Type Ia and II supernovae contributions to the metal enrichment in the intra-cluster medium observed with *Suzaku*

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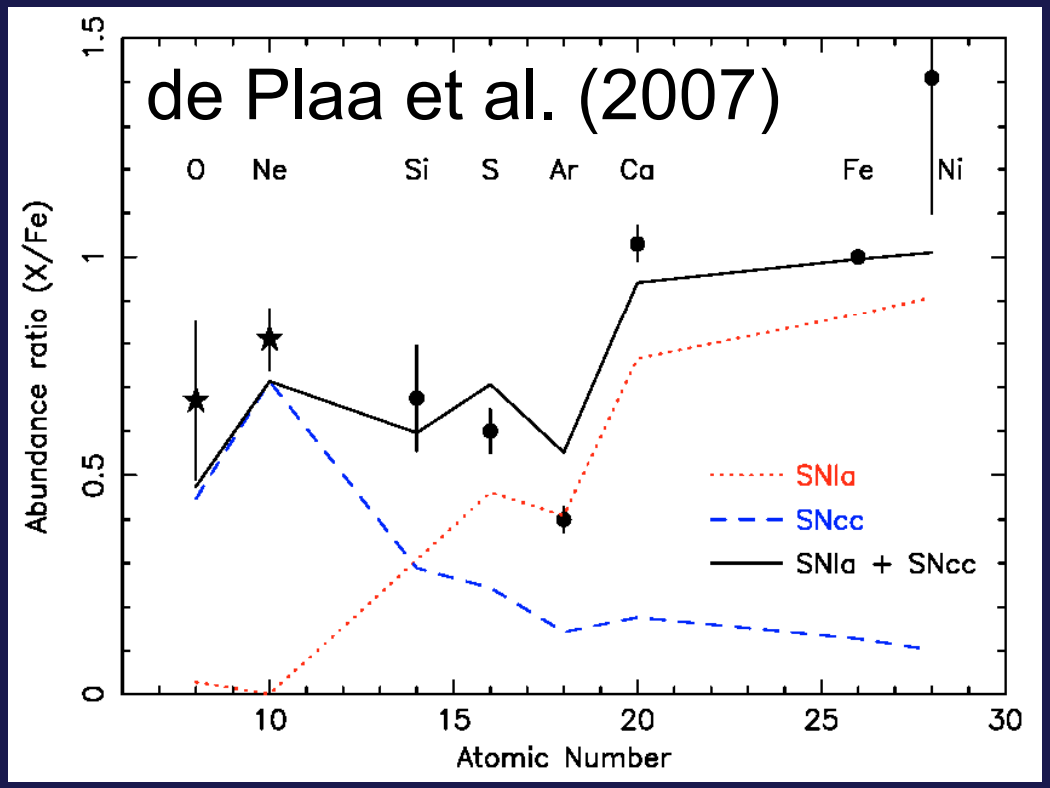
Kosuke Sato[1],
K. Tokoi[2], K. Matsusihta[1], Y. Ishisaki[2], N. Y. Yamasaki[3],
M. Ishida[3], and T. Ohashi[2]

[1] Tokyo Univ. of Science, [2] Tokyo Metropolitan Univ., [3] ISAS/JAXA

Introduction – past X-ray observations –

" *ASCA* " ⇒ Dupke & White (2000), Baumgartner et al. (2005)
" *XMM* " ⇒ de Plaa et al. (2006, 2007), Werner et al. (2006)



XMM

- 22 clusters
- O in the only central region
- Mg with large uncertainties

SNe II/Ia ratio ~3.5

Poor information from SNe II products

Suzaku

- Low & stable background level
- Higher sensitivity below ~1 keV

Determination of O & Mg synthesized in SNe II

Selected clusters and groups

- ✓ Nearby and Bright objects in early *Suzaku* observations
- ✓ Moderate low temperature (kT<4 keV) for O measurement

Obs.	redshift	r_{180} (Mpc)	date
A1060	0.0114	1.53	22/Nov./2005
AWM7	0.0172	1.65	5/Aug./2006
HCG62	0.0145	1.08	23/Jan./2006
NGC507	0.0165	1.08	28/Jul./2006

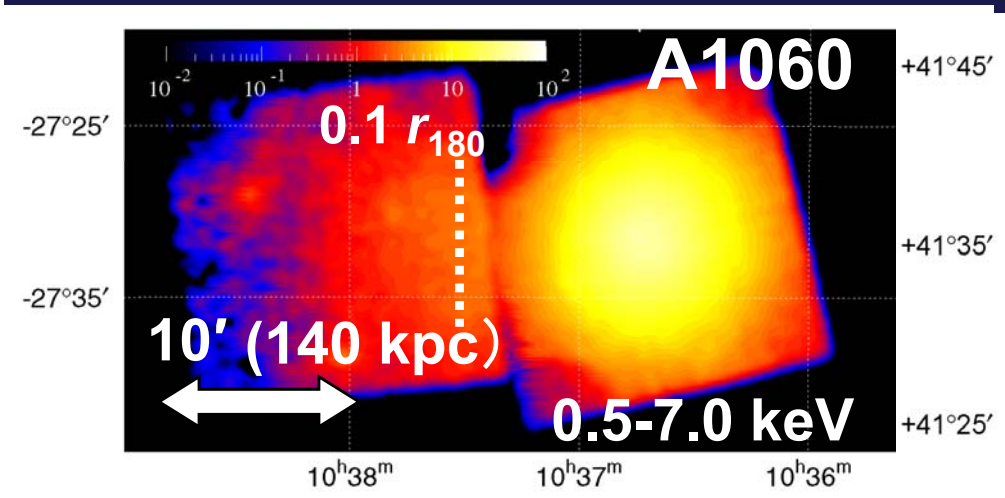
Sampling ranging: Groups (~1.5 keV) ~ Clusters (~4 keV)
Not including in de Plaa et al. (2007)

