

High Energy Phenomena and Magnetic Fields in Clusters of Galaxies

Sugawara, Takizawa, Nakazawa (2009)
Nakazawa,,, Takizawa,,,, et al. (2009)
Takizawa (2008)

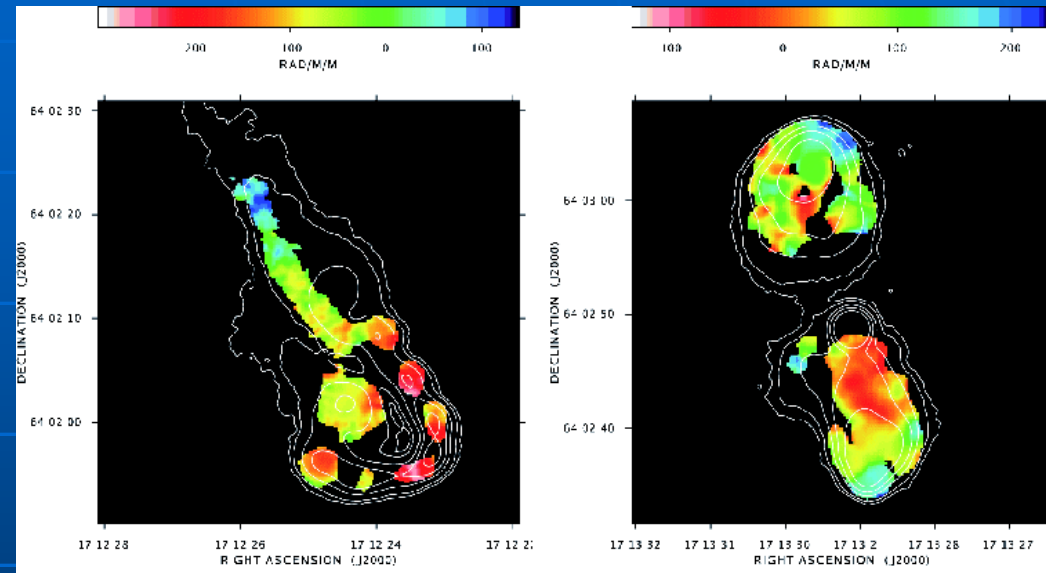
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2013.6.6
SKA Science Workshop in East Asia 2013
@Nagoya University

Observational Evidence of Intracluster Magnetic Field (1): Faraday Rotation

- Polarized plains of linear polarized radio wave rotate when propagating through the magnetized plasma.

$$\Delta\theta = \frac{2\pi e^3}{m^2 c^2 \omega^2} \int_0^d n B_{\parallel} ds.$$

- Polarized radio sources observations in and behind clusters suggest random magnetic field structures.



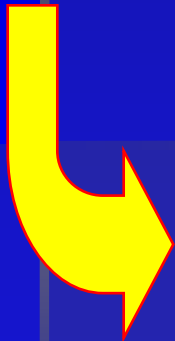
Faraday rotation measure map of the radio sources in Abell 2255
Color: FRM
Contour: radio
Govoni et al. 2006

Observational Evidence of Intracluster Magnetic Field (2): Radio Halos / Relics

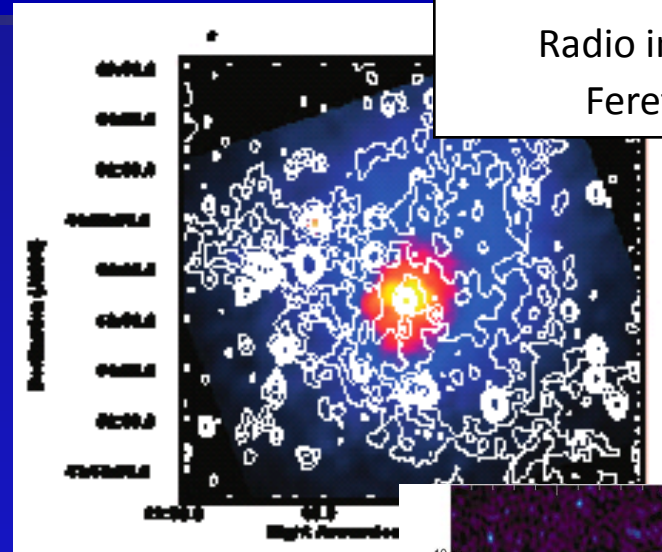
Non-thermal radio emission from merging clusters of galaxies

