Wide band X-ray imaging of clusters of galaxies

2013/12/28 理科大
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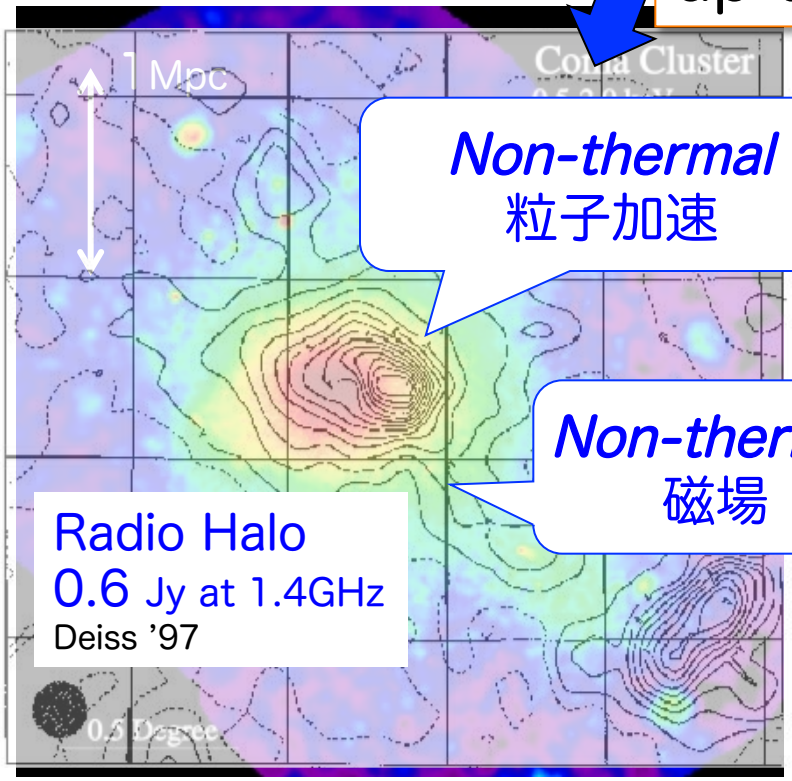
1: Variety of energy release paths in cluster merging

Energy input
up to 10^{64} erg

Coma cluster



Non-thermal
粒子加速

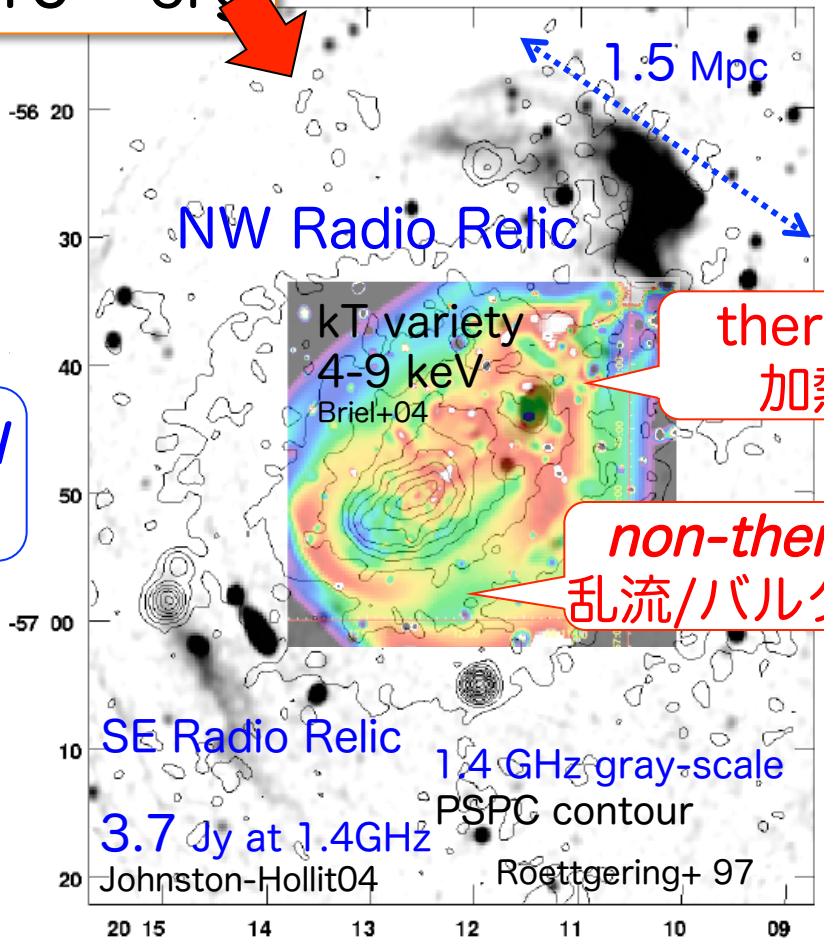
Non-thermal
磁場

Radio Halo
0.6 Jy at 1.4GHz
Deiss '97

Coma cluster PSPC-image (Snowden)

Coma-C 1.4 GHz contour (Deiss '97)

Abell 3667



thermal
加熱

non-thermal
乱流/バルク運動

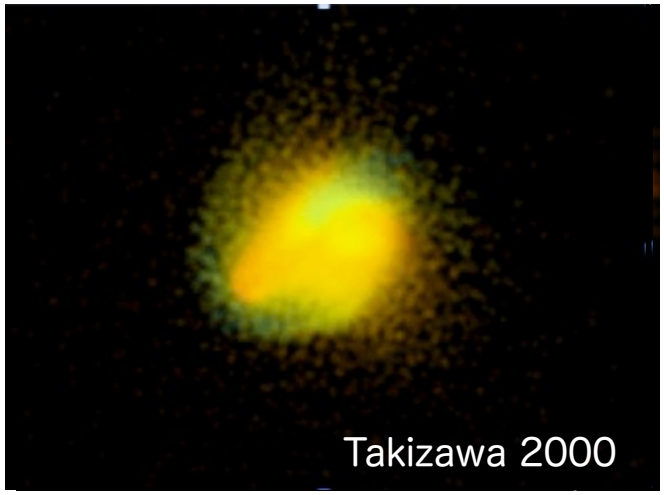
2 : Diagnosing the components

① IC emission = *B-field* (w/ radio)+ particle acc.

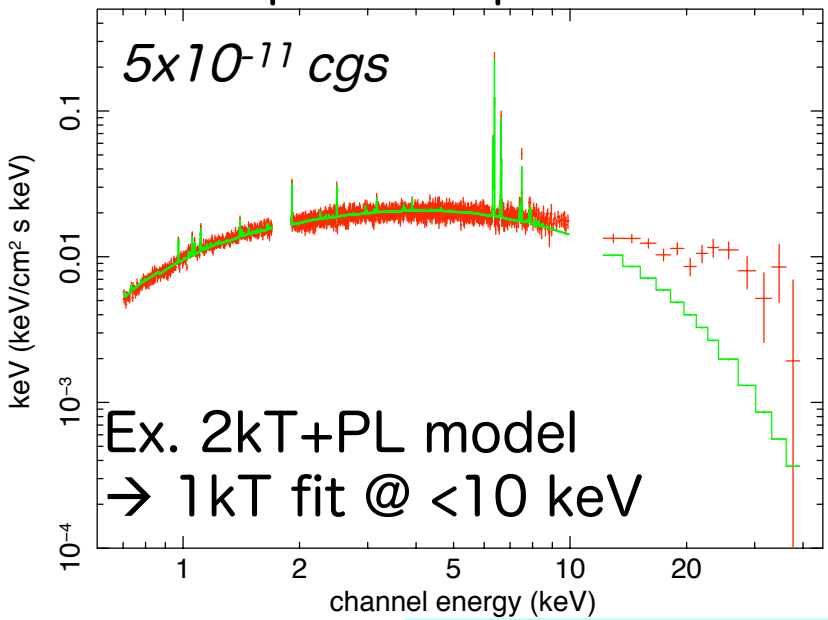
② Very hot component = right at the merger

