Suzaku observations of clusters of galaxies

Kyoko Matsushita

- Advantages of Suzaku XIS observations
  - low background
  - good energy resolution at low energy band
  - O and Mg abundances of ICM

The fornax cluster (Matsushita et al. 2007), A1060 (Sato et al. 2007)
AWM7, HCG62, NGC 507 group (Sato et al. 2007)

  - Temperature profiles of ICM

A1060 (Sato et al. 2007), AWM7 (Sato et al. 2007)

  - Non-detection of bulk-motions

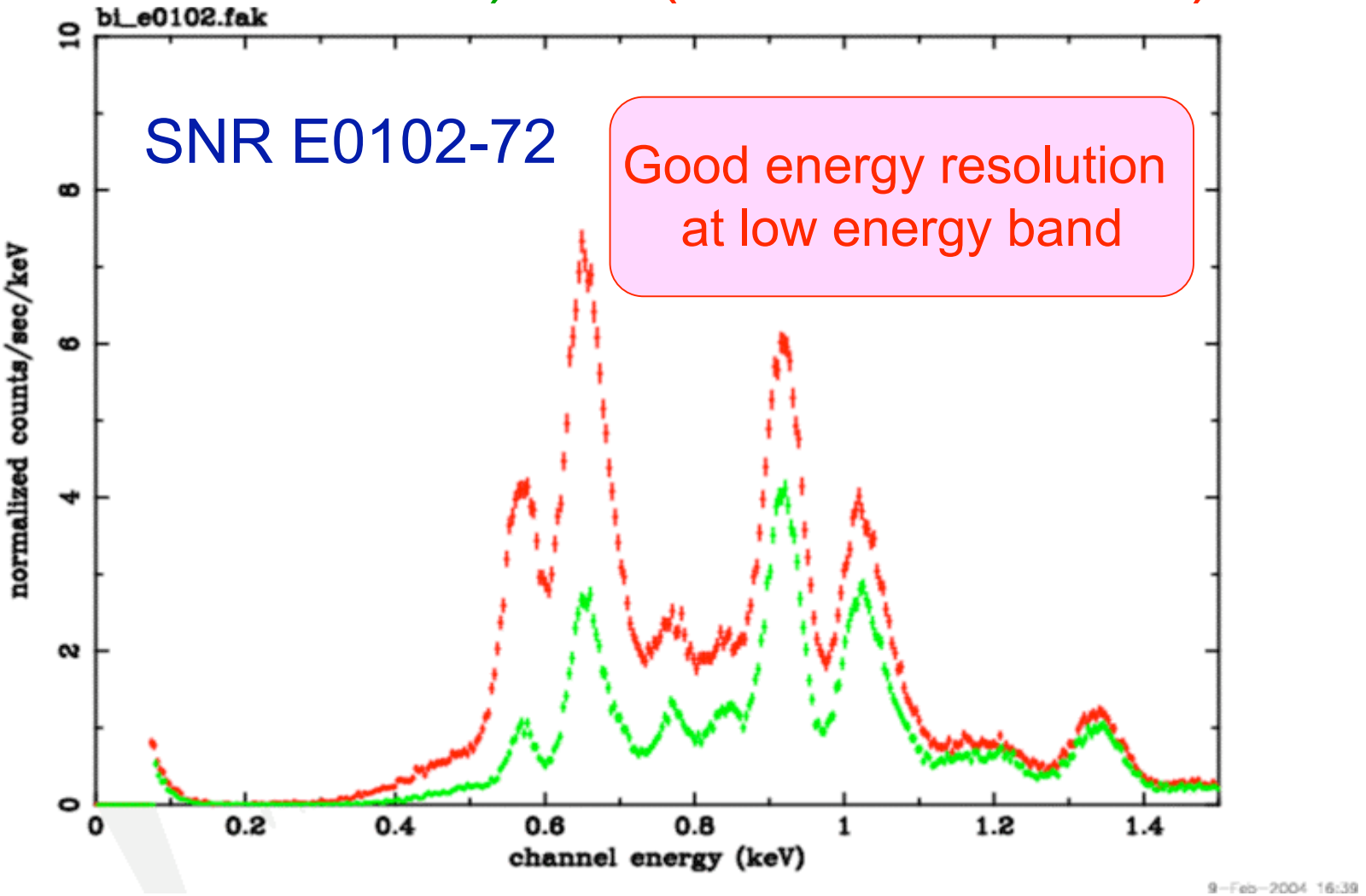
Centaurus cluster (Ota et al. 2007), AWM7, etc.

- Suzaku HXD
  - Upper limit of hard X-ray component

A3376(Kawano et al.),
A1060, Centaurus (Kitaguchi et al. 2007 - poster)

