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Non-thermal emission and very hot component in clusters of galaxies

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Collaborators

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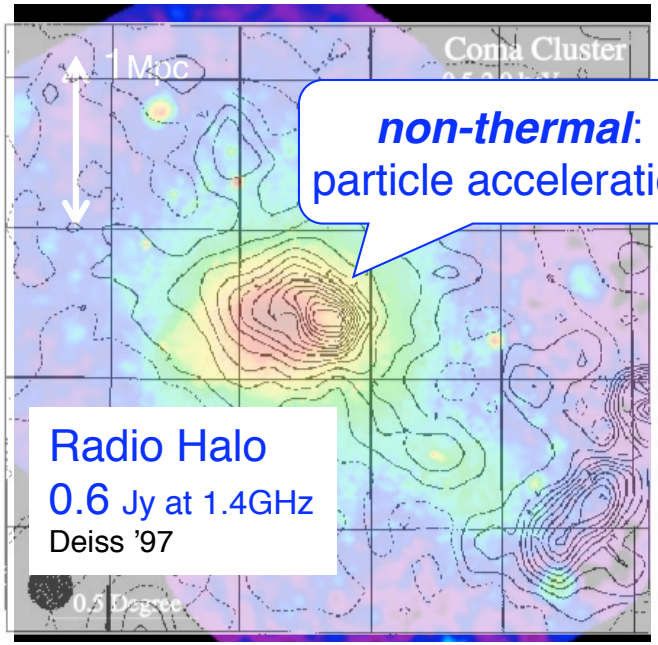
Motokazu Takizawa (Yamagata Univ.) – A3667, A2319

and the Suzaku-team

Energetic Merger of Clusters of Galaxies

Cluster merging = Frequent and ***Major*** energy release in the history of the universe

Coma cluster



non-thermal: particle acceleration

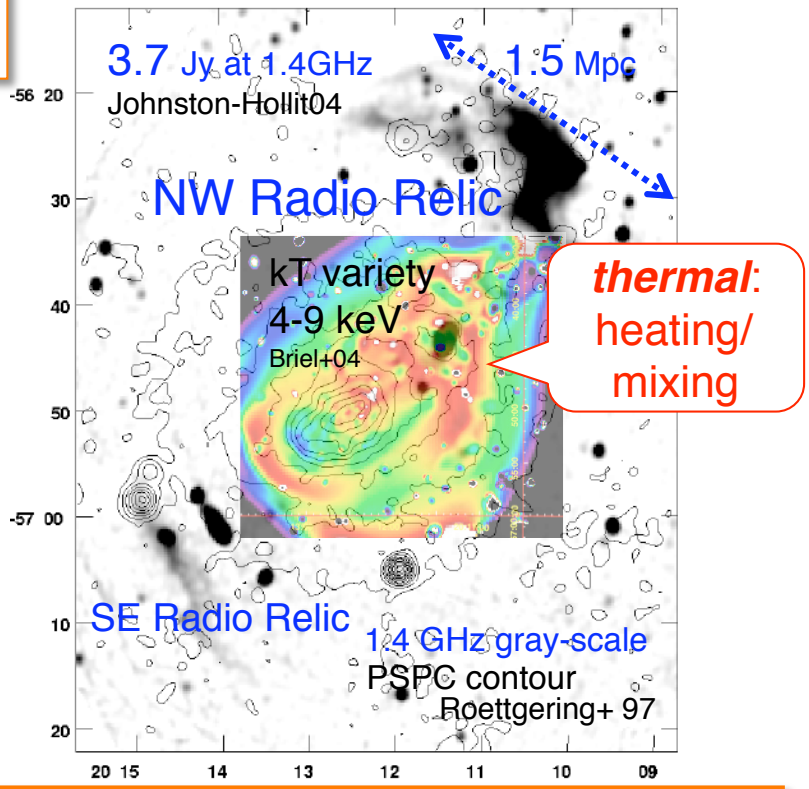
Radio Halo
0.6 Jy at 1.4GHz
Deiss '97

Coma cluster PSPC-image (Snowden)

Coma-C 1.4 GHz contour (Deiss '97)

Energy input up to 10^{64} erg

Abell 3667



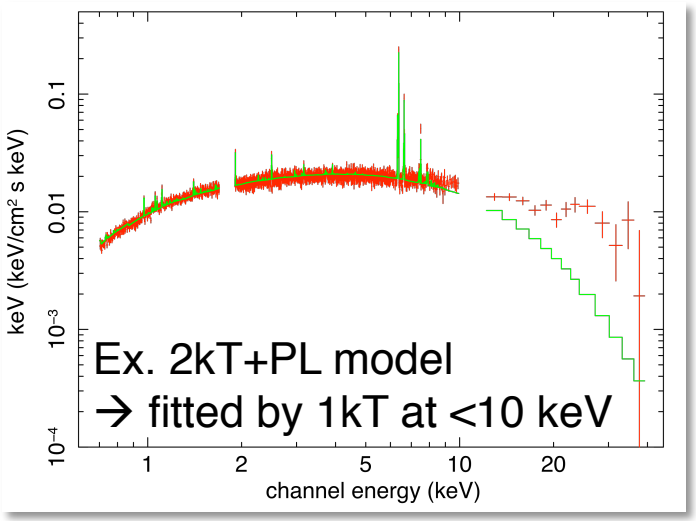
thermal: heating/ mixing

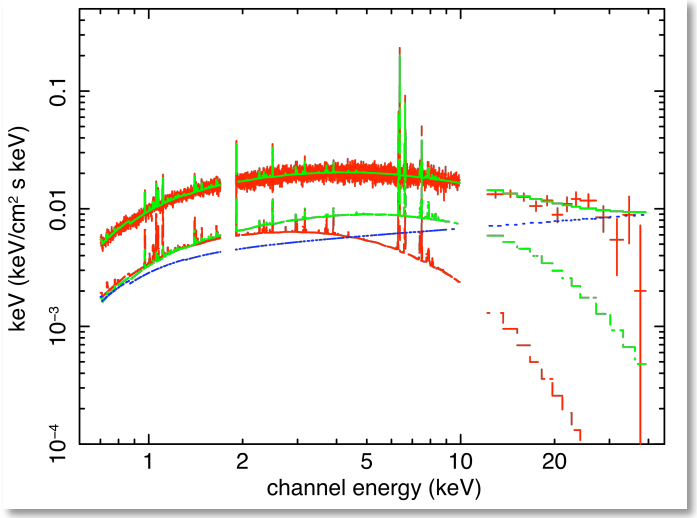
Merging cluster study
-physics of energy release
-roles of non-equilibrium phases (kinetic, NT, B)
→ cluster formation, mass-est. etc…

Resolve spectral components

-IC from Hi-E-electrons (PL-like) =
Magnetic field *B* (w/ radio obs.) + Non-thermal pressure?
-Hottest component = Merger velocity / phase / geom.

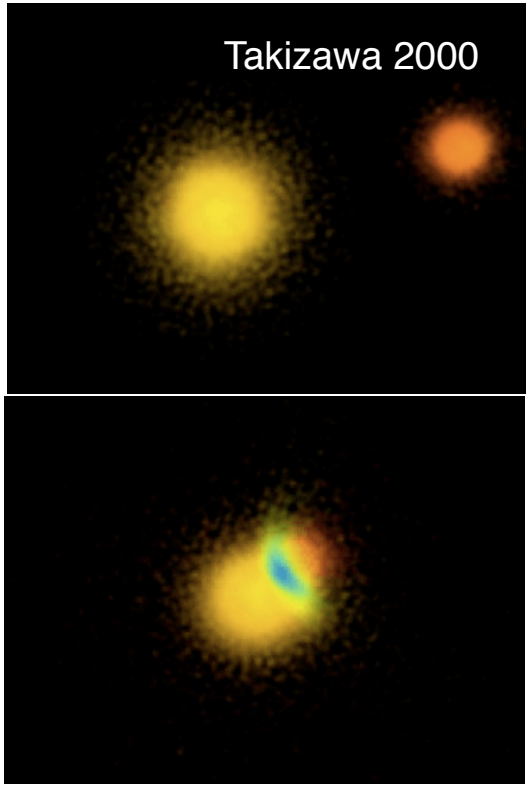
e.g. Randall&Sarazin 2002





How can we distinguish spatially overlapping components ?

