Study of polarized emission in radio halos and filaments in the SKA era

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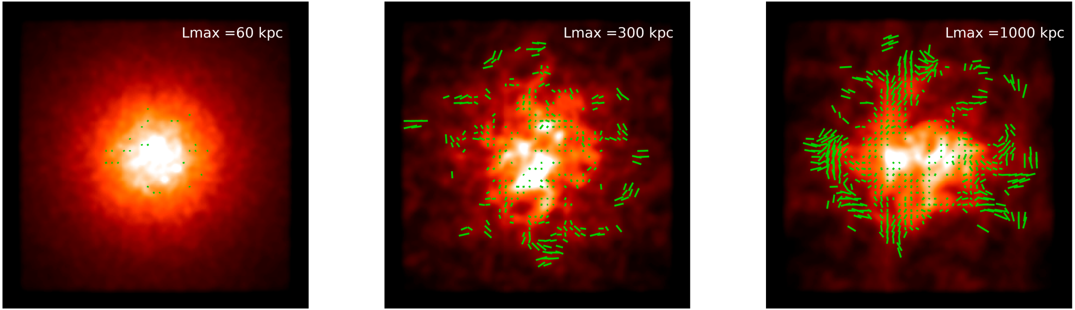
Outline

1. Context
2. Polarized emission in A523
3. Perspectives with SKA-MID AA* telescopes
4. Summary & Conclusions

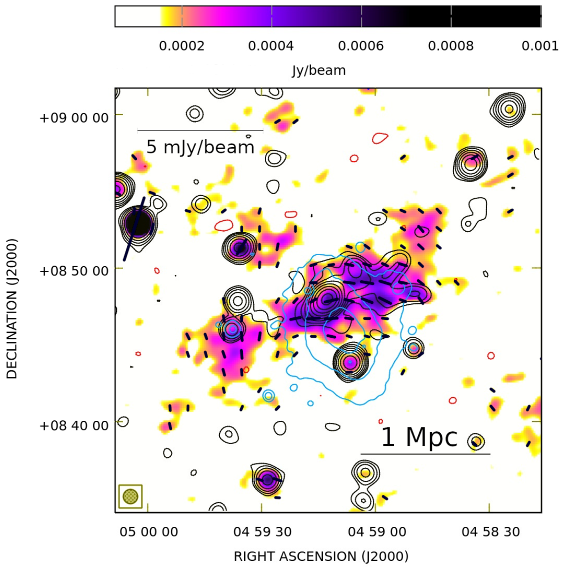
Context

Diffuse synchrotron emission in galaxy clusters and filaments $\rightarrow$ ultra-relativistic electrons ($\gamma \simeq 10^4$) and magnetic fields (μG), see e.g. van Weeren et al. (2019).



Total (colors) and polarized (vectors) intensity of radio halos at 1.4 GHz: magnetic field power spectrum fluctuating between 4 kpc and, respectively, 60, 300, and 1000 kpc with a Kolmogorov index $-11/3$ (Murgia et al. 2004).

Polarized emission in the galaxy cluster A523: observations at 1.4 GHz



First time that a radio halo polarized signal on scales $\gtrsim$1 Mpc.

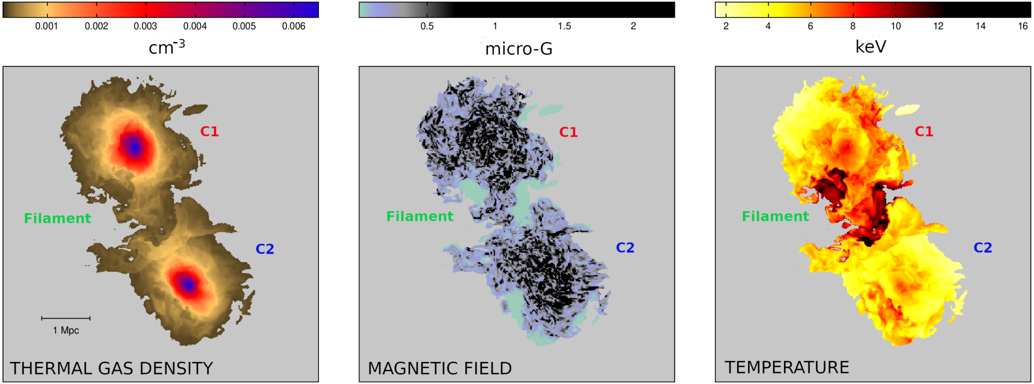
I dominated by confusion noise ($\sigma_{\rm I} = 0.15\,{\rm mJy/beam}$), while Q and U not ($\sigma_{\rm P} = 0.05\,{\rm mJy/beam}$).