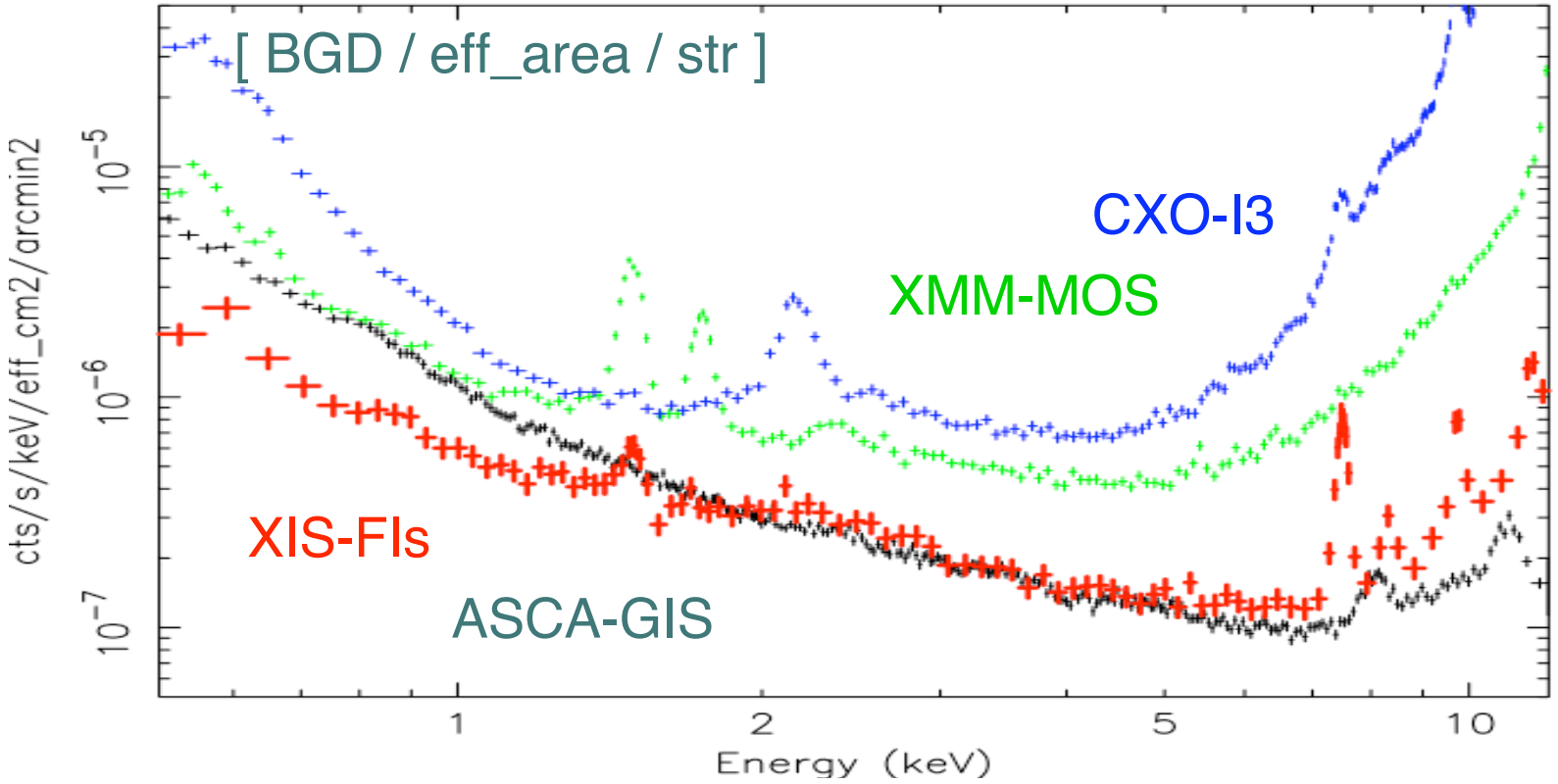
Suzaku XIS

3 FI (front illuminated), 1BI(back-illuminated)



Background of the XIS

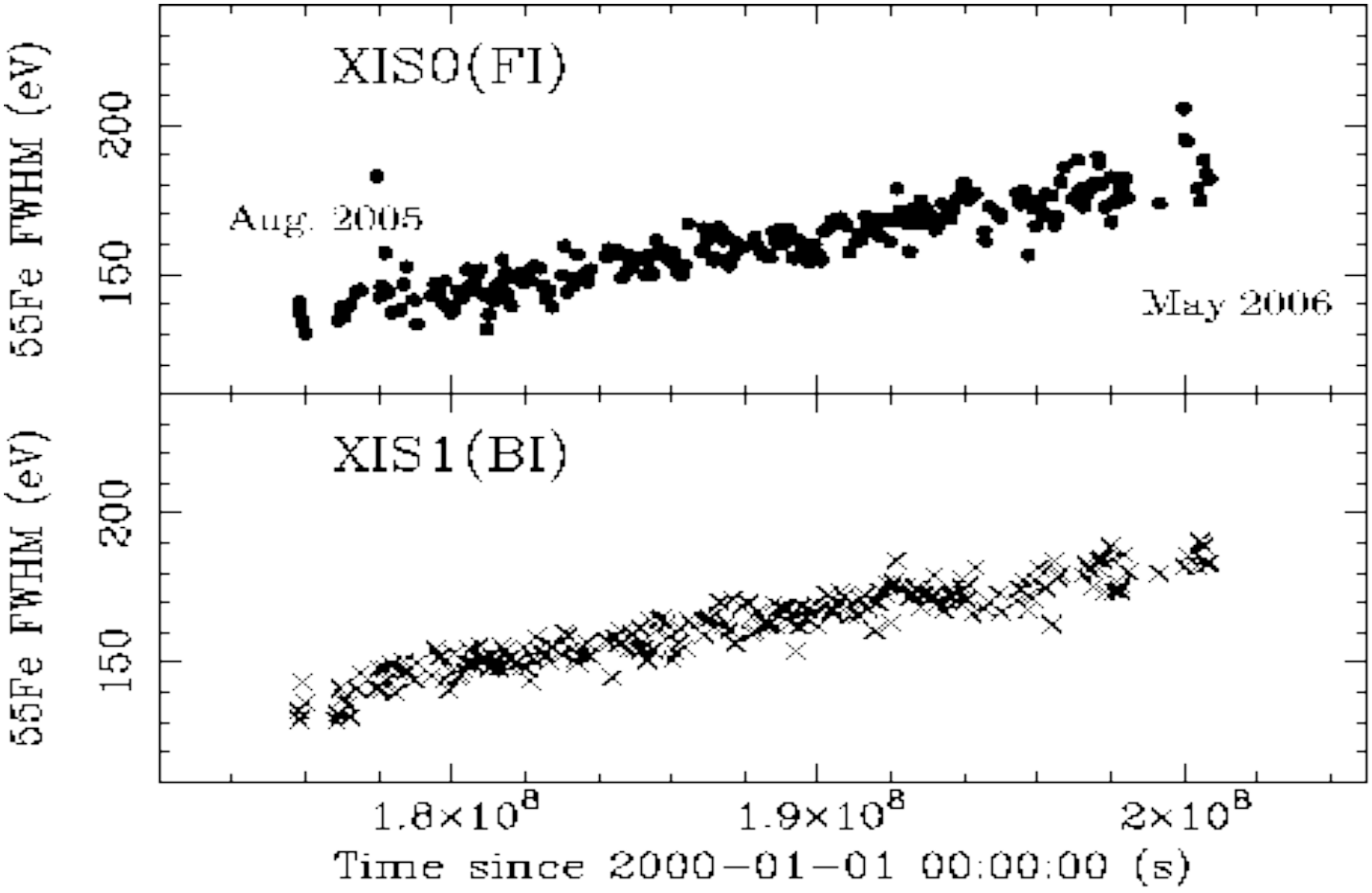
The lowest "*diffuse*" BGD



Among the largest eff. Area

Powerful tools for diffuse survey

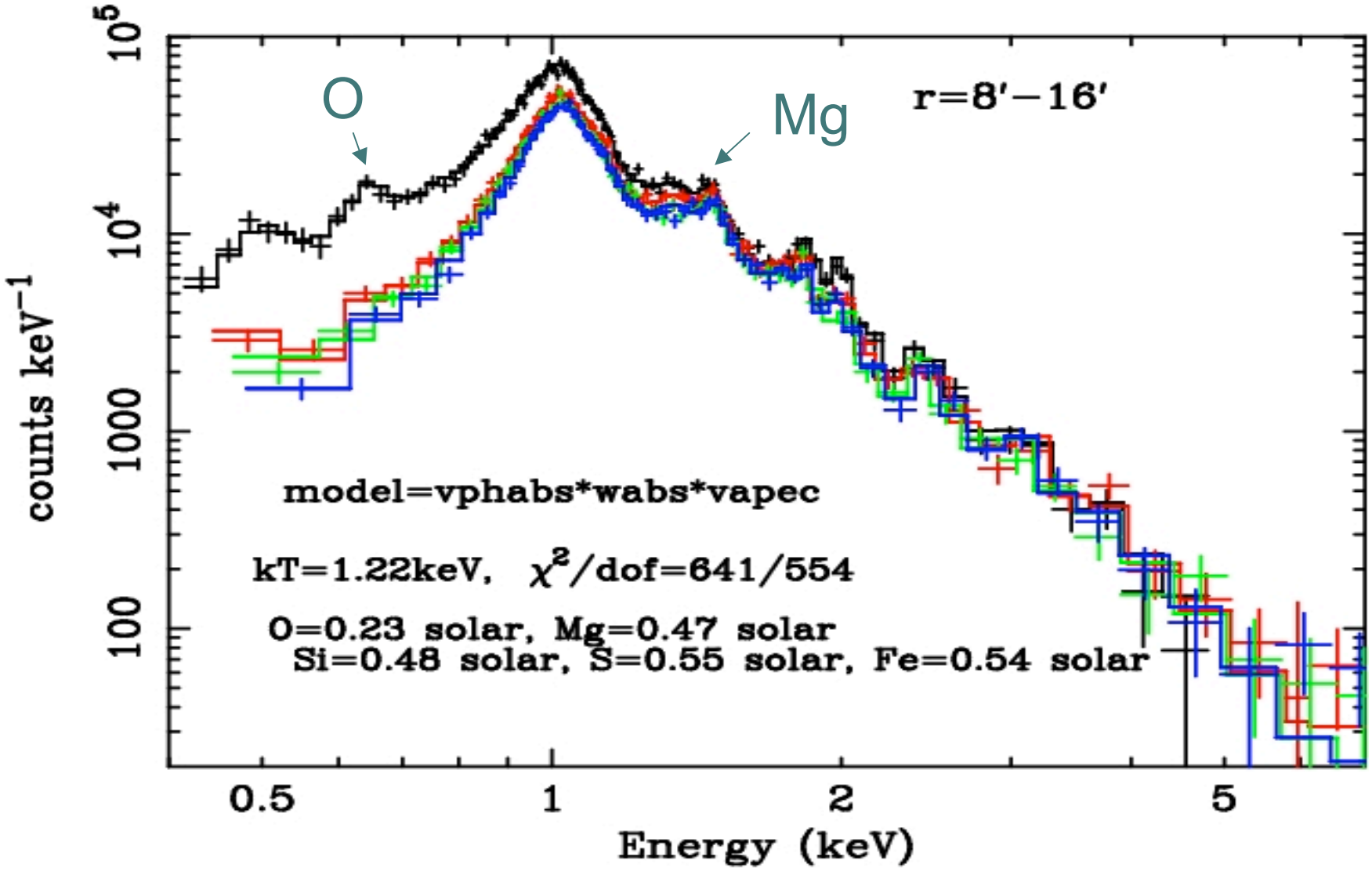
The time history of the energy resolution



