Radio-Xray observations at Galaxy Cluster shock

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SnowCluster — March 21st, 2018
MERGERS

- Disturbed morphology
- One or more surface brightness and temperature discontinuities:
  - shock: $\Delta T < 1$
  - cold front: $\Delta T > 1$

RADIO
(a reminder from Reinout’s talk…)

- HALO
- RELIC
- Tailed shape in galaxy cluster
- Lobed shape in the field
- Flat spectrum in the nucleus, steep spectra in the lobes

- RADIO GALAXIES
- CENTRALLY LOCATED
- Mpc-size (roundish)
- Unpolarized
- Steep spectra
- Particle acceleration from merging turbulence

- RELICS
- Located in the outskirts
- ~Mpc-size (elongated)
- Polarized
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Credit: Radio: NRAO/AUI/NSF
RADIO

The “Sausage” Cluster — Diffusive Shock Acceleration mechanism

van Weeren+10, Stroe+13, Hoang+17, Di Gennaro+prep

THE “SAUSAGE” CLUSTER

- Diffusive shock acceleration
- Centrally located
- Mpc-size (roundish)
- Unpolarized
- Steep spectra
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OPEN QUESTIONS

• What are the properties of relic-shocks (ZwCl 0008) ?

• Do we (really) understand the spectral index gradients (“Sausage” Cluster) ?
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• Do we (really) understand the spectral index gradients ("Sausage" Cluster)?
ZwCl 0008.8+5215

- $z = 0.104$
- LLS$_{RE} \sim 1.4$ Mpc; LLS$_{RW} \sim 300$ kpc (van Weeren+11)
- $M_{200,E} \sim 5.7 \times 10^{14}$ M⊙
- $M_{200,W} \sim 1.2 \times 10^{14}$ M⊙ (Golovich+17)
- merger angle $\leq 40°$ (Golovich+17)
- $T_{500} = 3.85 \pm 0.05$ keV

Blue: radio (WSRT 1.4 GHz, van Weeren+11)
Orange: X-ray ($\sim 400$ ks Chandra, Di Gennaro+ in prep.)
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- $M_{200,W} \sim 1.2 \times 10^{14} \, M_\odot$  (Golovich+17)
- merger angle $\lesssim 40^\circ$  (Golovich+17)
- $T_{500} = 3.85 \pm 0.05 \text{ keV}$

**blue:** radio (WSRT 1.4 GHz, van Weeren+11)
**orange:** Xray (~400 ks Chandra, Di Gennaro+ in prep.)

**colour:** Week Lensing mass distribution (Golovich+17)
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**Western edge?**

**Eastern edge?**

**bullet**
The western edge

The image shows a map of a galaxy cluster, with a dashed line indicating the western edge. The cluster has a cluster mass at the center, with a temperature peak around 500 keV. The mass within 500 kpc is given as $M_T = 1.50^{+0.64}_{-0.42}$, and the mass at the western edge is $M_W = 1.49^{+0.88}_{-0.46}$. The background shows the distribution of temperature and emission along the edges of the cluster.
The western edge

\[ M_T = 1.50^{+0.64}_{-0.42} \]

\[ M_X < 2.4 \]

\[ M_S = 1.49^{+0.88}_{-0.46} \]
The western edge

\[ \mathcal{M}_{\text{radio}} = 2.4^{+0.4}_{-0.2} \]

\[ \mathcal{T}_{500} \]

\[ \mathcal{M}_{\text{X}} < 2.4 \]

\[ \mathcal{M}_{\text{S}} = 1.49^{+0.88}_{-0.46} \]

\[ \mathcal{M}_{\text{T}} = 1.50^{+0.64}_{-0.42} \]
The western edge

$\mathcal{M}_{\text{radio}} = 2.4^{+0.4}_{-0.2}$

$\mathcal{M}_S = 1.49^{+0.88}_{-0.46}$

$\mathcal{M} = 2.71^{+6}_{-0.98}$
A case for re-acceleration?

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SnowCluster — 21 March 2018
A case for re-acceleration?

New JVLA (1-2 GHz, PI: R.J. van Weeren) and LOFAR (150 MHz, PI: G. Di Gennaro)
A case for re-acceleration?

1-2 GHz JVLA C-array (9.5'' × 8.3'')

 rms ~ 35 μJy/beam

1-2 GHz JVLA D-array (35.4'' × 26.8'')

 rms ~ 10 μJy/beam
A case for re-acceleration?

1-2 GHz JVLA C-array (9.5” × 8.3”)

1-2 GHz JVLA D-array (35.4” × 26.8”)

… waiting for LOFAR

… waiting for LOFAR

A1033 — JVLA

degasperin+17 (and his talk!)

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The eastern edge

\[ M_T = 1.07^{+0.44}_{-0.41} \]

\[ M_S = 1.06^{+0.08}_{-0.05} \]
The eastern edge

\[ \mathcal{M}_S = 1.06^{+0.08}_{-0.05} \]

\[ \mathcal{M}_T = 1.07^{+0.44}_{-0.41} \]

\[ T_{500} \]

\[ M_X < 1.5 \]
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The eastern edge

\[ \mathcal{M}_{\text{radio}} = 2.2^{+0.2}_{-0.1} \]

\[ M_T = 1.07^{+0.44}_{-0.41} \]

\[ M_X < 1.5 \]

\[ M_S = 1.06^{+0.08}_{-0.05} \]

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• What are the properties of relic-shocks (ZwCl 0008) ?

• Do we (really) understand the spectral index gradients (“Sausage” Cluster) ?
CIZAJ2242.8+5301: the “perfect” relic

INGREDIENTS:
• Mach number (injection spectrum)
• Magnetic field
• Downstream aging
• Geometry (projection)
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... but ...

INGREDIENTS:

- Mach number (injection spectrum)
- Magnetic field
- Downstream aging
- Geometry (projection)

Spoiled by Reinout yesterday...
SUMMARY

• Deep Chandra (~400 ks) and 1.4 GHz WSRT (van Weeren+ 11) observations of a double-relic cluster (ZwCl0008)
  ➡ ~1 Mpc-size shocks in the East and in the West from the X-ray image
  ➡ Western relic: re-acceleration of plasma from radio tail(s) ?
      🟢 waiting for deep low-frequency observations
  ➡ Eastern edge: no coincidence with the radio relic

• The “Sausage” Cluster is made up of filaments and simple aging model does not explain spectral index gradient
BACK UP SLIDES
The western edge

\[ M = 1.14^{+0.73}_{-0.13} \]

\[ M = 2.71^{+6}_{-0.98} \]

\[ M = 1.61^{+1.80}_{-0.60} \]

\[ M_{\text{radio}} = 2.4^{+0.4}_{-0.2} \]

\[ M_S = 1.49^{+0.88}_{-0.46} \]
Spectral index aging (without any “projection effects” included):