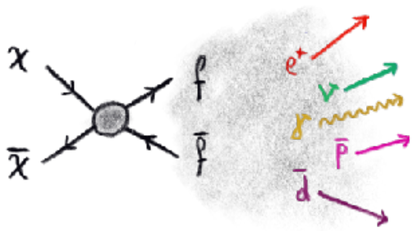
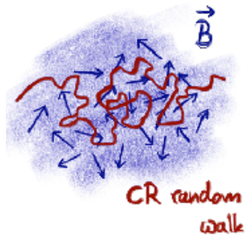
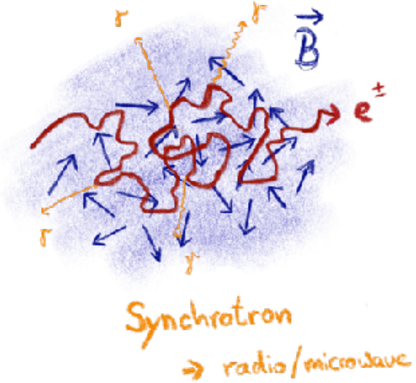
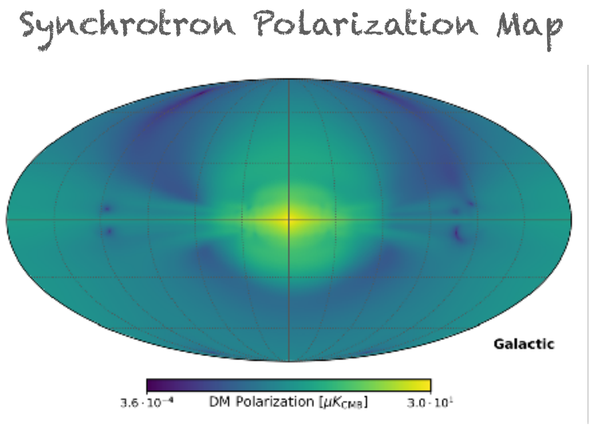
Michael Korsmeier - 2022/04/28









BSM Meeting

Dark Matter Constraint from Planck Observations of Galactic polarized Synchrotron Emission

DM - CR $e^{\pm}$ - Synchrotron - Planck - Polarization

Dark Matter constraints from Planck observations of the Galactic polarized synchrotron emission

Silvia Manconi,[1,*] Alessandro Cuoco,[2,3] and Julien Lesgourgues[1]

[1] *Institute for Theoretical Particle Physics and Cosmology, RWTH Aachen University, Sommerfeldstr. 16, 52056 Aachen, Germany*

[2] *Dipartimento di Fisica, Università di Torino, via P. Giuria, 1, I-10125 Torino, Italy*

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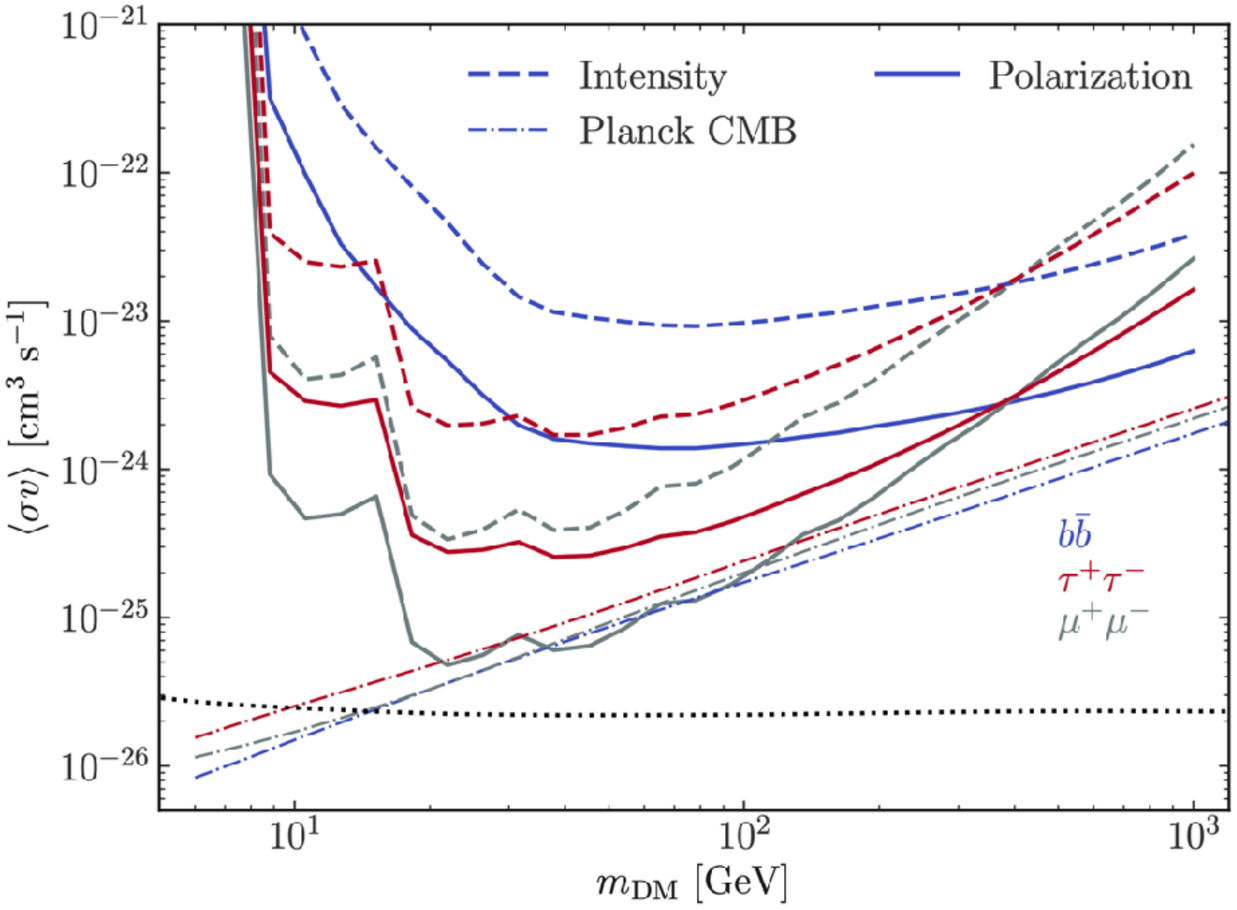
Dark Matter (DM) annihilation in our Galaxy may produce a linearly polarized synchrotron signal. We use, for the first time, synchrotron polarization to constrain the DM annihilation cross section by comparing theoretical predictions with the latest polarization maps obtained by the Planck satellite collaboration. We find that synchrotron polarization is typically more constraining than synchrotron intensity by about one order of magnitude, independently of uncertainties in the modeling of electron and positron propagation, or of the Galactic magnetic field. Our bounds compete with Cosmic Microwave Background limits in the case of leptophilic DM.

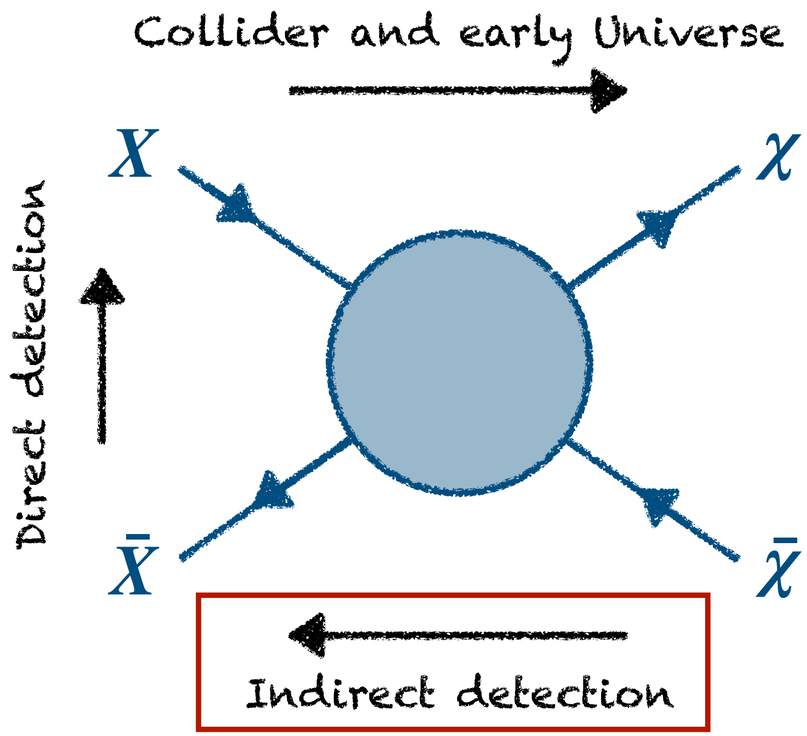
arXiv:2204.04232v1

Take home message

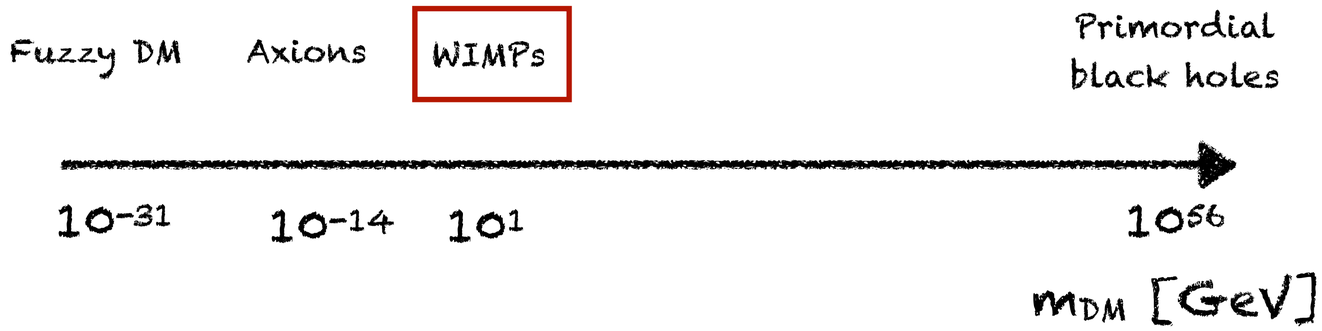


- **Novelty:** Exploitation of synchrotron polarization to derive DM limits
- Polarization is more constraining than intensity
- Leptonic DM bounds are competitive with CMB limits
- Provided limits are conservative (no-background assumption)

