Radio emission from galactic and extragalactic dark matter

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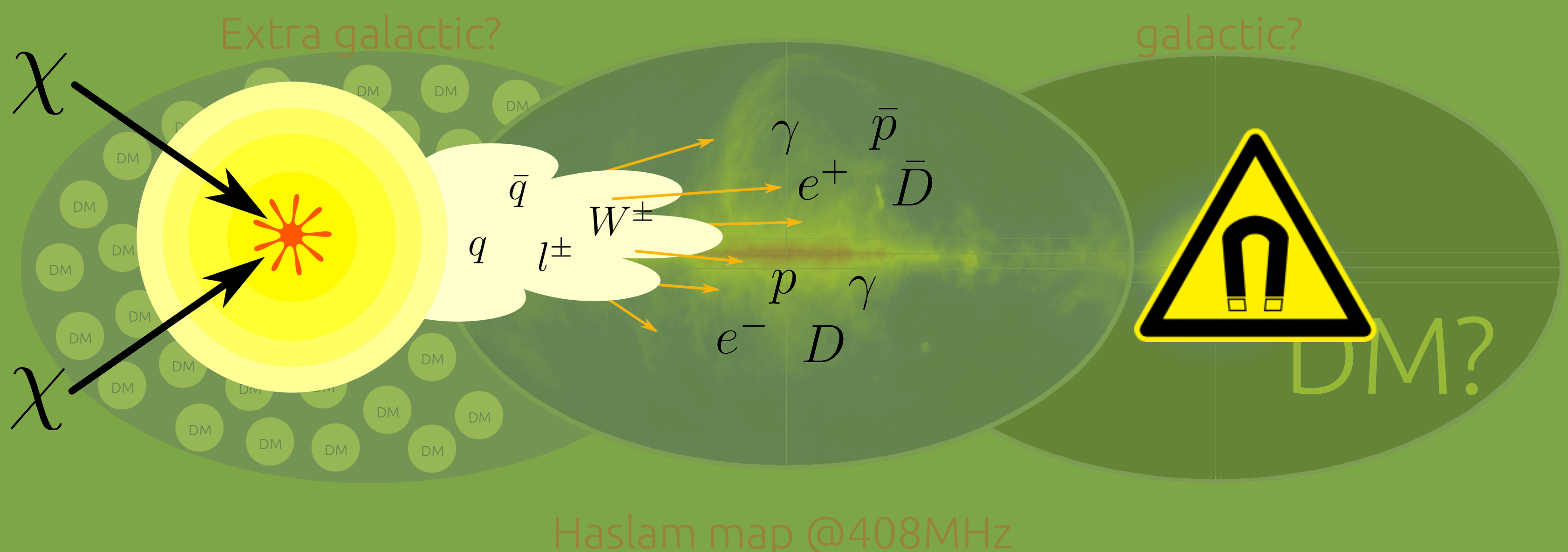
Based on:

Galactic synchrotron emission from WIMPs at radio frequencies / JCAP01(2012)005, 1110.4337
Possibility of a Dark Matter Interpretation for the Excess in Isotropic Radio Emission Reported by ARCADE / PRL 107,271302 (2011), 1108.0569
Radio data and synchrotron emission in consistent cosmic ray models / JCAP01(2012)049, 1106.4821
Cosmological Radio Emission induced by WIMP Dark Matter / JCAP03(2012)033, 1112.4517