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)

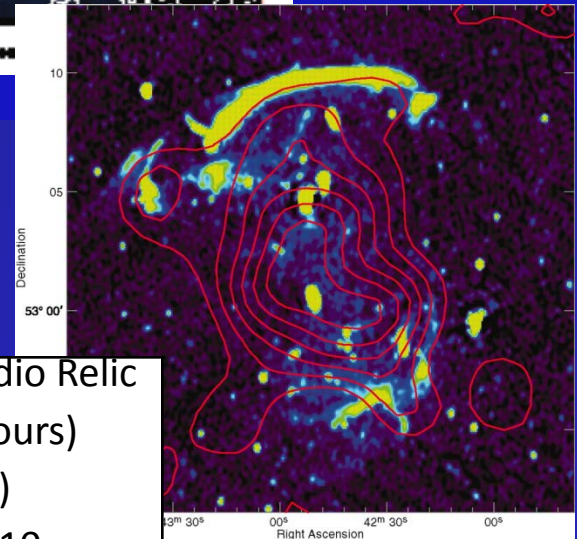
Feretti et al. 1997

CIZA J2242.8+5301 with Radio Relic

Rosat X-ray image (contours)

Radio image (colors)

Van Weeren et al. 2010

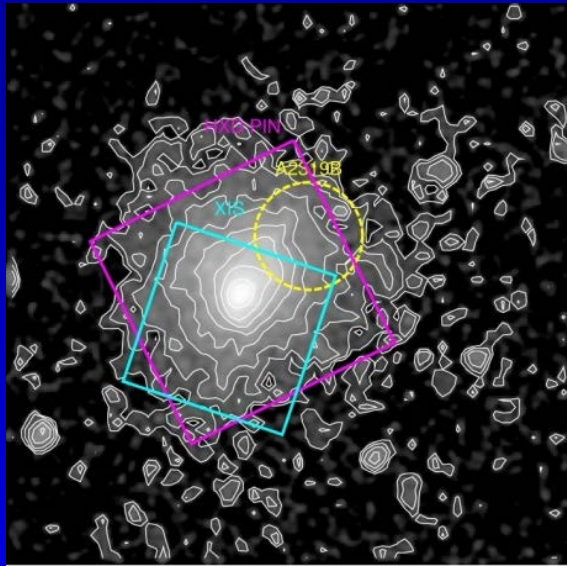


Intracluster Magnetic Field

- There is random magnetic field in the intracluster space, whose typical strength is $\sim \mu\text{G}$.
 - ◆ Shynchrotron radio halos/relics
 - ◆ Faraday rotation measure
- $P_B \sim 0.01 P_{\text{th}}$ not important?
 - ◆ suppression of fluid instabilities
 - ◆ suppression of heat conduction
 - ◆ Particle acceleration (magnetic turbulence, shock)
- Not only field strength, but also field structures are important.

Suzaku Results of Abell 2319

(Sugawara, Takizawa & Nakazawa 2009)

