# Detection of Hard X-ray Emission from the Hottest Abell Galaxy Cluster A2163 with *Suzaku*

Naomi Ota (Nara Women's University)
G. W. Pratt, T. Kitayama, T. Oshima,
H. Matsuo, M . Tsuboi & T. H. Reiprich

# Motivation

✤ Search for non-thermal/very hot thermal gas in merging clusters

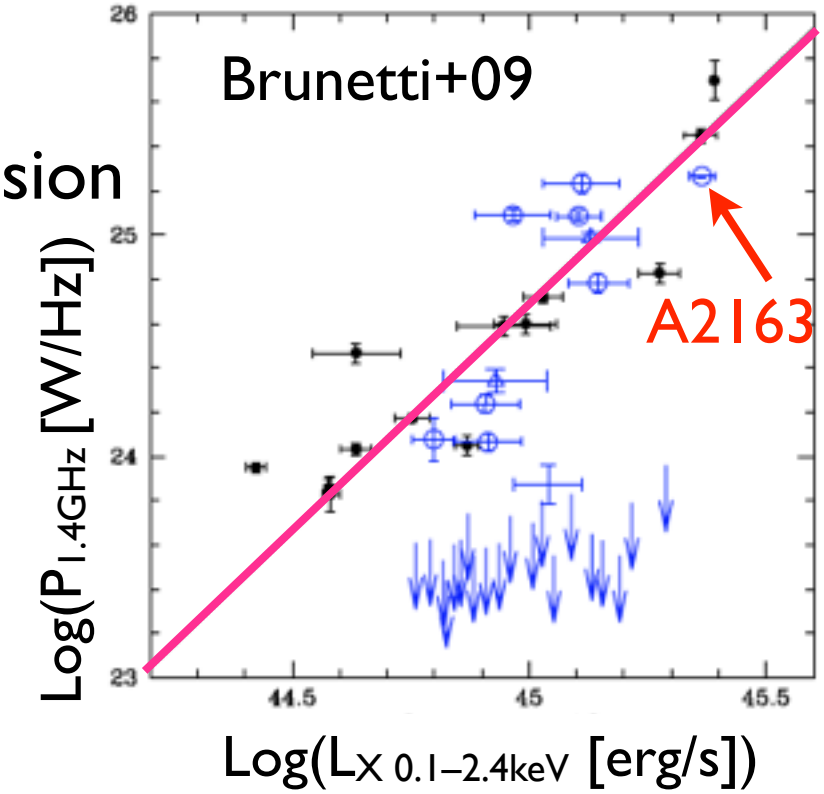
- A cluster merger has a typical kinetic energy ~ $10^{64}$ erg

➡ gas heating and particle acceleration

- Radio halo in merging clusters
- Inverse Compton hard X-ray emission

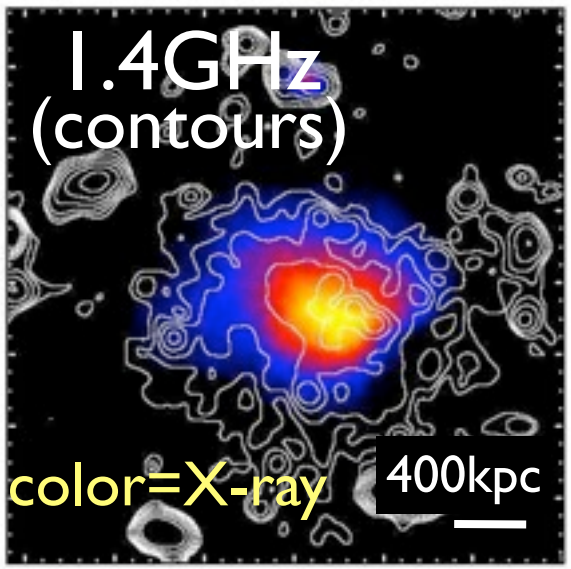
See e.g., Rephaeli+08 for review

"*Is there any scaling relation for non-thermal X-ray emission?*"

