+05 and constat SB over radio halo and relic
- Conservative approach, if NT emission shows substantial variation it will be easier to detect

1. If BSAX and RXTE measures correct highly significant detection expected
2. The above is true only if bkg is within factor of 2 of expectations and systematic uncertainies are within 5%



A2256

If BSAX IC detection is real:

detection and possibly spatial/spectral characterization

If not:

tighter upper limit, detection maybe if emission is concentrated

Similar results apply to A3667 and Perseus

Summary

- Detection of non-thermal emission in clusters is highly controversial.
- If detections are real first generation of hard X-ray telescopes should be able to confirm them beyond doubt and provide some spatial/spectral characterization.
- If not than the likely outcome will either be more stringent upper limits on X-flux and lower limits on B field or possibly detections.