"wide-band observation"



Today's talk

Observational aspects of cluster wide-band spectra

1: Hard X-ray survey of Coma cluster
Beppo-SAX/PDS and **Suzaku,** INTEGRAL and Swift/BAT

2: **Suzaku**/XMM survey of Abell 3667
-IC upper limit and strong (> 2 μG) magnetic field
-detection of "very hot (>~ 13 keV) component"

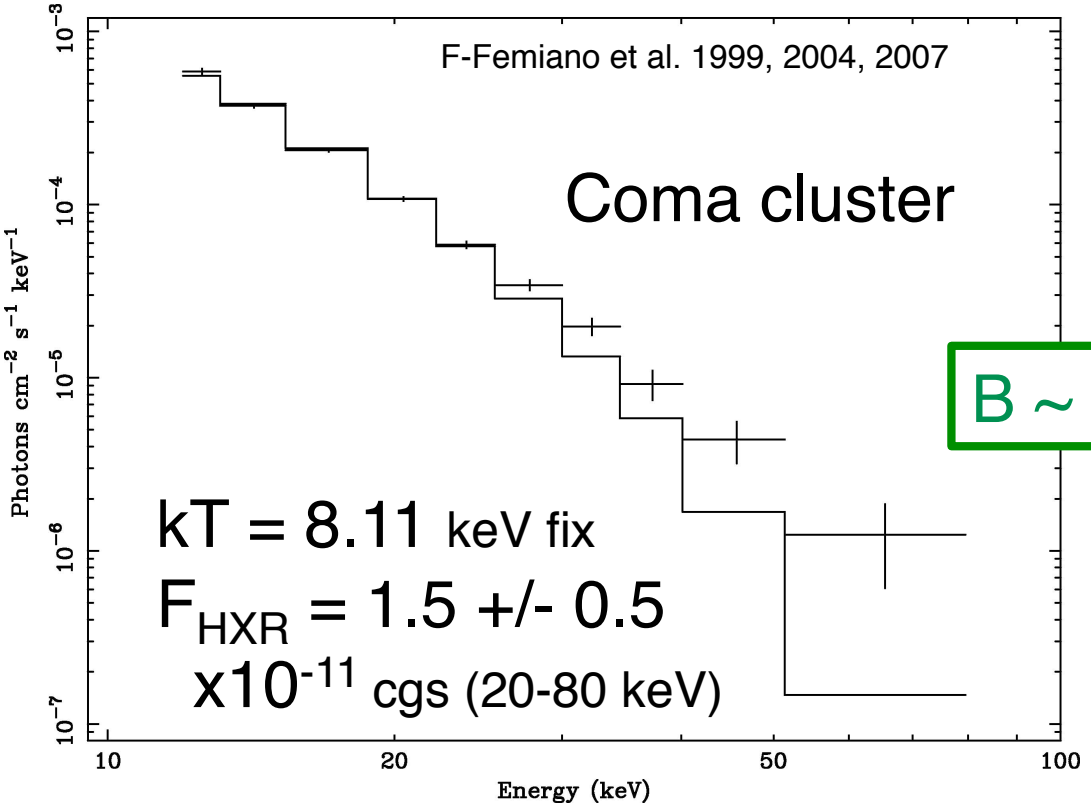
3: Prospects for near future observatories
-**ASTRO-H** (and NuSTAR)

4: Conclusion

1: Search for IC emission from Coma

Beppo-SAX
PDS spectra

hard X-rays



B ~ 0.1 μG

+RXTE

-Claim for detection of IC emission from Coma, A2256,+

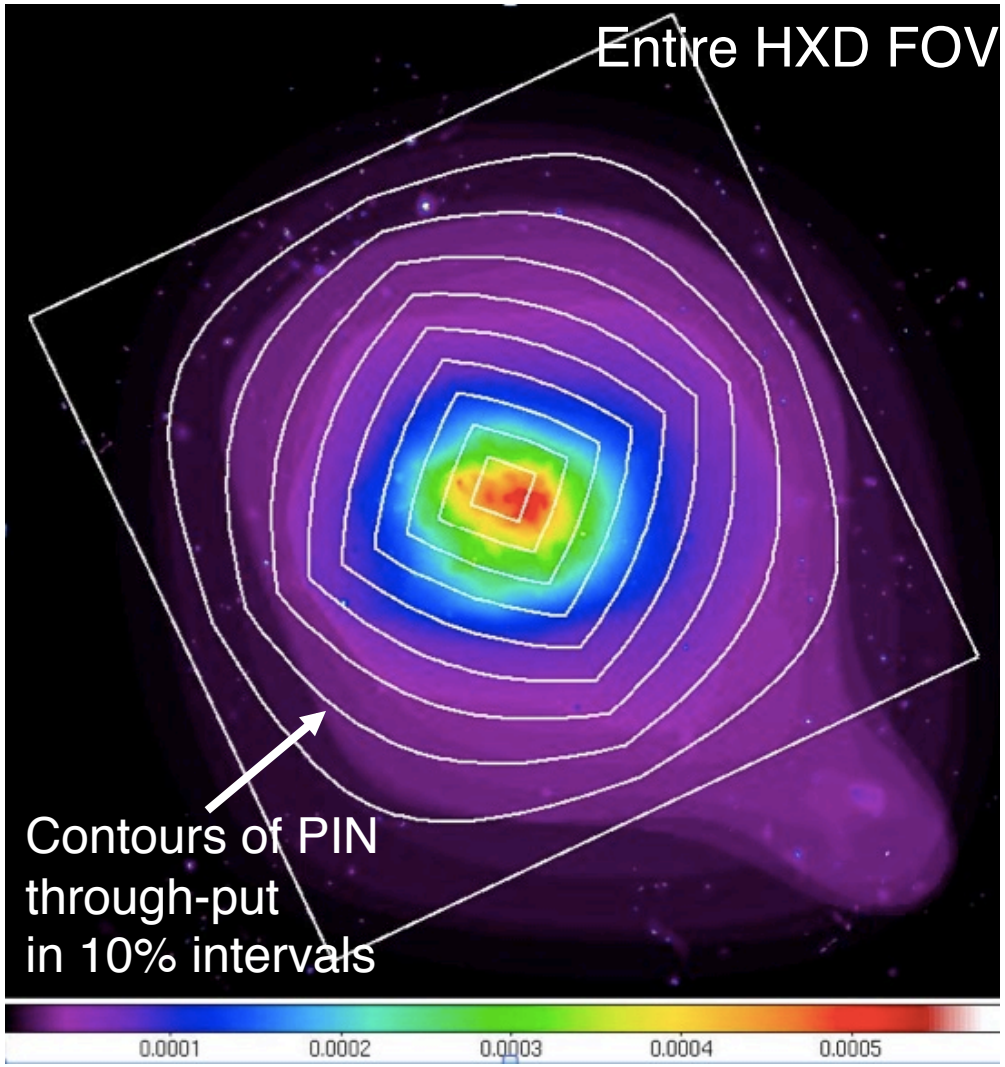
also Rephaeli+ 1999, F-Femiano+ 2000, Nevalainen+01 etc.