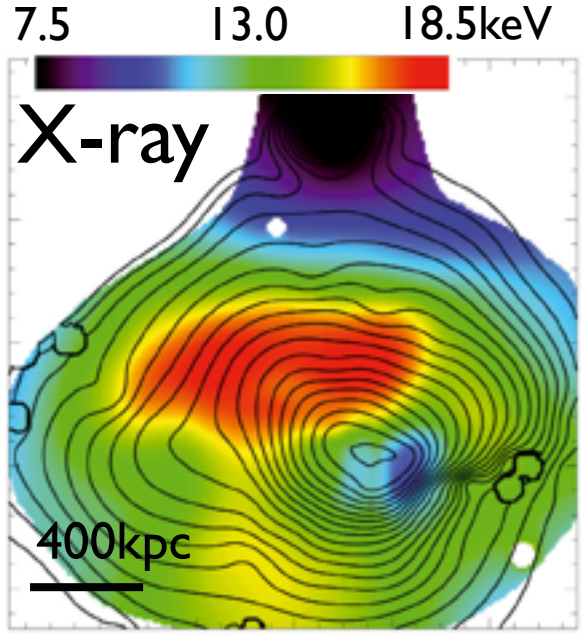


# The hottest Abell cluster A2163 at $z$=0.2

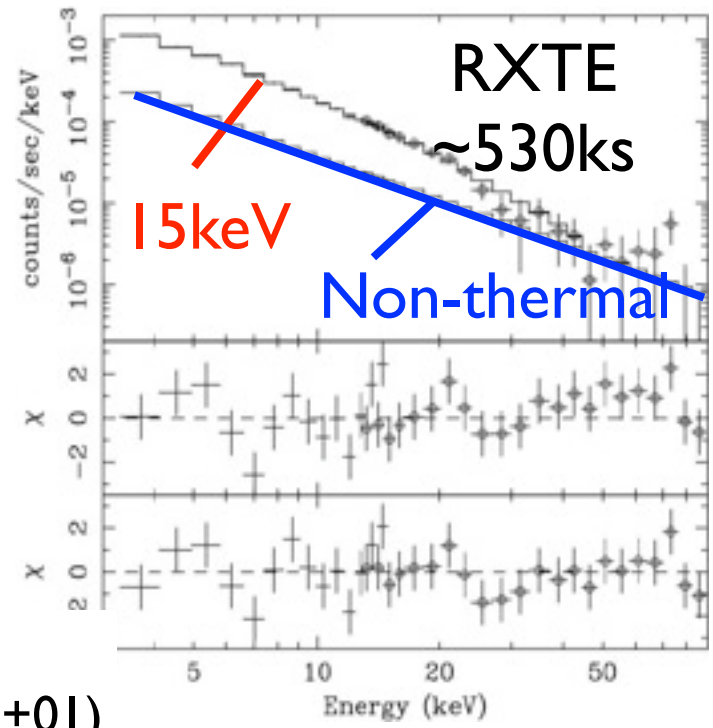
✤ Previous observations




(Govoni+04; Feretti+04)




Shock in NE
(e.g., Bourdin+11;Markevich+01)




- RXTE $F_{NT}= 1.1^{+1.7}_{-0.9} \times 10^{-11}$ erg/s/cm$^2$ (Rephaeli+06)
- see also Feretti+01; Million & Allen+09

