Magnetic field in CGM of high-z galaxies using ASKAP

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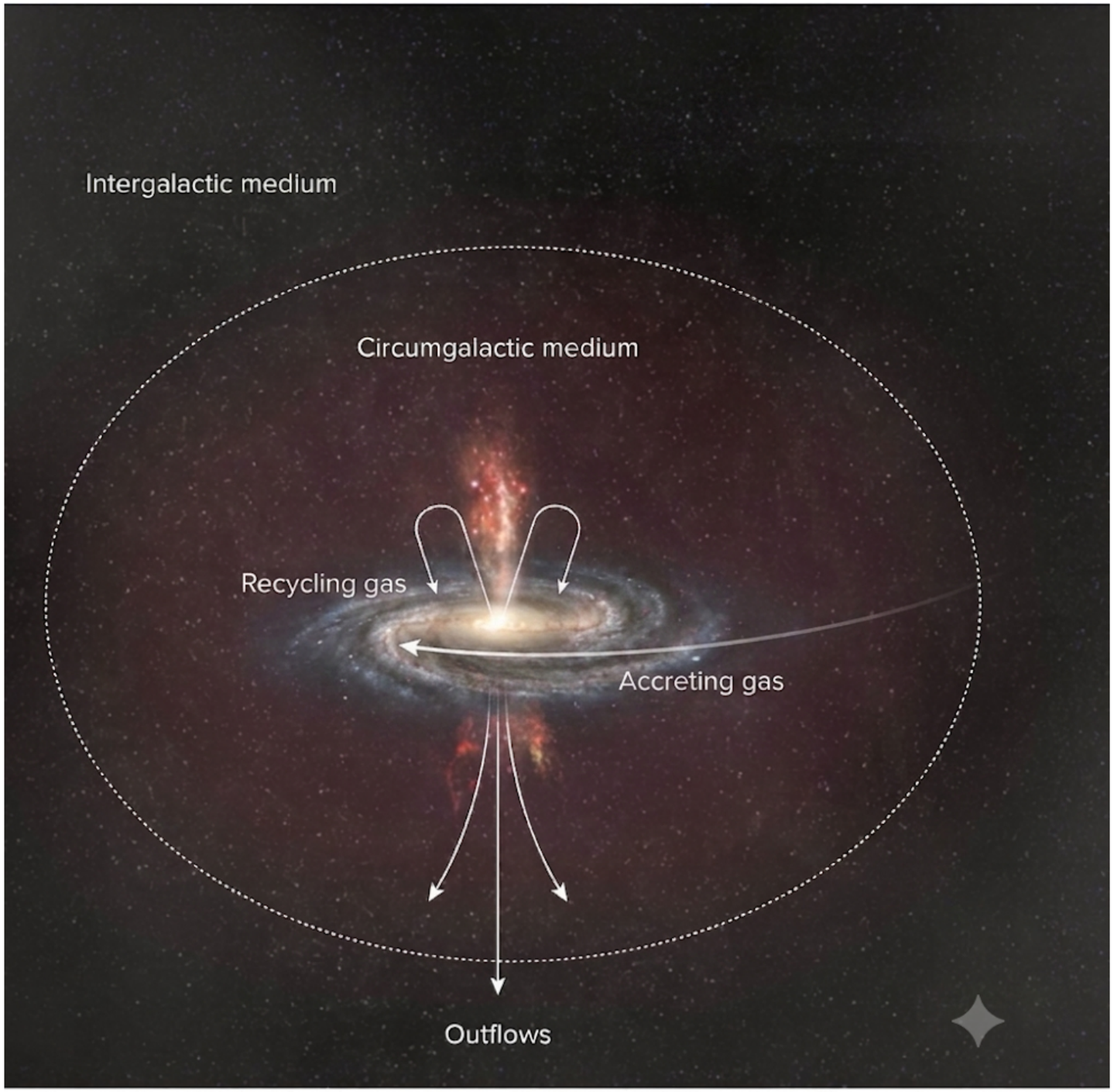
Schematic diagram of galaxy disk and CGM



SOURCE: J. TUMLINSON *ET AL* / *AR ASTRONOMY AND ASTROPHYSICS* 2017;
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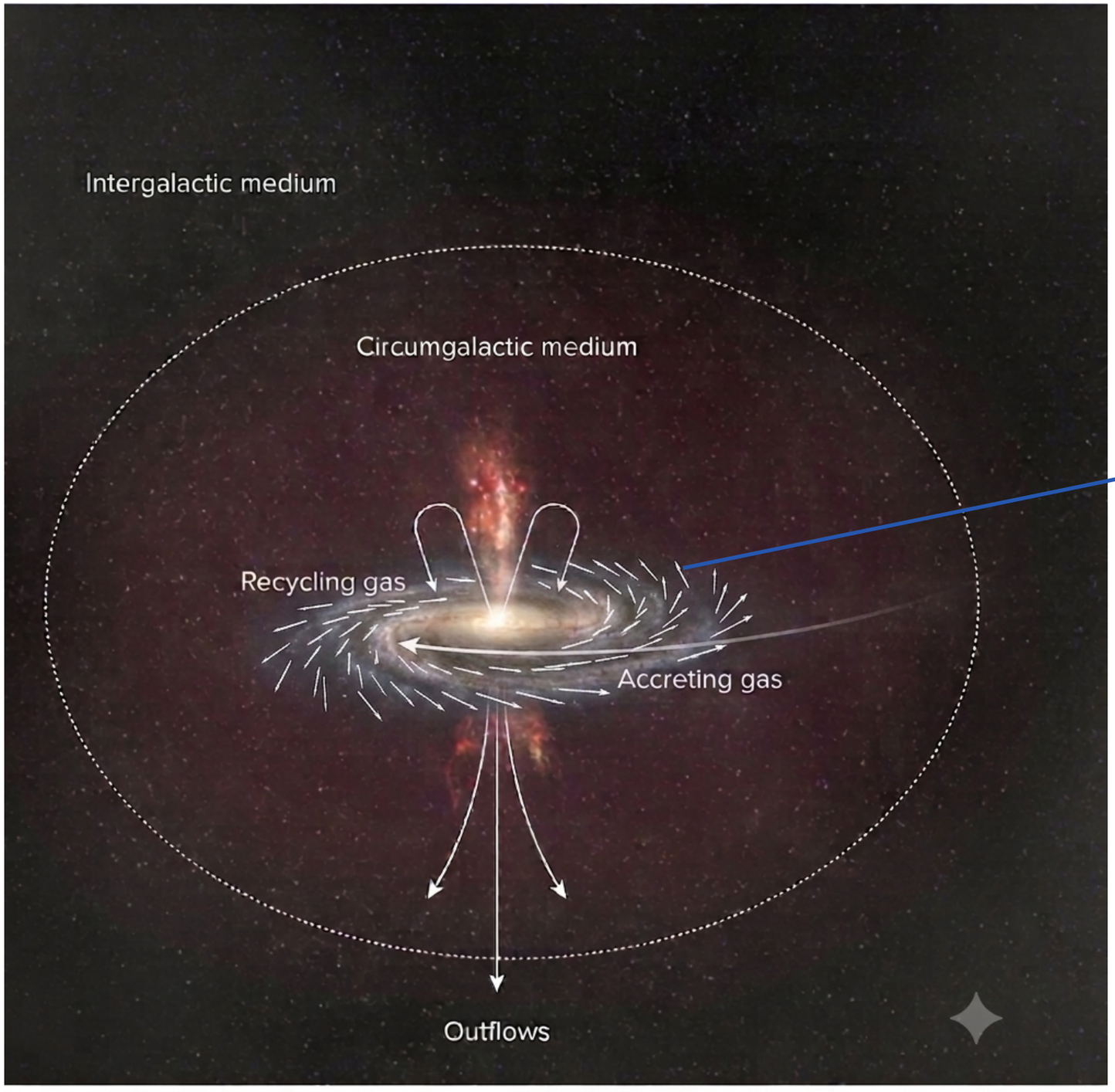

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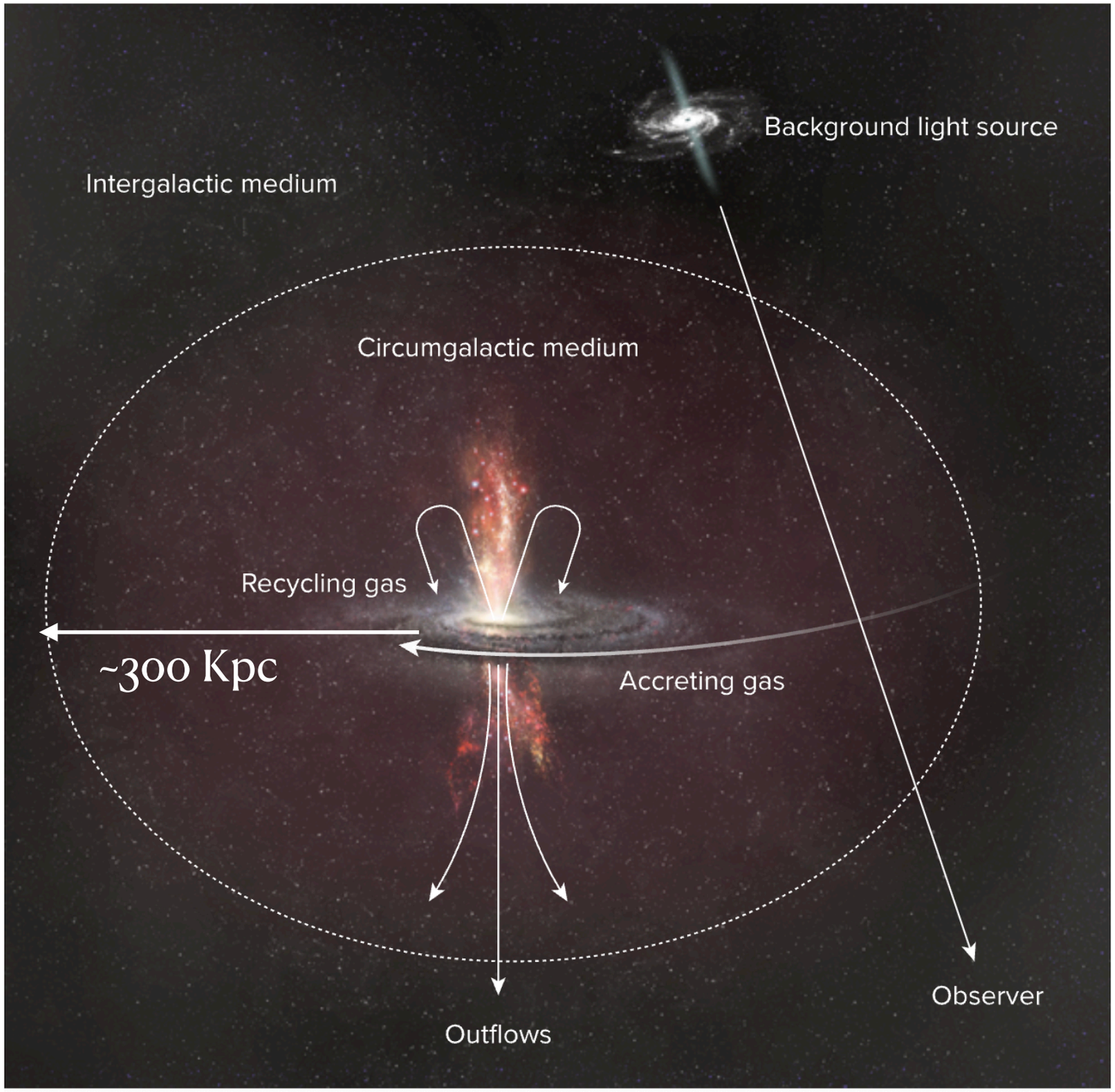
Dust polarisation can probe the magnetic field in the disk

Schematic diagram of galaxy disk and CGM



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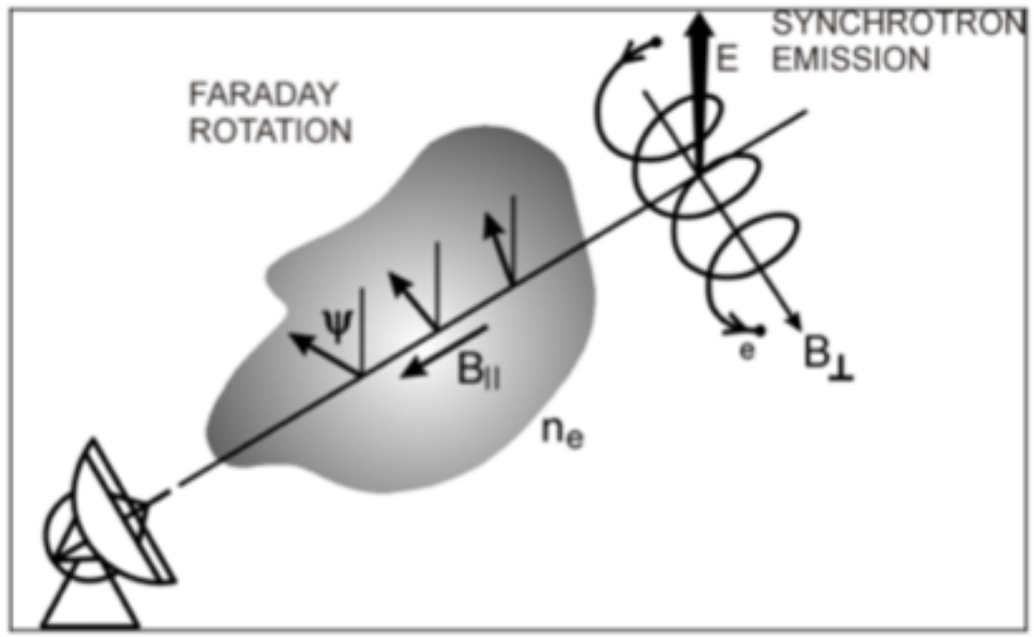
Faraday rotation: rotation plane of polarisation due to magnetised plasma in the foreground => quantified by Rotation measure