① IC-X-rays

② Very hot component



Expected spectra

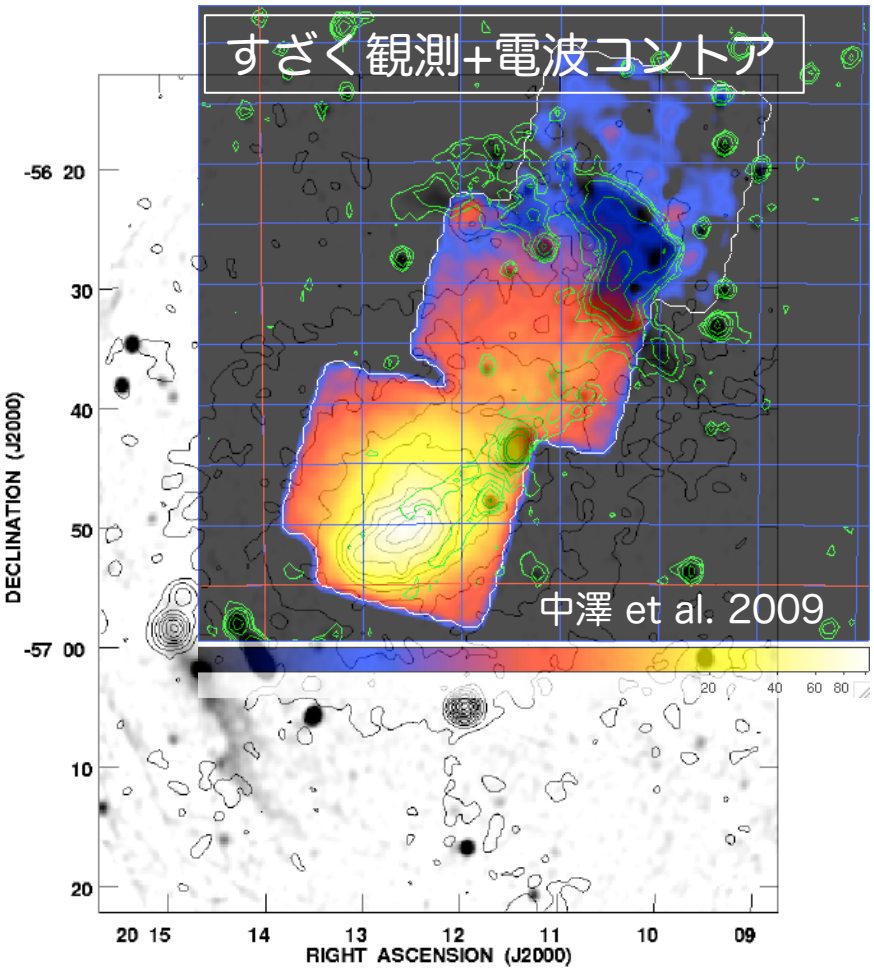


How can we distinguish the ICM thermal + very hot + IC X-rays?

→ Wide-band

3-1: Very hot component in A3667

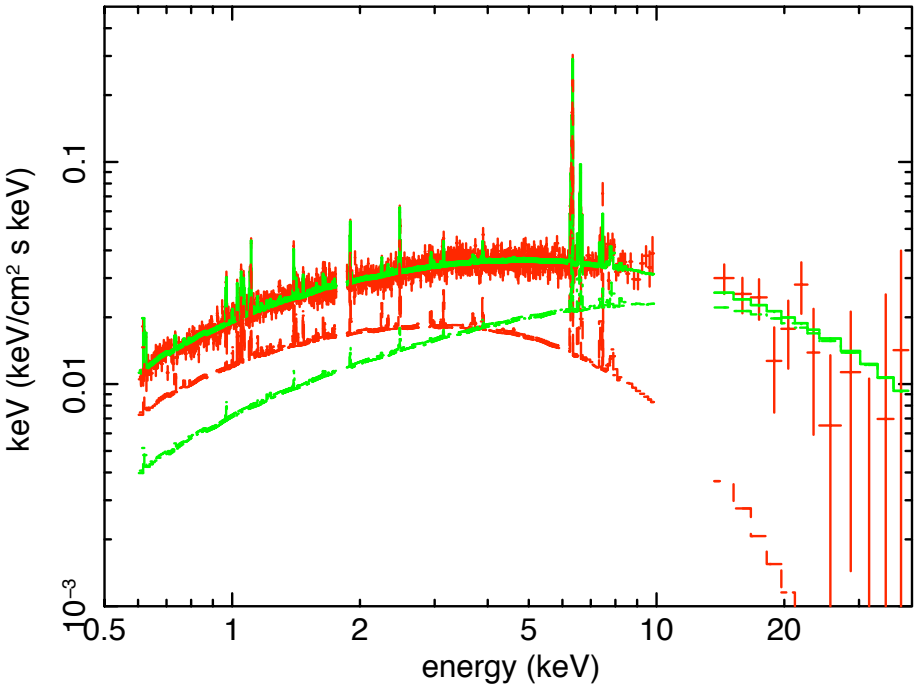
Abell 3667 Nakazawa+ 09



Roettgering+ 97

① Very hot component (~20 keV) detected

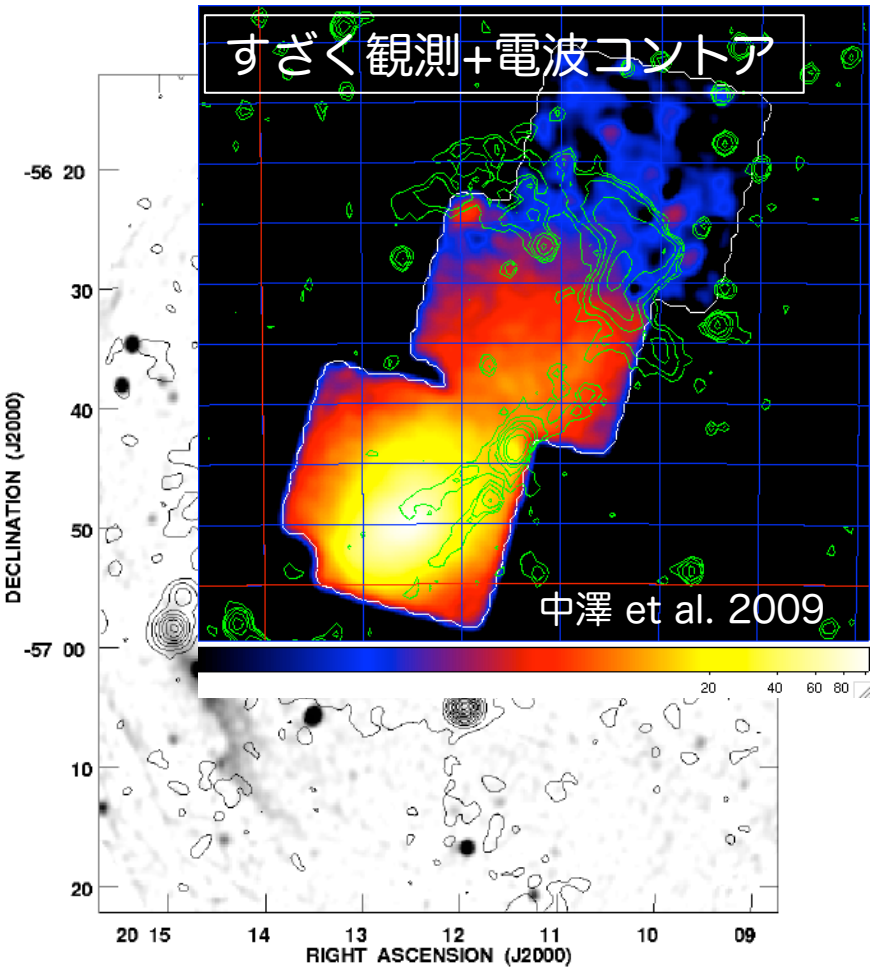
➡ Right at merger



e.g. RX J1347.5−1145 (Ota+ 2008)