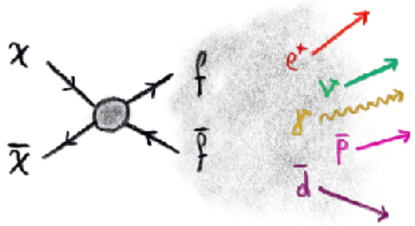
Dark Matter Searches



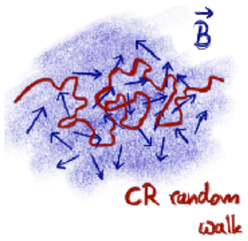
Discussed in this paper



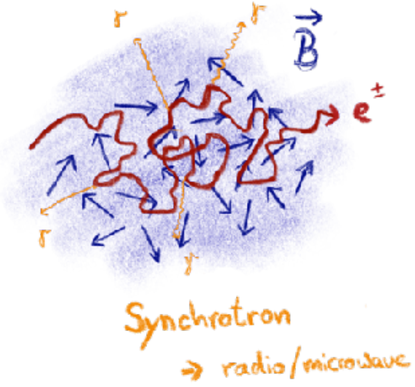
General Idea



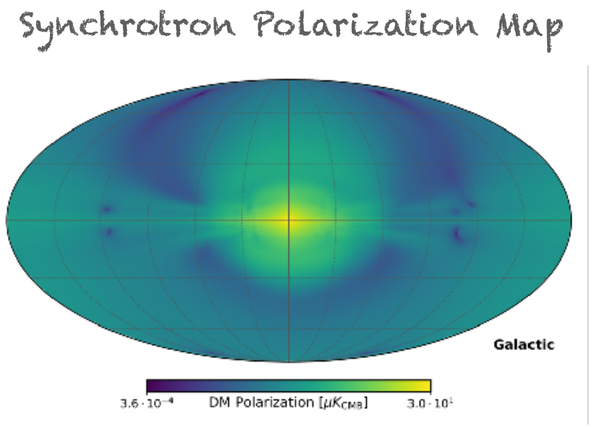
Dark Matter annihilation in the Galactic halo



Propagation of electrons and positron

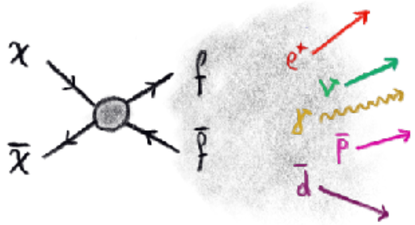


Production of radio/ microwave by synchrotron



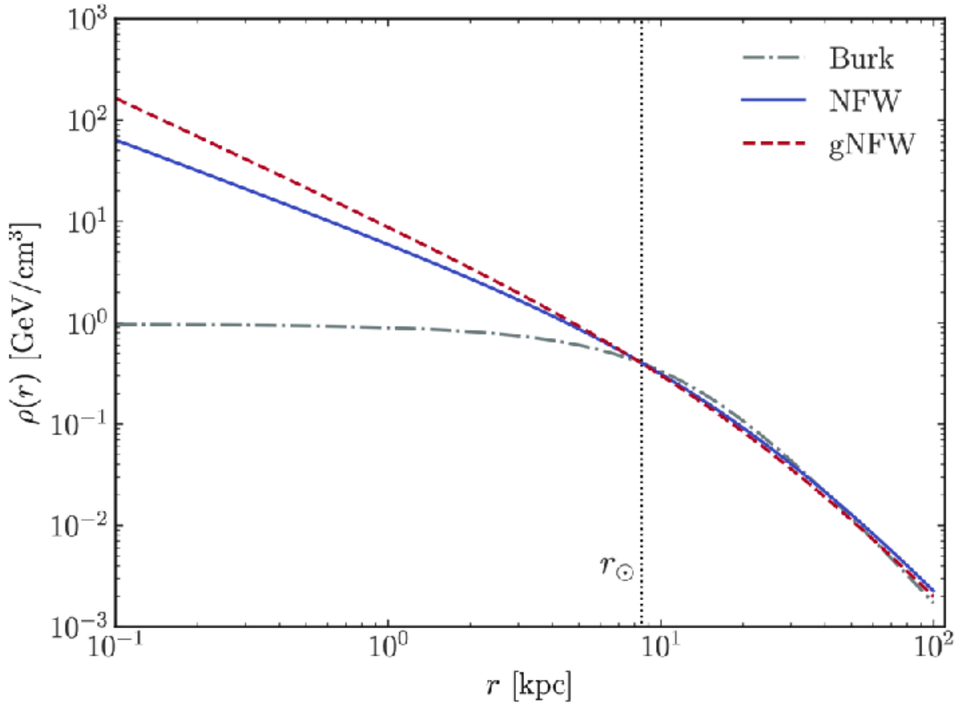
Comparison of the prediction with Planck (I and P)

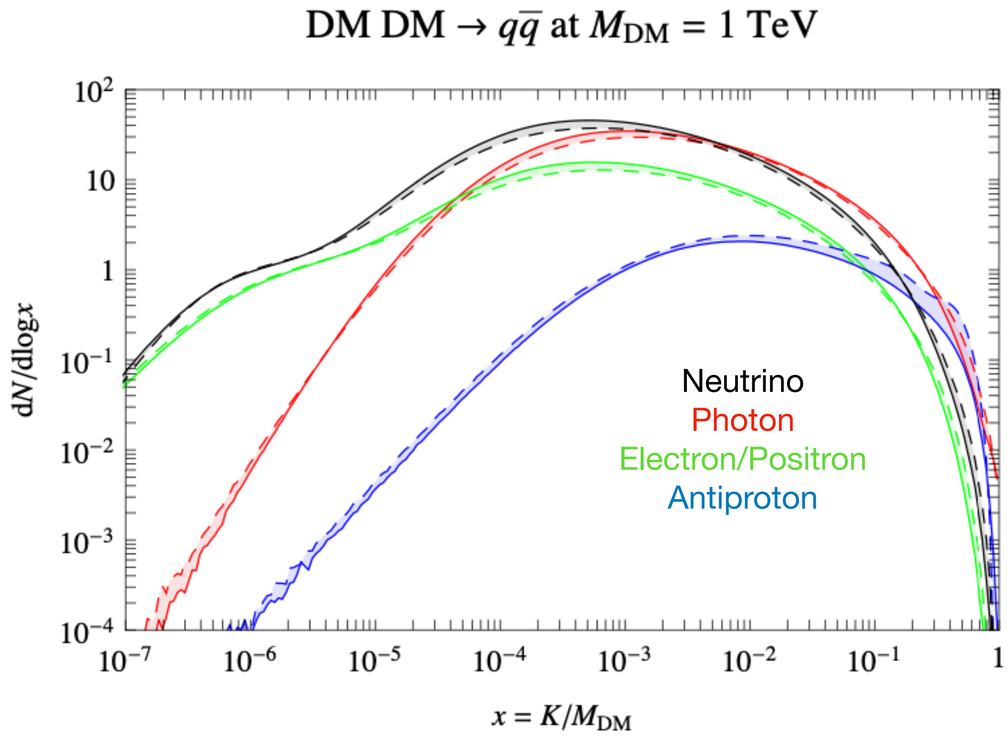
Galactic Dark Matter Annihilation



References:
[PPPC4DM, Cirelli et. al]