FPOL=24 % central patch, $\gtrsim$40% peripheral patches

$B_0 \approx 0.5\,\mu$G, $\Lambda_{\rm B} \approx 1.3\,$Mpc

Low Galactic latitude, Galactic origin?

Vacca et al. (2022)



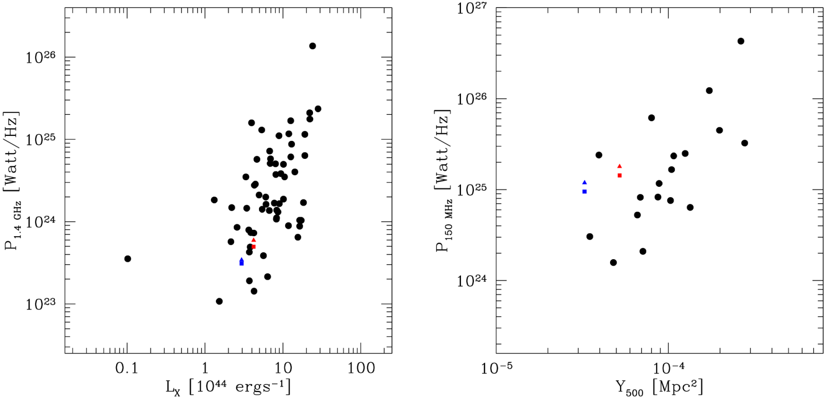
MHD simulation (provided by Xu et al. 2012) from z=30 to z=0 injection of magnetic fields by AGNs at z=2-3, see Vacca et al. (2023)

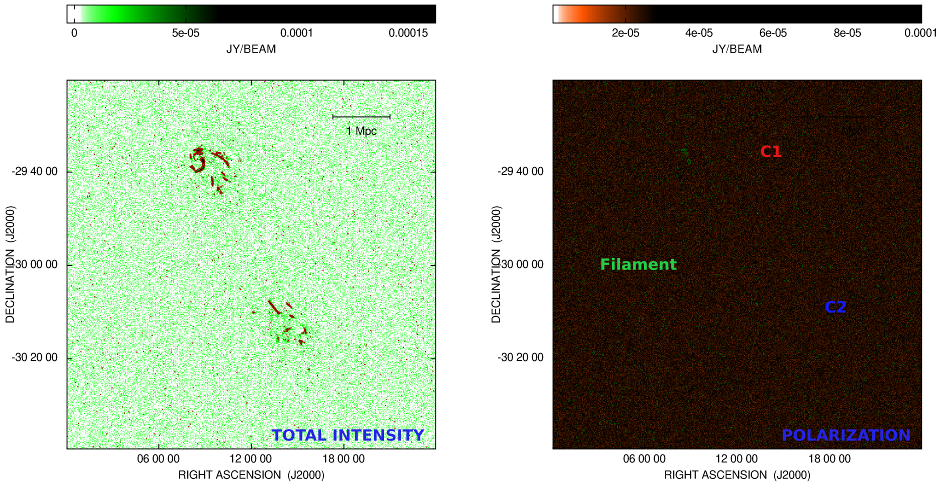
Perspectives with SKA-MID AA* telescopes

$N(\gamma)d\gamma = N_0\gamma^{-\delta}d\gamma$

$\gamma_{\rm min}$=300, $\gamma_{\rm max}$ =1.5×10^4, δ=4.2

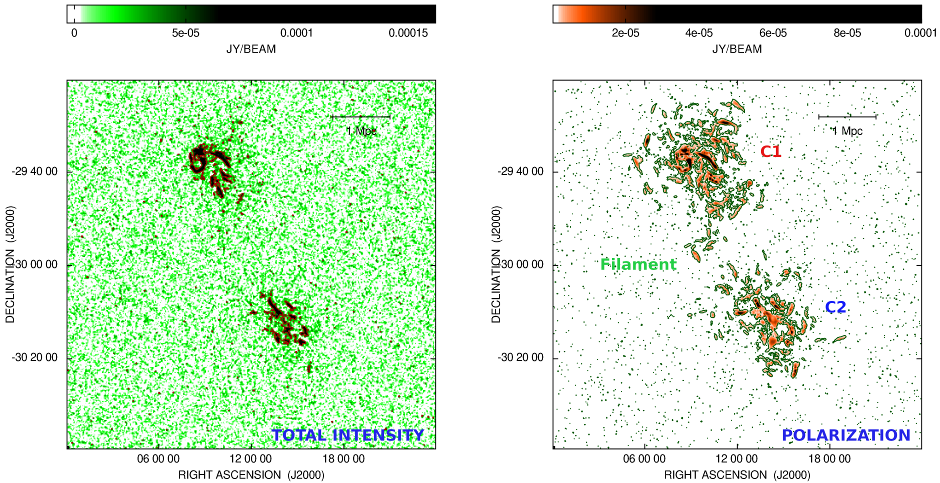
N_0 adjusted to guarantee $u_{\rm el} = u_{\rm B}$ and $u_{\rm el} = 0.003 u_{\rm th}$