With Charge-Injection mode,
energy resolution – 140-150 eV

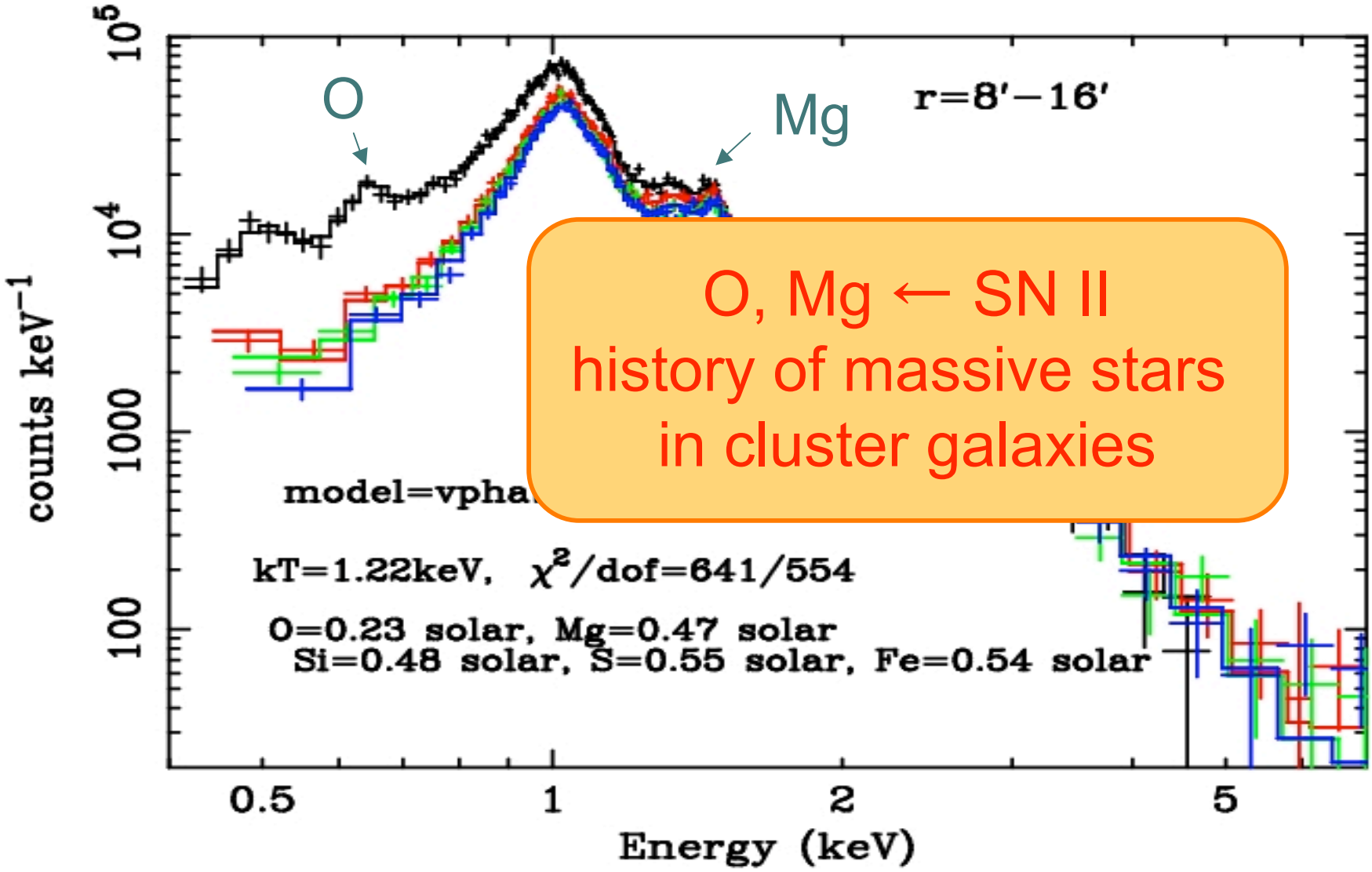
O and Mg abundances

Spectra of the Fornax cluster



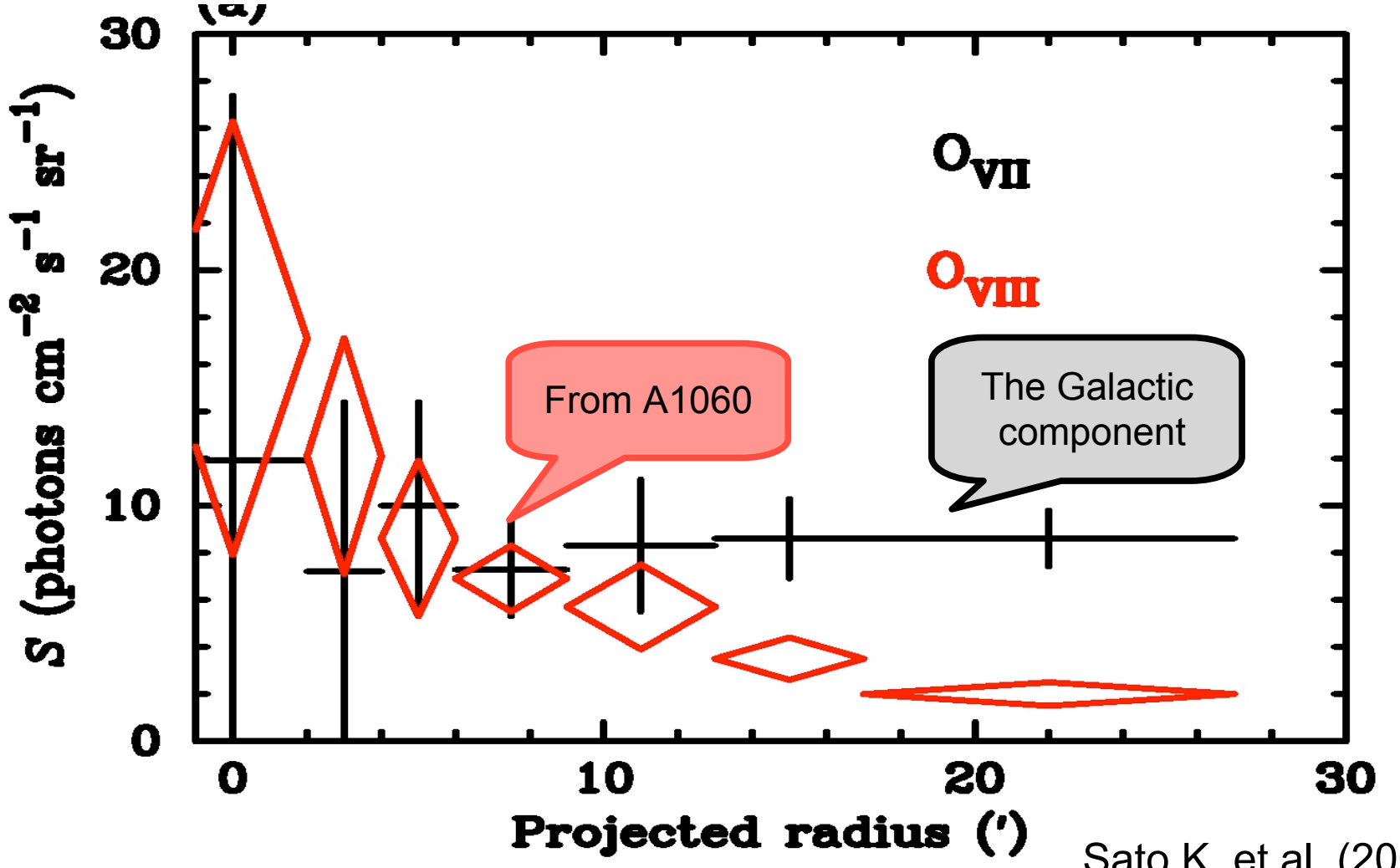
O and Mg abundances

Spectra of the Fornax cluster



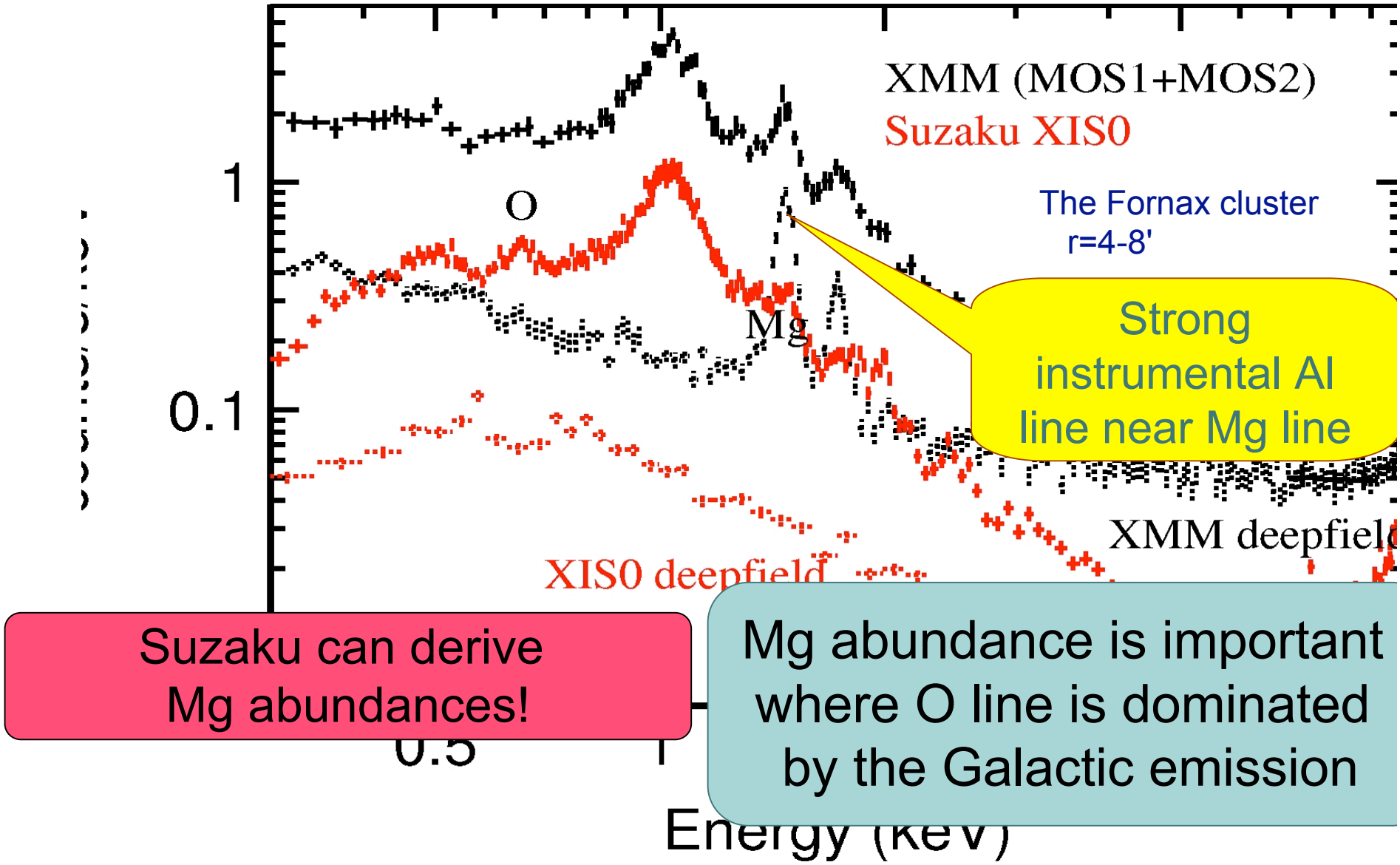
The effect of the Galactic componen

Surface brightness of OVII, OVII lines of A1060

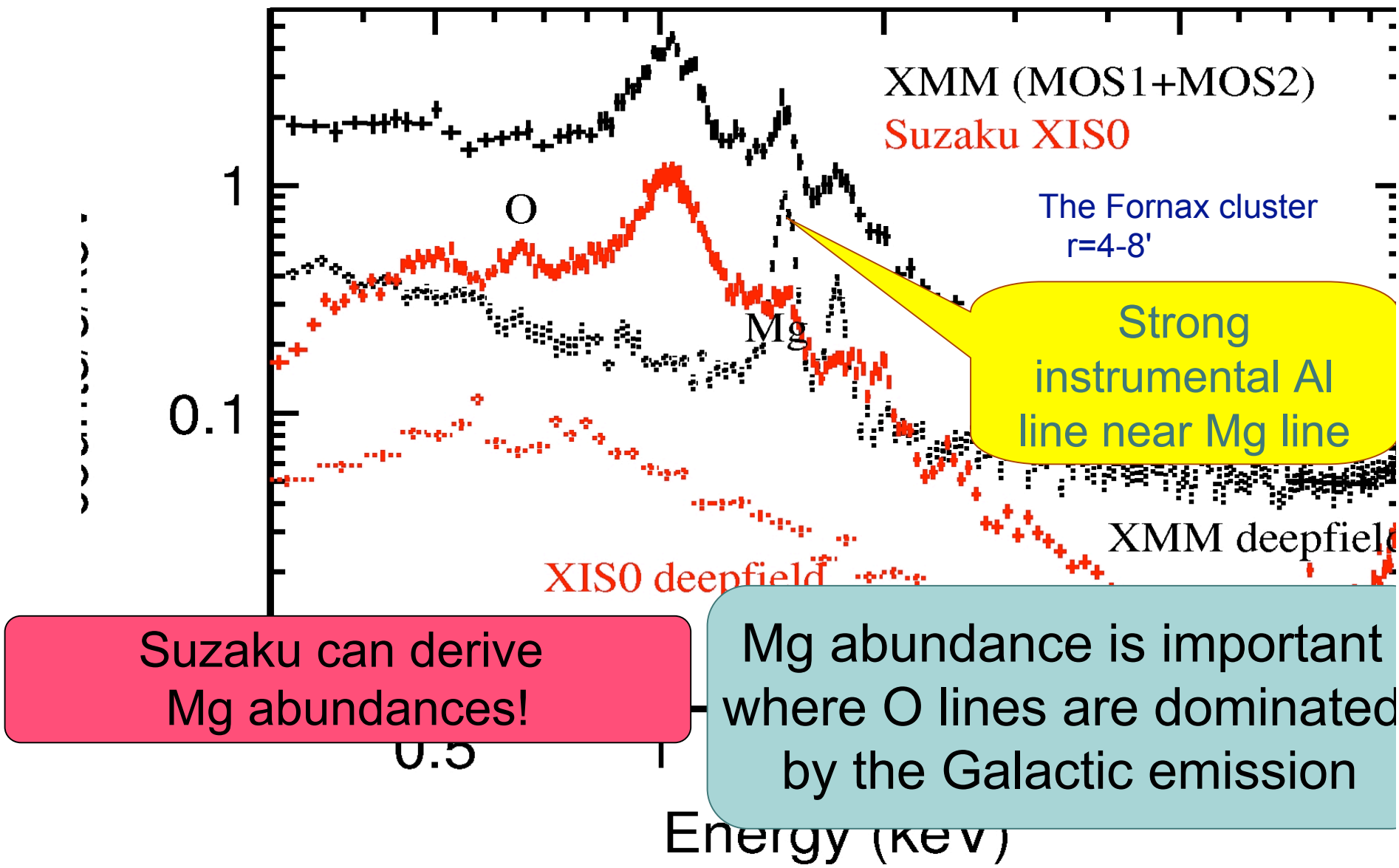


Sato K. et al. (2007)

Mg abundance of ICM

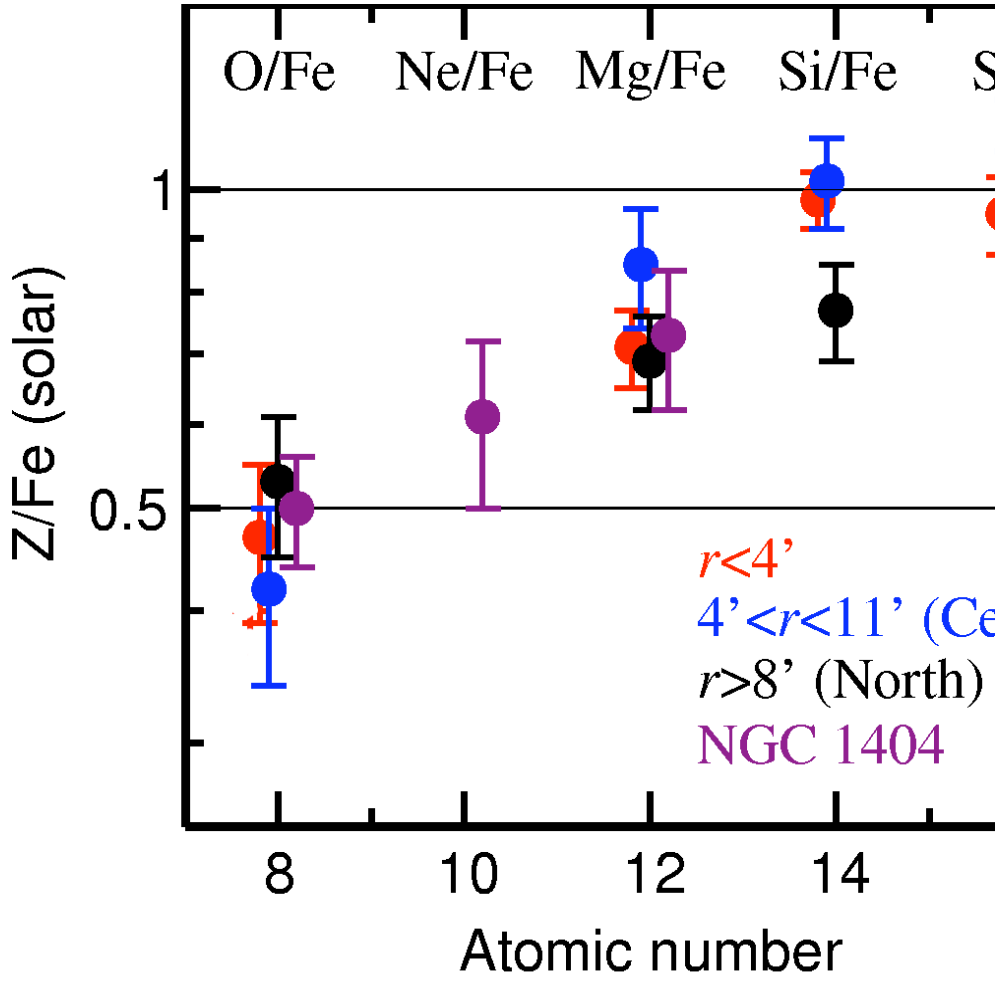


Mg abundance of ICM



Abundance pattern of the Fornax cluste

- cD, E, ICM
  - similar abundance pattern
  - Low O abundance
- Similar pattern with those in the center of clusters observed with XMM
- Suzaku can derive O and Mg abundances in the ICM



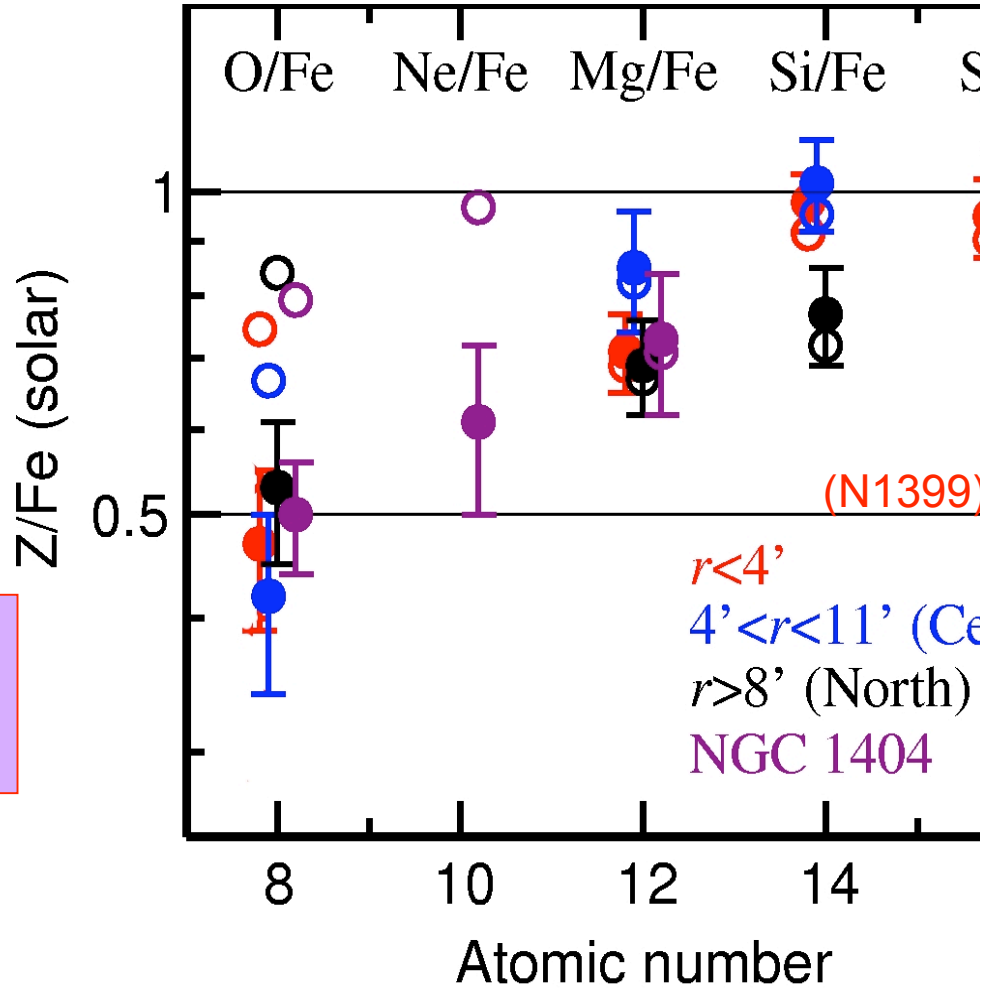
Solar abundance by Feldman (1992)

New solar abundance

Solar abundances of C, N,O, and Ne decreased by 0.2 dex considering 3D atmospheres and non-LTE (Asplund 2005)