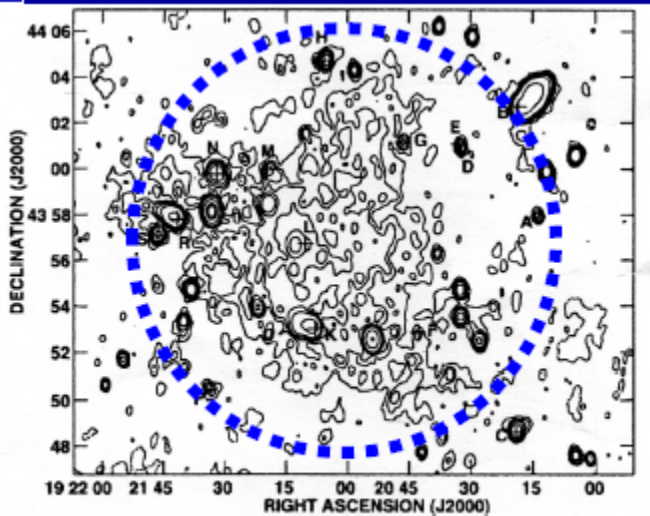
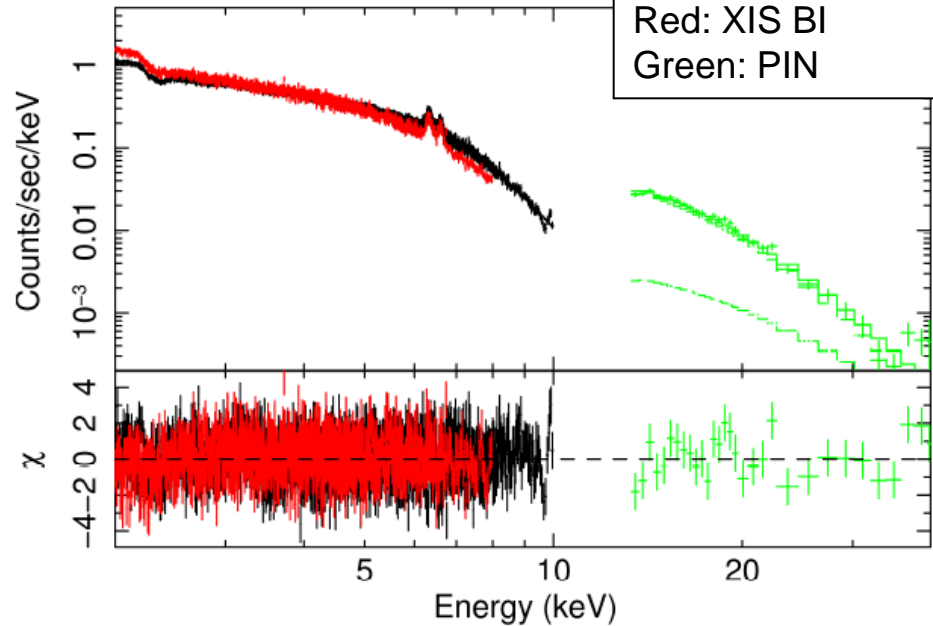


