Tracing magnetic fields in the cosmic web: insights from ASKAP and prospects with SKA

The Fifth National Workshop on the SKA Project

24-28 Nov. 2025

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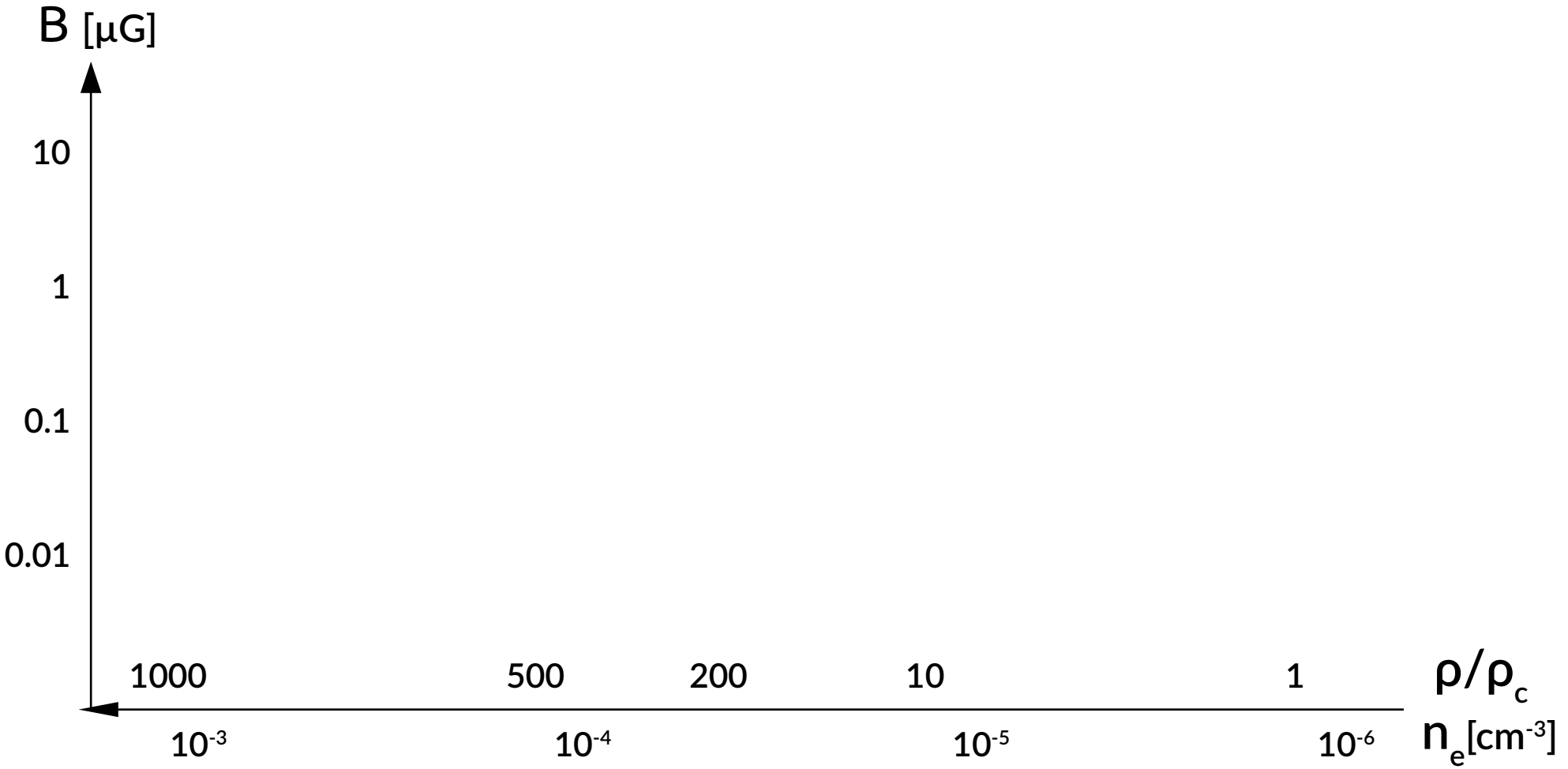
INAF - Istituto di Radioastronomia (Italy)

INAF ISTITUTO NAZIONALE DI ASTROFISICA

SPOKE 3 Astrophysics & Cosmos Observations

State-of-the-art picture (local Universe)



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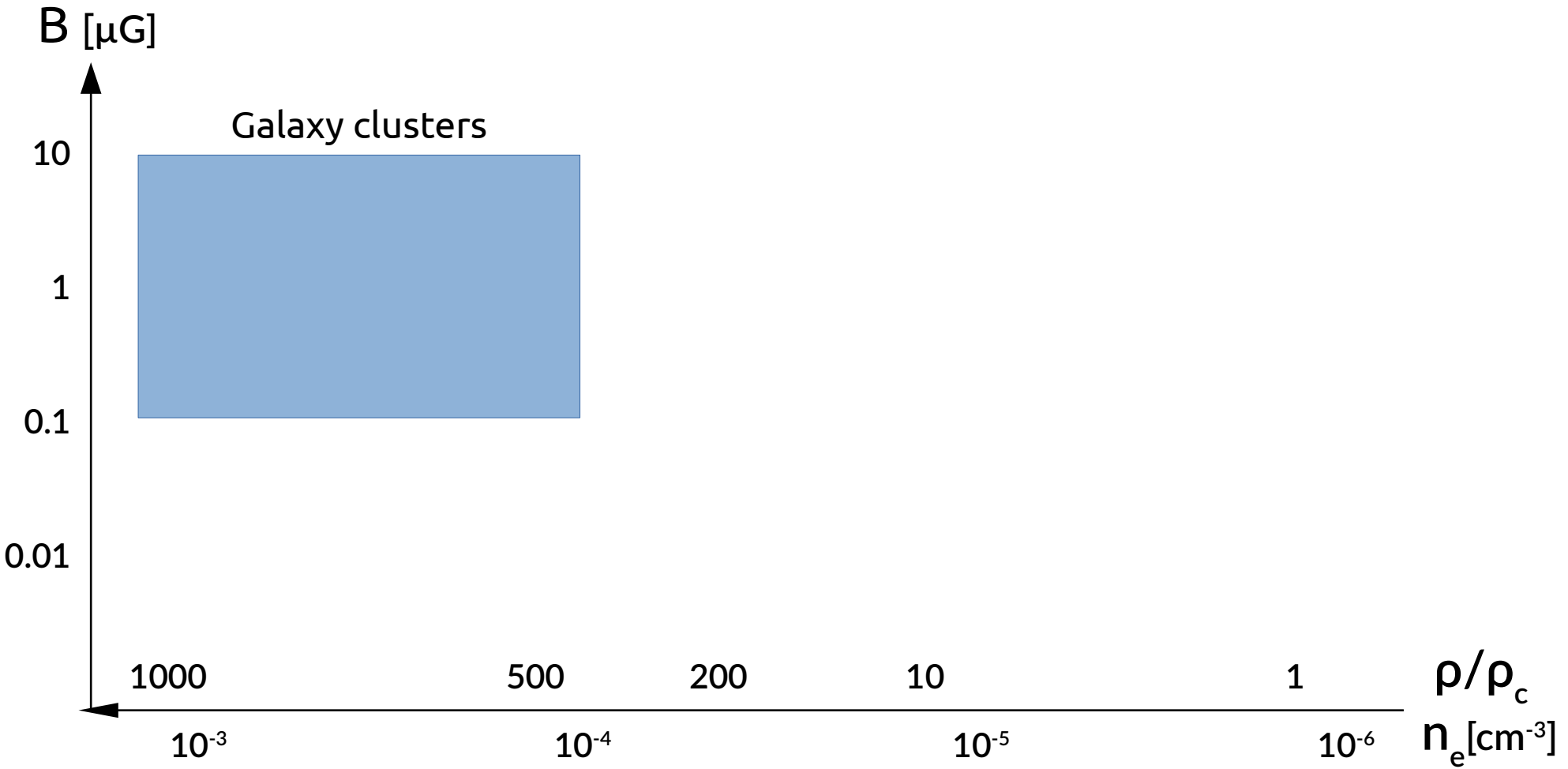


State-of-the-art picture (local Universe)

B [μG]

[Murgia+04,Bonafede+10,Vacca+12,Govoni+17,Stuardi+21,Osinga+22,25,Pagliotta+(CS)25]

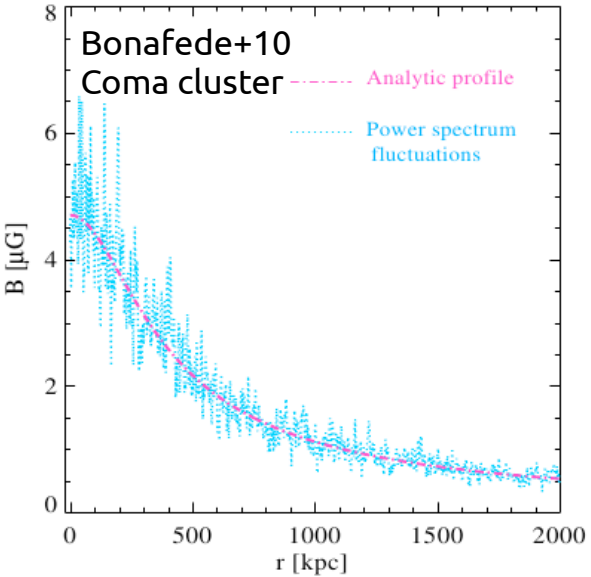
10

1

0.1

0.01

Galaxy clusters



Radial profile

$$|\boldsymbol{B}(r)| = \langle B_0 \rangle \left(\frac{n_{THe}(r)}{n_0} \right)^{\eta}$$

η=0.5-1

Power spectrum

$$E_B(k) \propto k^{-n}$$

Kolmogorof-like: n=-5/3

[see also Dominguez-Fernandez+19]

1000 500 200 10 1 ρ/ρ$_c$

10^{-3} 10^{-4} 10^{-5} 10^{-6} n_e[cm^{-3}]

State-of-the-art picture (local Universe)

B [μG]

10

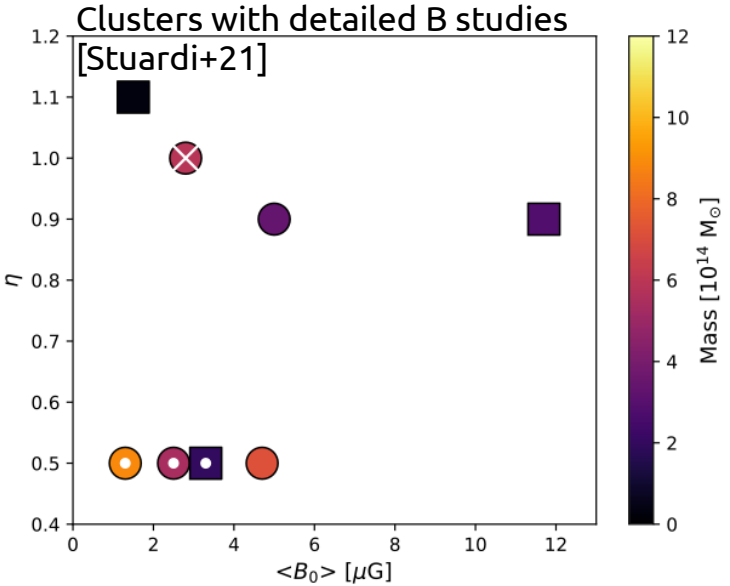
1

0.1

0.01

[Murgia+04,Bonafede+10,Vacca+12,Govoni+17,Stuardi+21,Osinga+22,25,Pagliotta+(CS)25]

Clusters with detailed B studies [Stuardi+21]