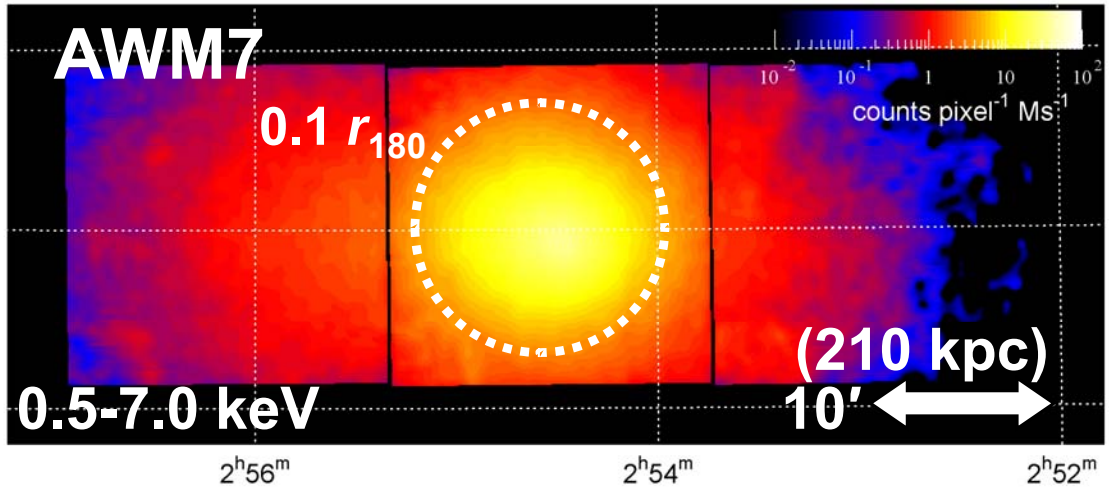
Measurements of the metal abundances and distributions to ~0.3 r_{180}

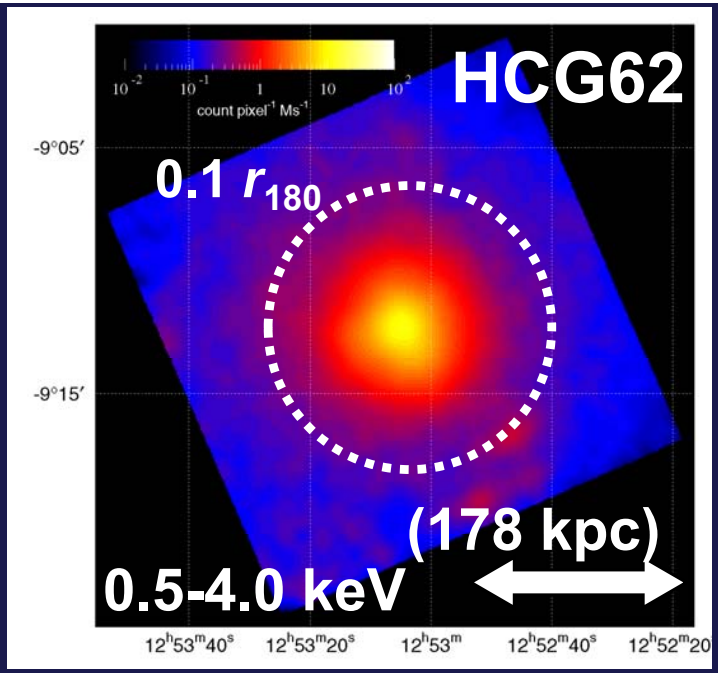
→ Analysis methods :
See in Sato et al. (2007a, 2007b) & Tokoi et al. (2007, A23)

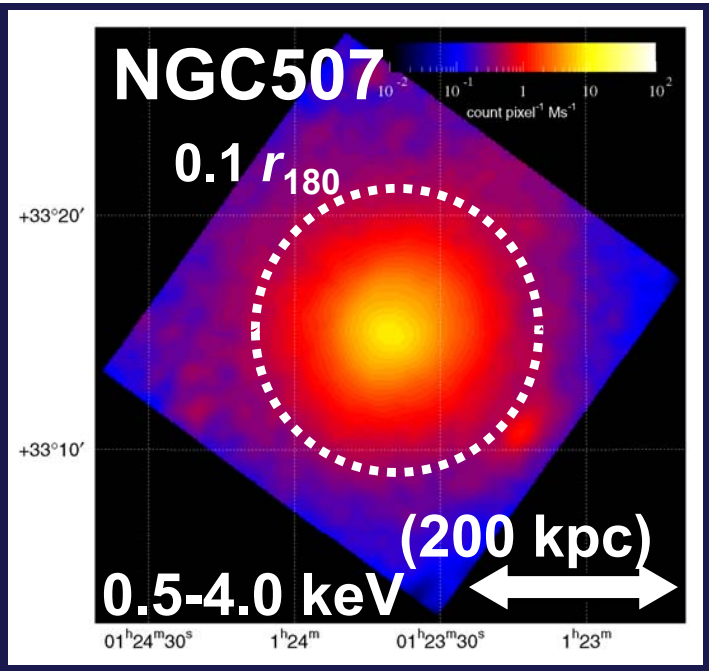
X-ray Images with *Suzaku*

- ✓ **Smoothed with σ = 16″gaussian, Exposure time corrected**
- ✓ **Cosmic X-ray Background, Non X-ray Background subtracted**