-limited significance, and sometimes debated i.e. Rosetti+ 2004

independent confirmation needed

Suzaku+XMM observation of Coma cluster

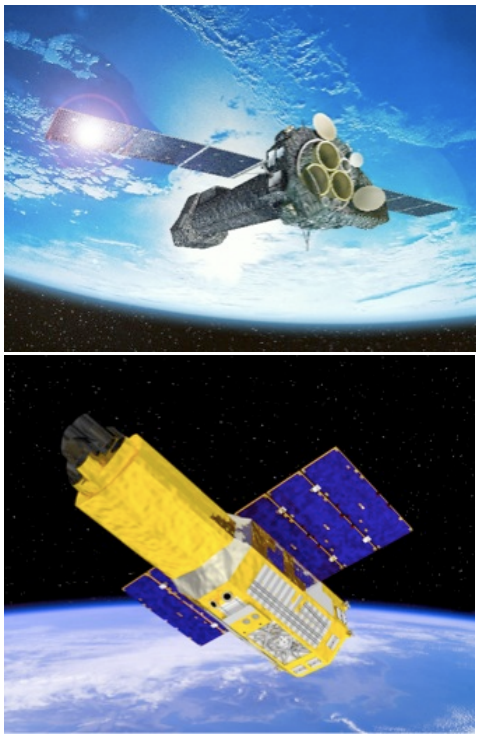
Obs. 2006/May



XMM 2-7.5 keV image, Schuecker et al. 2004

Wik+ 2009

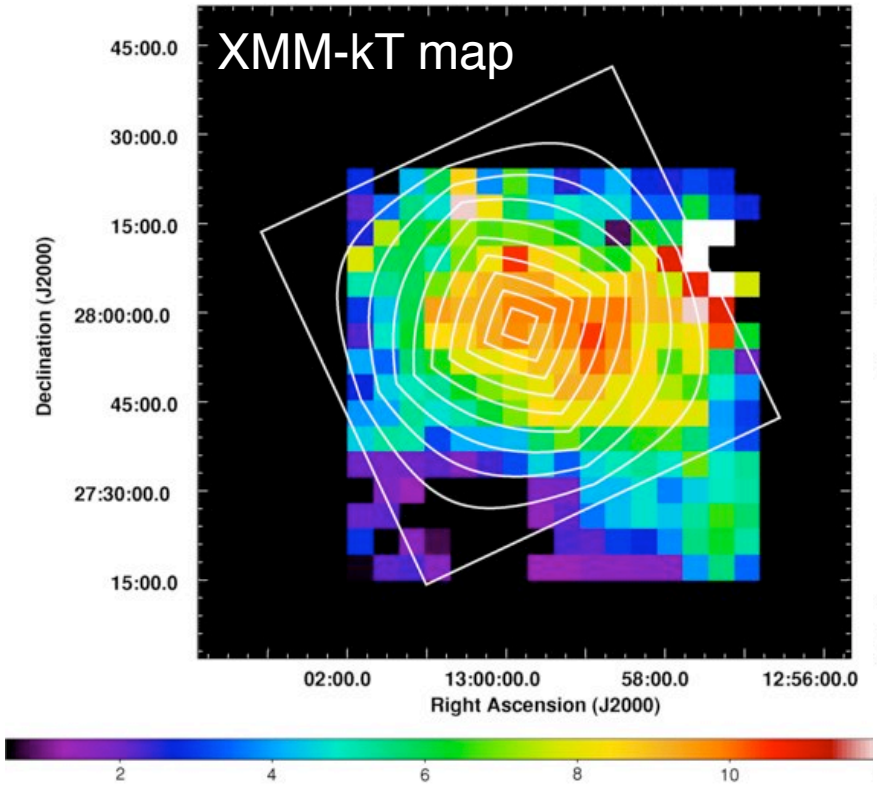
Combined fit using
"PIN-scaled" XMM
+
PIN spectra

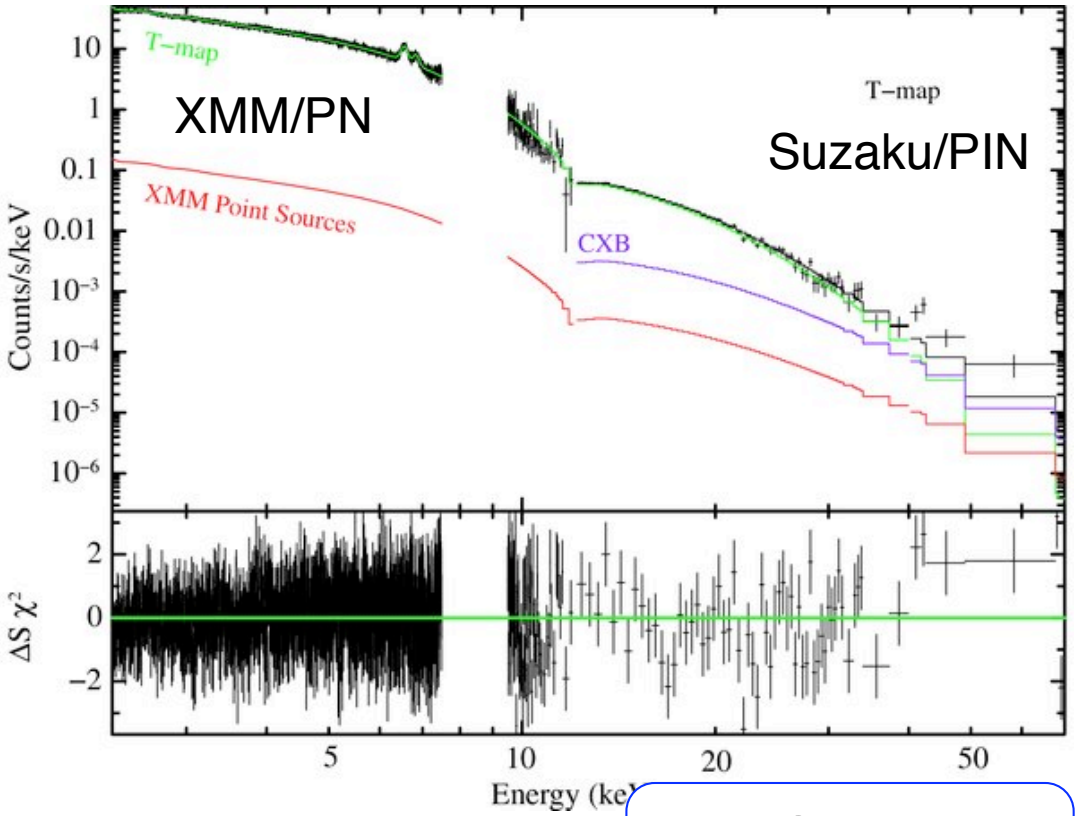


Suzaku+XMM observation of Coma cluster

Wik+ 2009

Multi-temperature + PL fit





requires no IC component

$F_{PL}(\Gamma=2.0) < 0.61$
$\times 10^{-11}$ cgs (20-80 keV)

kT = 8.5 +/- 0.1 keV

Inconsistent?