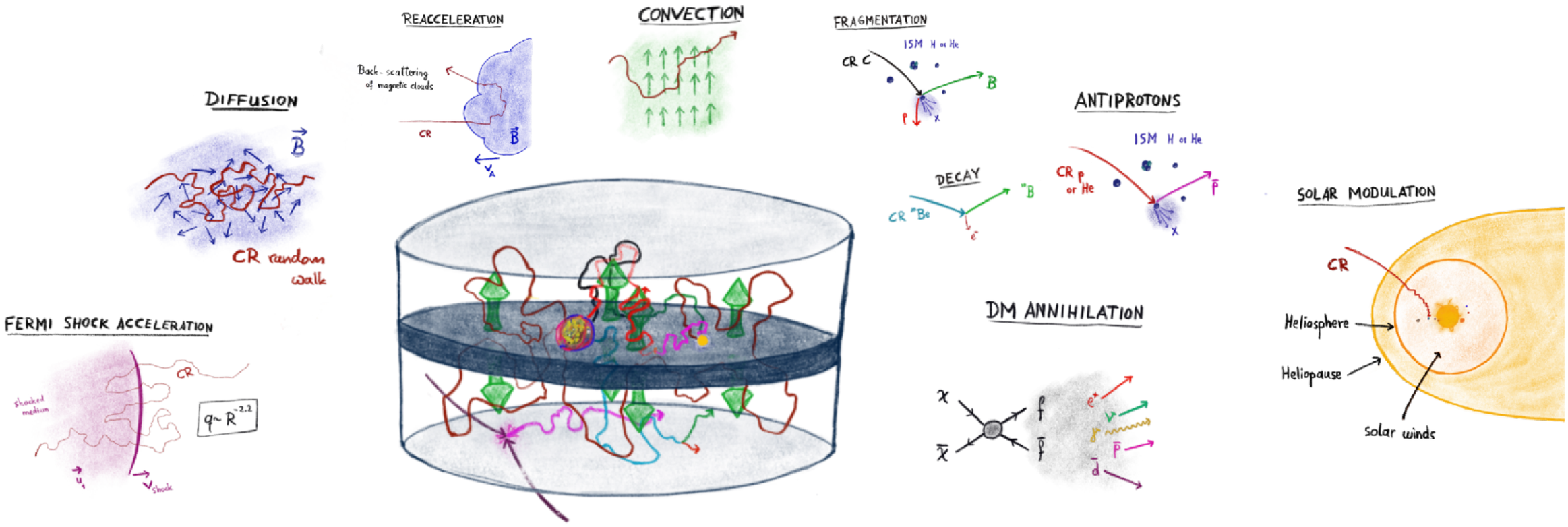
$$q_{e\pm}(\mathbf{x}, E) = \frac{1}{2}\left(\frac{\rho_{\rm DM}(\mathbf{x})}{m_{\rm DM}}\right)^2 \Sigma_f \langle\sigma v\rangle_f \frac{dN^f_{e\pm}}{dE}$$





Cosmic Ray Propagation

$$\frac{\mathrm{d}\psi}{\mathrm{d}t} = q(\boldsymbol{x}, p) + \boldsymbol{\nabla} \cdot (D_{xx} \boldsymbol{\nabla} \psi - \boldsymbol{V} \psi) + \frac{\partial}{\partial p} p^2 D_{pp} \frac{\partial}{\partial p} \frac{1}{p^2} \psi - \frac{\partial}{\partial p} \left(\frac{\mathrm{d}p}{\mathrm{d}t} \psi - \frac{p}{3} \boldsymbol{\nabla} \cdot \boldsymbol{V} \psi \right) - \frac{1}{\tau_f} \psi - \frac{1}{\tau_r} \psi$$



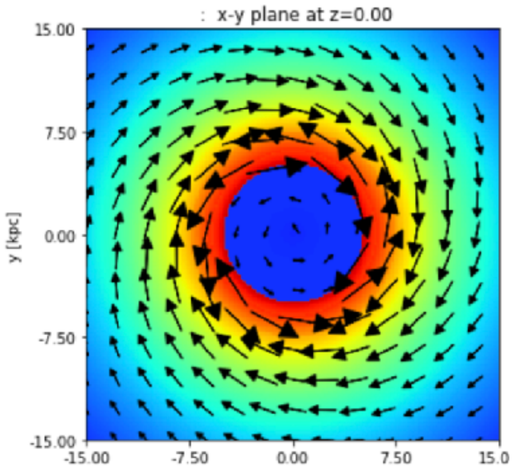
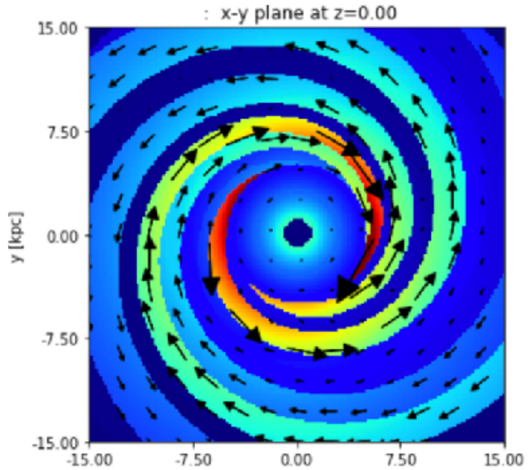
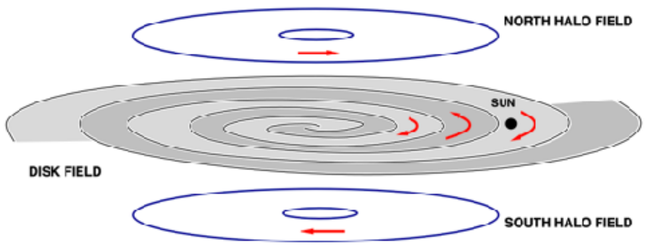
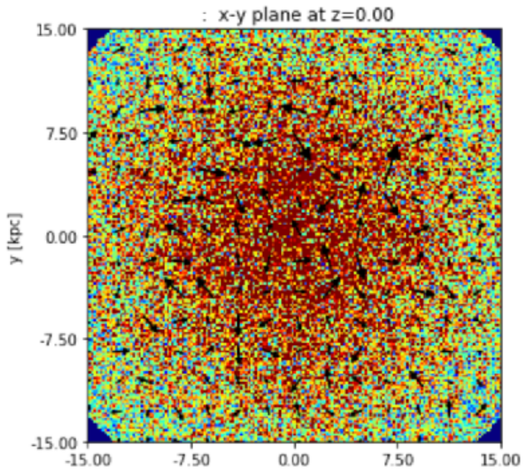
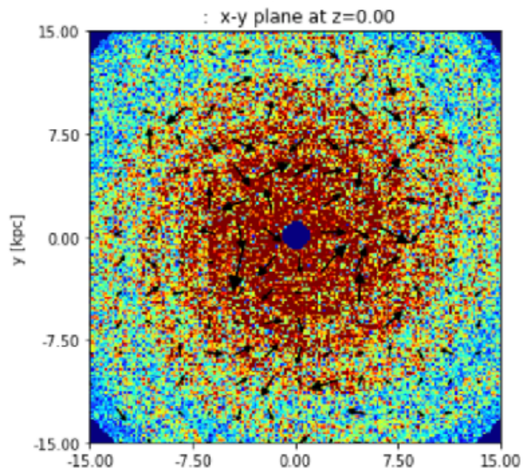
Cosmic Ray Propagation

Model	PDDE	DRE	BASE
Reference	[Orlando, 2017&, arXiv:1712.07127]	[Orlando, 2017&, arXiv:1712.07127]	[Korsmeier+, 2020, arXiv:2103.09824]
Method	**Plain Diffusion** Tuned with multifrequency data: CRs, gamma-rays, X-rays, synchrotron No reacceleration Break in the diffusion coefficient at ~ 4 GV	**Diffusion and Reacceleration** Tuned with multifrequency data: CRs, gamma-rays, X-rays, synchrotron Reacceleration is included No break in the diffusion coefficient	**Diffusion and convection** Constrained on CR nuclei data: Li, Be, B, C, N, O No reacceleration Break in the diffusion coefficient at ~ 4 GV

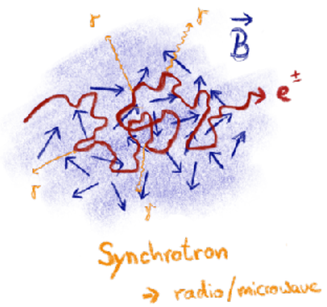
"We recall that the strength of the GMF is highly degenerate with the normalization of the CR e± density in the Galaxy, and a consistent assessment of the parameters of the GMFs should contextually fit also the CR e± injection and propagation parameters. We leave this assessment to future work…"

Magnetic Field Models

Figures from:
[Jaffe, 2019, arXiv:1904.12689]
[Pshirkov+, 2011, arXiv: 1103.0814]

Model	Sun+10	JF12	PSH+11
Reference	[Sun+, 2010, arXiv:1010.4394]	[Jansson+, 2012, arXiv:1204:3662] [Jansson+, 2012, arXiv:1210:7820]	[Pshirkov+, 2011, arXiv: 1103.0814]
Regular field			
Random field			Same as Sun+10

Synchrotron Emission



References:
[Strong et. al, 2011, arXiv:1108.4822]
[Orlando et. al, 2013, arXiv:1309.2947]