$$\psi = \mathrm{RM}\ \lambda^2 + \psi_0$$

ψ_0 is intrinsic polarisation angle

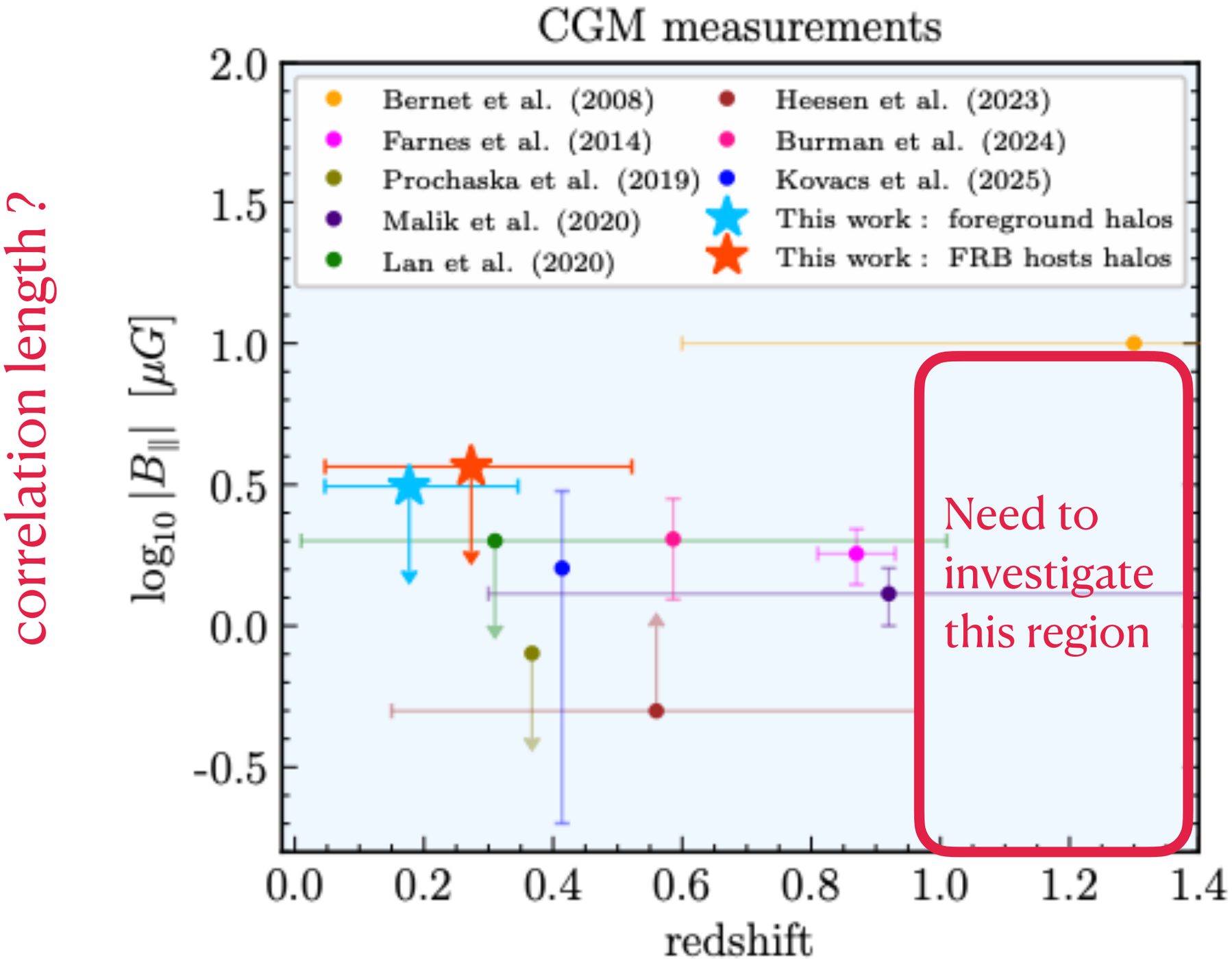
$$\mathrm{RM} \propto \int_{\mathrm{source}}^{\mathrm{observer}} B_{\parallel} n_e dl$$



If we account for expansion:

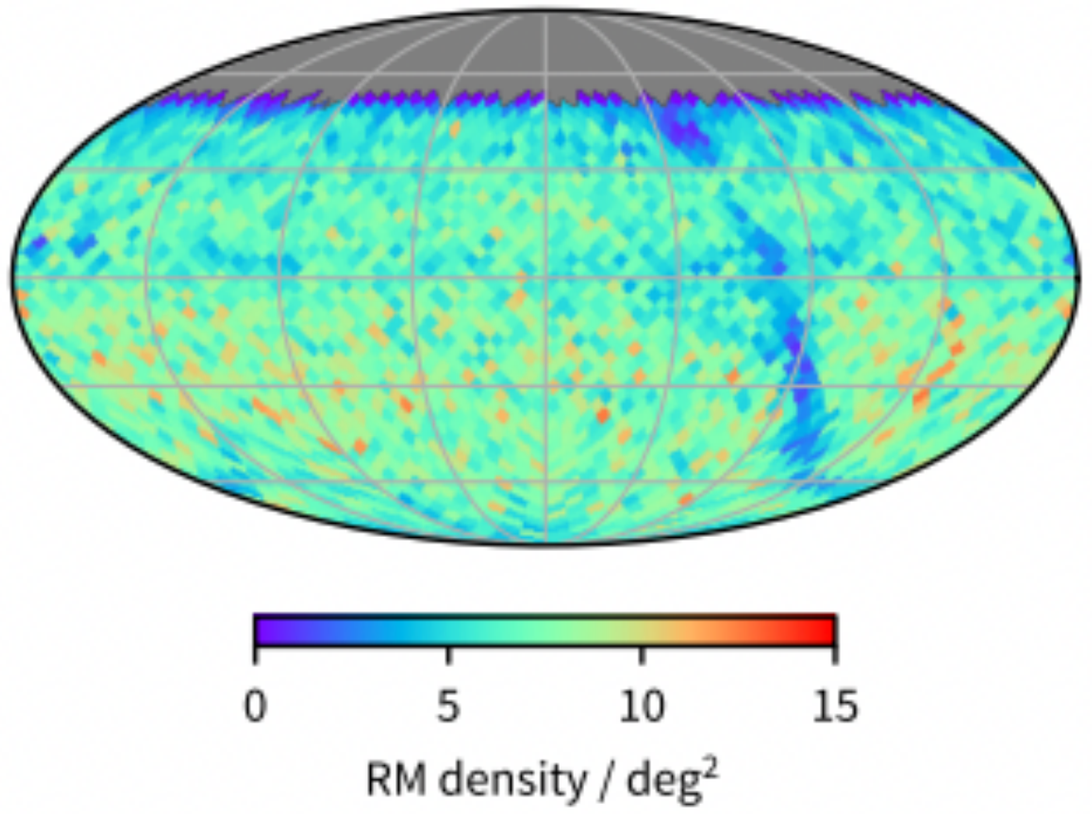
$$\mathrm{RM}(z_{\mathrm{emi}}) = \frac{\Delta\psi}{\Delta\lambda^2} = 8.1 \times 10^5 \int_{z_{\mathrm{emi}}}^{0} \frac{B_{\parallel(z)} n_e(z)}{(1+z)^2} \frac{dl}{dz} dz$$

- Summary of Magnetic field measurements (Khrykin et al, 2025)(2509.08896)



Faraday rotation observation from Australian SKA Pathfinder

- ✦ SPICE-RACS: Spectra and Polarisation in Cutouts of Extragalactic sources- Rapid ASKAP Continuum Survey
- ✦ Angular Resolution: 15''
- ✦ Max Declination 49 degrees
- ✦ Sources with good RM: 250,000
- ✦ Observed band: 799.5 to 1087.5 MHz
- ✦Median RM uncertainty ~2 rad m^{-2}
- ✦Source density: ~ 5 deg^{-2}



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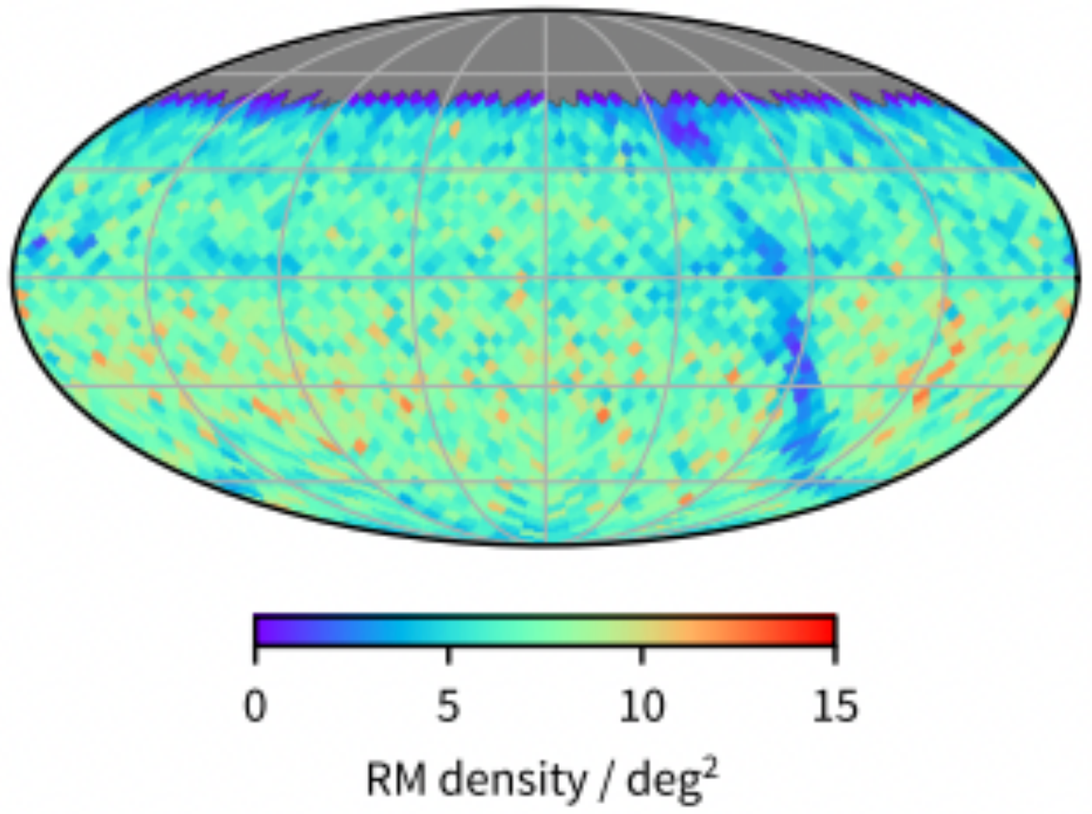

Up to now larger RM catalog NVSS ~ 40000 sources

Median RM uncertainty: ~ 10 rad m^{-2}

Source density: ~ 1 deg^{-2}

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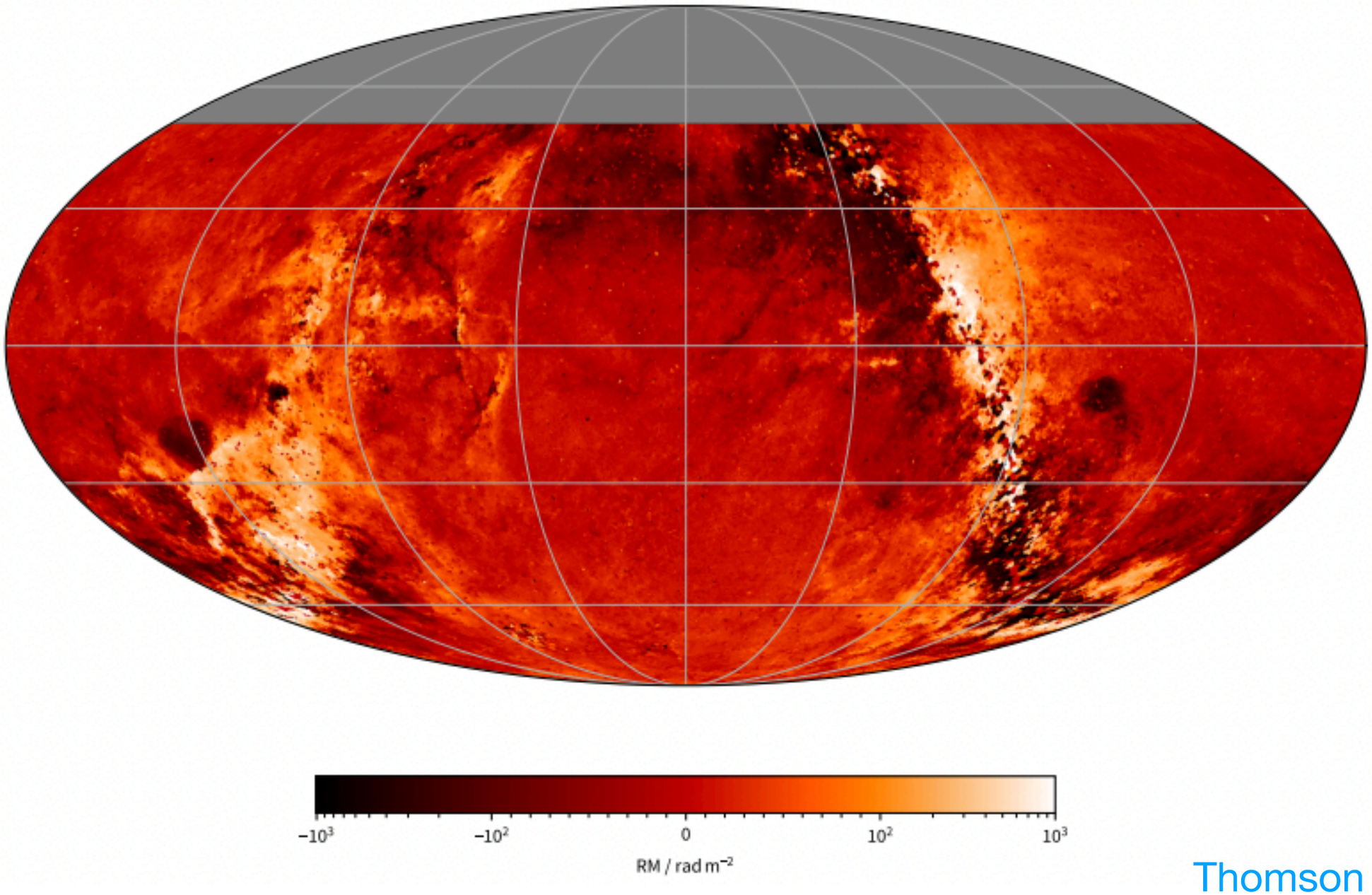
SPICE-RACS RM distribution