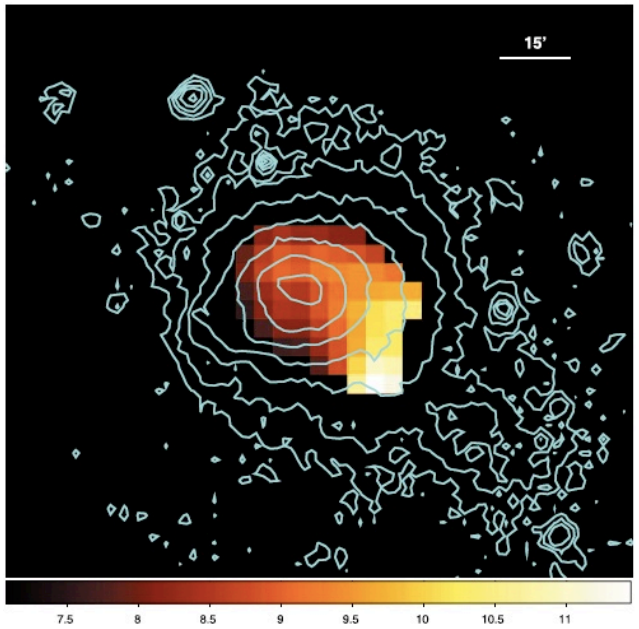
SAX/PDS
F_{PL} = 1.9 +/- 0.6
$\times 10^{-11}$ cgs (20-80 keV)
kT = 8.1 keV

0.79 Crab HXD
= “1” Crab PDS

INTEGRAL and Swift/BAT

INTEGRAL (beam = 12')

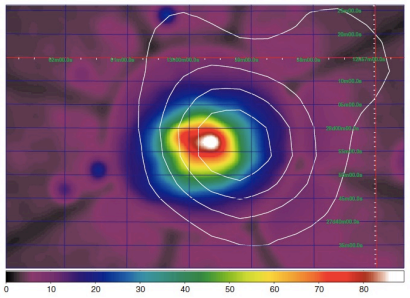
Lutovinov+ 2009

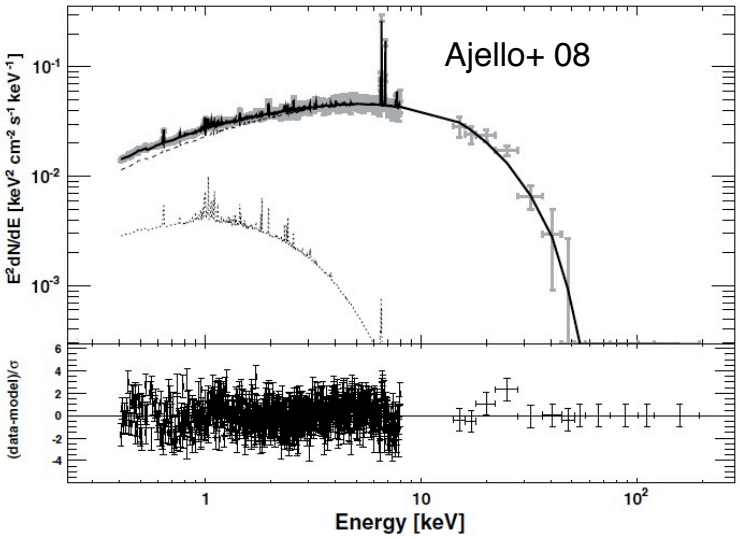


Also Renaud+ 07, Eckert+ 2007

-no point-source for the "HXR"
-hot (~11 keV) region to the sw
-PL < 1.5×10^{-11} cgs (20-80 keV)

BAT (beam = 22' / 10' in ana)





-2kT = 1.45 + 8.4 keV
-shift to the west
-PL < 0.34×10^{-11} cgs (20-80 keV)

requires no IC component

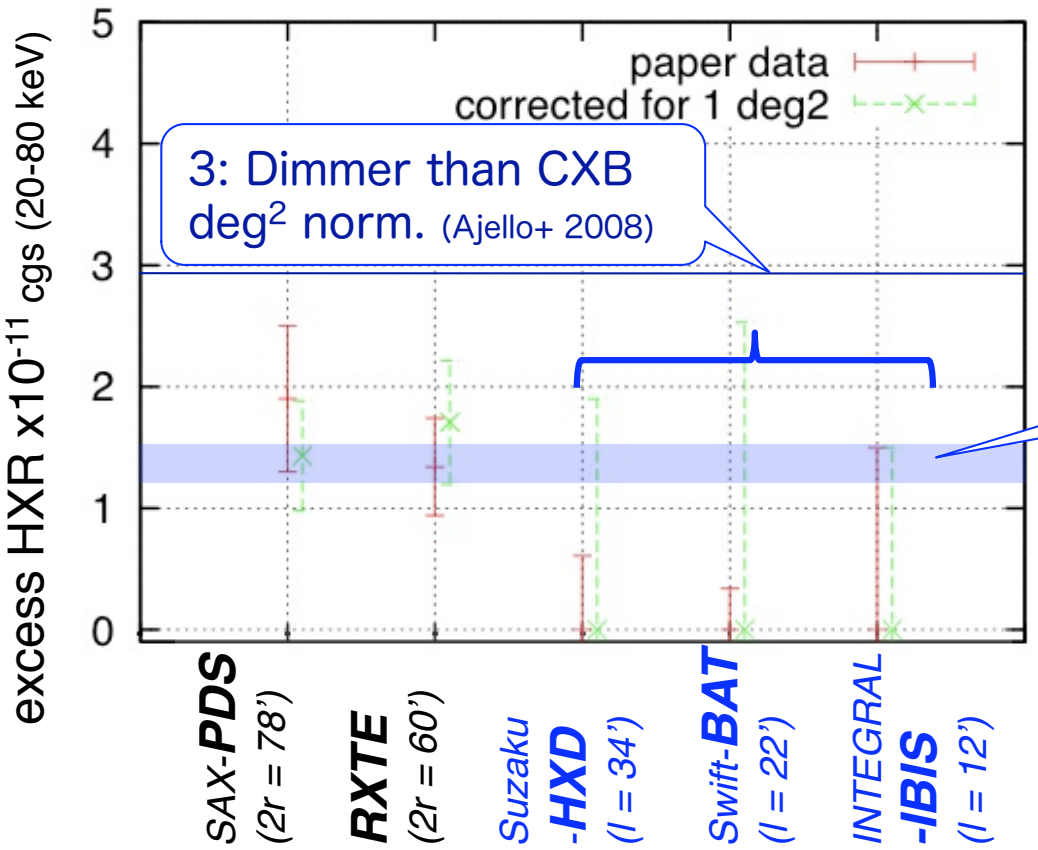
Inconsistent?

but still ..

PDS, Suzaku+XMM, IBIS and BAT

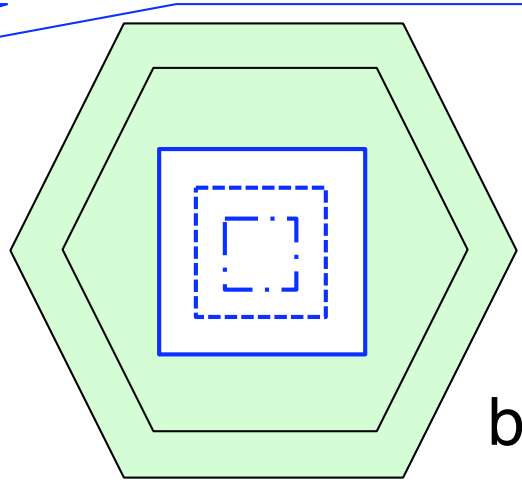
Note: Detectors are optimized for a source sized to their beam-size

e.g. Brunetti & Blasi 2005



1: New results = Upper limits only

2: consistent region, assuming "flat" emission

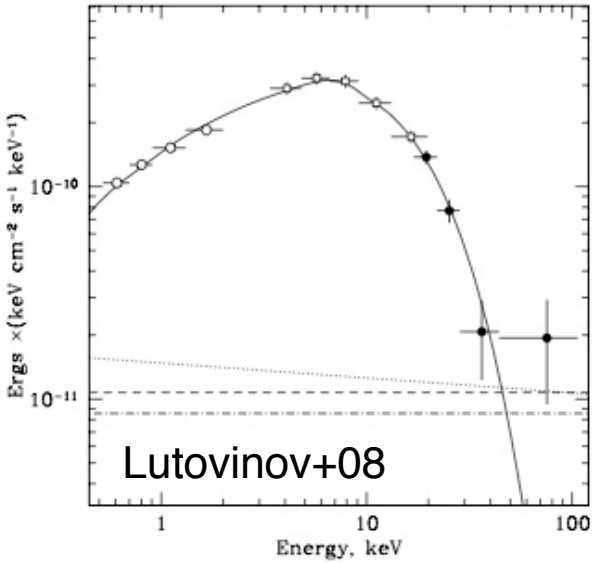


beam-size

PDS result not confirmed, *but* still consistent *if* widely distributed + carefully handle thermal component

