Filaments of the radio cosmic web: opportunities and challenges for the SKA

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X-ray → dense gas

- what fundamental physics can we learn from the WHIM?
- can the SKA detect the Cosmic Web?

Simulation: ENZO run of $(300\text{Mpc})^3$ with $2048^3$ cells - FV, Gheller & Bruggen 2014 MNRAS
3D rendering: SPLOTCH - C. Gheller
The WHIM and fundamental physics: (1) origin & amplification of cosmic magnetism

MAGNETIC FIELDS IN FILAMENT: UNKNOWN

- Seed fields? $10^{-16}$-$10^{-9}$ G (e.g. Neronov & Vovk 2011)
- Compression: $B > 0.001\% B_{eq}$
- Small-Scale dynamo $B \sim 0.1-10\% B_{eq}$ (Ryu+08)
- Faraday Rotation in COMA SE $B \sim 1\mu G$ (Bonafede+13)

MAGNETIC FIELDS IN A COSMOLOGICAL VOLUME

- Just compression
- Compression+dynamo

Small-Scale dynamo: only if $Re > 900$
(Schechchihin+04, Cho+09)
we need $dx < 1-2kpc$

...numerically challenging

2400^3 ENZO_MHD_GPU©Lugano (FV, Gheller, Wang, Brüggen)
MAGNETIC FIELDS IN A COSMOLOGICAL VOLUME

just compression

compression+dynamo

2400^3 ENZO_MHD_GPU@Lugano (FV, Gheller, Wang, Brüggen)
The WHIM and fundamental physics:

Radio emission from the ICM is teaching us about:
- magnetic fields
- cosmic rays energy budget
- diffusive shock acceleration
- turbulent acceleration
- effective plasma collisionallity

Radio emission from the WHIM can teach us about:
- plasma collisional scales in rarefied gas
- diffusive shock acceleration in low B-field
- CRS at the periphery of structures
- seeding & amplification of magnetism
- deflection of Ultra High Energy CRS
Synchrotron emission from the diffuse gas in filaments

- "primary" emission from shock accelerated electrons (as in relics)
- "secondary" emission from hadronic collisions

**PRIMARY**

\[ I_\nu \propto S \cdot n_p \cdot e_{\nu} \cdot T^{3/2} \cdot \left( \frac{B_0^{1+\delta/2}}{B_{\text{CMB}}^2 + B_0^2} \right) \]

**SECONDARY**

\[ \sim X_{\text{CRp}} \cdot n_p \cdot e_{\text{th}} \cdot \frac{B_{1}^{\alpha_{\nu} + 1}}{B_2^2 + B_{\text{CMB}}^2} \cdot \nu^{-\alpha_{\nu}} \]

**TOTAL**

(Images of observed and simulated synchrotron emission from filaments with annotations for primary and secondary emissions.)
What can different SKA instruments detect (during Phase 1)?

Assumptions:
- 3-sigma detection
- 2yr Survey or 1000hr exp.
- Baseline filtering
- Redshift 0.01 < z < 0.5
- B-field: 1-100 mG
- x_i = 0.0-0.001%
- FG are removed

→ n<sub>x</sub>: more sophisticated clean (e.g. Ferrari's talk)
what can different SKA instruments detect? (Phase 1 vs Phase 2)

- **SKA SUR/MID**: nearly **NO chance** of detection due to missing baseline. Only 1 giant filament every SKA-SUR FOV & 1000hr, $z > 0.4$, only brightest parts.
- **SKA LOW**: significant **CHANCE of detection** for $z < 0.1-0.2$ for efficient dynamo & shock acceleration.
- **Phase 1**: only brightest parts are detected.
- **Phase 2**: a **10%** fraction of the volume of filaments can be detected

bright knots are detected

a big portion of the filament is detected
Conclusions:

- If particle acceleration follows extrapolation from the ICM, the COSMIC WEB should shine in synchrotron at the \(\sim 0.01-0.1 \mu \text{Jy/arcsec}^2\) level.

- SKA-LOW-1 \(\rightarrow\) "tip of the iceberg"
- SKA-LOW-2 \(\rightarrow\) significant fraction
- SKA-MID/SUR \(\rightarrow\) nearly no chance

- Detections (and even non-detections) will open unexplored territory concerning cosmic magnetism, particle acceleration and plasma conditions in the WHIM.

THANKS