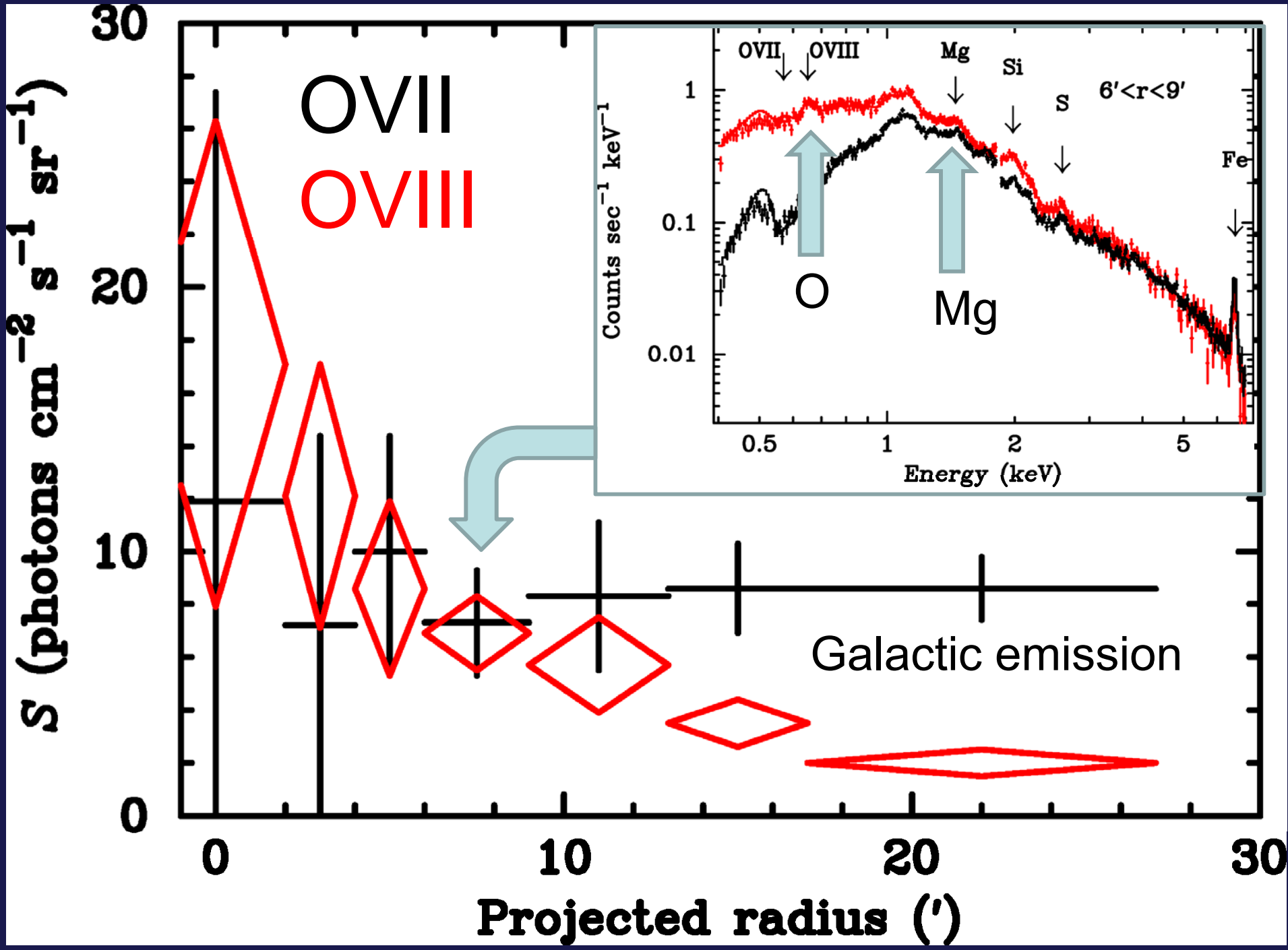




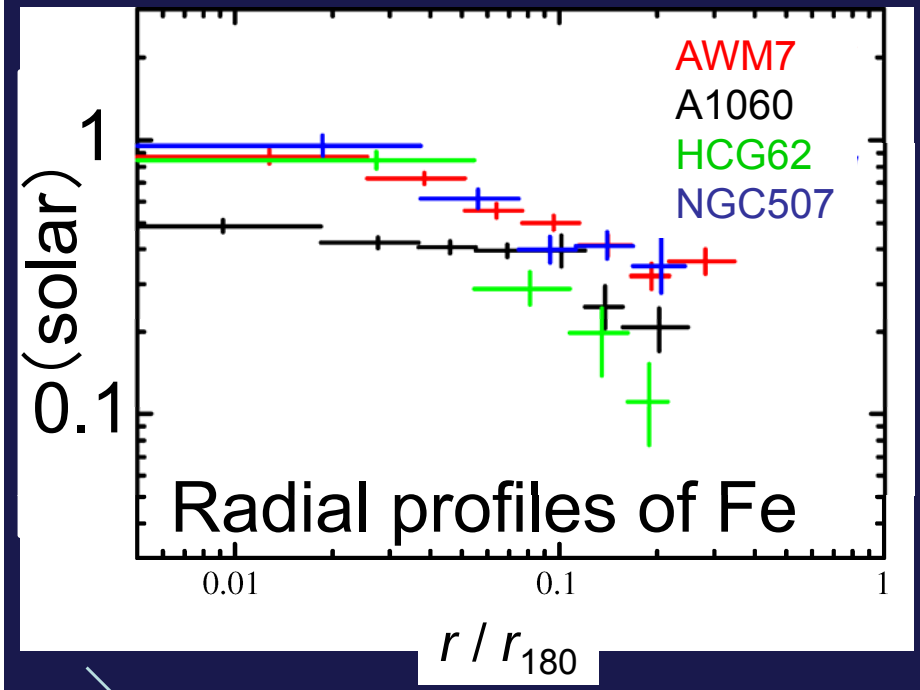




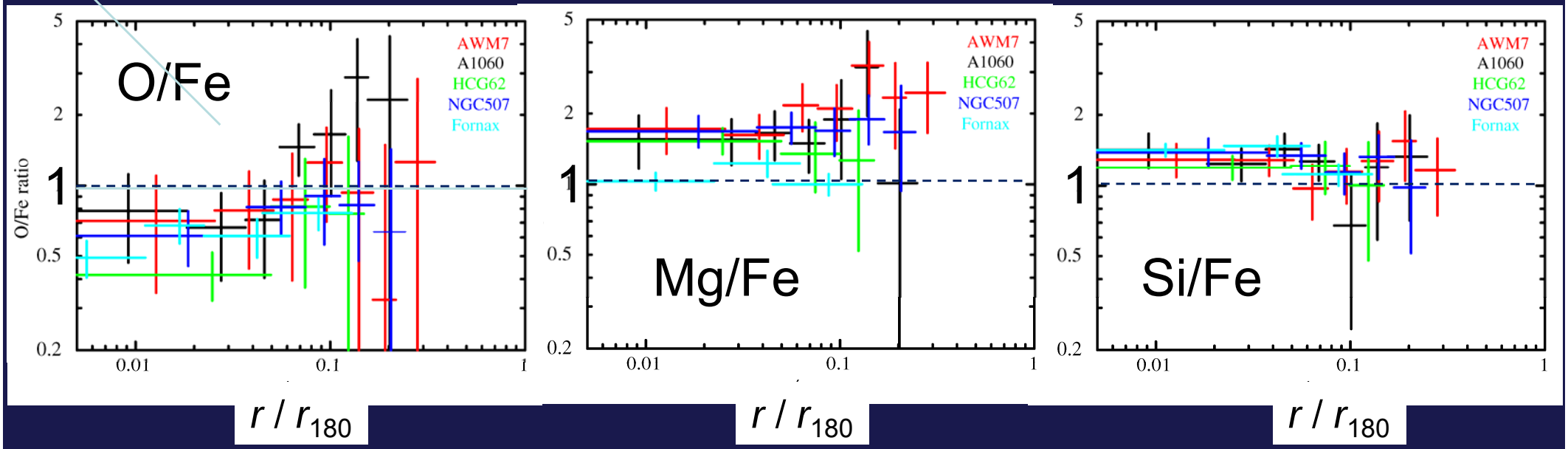
O & Mg measurements with *Suzaku*



Metal distributions



- From O to Fe radial profiles
  (solar: Anders & Grevesse 1989)
- Comparison the metals to Fe ratio
  Si, S / Fe : fairly flat ~1 – 2
  O, Mg / Fe : increase with radius?
  ⇒ Difference from SNe Ia or II ?