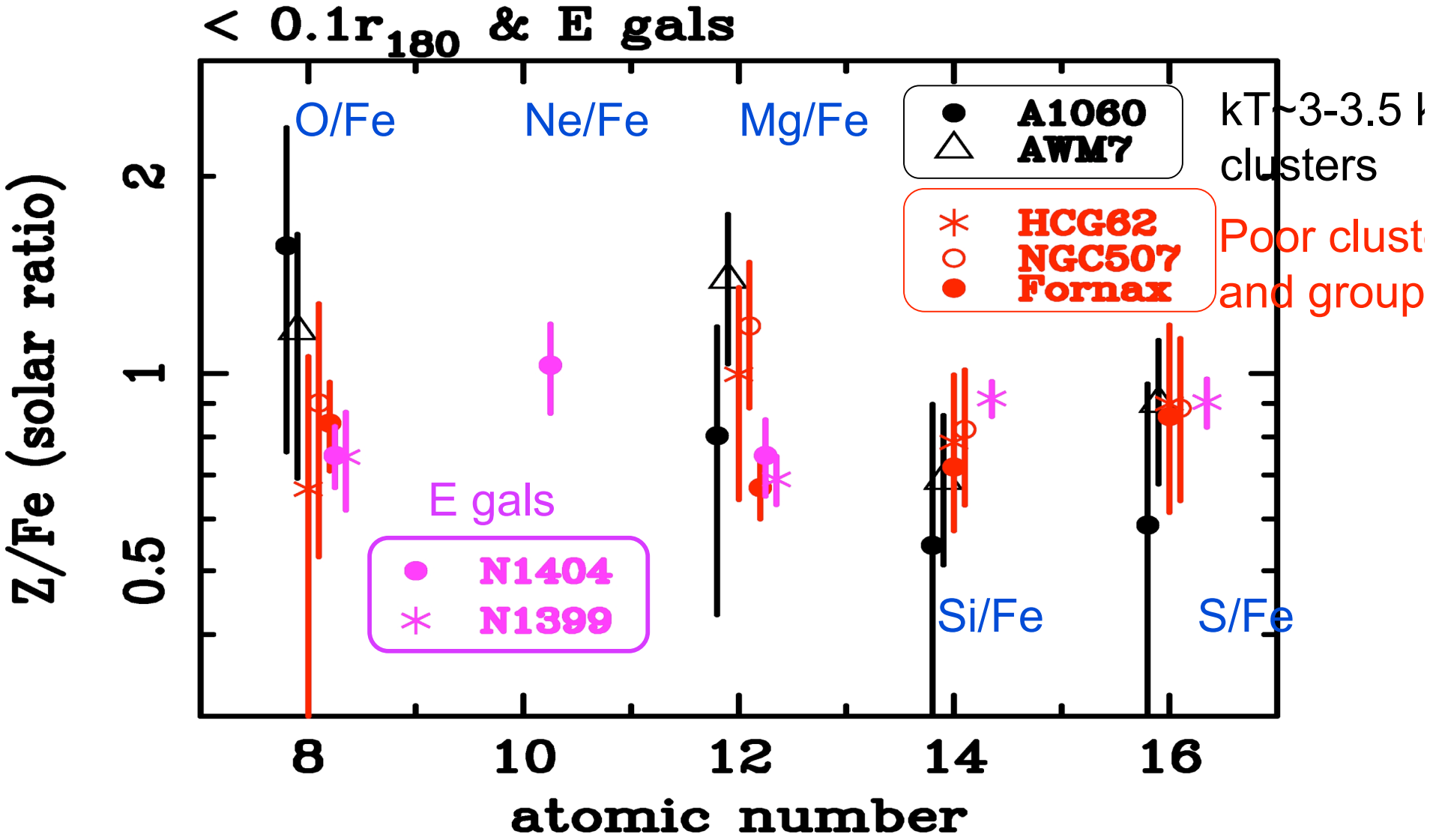
O/Ne/Mg/Si/S/Fe ratios
≃1 solar

Similar nucleosynthesis by SN Ia and SN II to our Galaxy?



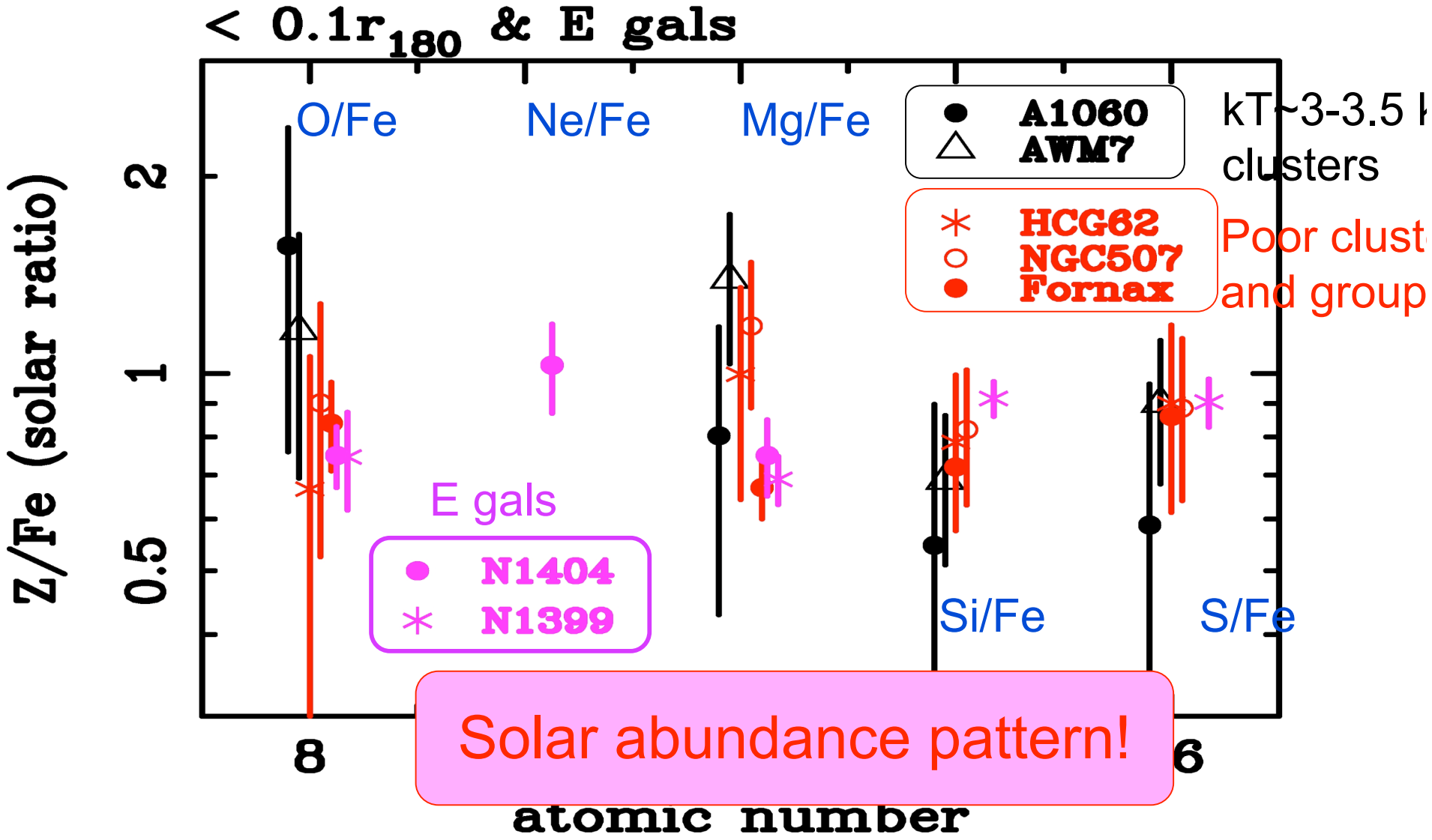
●: solar abundance by Feldman (1992)
○: solar abundance by Loddars (2003)