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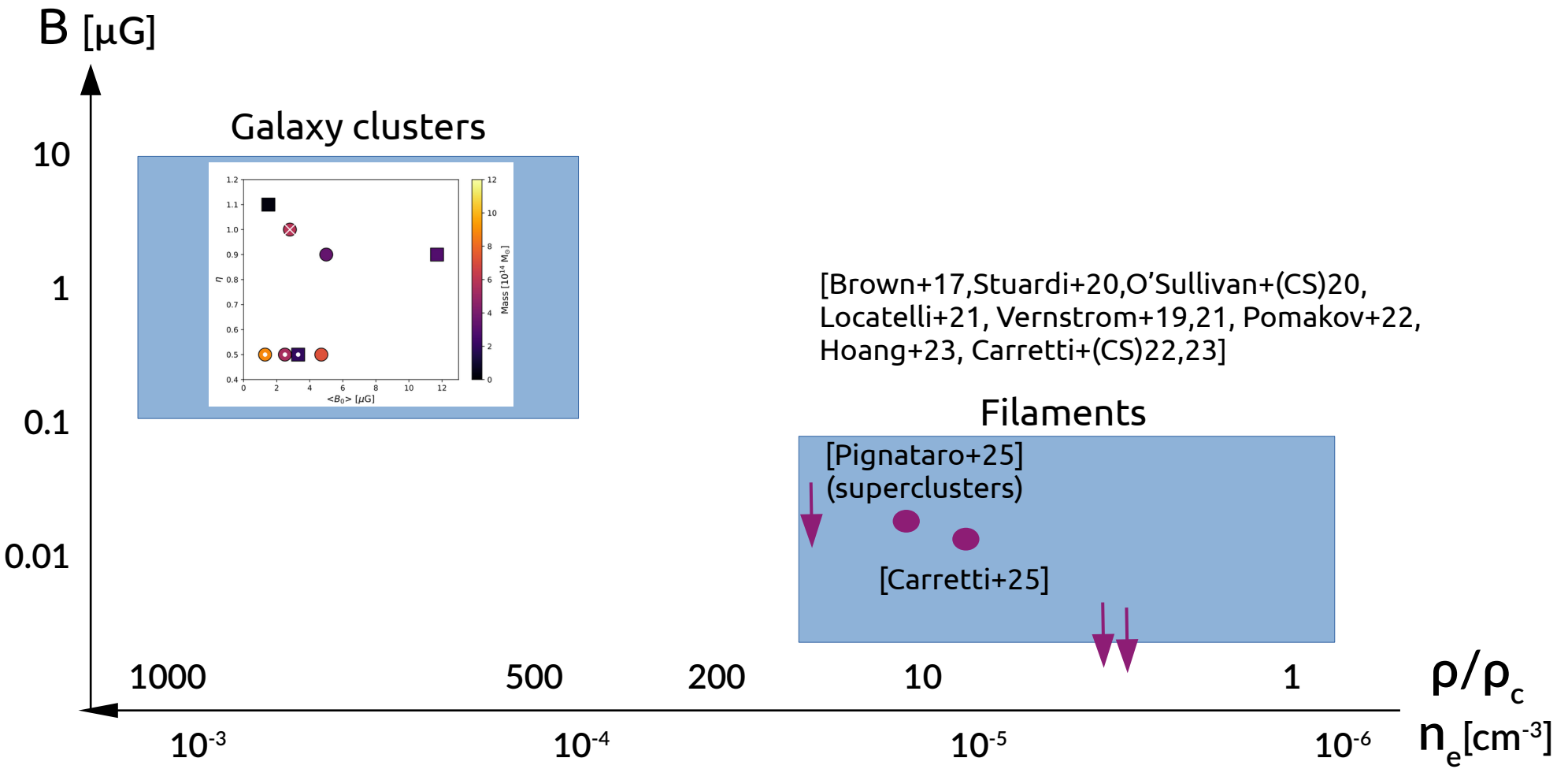

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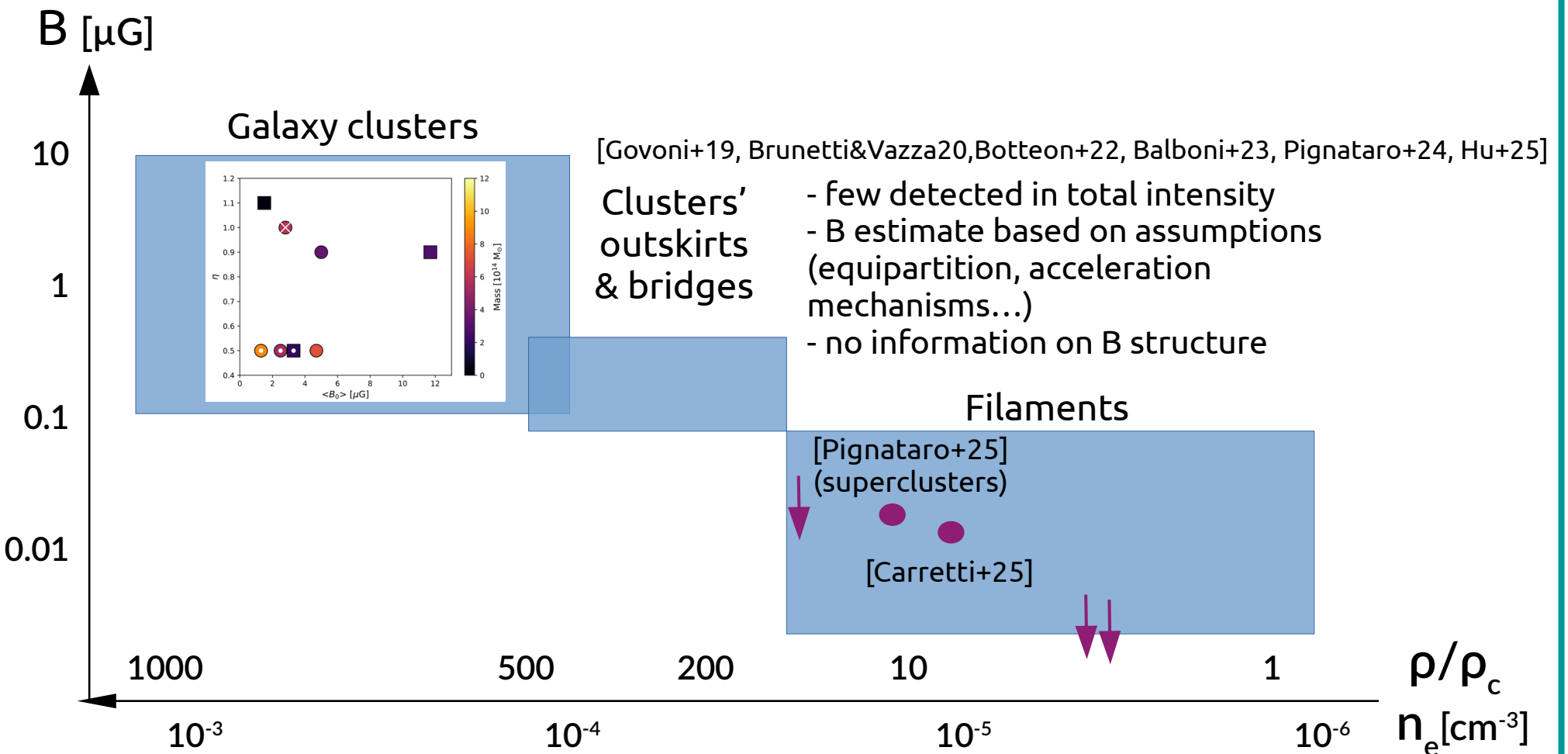

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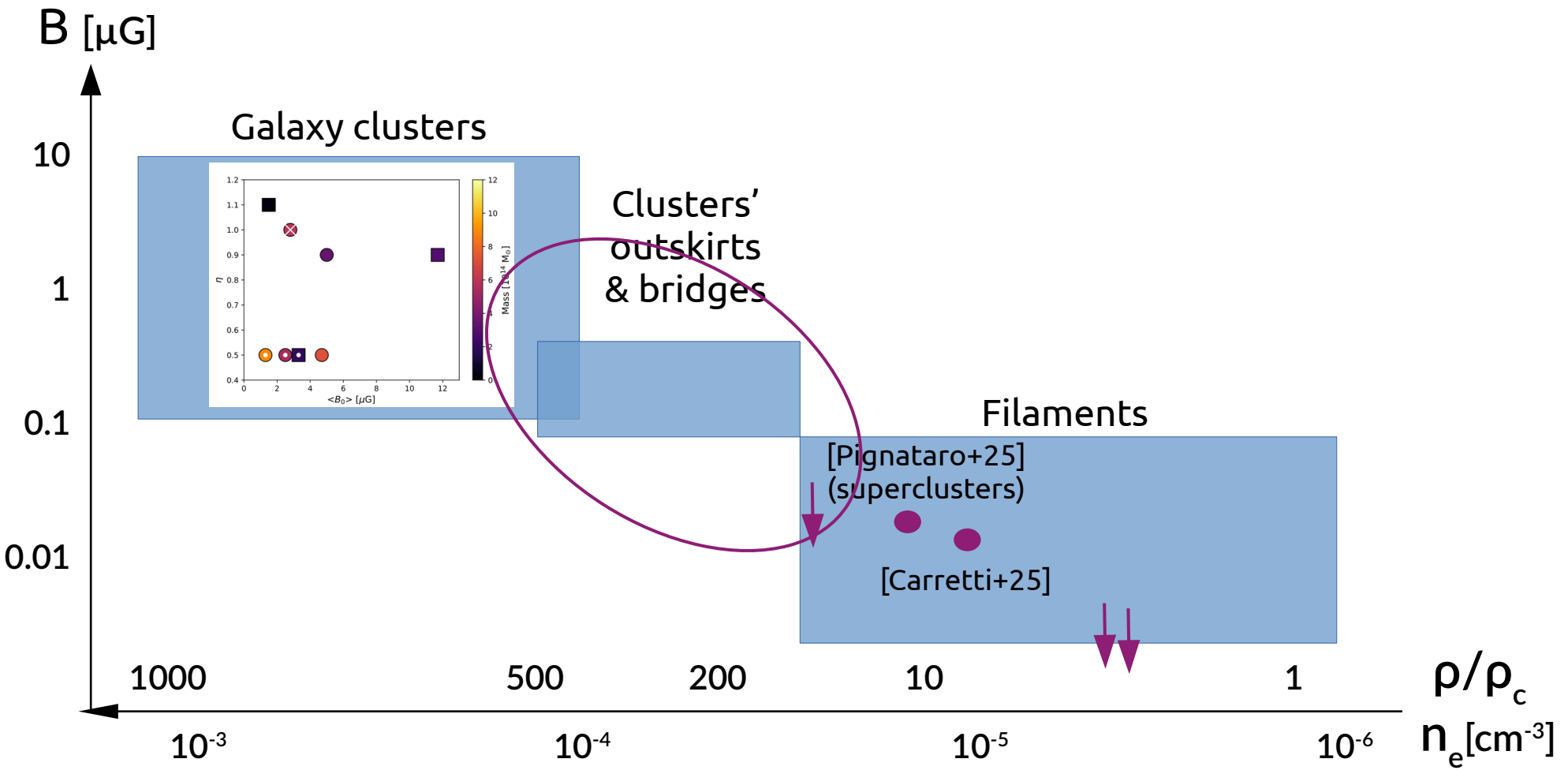
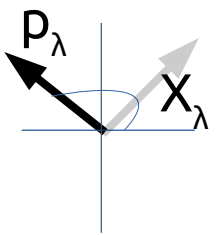