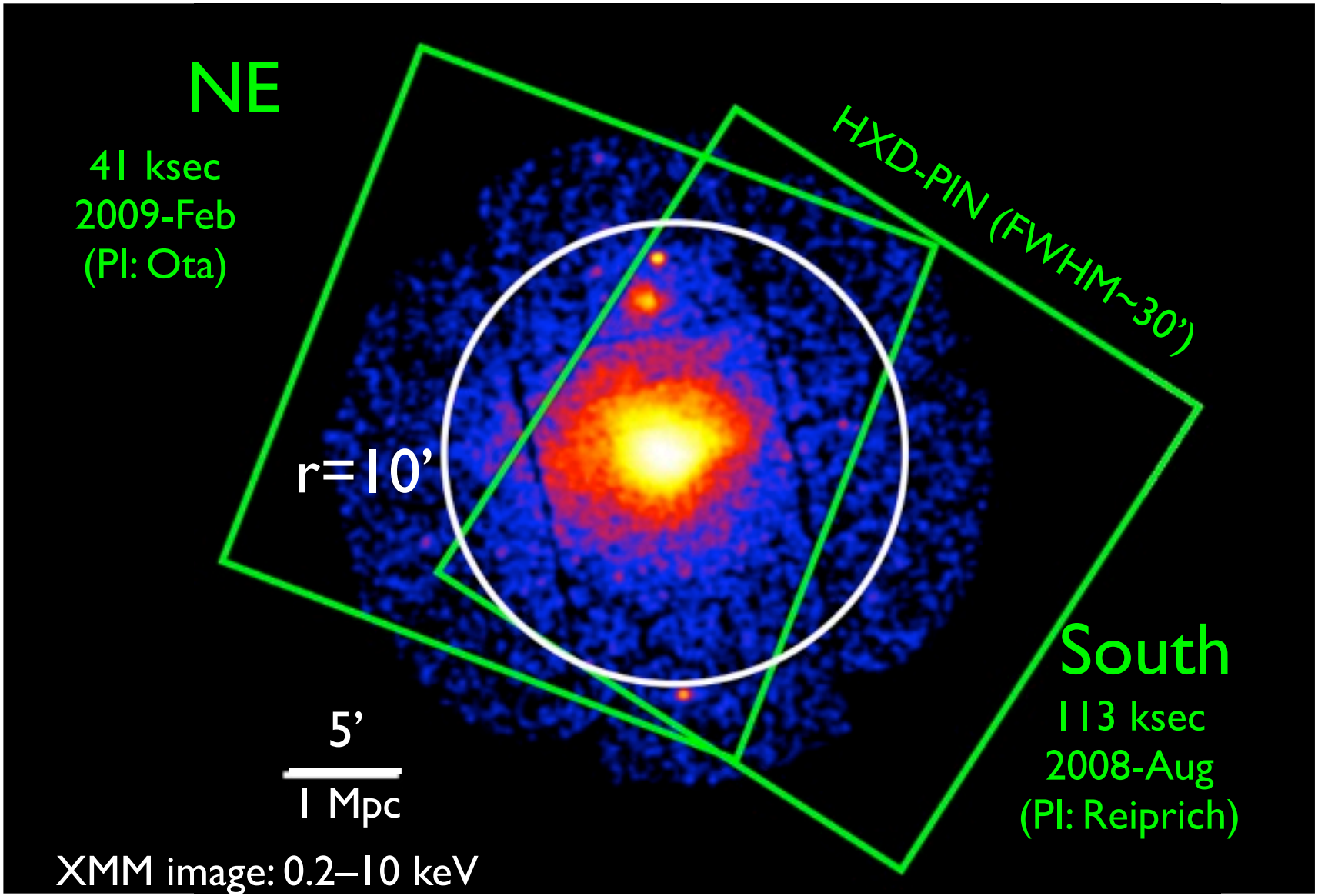
✤ Purpose of this study

- Constrain non-thermal hard X-ray emission with *Suzaku*+*XMM*

