

Dynamics and High Energy Phenomena of Merging Galaxy Clusters Explored with Astro-H

M. Takizawa (Yamagata Univ.), K. Nakazawa (Univ. of Tokyo), T. Kitayama (Toho Univ.), C. Sugawara (Yamagata Univ.), R. Nagino (Tokyo Univ. of Science), K. Matsushita (Tokyo Univ. of Science), and others

Sugawara, Takizawa, & Nakazawa (2008)

Takizawa, Nagino, & Matsushita (2010)

Yamada, Kitayama, et al. (2012)

Takizawa (2005)

High Energy Phenomena of Clusters of Galaxies

Non-thermal radio emission from merging clusters of galaxies

synchrotron radio

$\gamma \sim 10^4$ electrons + 0.1-10 μG B



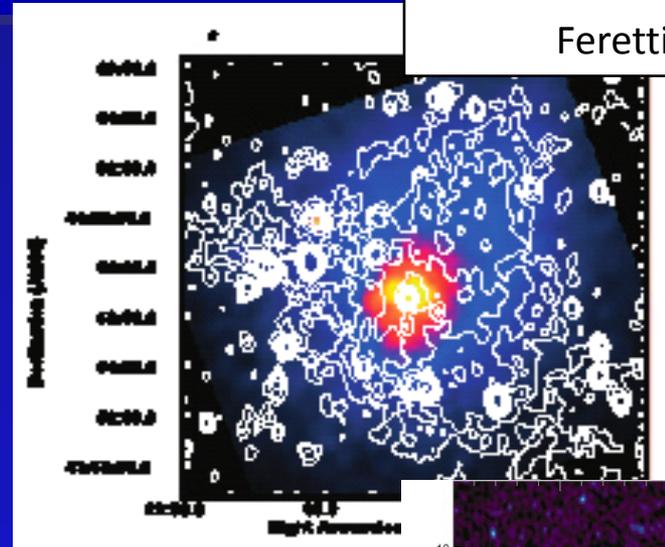
Hard X-ray will be emitted through Inverse Compton with CMB

Abell 2319 with Radio Halo

Rosat X-ray image (colors)

Radio image (contours)

Feretti et al. 1997

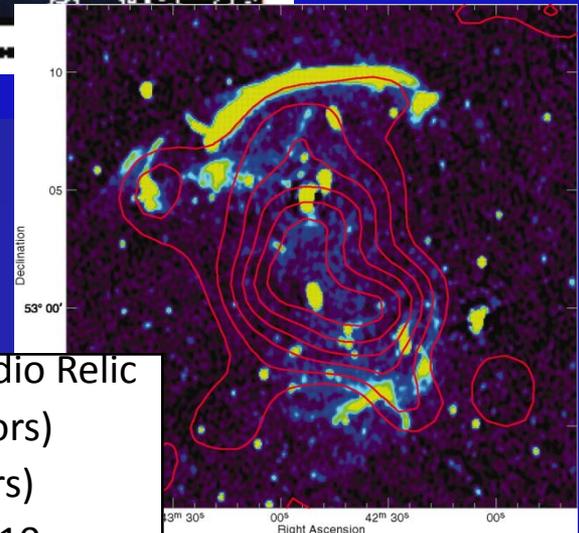


CIZA J2242.8+5301 with Radio Relic

Rosat X-ray image (colors)

Radio image (contours)