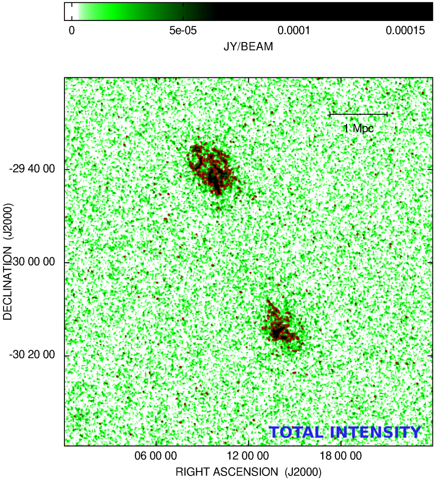
SKA-MID AA* 2″, 15 min, BW 950-1760 MHz, ch 1 MHz, $u_{\rm el} = u_{\rm B}$ at each point of the computational grid

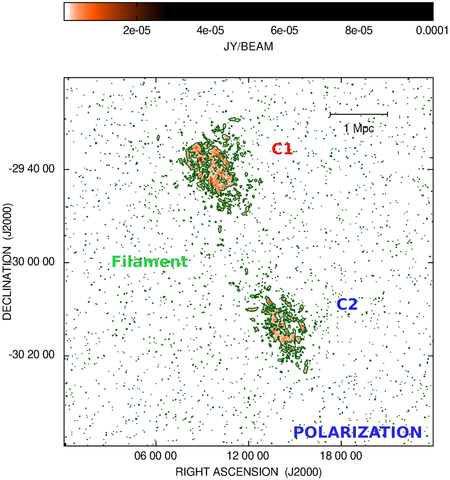
$\sigma_{\rm I} = \sigma_{\rm Q} = \sigma_{\rm U} = 8.5\,\mu$Jy/beam



SKA-MID AA* 17$''$, 50 h, BW 950-1760 MHz, ch 1 MHz, $u_{\rm el} = u_{\rm B}$ at each point of the computational grid
$\sigma_{\rm I} = 12.6\,\mu$Jy/beam, $\sigma_{\rm Q} = \sigma_{\rm U} = 0.3\,\mu$Jy/beam

Perspectives with SKA-MID AA* telescopes



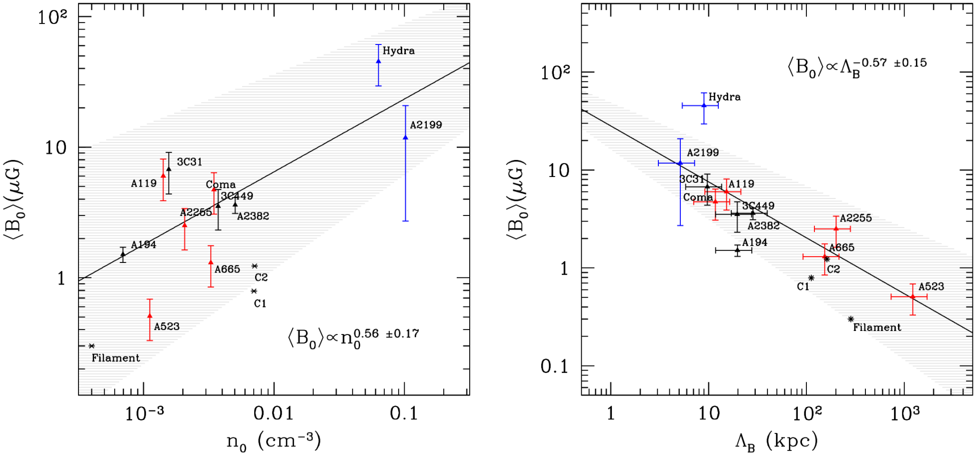


SKA-MID AA* 17$''$, 50 h, BW 950-1760 MHz, ch 1 MHz, $u_{\rm el} = 0.003 u_{\rm th}$ at each point of the computational grid
$\sigma_{\rm I} = 12.6\,\mu$Jy/beam, $\sigma_{\rm Q} = \sigma_{\rm U} = 0.3\,\mu$Jy/beam