Motivation

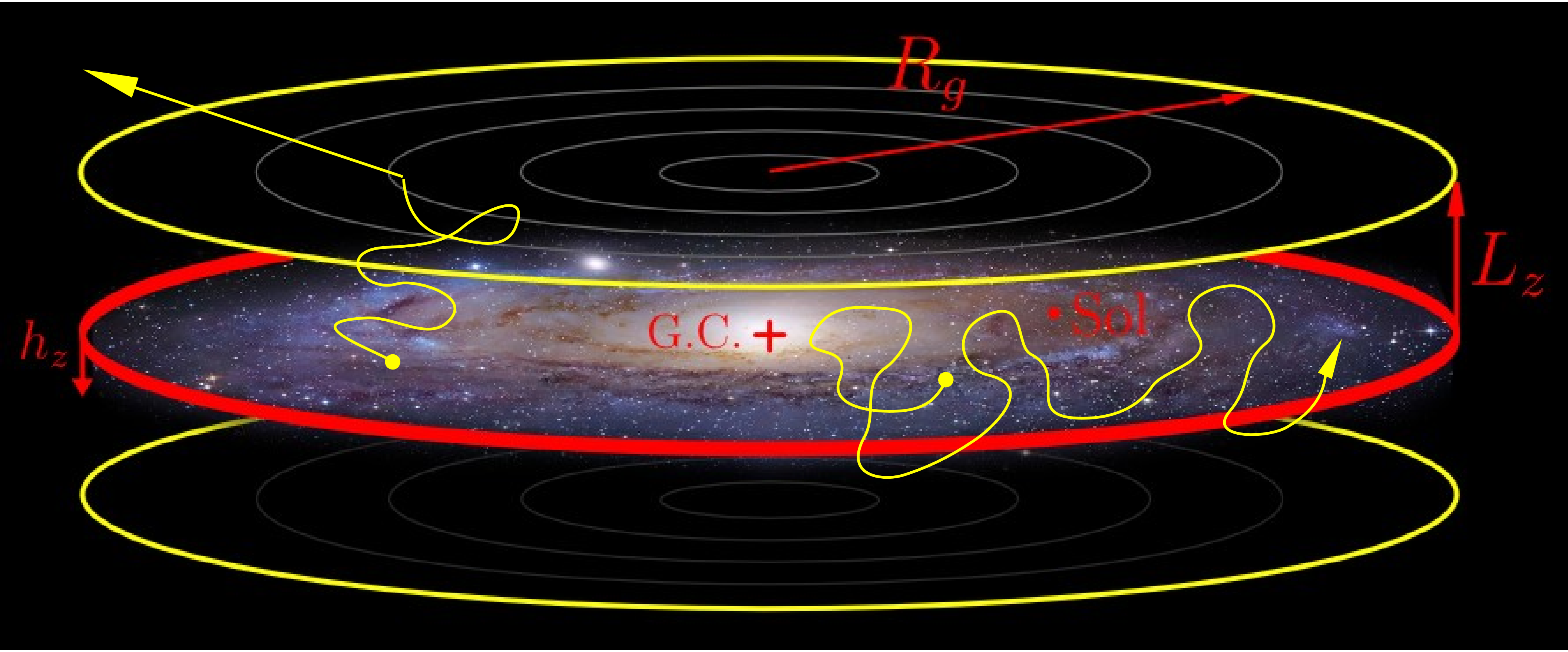
Possible contribution to the radio sky from WIMP dark matter



Outline

- Cosmic rays propagation
- Synchrotron emission
- Synchrotron from Galactic Dark Matter
- Extragalactic radio: ARCADE 2 excess
- Conclusions

