On the Depolarization of the Observed Emission From Radio Relics

Denis Wittor

with F. Vazza, Matthias Hoeft and M. Brüggen

21.03.2018

MAGCOW

ERC Starting Grant

ALMA MATER STUDIORUM

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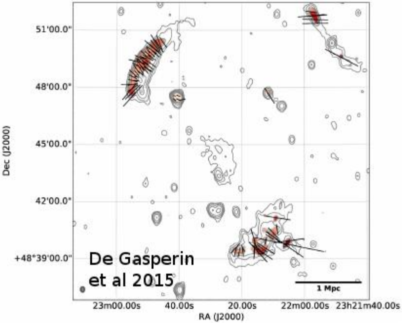
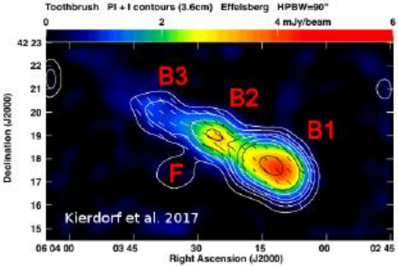
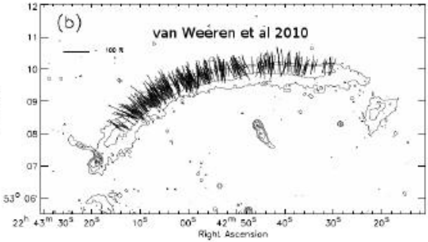
A.D. 1088

Polarization of Radio Relics



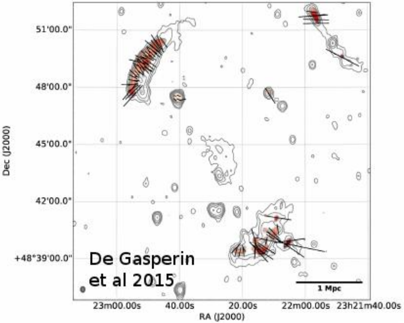


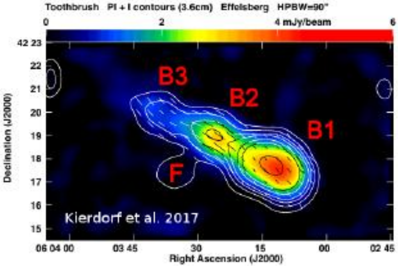


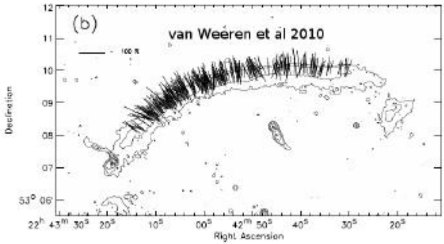
Polarization of Radio Relics

- highly polarized 10 – 50 %
- a lot of observations (Bonafede et al. 2009, van Weeren et al. 2010, Kale et al. 2012, de Gasperin et al. 2015, Kierdorf et al. 2017, ...)
- barley no simulations (Skillman et al. 2013)

Polarization of Radio Relics







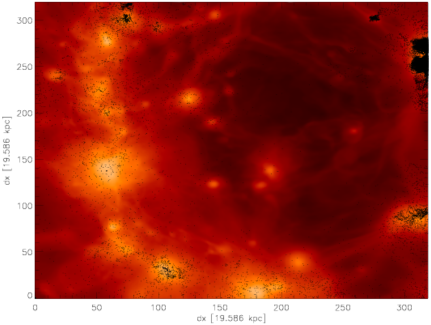
Polarization of Radio Relics

Use polarized emission from radio relics to study the magnetic field properties using numerical simulations.