Wide band spectrum

Black: XIS FI

Red: XIS BI

Green: PIN

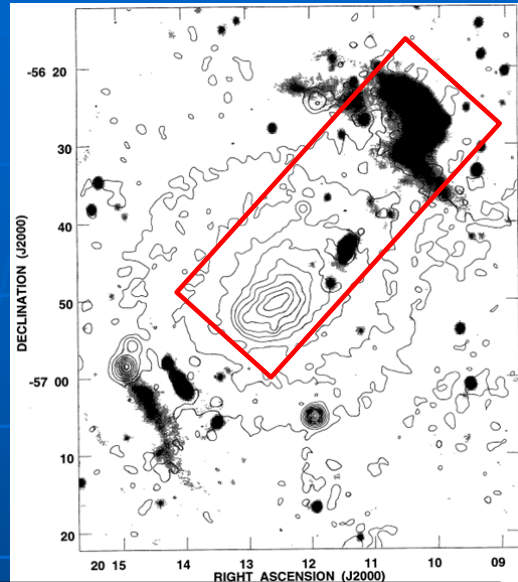


Feretti et al. 1997

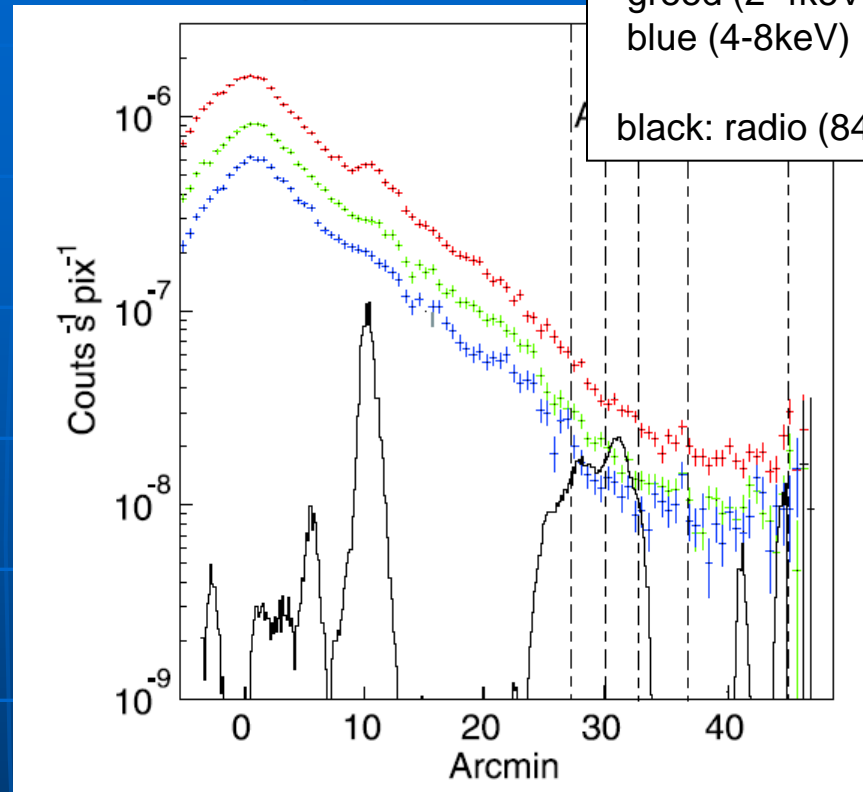
- $F_{\text{nth}}(10\text{-}40\text{keV}) < 3 \times 10^{-11} \text{ erg/s/cm}^2$
- $B > 0.3 \mu\text{G}$
- $U_B/U_{\text{th}} > 3 \times 10^{-5}$
- $U_{\text{CRe}}/U_{\text{th}} < 5 \times 10^{-4} (5.7 \times 10^3 < \gamma < 1.1 \times 10^4)$

Suzaku Results of Abell 3667

(Nakazawa ,,,,Takizawa,,,et al. 2009)



X-ray (contours)
Radio (gray sacs)
Rottgering et al. (1997)



Projectd X-ray image
red (1-2keV)
greed (2-4keV)
blue (4-8keV)
black: radio (843MHz)

- $F_{nth}(10-40keV) < 3.9 \times 10^{-13} \text{ erg/s/cm}^2$
- $B > 2.2 \mu\text{G}$
- $U_B/U_{th} > 0.12$, Magnetic fields could have a significant impact on gas dynamics.
- $U_{CRe}/U_{th} < 0.15$ ($5 \times 10^2 < \gamma < 4 \times 10^4$)

Magnetic Field Structures and Mergers

- Cluster mergers and resultant moving substructures

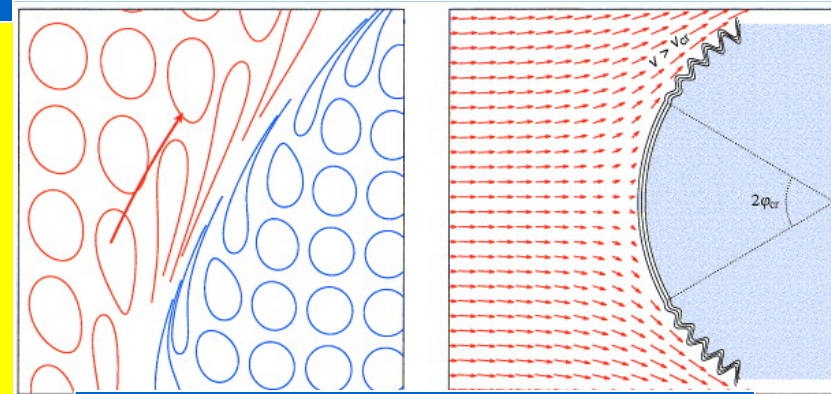
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bulk flow motions and turbulence in the ICM