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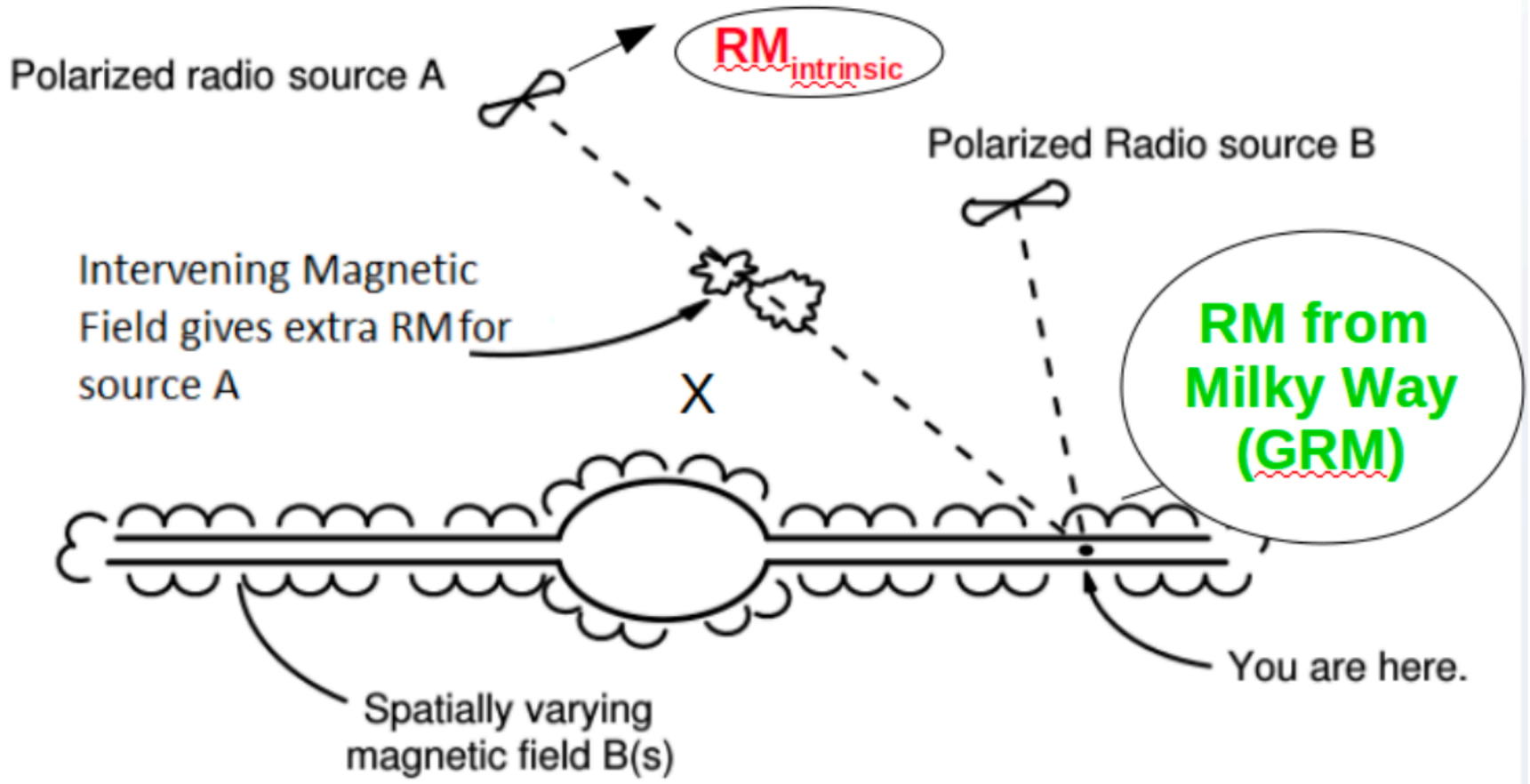
- Pictorial representation of two line of sight to depict the technique,



- **Optical observations:** To detect the intervening galaxies (Used Mg II doublet lines)
- $\mathrm{RM_{obs}(A)} = \mathrm{GRM} + \mathrm{RM_{interven}} + \mathrm{RM^{1}_{IGM}} + \mathrm{RM_{intrinsic}}$

- **Radio Observations:** Polarisation Observation of the quasars for the Rotation Measure.
- $\mathrm{RM_{obs}(B)} = \mathrm{GRM} + \mathrm{RM_{IGM}} + \mathrm{RM_{intrinsic}}$

[1] RM_{IGM} is very small (due to small number density and magnetic fields)

DATA Used and Sam

- SPICE-RACS DR2 RMs —> snr_polint > 8, fracpol > 0.005, de-duplication
- We have ~250,000 RM components. (DR2, Thomson et al, 2026)
- DESI DRI quasar catalog having 1.6 M sources. (Karim et al 2025)
- We positional cross-match them with 3 arcsec separation.

- Total sources: 2483
- To identify the foreground galaxies, we used Mg II doublet lines from the DESI DRI Mg II catalog having 270,529 sources (Karim et al 2025; Napolitano et al, 2023)
- Total sightlines with foreground Mg II absorbers: 612 sources.

- Redshift distributions of QSO and Mg II absorbers.
- 259 sources with Zqso > 2 with Mg II absorbers.
- 451 sources with Zqso > 2 without Mg II absorbers.

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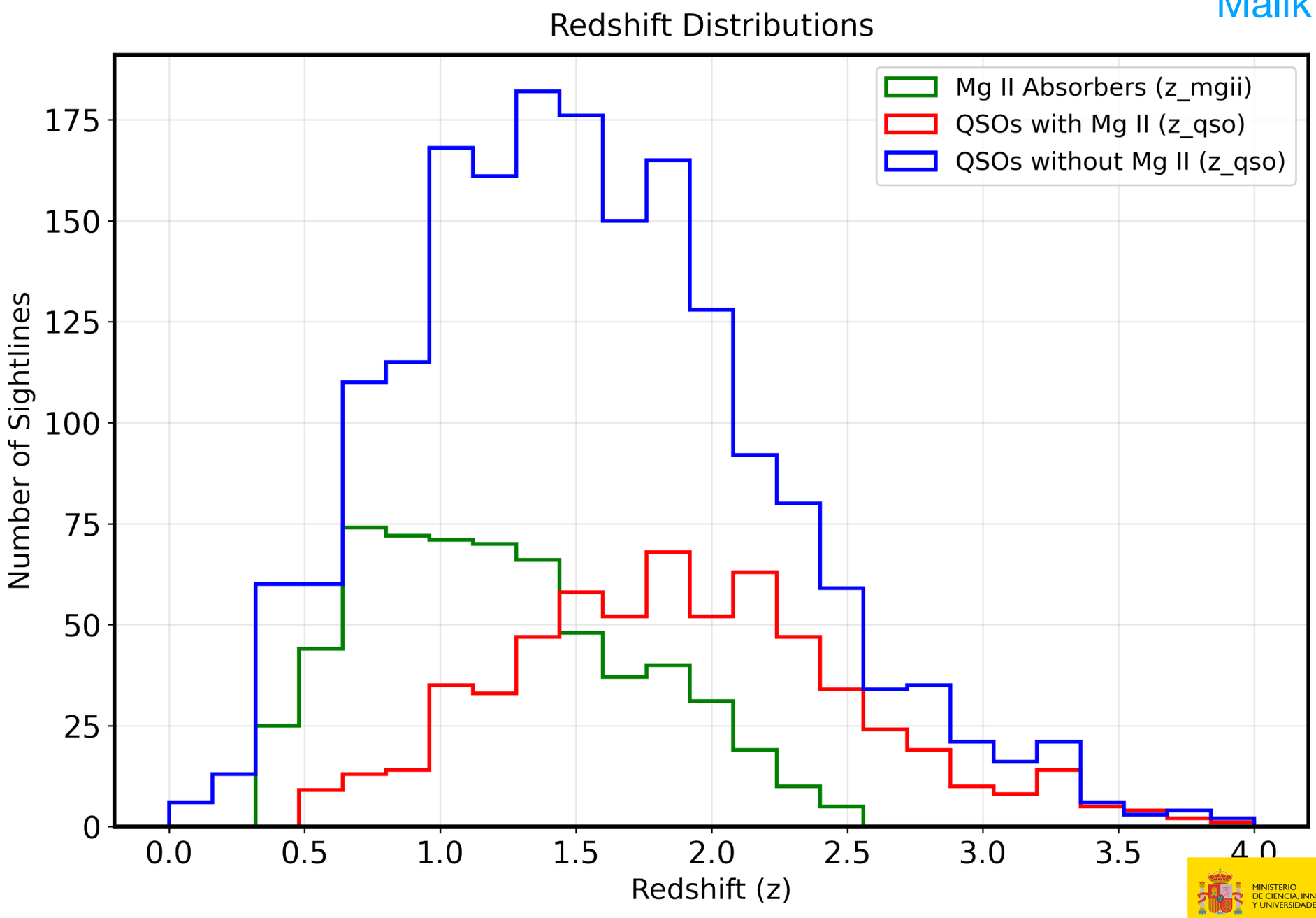
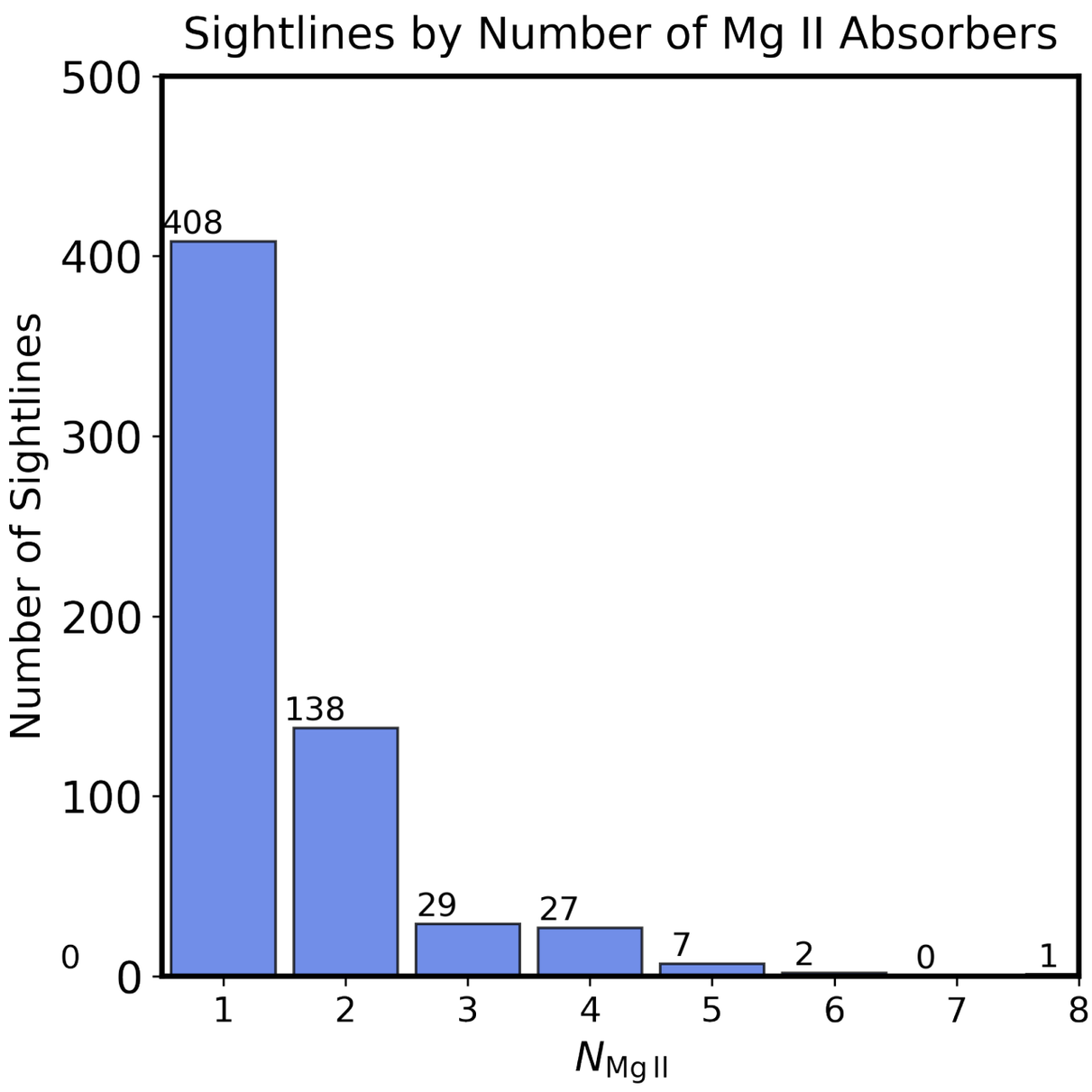
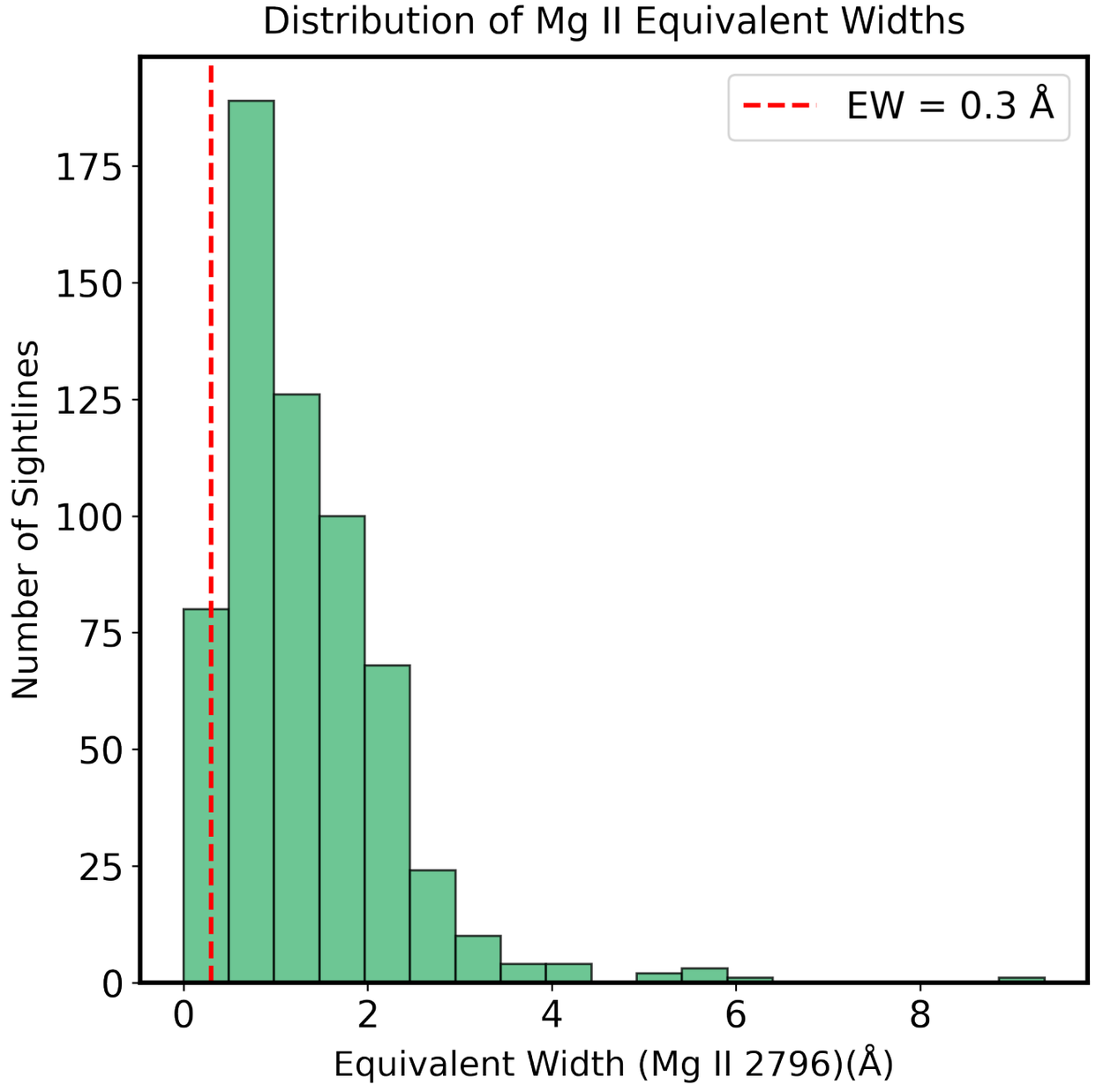