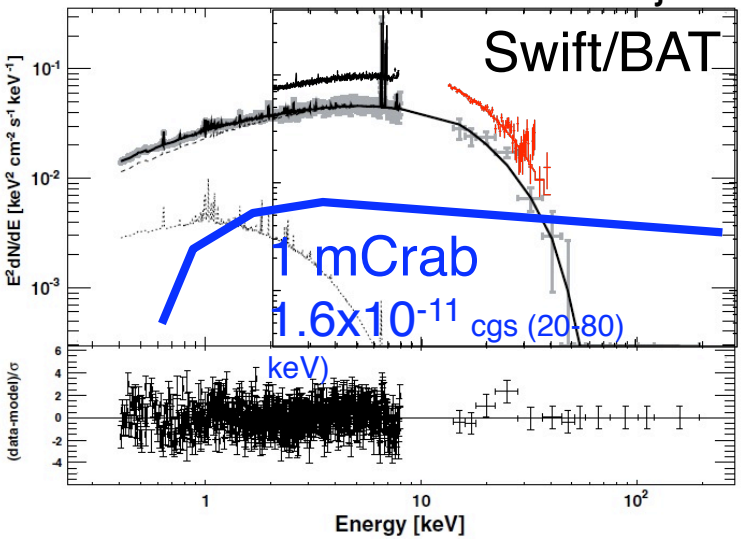
Comparison of IBIS, BAT and Suzaku

INTEGRAL



BAT and Suzaku

Ajello+08



Beam

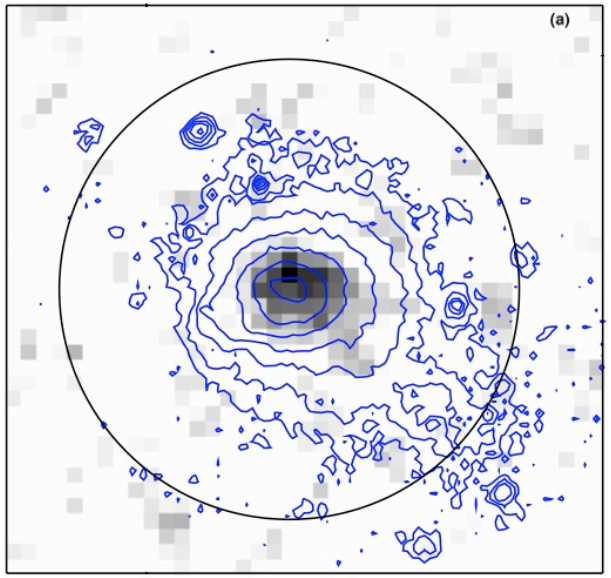
PDS *(2r = 78')*

RXTE *(2r = 60')*

HXD *(I = 34')*

BAT *(I = 22')*

IBIS *(I = 12')*



Personal impression summary

-PDS (HEXTE): wide-FOV, good sens for ext. em.

-IBIS: 12' resolution

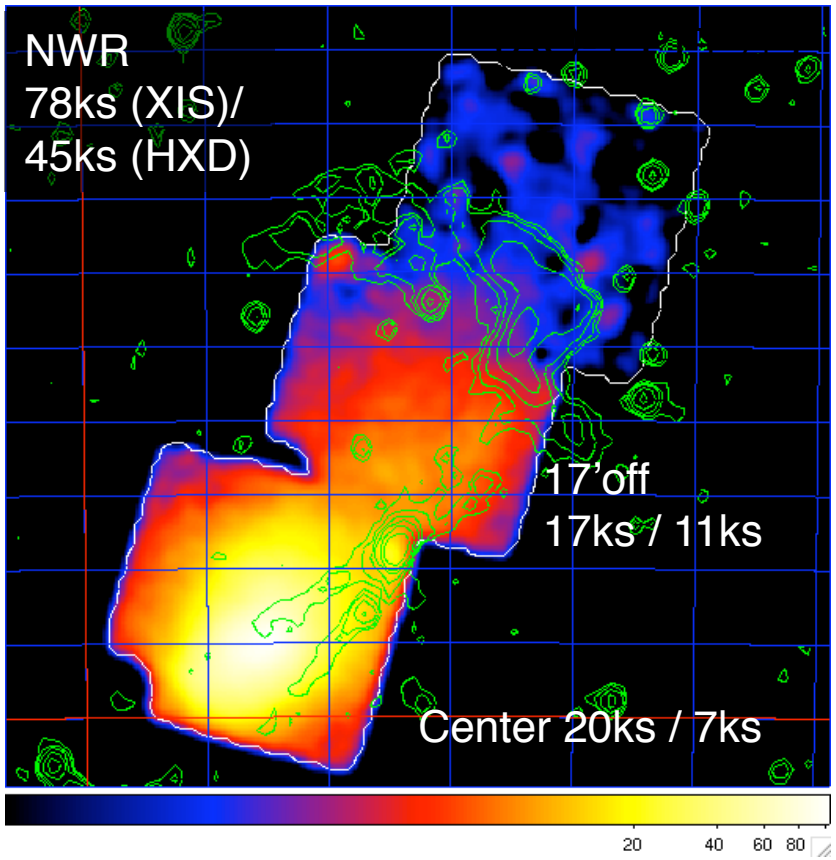
-BAT: good at ~100 keV = at PL

-Suzaku/PIN: good at ~ 30 keV, high-sig. spectra

good at thermal diagnostics

2: Suzaku+XMM survey of A3667

XIS 1-8 keV mosaic image



$kT \sim 7.2$ keV、 $z = 0.0556$

$F_{(0.4\text{-}2.4\ \mathrm{keV})} = 2\times10^{-10}$ erg/s

kT variance (Maxim+98, Briel+05)、

Cold Front,

The brightest radio relics

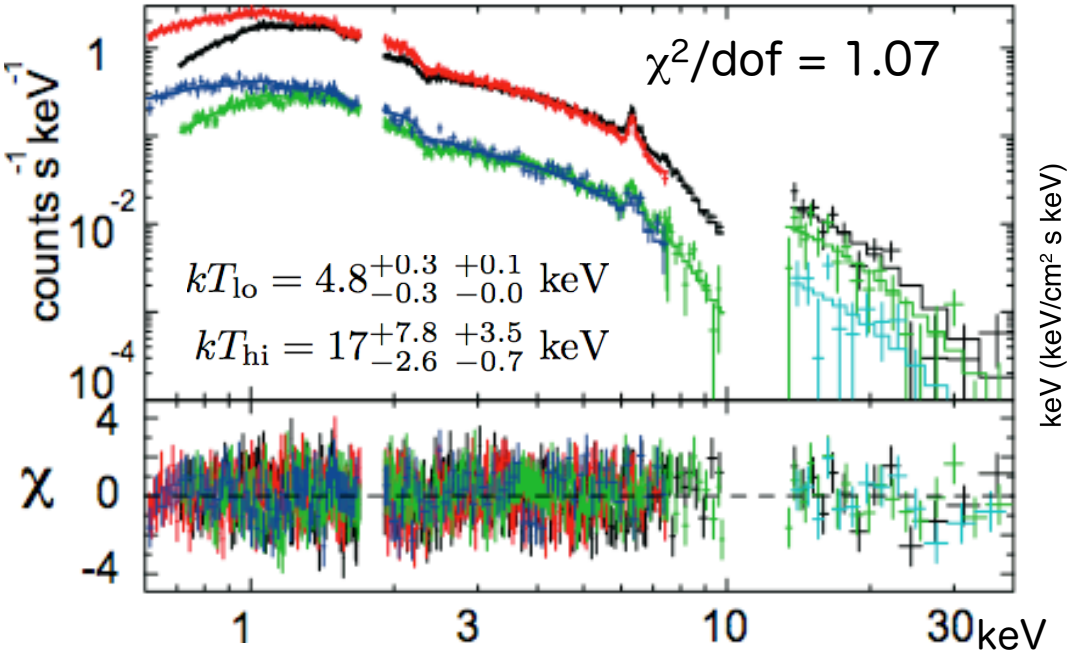
Right at merging!