3-2 IC search in A3667 relic

Abell 3667　Nakazawa+ 09



Roettgering+ 97

② No strong IC hard X-rays

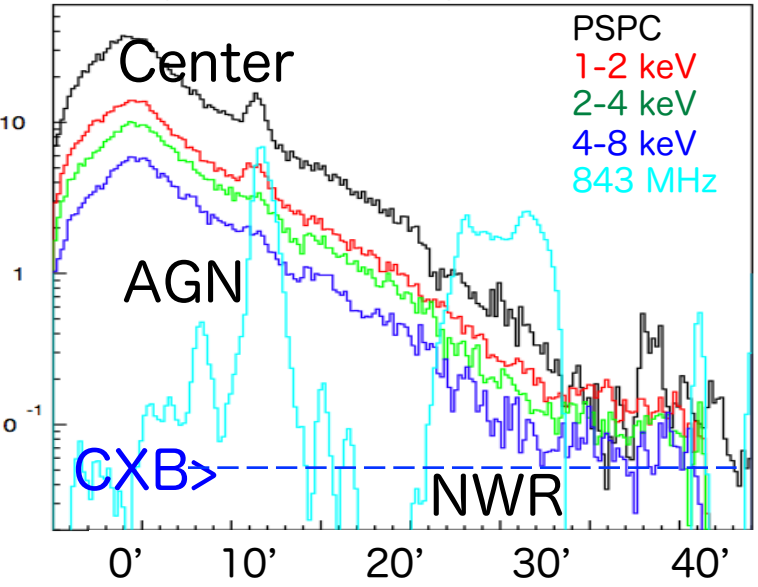
→how about

in 2-10 keV X-rays?

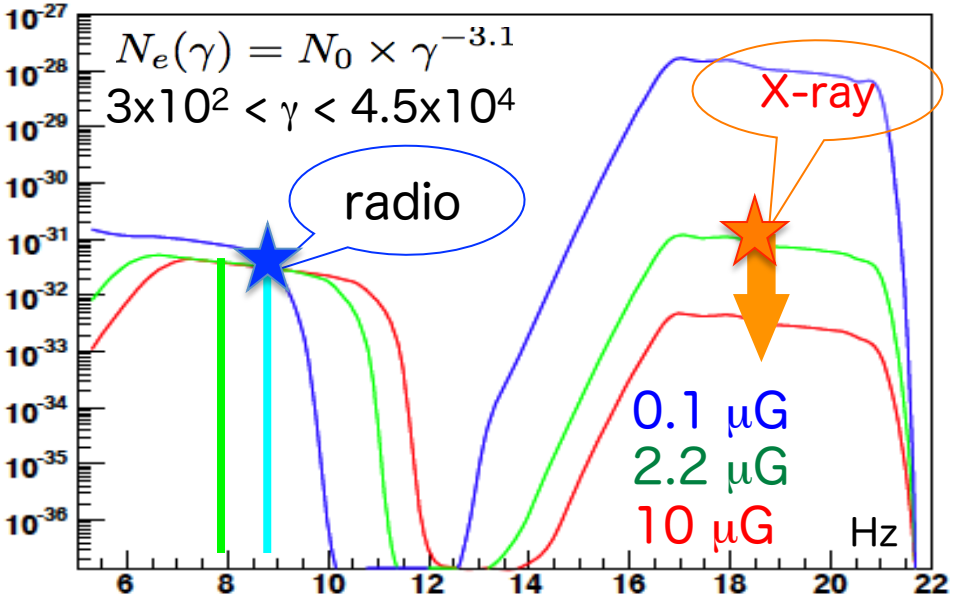
3-2 IC search in A3667 relic

Abell 3667 Nakazawa+ 09

projected image



vFv



→ No IC 2-10 keV X-rays

→ > *2 uG* of B-field in cluster periphery

NT pressure by GeV-e + B is > 20% of ICM

→ Non-negligible NT contribution

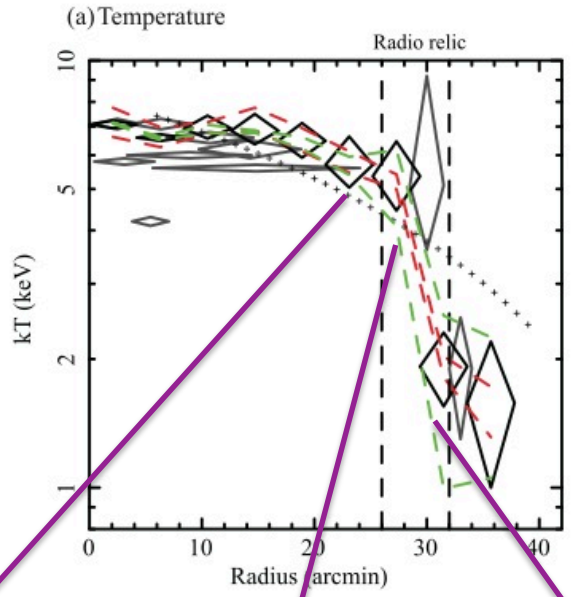
Pressure:
ICM ~ 1.2 eV/cm^3
B > 0.1 eV/cm^3
GeV-e < 0.1 eV/cm^3

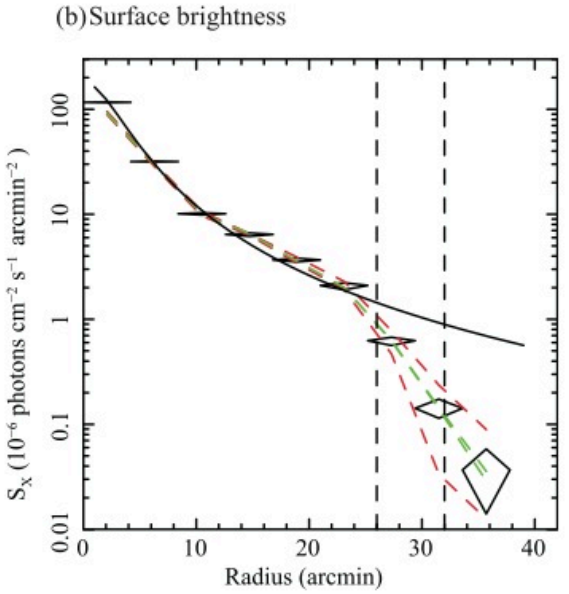
3-3 M~2.4 shock detection

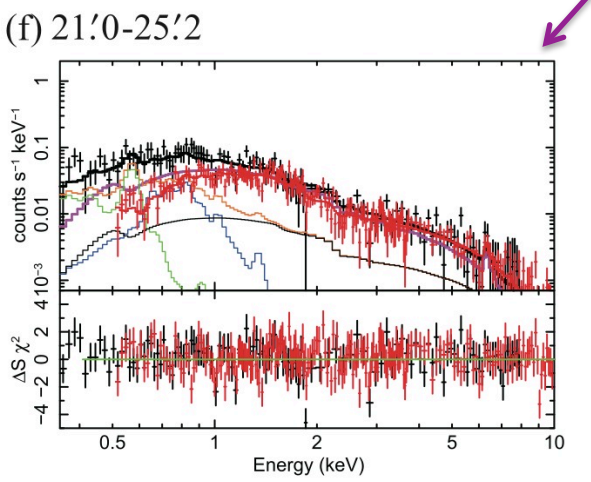
Suzaku XMM

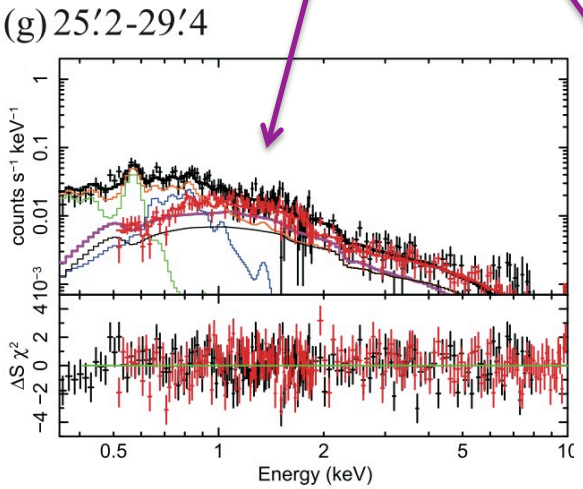
Finoguenov+10, Akamatsu+ 2012, Akamatsu & Kawahara 2013

