Planck observations of the Galactic polarized synchrotron emission and Dark matter constraints

Manconi, Cuoco, Lesgourgues, PRL (2022)
ArXiv:2204.04232

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Sestri Levante
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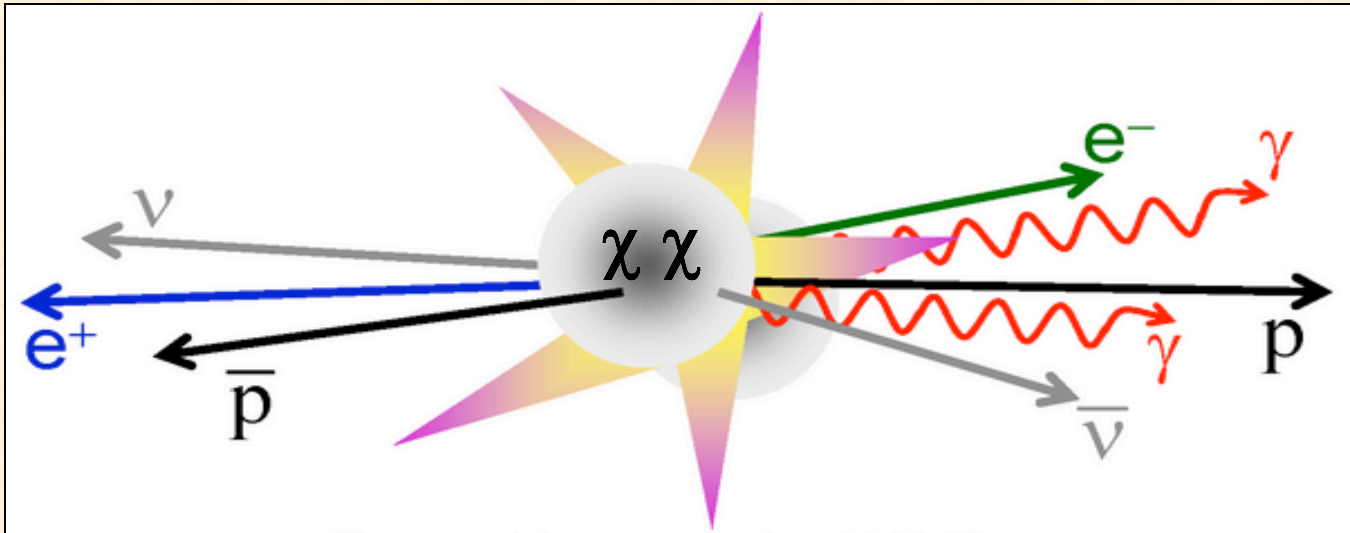
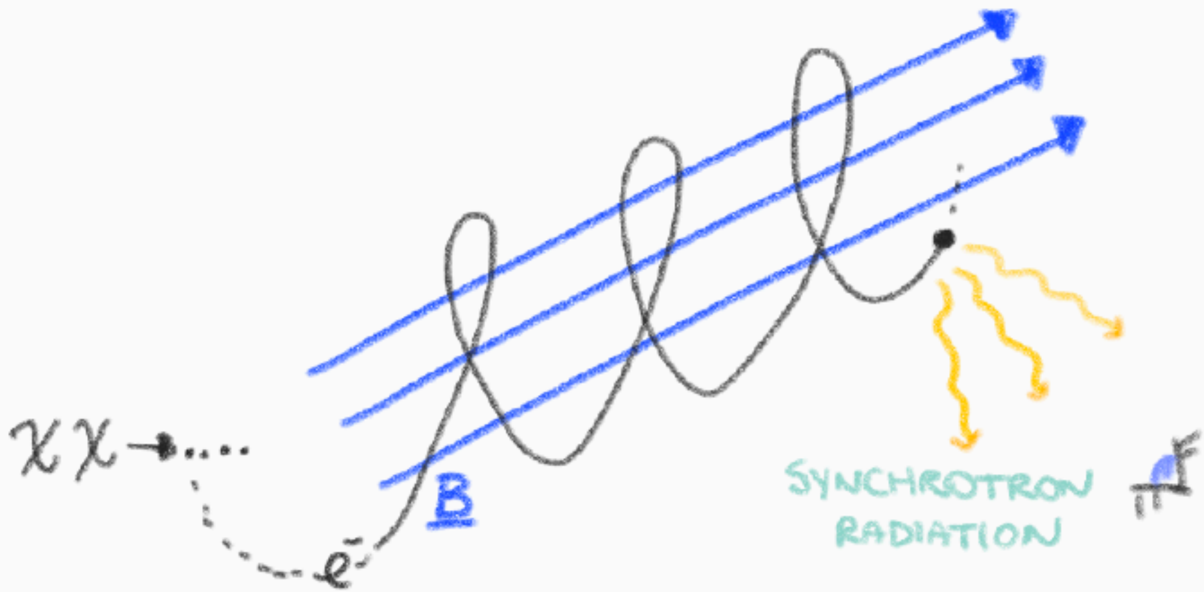
Indirect Detection of Dark Matter: the General Framework

1) **Dark Matter Annihilation** Typical final states include heavy fermions, gauge or Higgs bosons

2) **Fragmentation/Decay** Annihilation products decay and/or fragment into some combination of electrons, protons, deuterium, neutrinos and gamma rays