Abundance pattern of ICM and ISM of E gals



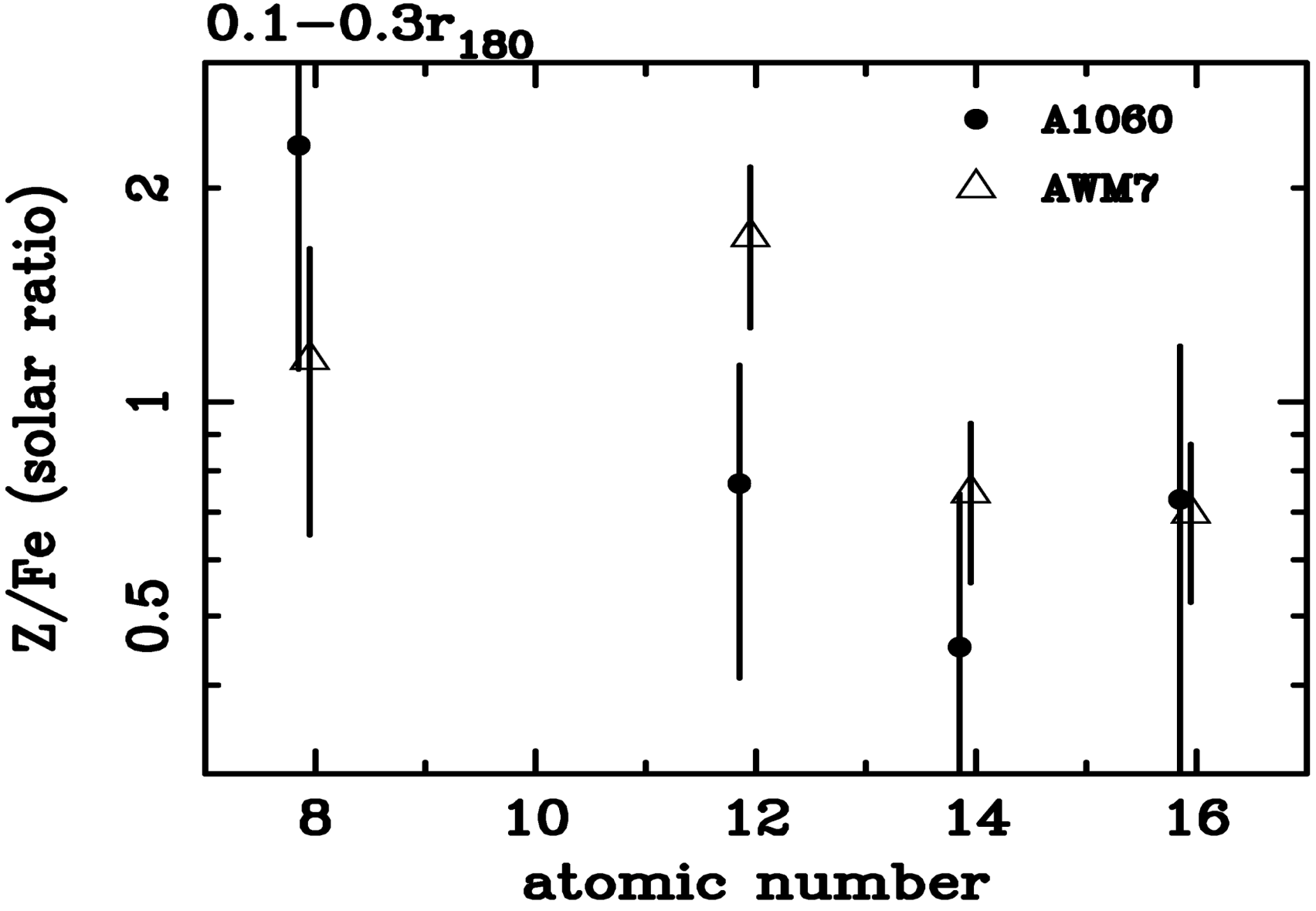
solar abundance by Loddars (200

Abundance pattern of ICM and ISM of E gals

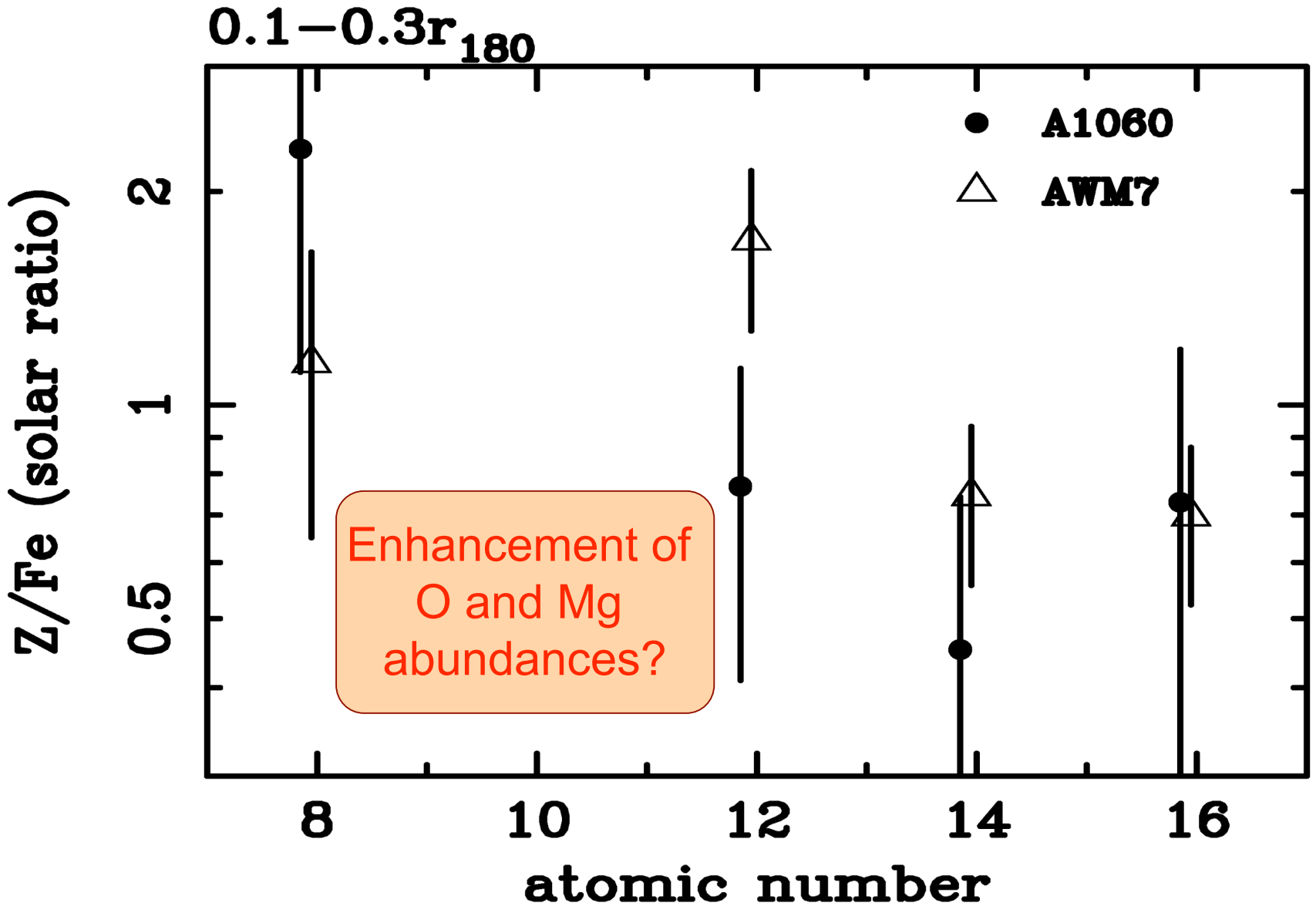


solar abundance by Loddars (200

Abundance pattern at 0.1-0.3 r_{180}



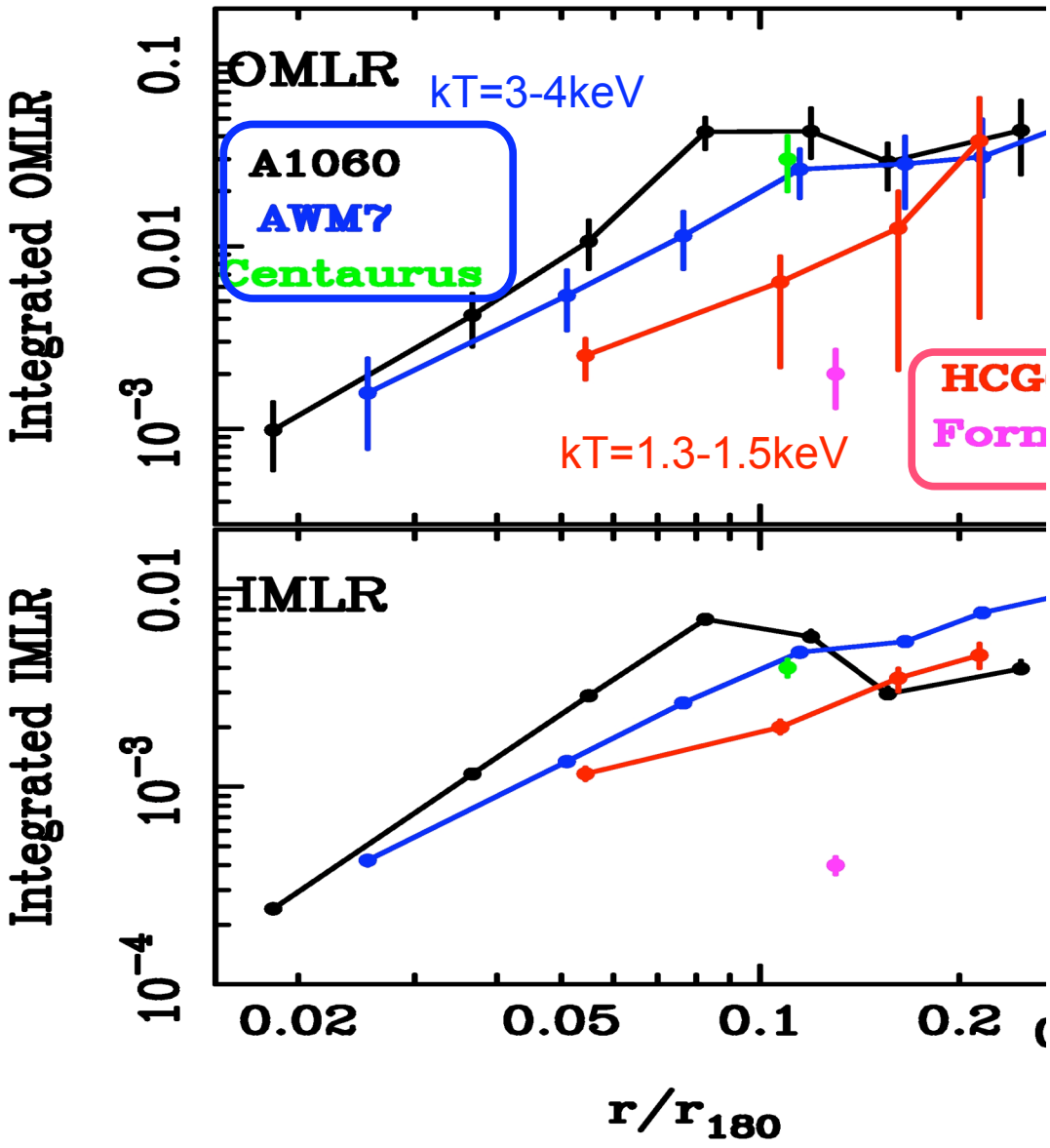
Abundance pattern at 0.1-0.3 r_{180}



O and Fe mass to light ratios (OMLR&IMLR)

>0.1-0.2r_{180}
IMLR&OMLR
become constant

Poor clusters, groups
Small IMLR and OMLR



Small OMLR, IMLR in the Fornax cluster

Chandra image of the Fornax cluster (Scharf et al. 2004)

- Gas mass/stellar luminosity of the Fornax cluster is small
  - ICM in poor cluster is more extended than those in rich clusters
    - Excess entropy and heating
  - Metal distribution may be used as a tracer of histor of history of heating since timescales of metal enrichment and heating determine the metal distribution.
- In the Fornax cluster, ICM and ISM have the same abundance pattern
  - ⇒part of O and Mg come from stellar mass loss?
  - Most of O from old SN II may lie beyond?

Summary of O and Mg abundances

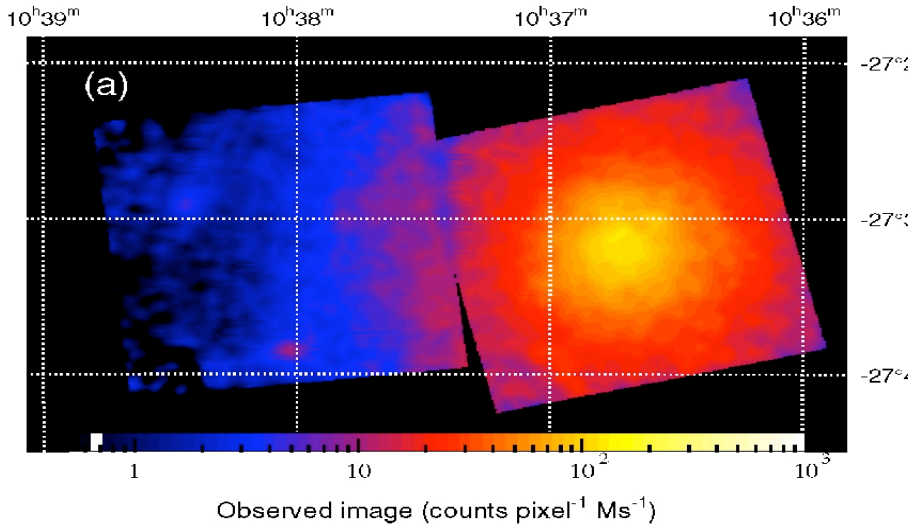
- O and Mg were synthesized by SN II
  - reflect history of massive stars in clusters
- Suzaku can derive O and Mg abundances
- Using the new solar abundances, O/Mg/Si/S/Fe ratios of ICM within $0.1r_{180}$ and ISM in E gals are solar abundance ratios
  - Similar nucleosynthesis to our Galaxy?
- Enhancement of SN II/SN Ia at $> 0.1r_{180}$?
- IMLR and OMLR are smaller in groups and poor clusters
  - Most of the metals may be outside of the observed region
  - History of ICM

Temperature profiles

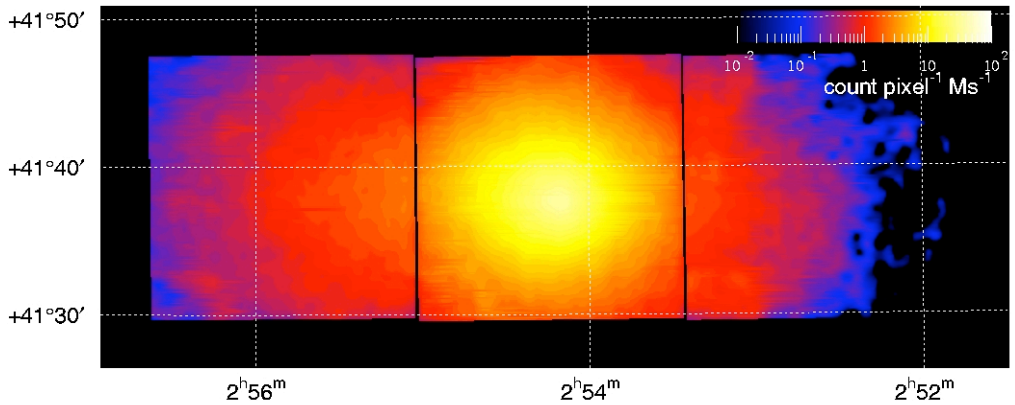
- A1060 Sato K. et al. (2007)
  - steep temperature gradient
- AWM7 Sato K. et al. in prep.
  - Flat temperature profile
- Other clusters in SWG time
  - A2052 Tamura et al. in prep.
  - A1795 up to virial radius
  - A1413 up to virial radius