Summary & Conclusions

- Polarized diffuse synchrotron emission in galaxy clusters revealed for the first time on scales $\gtrsim$1 Mpc;
- While total intensity emission is deeply affected by confusion noise, the polarized signal is not and allows us to study magnetic fields in galaxy clusters and filaments also when the total intensity signal is below the confusion noise;
- Polarimetric low-spatial resolution observations represent a powerful tool to study magnetic fields ordered on large scales;

Summary & Conclusions



Vacca et al. submitted to the New SKA Book (see also Govoni et al. 2017)

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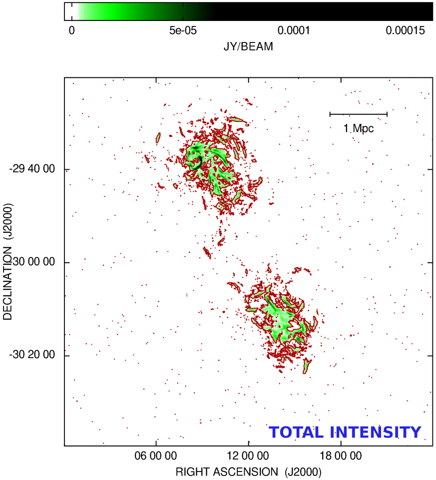
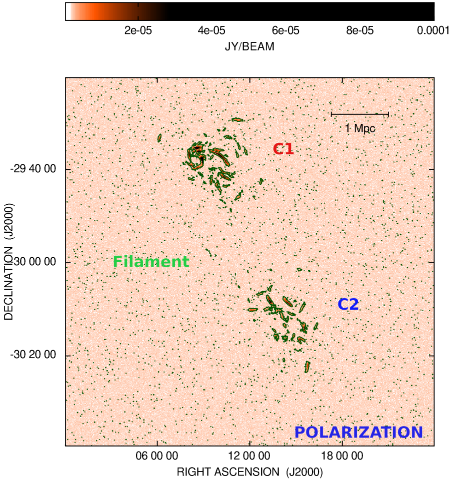
- Polarized diffuse synchrotron emission in galaxy clusters revealed for the first time on scales $\gtrsim 1$ Mpc;
- While total intensity emission is deeply affected by confusion noise, the polarized signal is not and allows us to study magnetic fields in galaxy clusters and filaments also when the total intensity signal is below the confusion noise;
- Polarimetric low-spatial resolution observations represent a powerful tool to study magnetic fields ordered on large scales;
- Deep pointed observations with SKA-MID AA* telescopes are necessary in order to map the magnetic field over all the cluster volume and along gas filaments connecting them (predictions with AA4 give comparable results).

THANKS ⋆

Backup slides

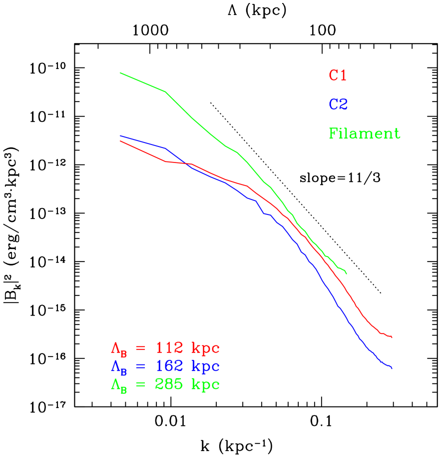


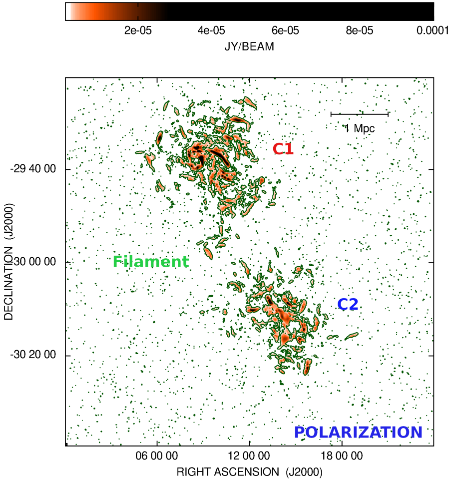


SKA-MID AA* 2$''$, 50 h, BW 950-1760 MHz, ch 1 MHz, $u_{\rm el} = u_{\rm B}$ at each point of the computational grid

$\sigma_{\rm I} = \sigma_{\rm Q} = \sigma_{\rm U} = 0.6\,\mu$Jy/beam

Perspectives with SKA-MID AA* telescopes





SKA-MID AA* 17″, 50 h, BW 950-1760 MHz, ch 1 MHz, $u_{\rm el} = u_{\rm B}$ at each point of the computational grid
$\sigma_{\rm I} = 12.6\,\mu$Jy/beam, $\sigma_{\rm Q} = \sigma_{\rm U} = 0.3\,\mu$Jy/beam