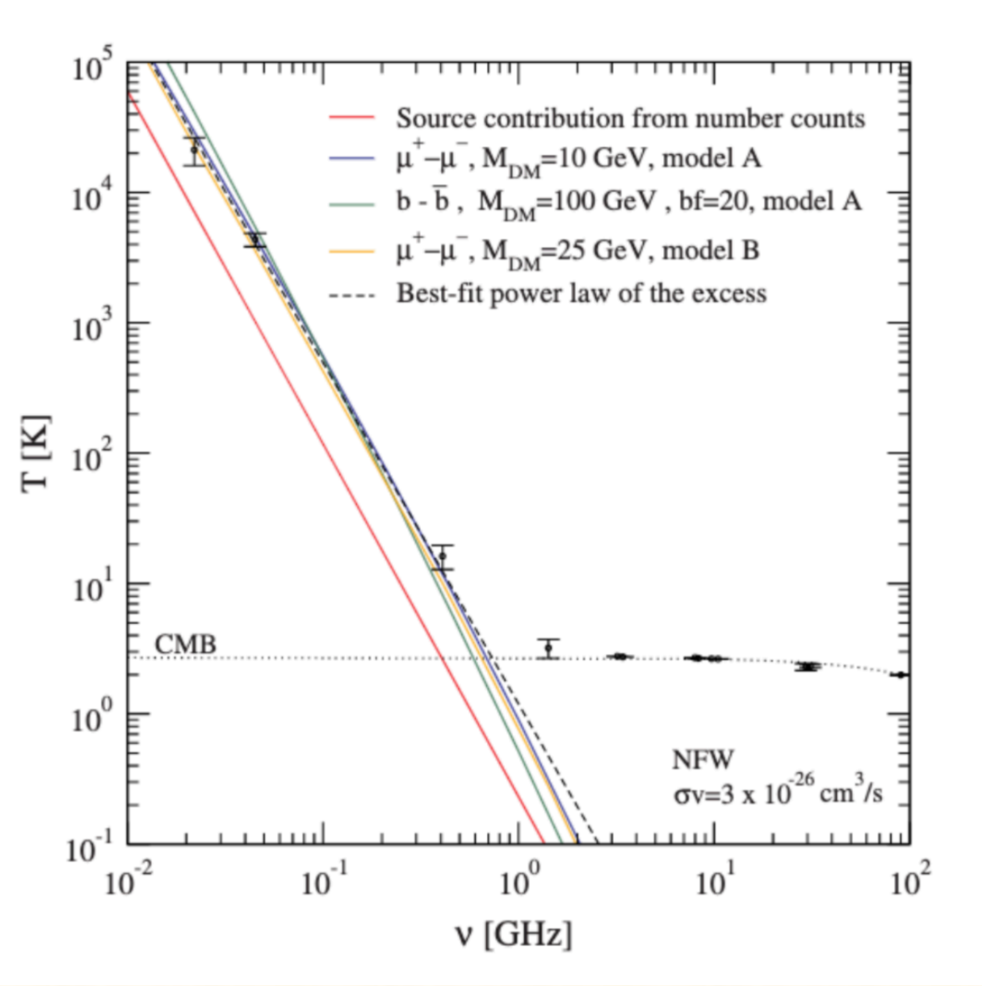




Secondary dark matter radiation

radio - microwave

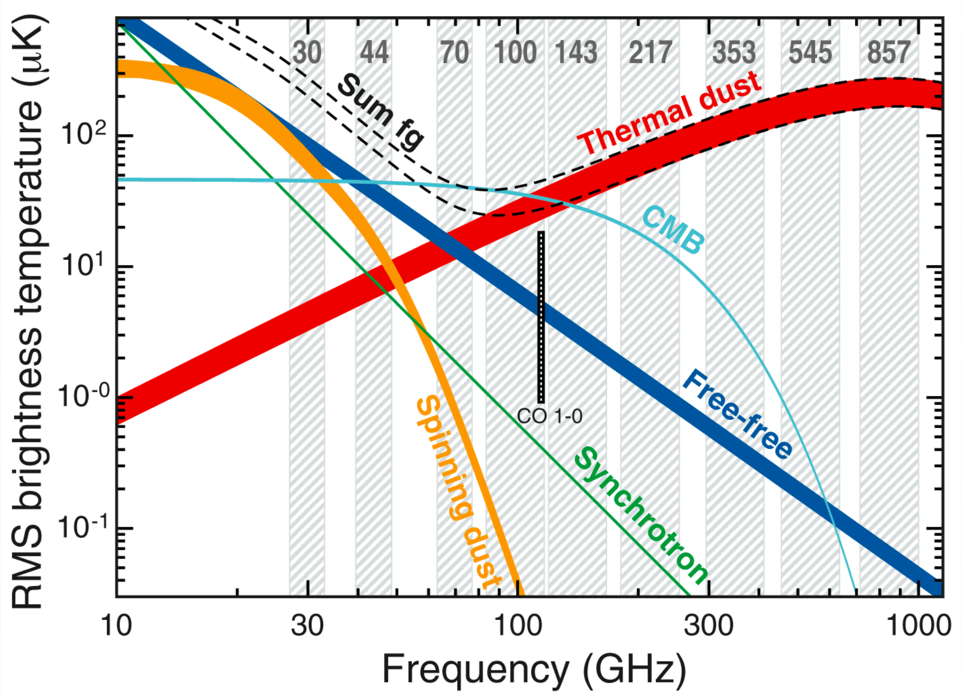
The ARCADE Excess

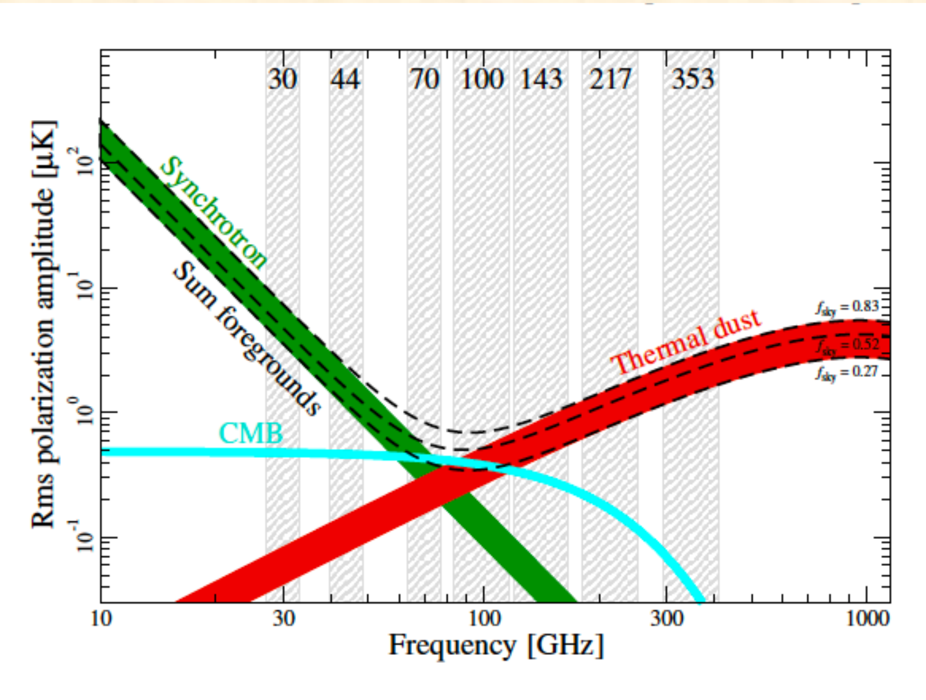


The observed extra-galactic radio background below 1 GHz is in excess w.r.t. the extrapolation from source counts. The excess could be due to radio emission from DM.