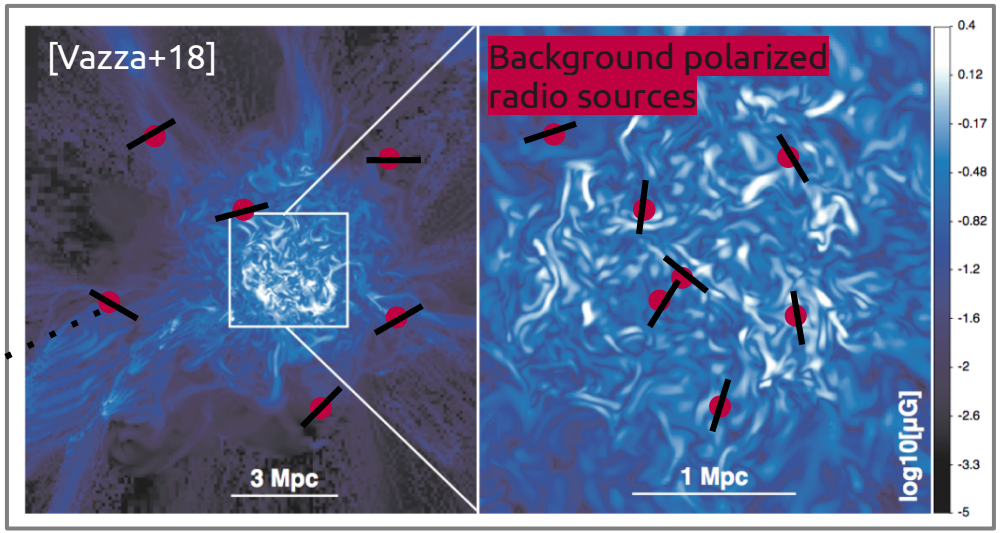
Methods: Polarization and Faraday Rotation Measure (RM)

$$p_\lambda = p_0 e^{2i(\chi_0 + RM\,\lambda^2)}$$

Rotation $\propto \lambda^2$



Observed polarization



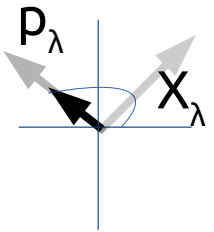
$$RM \propto \int_{source}^{observer} n_{THe} B_{LOS} dl_{LOS}$$

(depends on B direction!)
Galactic RM subtracted
RRM=RM-GRM

Methods: Polarization and Faraday Rotation Measure (RM)

$$p_\lambda = p_0 e^{2i(\chi_0 + RM\,\lambda^2)} e^{-2\sigma_{RM}^2 \lambda^4}$$

Rotation $\propto \lambda^2$
Depolarization $\propto \lambda^4$
[see also Tribble+91]



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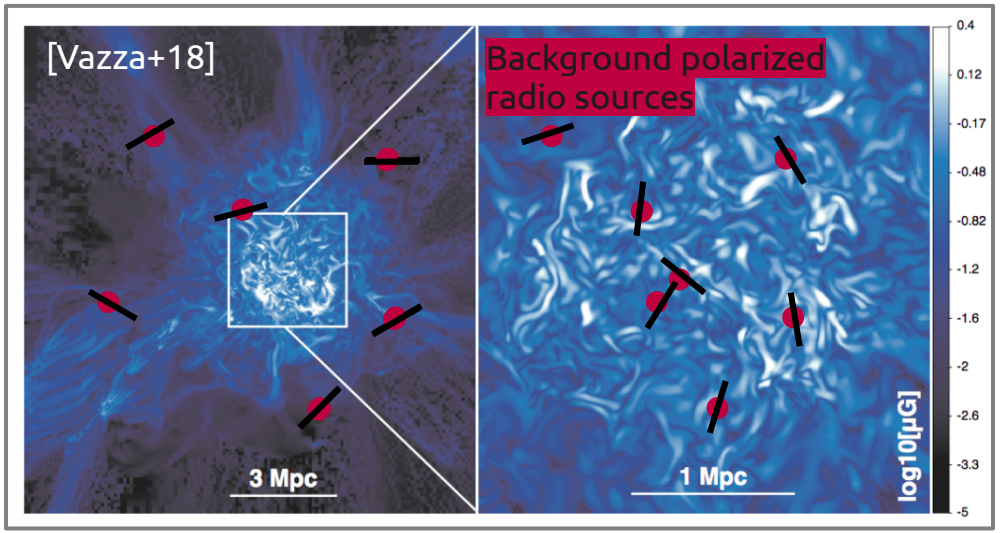


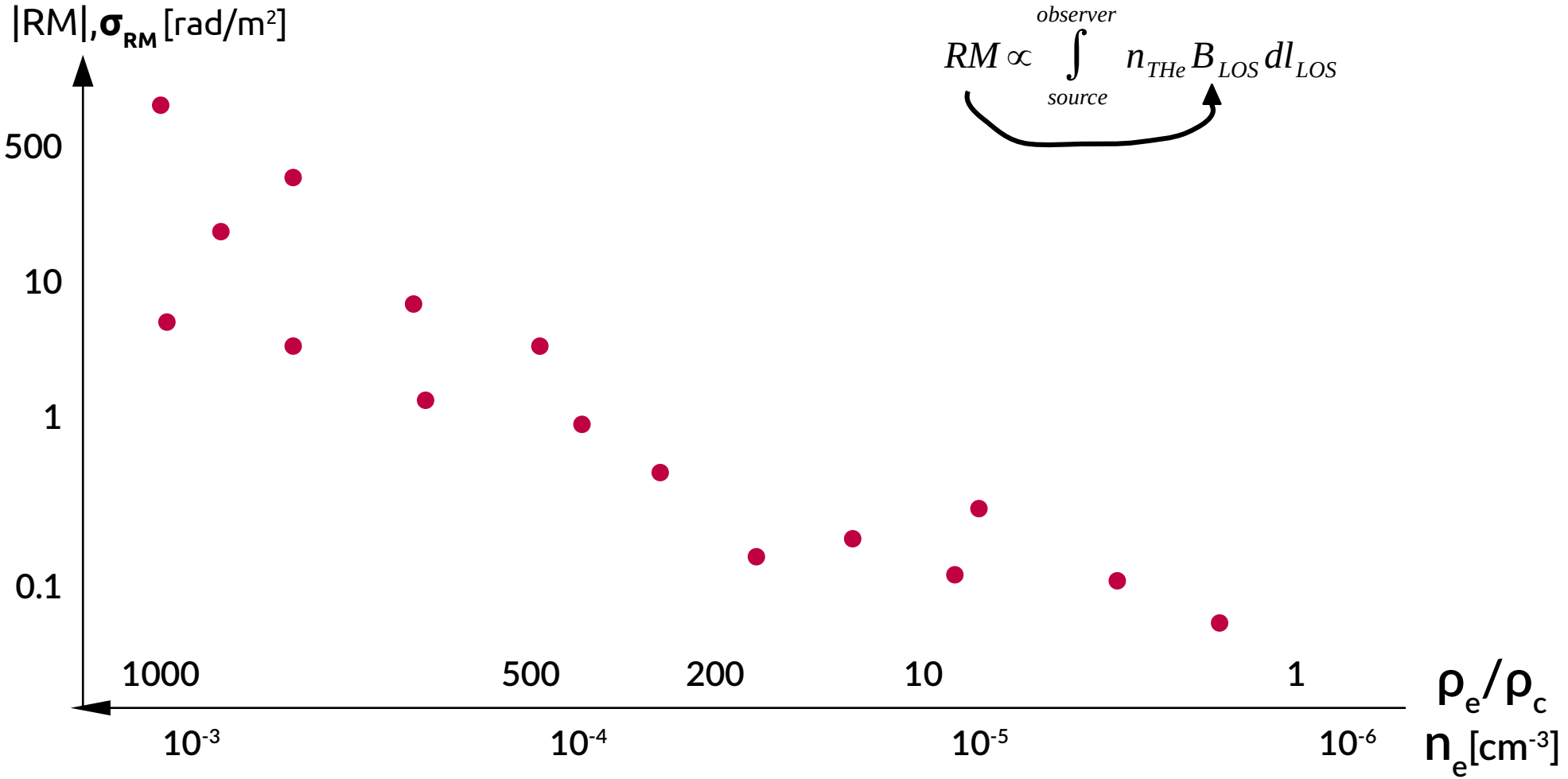
$$RM \propto \int_{source}^{observer} n_{THe} B_{LOS} dl_{LOS}$$

(depends on B direction!)
Galactic RM subtracted
RRM=RM-GRM

$$\sigma_{RM}^2 \propto \Lambda_c \int_{source}^{observer} (n_{THe} B_{LOS})^2 dl_{LOS}$$

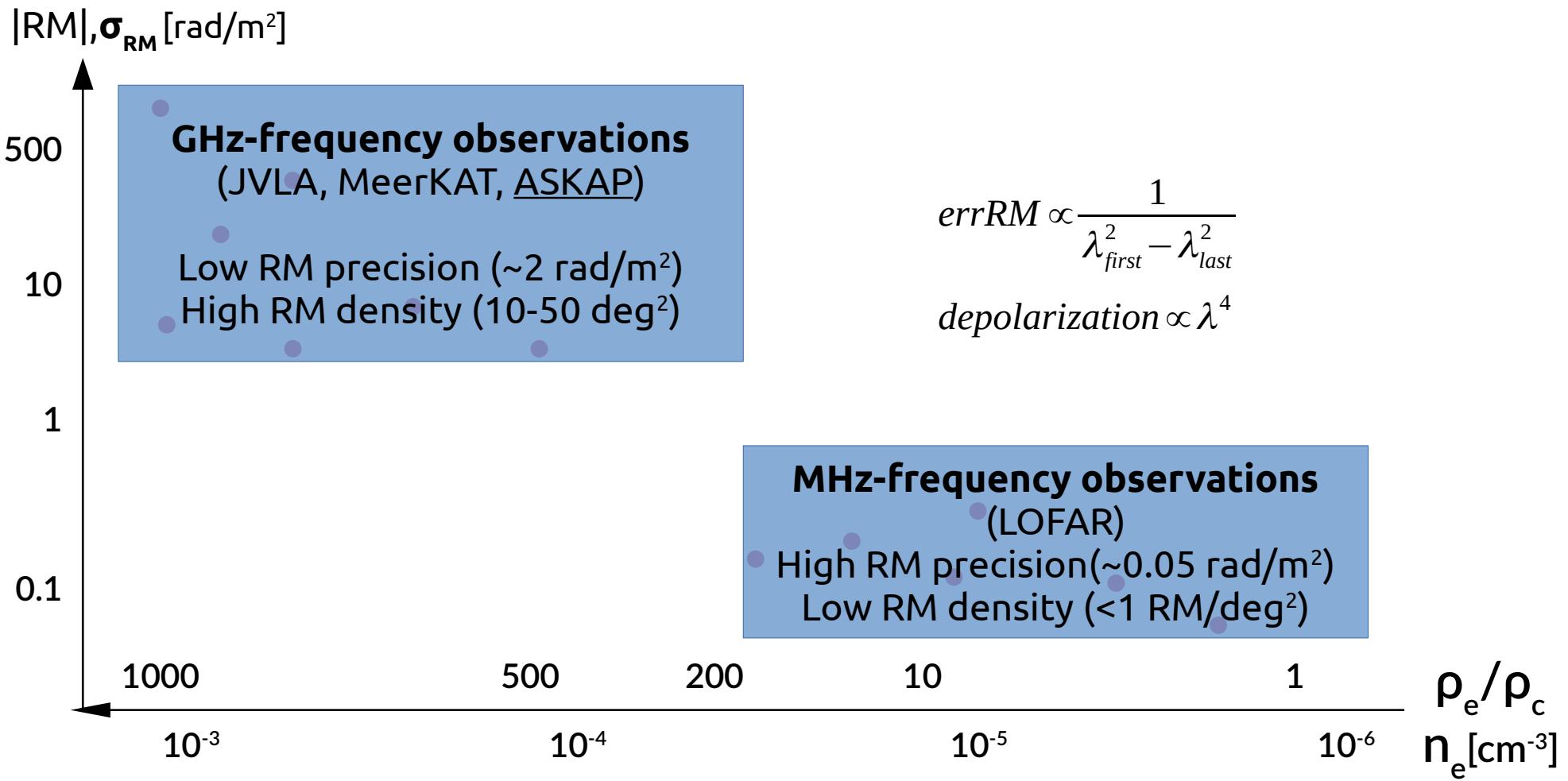
(single-scale model, Λ_c correlation scale)