- Intensity traces the total magnetic field (regular+random)
- Polarization only traces the regular magnetic field
- Emission from a regular magnetic field is **linear** polarized
- Intensity is obtained by integration along the line of sight

$$\epsilon_{par}(\nu) = \frac{\sqrt{3}}{2}\frac{e^3}{mc^2}B_{perp}\,[F(x) - G(x)]$$

$$\epsilon_{perp}(\nu) = \frac{\sqrt{3}}{2}\frac{e^3}{mc^2}B_{perp}\,[F(x) + G(x)]$$

$$x = \nu/\nu_c$$

$$\nu_c = \frac{3}{4\pi}\frac{e}{mc}B_{perp}\gamma^2$$

$$F(x) = x\int_x^{\inf} K_{5/3}(x')\,dx'$$

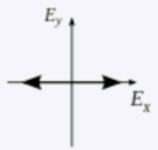
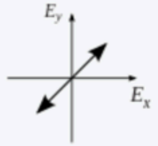
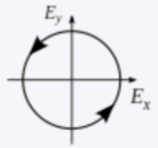
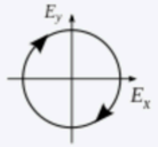
$$G(x) = x\,K_{2/3}(x)$$

$$\epsilon_{rand}(\nu) = C\,x^2[K_{4/3}K_{1/3} - \frac{3}{5}x(K_{4/3}K_{4/3} - K_{1/3}K_{1/3})]$$

$$I(\nu) = \int \epsilon(\nu)\,ds$$

Polarization

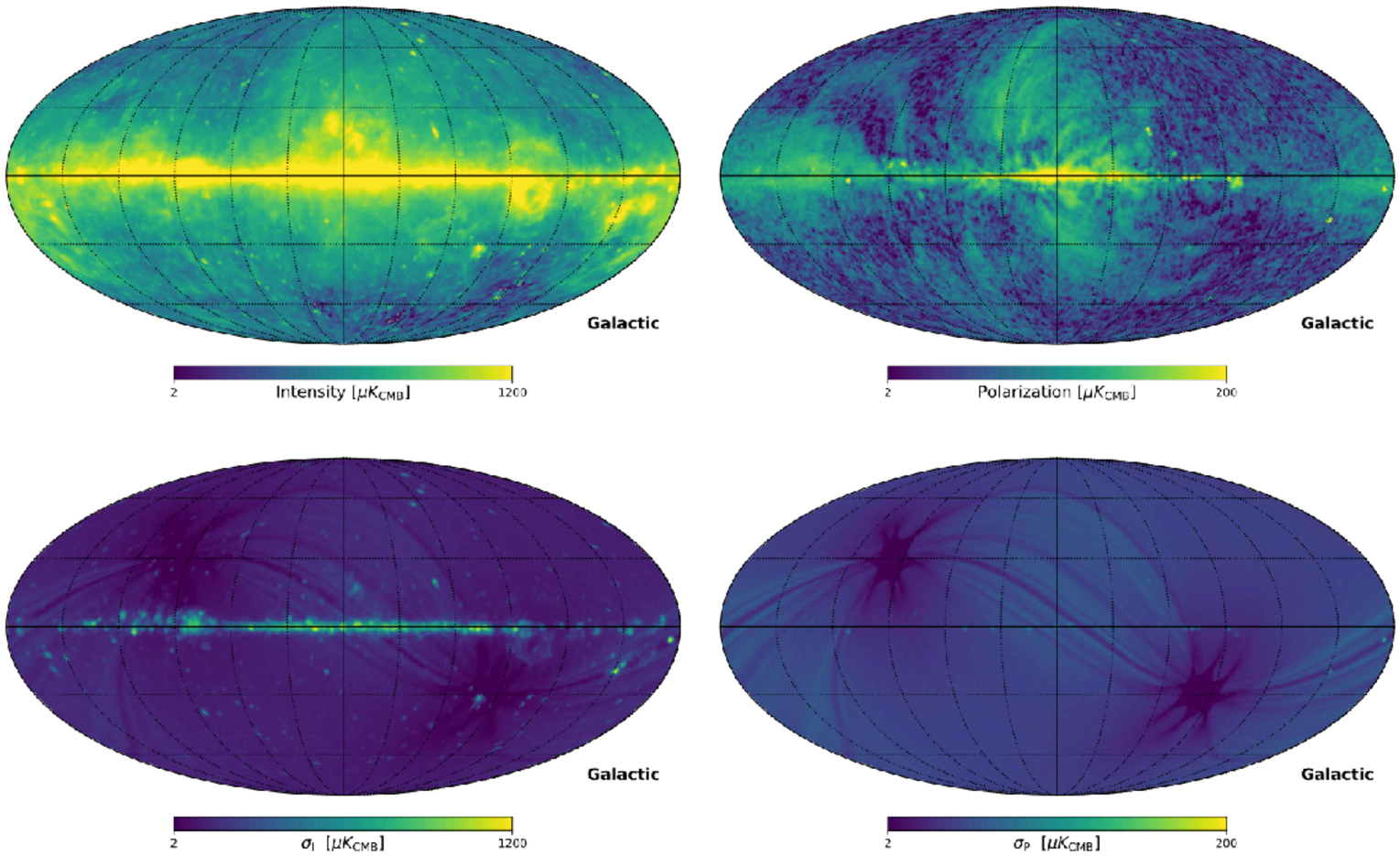
References:
[Wikipedia]

Polarisation	Polarisationszustand	Stokes-Vektor
linear, horizontal		$\begin{pmatrix}1\\1\\0\\0\end{pmatrix}$
linear, vertikal		$\begin{pmatrix}1\\-1\\0\\0\end{pmatrix}$
linear, +45°		$\begin{pmatrix}1\\0\\1\\0\end{pmatrix}$
links-zirkular		$\begin{pmatrix}1\\0\\0\\-1\end{pmatrix}$
rechts-zirkular		$\begin{pmatrix}1\\0\\0\\1\end{pmatrix}$
unpolarisiert		$\begin{pmatrix}1\\0\\0\\0\end{pmatrix}$

$$S_0 = I = P_{0^\circ} + P_{90^\circ} = \langle E_x^2 + E_y^2 \rangle$$
$$S_1 = Q = P_{0^\circ} - P_{90^\circ} = \langle E_x^2 - E_y^2 \rangle$$
$$S_2 = U = P_{45^\circ} - P_{135^\circ} = \langle 2E_x E_y \cos\delta \rangle$$
$$S_3 = V = P_{\mathrm{RZ}} - P_{\mathrm{LZ}} = \langle 2E_x E_y \sin\delta \rangle$$

Here they consider the intensity (I) and the polarization ($P = \sqrt{Q^2 + U^2}$)

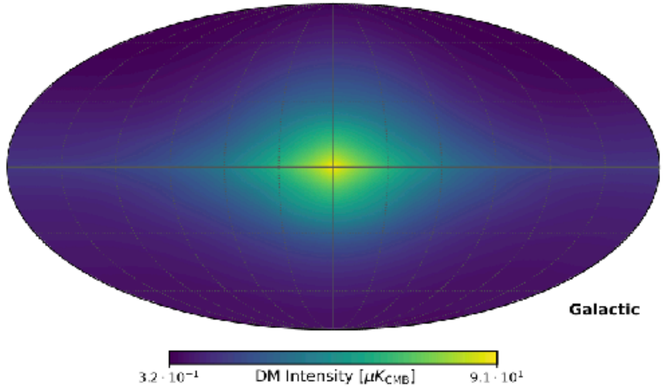
Planck data - 30 GHz

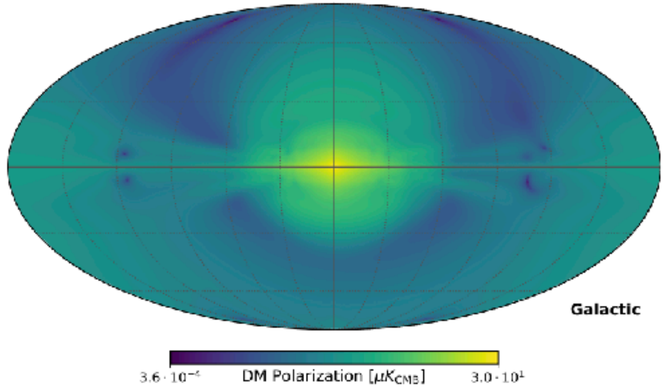


- CMB is subtracted
- Astrophysical background is not subtracted
  → conservative limits
- Further data:
  44 GHz
  70 GHz