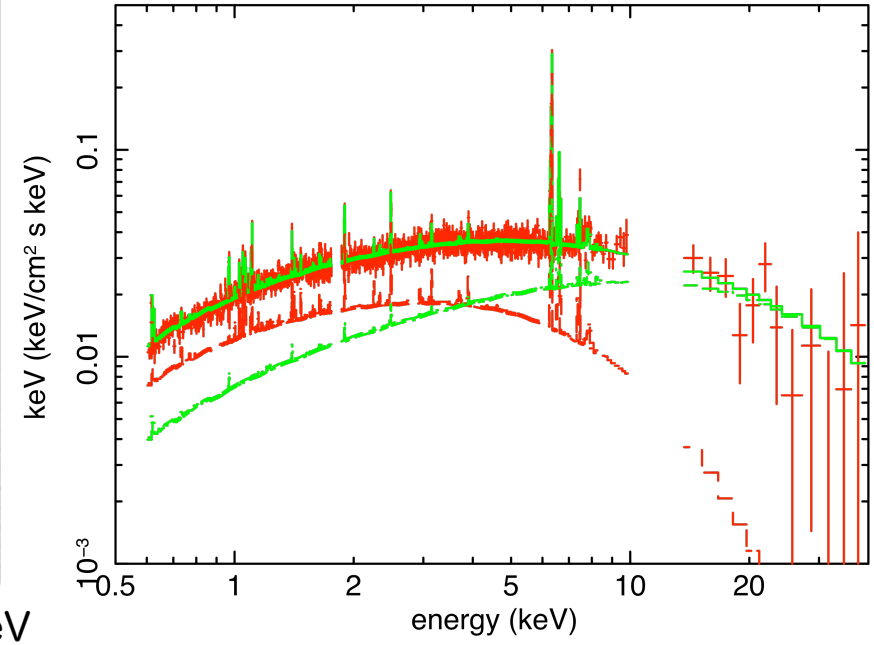
Suzaku mapping with
a wide-band coverage

How is the thermal emission?
Are there NT emission?

Detection of very hot component

ALL (ex. NWR-XIS) XIS+HXD spectra





-Requires 2kT
a > 13 keV component?

1: “very hot component”

e.g. RXJ1347 cluster Ota+09

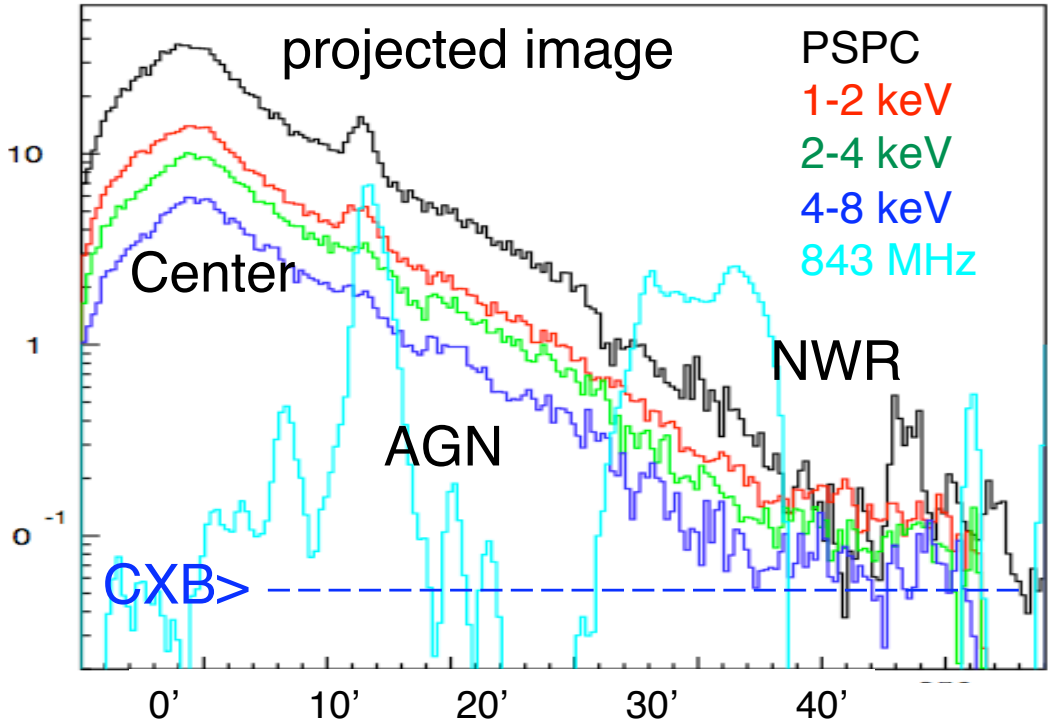
2: No PL component

$F_{\rm PL(NWR)}$ = -0.7 +/- 1.8 +/- 5.7

90% UL < 0.5 x10^{-11} cgs

the same UL with XMM+Suzaku ana

Magnetic field in the Radio relic



If Γ=2.1 PL then B > 2.2 μG

•Suzaku-XIS detects X-rays out to 40'

•"NWRelic" is X-ray dark

3: Little IC X-rays

$<4\times10^{-13}$ cgs (10-40 keV)

Re- acceleration of AGN lobe?