- Subsample with Mg II absorbers and its characteristics





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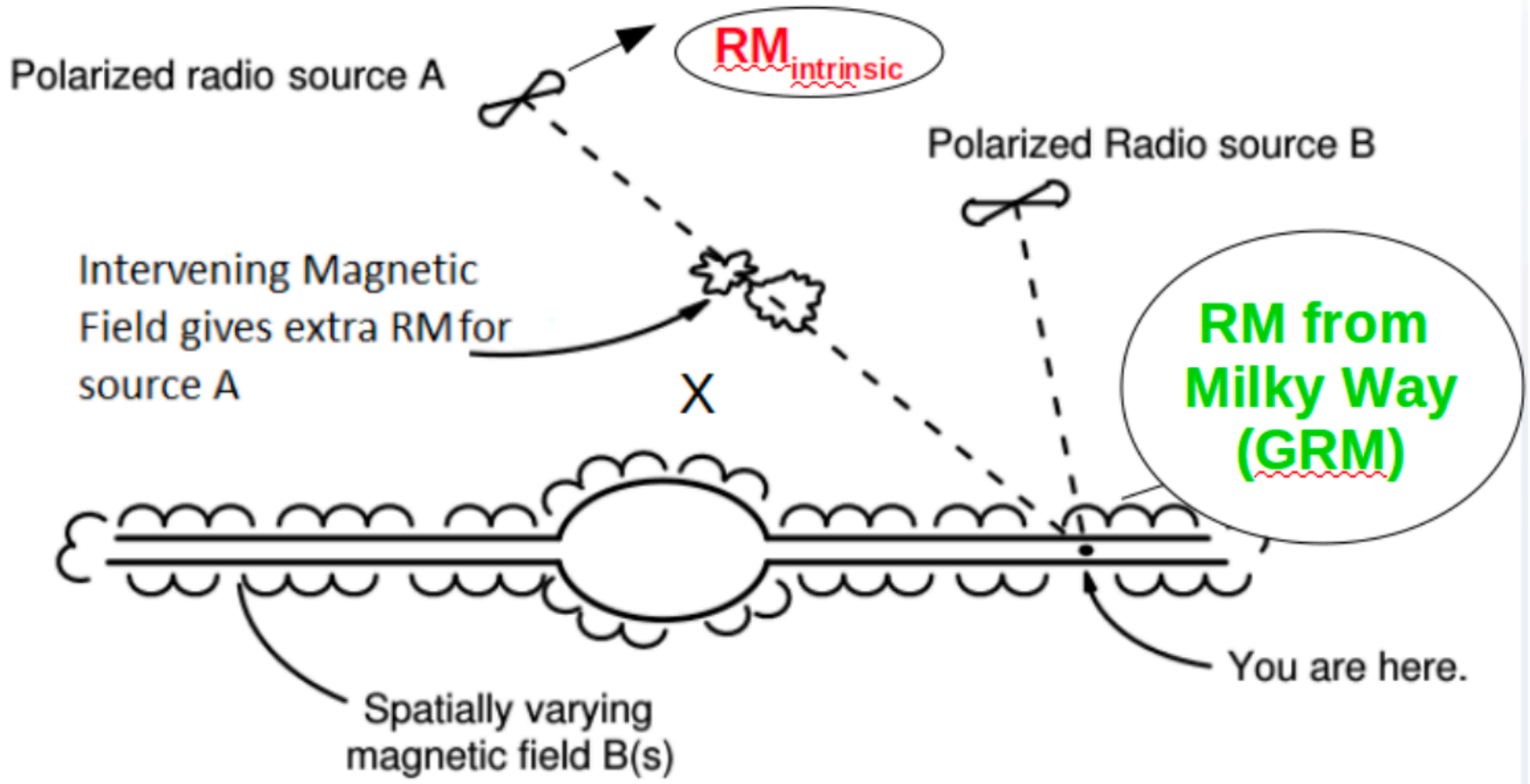

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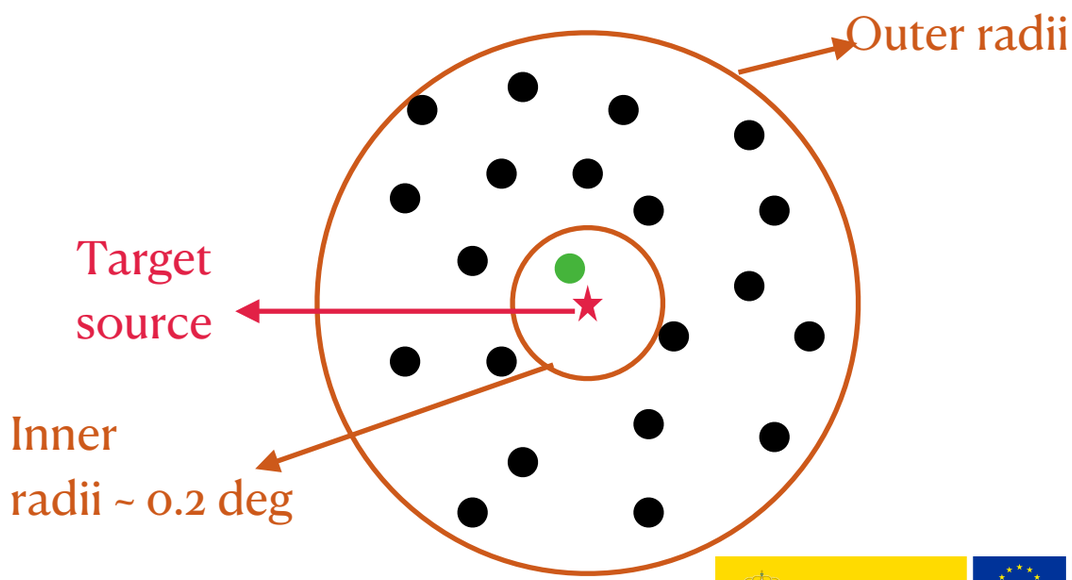
Milky Way Galactic Rotation Measure removal

Milky Way RM (GRM) estimates

- Target Sample : **2483** sources
- We have used annulus method for each sources (Anderson et al, 2024).
- Reference catalog: ~ 250,000 RACS RM components
- We should avoid RM components within r_inner ~ 0.2 deg
- Consider 20 RM components in the nearest neighbours of each target sources with the above condition
- GRM ~ Median of 20 RM components
- $\sigma_{GRM} = \frac{\sigma_{\rm mad}}{\sqrt{N}}$ N ~ 20



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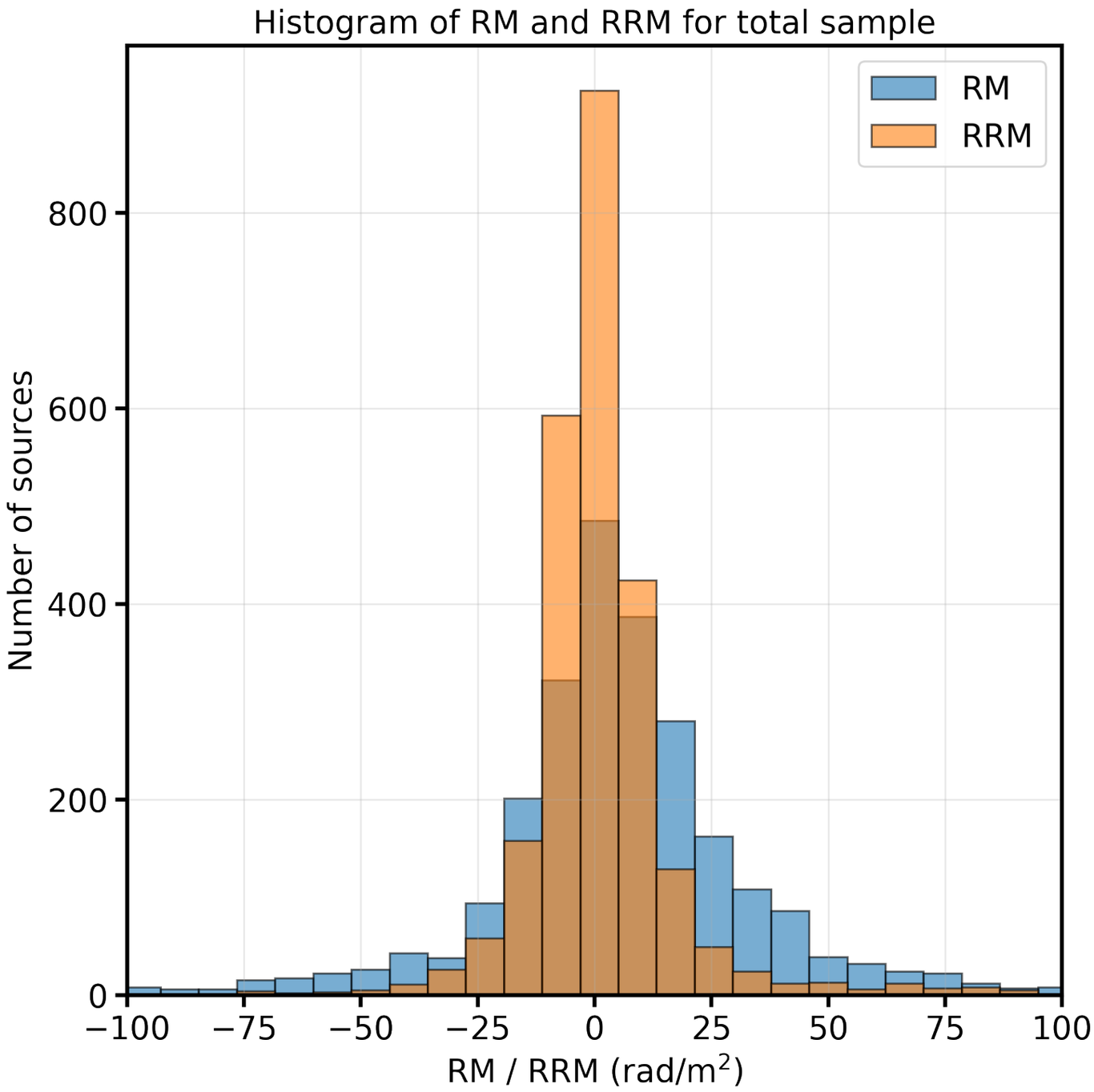
Data Characteristics