Temperature profiles of A1060 and AWM7

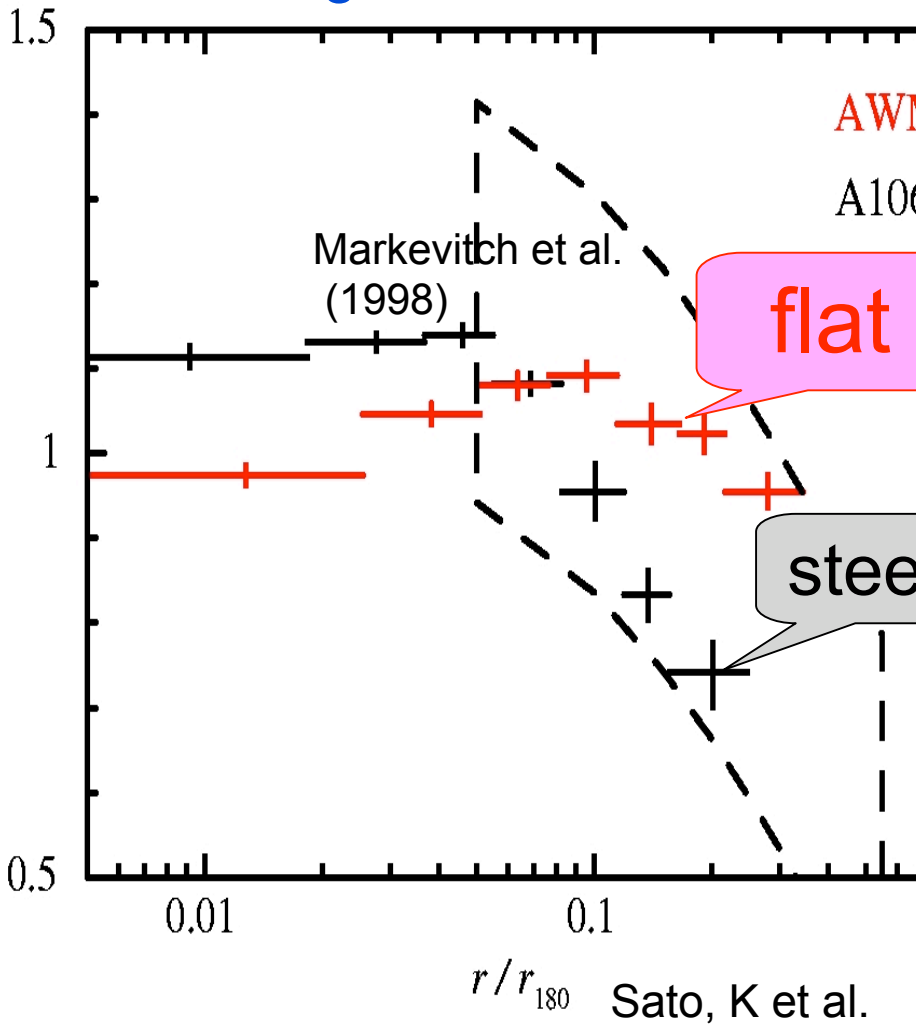
- A1060 non-cD k<T>=3.0keV



- AWM7 cD k<T>=3.5keV



regular clusters



Absence of bulk motions in the ICM

Centaurus cluster

Chandra

velocity gradient of

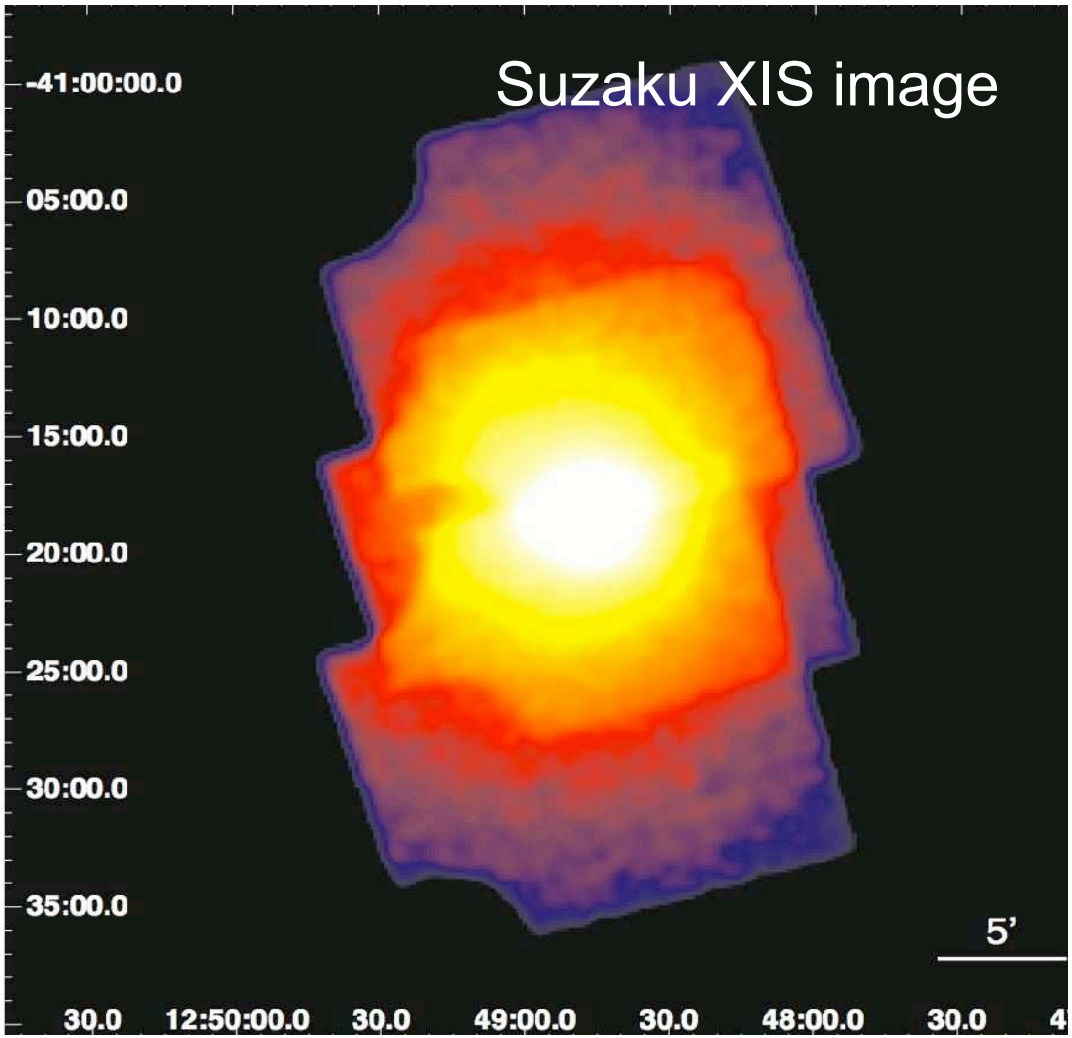
2400±1000 km/s

100 kpc scale

(Dupke & Bregman 2001)

Suzaku

Ota et al. 2007



Absence of bulk motions in the ICM

Centaurus cluster

Chandra

velocity gradient of

2400±1000 km/s

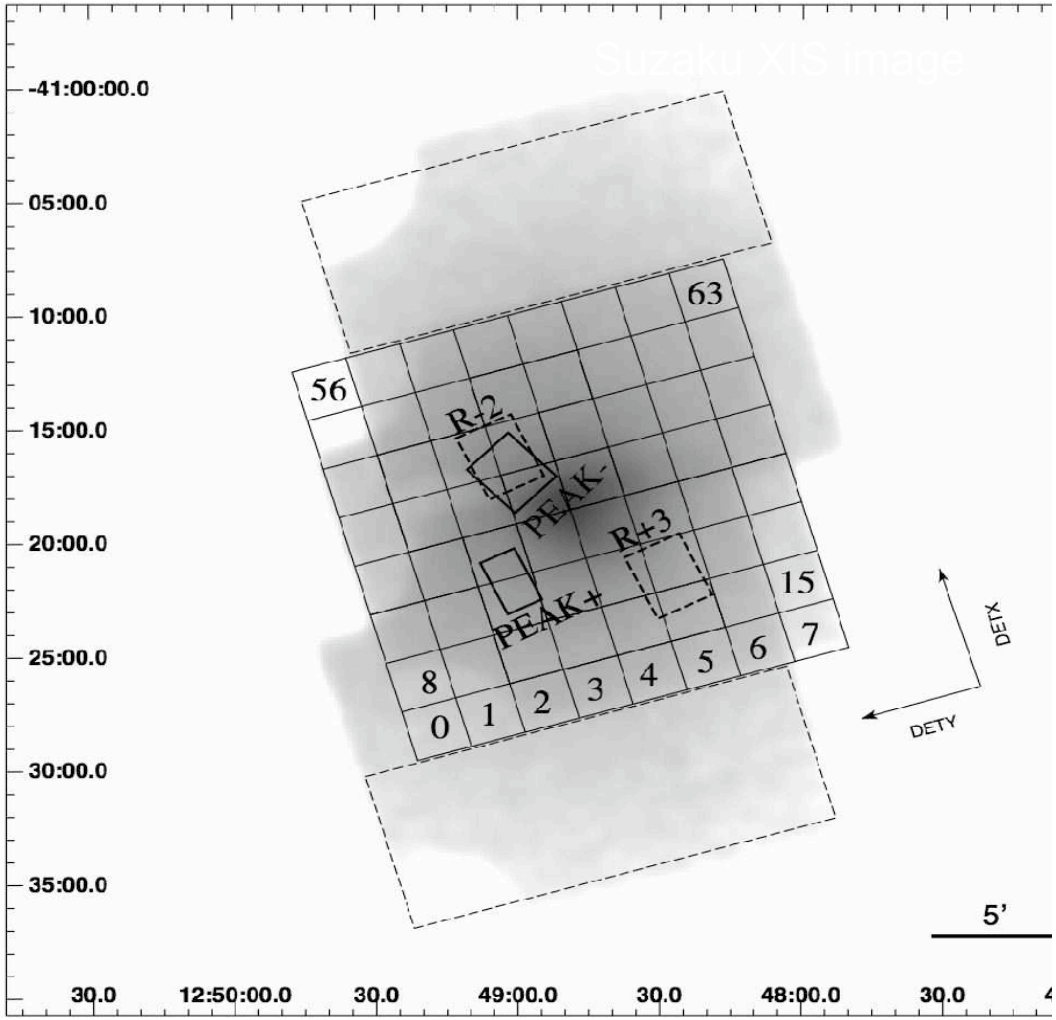
100 kpc scale

(Dupke & Bregman 2001)

Suzaku

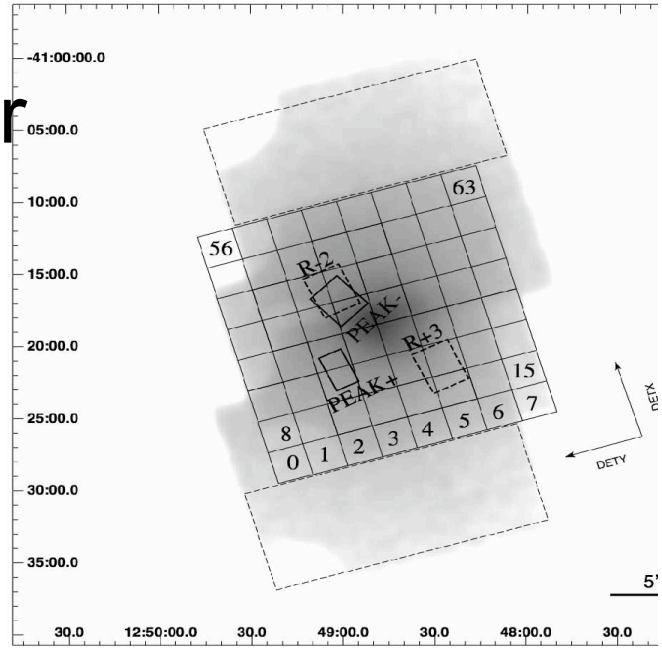
velocity of 64 cells

Ota et al. 2007

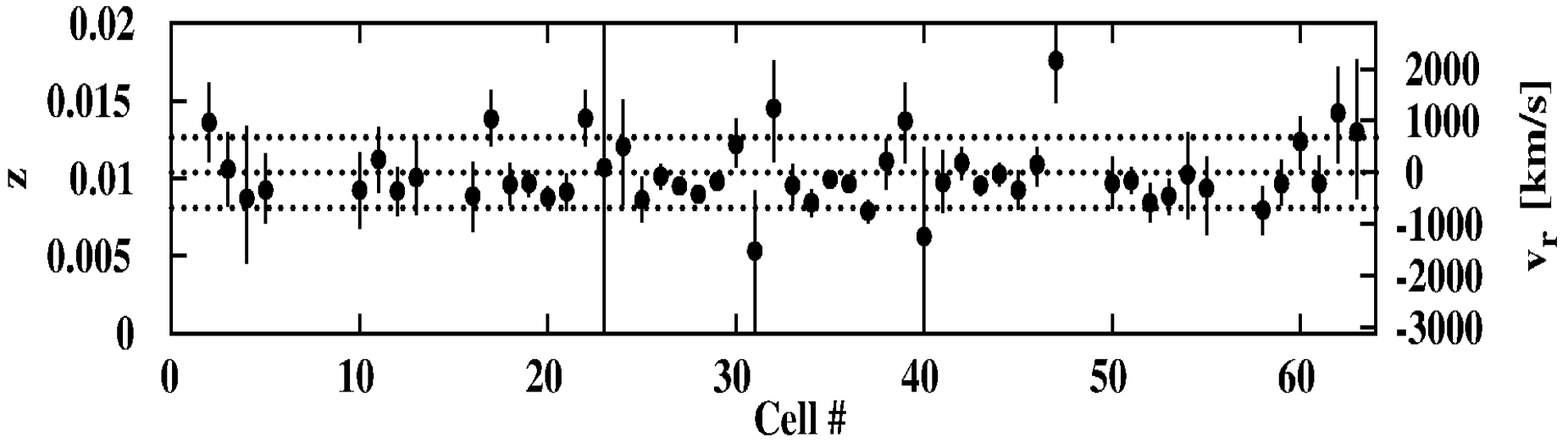


Absence of bulk motions in the ICM

- |Δv|<1400km/s in the Cen cluster
  (systematic error of the gain)



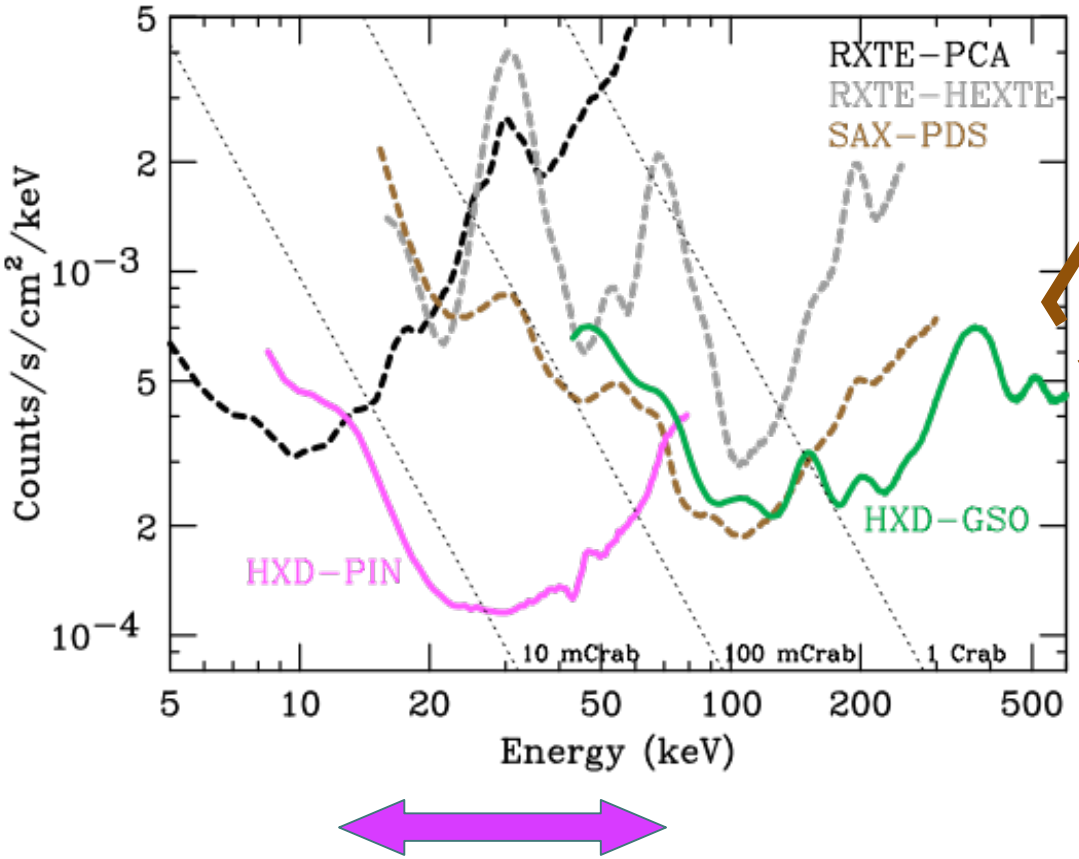
- Absence of bulk motions in
  other clusters