Fornengo, Lineros, Regis, Taoso, PRL 2011

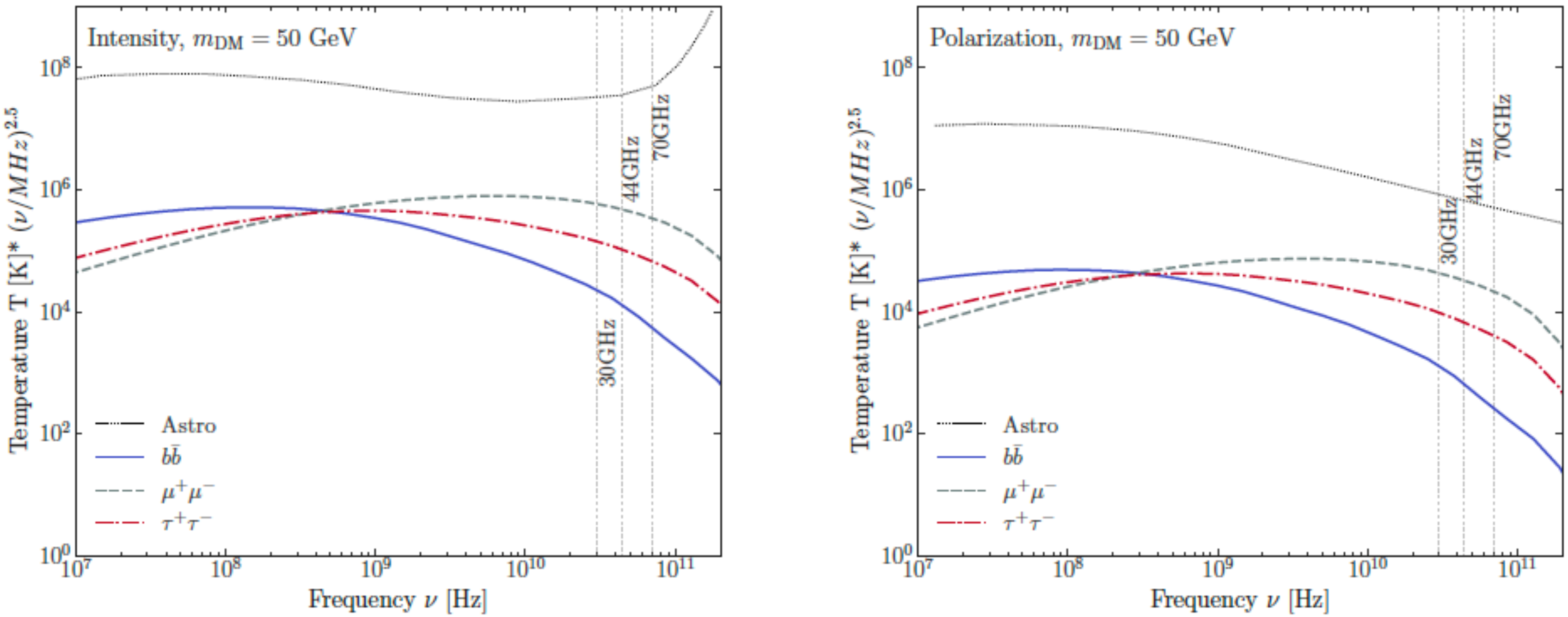
Radio emission in the Galaxy





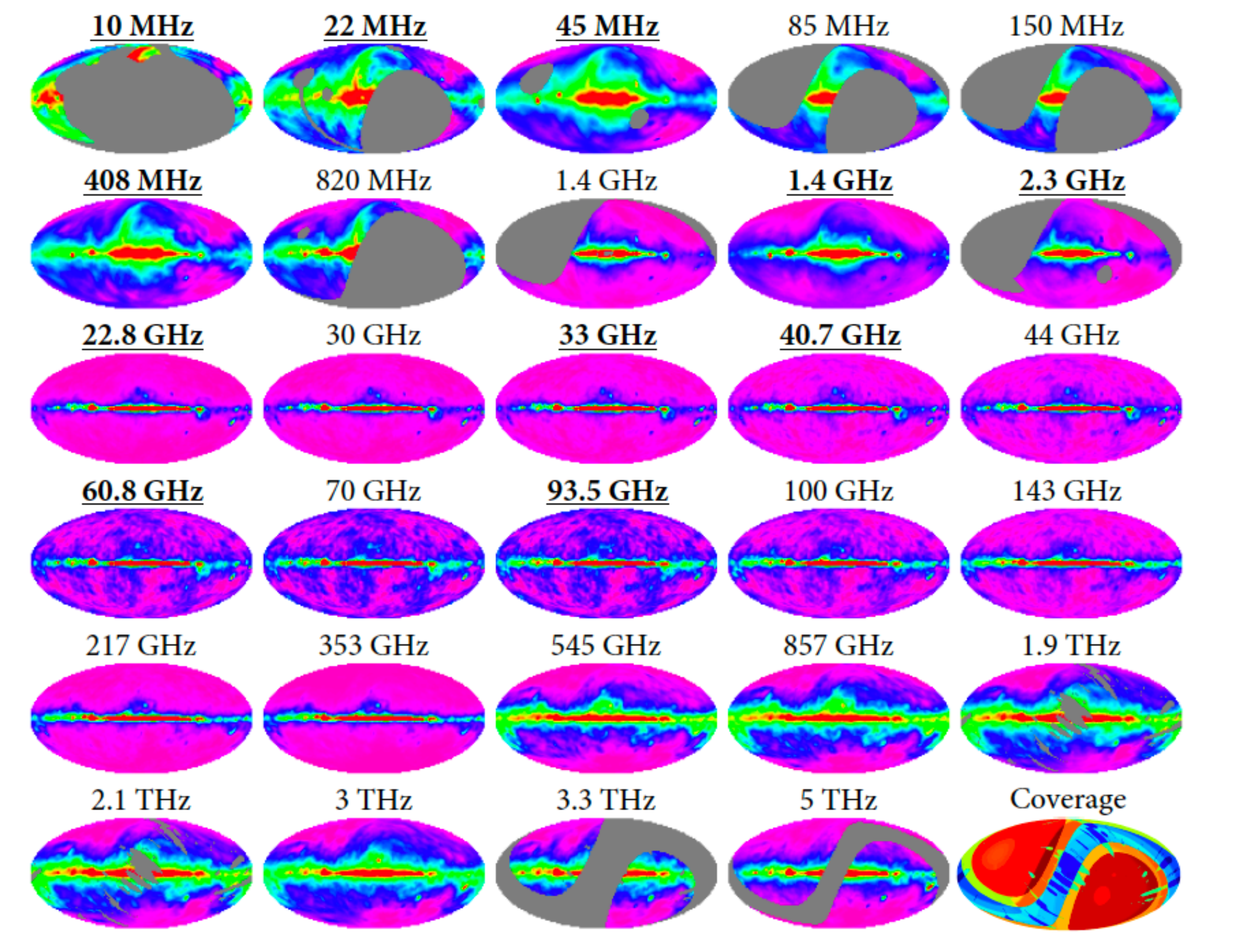
In intensity at 30 GHz there is synchrotron free-free and spinning dust.
In polarization at 30 GHz there is only synchrotron

DM spectra



Intensity, $m_{DM} = 50$ GeV
Polarization, $m_{DM} = 50$ GeV
Temperature T [K]* $(\nu/MHz)^{2.5}$
Frequency ν [Hz]
30GHz
44GHz
70GHz
Astro
$b\bar{b}$
$\mu^+\mu^-$
$\tau^+\tau^-$

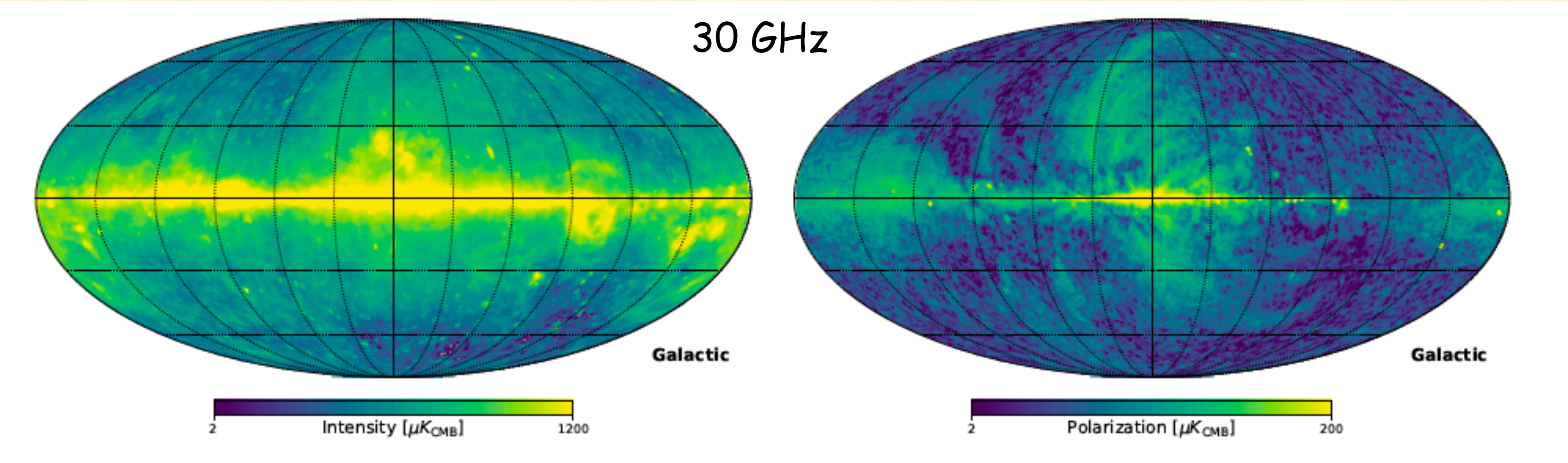
All-sky Radio Intensity emission



The all-sky radio intensity is well-measured in a wide range of frequencies.