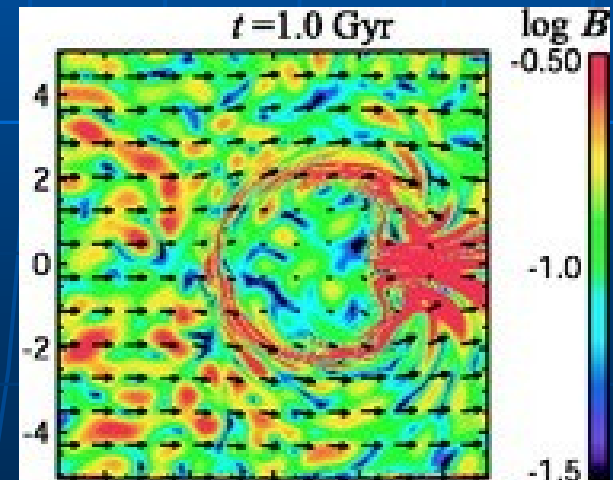
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impact on magnetic field structures

- Field structures parallel to the contact discontinuity???
- Ordered magnetic field???
- Investigate mergers of clusters with random magnetic field



Schematic view of field structure near the cold front
Vikhlinin et al. (2001)



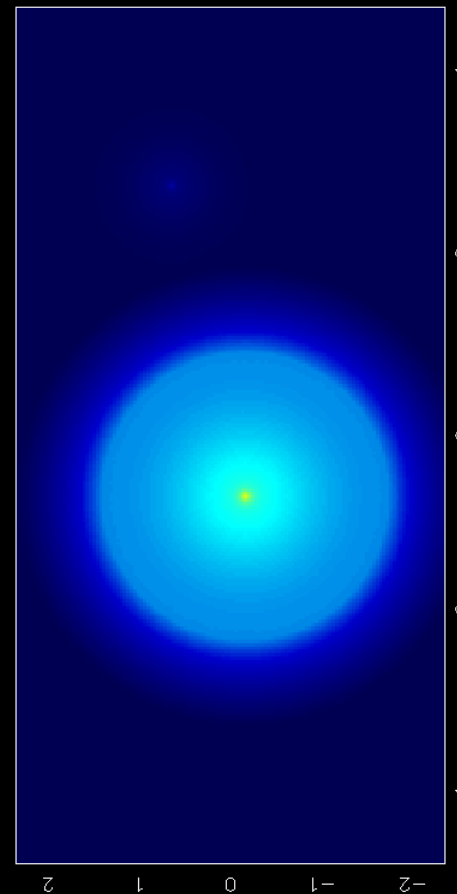
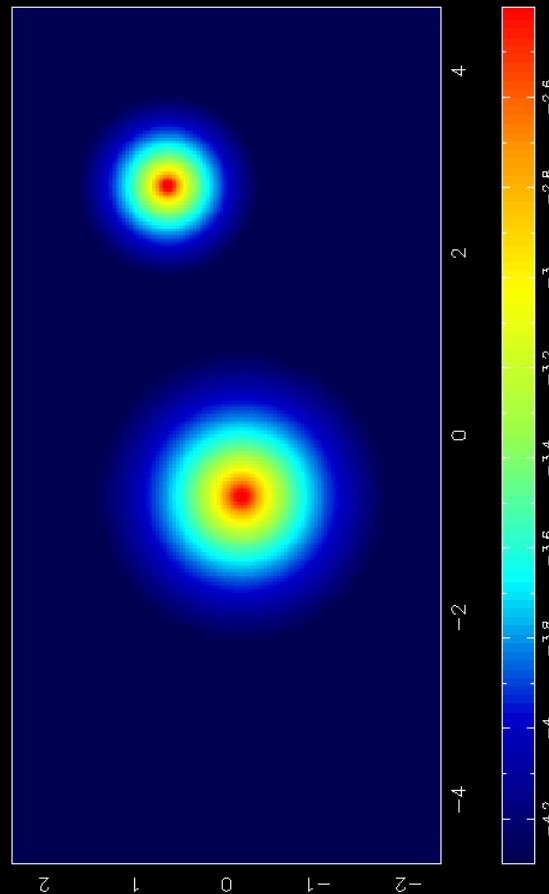
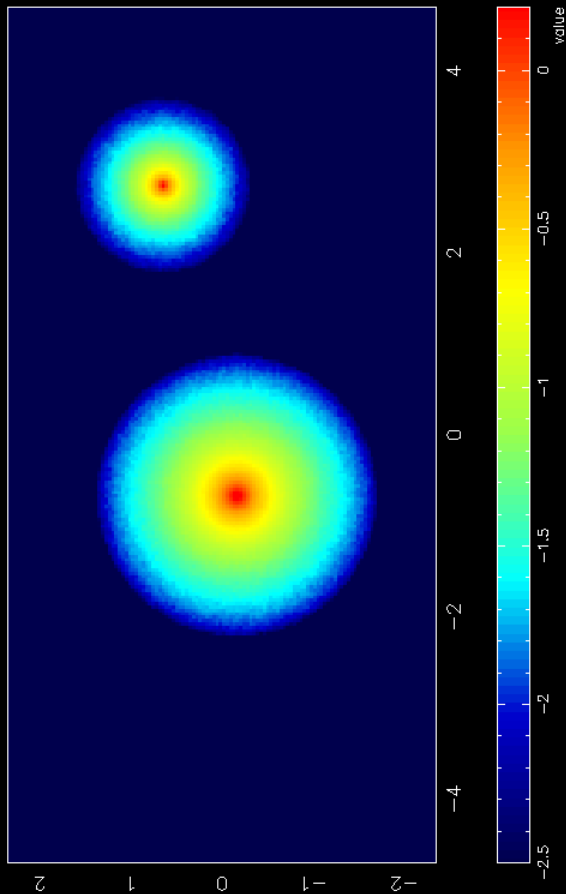
MHD simulation of moving subclump (Asai et al. 2007)