- Histogram of RM and RRM
- RRM = RM - GRM
- GRM from annulus method used



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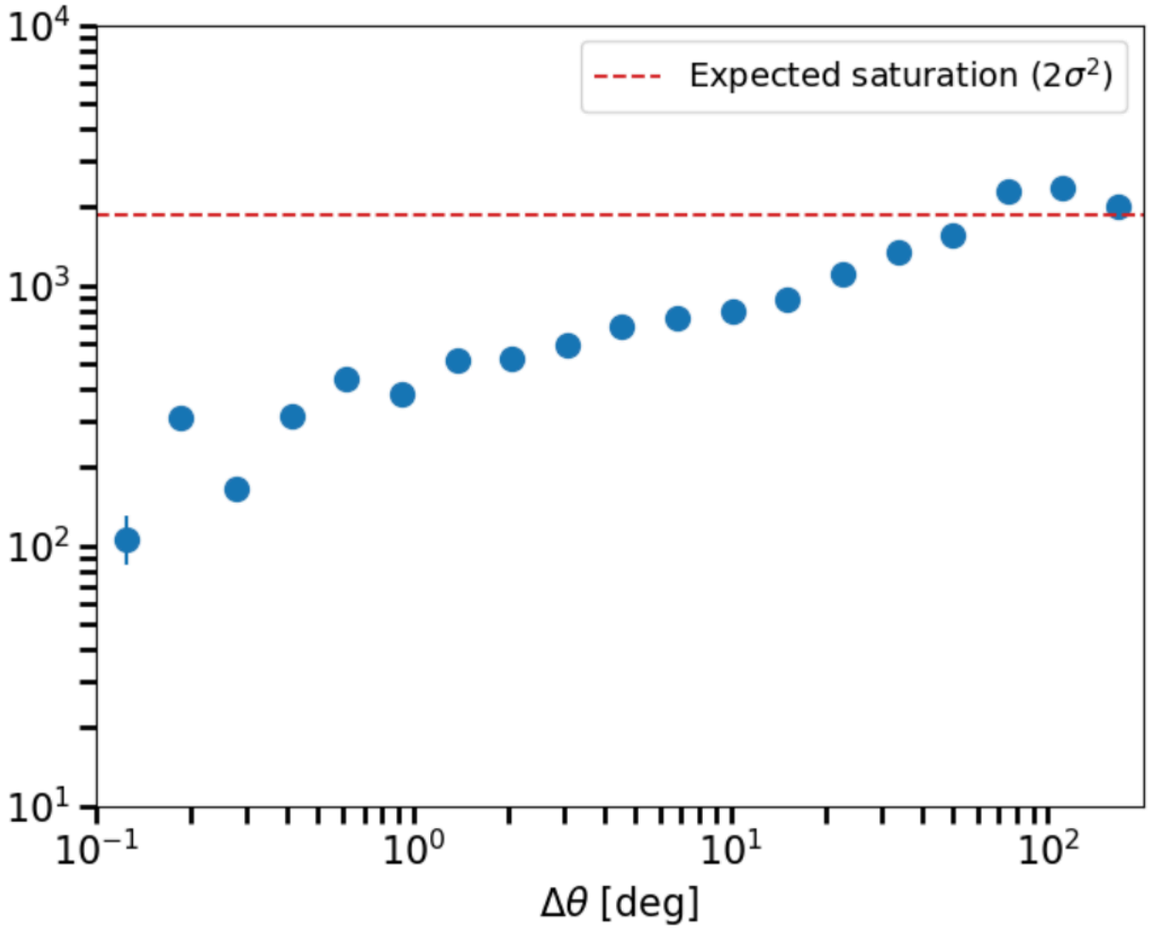
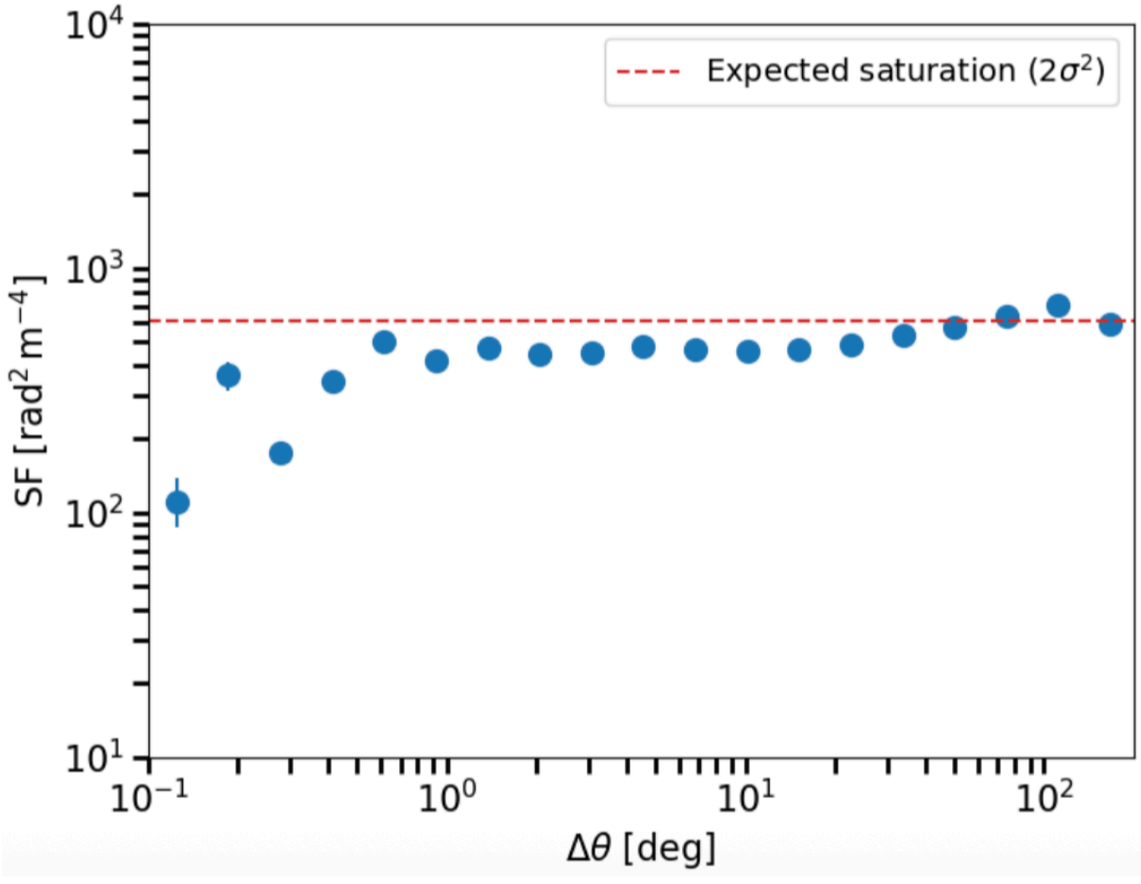
Structure function of RM and RRM

- Structure of RM (left panel) show that it has significantly contribution from Milky Way and it is scale dependent.
- After removing GRM, the residual RM (**RRM = RM-GRM**) show that large scale contributions from Milky Way not there.





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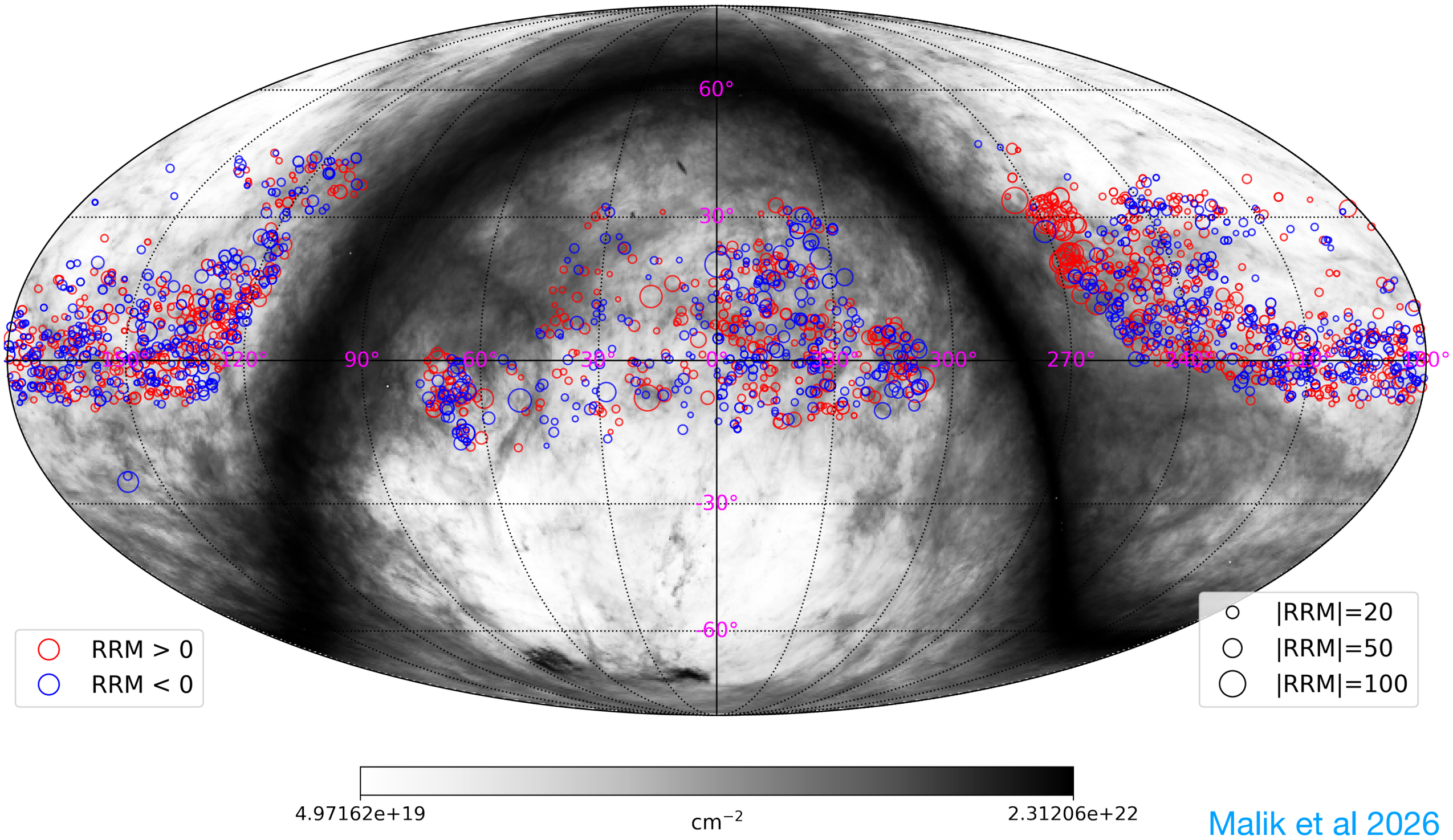
Is Milky Way effect completely removed?

HI4PI map with RRM full sample



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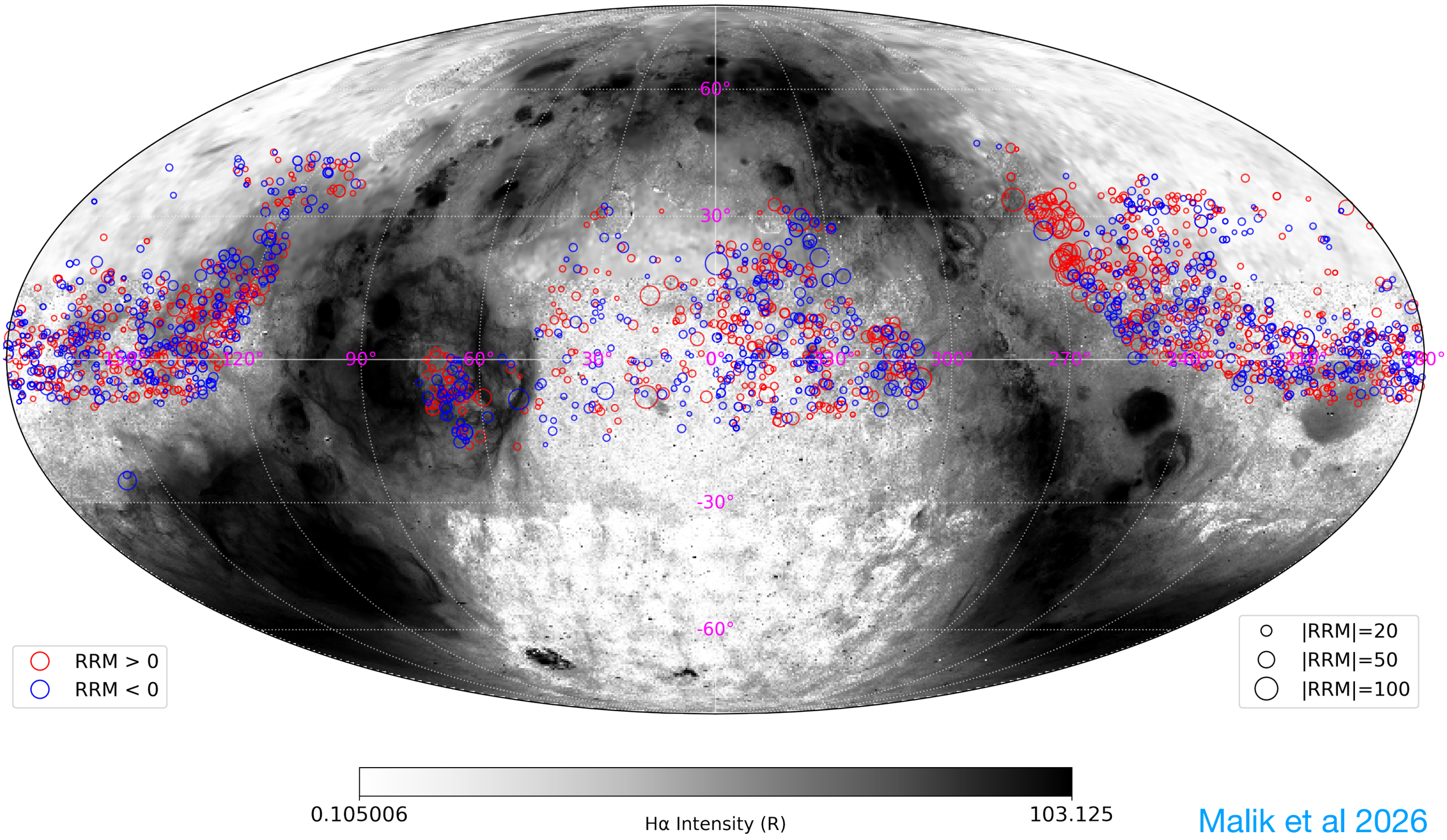
HI4PI Collaboration, Bekhti et al, 2016