Zheng,Tegmark+, arXiv:1605.04920

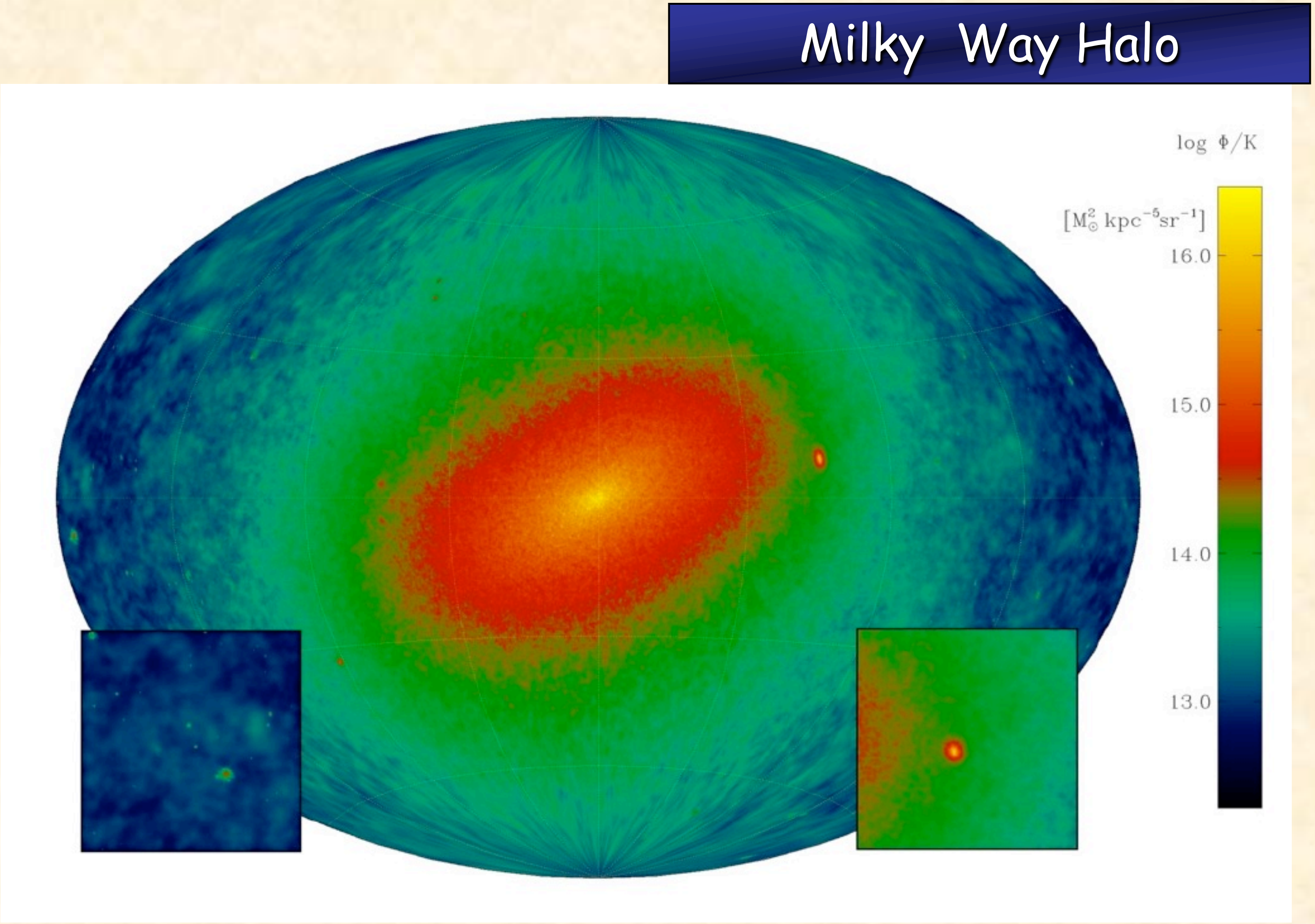
Planck Intensity and Polarization maps



Updated all-sky radio polarization data are available from Planck measuremnets.

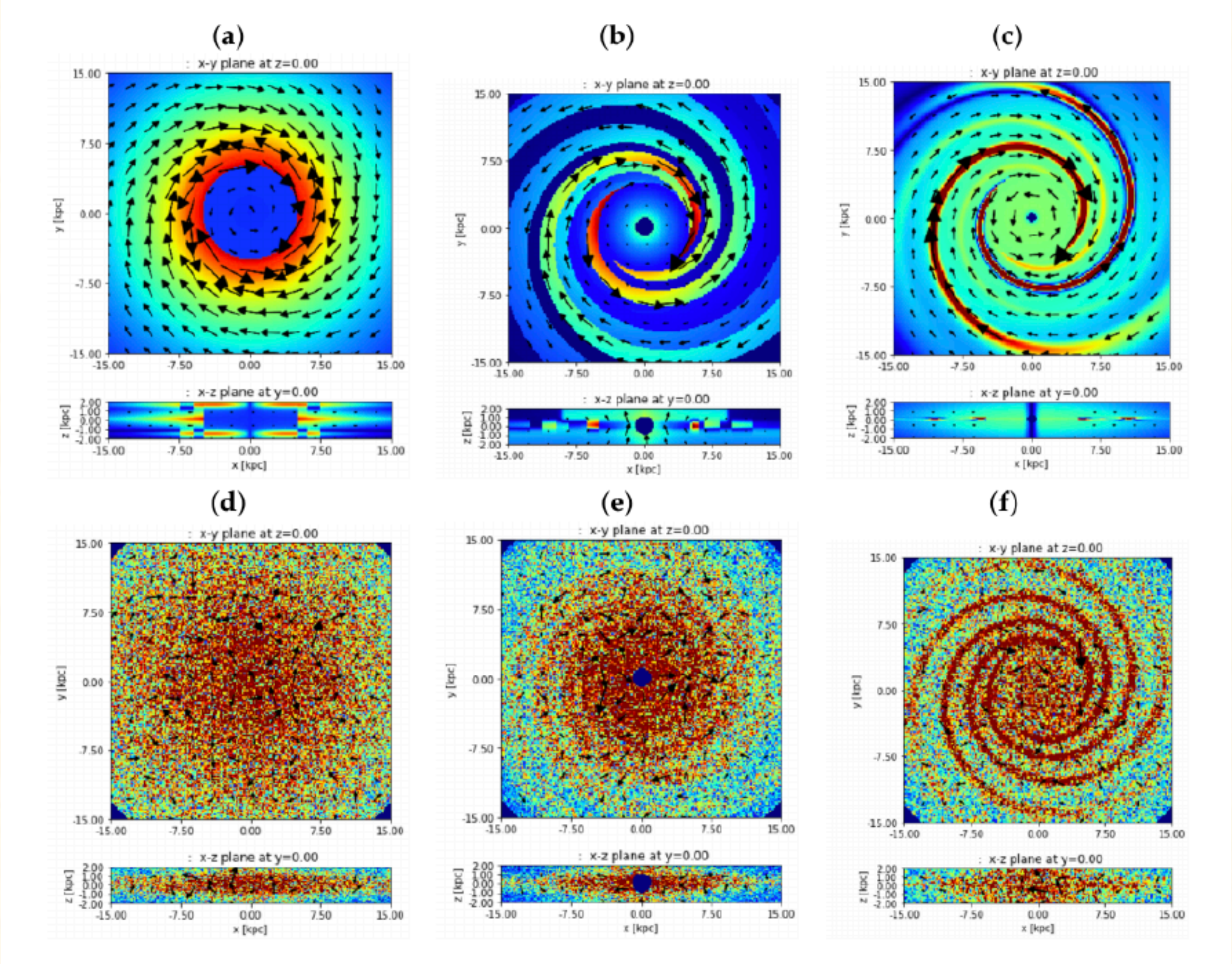
We use these measurements to derive conservative DM constraints requiring that the DM signal does not exceed the observed emission