Van Weeren et al. 2010

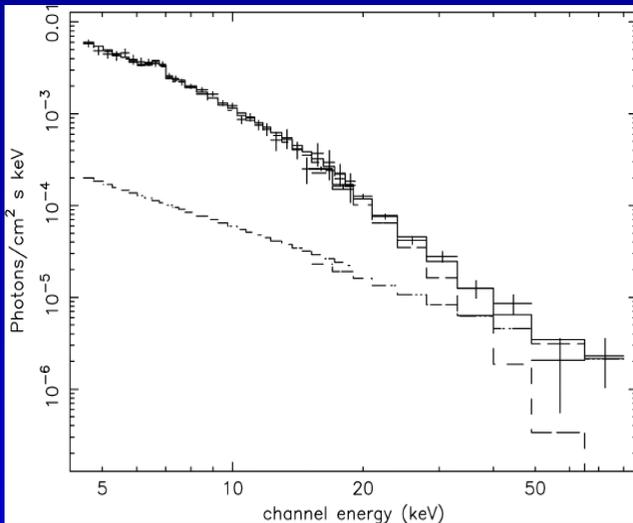


Particle acceleration and Gas Motion

- Particle acceleration processes are likely related with (magnetized) plasma motion.

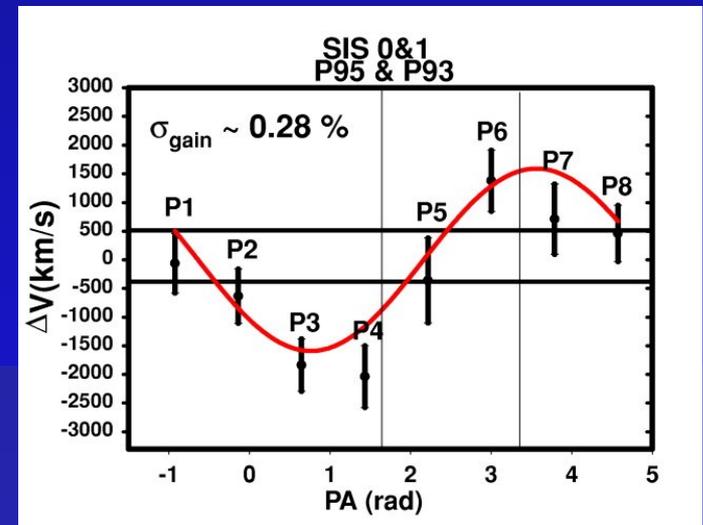
shocks or magnetic turbulence or ???
- Information about both “gas motion” and “high energy particles” (and magnetic field) are crucial.
- Combination of “X-ray spectroscopy with high energy resolution” and “Hard X-ray observation” are necessary.

Before Suzaku



Detection of Non-thermal
hard X-ray from Coma by B-SAX??
(Fusco-Femiano et al. 1999, 2005etc)

Possible detection of gas bulk
motion ($\sim 1500\text{km/s}$) by ASCA and
Chandra,,,,,,,,,
(Dupke et al. 2001 for Centaurus
cluster etc)



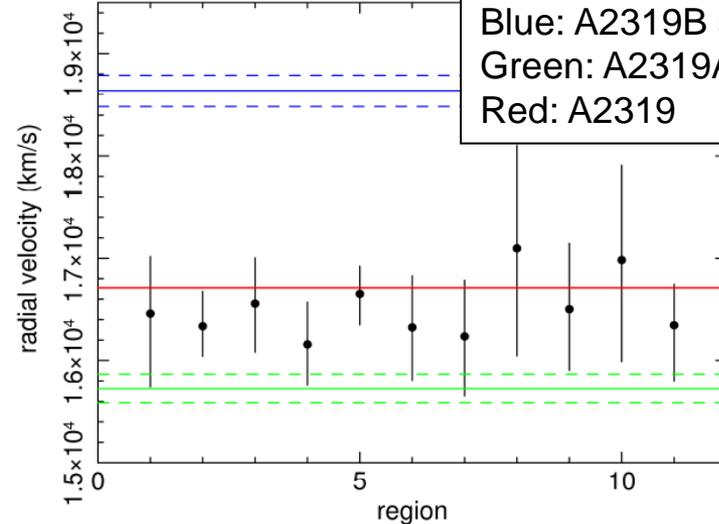
However, later Suzaku results are negative for the both.
(Wik et al 2009, Ohta et al. 2006 etc)。