SIMULATIONS

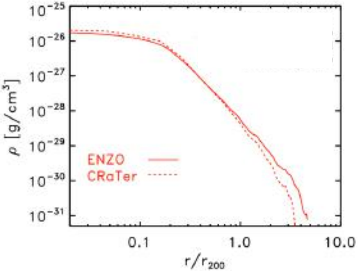
Cosmological Simulations with ENZO

- by Bryan et. al 1997 $\cdots$ 2014
- dark matter: N-body particle mesh-solver
- baryonic matter: adaptive mesh method

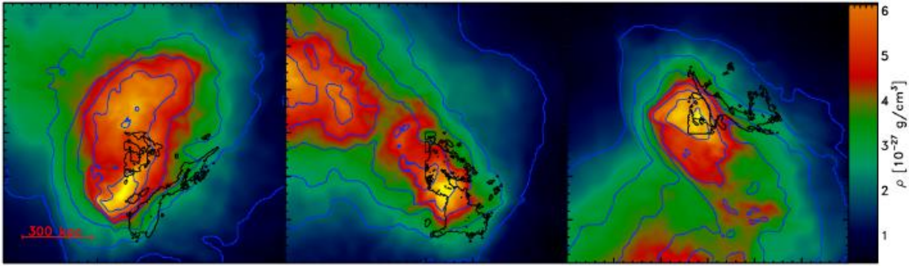


Lagrangian Analysis with CRaTer

- follow baryonic mass passively
- detect shocks using temperature jumps
- compute shock injected cosmic-ray electron spectrum
- e.g. Wittor et al. 2016, 2017



High Resolution Radio Relic



ENZO simulation

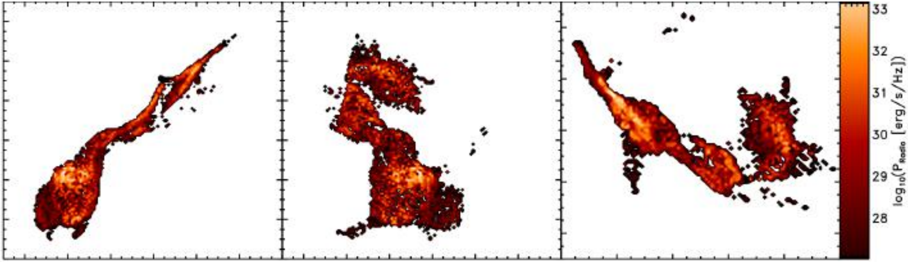
- resolution $\mathrm{d}x \approx 4$ kpc
- timestep $\mathrm{d}t \approx 4$ Myr

CRaTer simulation

- $5 \cdot 10^7$ tracers in a $(1600 \text{ kpc})^3$ volume
- $m = 2 \cdot 10^6 \text{ M}_\odot$
- $5 \cdot 10^5$ shock injected spectrum following Hoeft & Brüggen 2007

color: density
blue: pressure
black: radio

Radio Relic Close-Up

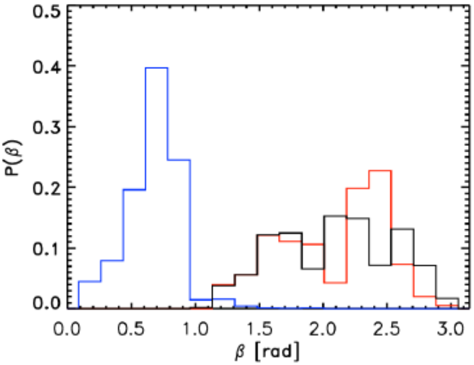


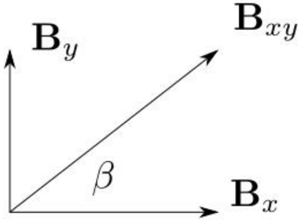
Goal: Polarized Emission (Burn 1966)

$$P_{\mathrm{burn}}(\lambda^2) = \frac{\int\limits_{\mathrm{los}} P_{\mathrm{tot}} \Pi \exp\left(2i\left(\beta + RM\lambda^2\right)\right) \mathrm{d}s}{\int\limits_{\mathrm{los}} P_{\mathrm{tot}} \mathrm{d}s}$$