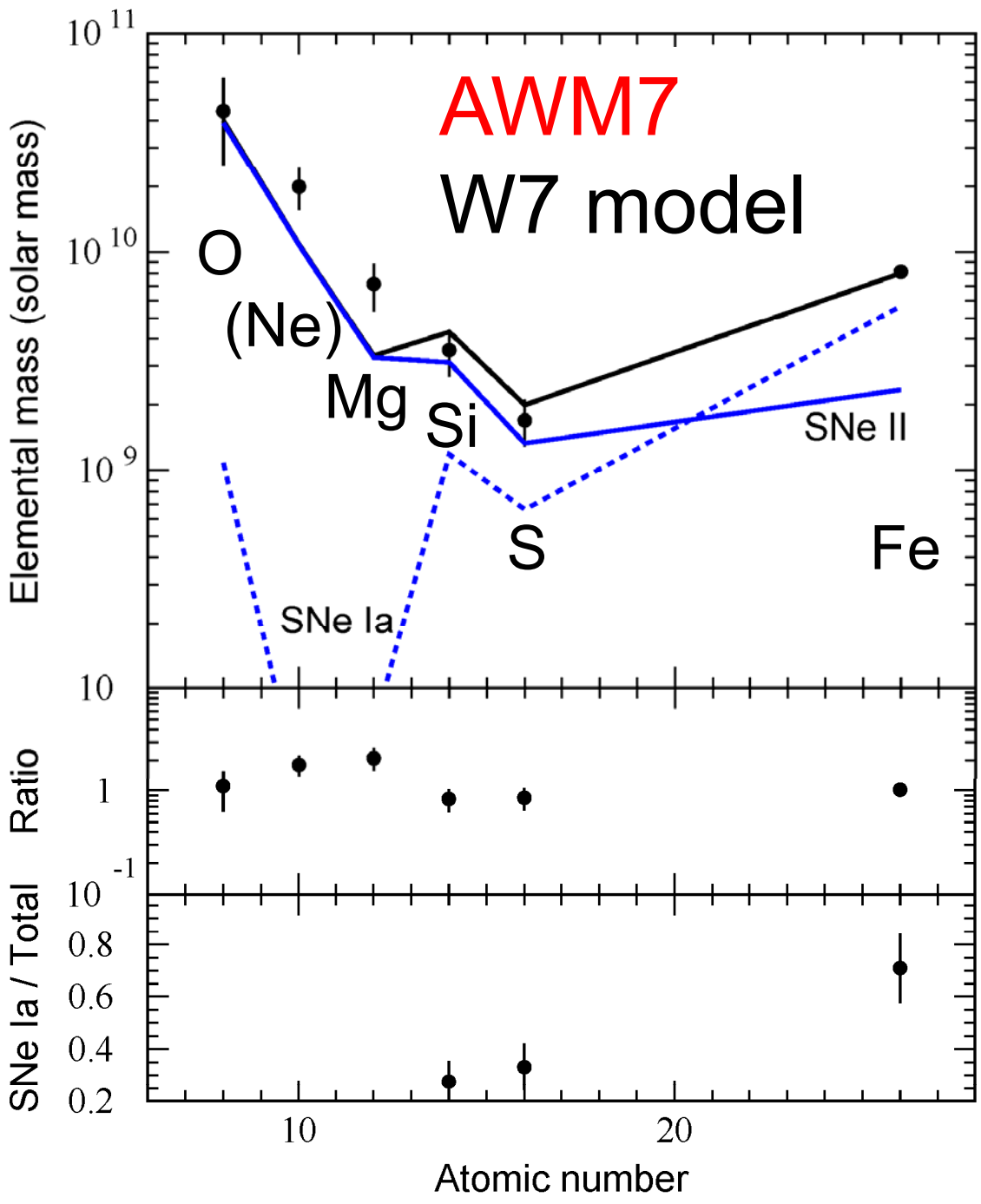
Numbers of Type Ia and II supernovae

How each metal is synthesized with SN Ia & II ?
⇒ Estimation of the numbers of SN Ia & II (N_{Ia}, N_{II})

Fit the amount of metals with nucleosynthesis model

SNe nucleosynthesis model
SNe Ia : W7 model (Nomoto et al. 1984)
WDD1 or 2 model (Iwamoto et al. 1999)
SNe II : 10 – 50 $M_{\odot}$ (Salpeter Initial Mass Function)
$\psi(M) \propto M^{-2.35}$
Progenitor Metallicity Z = 0.02 (Nomoto et al. 2006)