Hα map with RRM full sample



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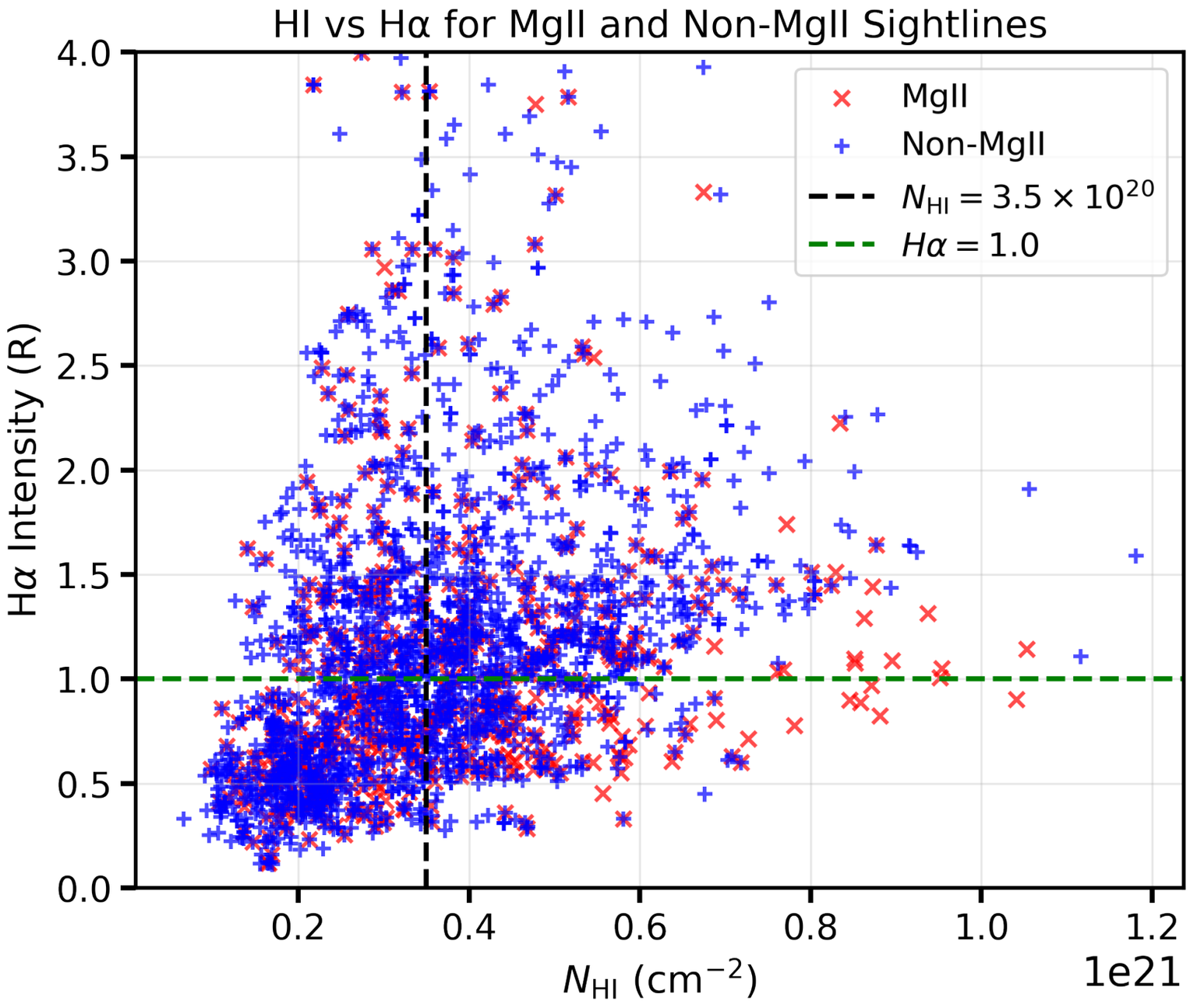
Hα map Haffner et al, 2003

Scatter plot of Hα & HI

- Distribution of the Hα and HI in the Quasars sightline.



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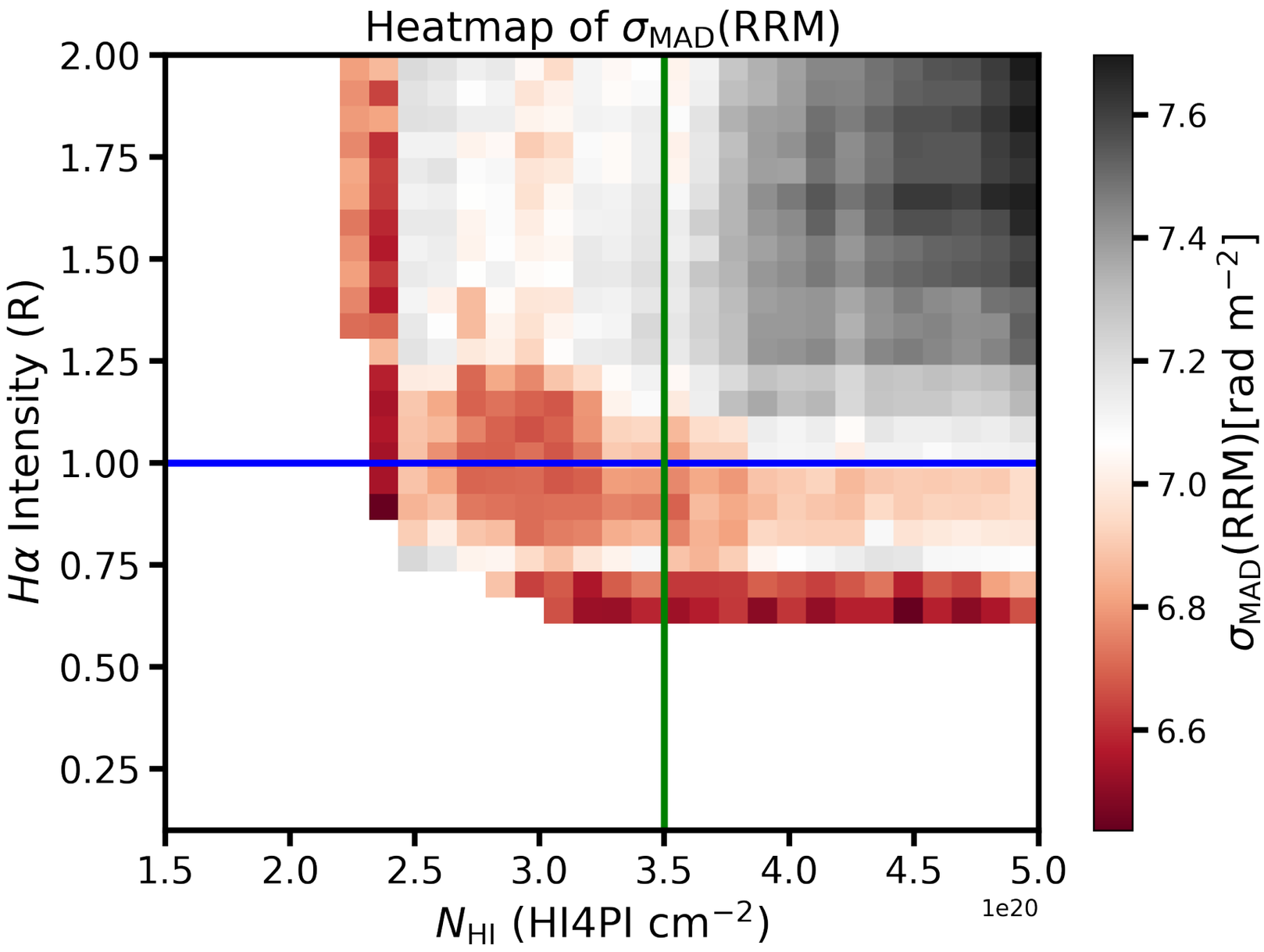
- Heatmap of Dispersion (σ_{MAD}) for various cutoff in N_{HI} density and Hα intensity.



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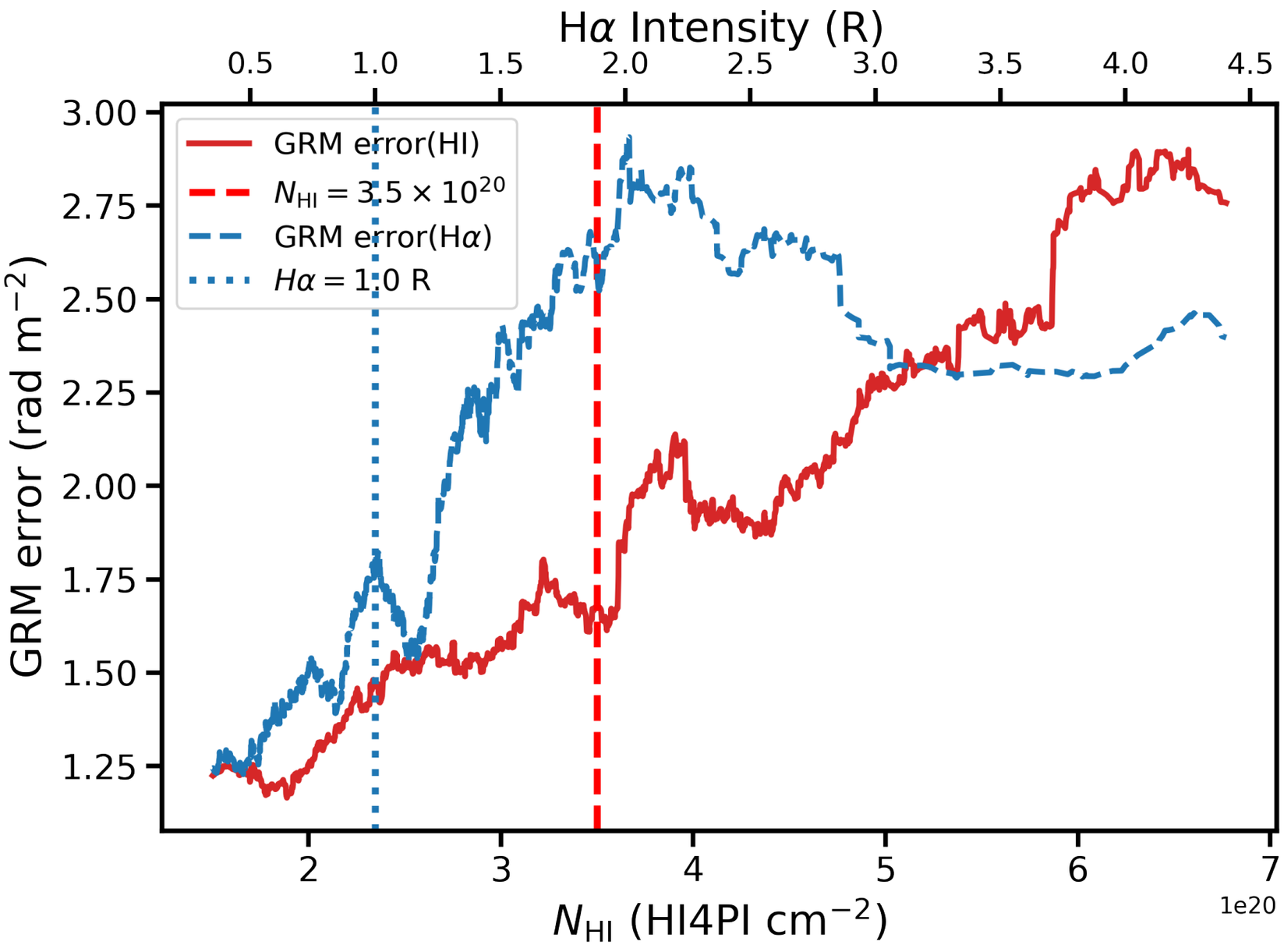
- Plot of GRM error versus N_{HI} density (x-axis bottom) and Hα intensity (top axis).