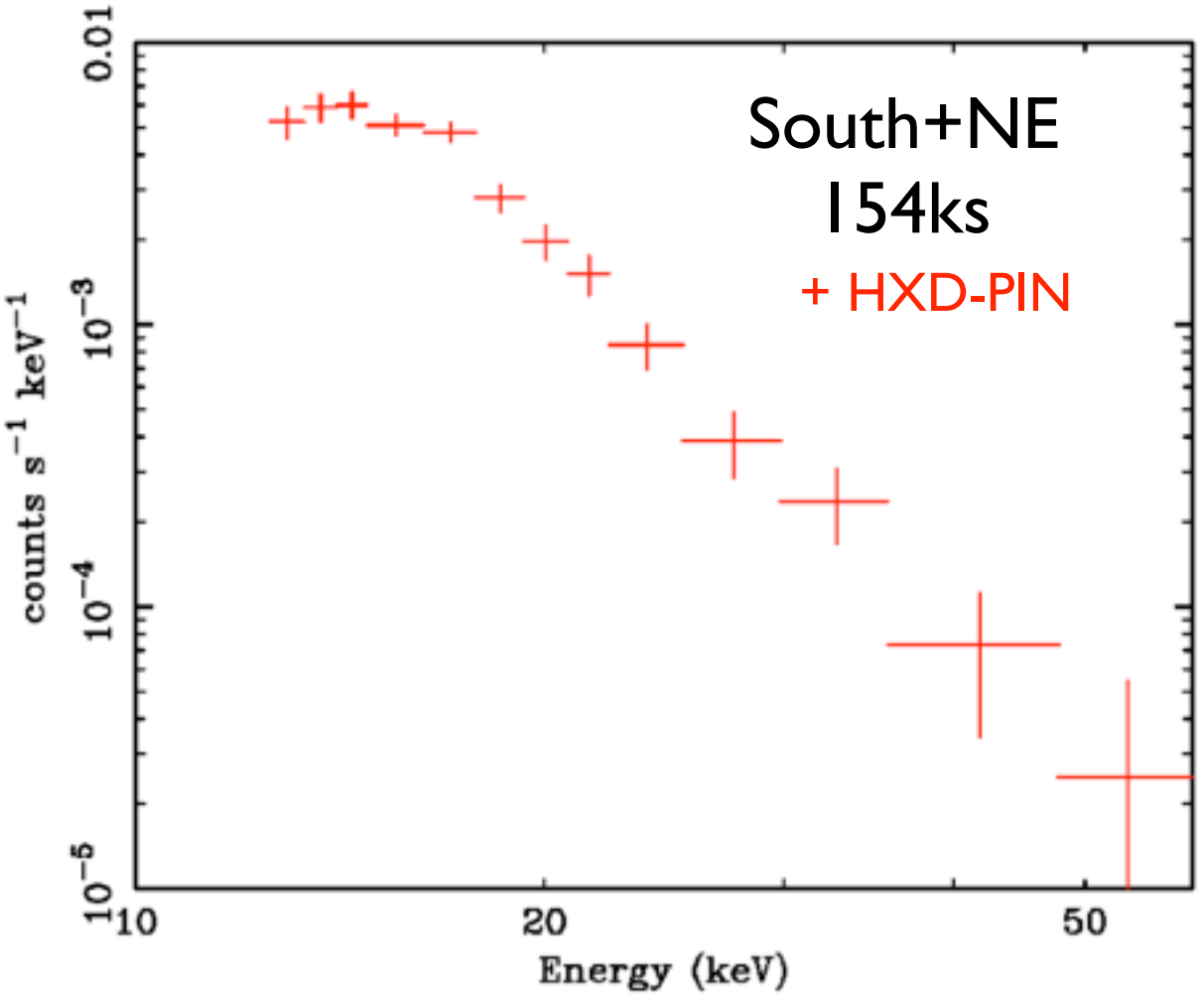
→Origin of hard X-ray emission and physics of shock heating due to merging