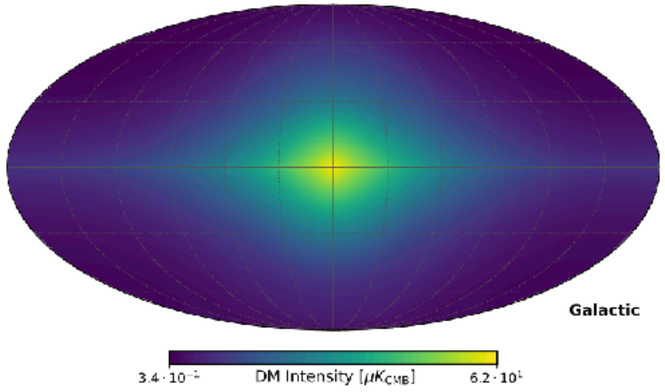
Different GMF

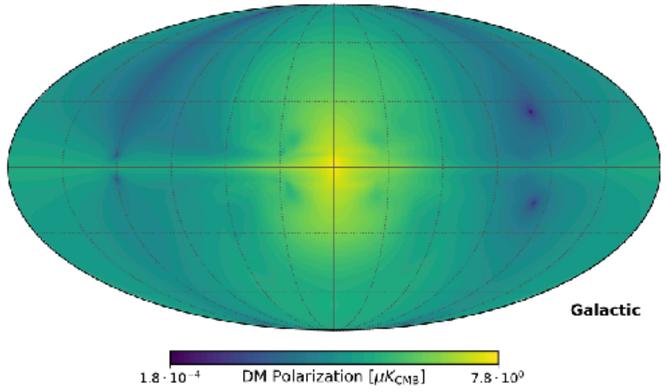
Psh+11



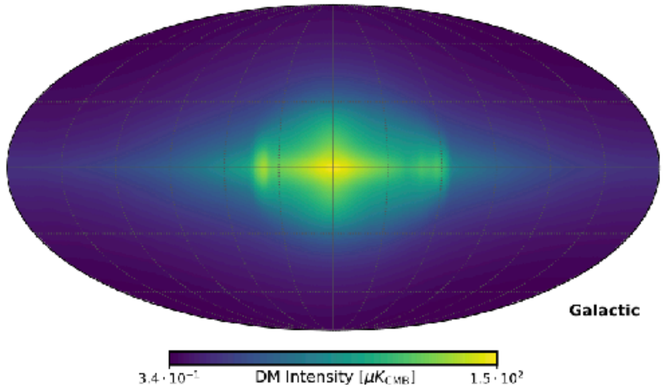


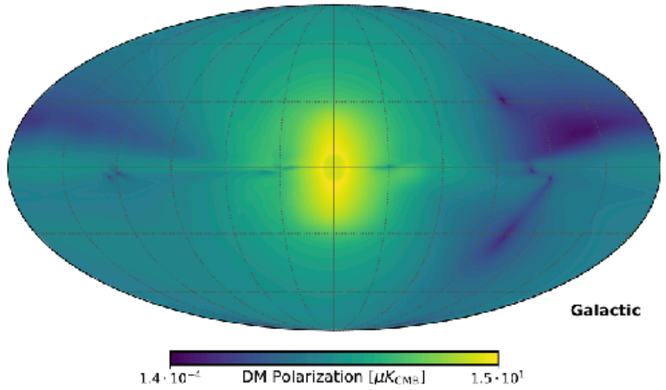
Sun+10



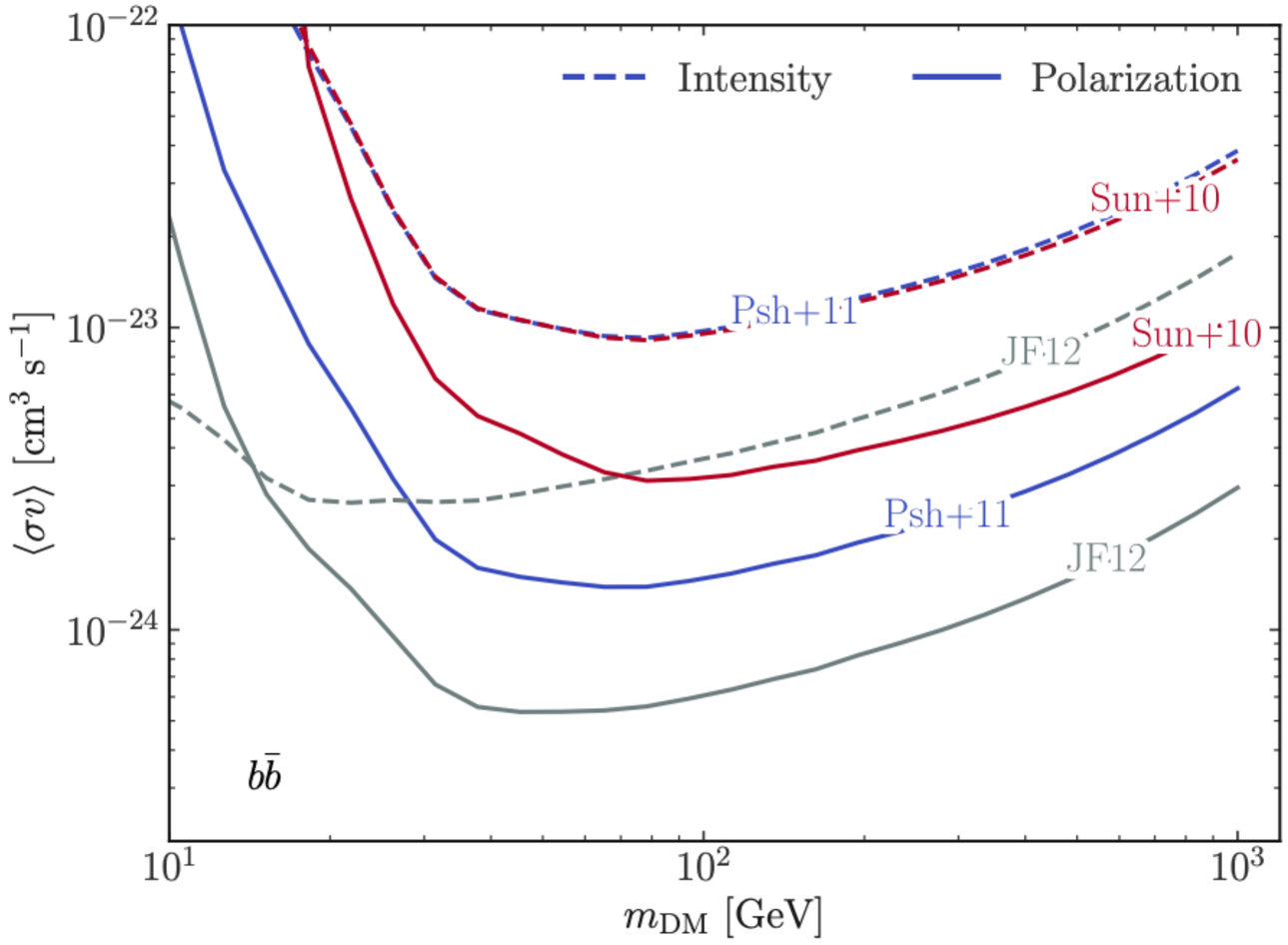


JF12





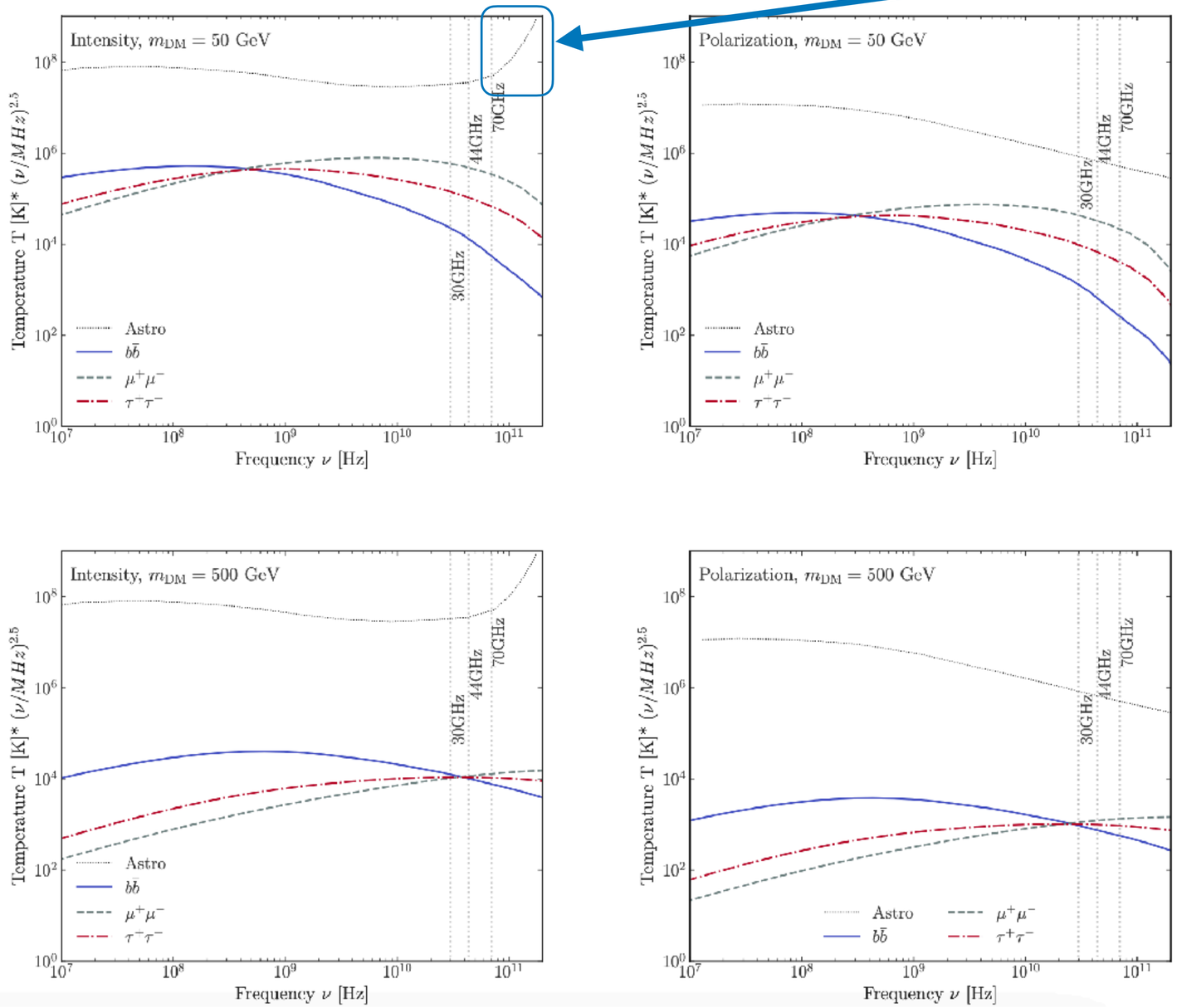
Impact GMF



- Polarization provides stronger limits **independent of the GMF** model

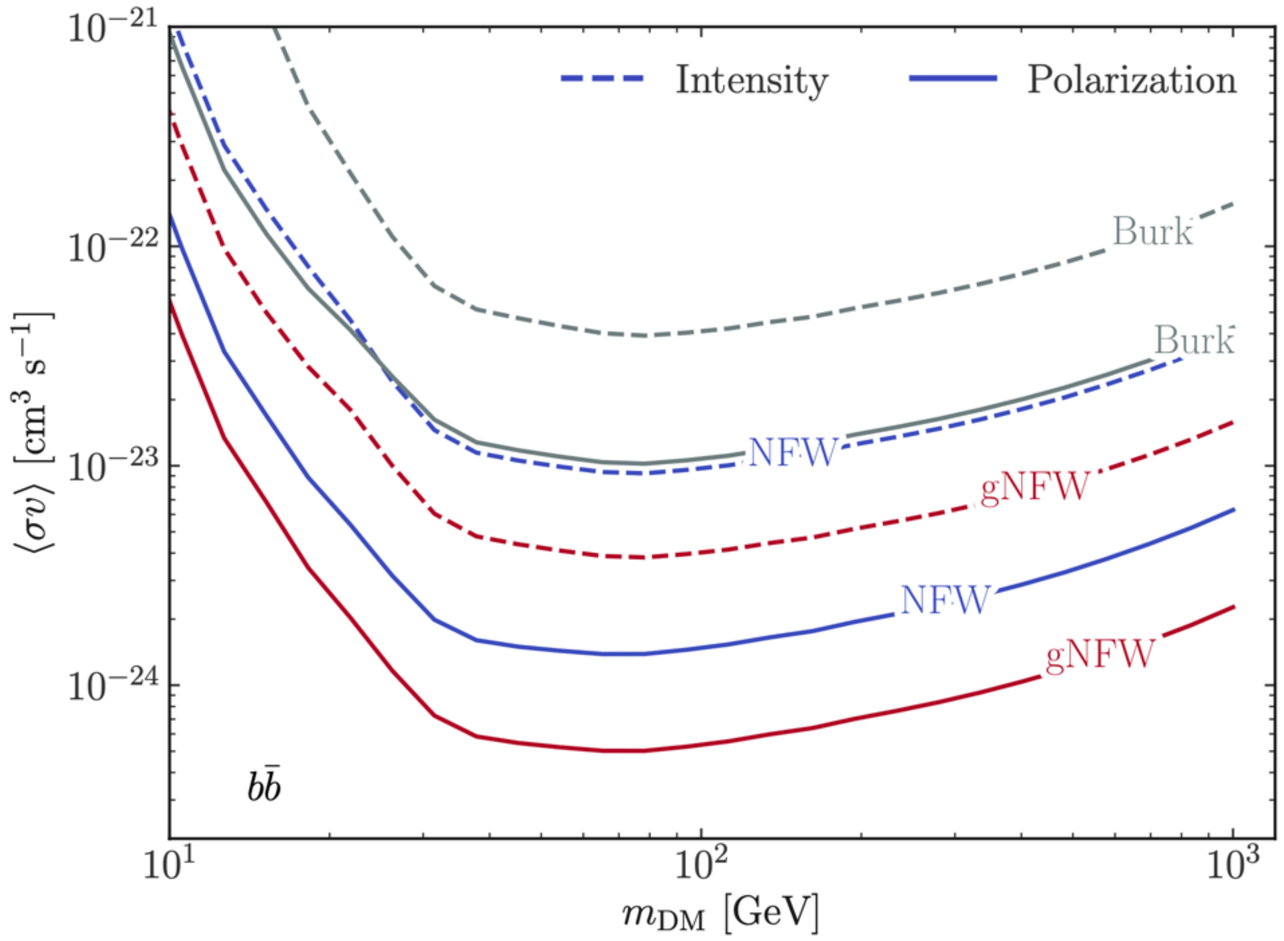