Suzaku Merits in hard X-ray surveys

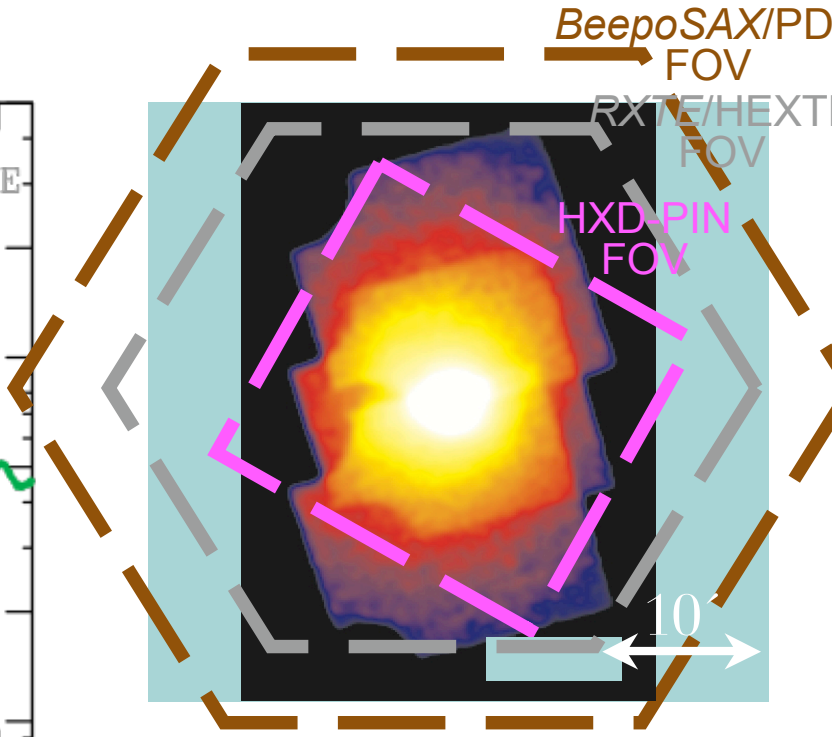
Residual background level

(Kokubun et al., 2006)



The lowest background

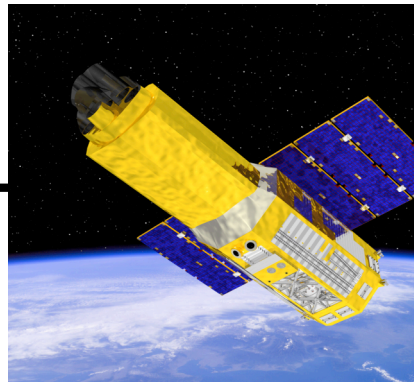
Narrower Field of View



Suzaku/XIS image of the Centaurus cluster

(Ota et al., 2006)