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Scatter plot of Halpha & HI intensity

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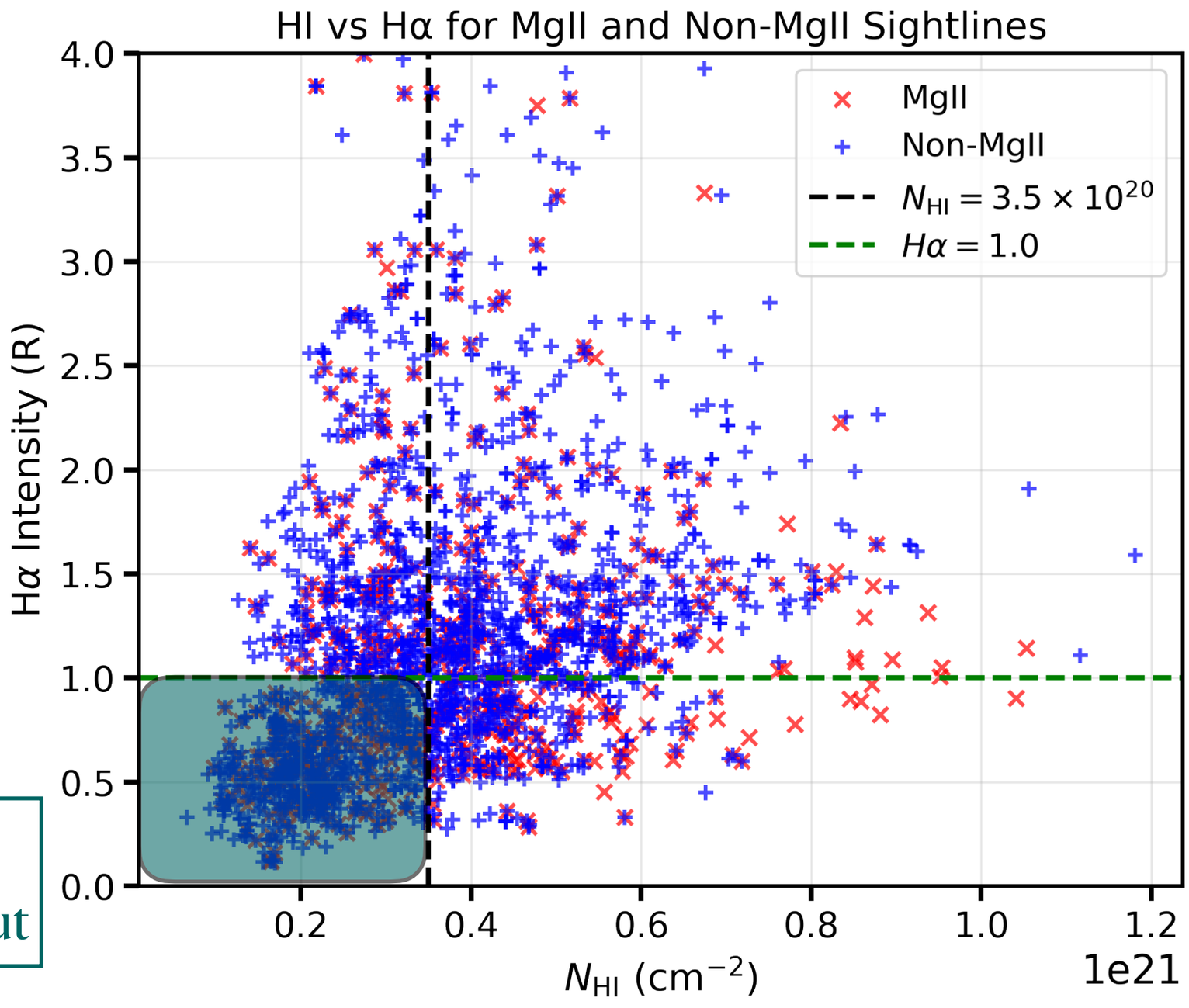

With
HI & Hα cut

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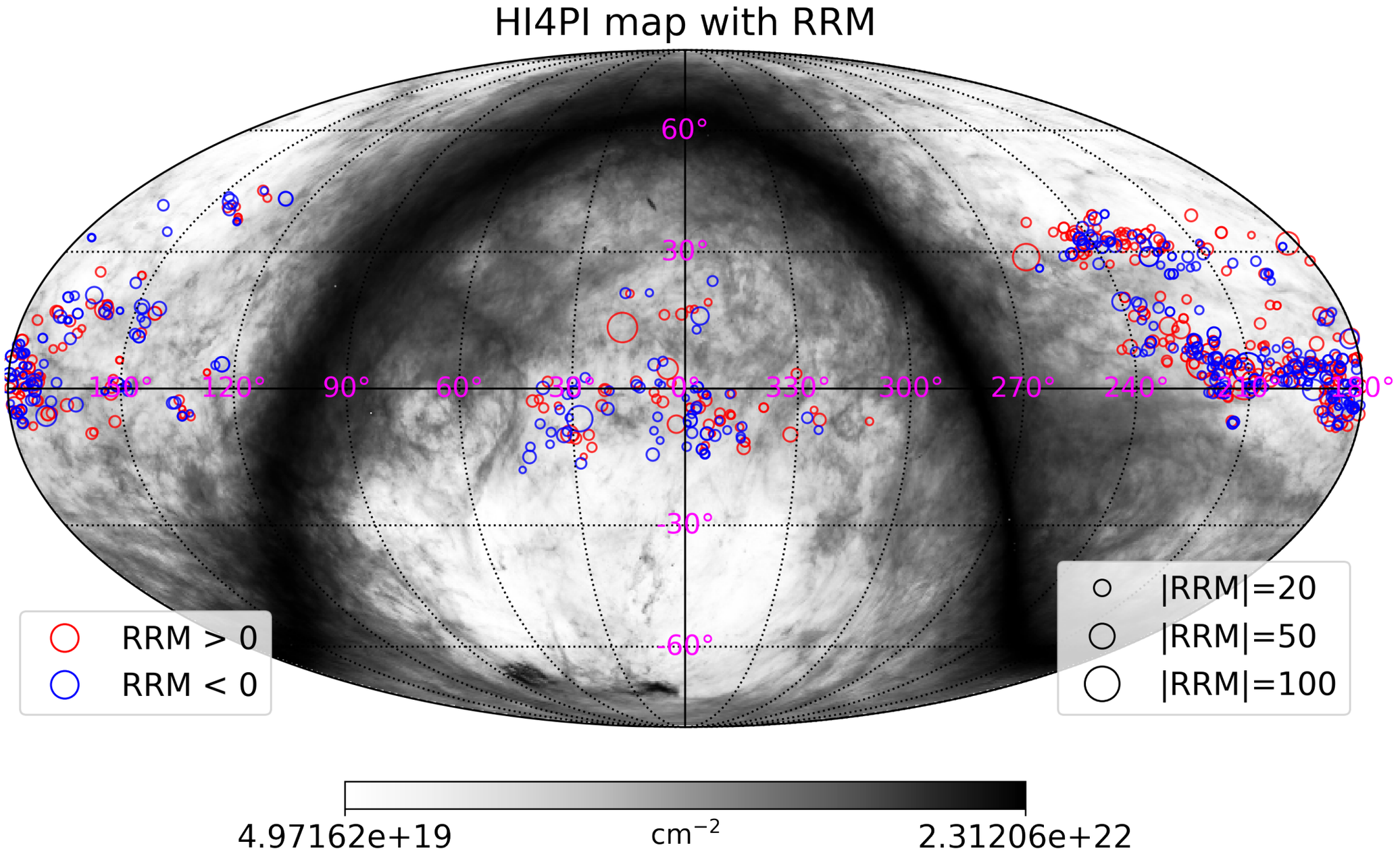
Clean sample

2483 sources => 757 sources



|Gb| > 20 degrees, Milky Way contribution has been removed

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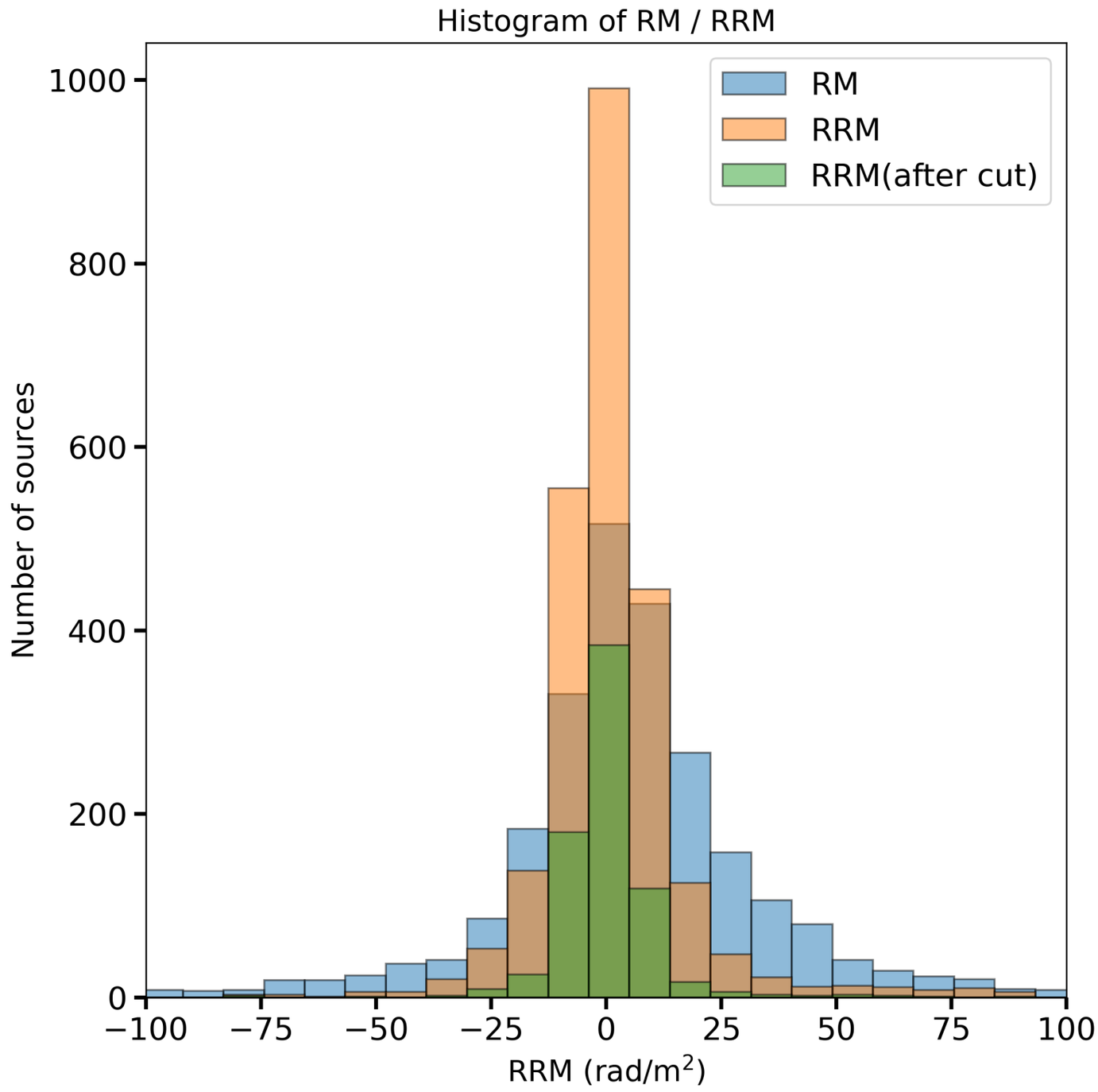
Data Characteristics

- Histogram of RM and RRM
- RRM = RM - GRM
- GRM from annulus method used
- Median redshift of these absorbers z_{MgII} ~ **1.14**
- **With Mg II absorbers: 191**
- **Without Mg II : 566**



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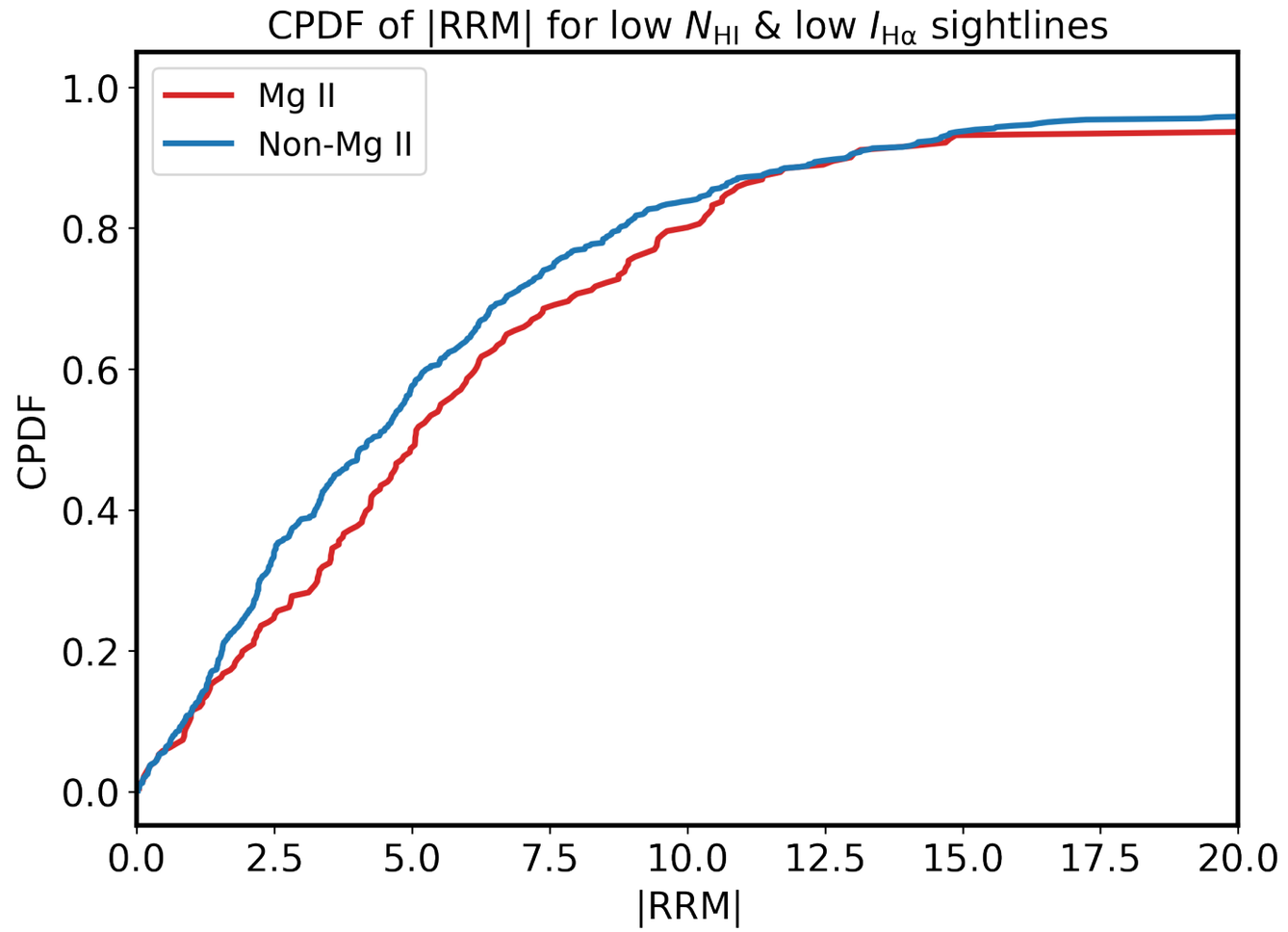
Results