Impact of the Frequency

mostly thermal dust emission



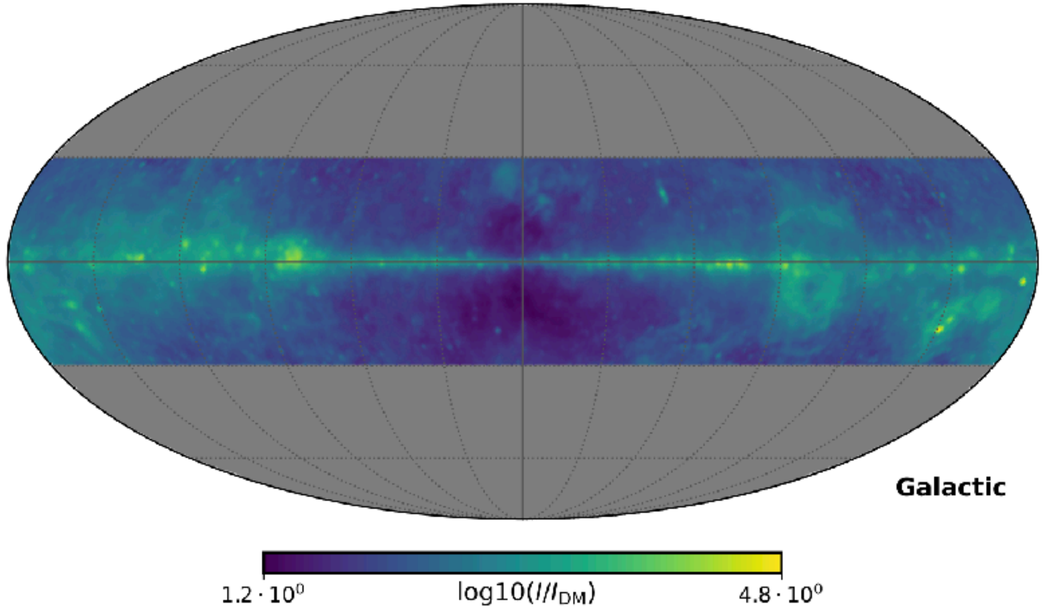
- Hadronic final states have softer spectra
- Peak frequency increases with DM mass
- Above 100 GHz thermal dust emission dominates

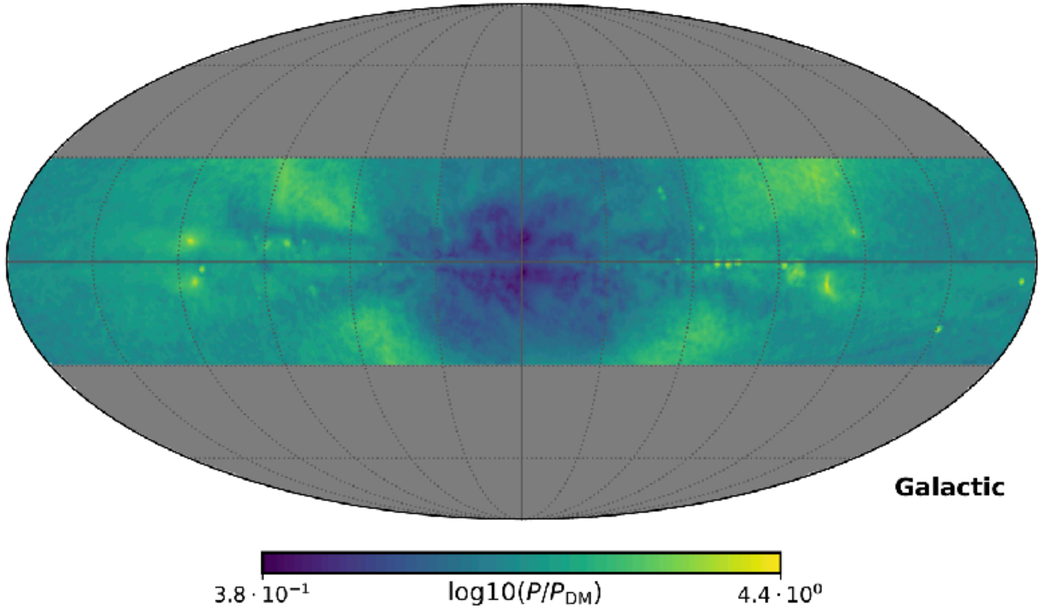
Impact of the DM density profile



- Stronger limits for *more* cored profiles
- Impact of DM density profile is larger for polarization than for intensity