Cosmic rays propagation

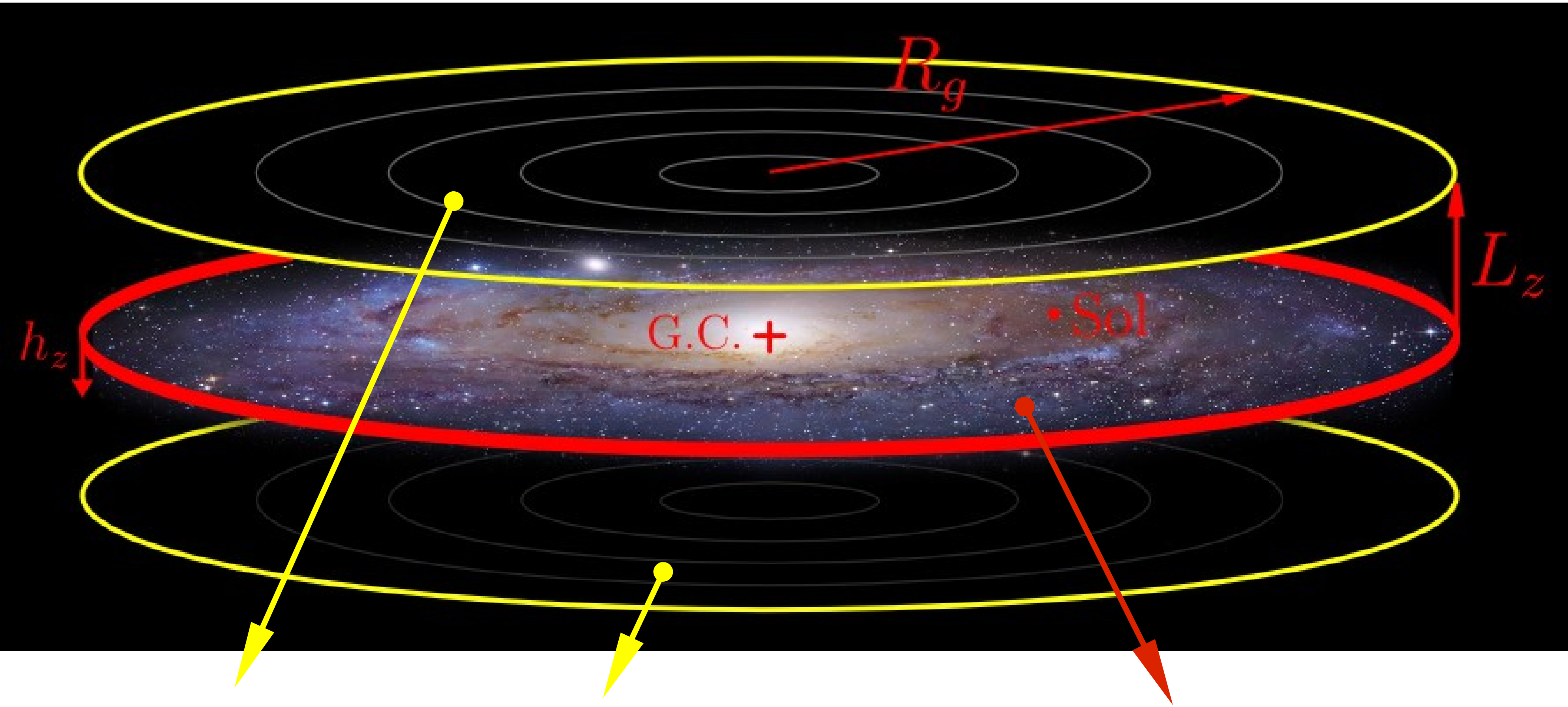


Ginzburg and Syrovatskii. 1964

The region of propagation corresponds to a cylinder, matching the Galactic dimensions