→Magnetic field in the cluster

# Suzaku observations of A2163



# HXD spectrum of A2163



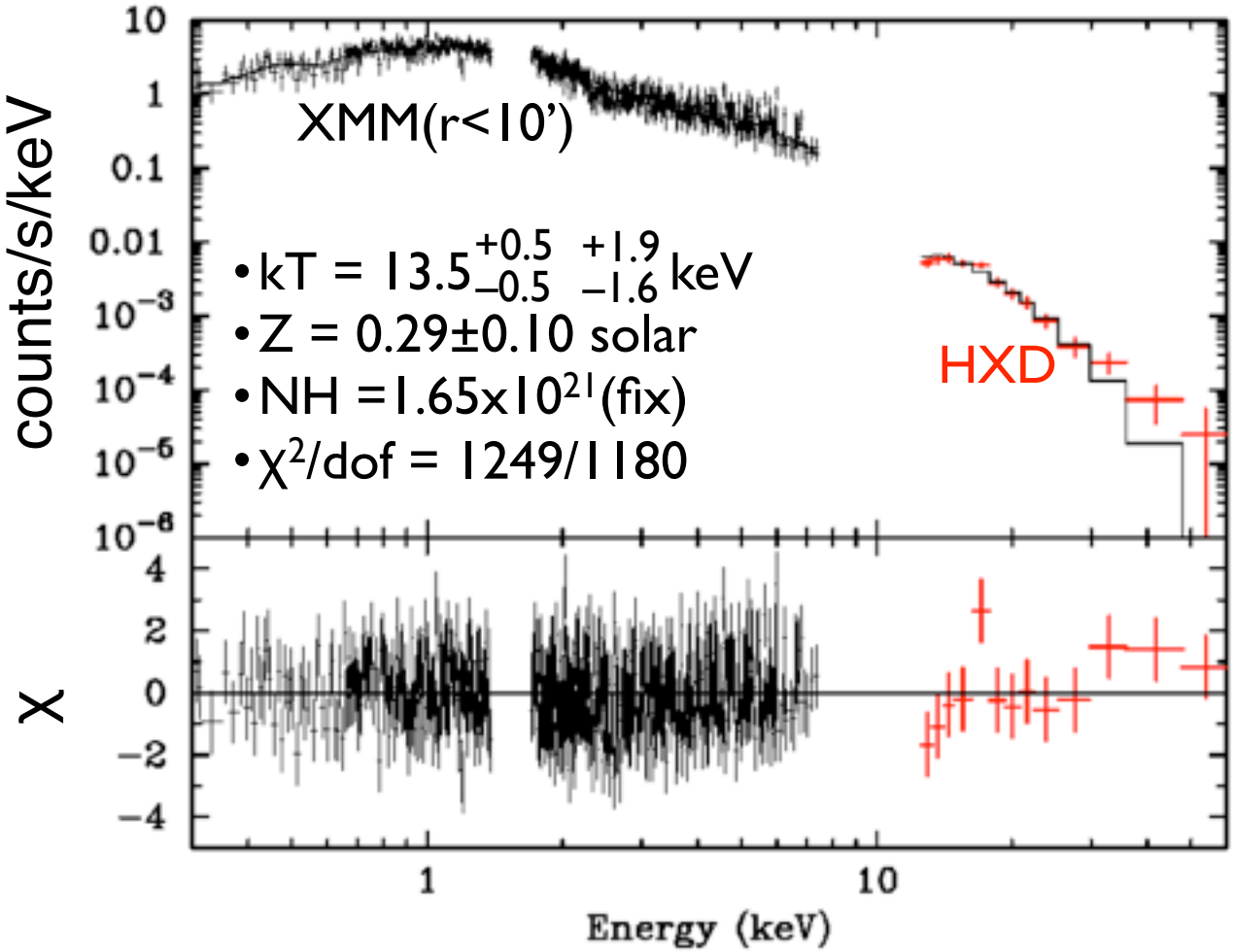

NXB, CXB subtracted
Point sources are negligible
NXB systematic error ~2%

>5σ significance

✤ 12–60 keV flux
F = 1.52 ± 0.06 (± 0.28) x $10^{-11}$ erg/s/cm$^2$

# XMM+HXD broad-band spectral analysis

✤ APEC model

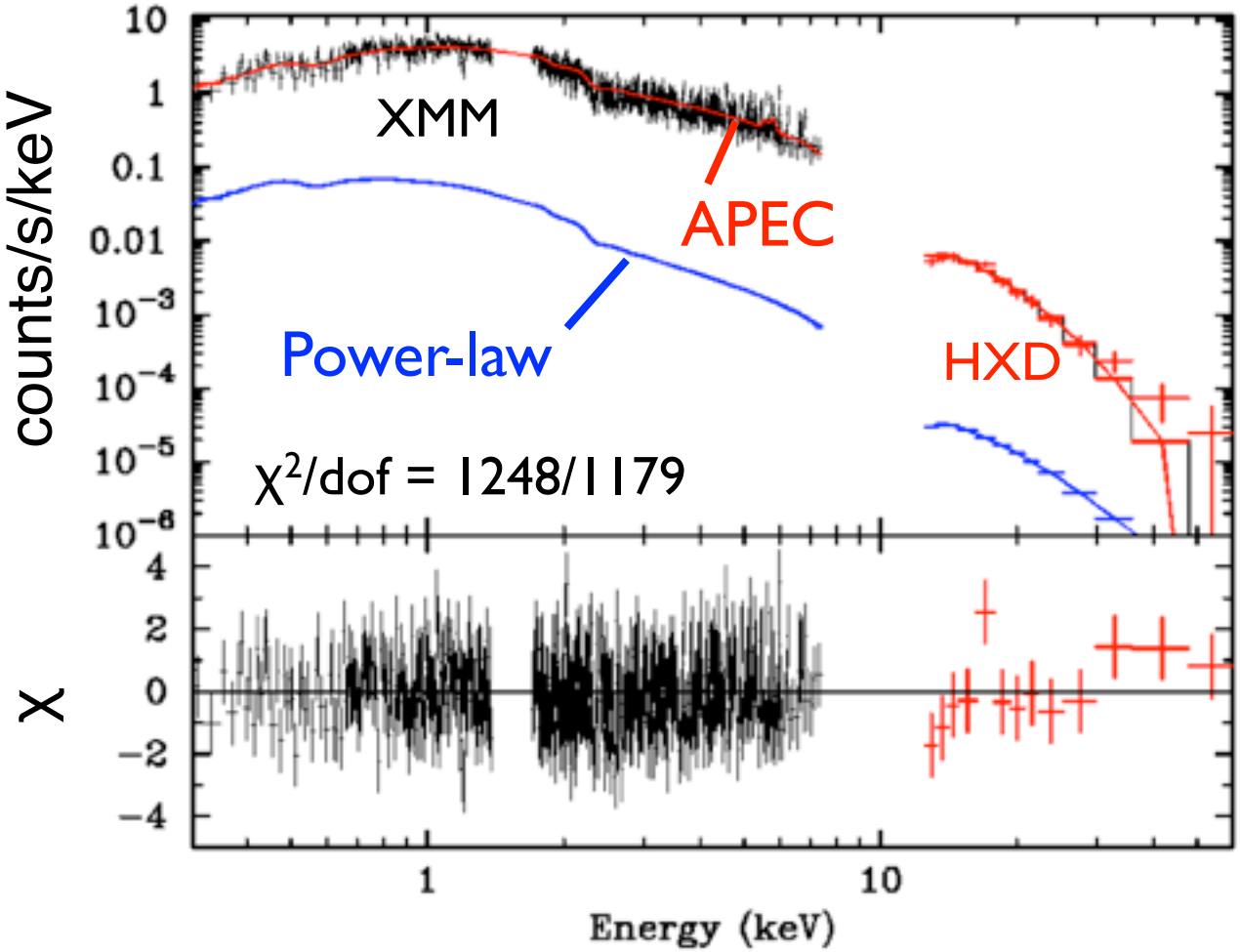



- 0.3~60 keV spectra can be fitted with a kT~14 keV thermal model