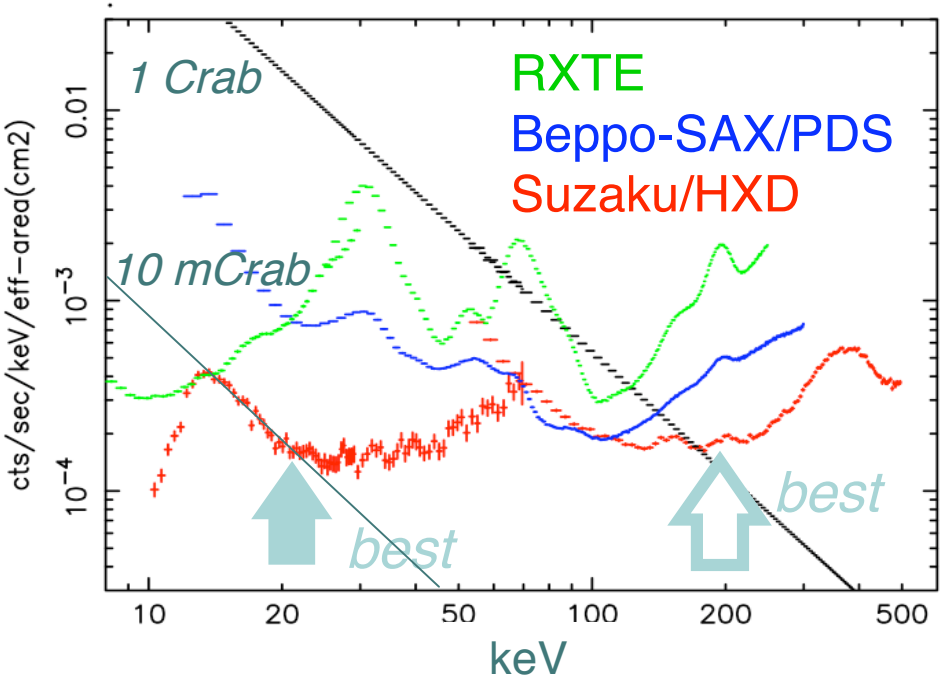
Suzaku Merits in hard X-ray surveys



The HXD

Wide-band, high sensitivity

The lowest BGD



0.3 mCrab 10-40 keV
with BGD sys. = 3%

Narrower Field of View

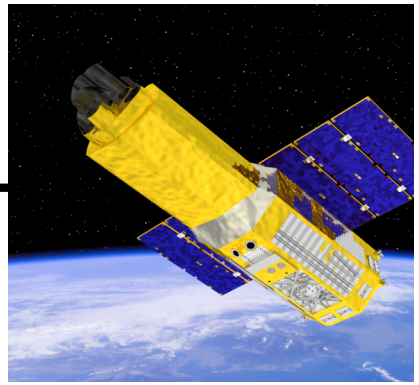
0.55 deg

BGD statistic
& systematic err ↓

Contamination ↓

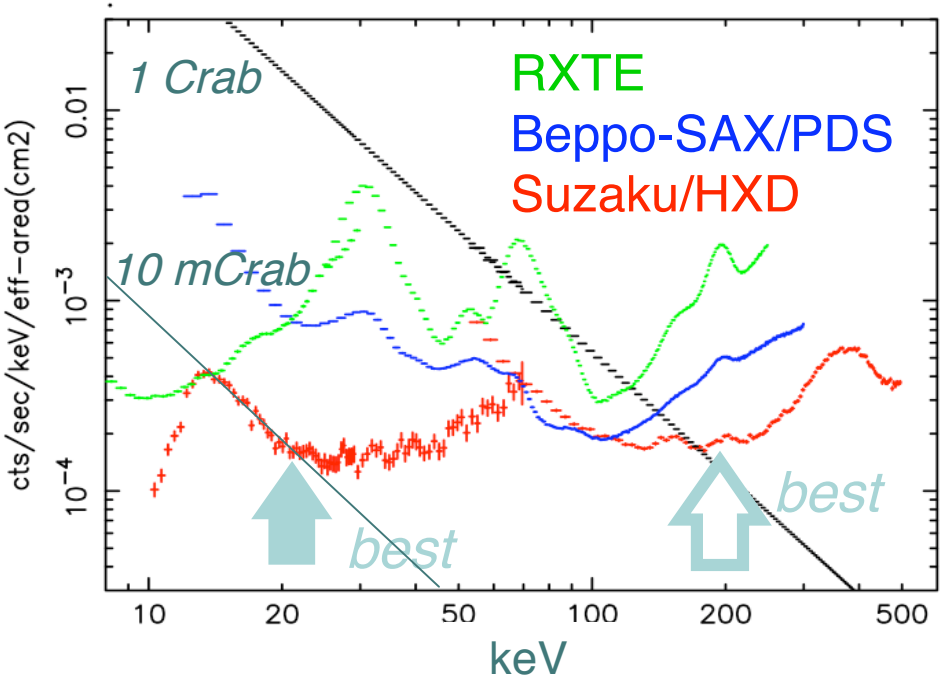
Identification ↑

Suzaku Figure of Merits
in hard X-ray surveys



The HXD

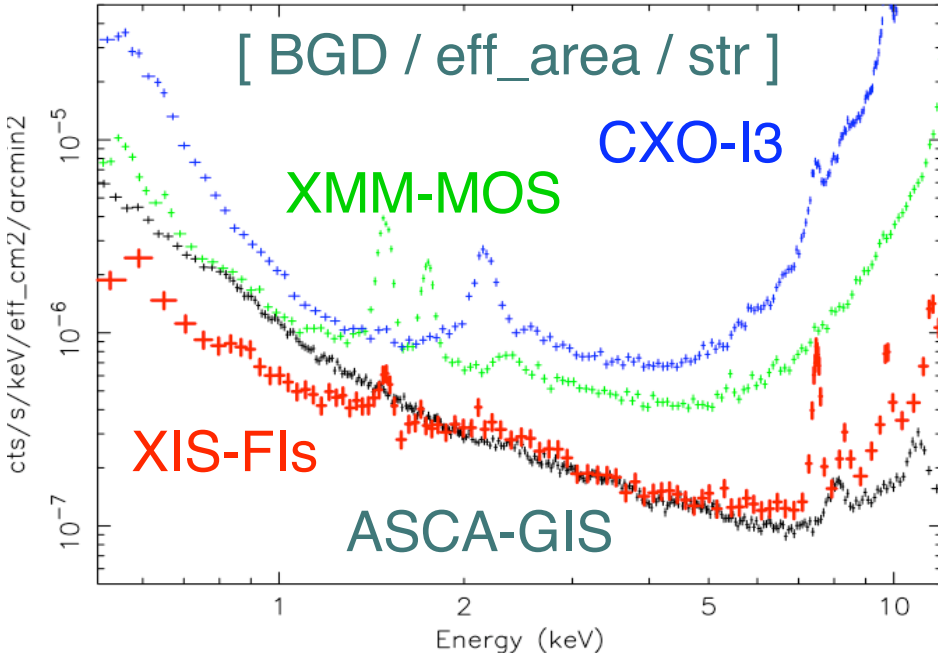
The lowest BGD



0.3 mCrab 10-40 keV
with BGD sys. = 3%

The XIS

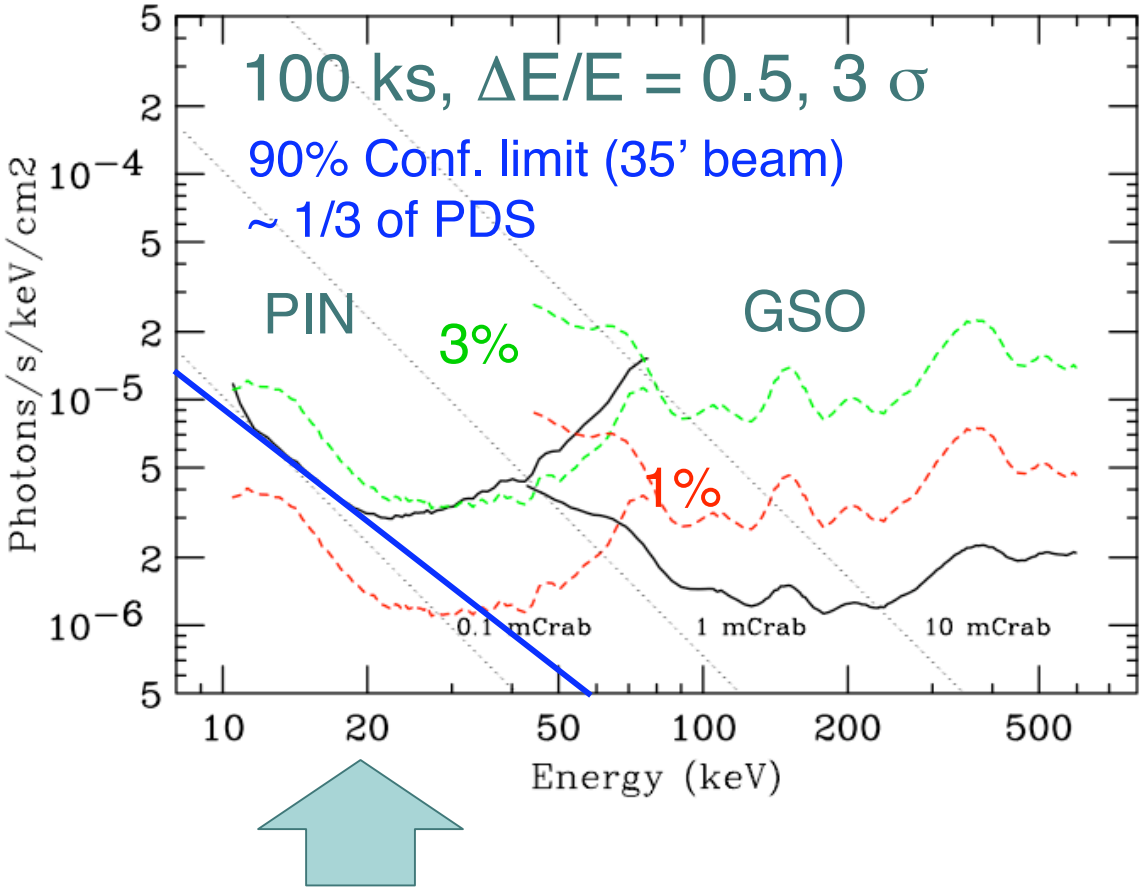
The lowest "*diffuse*" BGD



Among the largest eff. Area

Powerful tools for diffuse surve

HXD Sensitivity

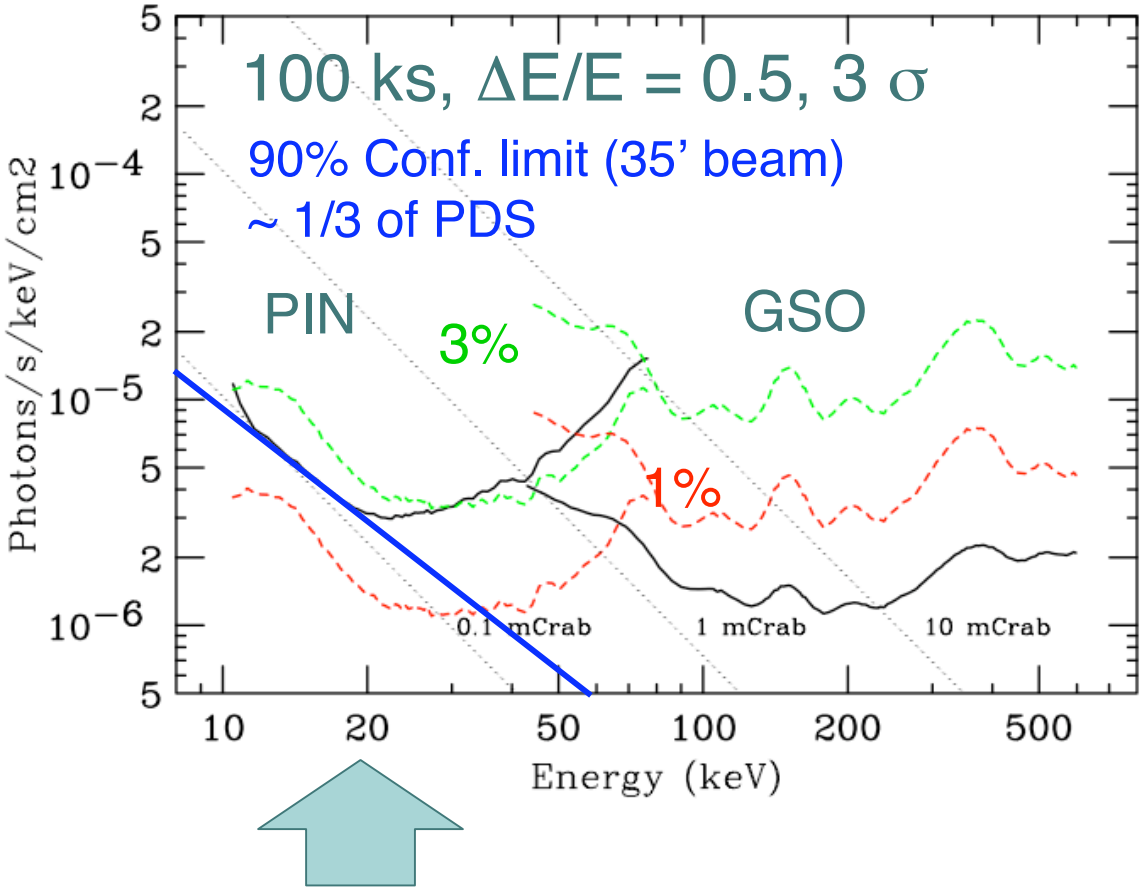


BGD systematics
Current :
5%→0.5 mCrab equiv.
with ~30 ks Obs.
Goal :
1%→0.1 mCrab equiv.
with ~200 ks Obs.

(90% confidence level)

- Best at 10-40 keV (+ and 150-250 keV)

HXD Sensitivity



BGD systematics

Current :

3.5%→0.35 mCrab equiv

with ~30 ks Obs.

Goal :

1%→0.1 mCrab equiv.

with ~200 ks Obs.

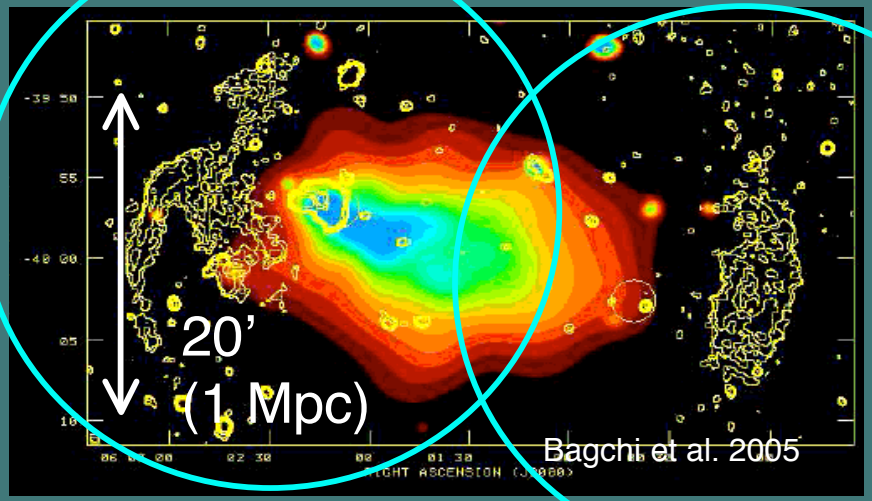
(1σ level)

- Best at 10-40 keV (+ and 150-250 keV)

Abell 3376

Observation of near-by, low/med-kT, merging cluster

Suzaku HXD-PIN FOV
(0.57 deg FWHM)



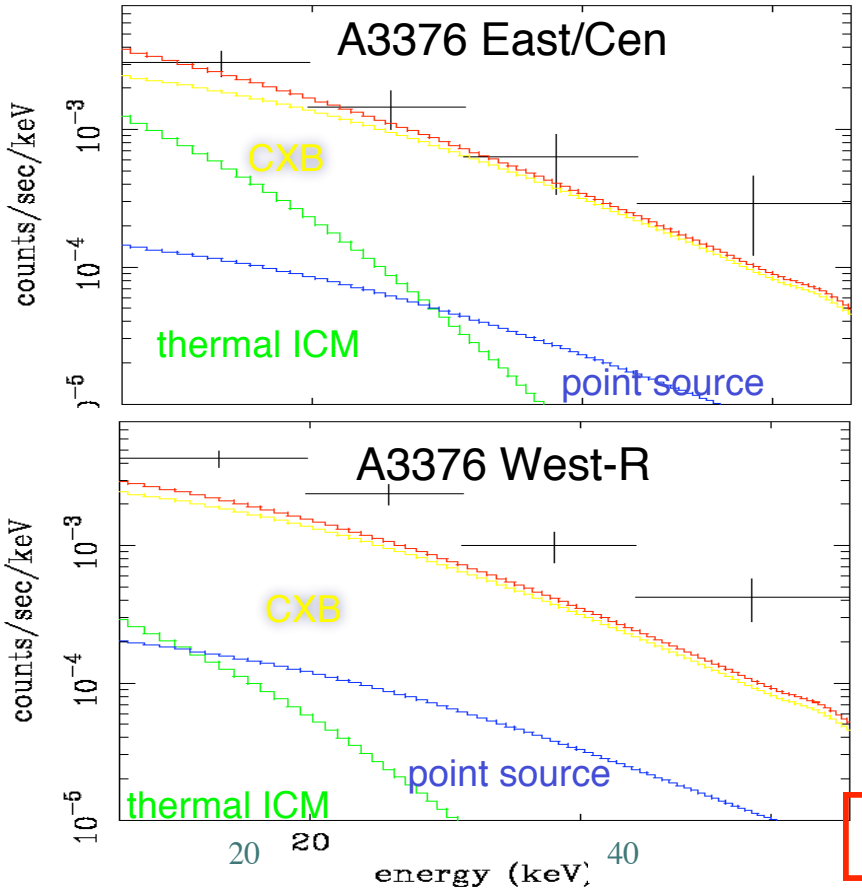
- kT = 4 keV, z = 0.046
- double radio relic
  (100 mJy:1.4GHz)
- highest PDS detection
  2.7 σ (by Navelinen et al.

Suzaku SWG observations
The East Relic/Center and West Relic

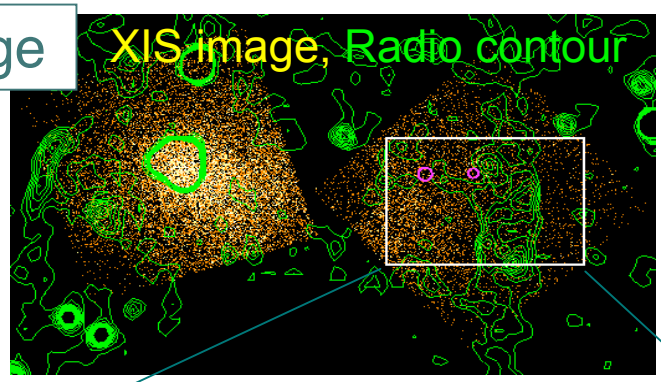
Beppo-SAX PDS FOV
(1.4 deg FWHM)

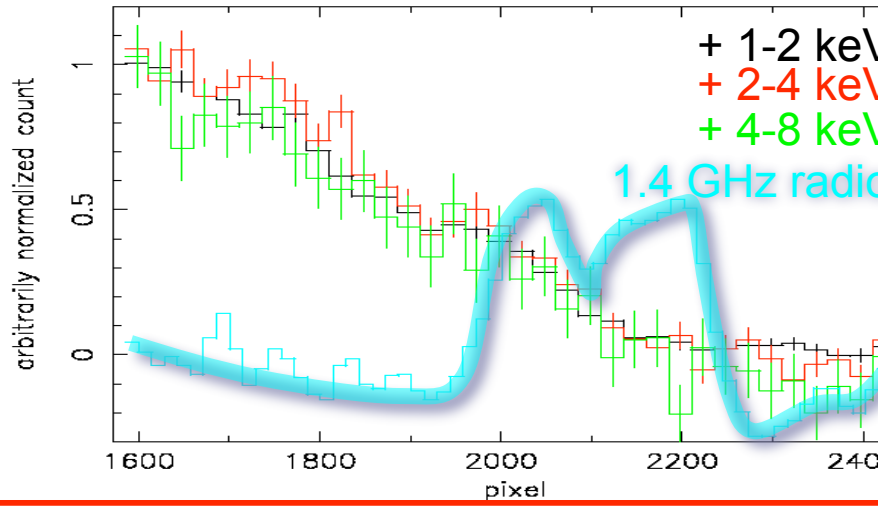
Abell 3376 HXD spectra (Kawano et al. 2007 in prep

HXD-PIN spectra



XIS image





No signature of hard excess in the XIS image

HXD Non-thermal upper limit in 15~50 keV (Γ = 2.0 PL)

$5.1 \pm 1.8 \pm 4.0 \times 10^{12}$ erg/s/cm^2 (1 sigma)

stat. err sys. err

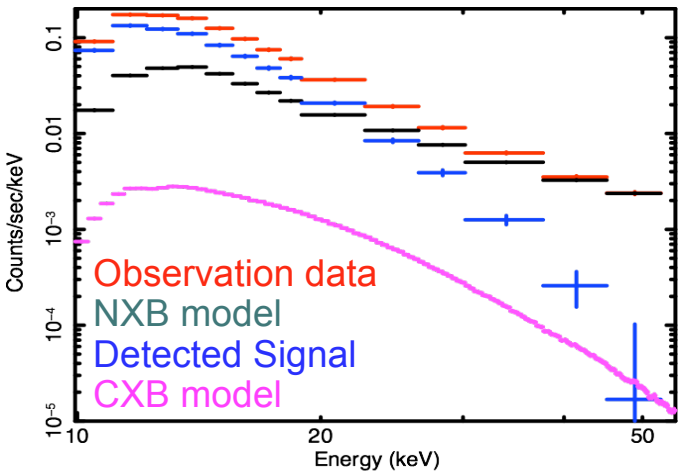
→ Upper limit : < 10.9×10^{12} erg/s/cm^2

Hard X-ray Emission from Nearby Galaxy Clusters

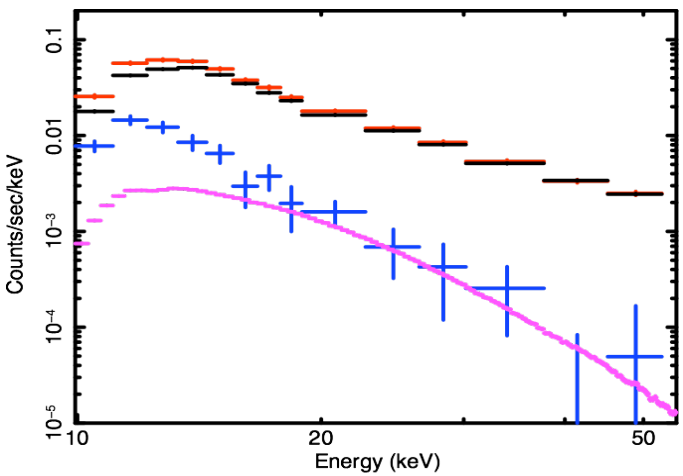
T. Kitaguchi et al. (Univ. of Tokyo) see poster

No non-thermal hard X-ray emission from nearby relaxed clusters

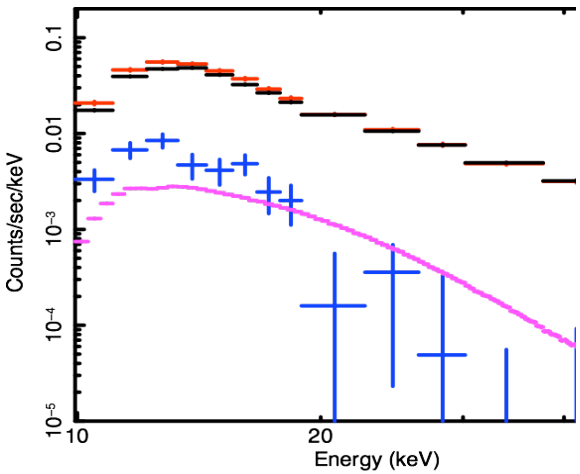
the Perseus cluster



the Centaurus cluster



Abell 1060



The detected signals can be accounted for by the thermal ICM emission.

Suzaku observations of clusters of galaxies

Kyoko Matsushita

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  - Low background
  - Better energy resolution at low energy band
  - O and Mg abundances of ICM

The fornax cluster (Matsushita et al. 2007), A1060 (Sato et al. 2007)
AWM7, HCG62, NGC 507 group (Sato et al. 2007)

  - Temperature profiles of ICM

A1060 (Sato et al. 2007), AWM7 (Sato et al. 2007)

  - Non-detection of bulk-motions

Centaurus cluster (Ota et al. 2007), AWM7, etc.

- Suzaku HXD
  - Upper limit of hard X-ray component

A3376(Kawano et al.),
A1060, Centaurus (Kitaguchi et al. 2007 - poster)