Suzaku Results of Abell 2319

(Sugawara, Takizawa & Nakazawa 2009)

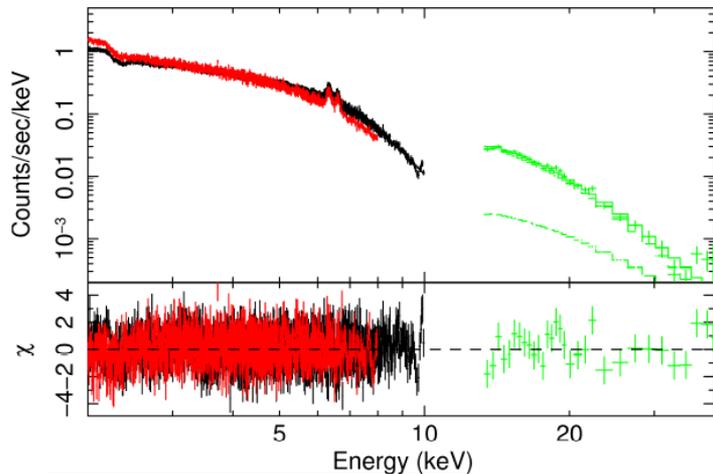
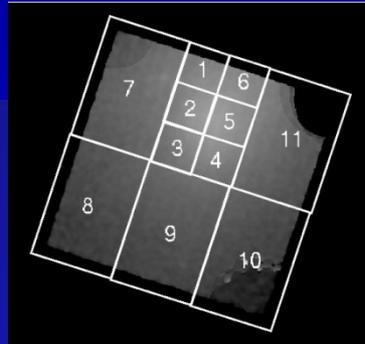
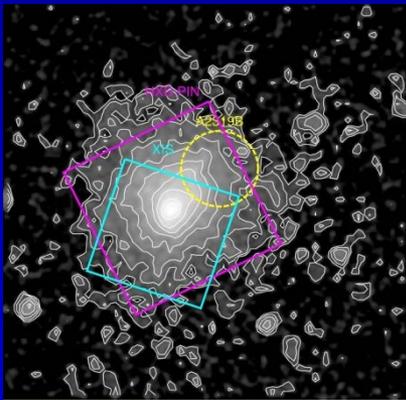
Line-of-sight velocity

Blue: A2319B subgroup
Green: A2319A subgroup
Red: A2319



• $\Delta v < 940^{+1083}_{-1131}$ km/s.
(cf. $c_s \sim 1700$ km/s)

- $F_{\text{nth}}(10\text{-}40\text{keV}) < 3 \times 10^{-11}$ erg/s/cm²
- $B > 0.3 \mu\text{G}$
- $U_B / U_{\text{th}} > 5 \times 10^{-4}$
- $U_{\text{CRe}} / U_{\text{th}} < 3 \times 10^{-5}$
($5.7 \times 10^3 < \gamma < 1.1 \times 10^4$)