pressure around the NWRelic

ICM ~ 1.2 eV/cm^3

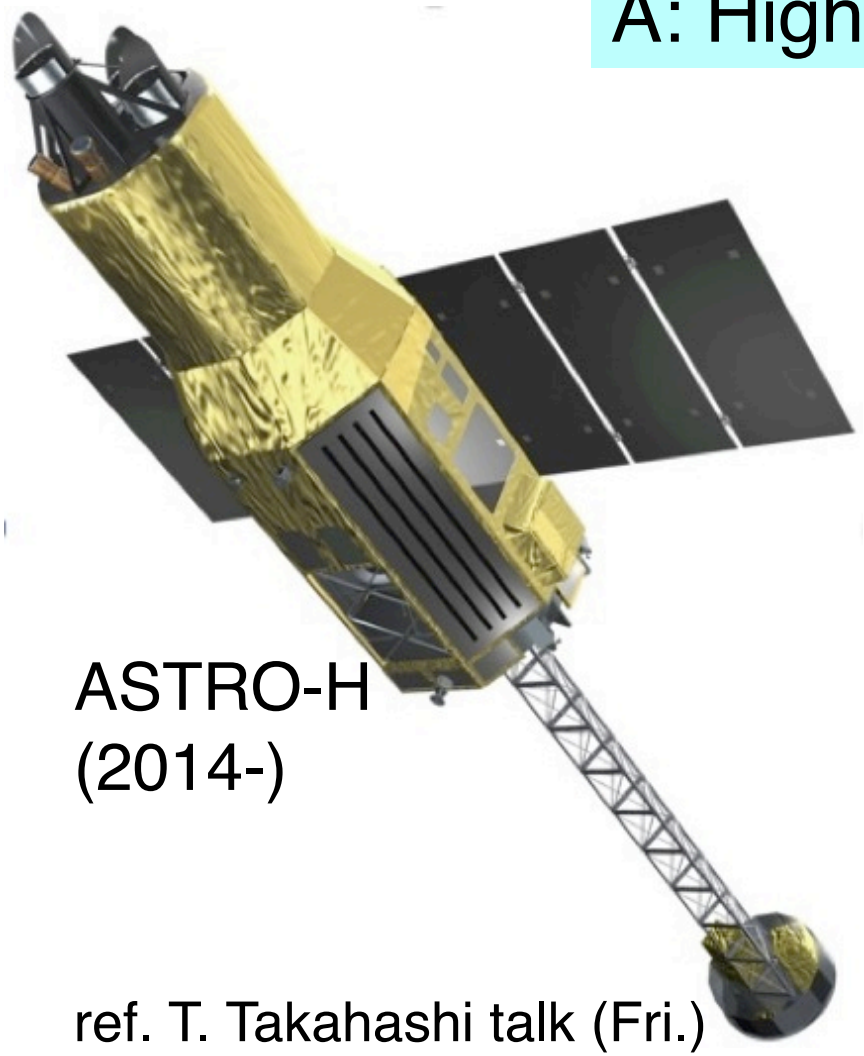
B > 0.1 eV/cm^3

GeV-E < 0.1 eV/cm^3

Non-negligible NT pressure?

3: The future, ASTRO-H and NuSTAR

A: High-resolution spectroscopy (7 eV)

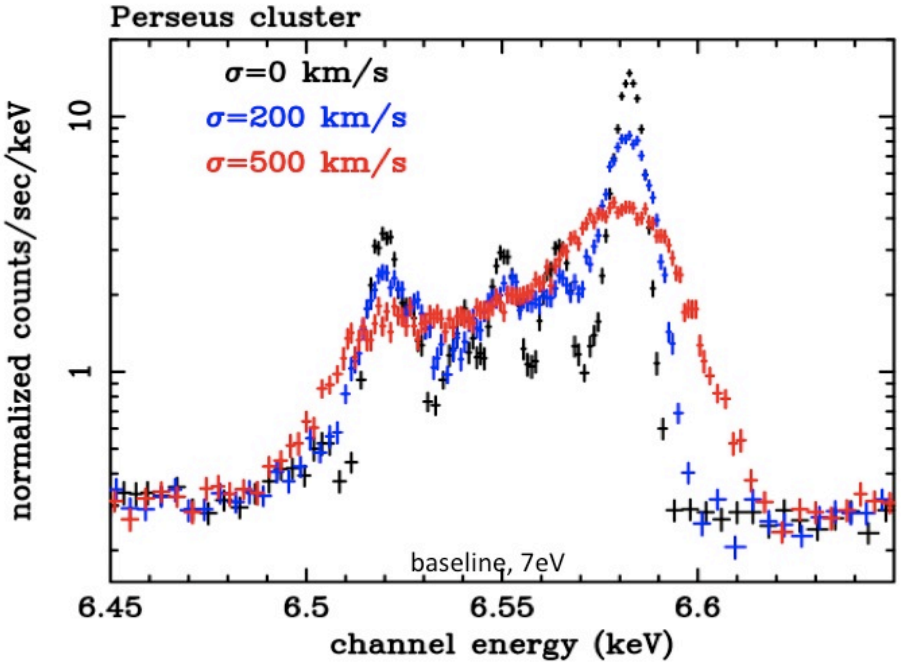


ASTRO-H
(2014-)

ref. T. Takahashi talk (Fri.)

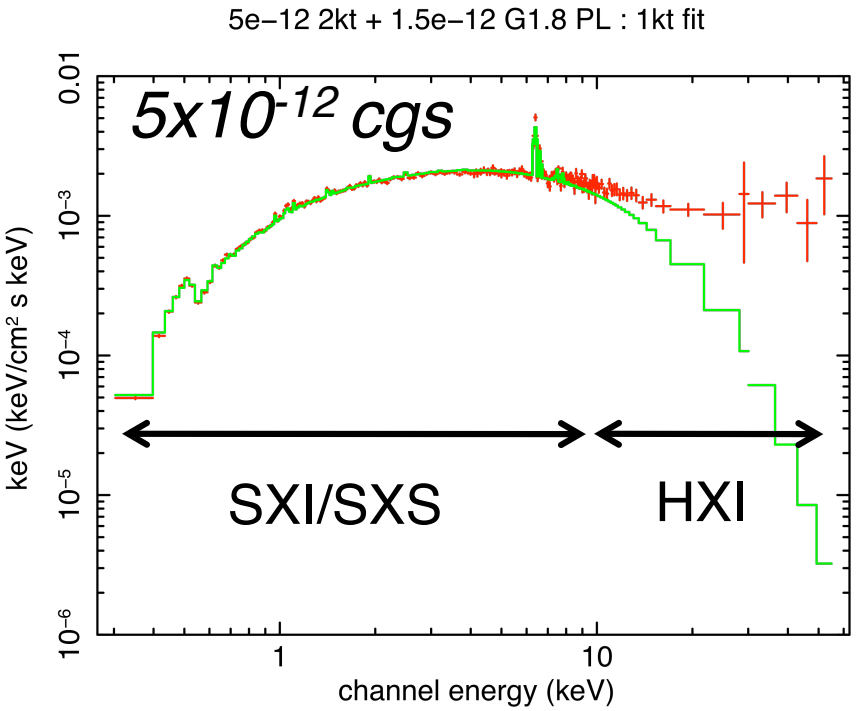
Turbulence, bulk-motion,
multi-phase-kT

Perseus cluster center
7eV SXS



Matsushita, Ota, Ohashi 09 A-H report

ASTRO-H wide-band simulation

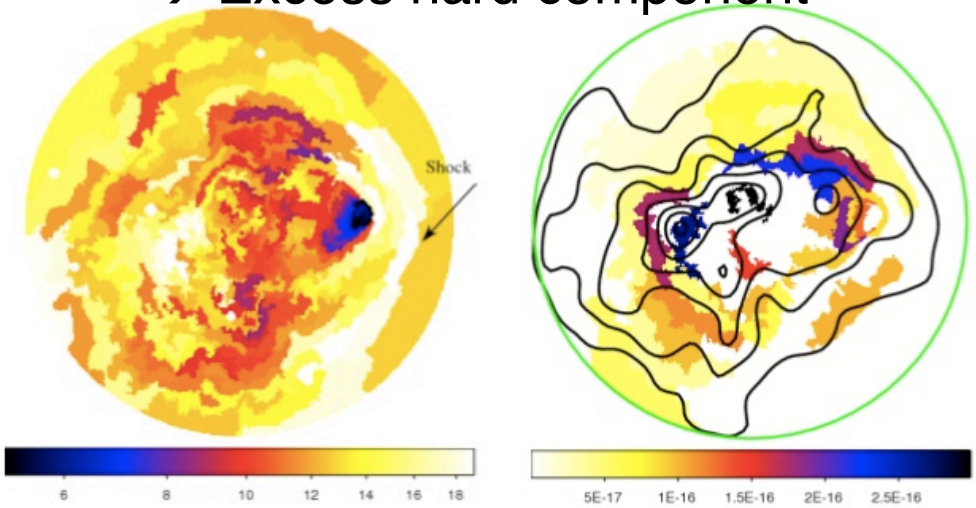


B: wide-band imaging spectroscopy (up to 80 keV)