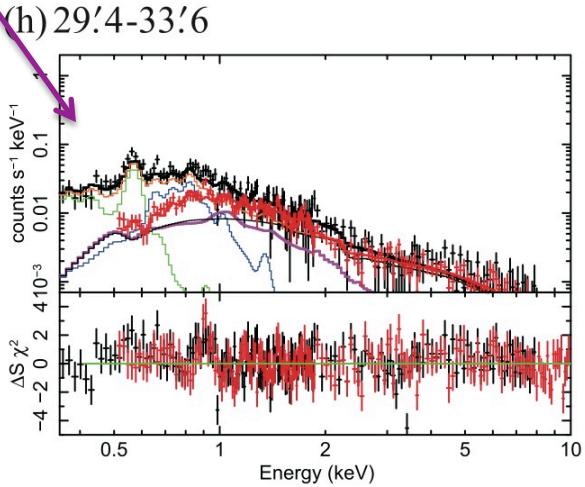
- Suzaku-XIS detects X-rays pressure jump, suggesting a Mach~2.4 shock
- Consistent with XMM











4：ASTRO-H Era is coming

Hard X-ray Telescope x2

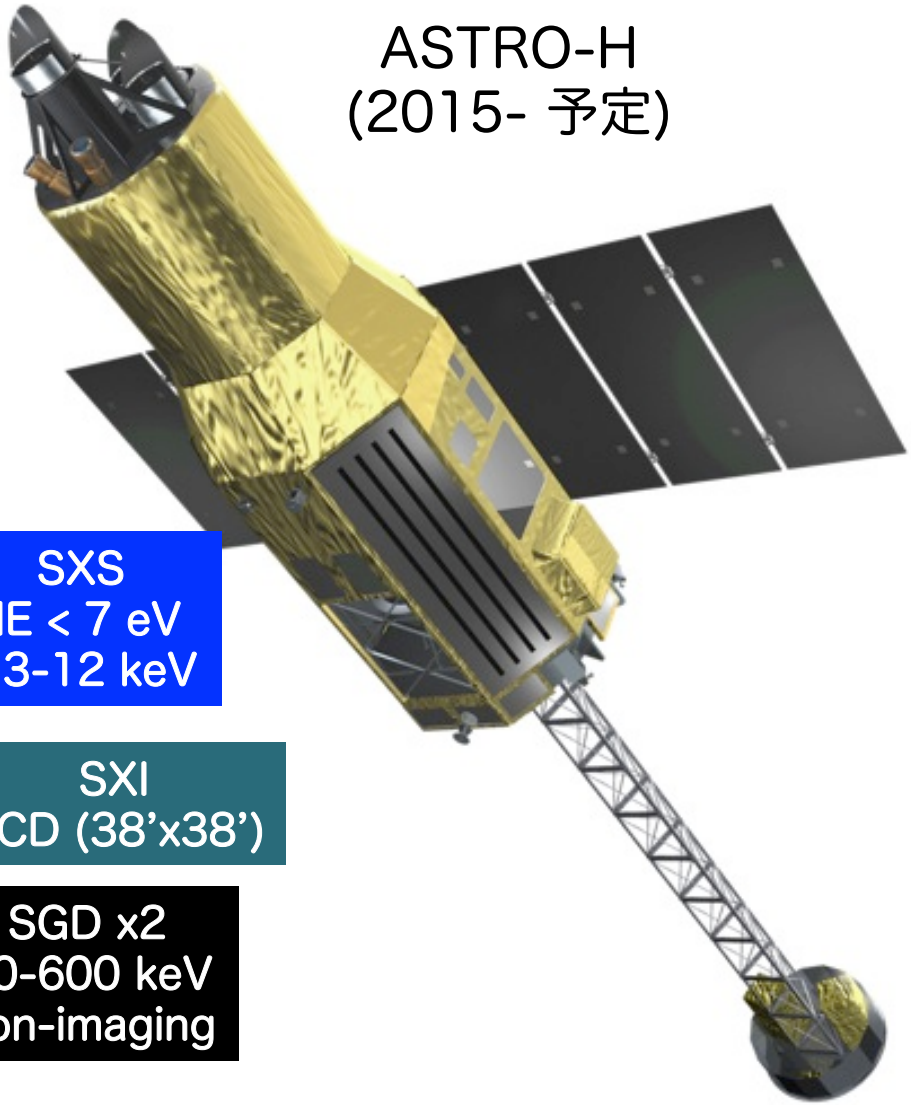
Hard X-ray imager x2
9'x9', HPD 1.7', 5-80 keV

SXS
dE < 7 eV
0.3-12 keV

SXI
CCD (38'x38')

SGD x2
60-600 keV
non-imaging

ASTRO-H
(2015- 予定)



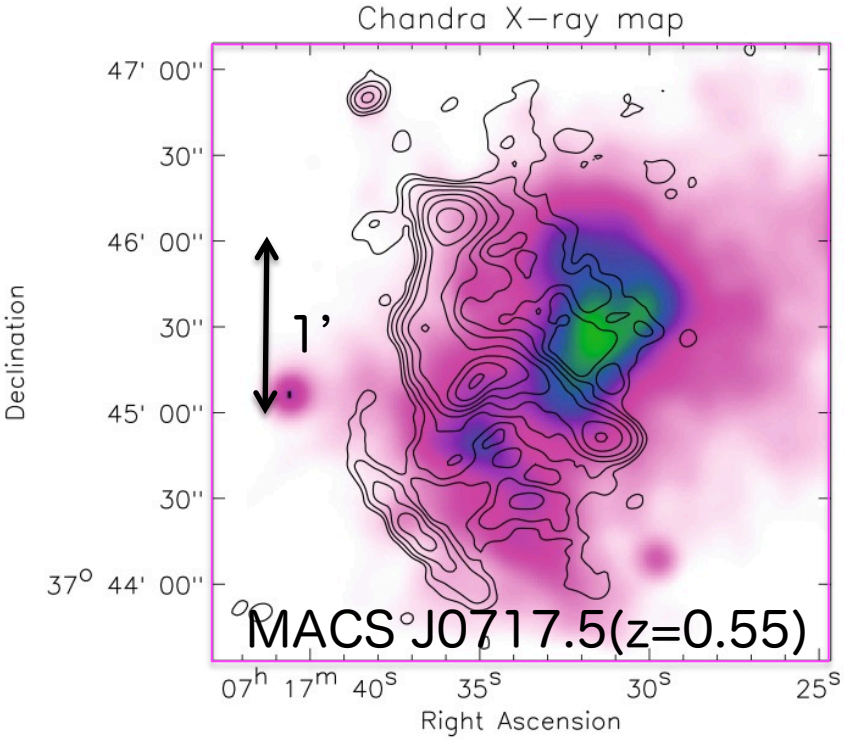
4-2: HXT/HXI wide-band obs.