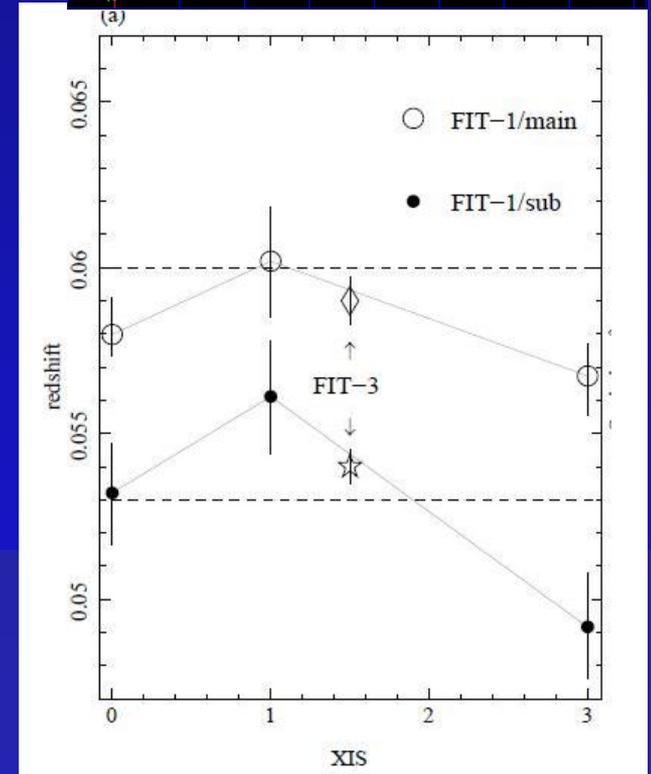
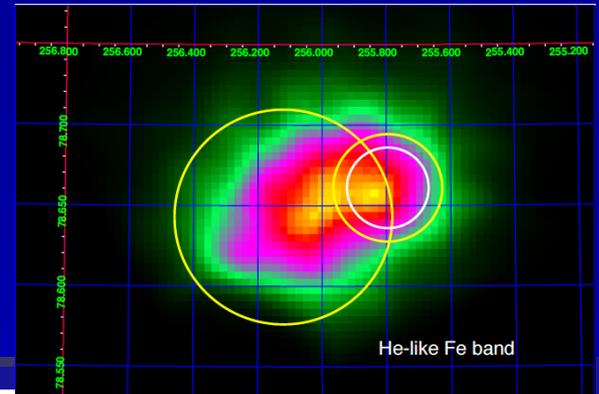


Wide band spectrum

Black: XIS FI
Red: XIS BI
Green: PIN

With Suzaku,,,

- Bulk Flow detection is very close. Actually, it is possible for limited objects with good conditions (see Tamura et al. 2011)。
- Detection of subsonic turbulence is impossible (Ohta et al. 2006, Sugawara et al. 2009etc)。
- Hard X-ray (<40keV) is surely detected from rich clusters, and their spectrum is likely thermal. Secure upper limits of non-thermal component are obtained (Wik et al. 2009, Sugawara et al. 2009, Nakazawa et al. 2009 etc)。
- Anyway, It is a very important step that we can get information about “gas motion” and “high energy particles” simultaneously.



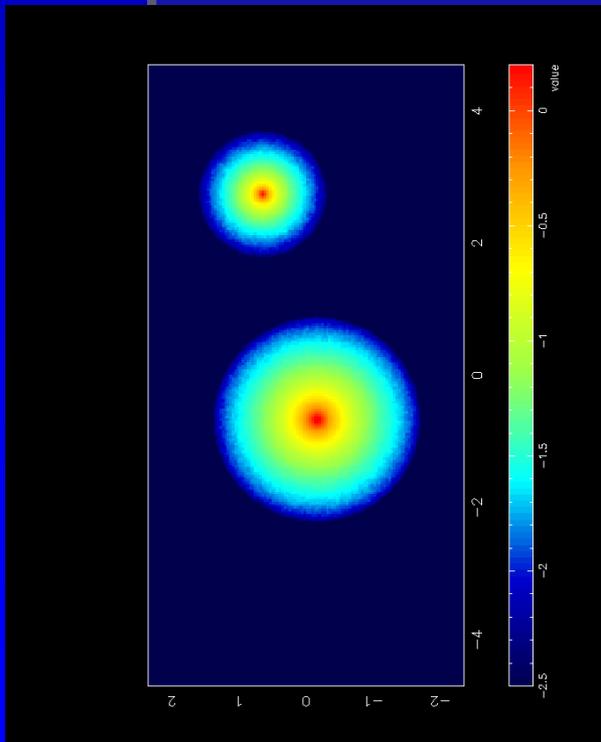
Line-of-sight velocity of
A2256

Tamura et al. (2011)