- Π: fractional polarization
- β: intrinsic angle of polarization
- $\Phi\lambda^2$: Faraday Rotation

Intrinsic Angle of Polarization

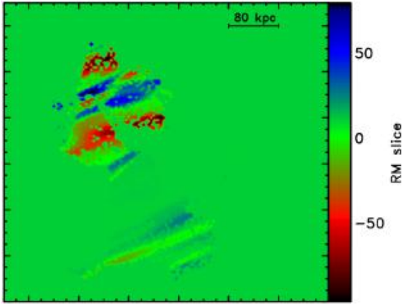


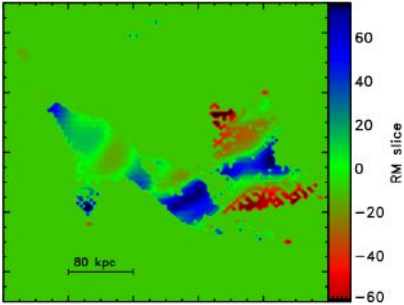


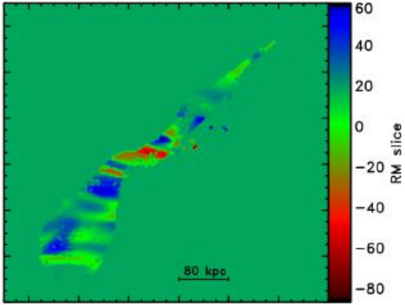
Color: different LoS

black: $0.5 \cdot \pi < \beta < \pi$
blue: $0.5 \cdot \pi < \beta < \pi$
red: $0 < \beta < 0.5 \times \pi$

Depolarization







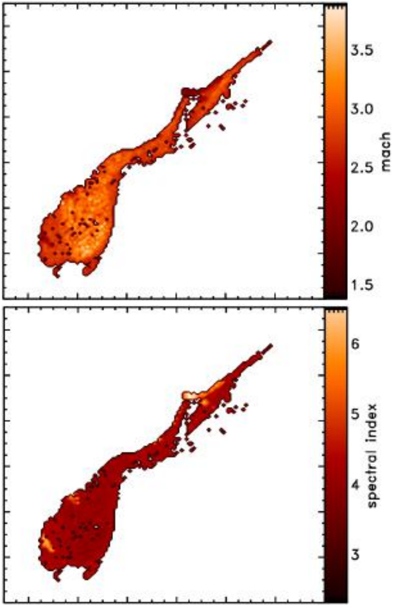
Depolarization

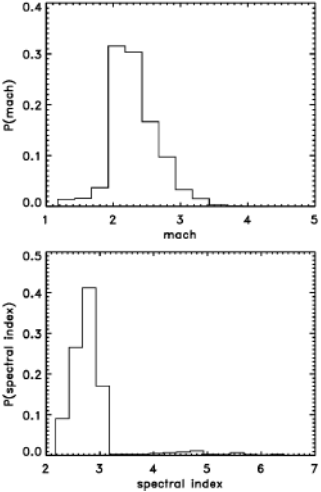
- Faraday Rotation $RM\lambda^2$:

$$RM \propto \int n_e \mathbf{B}_{\|} \mathrm{d} los$$

- instrumental depolarization not included

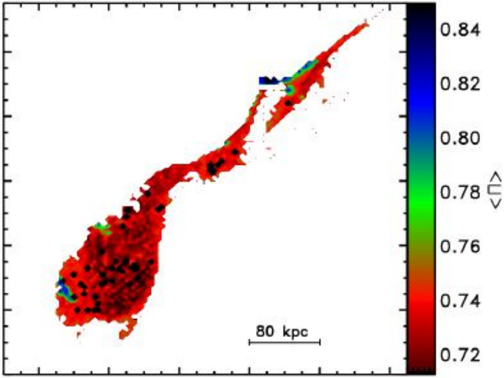
Mach Number and Spectral Index





- $\langle M \rangle \approx 2.3$
- $\langle s \rangle \approx 2.8$

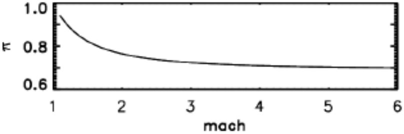
Fractional Polarization



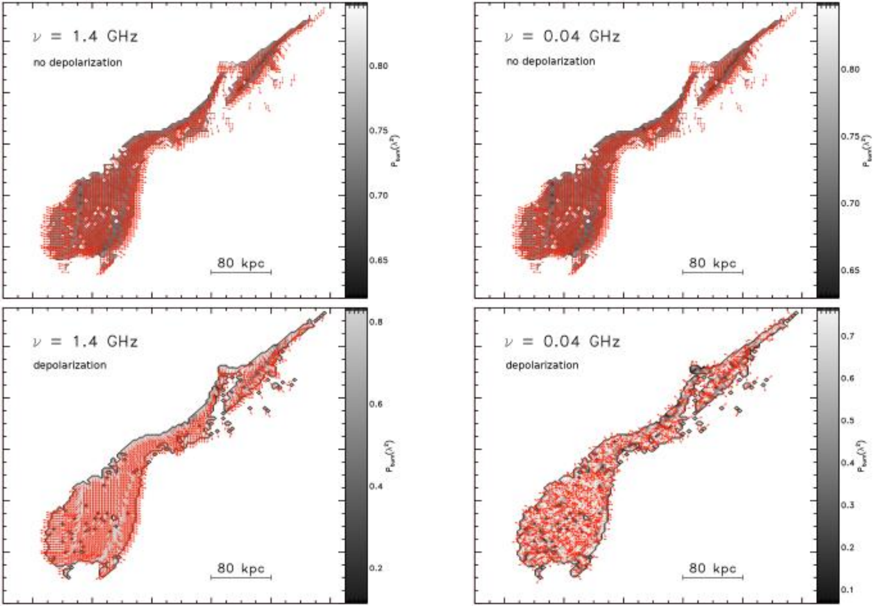
For a distribution of electrons

$$\Pi = \frac{3\alpha_{inj} + 3}{3\alpha_{inj} + 7}$$

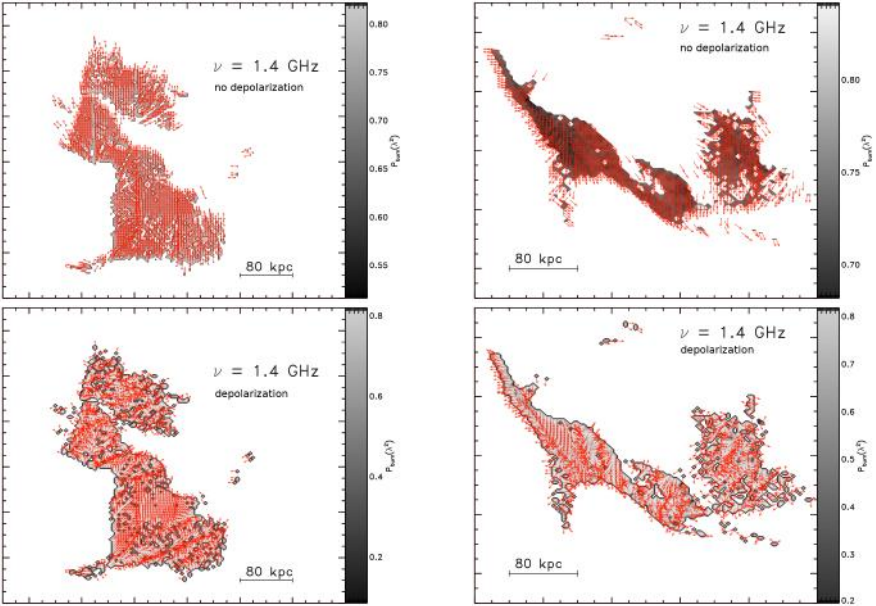
$$\alpha_{inj} = 2\frac{M^2 + 1}{M^2 - 1}$$