Fitting results

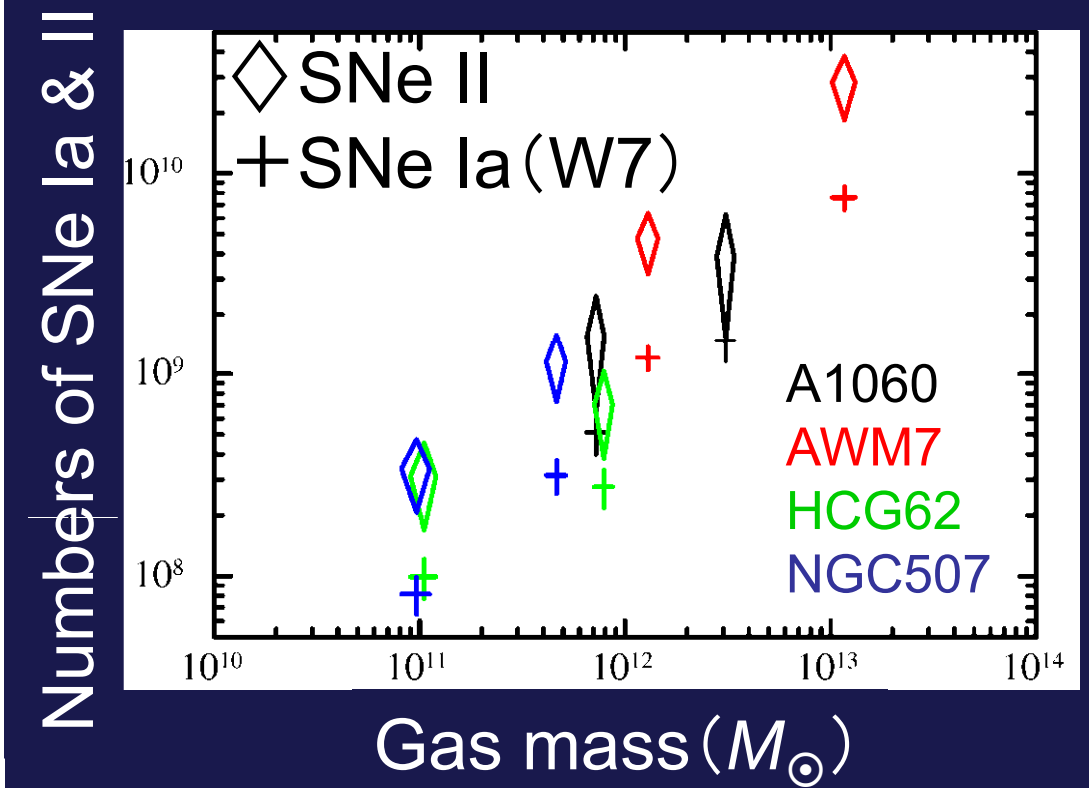


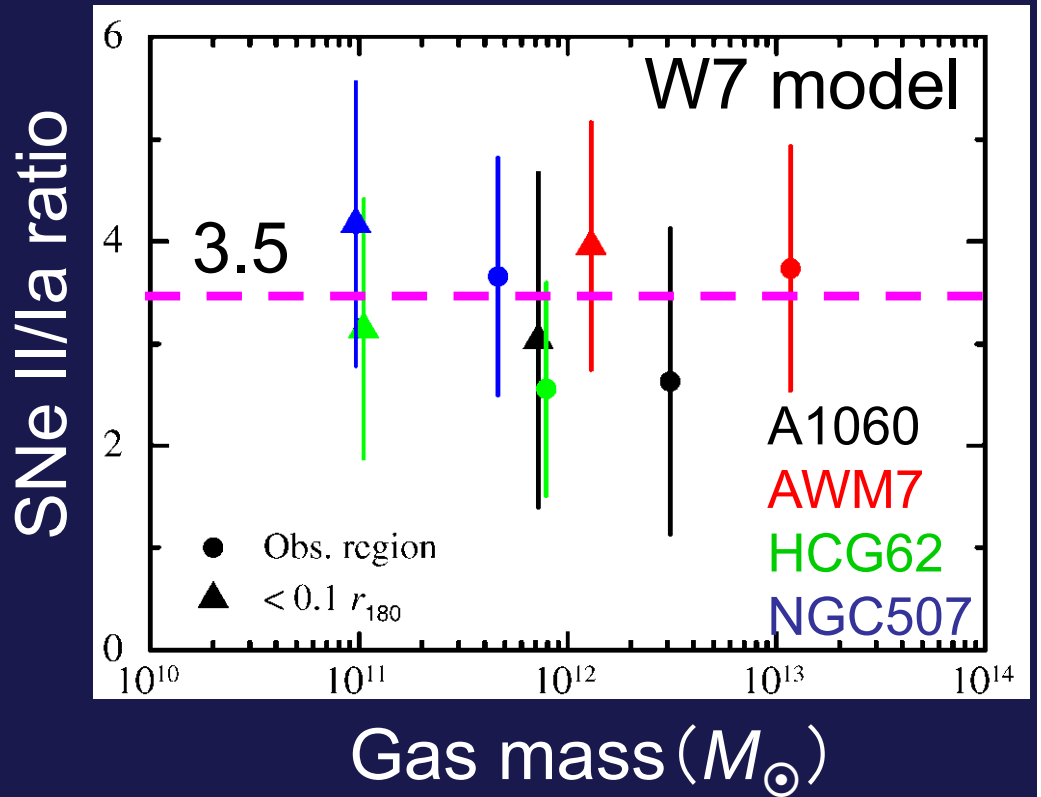
χ^2 / d.o.f.
= 15.9 / 3

N_{II} / N_{Ia}
= 4.0 ± 1.2

- ✓ Fits are not acceptable.
- ✓ ~75% of Fe,
  ~40% of Si and S
  from SNe Ia

Numbers and Ratio of SNe Ia & II





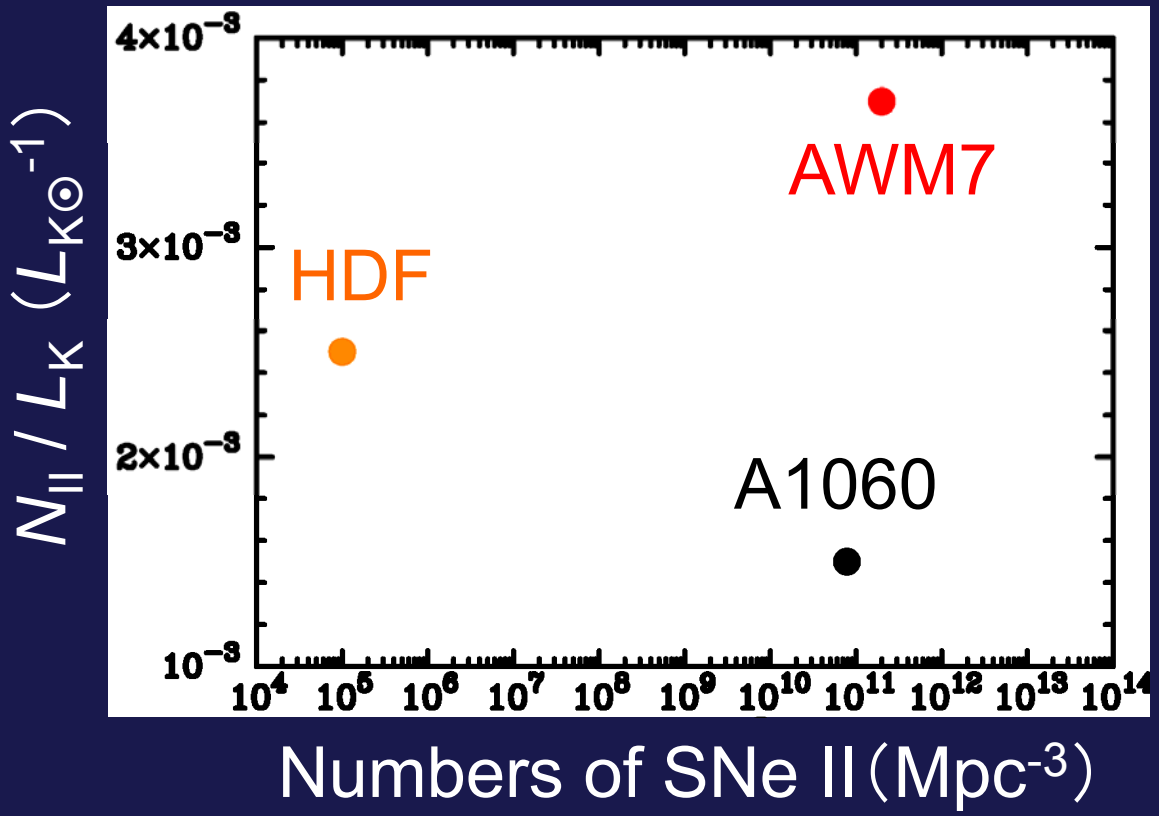
- Numbers of SNe Ia & II ∝ the gas mass
- SNe II/Ia Ratio: ~3.5 (W7 and WDD2), ~2.5 (WDD1)

cf. Clusters (*XMM* ; de Plaa et al. 2007): ~3.5
Our Galaxy (Tsujimoto et al. 1995): ~6.7
LMC & SMC (Tsujimoto et al. 1995): 3.3 – 5

Comparison of Numbers of SNe II