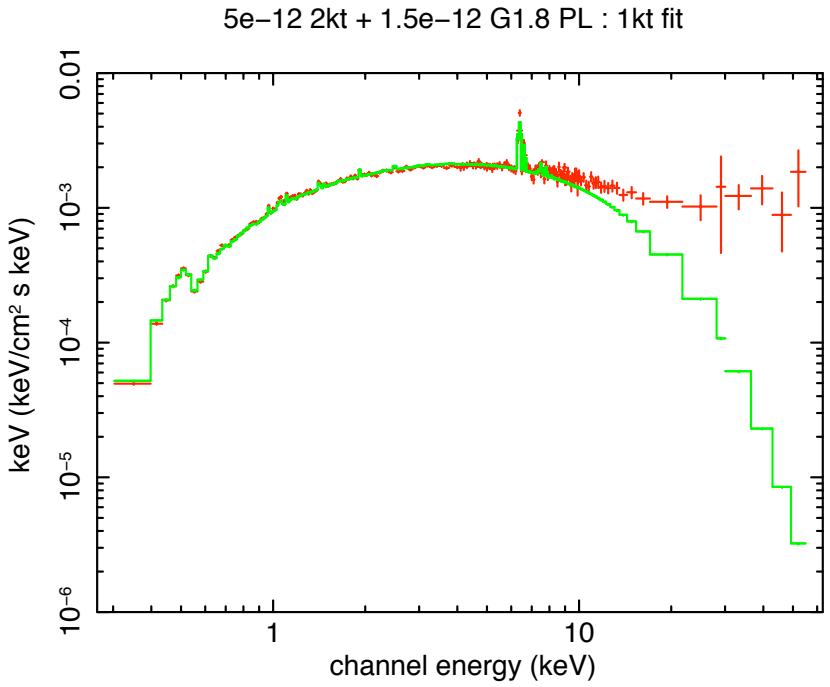
MANY mergers at z=0.3~0.6 with Synchrotron emission

+IC *z*-correction $F_{\rm HXR}/F_{\rm radio} \propto (1+z)^{3+\alpha}/B^{\alpha+1}$

Petrosian 08
原論文では Γがαに

Optimistic case





- 電波表面輝度はA3667の3.5倍→ *z*補正で 5.5倍
- サイズは1/60 → 撮像

遠方ほどCMBが「高温」に

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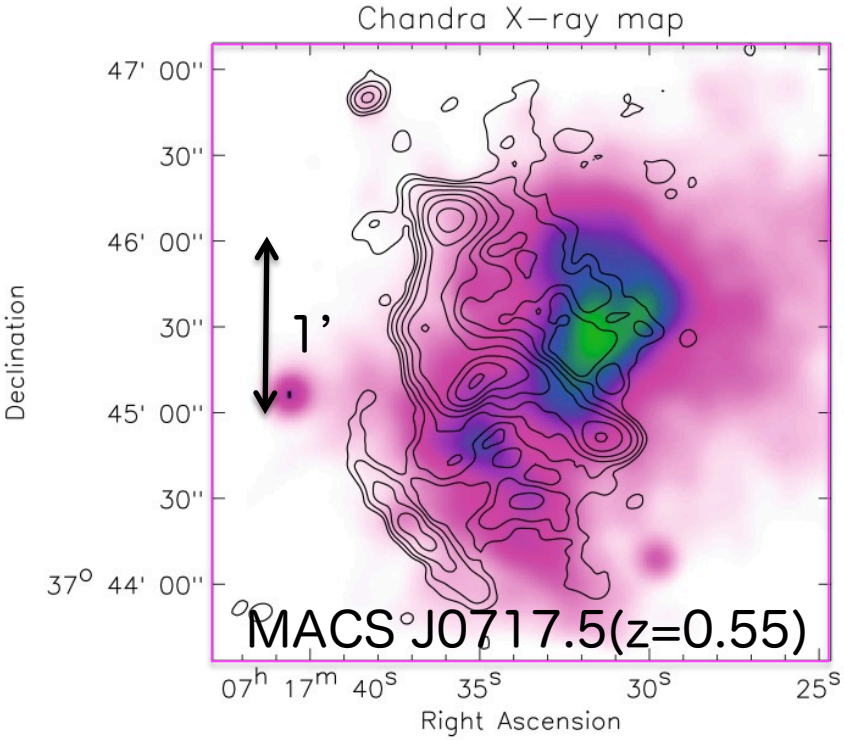

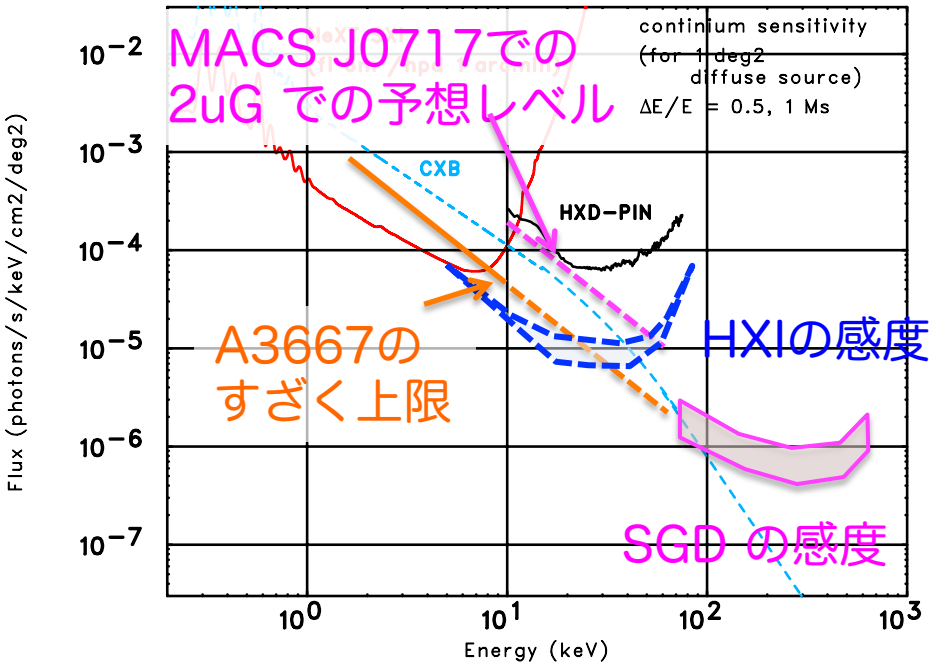

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遠方ほどCMBが
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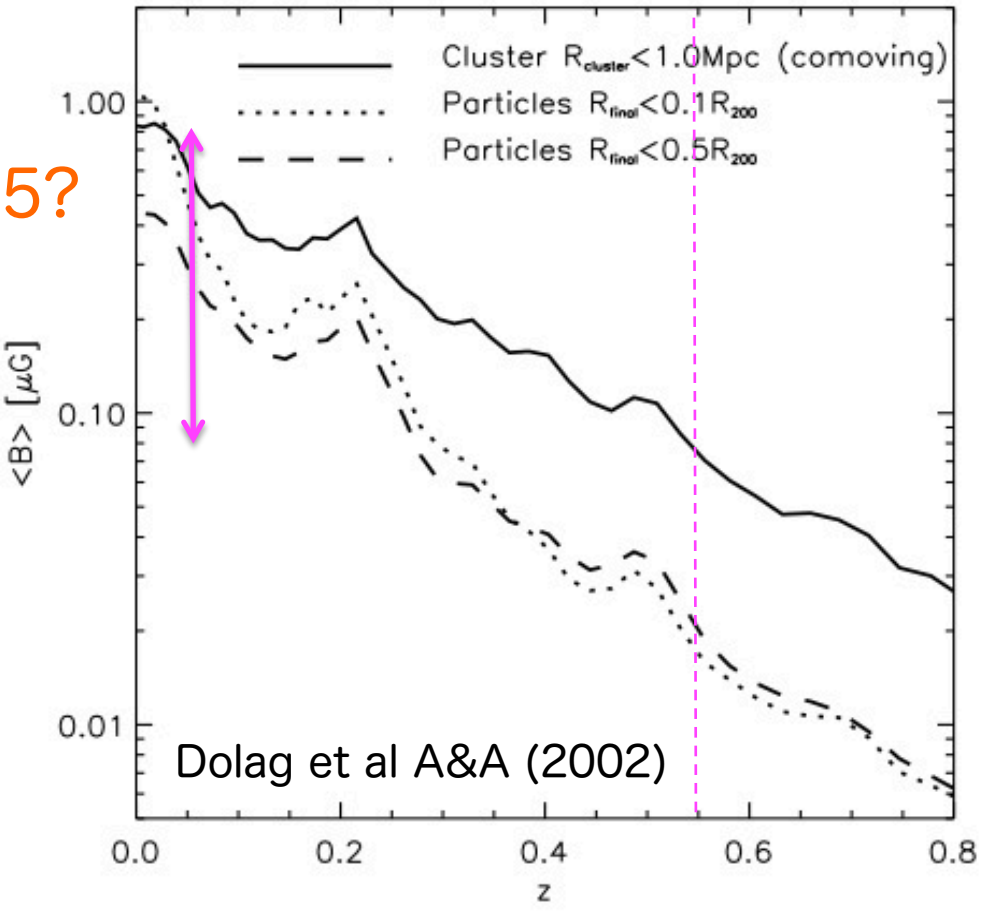
4-3: IC detection, future possibility

Speculative

B-field growth?
U_B = x0.01 lower @ z=0.5?
→ F_{IC}/F_R = x100 ?