Movies (Takizawa 2008)

Mass density
(mostly dark matter)

Gas density

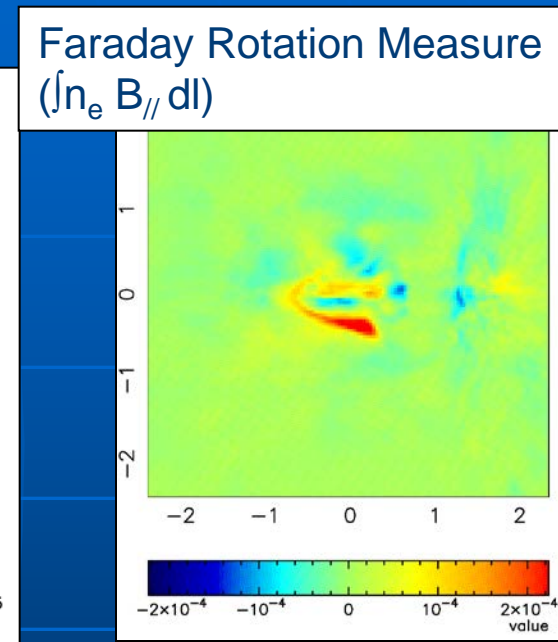
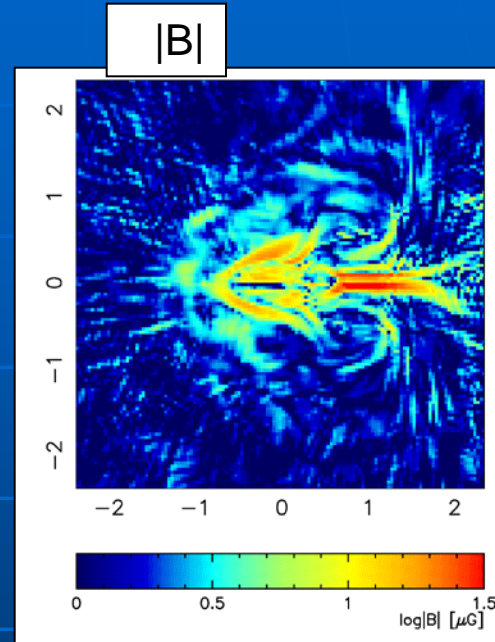
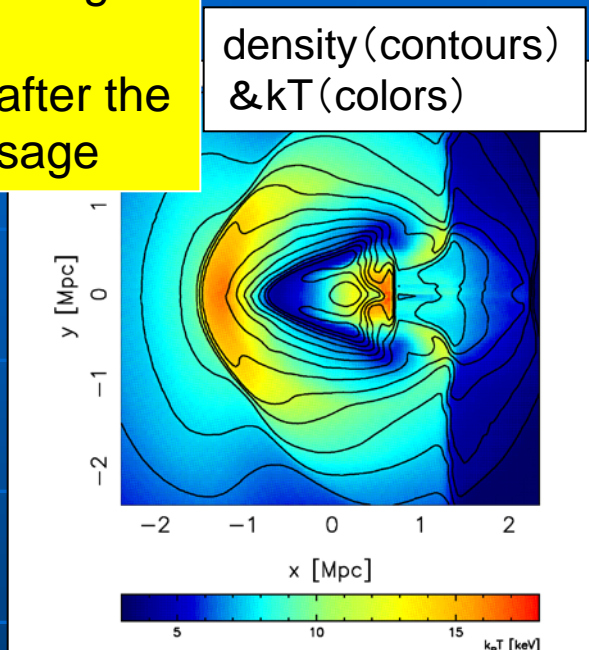
Gas temperature



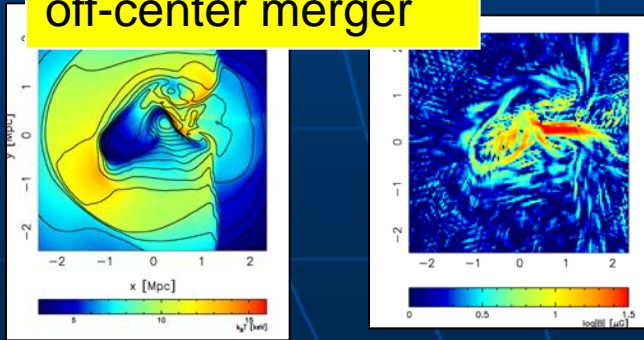
MHD Simulations Results(1)

Takizawa (2008)

1 : 4
head-on merger
0.66Gyr after the
core passage



1 : 4
off-center merger



- ◆ Low temperature region surrounded by the magnetic field (high Faraday Rotation Measure)
- ◆ ordered magnetic field structure behind the small subclump
- ◆ These structures are partly recognized in Faraday rotation measure maps.

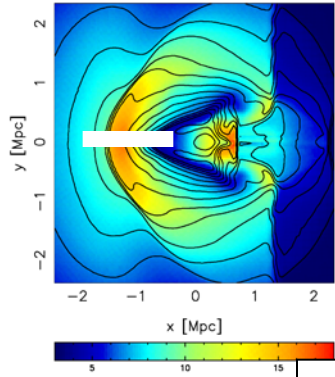
MHD Simulations Results(2)

Takizawa (2008)

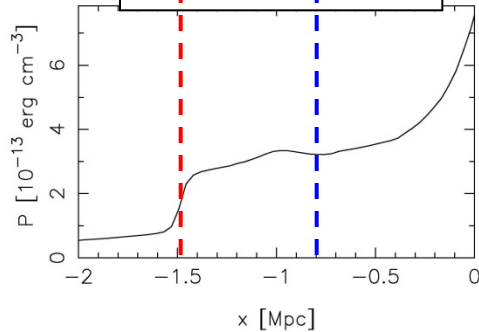
Physical quantity profiles in front of the substructure along the collision axis.