DM distribution



DM distribution peaked at GC. Possible presence of clumps/substructures

Galactic Magnetic Field

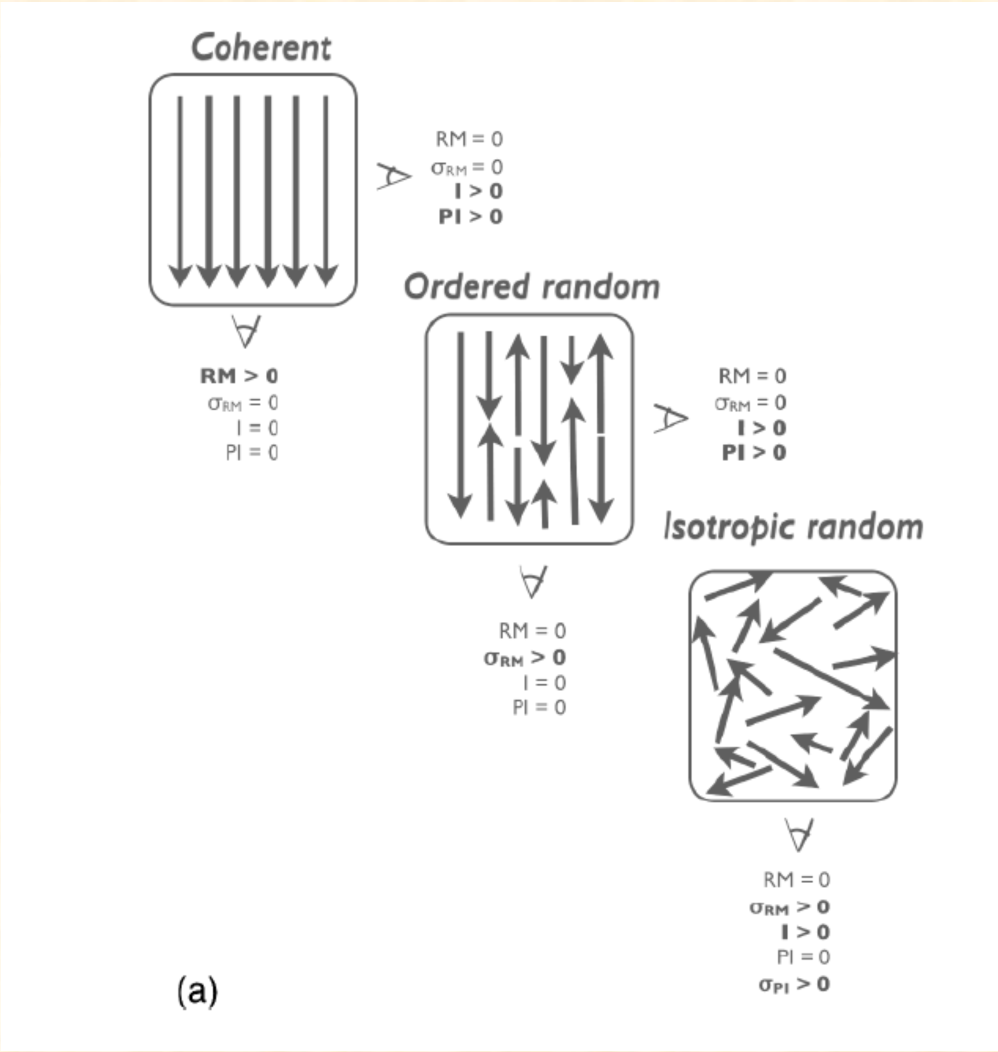


GMF has two components: Random and Regular

We use:
Phshirkov et al. 2011
Sun et al. 2010
Jansson & Farrar 2012

Jaffe, Galaxies 7, 52 (2019)

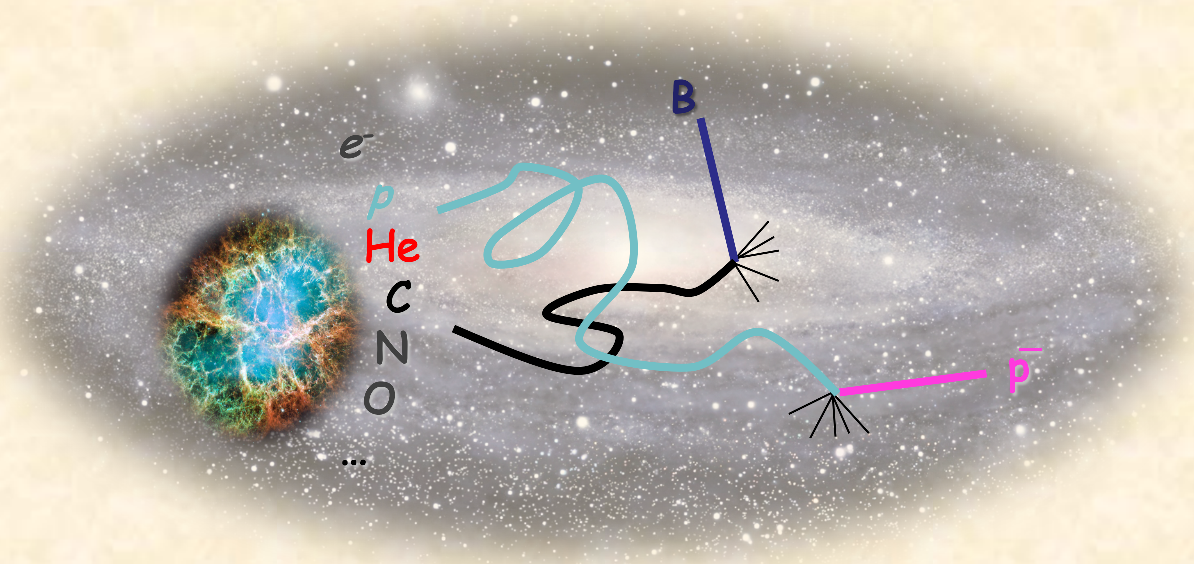
Synchrotron intensity and Polarization



Jaffe, Galaxies 7, 52 (2019)

The random component is typically dominant but does not produce Polarization, which is instead, only produced by the regular (and striated random) component

Cosmic-Ray Propagation



We use GALPROP to solve the propagation equation and derive the density of e+e- from DM at each point in the Galaxy.

We also use GALPROP to calculate the intensity and polarization synchrotron emission from DM e+e-