→ MUCH stronger IC in far universe?

Need for high sensitivity radio-halo/relic Radio RM observations

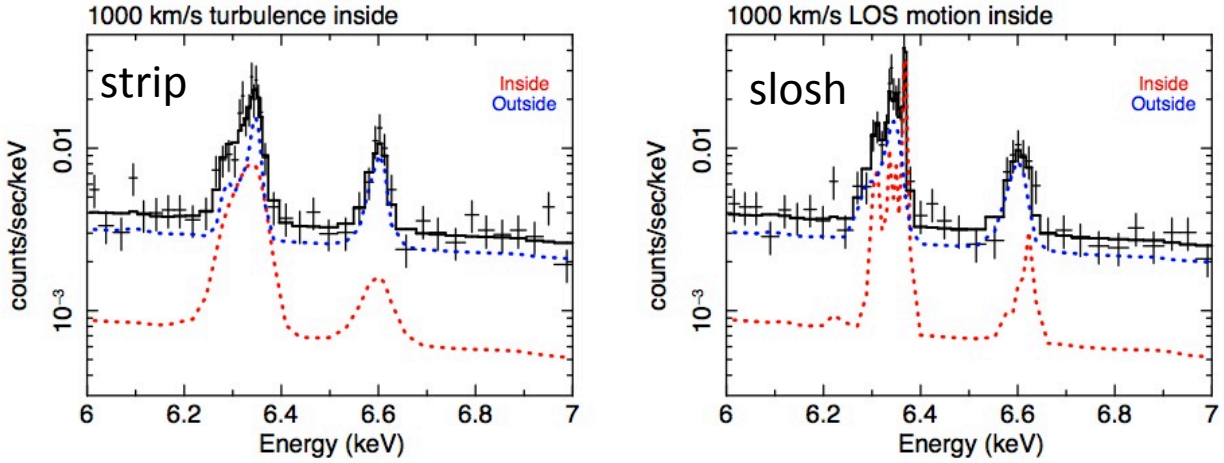


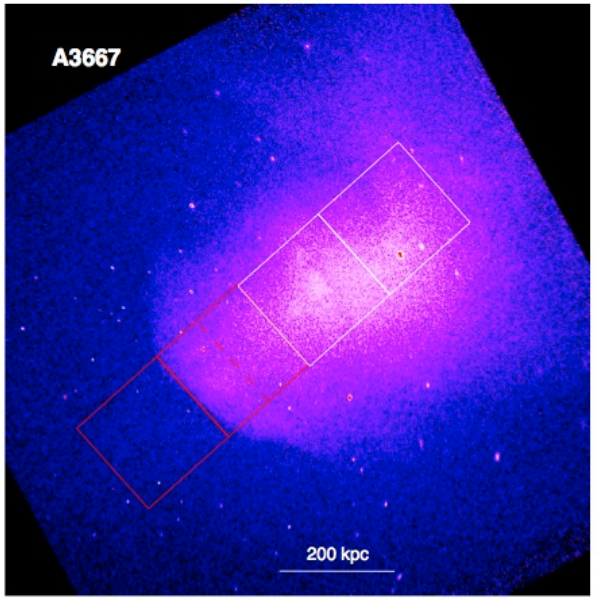
4-4: …with SXS *kinetic energy* measurement

ASTRO-H for the 1st time measure "meaningful" turbulence

= *transonic* motion feasible

- Abell 3667 case (from A-H white paper)





ICM turb.

Heat

Bulk Motion

IC radiation

Simulation

SKA：Rot. Measure map

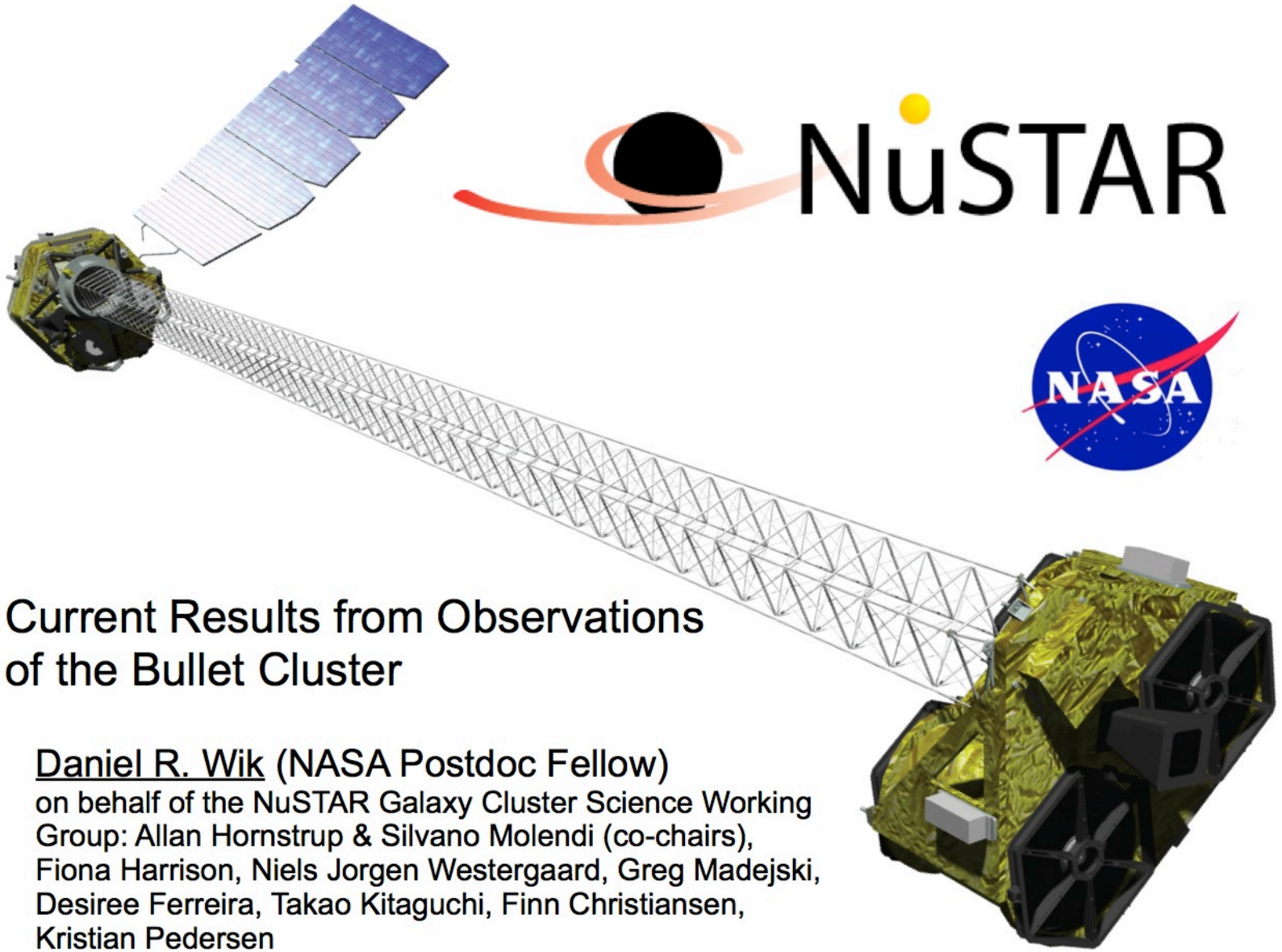
SZ効果

Weak lensing

ICM stripping (Ha, HI)