- Number of SNe II expected from Star Formation Rate of Hubble Deep Field (Madau et al. 1998)
- Numbers of SNe II expected from the metal mass observed with *Suzaku*

Normalized by K-band（2MASS） luminosities

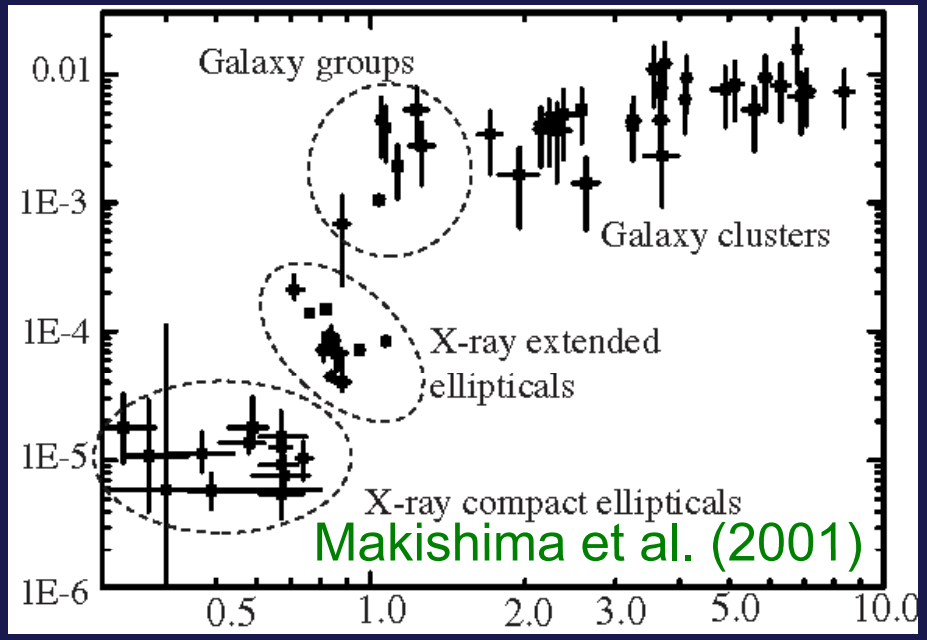


Now, only the metals in the ICM, not including in the stars (galaxies)

Considering in the stars, the results with X-ray increase by factor ~2

Mass-to-Light Ratio: MLR

Metals are synthesized in stars (galaxies):
Compare $M_{\mathrm{metal},\,<R}$ (in units of $M_\odot$)
with B-band luminosity $L_{\mathrm{B},\,<R}$ (in units of $L_\odot$)



