X-ray and Radio Observations of the Radio Relic Galaxy Clusters 1RXS J0603.3+4214 and RXC J1053.7+5453

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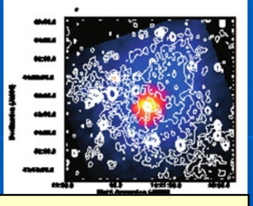
(Abstract)

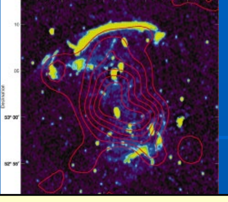
We study two galaxy clusters with radio relics, 1RXS J0603.3+4214 and RXC J1053.7+5453, through X-ray and radio observations. Radio relics are diffuse non-thermal radio sources found in outskirts of galaxy clusters. Because of their shape and location, they are thought to be related to cluster merger shocks. The galaxy cluster 1RXS J0603.3+4214 has a well-known linear-shape "toothbrush" radio relic. We investigate the temperature structure across the relic to constrain the Mach number of the associated shock. The results are compared with radio spectral results, which suggest that a simple diffusive shock acceleration model does not hold for this relic. The RXC J1053.7+5453 harbors a standard arc-like relic. We also get the Mach number from the temperature profile for the first time.

Introduction

- Some merging galaxy clusters have diffuse non-thermal radio emitting regions (E_e~GeV, B~μG).
- Radio halos and mini halos
  Located near the center, similar to X-ray morphology
  Associated with ICM turbulence???
- Radio relics
  Located in the outskirts, arc-like shape,
  Likely associated with ICM shocks?



Abell 2319 with Radio Halo
Rosat X-ray image (colors)
Radio image (contours)
Feretti et al. (1997)



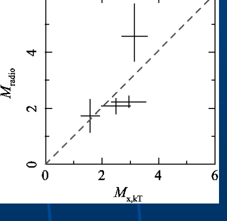
CIZA J2242.8+5301 with Radio Relic
Rosat X-ray image (contours)
Radio image (colors)
Van Weeren et al. (2010)

Mach Number Estimation of Shocks at Radio Relics: Two Methods

- From Radio observations, we get $F_\nu \propto \nu^{-\alpha}$ --> $N(E_e) \propto E_e^{-(2\alpha+1)}$
  With a (simple) diffusive shock accerelation model,
  ---> $M_{Radio}^2=(2\alpha+2)/(2\alpha-2)$
- From X-ray observations, we get T_{post} and T_{pre}
  With the Rankine-Hugoniot(RH) relation
  ---->$T_{post}/T_{pre}=(5M_X^4+14M_X^2-3)/(16M_X^2)$

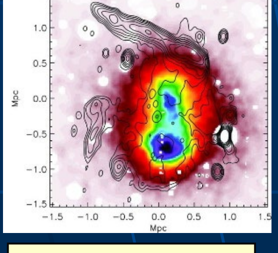
Radio Relics: Mach Number inconsistency???

- Akamatsu & Kawahara (2013) suggests that M_X and M_{radio} seem to be consistent with each other.
- A simple model of diffusive shock acceleration is correct?
- However, sample size is obviously too small to say something definite.

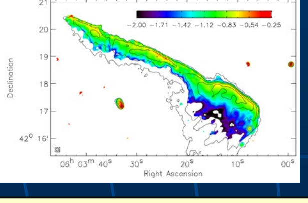


M_X vs M_{radio} from Akamatsu & Kawahara (2013)

1RXS J0603.3+4214 with "toothbrush-relic"



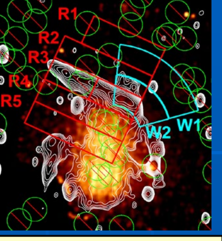
Ogrean et al. (2013)
Colors: X-ray(XMM)
Contours: radio(WSRT)



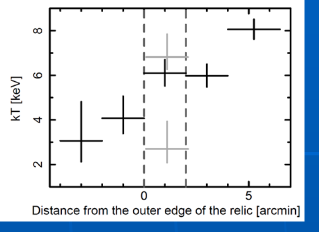
Radio spectral index map (LOFAR+VLA).
α=0.8±0.1----> $M_{radio}=2.8^{+0.5}_{-0.3}$
van Weeren et al. (2016)

Toothbrush-relic: Temperature Profile across the Relic (Itahana et al. 2015)

- We observed the toothbrush cluster with Suzaku to investigate a temperature profile across the relic.
- With RH condition, we obtaine $M_X = 1.50^{+0.37+0.25+0.14}_{-0.27-0.24-0.15}$.
- This value is significantly smaller than the radio results (M≃2.8), but similar to the Chandra results derived from the X-ray surface brightness analysis (M_X≃1.2, van Weeren et al. 2016).



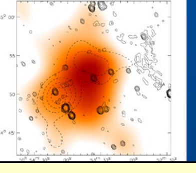
Colors: X-ray(Suzaku)
Contours: radio(WSRT)



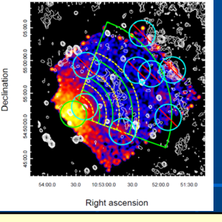
Temperature profile across the toothbrush relic

RXC J1053.7+5453: Temperature Profile across the Relic (Itahana et al. 2017)

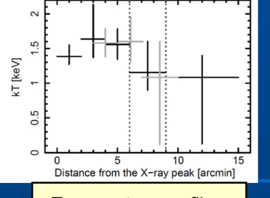
- We observed the RXC J1053.7+5453 cluster with Suzaku and measured the ICM temperature for the first time.
- With RH condition, we obtaine $M_X = 1.44^{+0.48+0.14+0.03}_{-0.91-1.34-0.04}$.
- Unfortunately, we do not have any radio spectral inormation.



van Weeren (2011)
Colors: X-ray(ROSAT)
Solid contours: radio(WSRT)
Dotted contours: galaxy distribution



Colors: X-ray(Suzaku)
Contours: radio(WSRT)

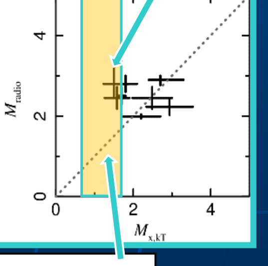


Temperature profile across the relic

Radio relic Mach number problem: updated version

- Sample size becomes slightly larger.
- Some radio results has been changed.
- Basically, M_X and M_{radio} seems to be consistent with each other, but some outliers like "toothbrush" may exist.

Toothbrush relic



Region for RXC J1053

Summary

- Diffuse non-thermal radio emssions are found in some clusters of galaxies (radio halos, mini halos, and relics). Radio relics are likely associated with shocks in the ICM.
- Comparison with X-ray and radio observation results provide us with implications of diffusive shock acceleration model.
- In toothbrush relic, there is a hint of inconsistency between X-ray and radio Mach number estimates.
- In RXC J1053, we measured ICM temperature for the first time and estimate Mach number of shock candidate at the relic.
- Basically, M_X and M_{radio} seems to be consistent with each other, but some outliers like "toothbrush" may exist.