Red: bow shock, blue: contact discontinuity

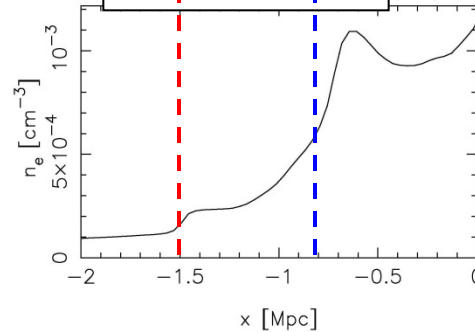
Magnetic field perpendicular to the collision axis is amplified around the contact discontinuity.



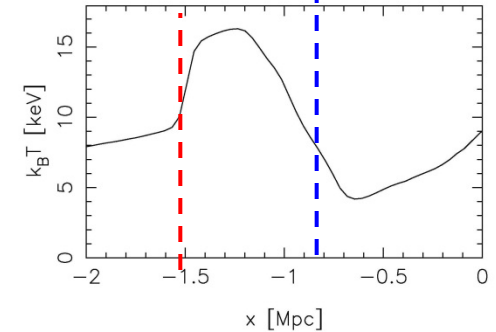
Gas pressure



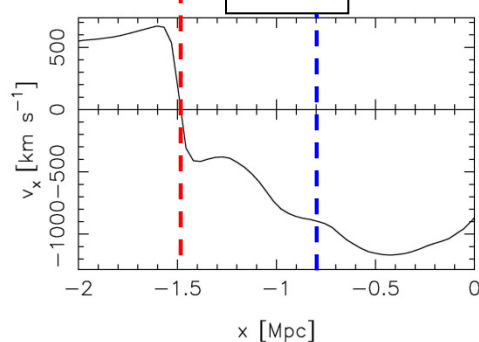
gas density



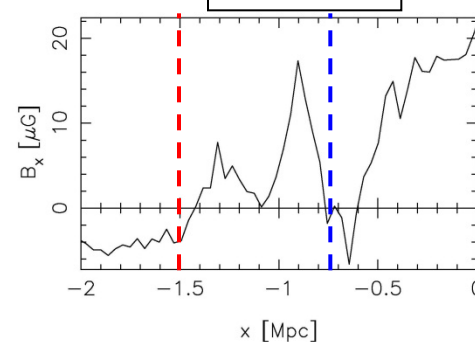
temperature



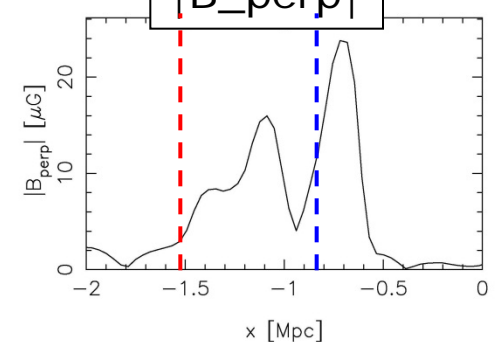
V_x



B_{para}



$|B_{perp}|$



Summary

- Constraint on the magnetic energy density in the intracluster space with Suzaku
 - Radio halo of A2319 (Sugawara, Takizawa, Nakazawa 2009)
 - Radio relic region of A3367 (Nakazawa,,Takizawa,, et al. 2009)
- Magnetic field structure evolution in merging clusters of galaxies using N-body + MHD simulations (Takizawa 2008).
 - Several kinds of characteristic magnetic field structures
 - Low temperature region surrounded by the magnetic field
 - Magnetic field structures perpendicular to the temperature gradients near the contact discontinuity.
 - Ordered magnetic field structures behind moving substructures.
 - Field structures associated with KH eddies
 - If we have Faraday rotation measure maps that cover cluster entirely, we can get information not only magnetic field structures but also gas motion.
 - >observation of CMB polarization (Ohno et al. 2003)、
How about SKA????