➡Hard X-ray emission is likely to be dominated by thermal emission

# Constraint on non-thermal emission

✤ APEC + Power-law with Γ=2.18 (the same index in radio; Feretti+04)




Free parameters
APEC: *kT*, *Z*, *norm*
Power-law: *norm*

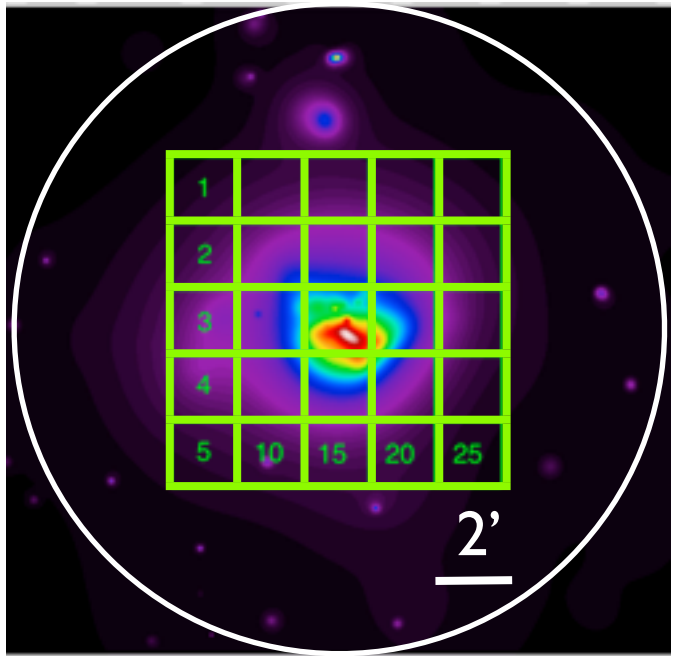
- No significant non-thermal emission in 12-60keV

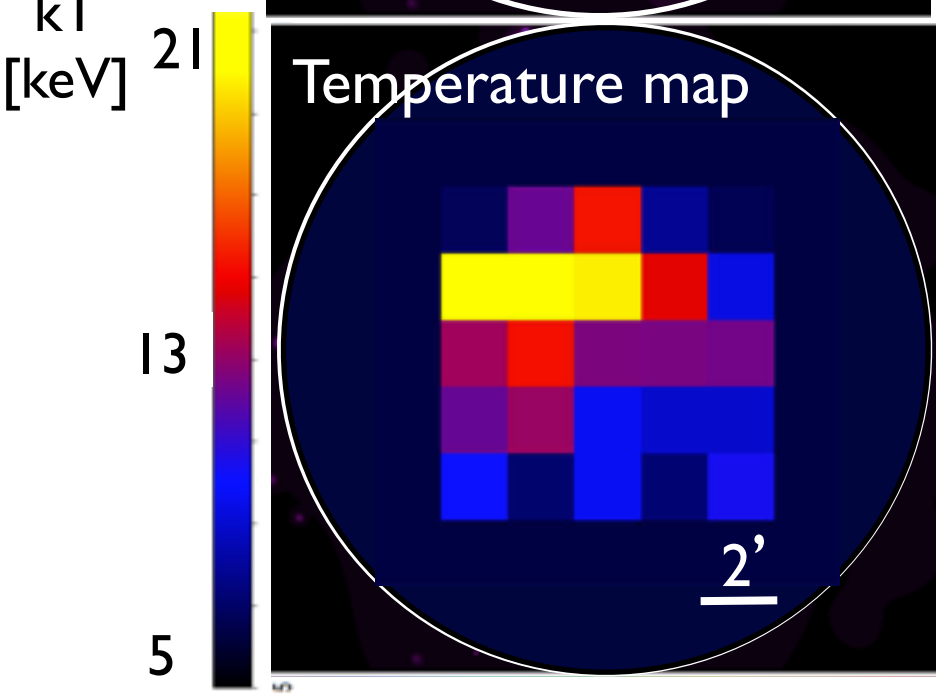
$F_{NT}$ < 1.2 x $10^{-12}$ erg/s/cm$^2$ for Γ=2.18 (90% upper limit)