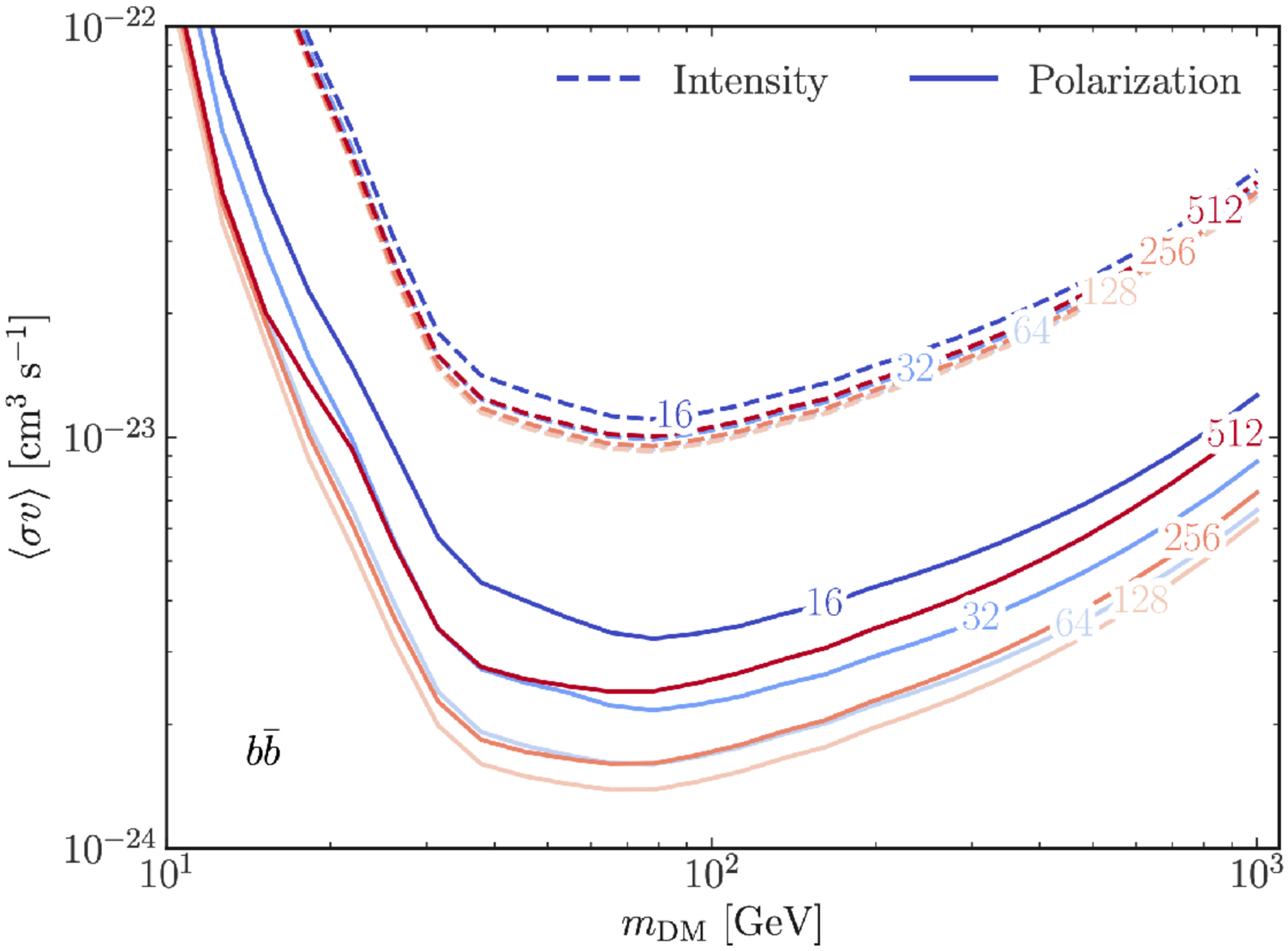
Region of Interest





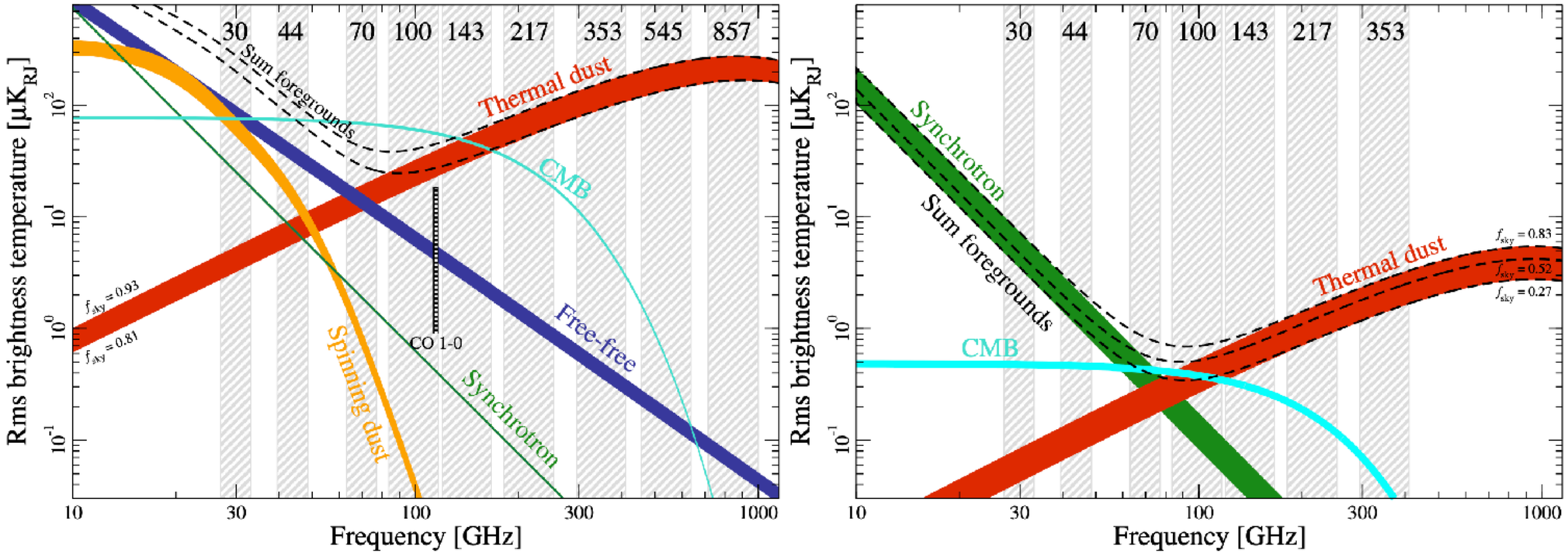
- Most important ROI is closer to the GC for polarization than for the intensity

Impact of Pixelsize



Possible Improvements?

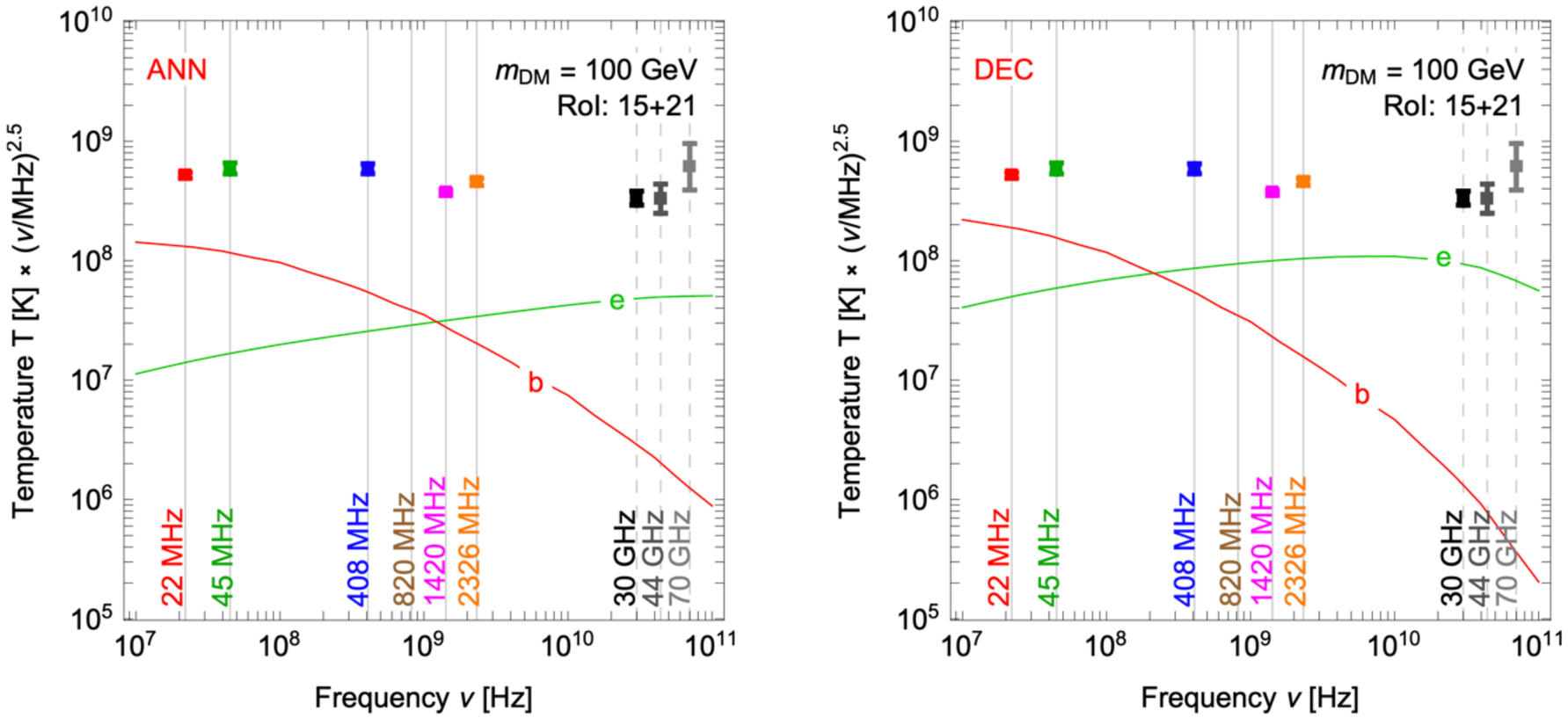
Reference:
[Planck, 2018, arXiv:1807.06205]



- At higher frequencies thermal dust becomes dominant
  → Possibly, improvements for low DM masses and hadronic final states

Possible Improvements?