5: NuSTAR status

Wik 2013

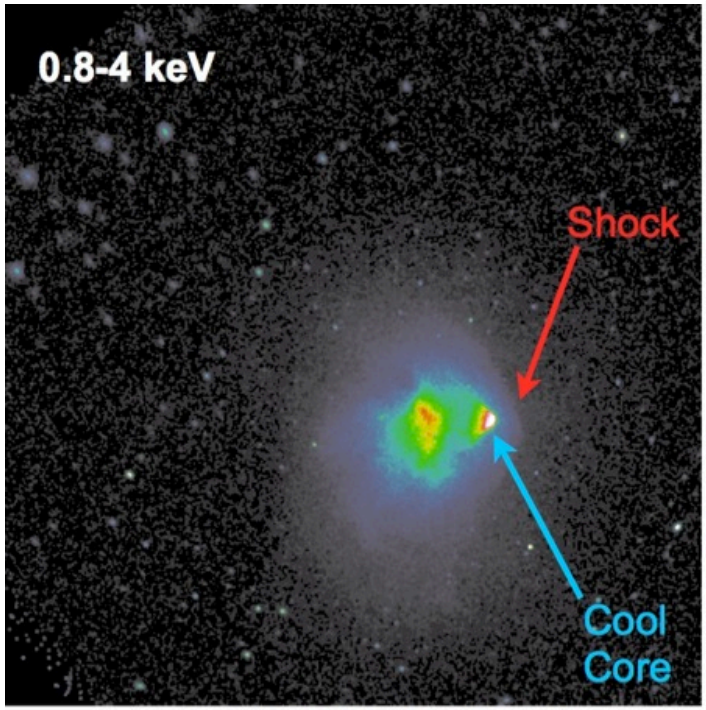


The Bullet Cluster

Wik 2013

NuSTAR

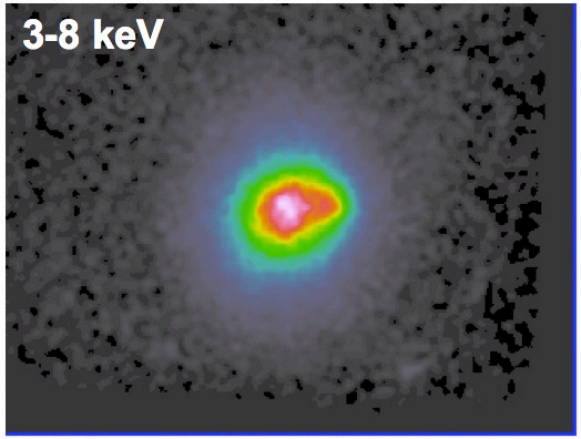
Chandra

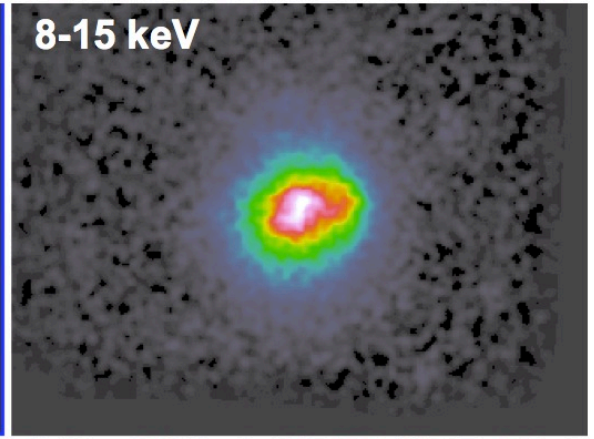


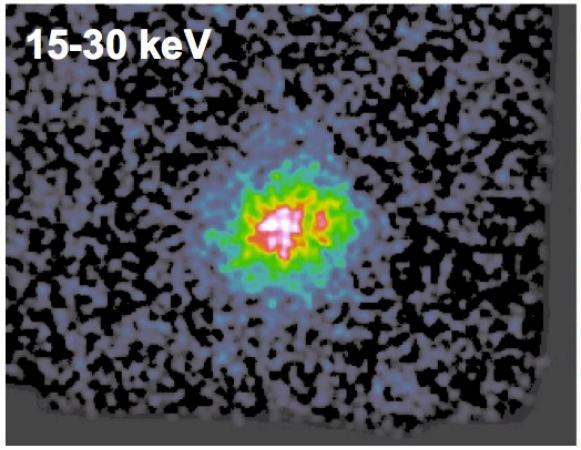
courtesy M. Markevitch

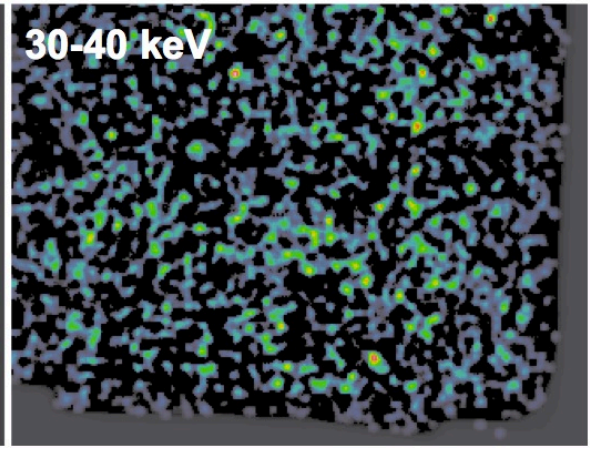
NuSTAR

Background-subtracted images



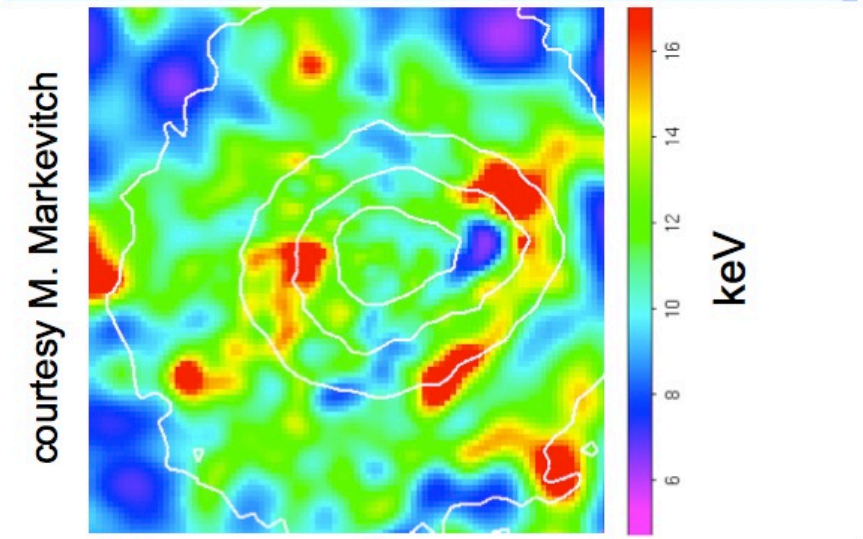


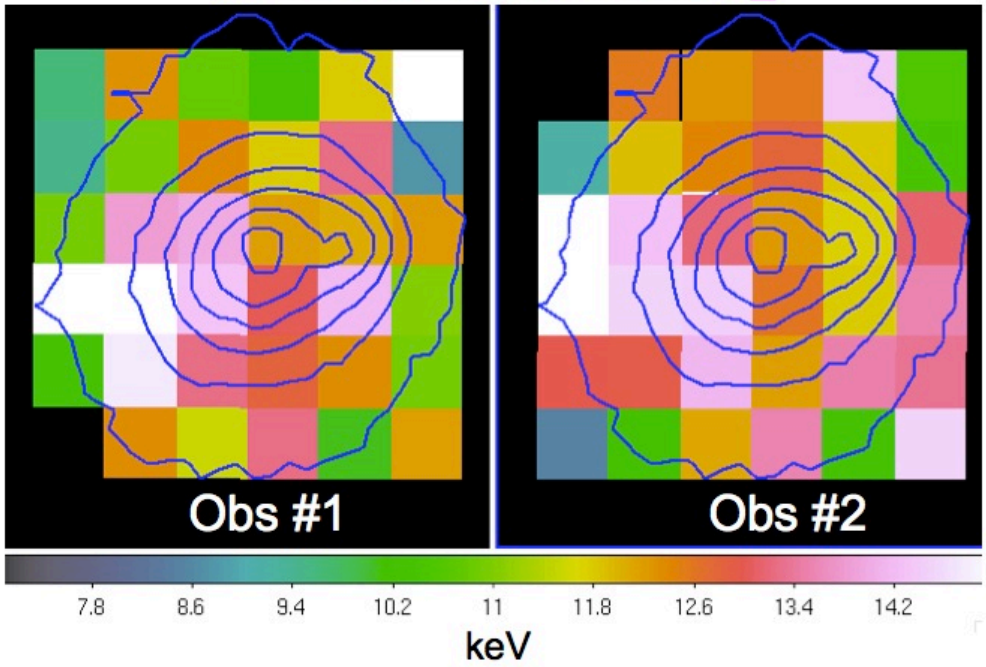




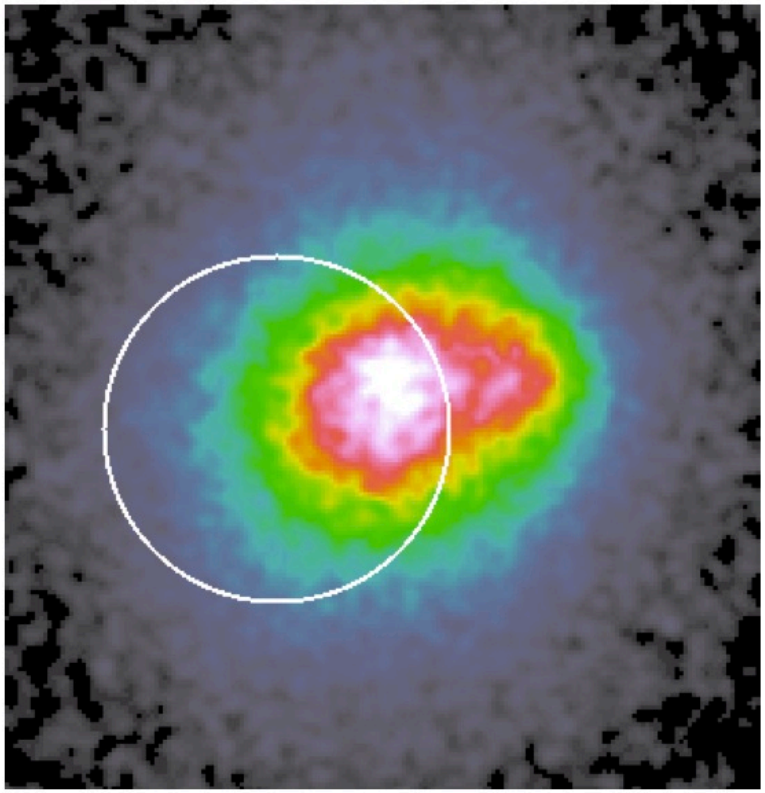
Bullet Cluster kT map

Wik 2013

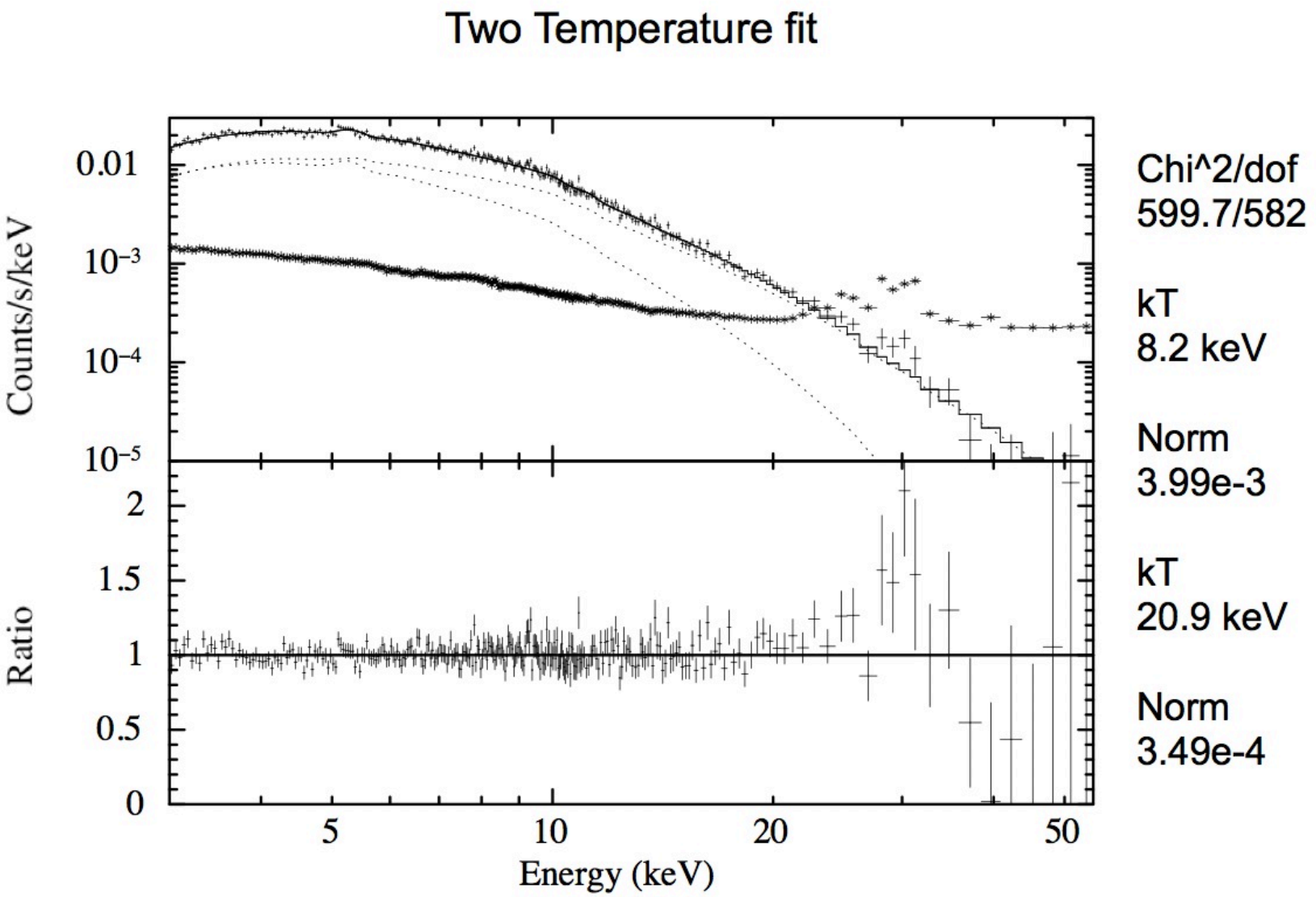




Source:
Maximize S/N while avoiding bullet to the west



Wik 2013



→ No strong IC hard X-rays, but better hot component determination

Summary

- Wide-band X-ray spectroscopy is the key to diagnose, the ICM and the heated ICM, as well as the Inverse-Compton component (there is also a need for “soft-band” wide-band, which is DIOS)

- Suzaku detected a very hot component and > 2 uG B-field in the NW-relic of A3667. In the latter case, non-thermal pressure is >20% of the thermal one w/o turbulence

- ASTRO-H has an “imaging” wide-band spectroscopy, coupled with high-reso. spectroscopy, enabling reach for z =0.2-0.5 active mergers

- ASTRO-H HXI will have comparable (point) and x2 better (diffuse) sensitivity compared to that of the NuSTAR in hard X-ray band, with combination with soft-X-ray (hi-res) spectroscopy.