$F_{NT}$ < 14.3 x $10^{-12}$ erg/s/cm$^2$ for Γ=1.5 (90% upper limit)

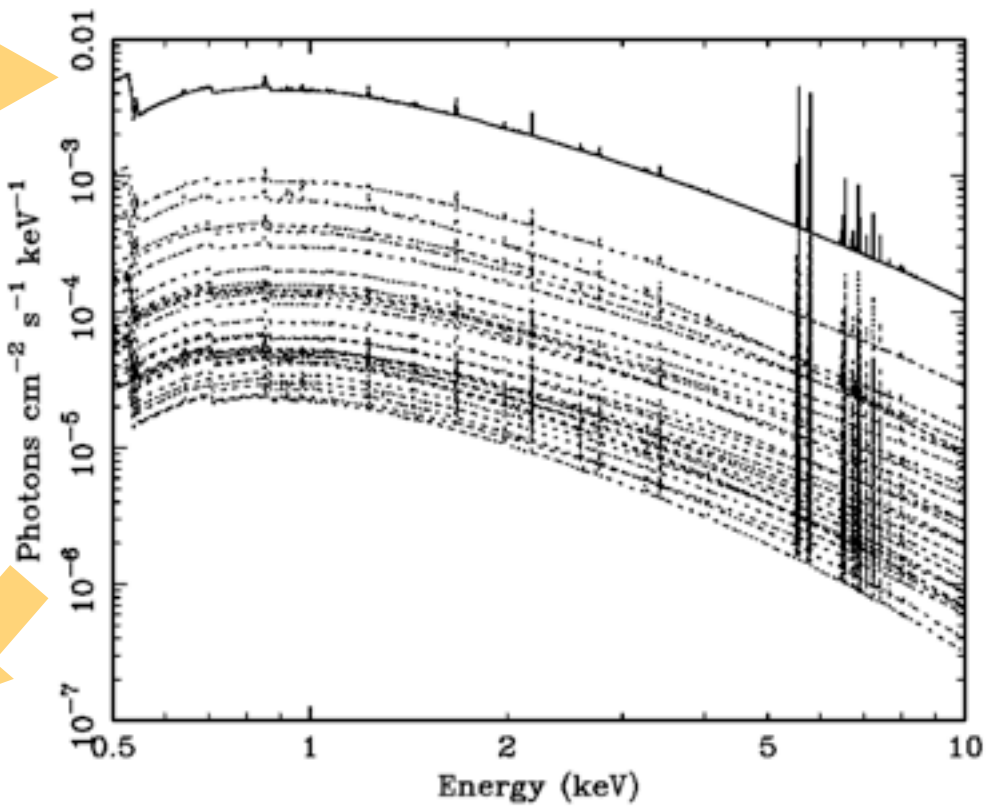
# Multi-temperature modeling with XMM

- Use XMM spectra in 2'x2' grids to construct the Multi-T model



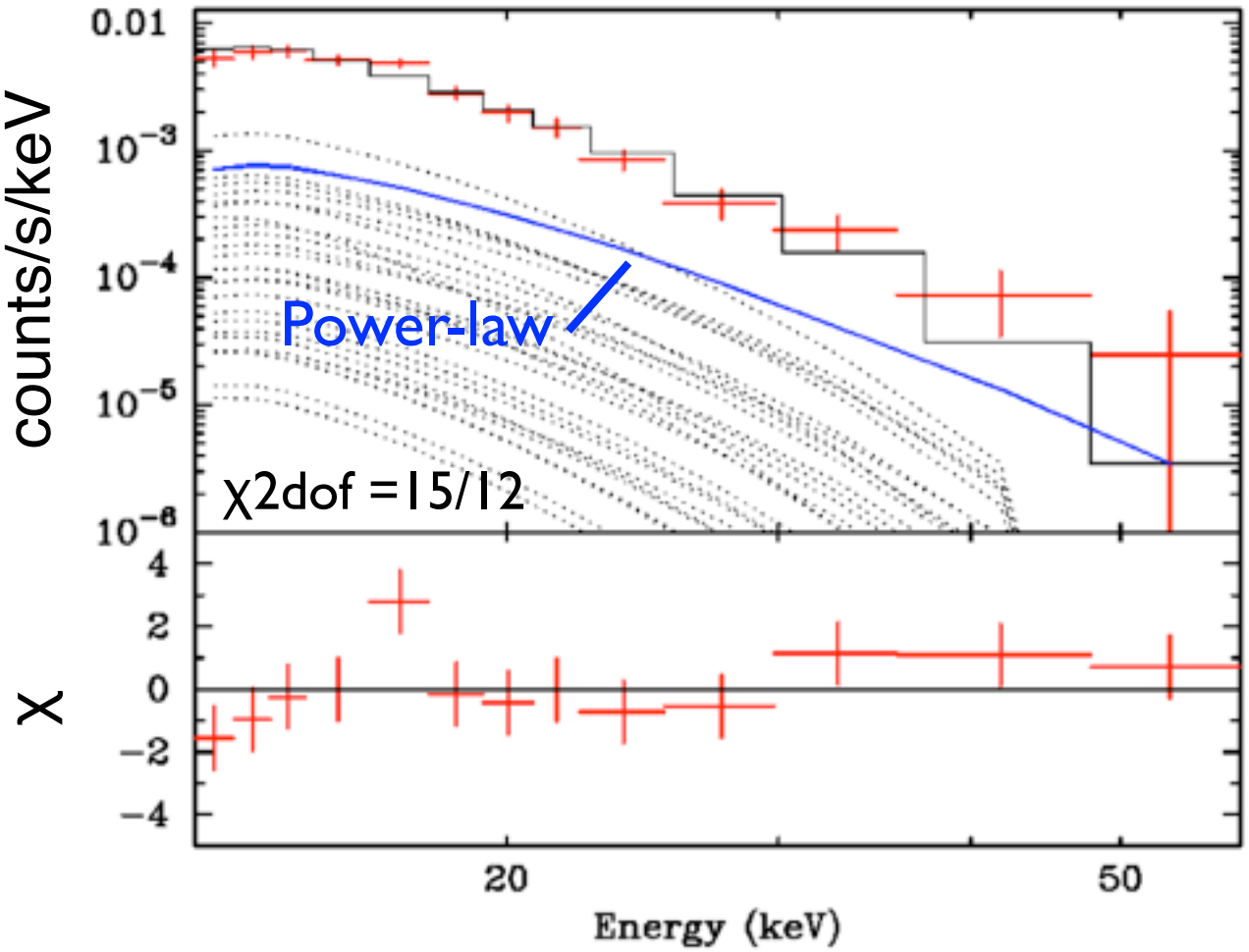

## Multi-T model




Temperature of the NE "shock" region:
$kT_{NE}$~18 keV, $L_{NE}$~5x$10^{44}$ erg/s

# HXD spectral fitting with Multi-T + Power-law model

✤ Multi-T APEC + Power-law




Multi-T model gives an acceptable fit to the PIN data. Additional power-law does not improve the fit

- The 90% upper limit on the non-thermal emission

$F_{NT} < 9.4 \times 10^{-12}$ erg/s/cm$^2$ for $\Gamma$=2.18

$F_{NT} < 12.8 \times 10^{-12}$ erg/s/cm$^2$ for $\Gamma$=1.5

3-times stronger constraint than RXTE

# Discussion

✤ Origin of hard X-ray emission from A2163

- Emission in the HXD band is well represented by the thermal models

- Very hot (~18 keV) gas in the NE shock contributes by ~15%

➡ The existence of high-temperature gas supports the scenario of recent ~0.5Gyr merger
(Bourdin+11; Takizawa+99; see also Ota+08 for the case of RXJ1347)

