Polarized Emission of Cluster Merger Shock Fronts

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Galaxy Clusters in Radio Emission

Coma Cluster

Halo

Relic

CIZA J2242+53

X-ray Emission

Radio Relics

~1.9 Mpc
10. arcmin

Venturi+1990

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Jee+15
Open Questions Effelsberg may Answer

- **Origin of cluster magnetic fields?**
  - Relics are highly polarized!
  - Most extended ordered magnetic fields in the universe
  - Resolved by Effelsberg beam
  - Low Faraday depolarization at high frequencies

- **Cosmic Ray acceleration mechanism?**
  - Steep spectra with spectral break?
  - Effelsberg is sensitive to high frequencies
  - NO missing large scale flux density!!
The Sample

Simple case
Sausage

A bit more tricky
Toothbrush

Known faint relic
ZwCl 0008

Faint relic candidate
Abell 1612

van Weeren et al. 2010, VLA 4.9 GHz
2 Mpc

van Weeren et al. 2012, WSRT 4.9 GHz
1.9 Mpc

van Weeren et al. 2011, GMRT 325 MHz
0.8 Mpc

van Weeren et al. 2011, WSRT 1.4 GHz
1.4 Mpc

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Sausage

Peak polarization ~ 55%
Toothbrush

Peak polarization
~ 50%
Integrated Synchrotron Spectra

NO evidence for spectral steepening!! (until 8 GHz)
Depolarization in Toothbrush

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**Strong Faraday depolarization**
by turbulent fields in the foreground cluster

**Needed:**
Decrease of field strength and/or electron density with increasing distance from cluster center

\[ DP = \rho_{1.38} / \rho_{8.35} \]

Data: WSRT, 1.38 GHz, van Weeren et al. 2010
Eff, 8.35 GHz, Kierdorf et al. 2017

→ Enables us to put constraints on the ICM
RM gradients?

12 rad m\(^{-2}\) / arcmin

15 rad m\(^{-2}\) / arcmin
Origin of RM gradients?

- **Internal to the relic?**  
  NO! – no internal Faraday depolarization

- **Milky Way foreground?**  
  NO! – gradients from MW are too small

- **Foreground cluster?**  
  coherent fields needed, but large-scale dynamo cannot work

- **Large-scale coherent field from Cosmic Web?**
New Observations

- $z=0.33 \rightarrow$ very far away
- Highly polarized (10-30%) already at 1.4 GHz
Summary

- Polarization discovered for all four test cases
  → Effelsberg excellent tool to study polarization of relics
  → New observations are promising

- Synchrotron spectra show purely power laws
  → no sign for steepening with single dish flux densities
  → Maybe beyond 8 GHz?

- Depolarization in Toothbrush
  → enable us to put constraints on the properties of the ICM

- RM gradients
  → coherent fields from cosmic web?