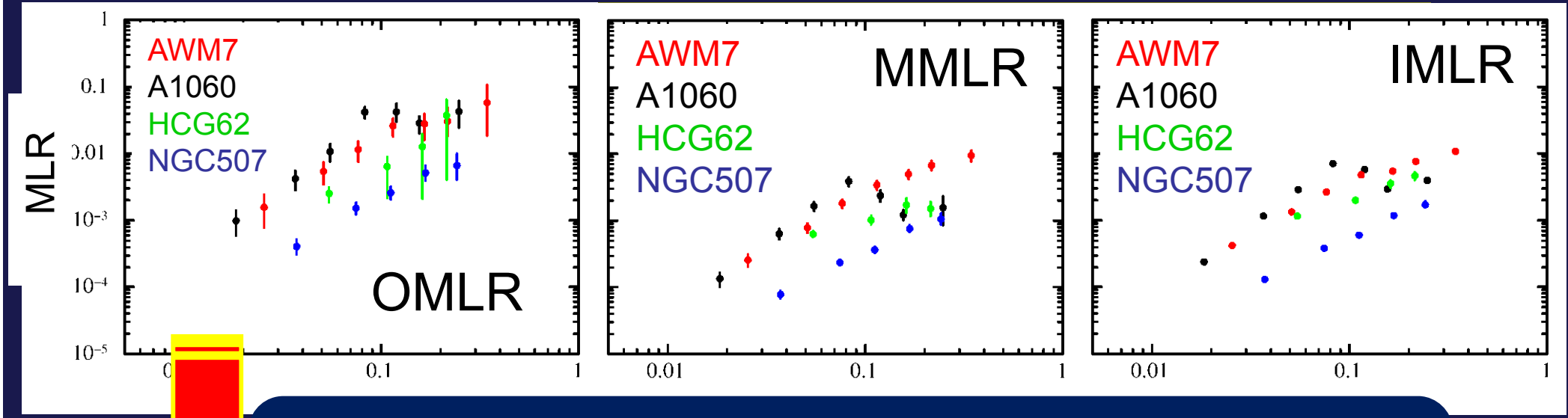
Also use K-band luminosity because of the comparison of galaxy type

$$\mathbf{MLR} = \frac{M_{\mathrm{metal},\,<R}}{L_{\mathrm{B\ or\ K},\,<R}} \left(\frac{M_\odot}{L_\odot} \right)$$

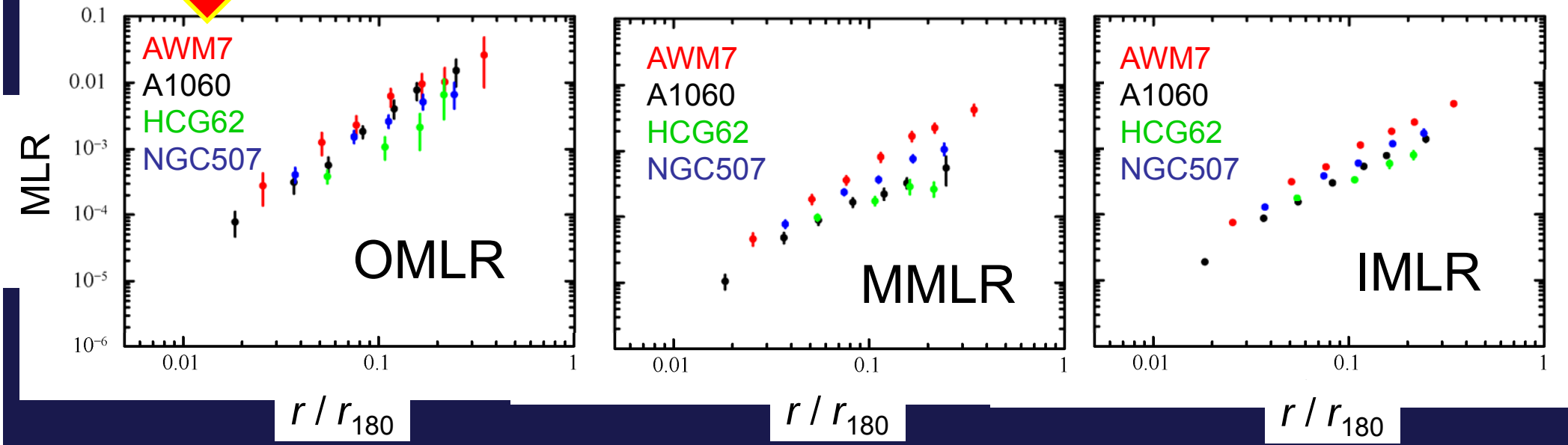
Oxygen Mass-to-Light Ratio: OMLR
Magnesium Mass-to-Light Ratio: MMLR
Iron Mass-to-Light Ratio: IMLR

First time

MLR（B-band vs. K-band）Sato et al. in preparation



With K-band, close to the MLR between clusters and groups



Summary

- Conducted spatially resolved spectral analysis of clusters & groups with *Suzaku*
- Measurements of the metals (O to Fe) to ~0.3 r_{180}
- Assuming nucleosynthesis models, we determined the numbers of SNe II in the past using the metal masses of O, Mg, Si, S, and Fe
- SNe II / Ia number ratio: ~3.5 (W7 and WDD2)
- The Numbers from X-ray observations are consistent with the number from SFR in HDF
- Measurements of OMLR & MMLR for the first time
- MLRs with K-band are close between clusters & groups