Methods: Polarization and Faraday Rotation Measure (RM)



$$RM \propto \int_{source}^{observer} n_{THe} B_{LOS} dl_{LOS}$$

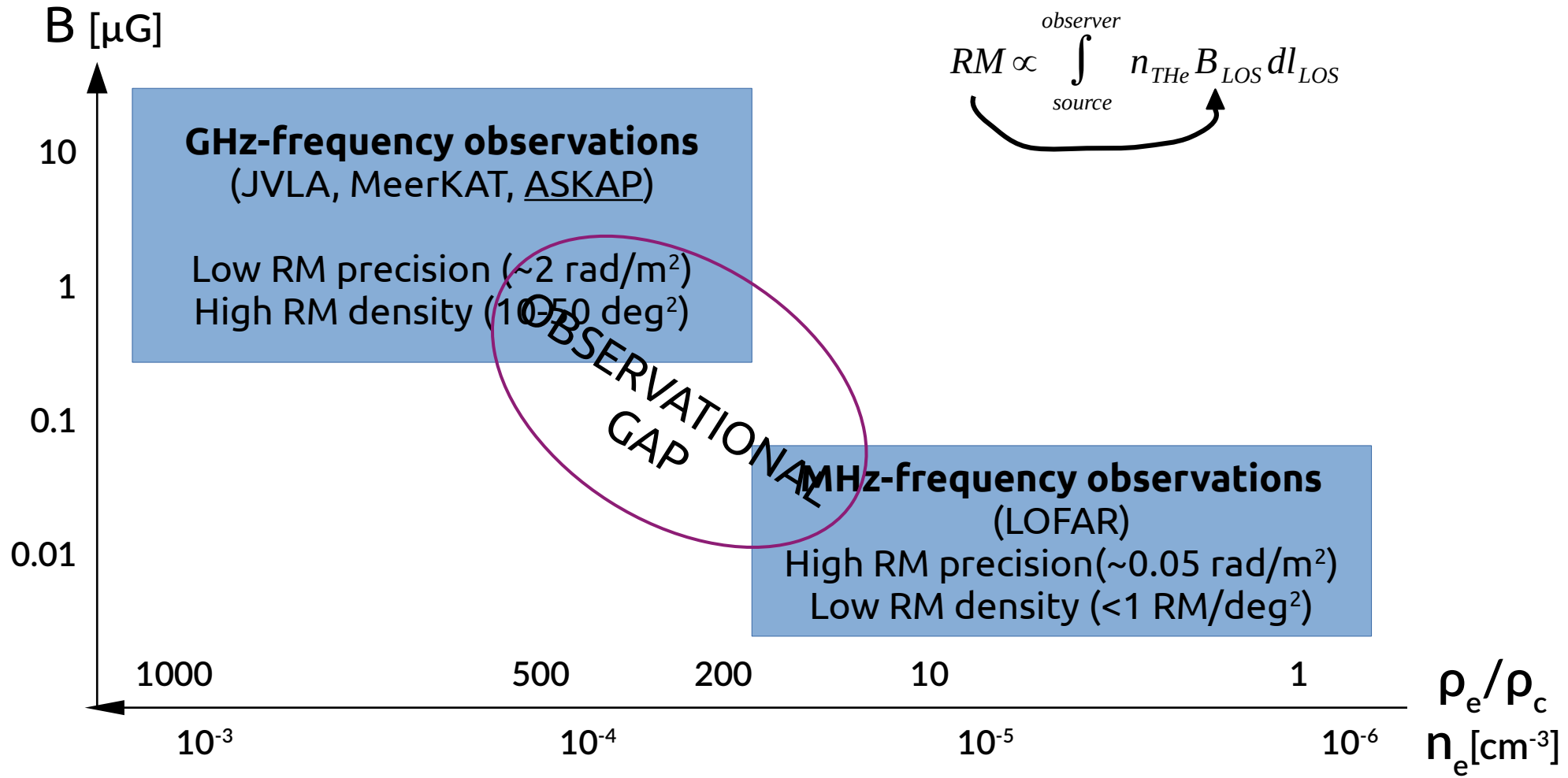
SKA precursors and pathfinders



$$errRM \propto \frac{1}{\lambda^2_{first} - \lambda^2_{last}}$$

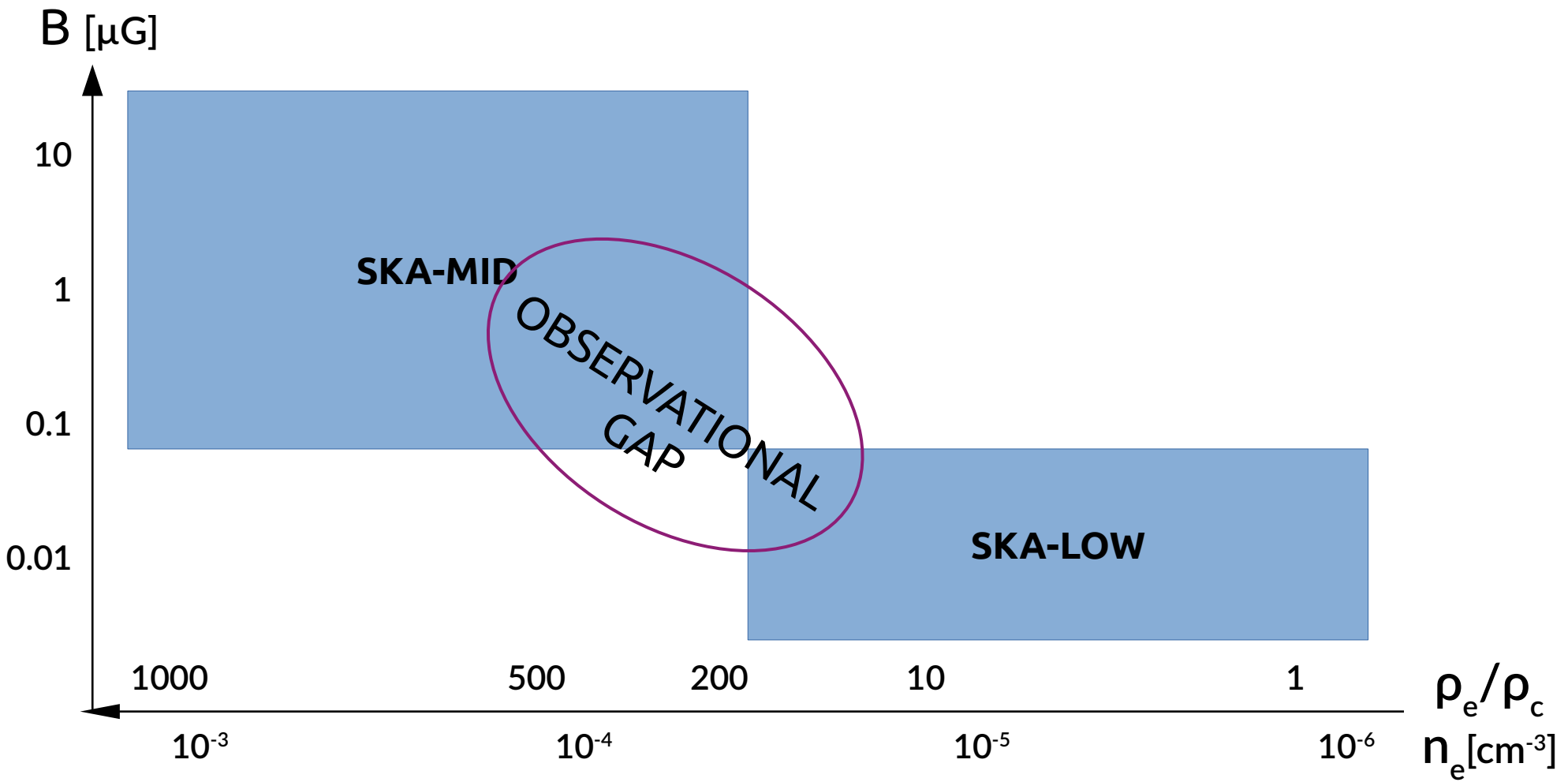
$$depolarization \propto \lambda^4$$

SKA precursors and pathfinders

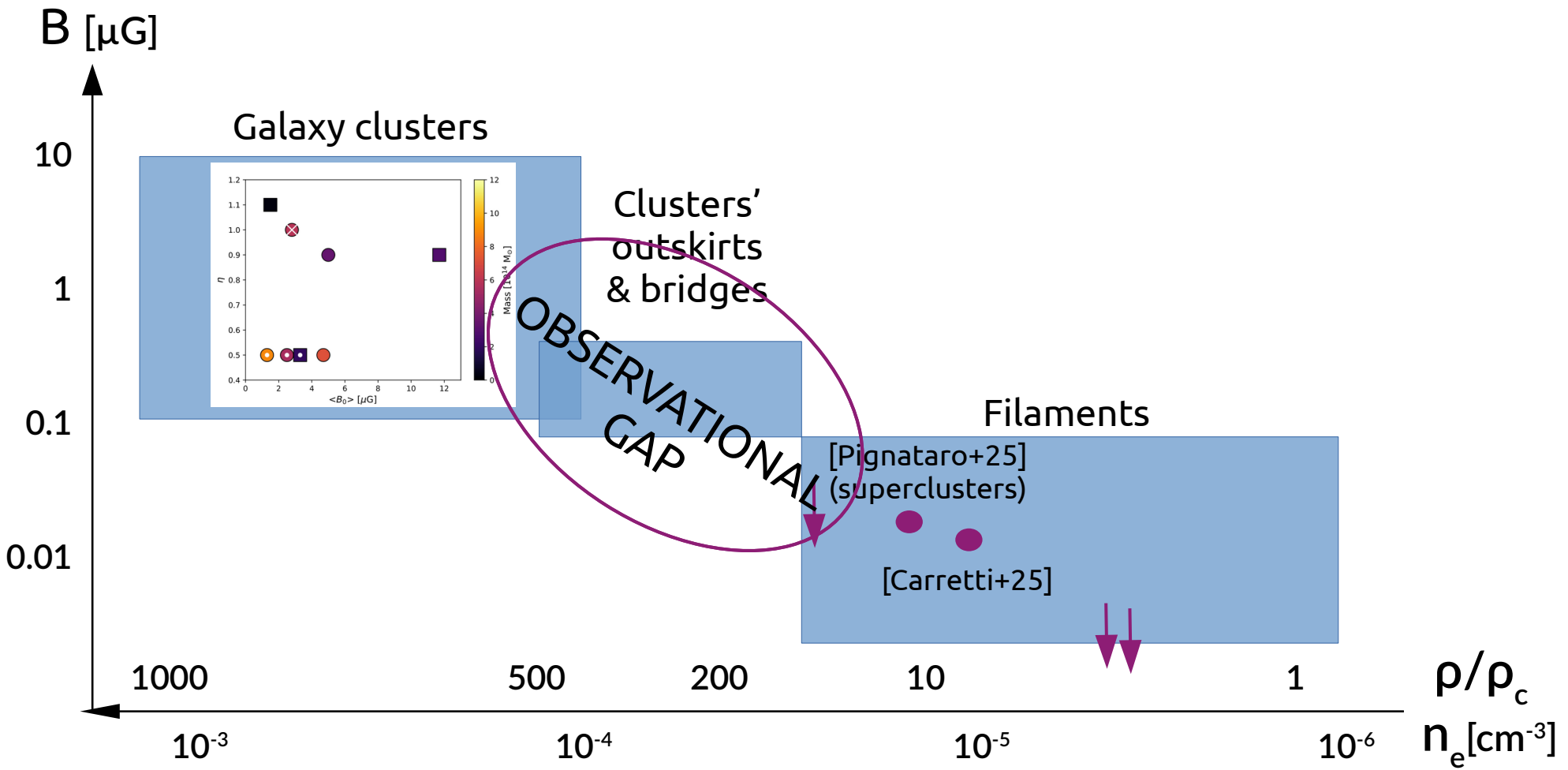


$$RM \propto \int_{source}^{observer} n_{THe} B_{LOS} dl_{LOS}$$

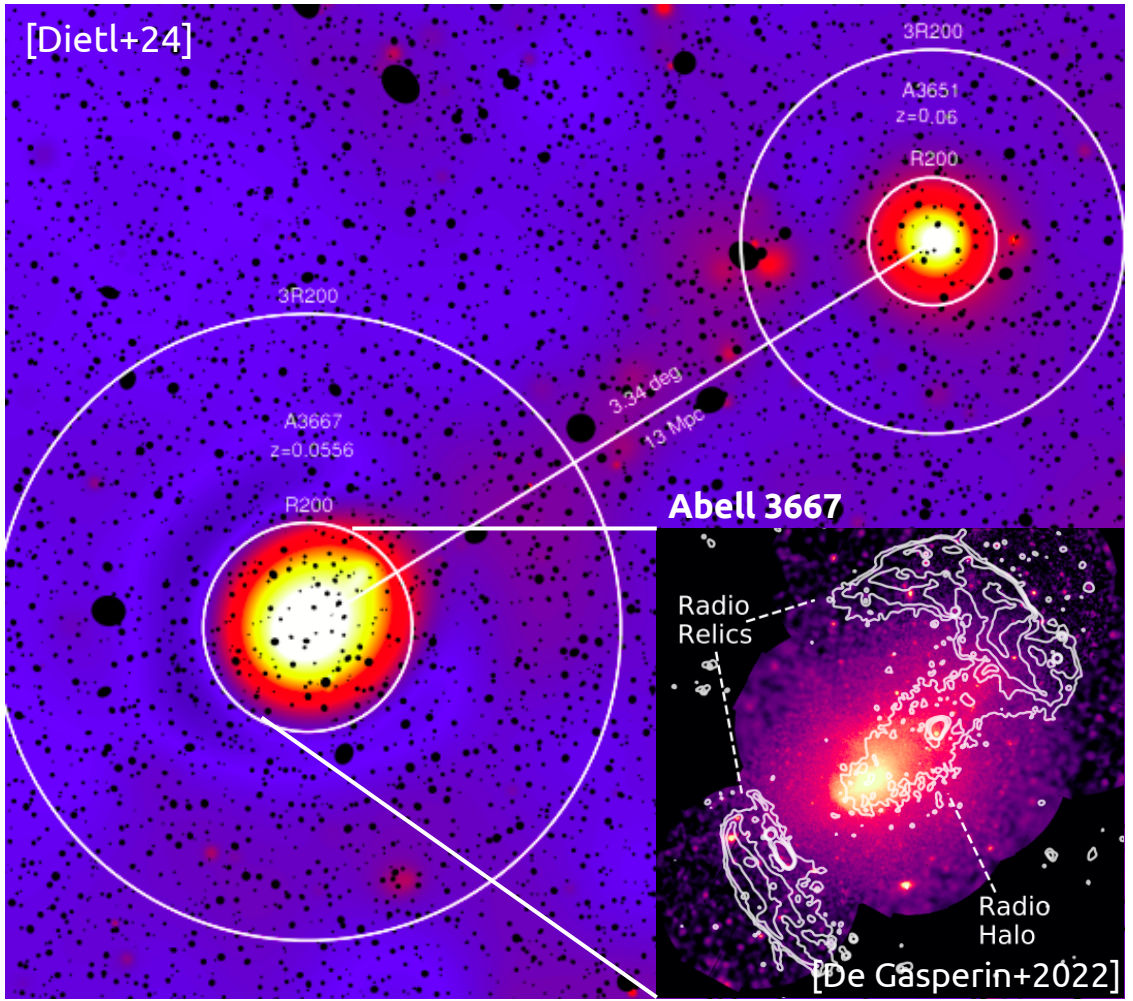