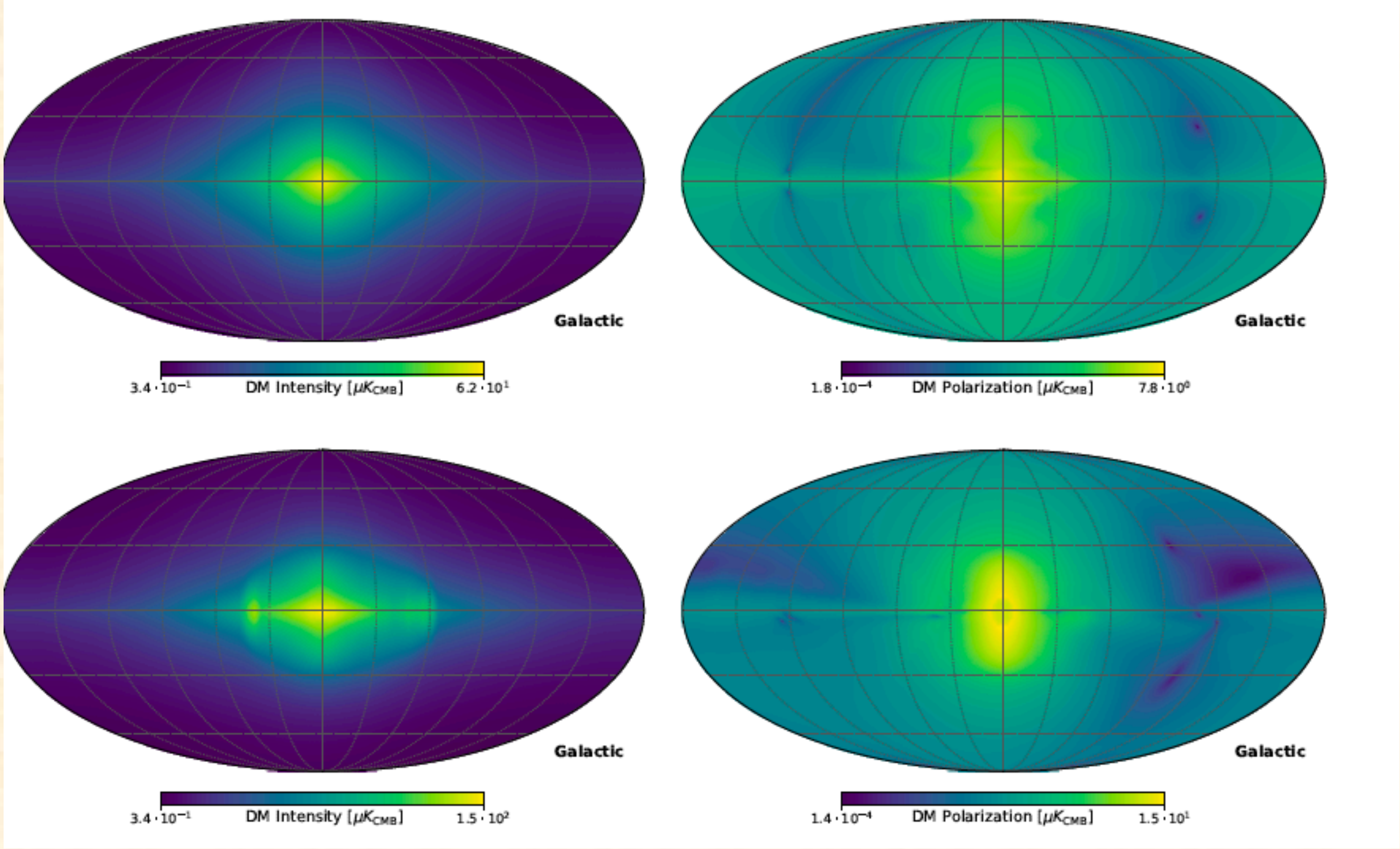
Astrophysical Sources:
•SNR or Pulsars

➢**Primary CRs**:
p, He, C, …

Interaction with ISM:
•Fragmentation or production

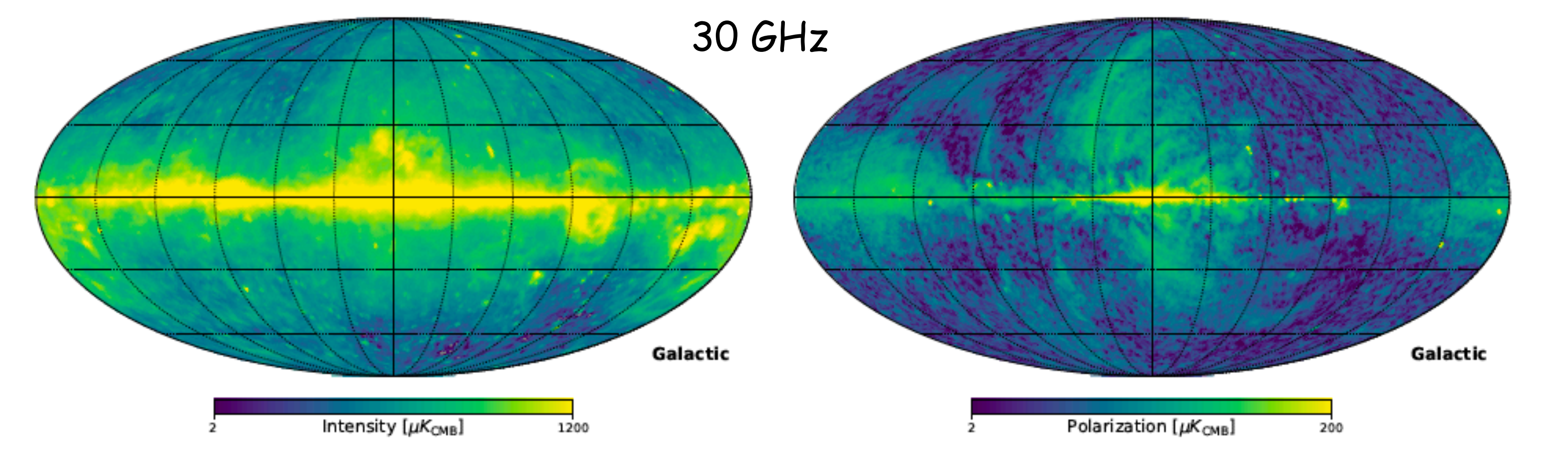
➢**Secondary CRs**:
$\bar{p}$, Li, B, …

DM maps



DM intensity (left) and Polarization (right) maps at 30 GHz
for m_{DM}=50 GeV annihilating into $\mu^+\mu^-$.
Sun+10 GMF (upper row) and JF12 GMF (lower row)

Planck Intensity and Polarization maps



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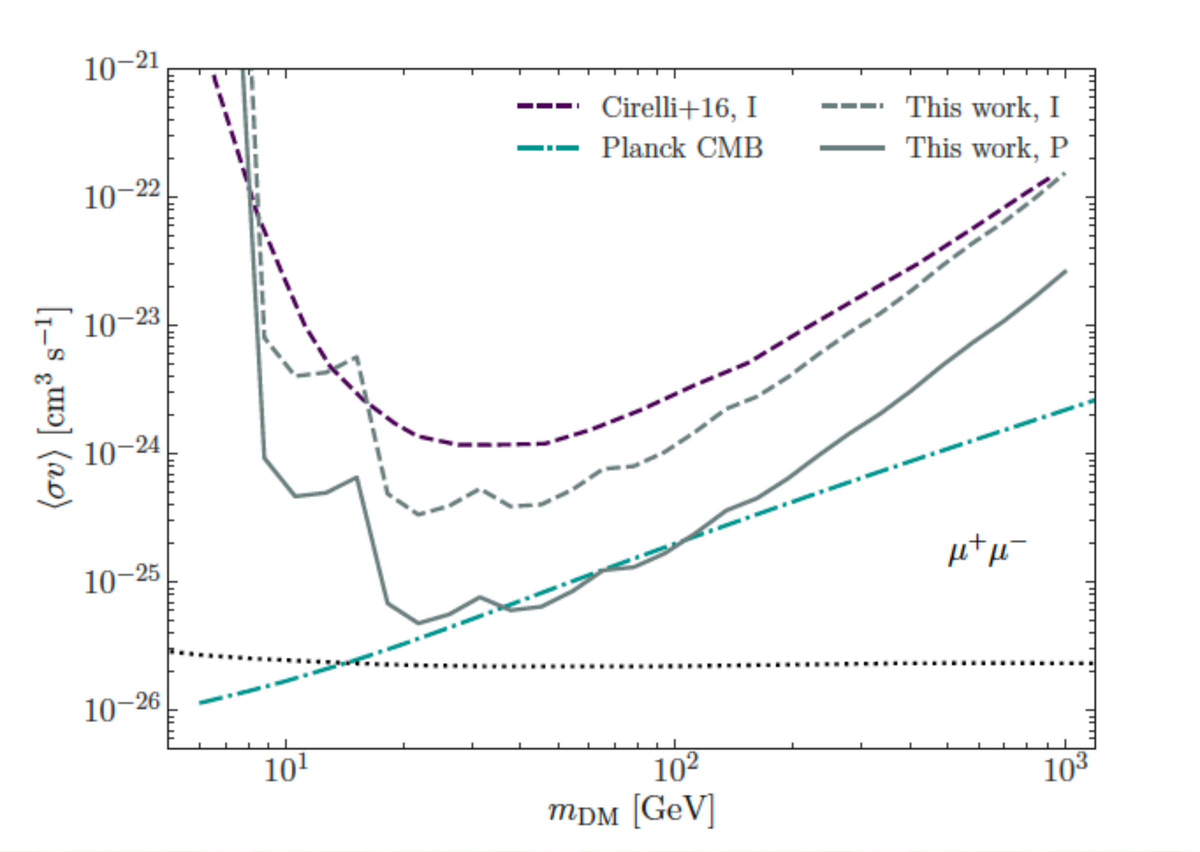
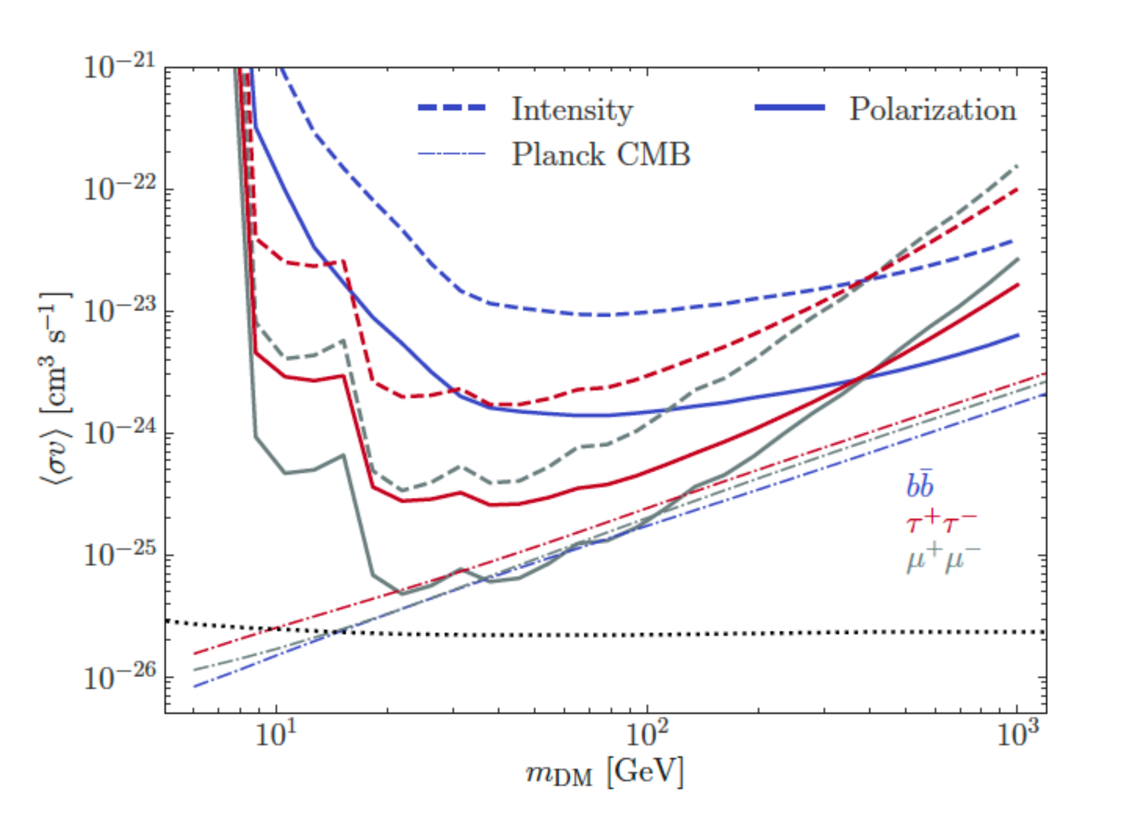
DM constraints



