NON THERMAL RADIO PHENOMENA IN GALAXY CLUSTERS

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OUTLINE

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GALAXY CLUSTERS

- **80% Dark Matter**
- **17% Hot Baryonic Matter (ICM)**
- **3% Cold Baryonic Matter (Stars and Gas)**
NON-THERMAL PROPERTIES

ICM:
- Thermal plasma
- Relativistic electrons ($\sim \text{GeV}$)
- Magnetic field ($\sim \mu \text{G}$)

Non-thermal phenomena
- Radio
- EUV
- HXR
- HALOS
- MINI-HALOS
- RELICS

Present only in unrelaxed clusters
RADIO HALOS

• Extended (≥1 Mpc) diffuse emission

• Located at the centre of galaxy clusters

• Fairly regular morphology (in good spatial coincidence with the hot X-ray emitting gas)

• Radio emission unpolarized

• Low surface brightness (~μJy/arcsec² at 1.4 GHz)

• Steep spectrum $\alpha = 1.2 - 1.4$ (USSRH up to 2)

\[ S_\nu \propto \nu^{-\alpha} \]

\[ \alpha = \frac{1 - \delta}{2} \]

\[ N(E) dE = N_0 E^{-\delta} dE \]

USSRH in Abell 521 (Brunetti et al 2008)
RADIO RELICS

• **Variety of morphologies** (elongated and arc-shaped are most common)
• **Located at the cluster periphery**
• **Steep radio spectra**
• **High fractional polarization**

3 types in literature:
(classification by Kempner et al 2003)

Slee et al. 2001
« Phoenix »

Slee et al. 2001
Fujita et al. 2002
« AGN relic »

(Johnston-Hollitt 2003)
« Radio Gischt »
PROPOSED MODELS

LARGE EXTENT

DIFFUSION TIME OF RELATIVISTIC ELECTRONS TO SPREAD OVER Mpc SCALES EXCEEDS RADIATION LIFETIME BY ~ TWO ORDERS OF MAGNITUDE

IN SITU RE-ACCELERATION/INJECTION
PROPOSED MODELS

• **PRIMARY MODELS**: electrons accelerated by **SHOCKS**
  via Fermi I processes (Ensslin et al 1998; Hoeft & Brueggen 2007)
  via adiabatic compression (Ensslin & Gopal-Krishna 2001)

and/or **TURBULENCE** induced during cluster mergers
via Fermi II processes (Brunetti et al 2001)
via MHD waves (Brunetti et al 2004; Cassano, Brunetti 2005)

• **SECONDARY MODELS**: relativistic electrons continuously injected by **HADRONIC COLLISIONS**
  between the thermal ICM ions and relativistic protons accelerated during the whole cluster history
  (Dennison 1980; Blasi & Colafrancesco 1999)
DIAGNOSTICS

**PRIMARY MODELS**

Spectral steepening and complex spatial distribution of spectral index (turbulence)

Straight spectra and spectral index gradient (shock)

**SECONDARY MODELS**

Predict flatter and straight spectra + stronger magnetic fields;

Spectral index distribution unrelated to the intracluster magnetic field strength, hence independent of the position in the cluster
**DIAGNOSTICS**

- **Spectral index studies** provide important information about energy spectrum of relativistic electrons, hence on re-acceleration processes.

- **Synchrotron emissivity**: total **magnetic field strength** in galaxy clusters.

- **Polarized emission**: projected orientation and degree of ordering.
CURRENT OBSERVATIONS

SUPPORTING THE SHOCK SCENARIO FOR RELICS

Macario et al. 2011

Van Weeren et al. 2010

SUPPORTING THE TURBULENCE RE-ACCELERATION SCENARIO FOR HALOES

Thierbach et al. 2003

Feretti et al. 2004
PRESENT WORK

- **Increase the statistics** of radio halos and relics with well defined integrated spectra and spectral index distribution maps in order to put models to the test.

- **Polarization studies** to obtain information on magnetic field in galaxy clusters.
COMA CLUSTER

First cluster where a radio halo and a relic were detected (Large 1959, Willson 1970, Ballarati et al. 1981)

J.O. Burns 1998

Brown & Rudnick 2011
RADIO RELIC 1253+275

1.18 ± 0.02

2.7 GHz Effelsberg
Thierbach et al. 2003

1.4 GHz VLA
Giovannini et al. 1985, 1991

608 MHz GMRT
Thierbach et al. 2003
PRELIMINARY RESULT (1)

WSRT 2.3 GHz

WITHOUT PRIMARY BEAM CORRECTION

Conv size = 26" x 11"
PRELIMINARY RESULT (2)

WITH PRIMARY BEAM CORRECTION ..?!

TO BE COMBINED WITH EFFELSBerg 13 cm OBSERVATIONS
Abell 2256

Bridle & Fomalont 1976
610 MHz

Clarke & Ensslin 2006
1703 MHz

VLA

Brentjens 2008
WSRT 350 MHz

RELIC

Clarke & Ensslin 2006
VLA 1369 MHz

VLA 1703 MHz

Kale & Dwarakanath
GMRT 150 MHz
CONCLUSIONS

- An increasing number of galaxy clusters exhibit **radio halos and relics**;

- **Troughout multiwavelenght observations** of such sources we can constrain the spectrum of the emitting particles and so put models to the test;

- **Polarization studies** enable to study magnetic field on galaxy clusters;

- **Combination of interferometric data with single dish data** provide both the high resolution of the interferometer and the short-spacing information of the single-dish observations.
THANKS