- We did not find any significant non-thermal hard X-ray emission

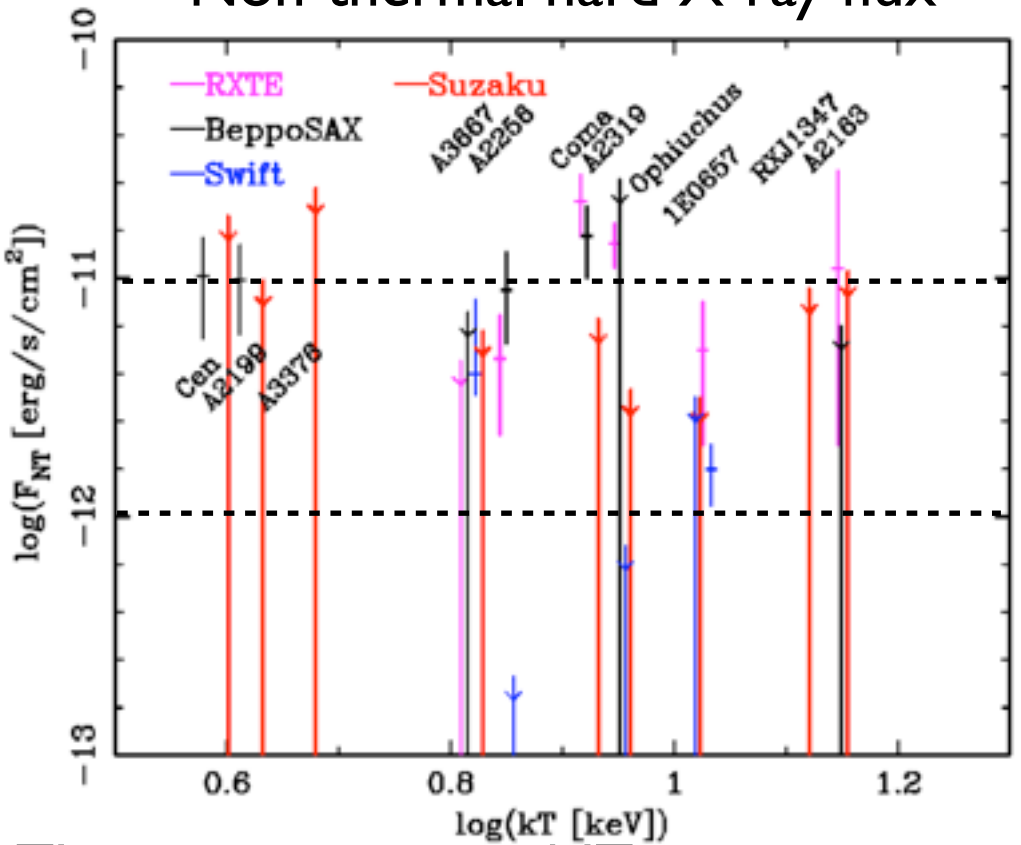
✤ Estimation of cluster magnetic field

- Using the relation $S_{IC}/S_{sync} = U_{CMB}/U_B$ & the radio flux $S_{syn}$=155mJy@1.4GHz,
  - $S_{IC} < 0.26$ μJy @12 keV → $B > 0.09$ μG for $\Gamma$=2.18
  - $S_{IC} < 0.20$ μJy @12 keV → $B > 0.006$μG for $\Gamma$=1.50

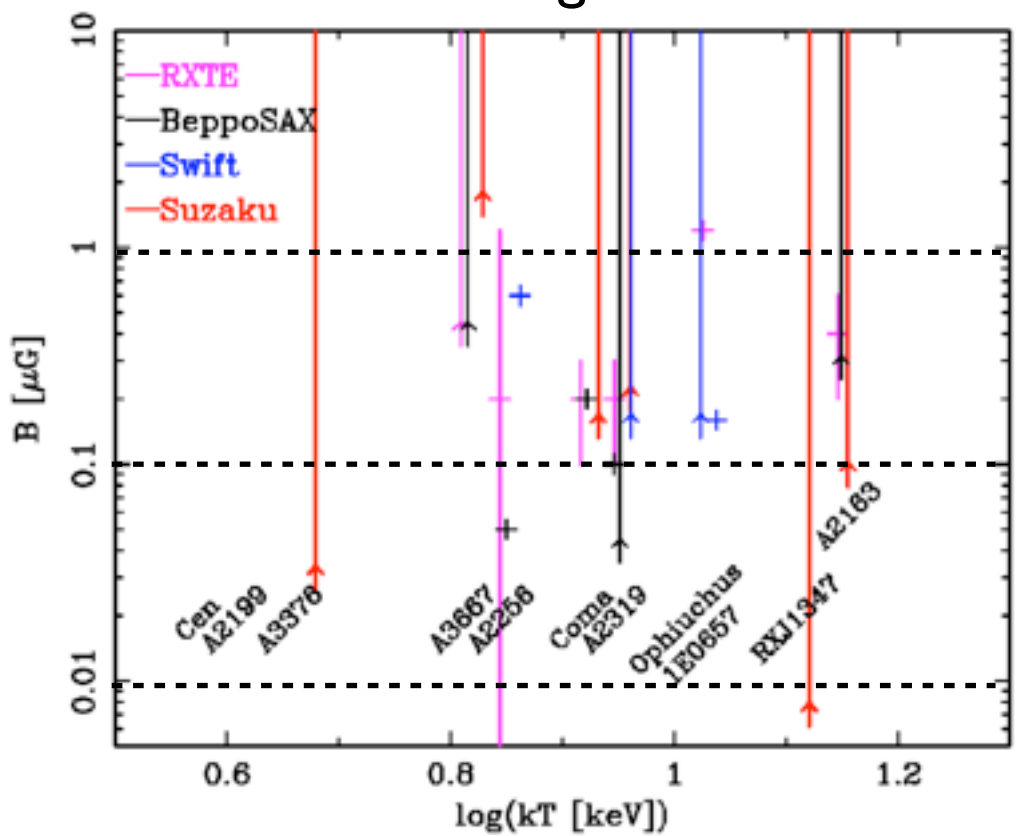
# Discussion #2

- Comparison with other clusters

## Non-thermal hard X-ray flux




## Cluster magnetic field




The upper limits on NT emission were reported in ~10 clusters with *Suzaku*

→ *no clear scaling relation is seen*

If B~1μG, x100 sensitivity is required to detect NT emission from A2163

RXTE & SAX (Rephaeli+08 review), Swift (Ajello et al. 09,10), Suzaku (Kitaguchi+07; Kawaharada+10; Kawano+09; Wik+09; Sugawara+09; Nakazawa+09; Fujita+08; Ota+08)

# Summary

✤ We have detected significant hard X-ray emission from A2163 with *Suzaku*

- From the XMM+Suzaku joint analysis, the hard X-ray emission is well represented by the single-T or multi-T thermal model
  - Very hot ($kT$~18 keV) gas in the NE shock contributes by ~15%
- Non-thermal X-ray flux is tightly constrained as $F_{NT} < 9 \times 10^{-12}$ erg/s/cm$^2$
  - thermal emission is dominant at hard X-ray

  →*determination of thermal component to high accuracy is indispensable!*
- Magnetic field in A2163 is estimated to be $B > 0.09$ μG

✤ What's next?

- Study more detailed property of shock-heated gas in the A2163 NE
- Application of this method to other clusters

✤ ASTRO-H!

- Imaging ability at hard X will enable
  - more accurate measurement of high-T thermal component which will dominate in hard band & identification of shock region to get higher S/N

  → detection of IC to B ~ 1μG level