Feedback at work: Radio sources in clusters

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OUTLINE

Radio sources in <u>cooling core</u> clusters

Radio galaxies at the center Mini-halos Small relics

 Diffuse Radio sources on <u>large scale</u> in <u>merging</u> clusters Halos Relics Relaxed Clusters (cooling core)





A 2029 (Lewis et al

Higher probability of radio emission from BCG (Best et al. 2006)



Radio emission from the <u>central</u> galaxy in nearby CC clusters (sample from Peres et al. 98):



Classical FRII R.G.

- radio quiet 16 %
- compact 22 %
- FRII 3%
- FR I 59 %





Radio (synchrotron) emission : (dominant galaxy)





CC cluster

Group



Hydra A - X-ray Chandra Mc Namara et al. 2000

Radio : Taylor et al. (VLA)

Most radio sources in cavities are FRI

The interaction between the AGN jets and the ICM is believed to be the primary feedback

mechanism between the BH and its environment

In the strong or several small episodes of energy release

→ radio bubbles

→ confinement



The radio features are buoyant bubbles

Energy is transferred from the relativistic to the thermal plasma. (Owen et al. 2000, Churazov et al. 2001, Böhringer et al. 2001)

→ interaction between CR and ICM: THE CRs AFFECT THE ICM

- Cavities are filled with cosmic rays which inflate
- the cavities and form a much larger lobe
- Bubbles can rise to the cluster outskirts
- Eventually the cosmic rays diffuse away from the

cavities, impact with/leak into the surrounding mediu

RADIO FEATURES TYPICAL OF CC CLUSTERS

1. Mini-halos at the center of cooling core clusters



First cluster where a radio MINI-HALO was detected Diffuse extended emission is developed around a POWERFUL RADIO GALAXY - 3C 84 - in a COOLING CORE cluster



X-ray: Ettori et al. 2000



Radio, Size = 350 kpc (Sijbring & De Bruyn 1993)





z = 0.228

kT = 11.1 keV $L_{x \text{ bol}} = 6.05 \ 10^{45} \text{ erg s}^{-1}$



Giovannini et al 1999 Bacchi et al 2003



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(Gitti, Brunetti, Feretti, Setti, 2003)



RBS797 (Gitti Feretti Schindler 2006)



Mini – halos : are ~ 100 – 400 kpc in size have steep spectra α ~ 1 some are polarized

They are rare:

3 in the CC clusters of the sample of Peres et al. (1 in clusters with detected X-ray cavities

RADIO FEATURES TYPICAL OF CC CLUSTERS

1. Mini-halos at the center of cooling core clusters

2. Central relics
 Ano parent galaxy clearly determined



M87 (Forman et al. 2007)



X-ray

X-ray

See Mathews and Brighenti 2008







DECLINATION (J2000)

Central relics have: very steep spectra α > 2 very high polarization degree

They are rare:

4 among the CC clusters of the sample of Peres et al. (2 in clusters with detected X-ray cavities

<u>Diffuse Radio Sources at the center of</u>

Relaxed - cool core - clusters :

- mini-halos
- central relics

steep spectrum radio sources
feedback

Rare phenomena, cannot be used to distinguish between CC and non-CC clusters

<u>Merging clusters</u> :

- radio halos



→ ON VERY LARGE SCALES

demonstrate CR/thermal interaction <u>CR affected by ICM</u>

Link between radio and X-ray emission



Figure 1. Correlation between the radio power at 1.4 GHz and the N-ray luminosity between [0.1-2.4] law for the GRHz.

Cassano Brunetti Setti 2006



A2163 - Feretti et al. 2001



A2744 - Orru' et al. 2007

Particle reacceleration fro turbulence in merging clust Merging clusters :

- radio halos

- radio relics

→ ON VERY LARGE SCALES

demonstrate CR/thermal interaction <u>CR affected by ICM</u>

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A3367: ROSAT FSPC overlaid with MOST sum 0 ٥٣ -56°30' -57°0' 21 20ⁿ18^m 14^{m} 12**m** 10^m

Right Ascension (J2000)



Rottgering et al. 1997

Declination (J2000)



Briel et al. 2001



XMM-Newton Image of X-ray Emission from Coma Cluster, 0.3-2.0 keV



Neumann et al. 2001



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ROSAT Feretti et al. 2003

XMM-Newton Solovyeva et al. 2008



XMM-Newton Solovyeva et al. 2008



A2345 (Bonafede et al. in prep.)



Giovannini & Feretti 2004

Particle reacceleration fro Shock waves in merging clu



A2255 : features at 2 MPC projected dist = virial rad

(Pizzo, De Bruyn, Feretti, Govoni 2008)

Cooling Core Cl

Merging Cl

Mini - Halos

Central small relics

Halos

Relics

Rare phenomena!

FUTURE PROSPECTS

Statistics

Link between radio and X-ray emission \rightarrow

structures - radio and X-rays radio spectra correlations CR/gas interaction confinement THANK YOU