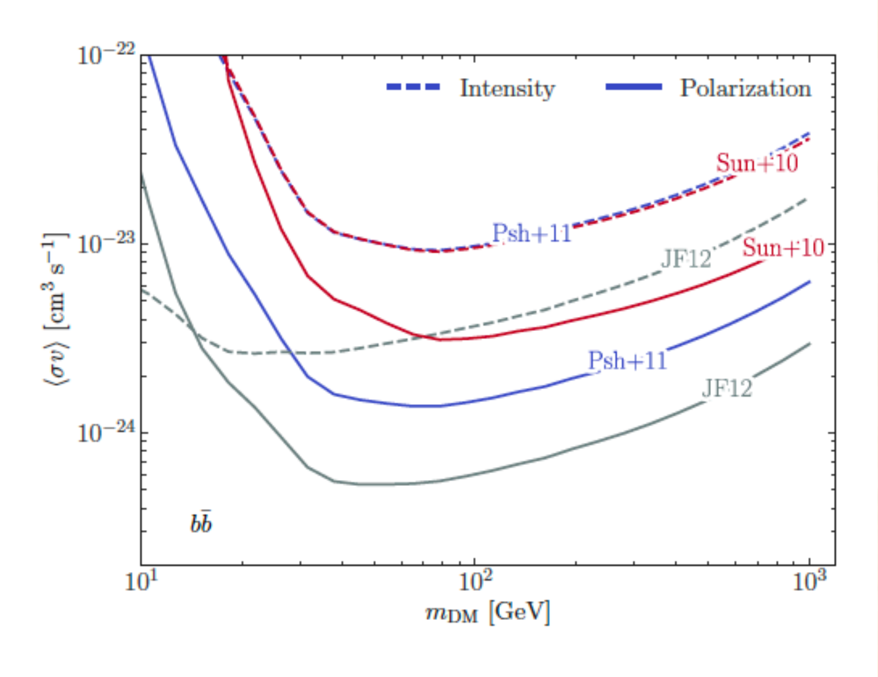
Polarization constraints are a factor 5-10 stronger than intensity constraints.
In the future, with a more "aggressive" approach modeling the backgrouns the constraints should be further improvable by a factor of a few

