

Argelander-Institut für Astronomie



NON THERMAL RADIO PHENOMENA IN GALAXY CLUSTERS

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PHYSICAL INTRODUCTION NON-THERMAL RADIO PHENOMENA IN GALAXY CLUSTERS PROPOSED MODELS DIAGNOSTICS CURRENT OBSERVATIONS

> PRESENT WORK

> PRELIMINARY RESULTS

> CONCLUSIONS

GALAXY CLUSTERS





17 % HOT BARYONIC MATTER (ICM)

3 % COLD BARYONIC MATTER (STARS AND GAS)

> 80 % DARK MATTER



NON-THERMAL PROPERTIES

ICM:

- THERMAL PLASMA
- RELATIVISTIC ELECTRONS (~GEV)
- MAGNETIC FIELD (~µG)



RH in Abell 2163 (Feretti et al. 2001)



RR in Abell 3376 (Bagchi et al. 2006)

PRESENT ONLY IN UNRELAXED CLUSTERS

RELICS

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 (~ μ JY/arcsec² at 1.4 GHz)



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



USSRH inAbell 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 »



A133

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



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)

• <u>SECONDARY MODELS</u>:

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



Frequency

	PREDICT FLATTER AND STRAIGHT SPECTRA +
SECONDARY MODELS	STRONGER MAGNETIC FIELDS;
	SPECTRAL INDEX DISTRIBUTION UNRELATED TO
	THE INTRACLUSTER MAGNETIC FIELD
	STRENGHT, 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 STRENGHT IN GALAXY CLUSTERS
- POLARIZED EMISSION : PROJECTED ORIENTATION AND DEGREE OF ORDERING

CURRENT OBSERVATIONS

SUPPORTING THE SHOCK SCENARIO FOR RELICS



Macario et al. 2011



CIZA J2242.8+5301

Van Weeren et al. 2010

SUPPORTING THE TURBULENCE RE-ACCELERATION SCENARIO FOR HALOES





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



Thierbach et al. 2003



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2.7 GHz Effelsberg Thierbach et al. 2003



PRELIMINARY RESULT (1)



PRELIMINARY RESULT (2)

WITH $+27^{\circ}40$ PRIMARY BEAM (B1950)+35'CORRECTION ..?! +30'Declination **TO BE** +25'**COMBINED** WITH +20'**EFFELSBERG 13** CM **OBSERVATIONS** +1552^m30^s $12^{h}53^{m}30^{s}$ $53^{m}00^{s}$ $52^{m}00^{s}$ Right Ascension (B1950)



PRELIMINARY RESULT

EFFELSBERG 4.75 GHz

A2256 TP 4.75 GHz 79°03' 78°53' DEC (1950) 78°43' DEC (1950) 78°33' 78°23' 17^h13^m 17^h09^m 17^h01^m 17^h05^m RA (1950)

TOTAL POWER EMISSION

POLARIZED INTENSITY A2256 PI 4.75 GHz 79°03' 78°53' 78°43' 78°33'-78°23' 17^h13^m 17^h05^m 17^h01^m 17^h09^m RA (1950)



- AN INCREASING NUMBER OF GALAXY CLUSTERS EXHIBIT RADIO HALOS AND RELICS;
- TROUGHT 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