$$R_g = 20\text{kpc} \qquad h_z \approx 100\text{pc} \qquad L_z = 1 - 20\ kpc$$

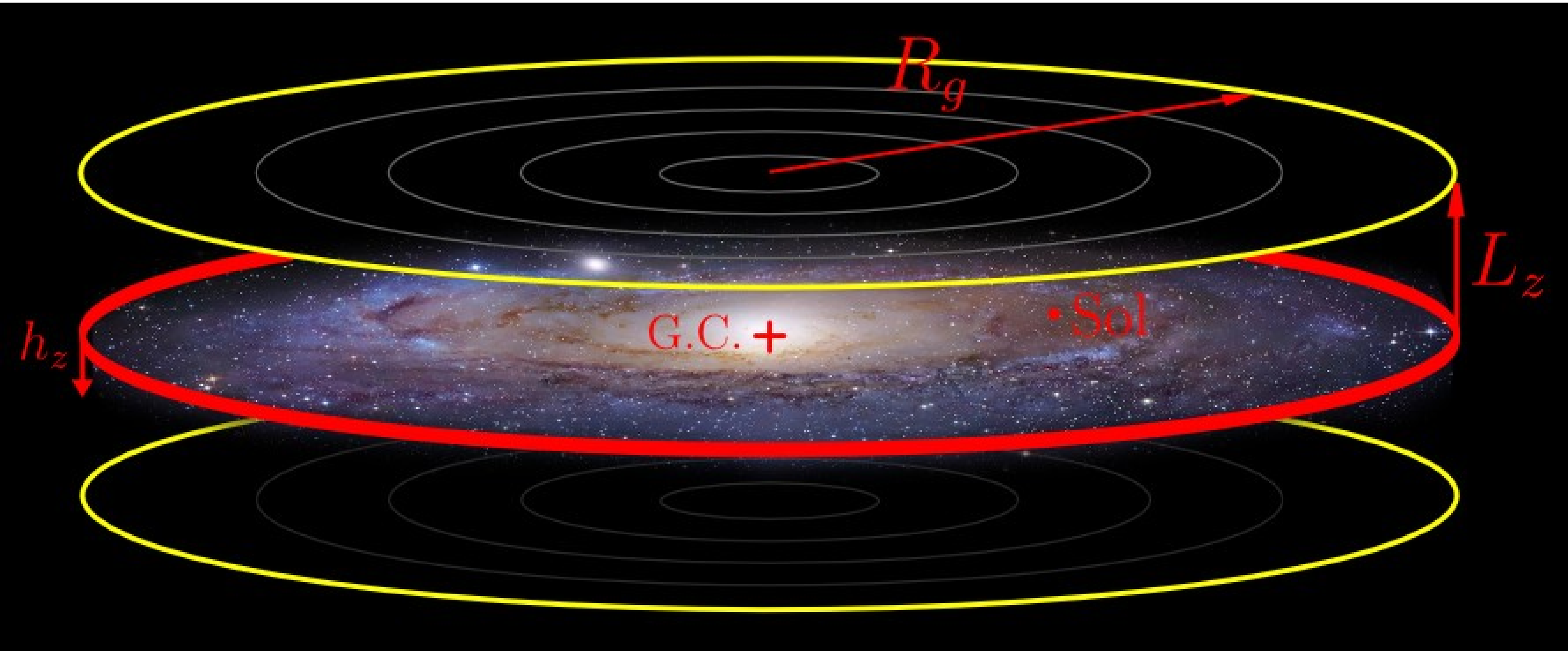
Cosmic rays propagation



Cylinder—Lz corresponds to the zone where inhomogeneous magnetic field is present (i.e. diffusive propagation)

Thin—disk models the galactic plane: sources, interactions with the ISM and reacceleration processes.

Cosmic rays propagation

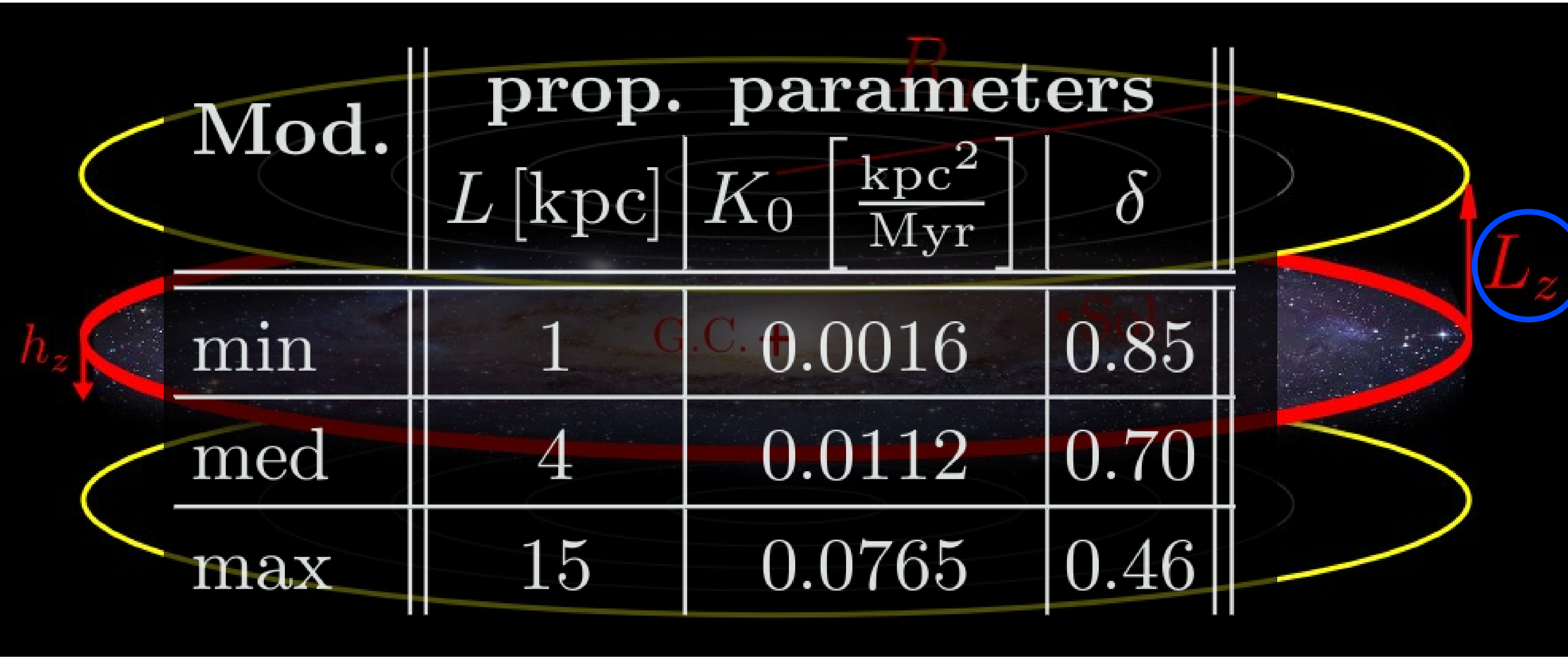


The transport equation describes the evolution of the density of cosmic rays

$$\frac{\partial \psi}{\partial t} + \nabla \cdot \left(-K_0 \epsilon^{\delta} \nabla \psi + \mathbf{V}_c \psi \right) + \frac{\partial J_\epsilon}{\partial \epsilon} = q_{\mathrm{src}}$$

