MeerKAT and ASKAP synergies: the discovery of a depolarizing HI tail in the western lobe of Fornax A

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Fornax A – VLA I image by Fomalont et al. 1989

D~20Mpc from us

R~1.3 Mpc from the cluster center
Fornax A – VLA P image by Fomalont et al. 1989

The “ant”

NGC 1310

Faraday effect:

\[ \Delta \psi = R M \cdot \lambda^2 \]
Fornax A - ATCA Pol image by Anderson et al. 2018

ATCA FDF peak
1.1-3.1GHz
20x30arcsec²
Fornax A - ATCA RM image by Anderson et al. 2018

*ATCA peak FD*
1.1-3.1GHz
20x30arcsec$^2$
Advection scenario

(x) External medium
(y) Lobe medium
(z) Advected thermal plasma

ATCA image
1.1-3.1 GHz
20x30 arcsec²

Faraday depth
Fractional pol
Fornax A - ASKAP P + HI & Hα by Kleiner et al. 2021

ASKAP peak P
1.1-1.3 GHz
12x12 arcsec²
Fornax A – ASKAP RM + HI & Hα by Kleiner et al. 2021
RM Histogram

$\langle RM \rangle = -17 \text{ rad/m}^2$

$\sigma_{RM} = 20 \text{ rad/m}^2$

$\langle RM \rangle = -13 \text{ rad/m}^2$

$\sigma_{RM} = 9 \text{ rad/m}^2$

RM Structure functions

$$S(dr) = \langle [RM(r) - RM(r + dr)]^2 \rangle$$
2D simulations – Magnetic field power spectrum

FARADAY tool by Murgia et al. 2004

The two regions host magnetic fields with a different geometry and strength
RM due to the ICM of the Fornax cluster?

\[ \sigma_{RM}(r) = K B_0 \Lambda_c^{0.5} n_0 r_c^{\frac{1}{2}} \frac{1}{(1 + \frac{r^2}{r_c^2})^{\frac{6\beta(1+\eta) - 1}{4}}} \sqrt{\frac{\Gamma[3\beta(1 + \eta) - \frac{1}{2}]}{\Gamma[3\beta(1 + \eta)]}} \rightarrow 10^{-26} \text{ rad/m}^2 \]

Thermal plasma \( n = n_0 \left( 1 + \left( \frac{r}{r_c} \right)^2 \right)^{-3\beta + 0.5} \)

Magnetic field \( B = B_0 \left( \frac{n}{n_0} \right)^\eta \)

3D simulations - RM due to the IGM of the Fornax A group?

$n = n_0 \left(1 + \left(\frac{r}{r_c}\right)^2\right)^{-3\beta + 0.5}$

$B = B_0 \left(\frac{n}{n_0}\right)\eta$

References: Babyk et al. 2018 (thermal plasma)
3D simulation - Faraday screen on the lobe surface

$$\text{RM}_1 = \text{RM}_{\text{tail}}(B_{\text{tail}}, n_{\text{tail}})$$

The HI tail is on the lobe surface

$$\text{RM} = \text{RM}_{\text{lobe}}(B_{\text{lobe}}, n_{\text{lobe}})$$

![Graph showing S(dr) vs. dr with data points and lines indicating different regions such as HI tail, Control region, and Residuals.](image_url)
The HI tail is inside the lobe - Equilibrium condition

\[ P_{nth} = P_{gas} + P_B \]

\[ B \sim 9-11 \, \mu G \]

References: Maccagni et al. 2020 (non-thermal jet pressure)
3D simulation - Faraday screen on the lobe surface

\[ \text{RM}_1 = \text{RM}_{\text{tail}}(B_{\text{tail}}, n_{\text{tail}}) \]

The HI tail is on the lobe surface

\[ \text{RM}_2 = \text{RM}_{\text{tail}} + \text{RM}_{\text{lobe}} \]

The HI tail is within the lobe

\[ B \sim 9-11 \, \mu G \]
\[ n = 0.0015 - 0.0018 \, \text{cm}^{-3} \]

\[ \text{HI tail} \quad B_0 n_0 = 0.025 \, \mu G \, \text{cm}^{-3} \]

\[ \text{Control region} \quad B_0 n_0 = 0.01 \, \mu G \, \text{cm}^{-3} \]

Residuals
\[ B_0 n_0 = 0.016 \, \mu G \, \text{cm}^{-3} \]
Conclusion

• The RM of the Fornax A lobes is not due to the ICM of the Fornax cluster

• It is unlikely that this is due to the IGM of the Fornax A group

• The HI tail could be driving its own magnetic field across the Fornax A lobe.
Backup slides
2D simulations - Magnetic field power spectrum

1) Assume a shape for the magnetic field power spectrum: power-law (minimum, maximum scale, slope) $|B_k|^2 \propto k^{-n}$

2) Generate a RM image from the magnetic field power spectrum

3) Evaluate the $S(dr)$ in the tail and control region and compare with data

4) Repeat
1) Assume a shape for the magnetic field power spectrum: power-law (minimum, maximum scale, slope) \( |B_k|^2 \propto k^{-n} \)

2) Generate a RM image from the magnetic field power spectrum

3) Evaluate the \( S(dr) \) in the tail and control region and compare with data

4) Repeat