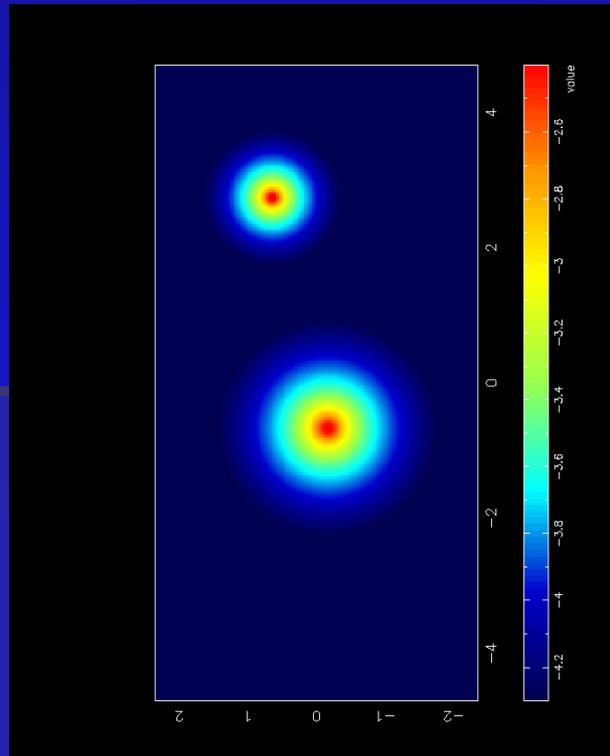
What we can observe for merging clusters at present

(Takizawa, Nagino, & Matsushita 2010)