...waiting for the SKA



...waiting for the SKA

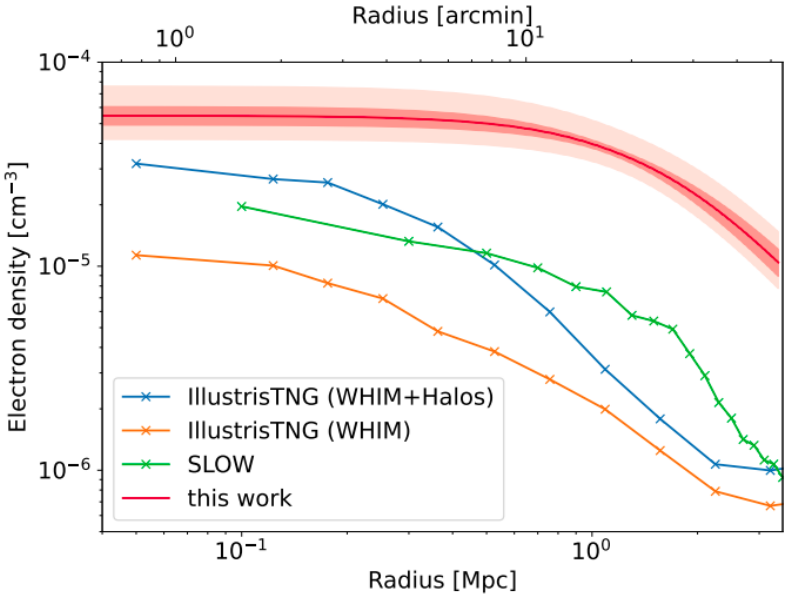


Going beyond R_{200}: the Abell 3667-3651 filament [Stuardi+ in prep.]



A >13 Mpc long X-ray filament detected in the SRG/eROSITA All-Sky Survey

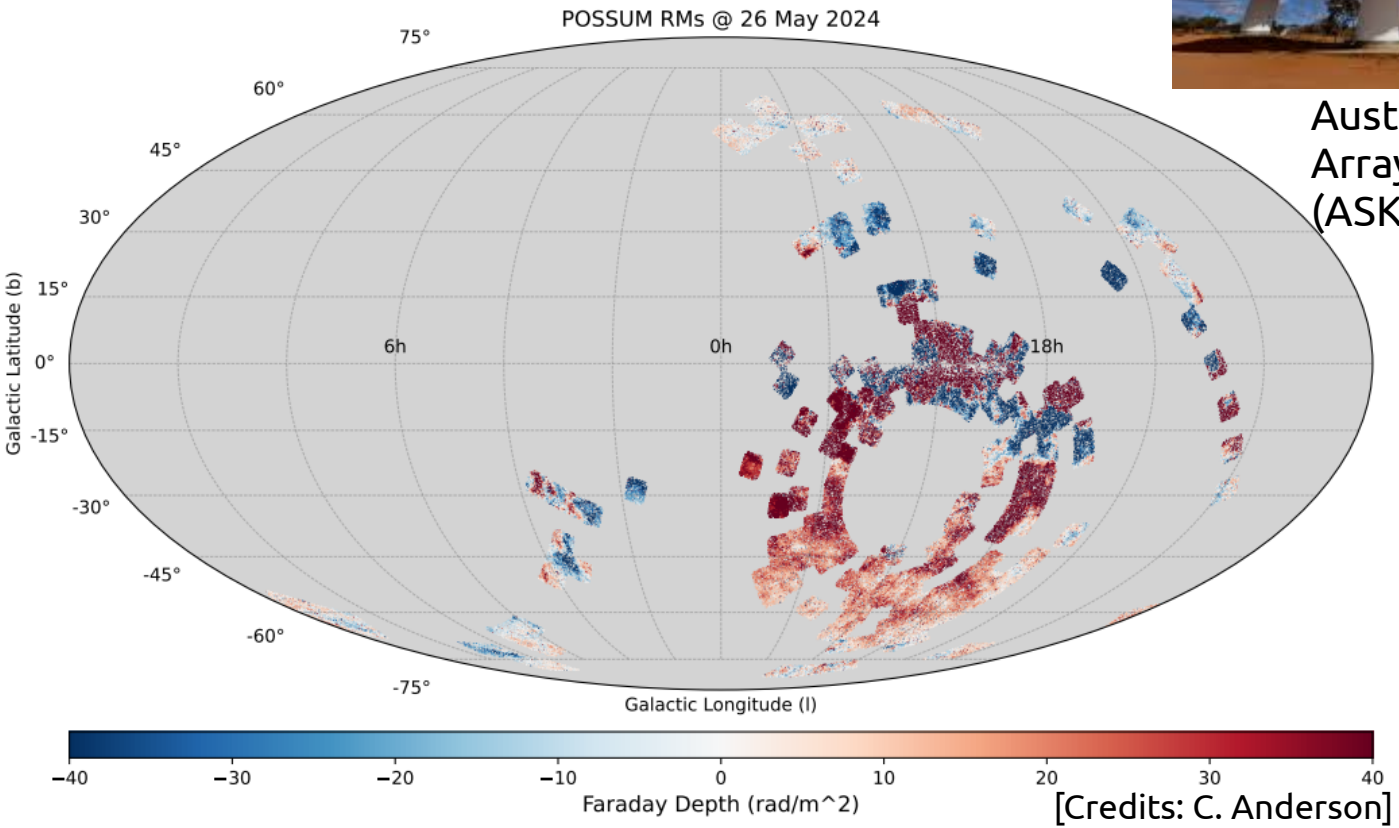
Confirmed with optical data



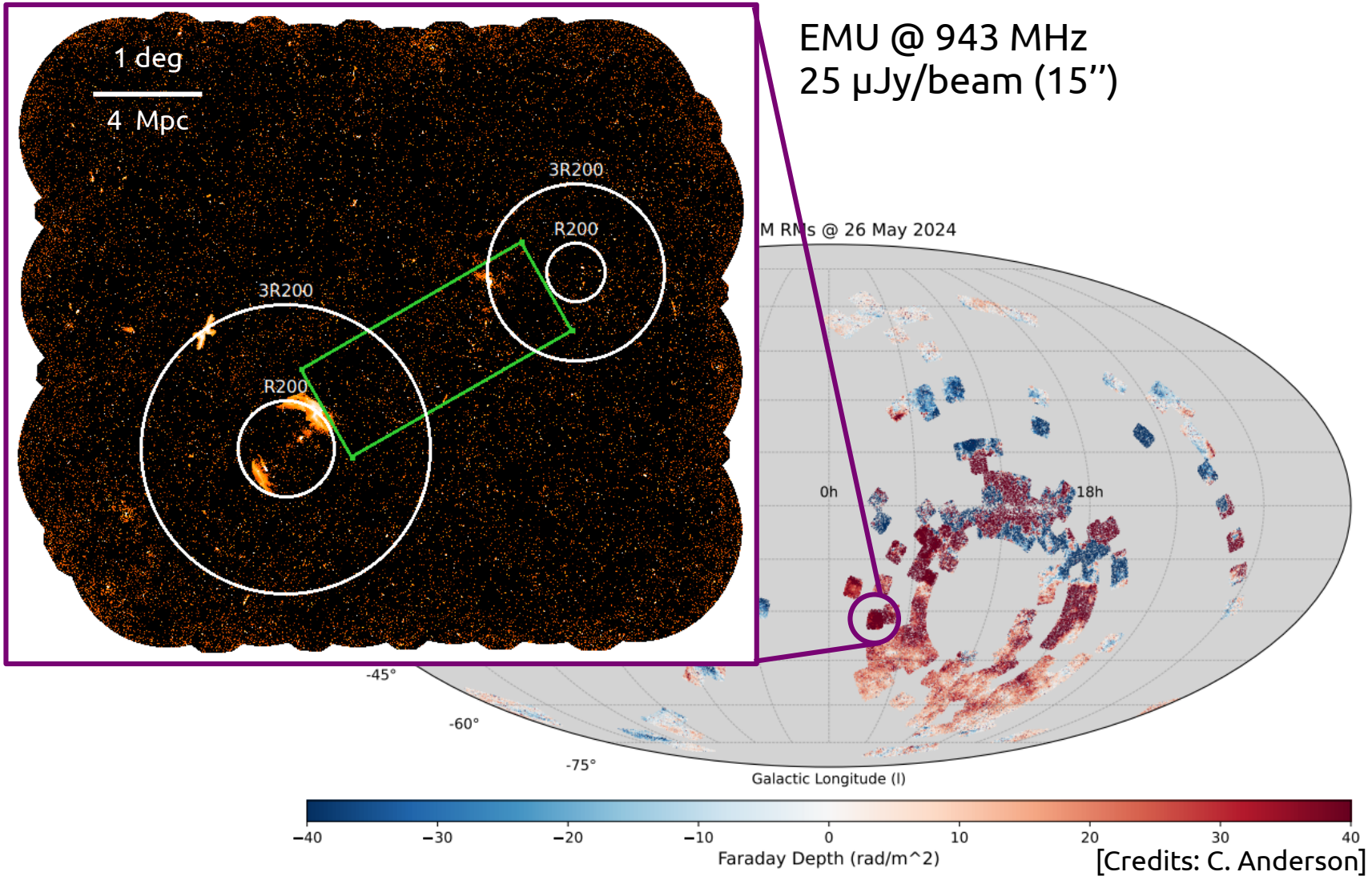
POSSUM
POLARISATION SKY SURVEY OF THE UNIVERSE'S MAGNETISM

Polarization survey of the southern sky 800-1088 MHz
30-40 RM/deg^2
→ public release next year!
[Gaensler+(CS)25]

