Magnetic Fields in the Shapley Supercluster of Galaxies

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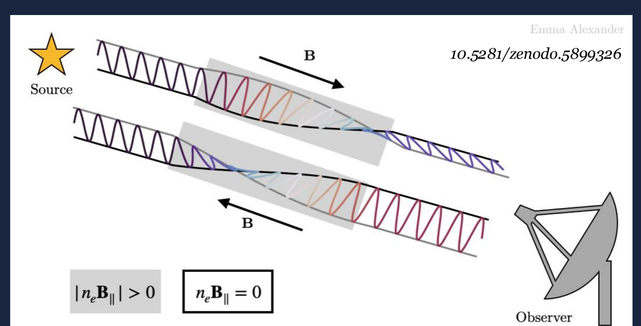
Polarised radio emission from astrophysical sources, such as synchrotron radiation from radio galaxies, experiences **Faraday Rotation** when it propagates through an ionised and magnetised plasma. This effect, rotates the polarisation vector of light by an amount called the Rotation Measure (RM).



$$\mathrm{RM} = \frac{e^3}{2\pi m_e^2 c^4} \int n_e(l) B_\parallel(l)\, dl$$

The RM can **probe the magnetic field parallel to the line of sight** in **ionised and magnetised plasmas**.

Modern-day radio telescopes like the *Australian Square Kilometer Array Pathfinder* (***ASKAP***) provide high quality **RM grids** that allow us to detect, characterise and model magnetised plasmas in a wide range of cosmic environments: from the filaments of the cosmic web or **galaxy clusters** to galaxies and stars.