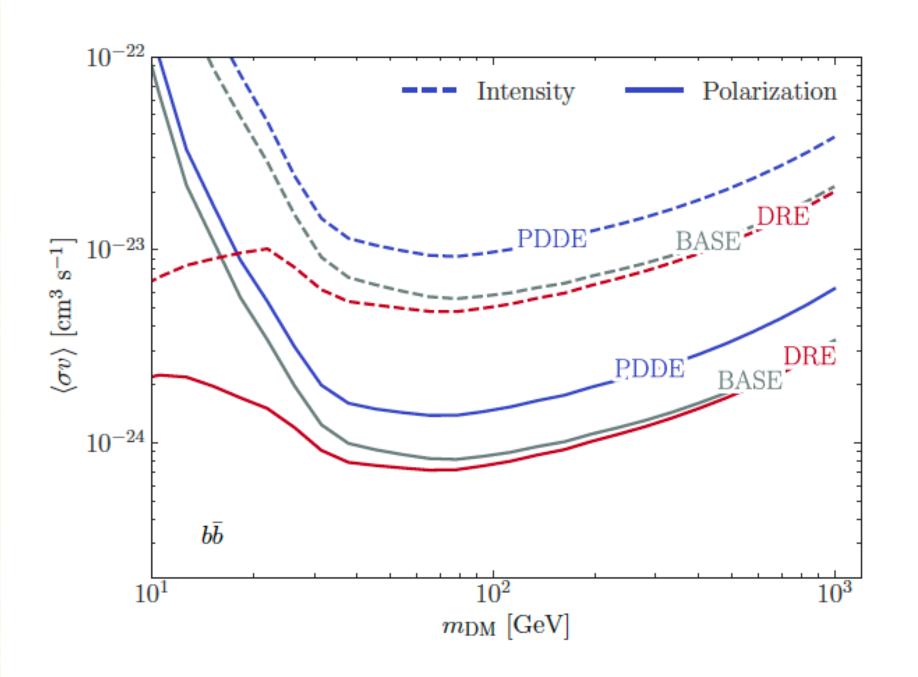
More DM Channels



Constraints for all 3 channels considered

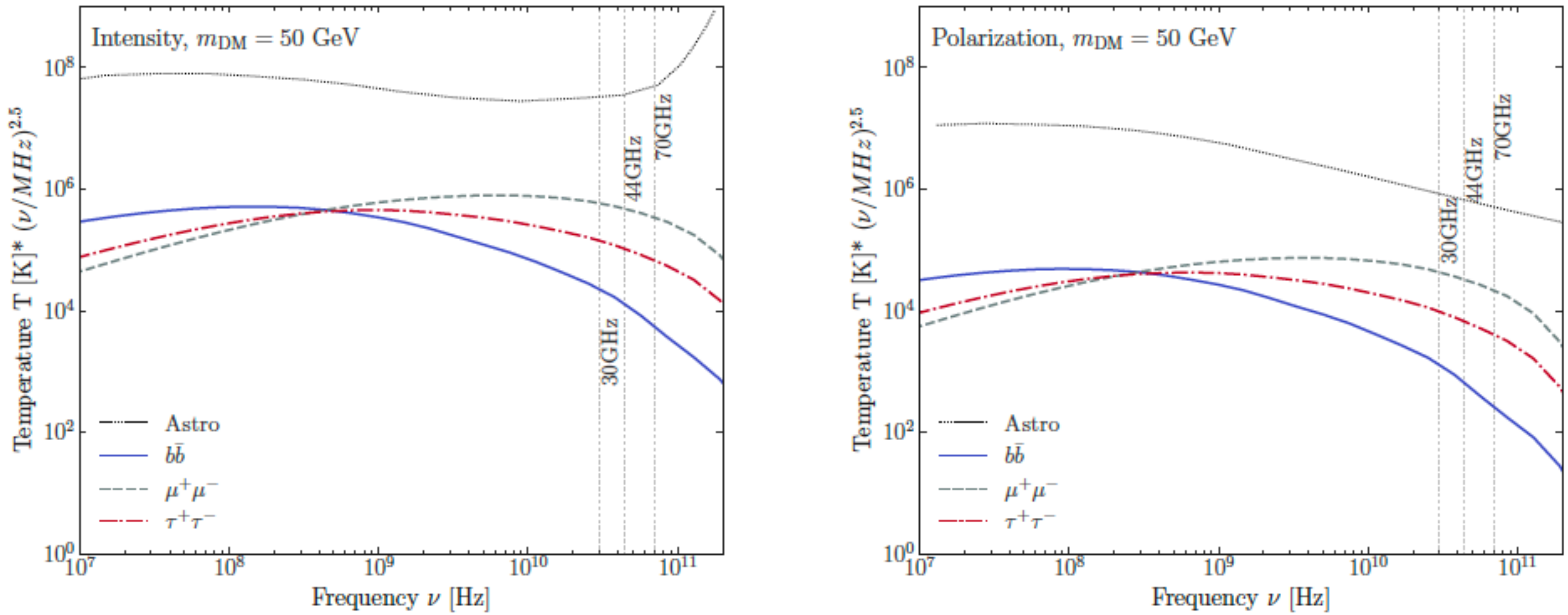
Systematics





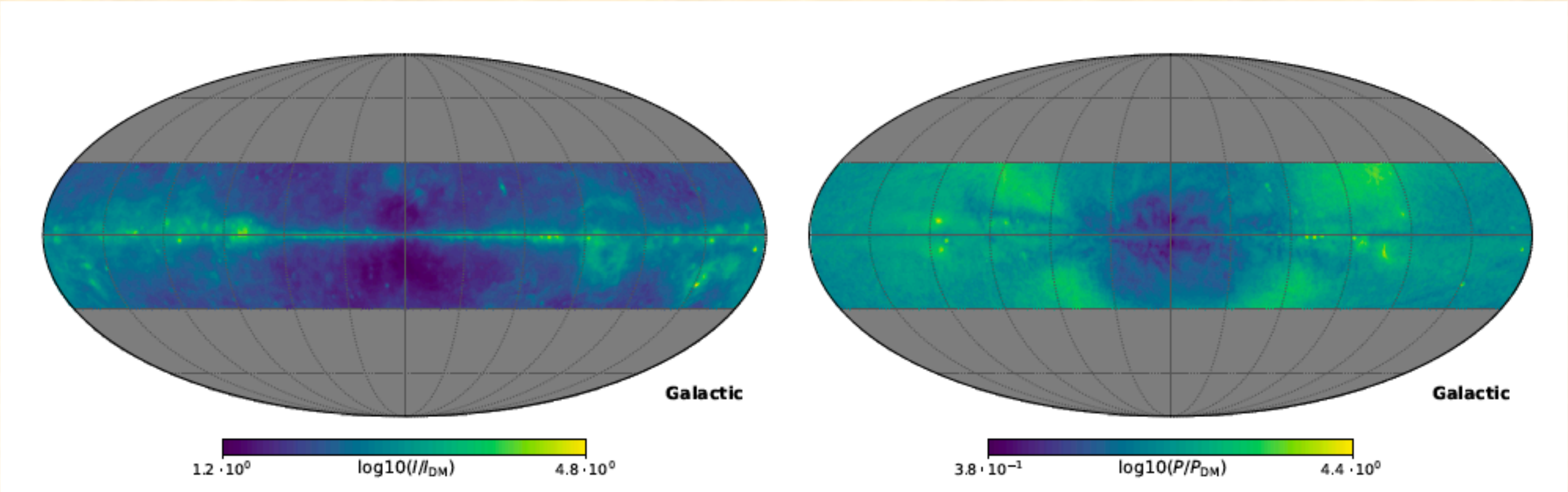
- Constraints variations for different GMF (left) and different CR propagation models (right), for bbar channel.
- Intrinsically, there is a factor 10 systematic. But polarization is always consistently more constraining than intensity

Why P is more constraining?



DM signal at 30 GHz fights against a lower background in polarization w.r.t. intensity

Data/Model ratio



Ratio of data/model for intensity(left) and polarization (right).
For intensity the best sensitivity is reached ~10 deg away from the Plane, while for polarization is closer due to some filament of low background which expends close to the GP.

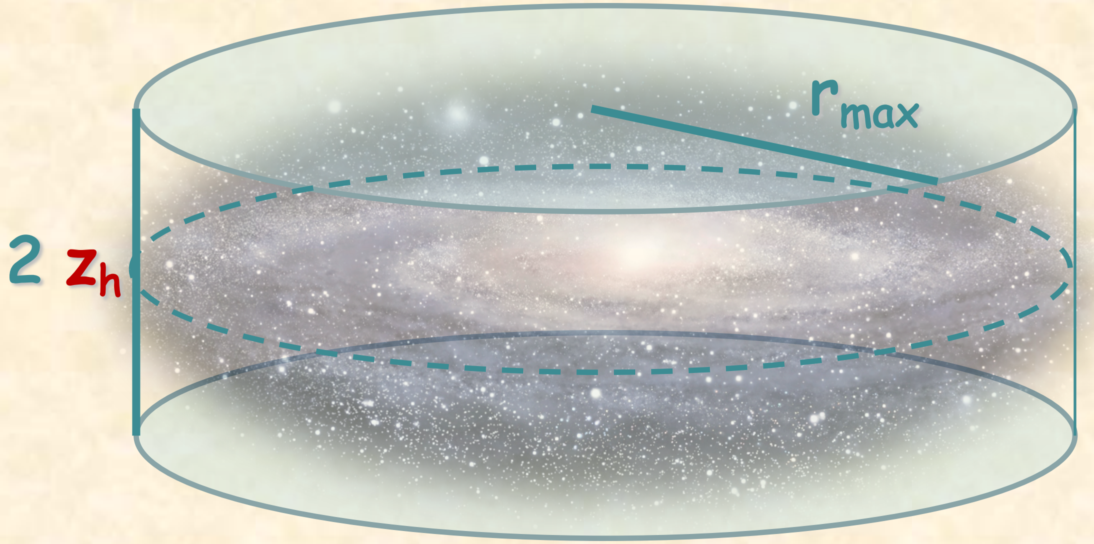
Summary and Conclusions

- A new observable for DM: Radio polarization!
- More sensitive than Radio intensity by a factor 5-10!
- Systematics due to the Galactic Magnetic field need to be improved
- Stonger constraints expected when modeling the backgrounds

Backup

Cosmic-Ray Propagation

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



Diffusion equation is typically solved fully numerically with GALPROP or Dragon, or semi-analytically with Usine.