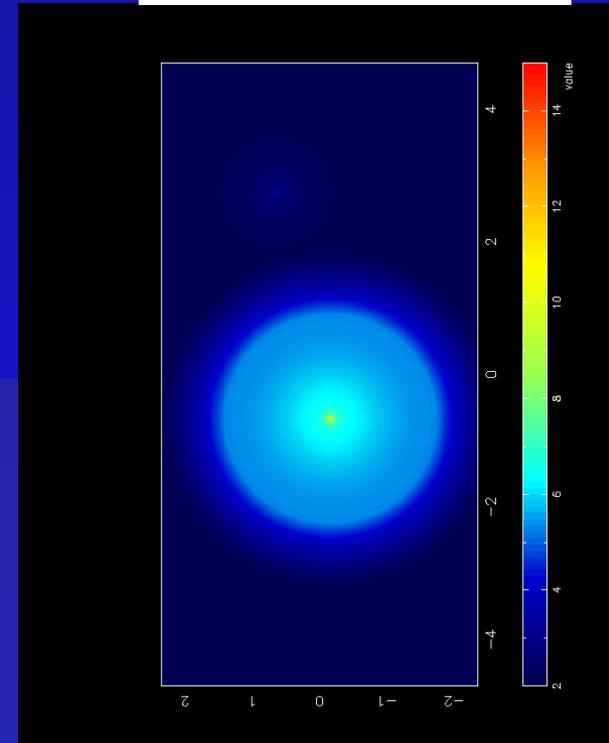
Mass distribution
--->lensing



Gas density
-->X-ray image



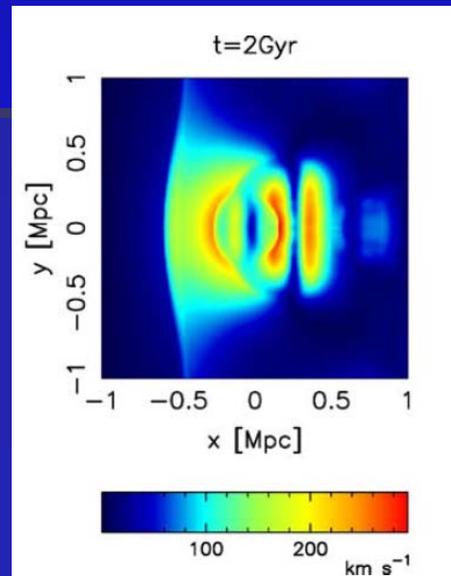
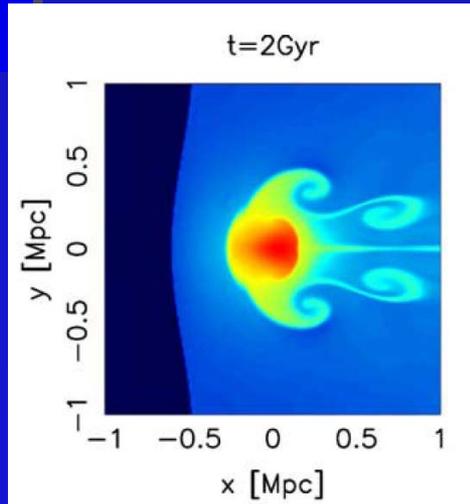
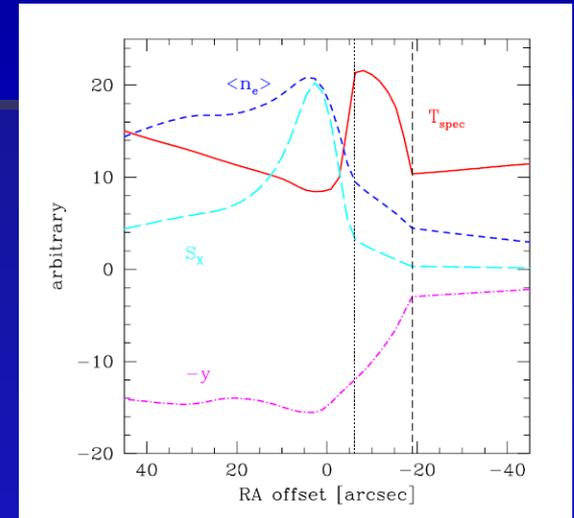
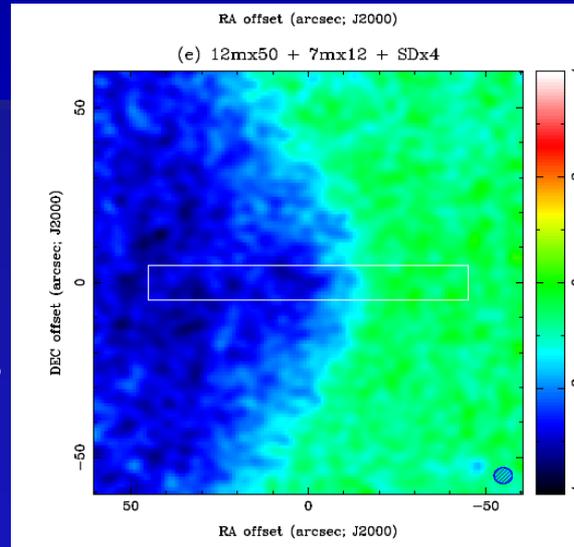
Gas temperature
-->X-ray spectrum



What we will be able to observe in the (near) future ???

SZ observation with ALMA
(Yamada et al. 2012)
Kitayama-san's talk

more sensitive to high kT
component such as shocks



“Map of velocity dispersion of ICM” will provide crucial information about turbulence. (Takizawa 2005)

This kind of study might be Possible with Astro-H SXS???

Summary

- Combination of “X-ray spectroscopy with high energy resolution” and “Hard X-ray observation” are crucial to explore high energy phenomena of galaxy clusters.
- Before Suzaku, some unreliable results about these issues confused us (at least, me).
- With Suzaku, supersonic bulk flow motion of ICM likely can be detected for limited objects, and detection of subsonic turbulence is impossible.
- Hard X-ray ($<40\text{keV}$) is surely detected from rich clusters, and their spectrum is likely thermal. Secure upper limits of non-thermal component are obtained.
- ASTRO-H/SXS and ALMA will give us new physical information for this field.