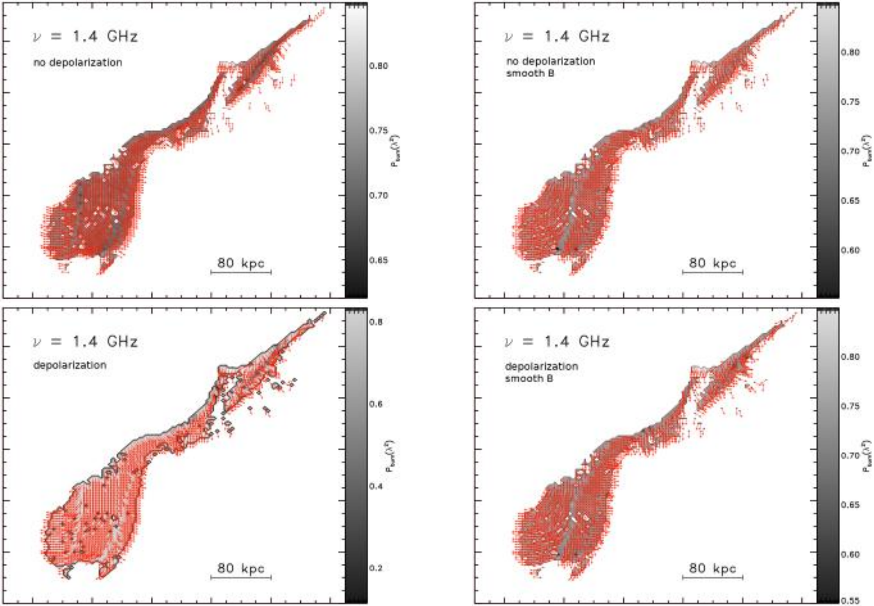
Polarized Emission



Polarized Emission: Different LoS



Polarized Emission: Smooth B

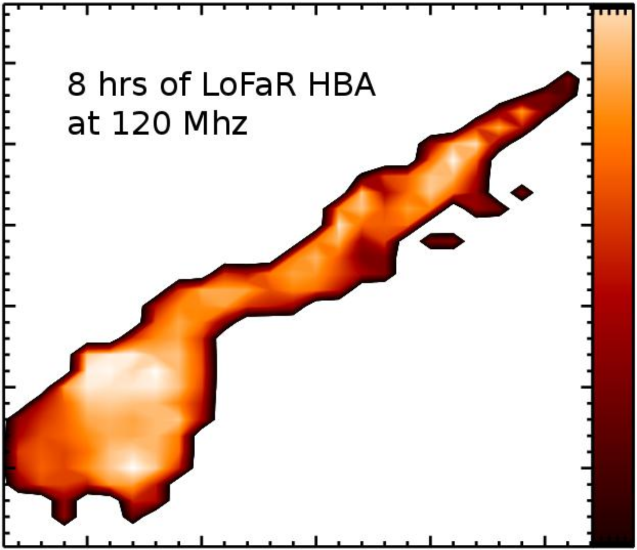


Summary & Outlook

- high resolution simulation of radio relics
  - high resolution grid simulation with ENZO
  - analysed using Lagrangian tracer particles
- followed electron spectrum injected by an $\langle M \rangle \approx 2.3$ shock
- computed the polarized emission
  - independent of the LoS
  - $\Rightarrow$ due to a laminar magnetic field

- connection to observations
- include cooling of electrons
- increase resolution ($\mathrm{d}x \approx 2$ kpc & $\mathrm{d}t \approx 2$ Myr)

Teaser



Thank you for you attention!

Any questions?