Spectral diagnostics in 1 arcmin

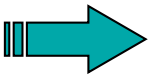
c.f. CXO residual analysis

→ Excess hard component



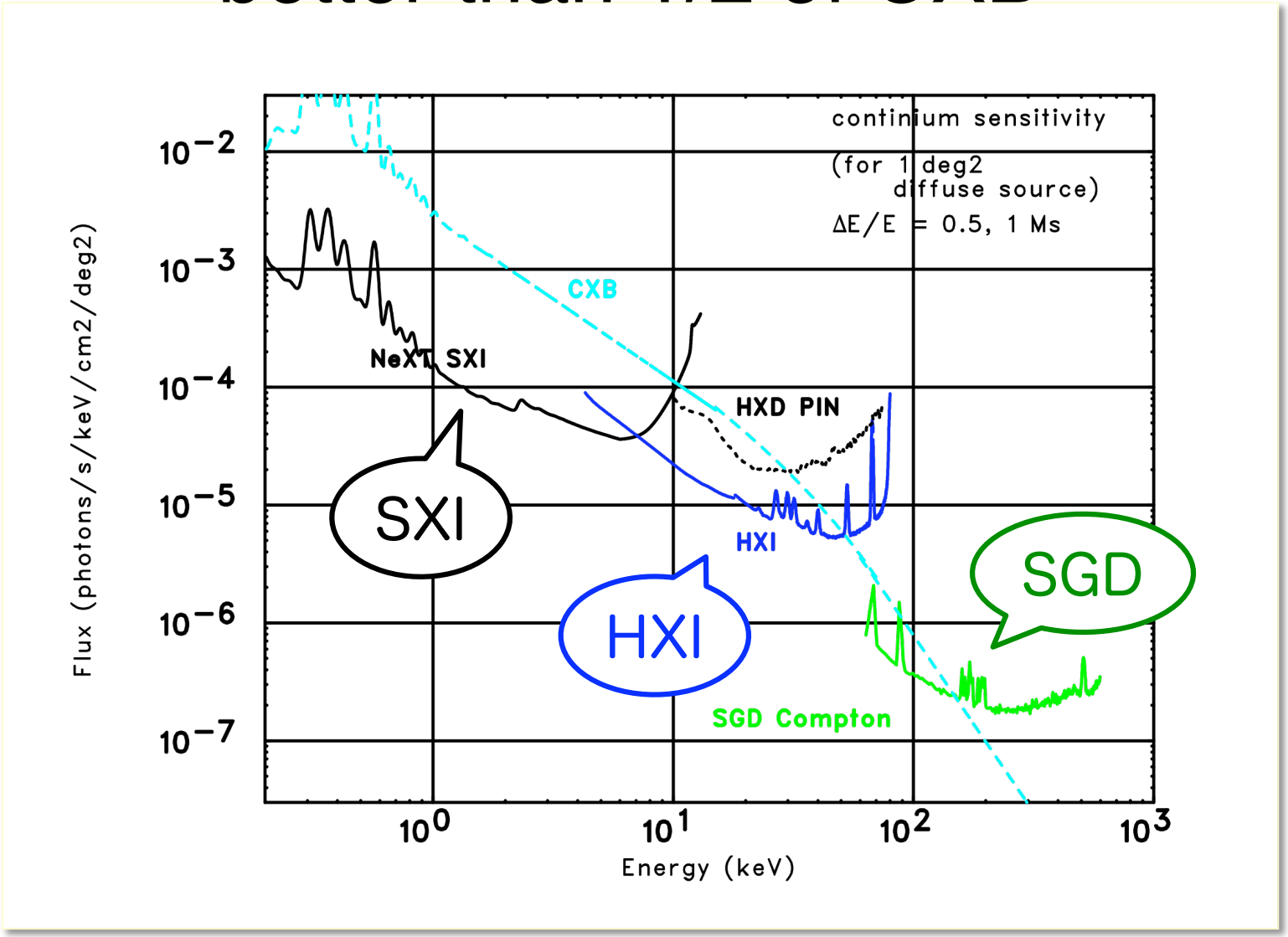
Million & Allen 2008

Perform similar analysis with much confidence using SXI+HXI (but FOV 9x9 arcmin²)



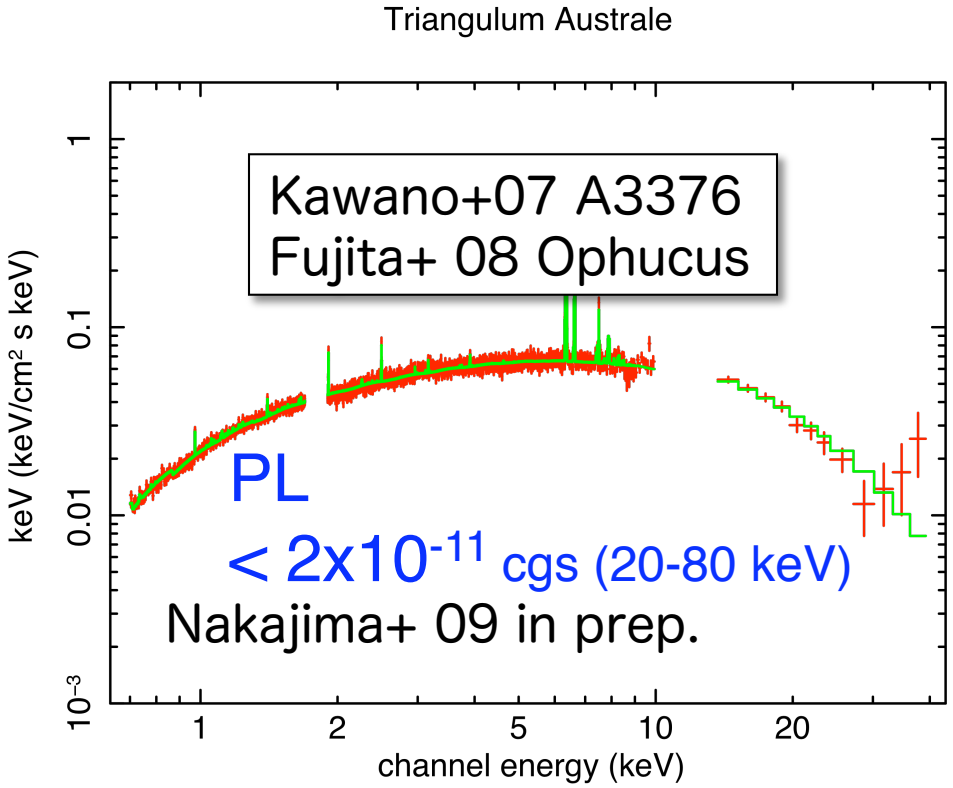
Local non-thermal emission +"Very hot component"

ASTRO-H:
Diffuse-source sensitivity better than 1/2 of CXB



c.f. Example of other works

advertisement as a Suzaku member



With good determination of kT, Suzaku is providing independent UL of IC PL and ICM temperature

Other major recent works

Ophiuchus
Eckert+08, *Poster P6.9*

A754, Perseus, Coma etc.
Ajello+08, *Poster* P6.5 (*Cappelluti*+)

1E0657 "Bullet"
Petrosian+06

A85 Durret+06,
"CXO mapping" Million+08,
…

Conclusion

Wide-band is important for diagnostics of mixed spectral component.

1: Excess hard X-rays from Coma cluster is **not** confirmed by Suzaku, INTEGRAL nor Swift/BAT. To be consistent with SAX/PDS, the emission should be widely distributed.

Determination of the thermal emission is a key issue for NT confirmation

2: Suzaku, with is good spectra up to ~40 keV, detected for the first time a "very hot component (>13 keV)" in A3667 (and RXJ1347).

The NW-radio relic region of A3667 has a magnetic field > 2.2 μG, and NT pressure is higher than ~17% of the thermal one.

3: ASTRO-H (and NuSTAR) will perform wide-band && spatially resolved X-ray mapping, a key tool for diagnostics of cluster X-ray spectra.