Time evolution — Diffusion — Convection — Energy evolution — Sources

Cosmic rays propagation



Mod.	prop. parameters		
	L [kpc]	K_0 $\left[\frac{\text{kpc}^2}{\text{Myr}}\right]$	δ
min	1	0.0016	0.85
med	4	0.0112	0.70
max	15	0.0765	0.46

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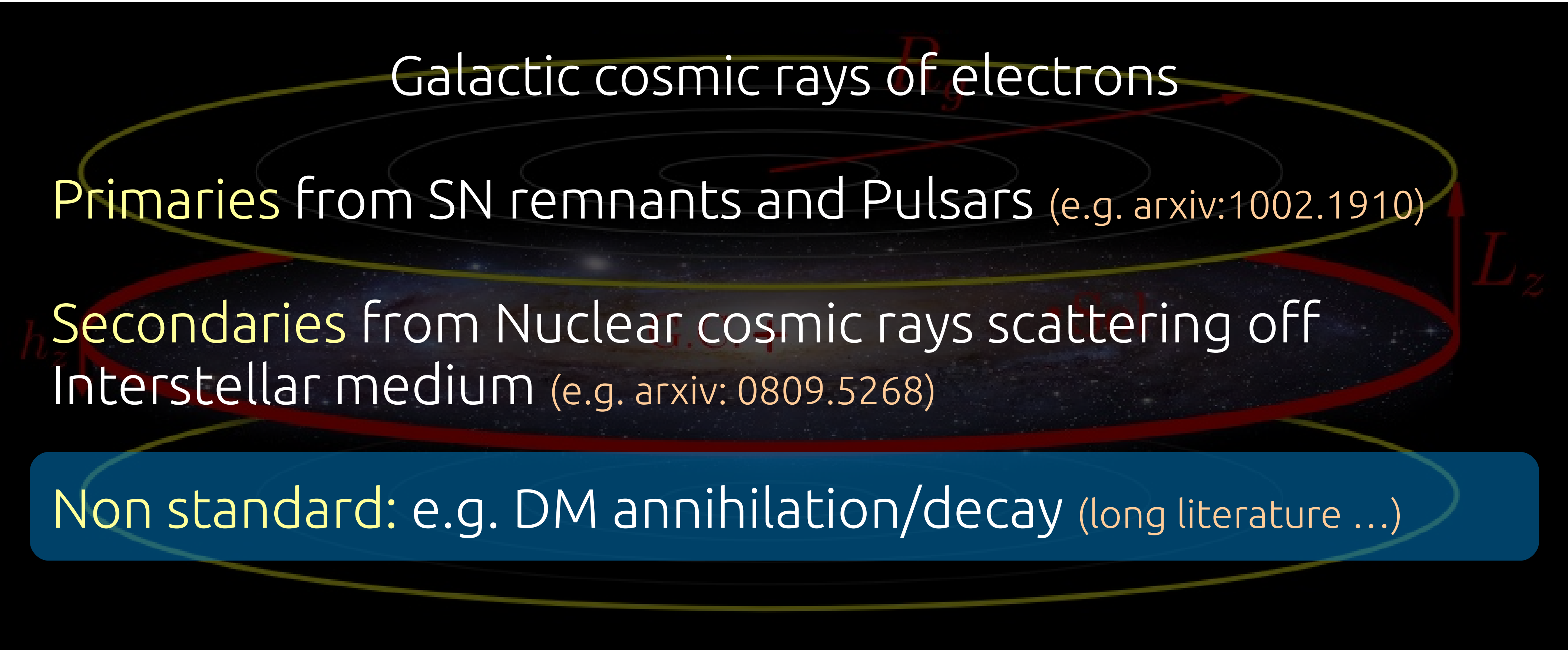
Diffusion