Reference:
[Cirelli+, 2016, arXiv:1604.06267]



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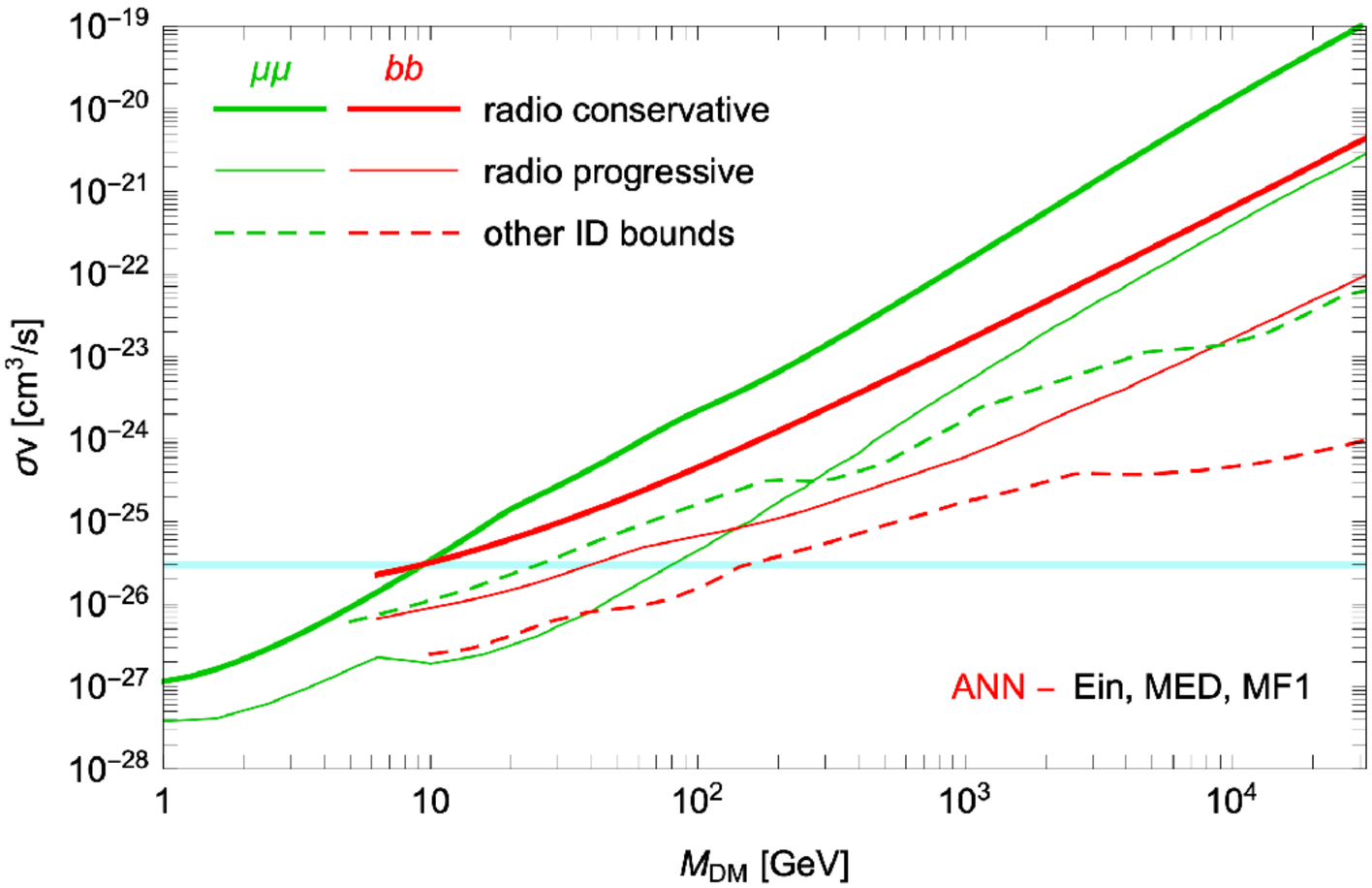
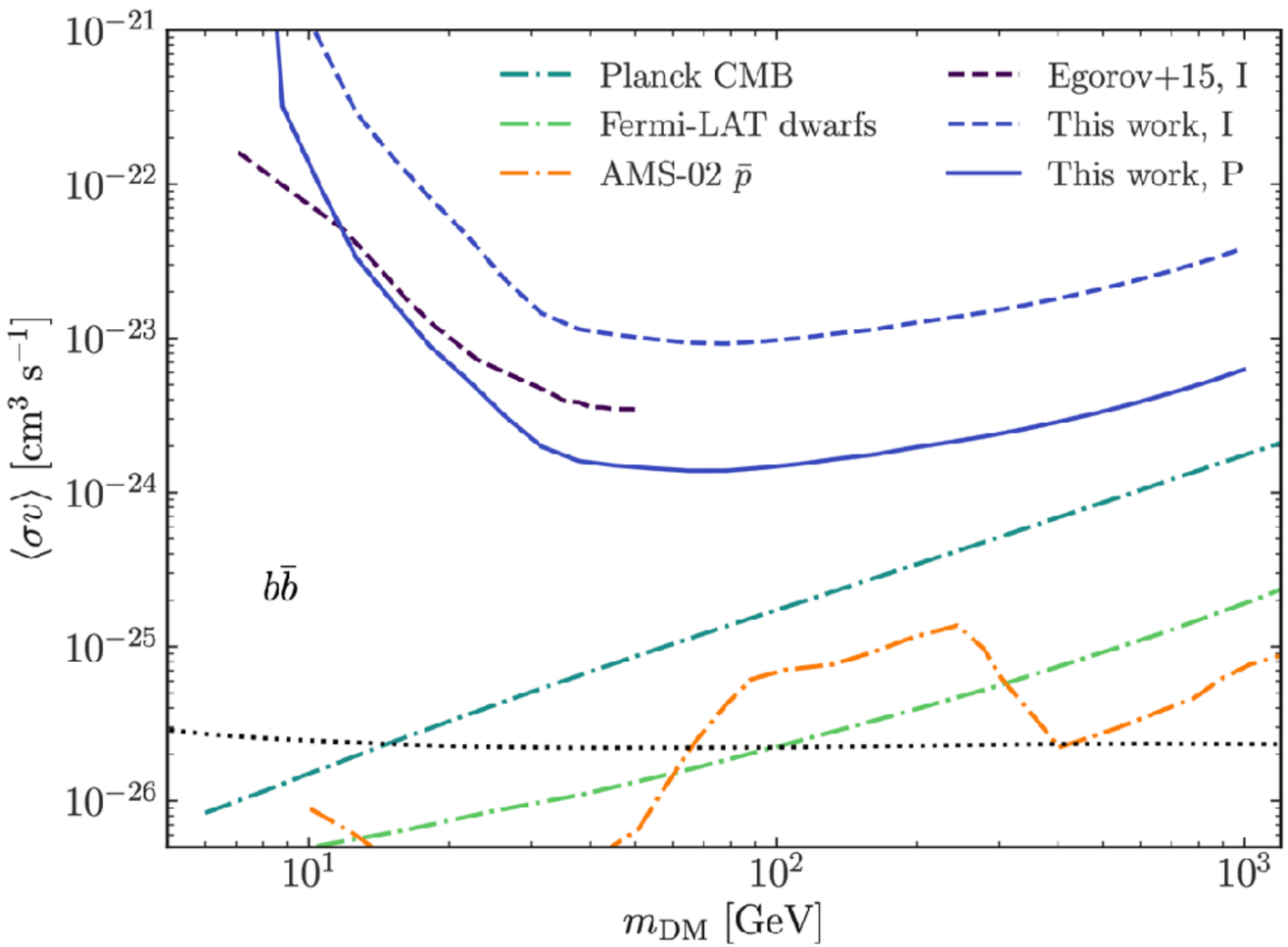
Possible Improvements?

Reference:
[Cirelli+, 2016, arXiv:1604.06267]



- With a *good* astrophysical background model limits could be improved (example from intensity)

Conclusion



- **Novelty:** Exploitation of synchrotron polarization to derive DM limits
- Polarization is more constraining than intensity
- Leptonic DM bounds are competitive with CMB limits
- Provided limits are conservative (no-background assumption)