Australian Kilometre Array Pathfinder (ASKAP)



[Credits: C. Anderson]



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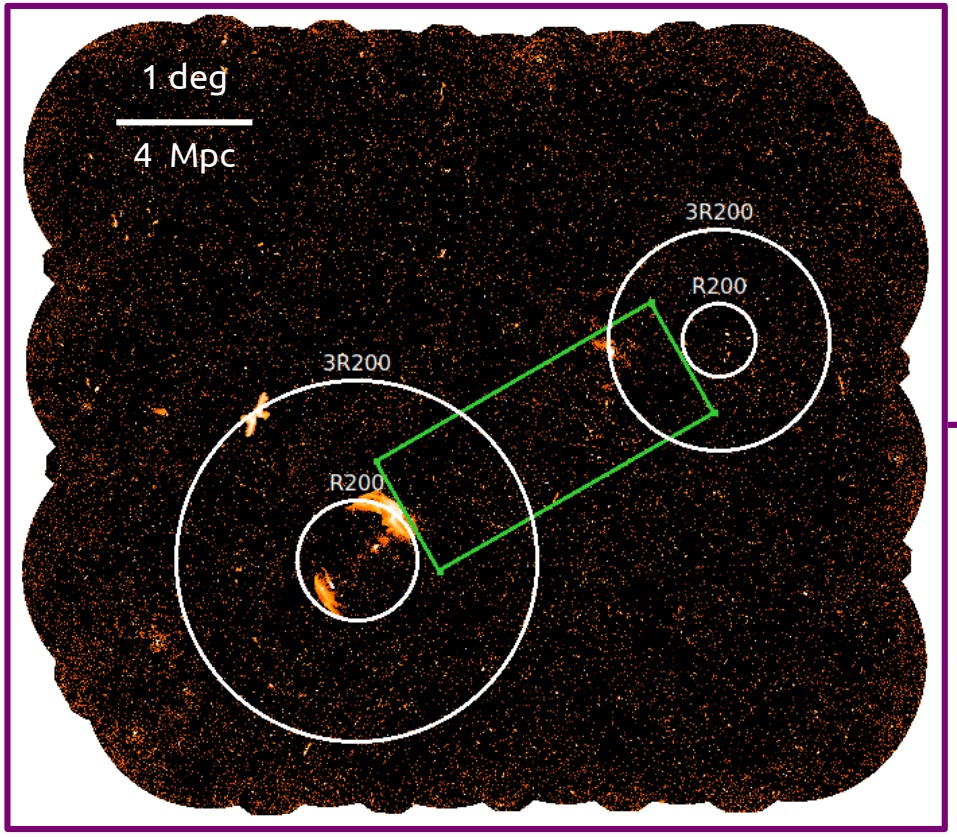
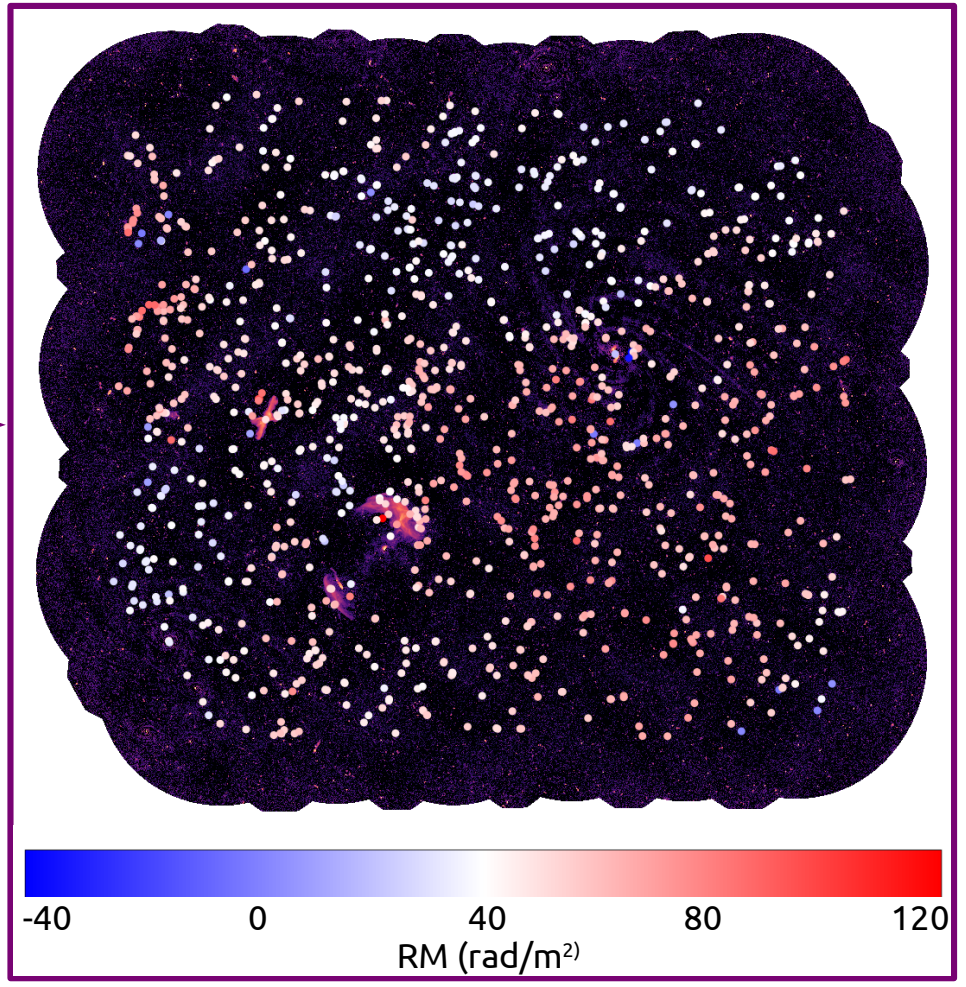
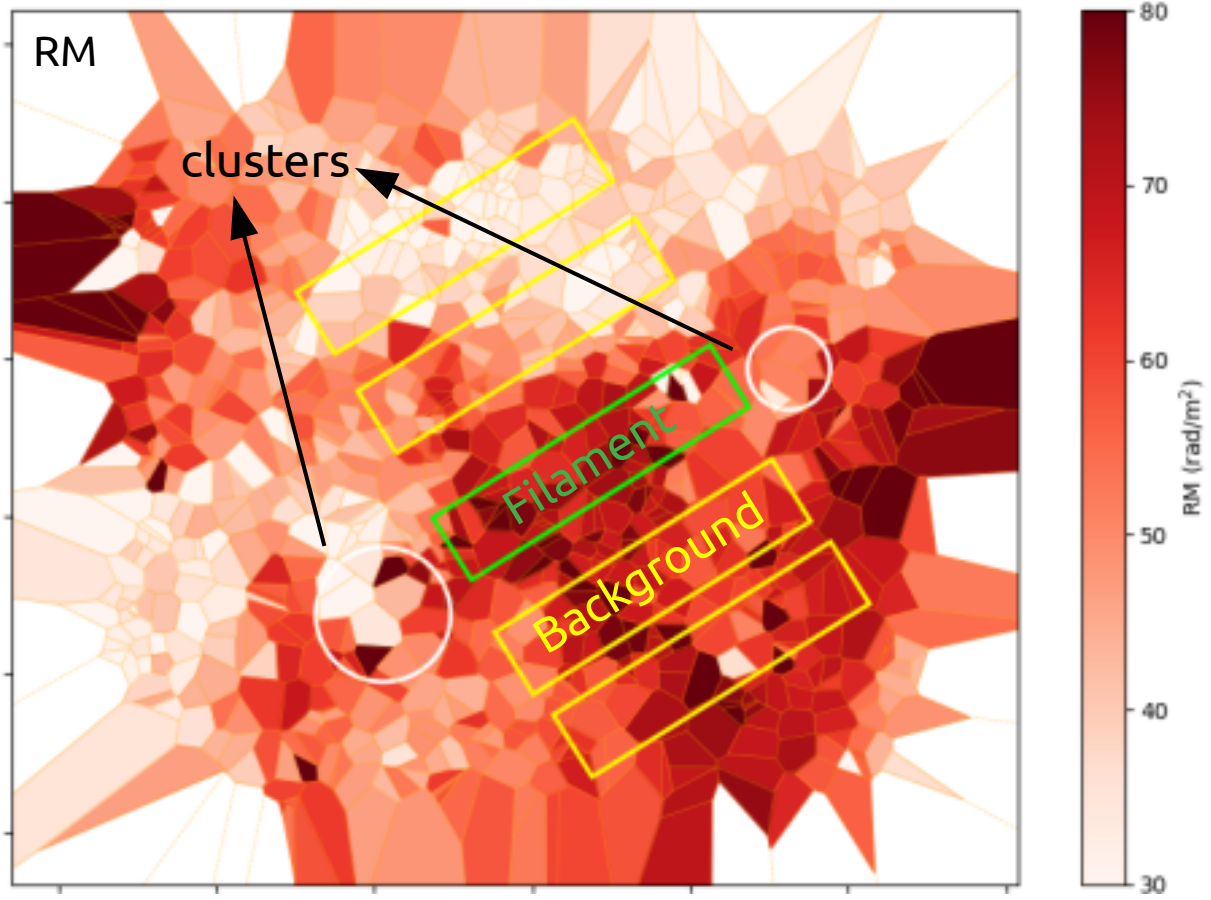
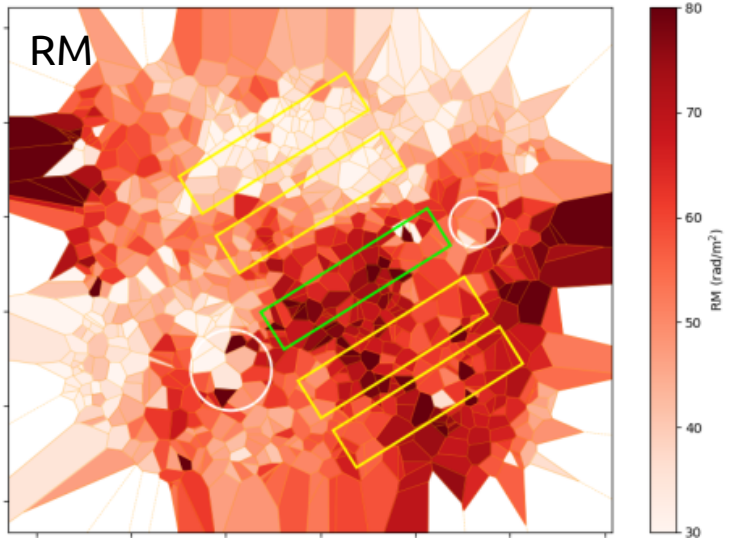




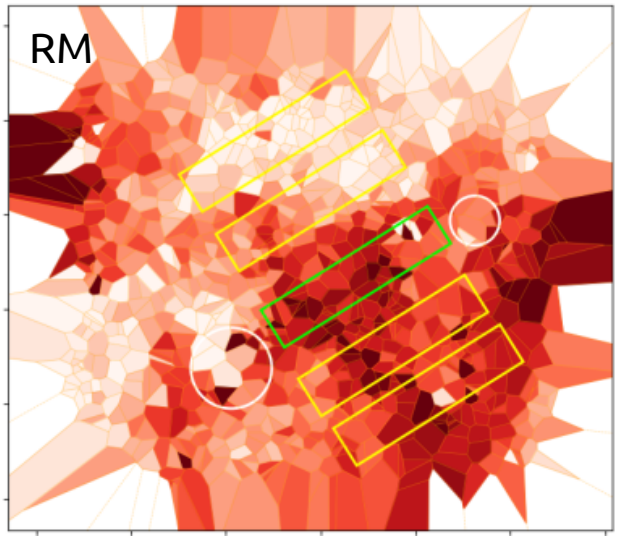
~32 RM/deg^2
46 across the filament

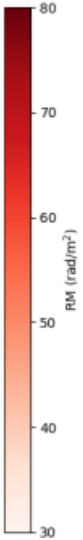


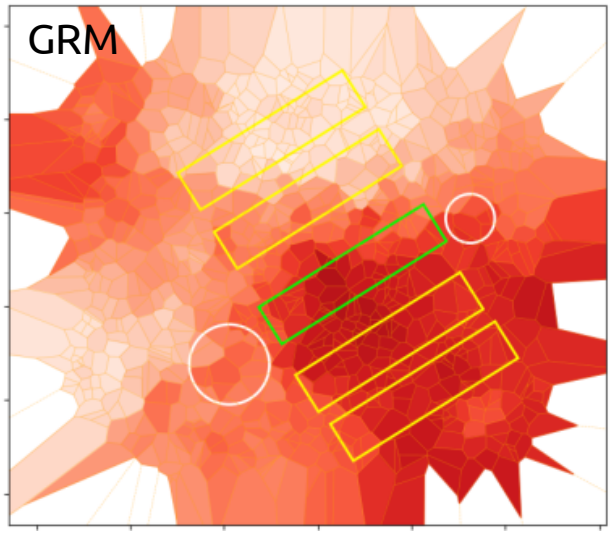
Galactic RM structures
on 0.3°-0.4° scale