One of the 36 ASKAP antennas. *Credit: CSIRO/Dragonfly Media*

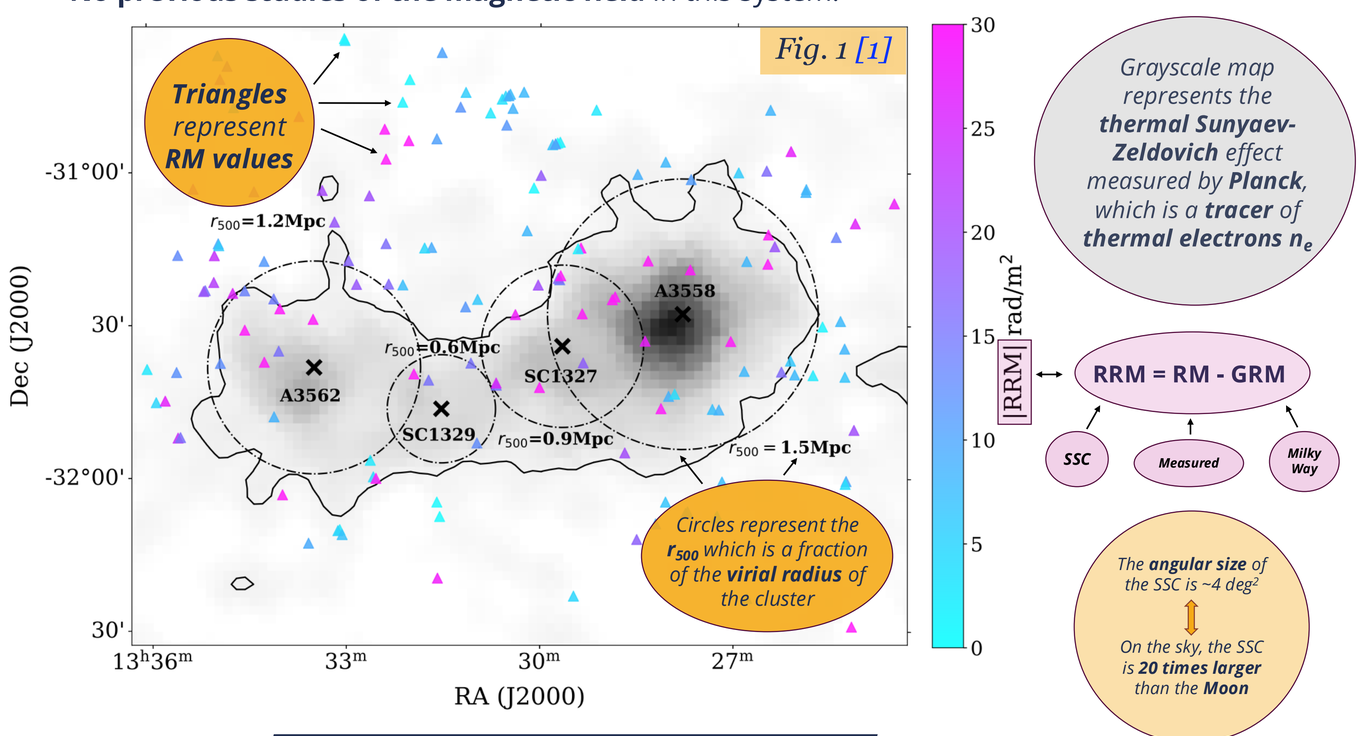
1. Motivation and objectives

- While **magnetic fields are ubiquitous** in the Universe, **their origin and the mechanisms that amplify them** to the values measured today **remain unknown**.
- To **uncover the origin of large-scale magnetic fields** in the filaments of the cosmic web, we first need to understand, measure and characterise magnetic fields in **galaxy clusters up to and beyond their virial radii**.
- **Galaxy clusters** are **permeated by ~μG magnetic fields**, **correlated on scales** of a few of **kpc** *(typical **size** of a **galaxy**)* up to **Mpc** *(typical **size** of a **cluster**, see Fig.1)*.
- The Intracluster Medium ***(ICM)*** is a turbulent **ionised and magnetised plasma.**
- The ICM can **Faraday rotate radio emission from very distant radio galaxies** ***(ASKAP RM data)***, providing an **excellent laboratory** to probe the properties of this magnetised gas.

I. Can we **detect** an **excess RM signal from the ICM?**
II. What is the **radial profile of the magnetic field** in galaxy clusters?
III. What **mechanism is amplifying** the magnetic field in the **intercluster region**?

2. Shapley Supercluster Core *(SSC)*

- Our **object of study**: the Shapley Supercluster Core *(z=0.05)* made up of **two galaxy clusters: A3558 and A3562**, and of **two massive galaxy groups** in the **intercluster region** between them.
- **No previous studies of the magnetic field** in this system.



3. Methods

- We performed a **statistical study** of the **ASKAP-POSSUM *[2]* RMs** *(see Fig. 1)*. A **higher scatter** *(standard deviation)* of the **RMs** whose **sightlines** go **through the SSC** with respect to those that pass outside it, indicates the presence of a **denser and more strongly magnetised plasma** *(on/off-target approach)*.

- **Magnetic field estimates** from RM observations are **model-dependent:**
  a. Previous studies have used **semi-analytic** modelling to produce **RM maps** ***(MiRò)***.
  b. We have also gone a step further using **local-constrained cosmological Magneto-Hydro-Dynamical *(MHD)* simulations *(SLOW)***, which provide **significant improvements** in **realistic ICM** modelling in a **cosmological context**.

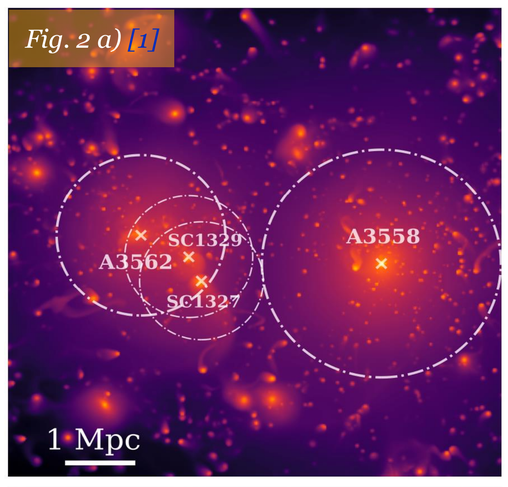
- **Bayesian model selection** analysis to determine which **magnetic field amplification mechanism is consistent** with the **data**.