- KS test : 96.4 %
- KS test reject null hypothesis of samples from same distribution.

$$\sigma_{\text{excess}} = \sqrt{\sigma^2_{\text{MAD, MgII}} - \sigma^2_{\text{MAD, noMgII}}}$$



σ_{mad} RRM after Hα cut (threshold = 1.0 R) HI cut (threshold =3.5×10^{20})

No of Mg II	Sigma_mad	Sightlines	Excess
N=0	6.48± 0.27	566	
N>0	7.69± 0.43	191	**4.13 ± 0.91**

Excess at 4.5 σ

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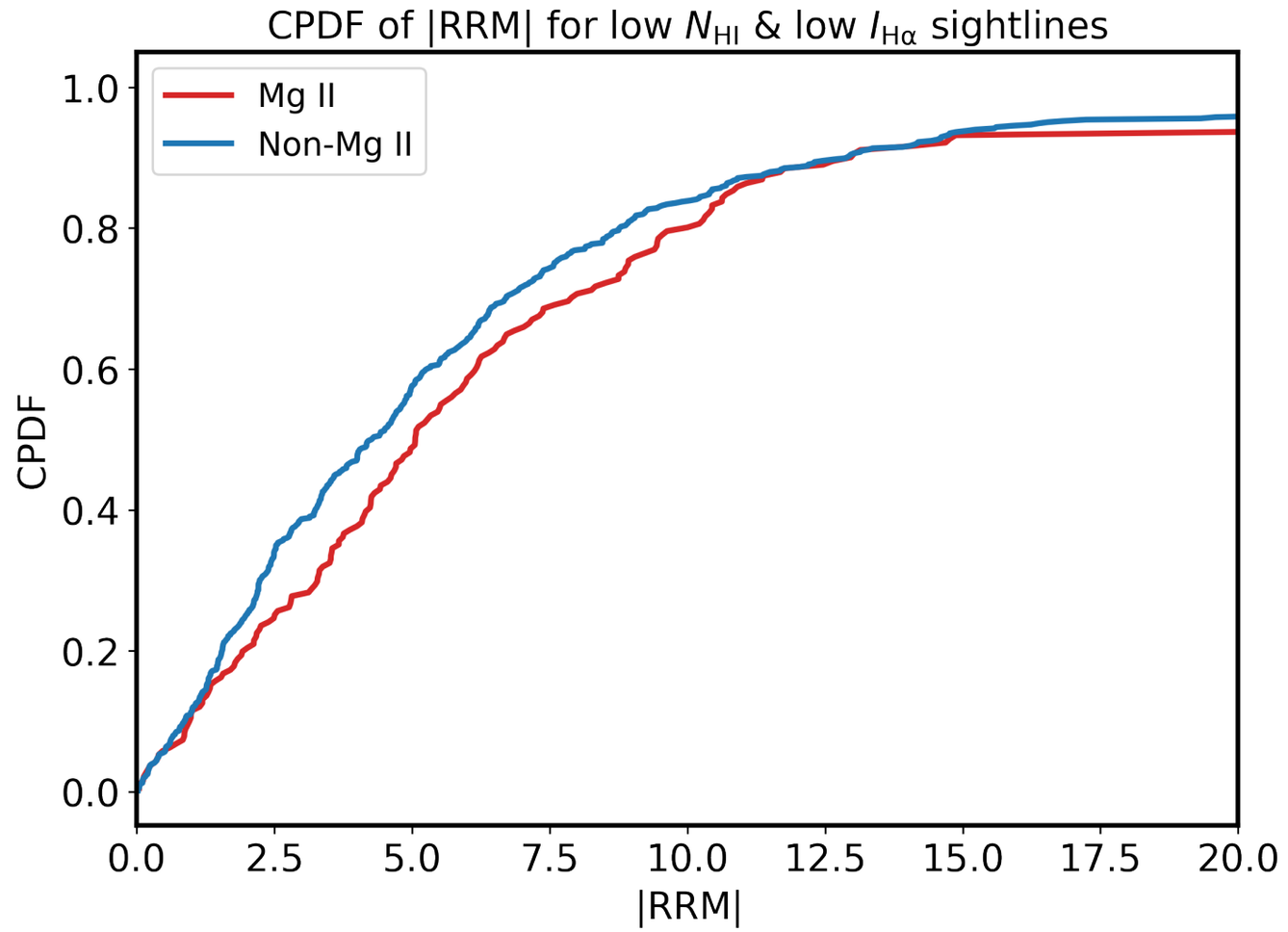

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N>0	7.69± 0.43	191	**4.13 ± 0.91**

Excess with original full sample
1.73 ± 1.65 rad m^{-2}

Excess at $4.5\,\sigma$

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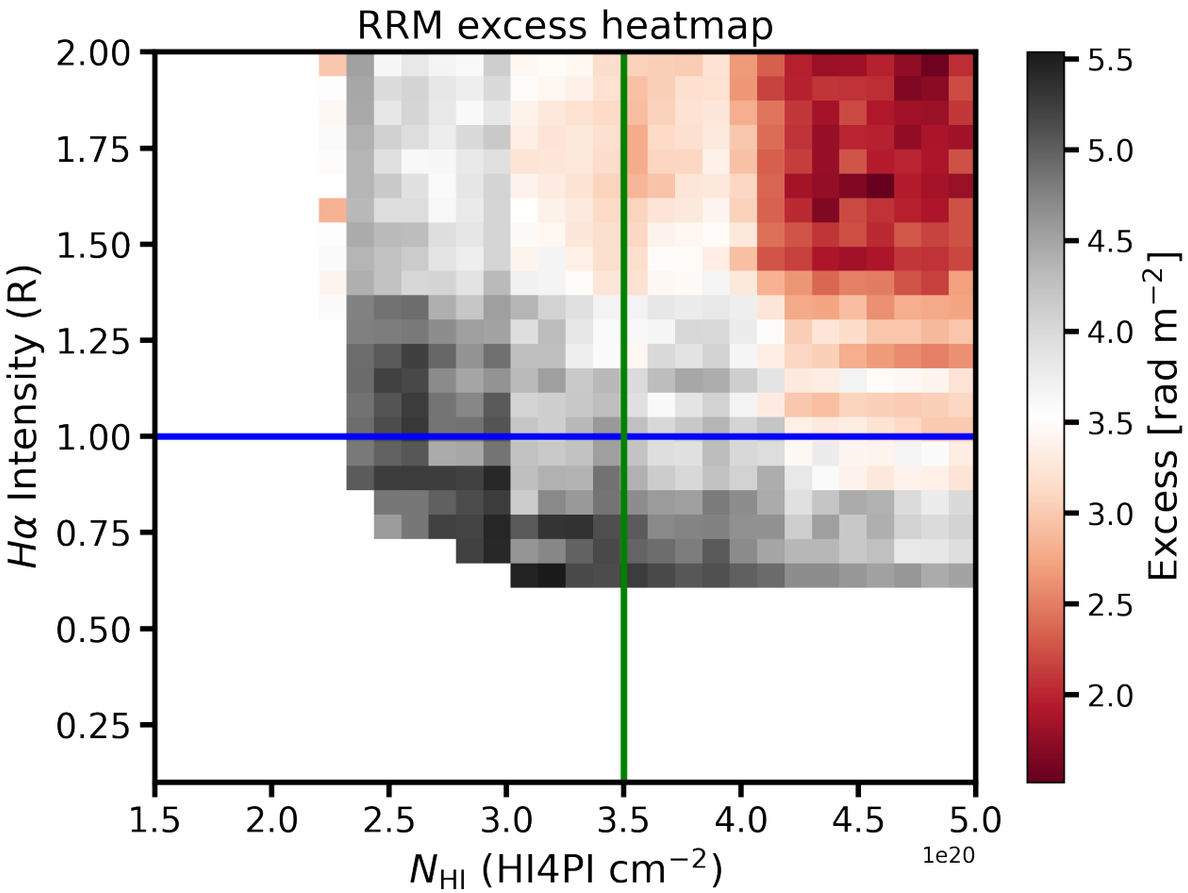
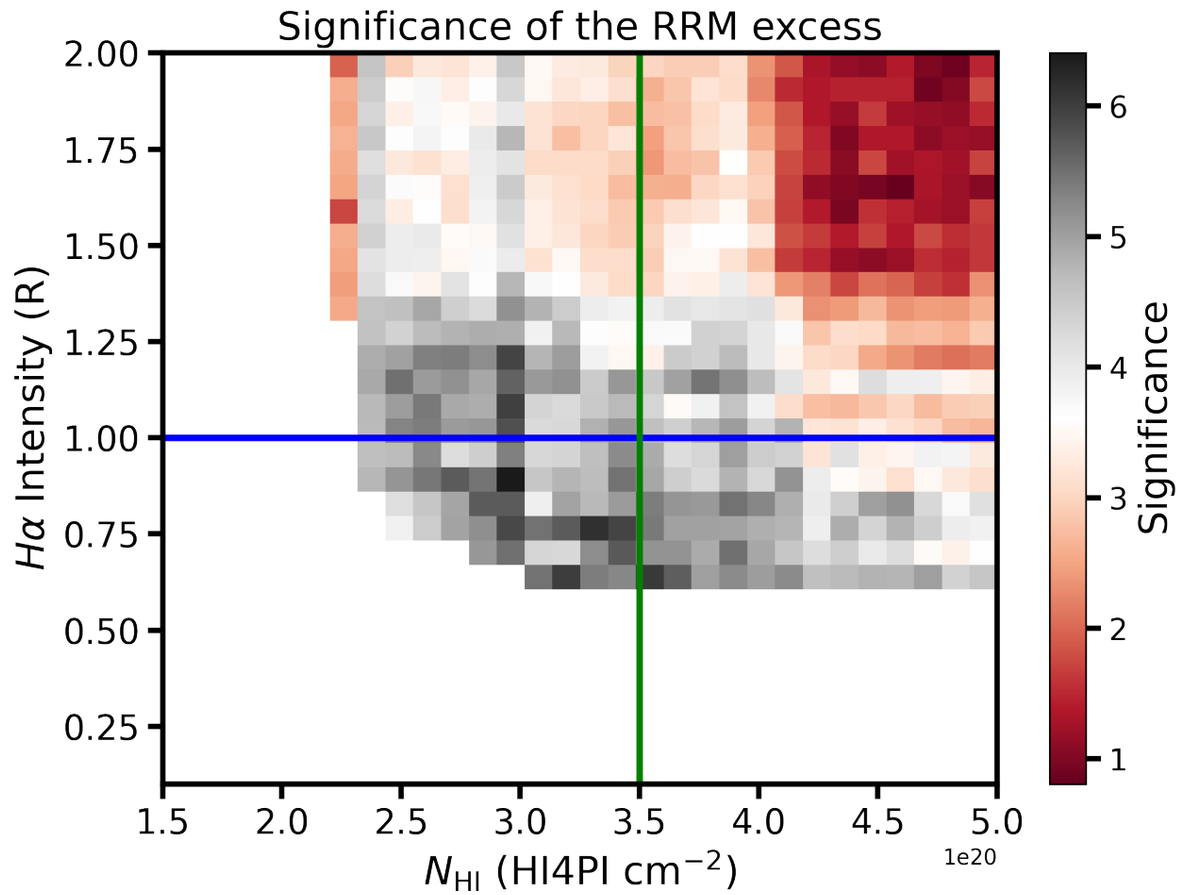
Results

σ_{excess} map (left panel) and significance (right panel) for different N_{HI} and Hα





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Estimate of Magnetic field strength

✦ Modelled the Faraday rotation as arising from a turbulent magnetised plasma (Gaenslar et a 2000)

$$\frac{\sigma_{\rm RM}}{\rm rad\ m^{-2}} = \frac{812}{2\sqrt{3}(1+z)^2}\left(\frac{n_e}{\rm cm^{-3}}\right)\left(\frac{B}{\mu\rm G}\right)\sqrt{\left(\frac{Ll}{\rm kpc^2}\right)},$$

✦ n_e is thermal election density, L is path length in CGM, l is coherence length

✦ Estimate the n_e from energy equipartition but crude approximation

B ~ 0.4- 0.8 μG at z~ 1.14

✦ n_e needs to be calculate more carefully, probably SZ effect can help us here.

✦ Any suggestions for n_e estimate?

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Conclusions

- Complied a sample of 2483 sources having 612 with Mg II absorbers. Redshift range out to 4.0 with 700 quasars having z > 2.
- Significant excess in RRM for sightlines $N_{\mathrm{MgII}} > 0$ (~4.0 ± 0.9 rad m^{-2})
- Developed a GRM annulus method with low GRM error.
- Removal of Milky Way effect from the observed RM of any background sources need more carefully treatment. GRM subtraction is not sufficient.
- Dispersion of RRMs has significantly correlated with HI and Hα of Milky Way. Need to consider sightlines with low HI and Hα only.
- Along with the dust polarisation observation from AtLAST, this can give the complete understanding of magnetic field in the galaxies.

Thanks for your time & attention

Questions/comments