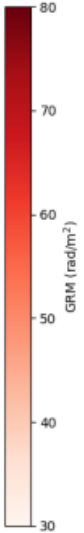


GRM estimated from the sources in the filed (annulus method, Anderson+21)



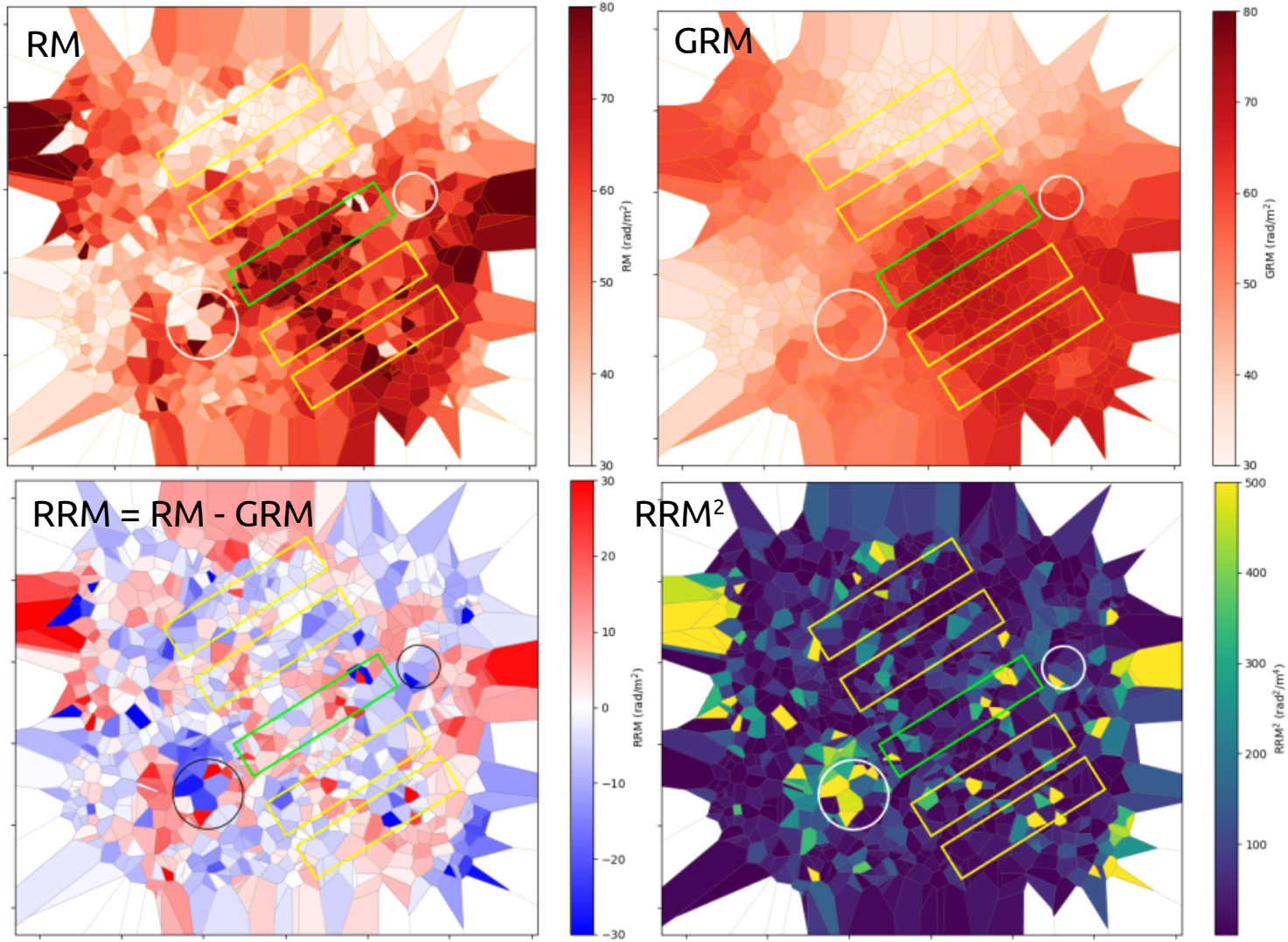


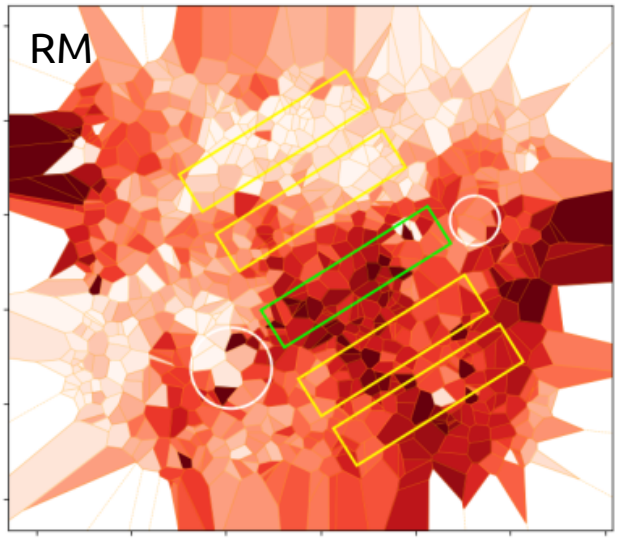


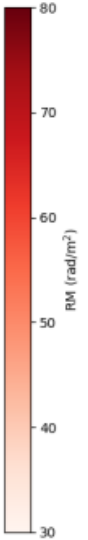


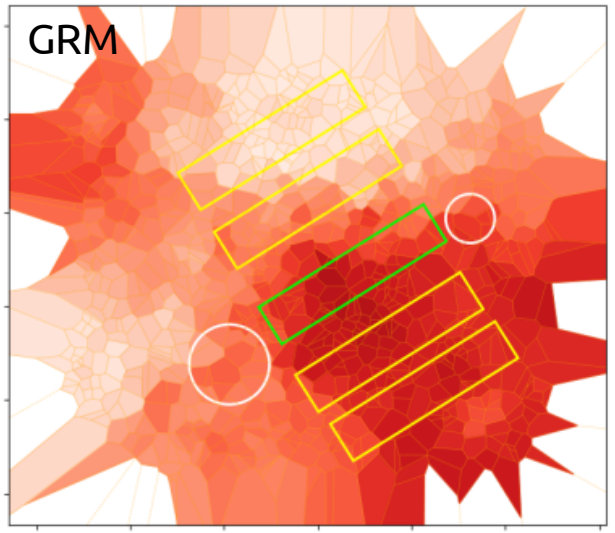
GRM estimated from the sources in the filed (annulus method, Anderson+21)

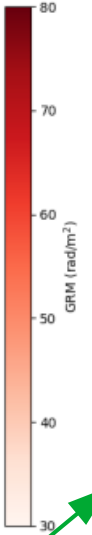
RRM=RM-GRM

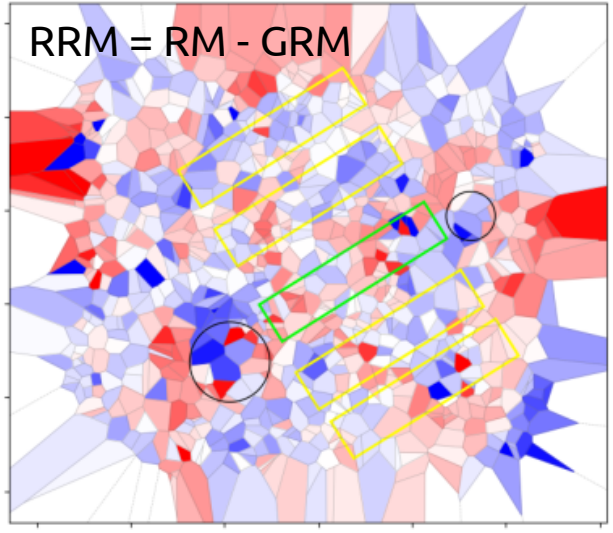

RM
RM (rad/m²)
80
70
60
50
40
30
GRM
GRM (rad/m²)
80
70
60
50
40
30
RRM = RM - GRM
RRM (rad/m²)
30
20
10
0
−10
−20
−30
RRM²
RRM² (rad²/m⁴)
500
400
300
200
100

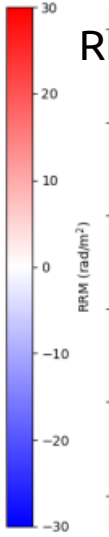


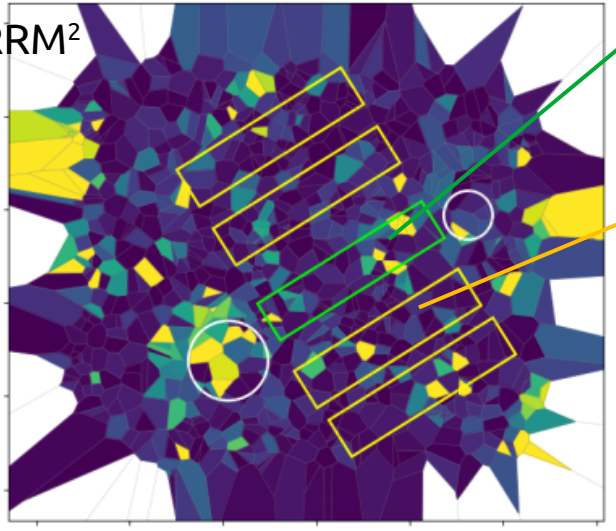


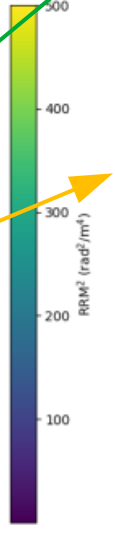












Filament:

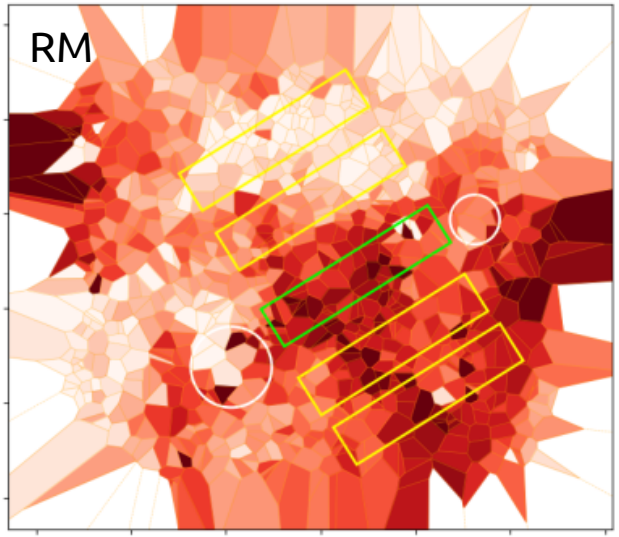
σ_{RRM}=9±2 rad/m²

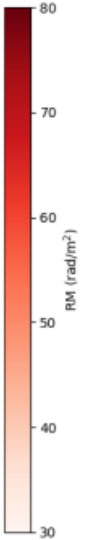
p=(5.1±0.6)%

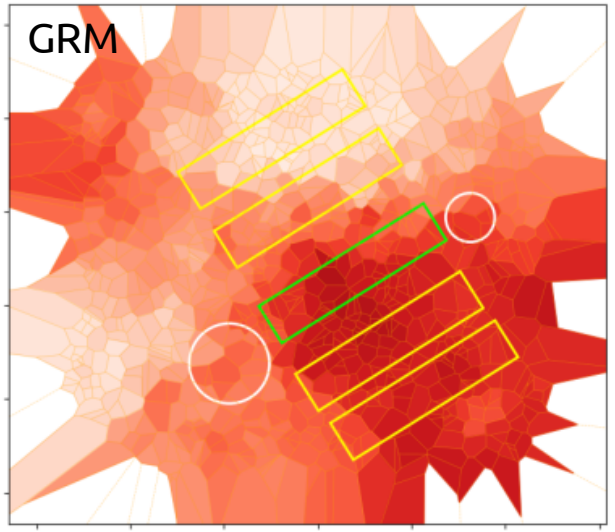
Background:

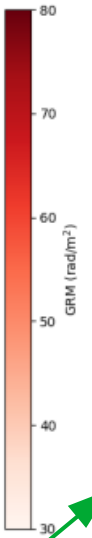
σ_{RRM}=7±1 rad/m²

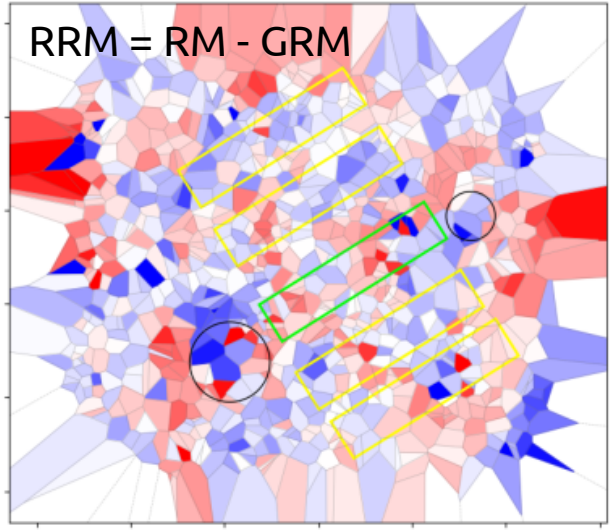
P=(5.7±0.7)%

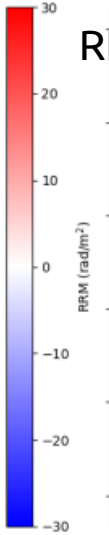


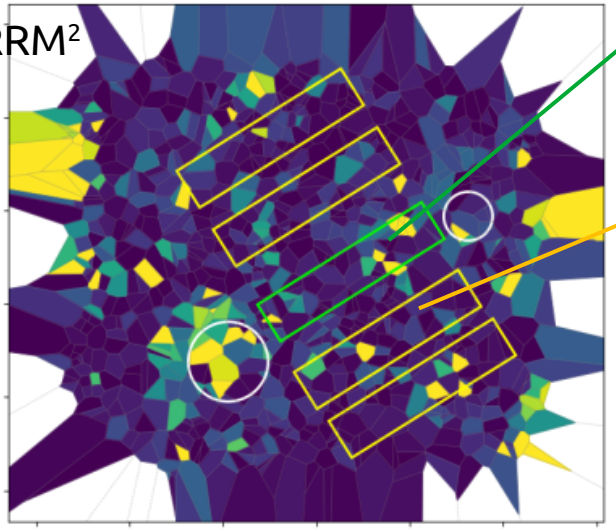


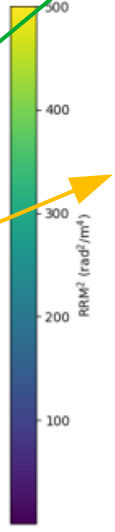












Filament:

σ_{RRM}=9±2 rad/m²

p=(5.1±0.6)%

Background:

σ_{RRM}=7±1 rad/m²

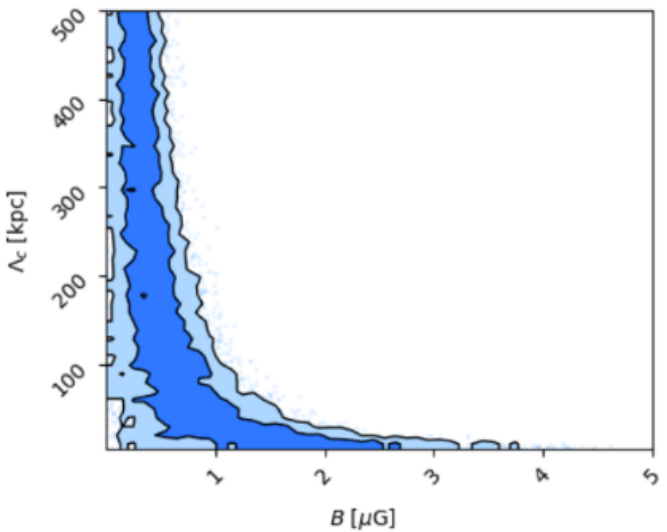
P=(5.7±0.7)%

→ $\sigma_{RM,filament}$=6±3 rad/m²

Going beyond R_{200}: the Abell 3667-3651 filament [Stuardi+ in prep.]

Assuming uniform n_e for a length L (from eROSITA) and single scale model
MCMC sampling of the (Λ_c, B) space

$$\frac{\sigma_{RM}}{\mathrm{rad/m^2}} = \frac{812}{\sqrt{3}} \frac{n_e}{\mathrm{cm^{-3}}} \frac{B}{\mu G} \sqrt{\frac{L}{\mathrm{kpc}} \frac{\Lambda_c}{\mathrm{kpc}}}$$



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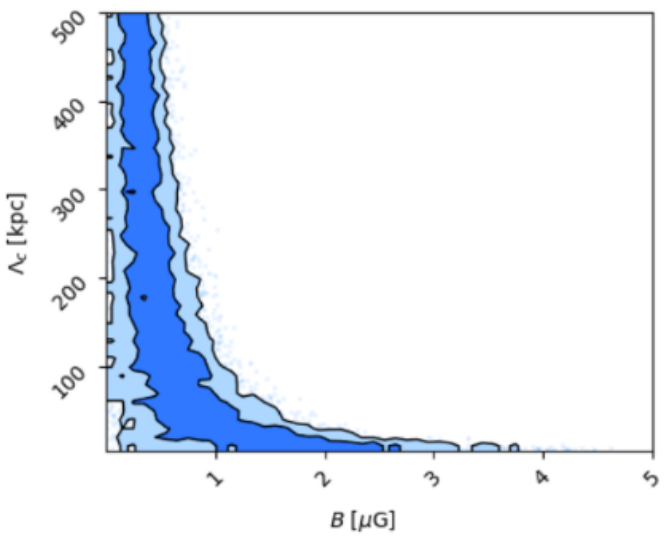

Mode at: B = 0.3 μG, Λ_c>100 kpc

Agrees with negligible depolarization within the beam (~20 kpc)

0.08<B<4.1 μG @ 95% confidence

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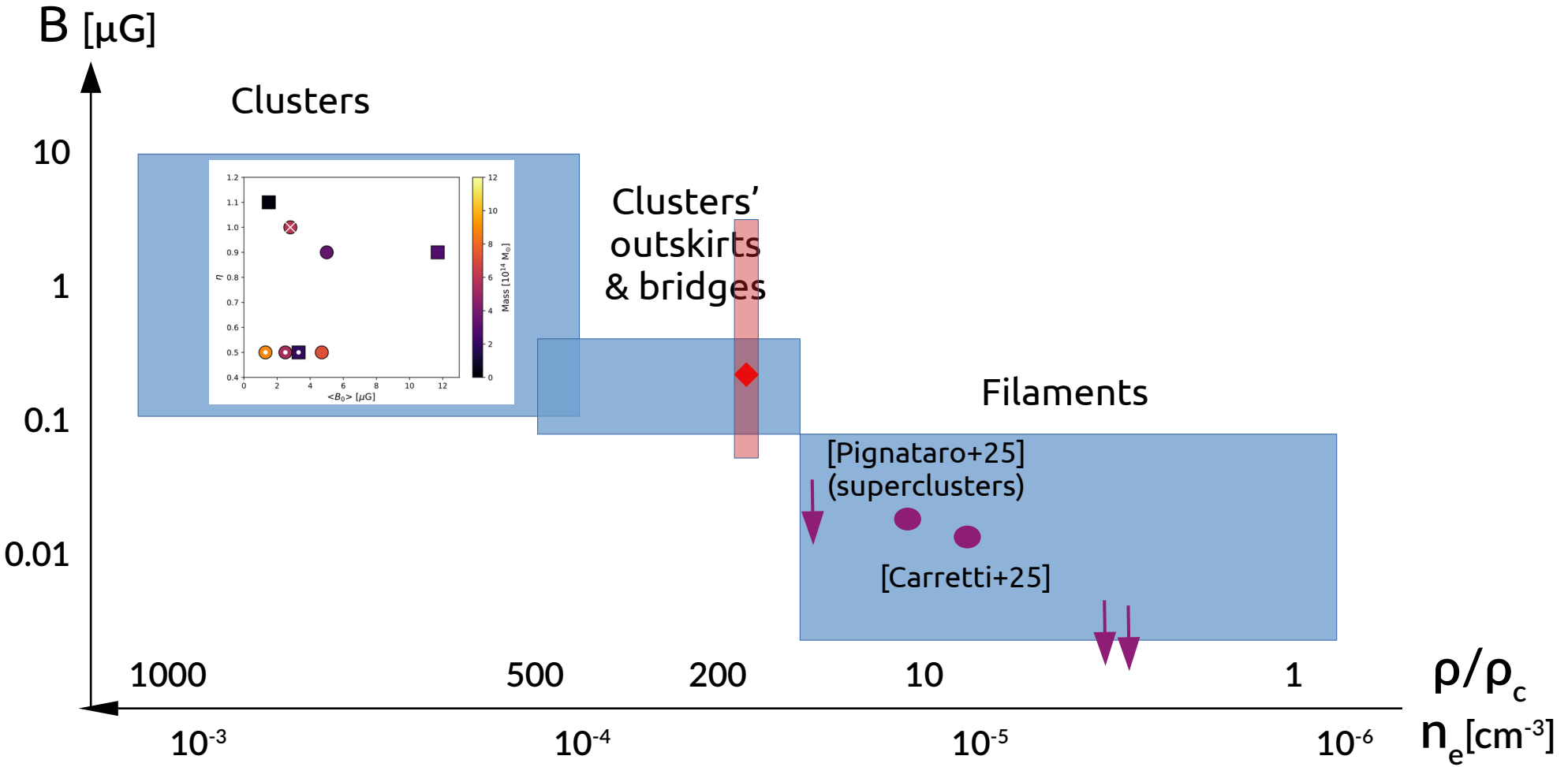


Going beyond R_{200}: the Abell 3667-3651 filament [Stuardi+ in prep.]

B [μG]

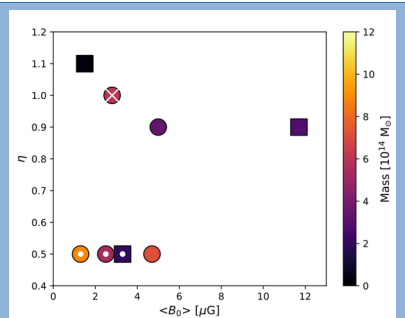
10

1

0.1

0.01

Clusters



Clusters' outskirts & bridges

Filaments

[Pignataro+25] (superclusters)

[Carretti+25]

Limitations

- marginal detection

→ need more RMs or low-frequency

- B derived with a very simple model
- n_e is probably over-estimated [Migkas+25]
- Galactic RM subtraction is challenging

1000 500 200 10 1 ρ/ρ$_c$

10^{-3} 10^{-4} 10^{-5} 10^{-6} n_e[cm^{-3}]

Conclusions

- We can already explore this new regime
  with POSSUM (ASKAP).

- The combination of SKA-LOW and SKA-MID RM grid will be the breakthrough needed to fill the observational gap.

- Galactic RM foreground requires better modeling,
  taking into account other Galactic tracers (work in progress).

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