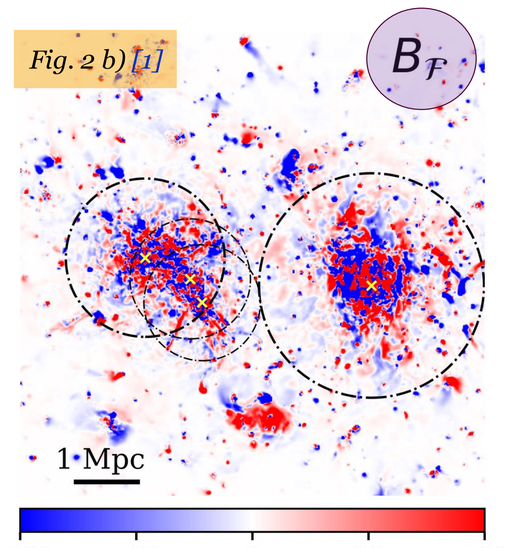
4. Results

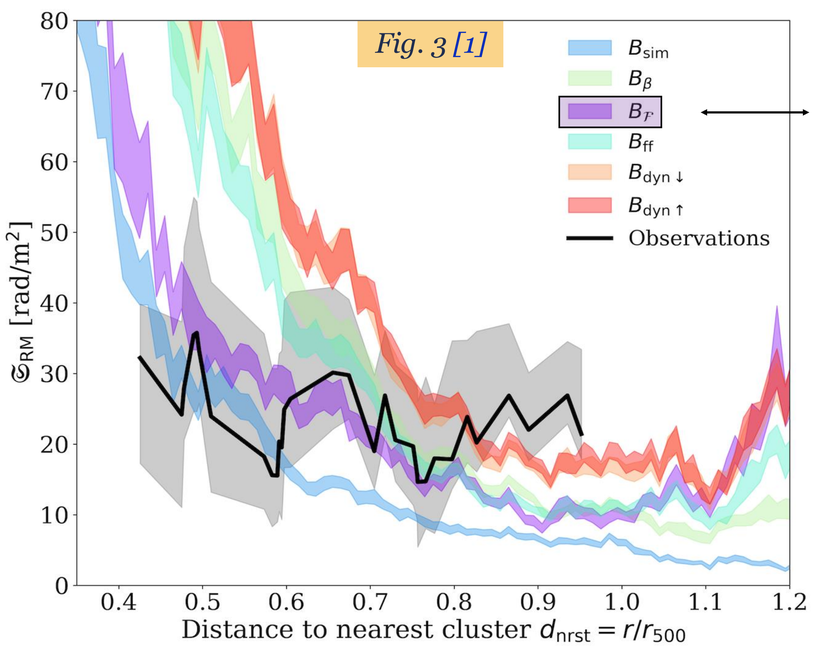
- **First detection of magnetised gas in the SSC from the excess RM scatter**:

$$\sigma_{\mathrm{RM}}^{\mathrm{SSC}} = 30.5 \pm 4.6\,\mathrm{rad/m^2}$$ ⟺ **7σ statistical significance!**

- From the *SLOW* **cosmological MHD simulations we have obtained**:
  - **SSC system *replica*** constrained to Local Universe observations *(Fig. 2 a)*.
  - **RM maps** for different **magnetic field amplification mechanisms** in the intercluster region *(Fig. 2 b)*.
  - **RM scatter profiles** with respect to the **distance to the** centres of the **clusters** $\mathfrak{S}_{\mathrm{RM}}$ *(Fig. 3)*.







5. Conclusions

- **SKA pathfinder radio telescopes** provide **high-quality data** to **detect magnetic fields** in the Universe through **Faraday rotation**.

- **First detection** of an excess **RM signal** from the **SSC** is **consistent with ~μG magnetic field strengths ↔ agreement** with **previous studies** of other clusters of galaxies.

- The **data favors** models in which **magnetic field** in the **intercluster regions** is **amplified** by the **turbulent pressure of the ICM**.

- However, the **trend** of the SSC RM signal **with distance to the clusters** is **flatter than** current **most accurate modelling** *(see Fig. 3)*.
  - Observational bias? Better modelling?

References

[1] *Alonso-López et. al. 2025 (A&A, under review)*

[2] *Gaensler, B. M., et. al. 2025*

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