Cosmic rays propagation



Galactic cosmic rays of electrons

Primaries from SN remnants and Pulsars (e.g. arxiv:1002.1910)

Secondaries from Nuclear cosmic rays scattering off Interstellar medium (e.g. arxiv: 0809.5268)

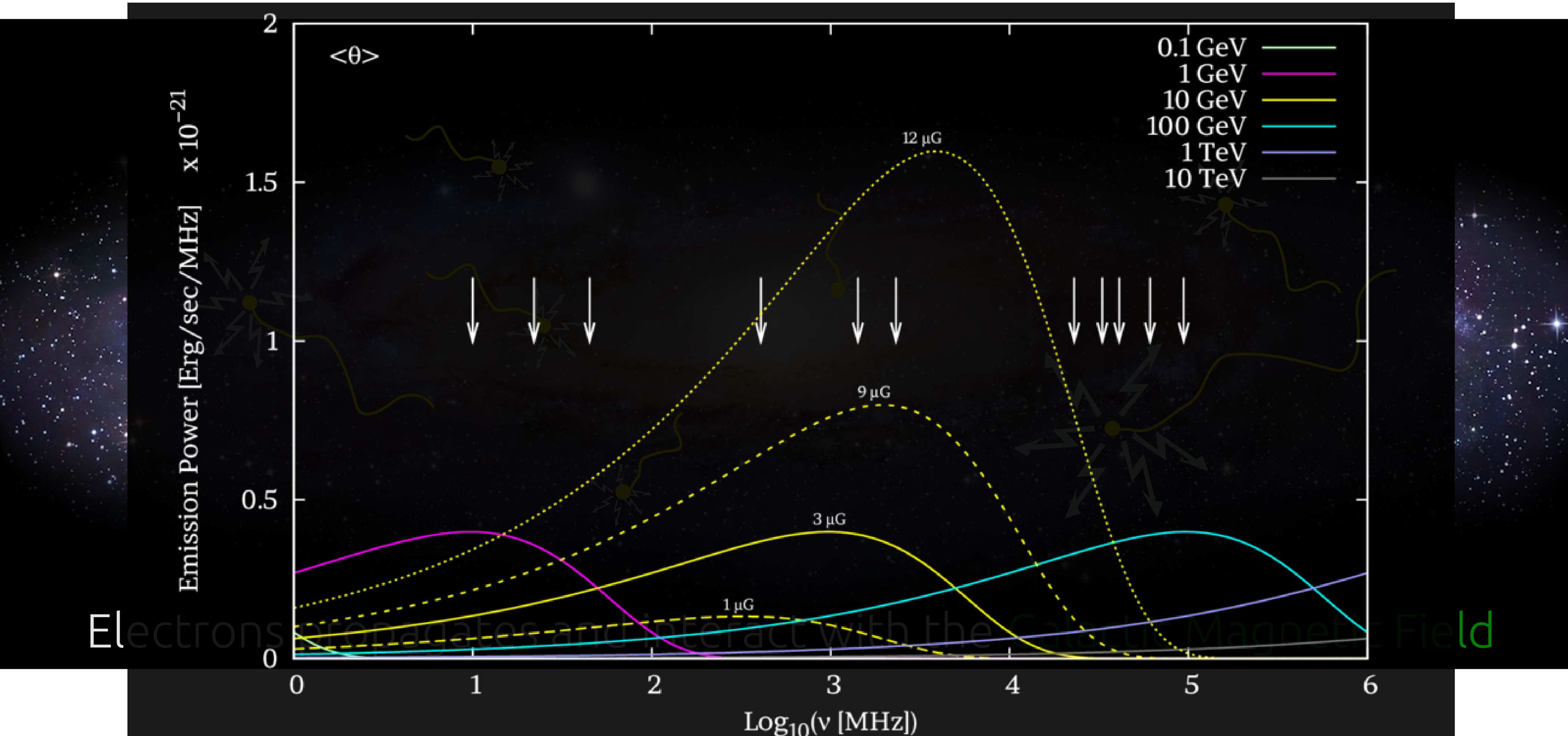
Non standard: e.g. DM annihilation/decay (long literature ...)

The transport equation describes the evolution of the density of cosmic rays

$$\frac{\partial \psi}{\partial t} + \nabla \cdot \left(-K_0 \epsilon^{\delta} \nabla \psi + \mathbf{V}_c \psi \right) + \frac{\partial J_\epsilon}{\partial \epsilon} = q_{\rm src}$$

Sources

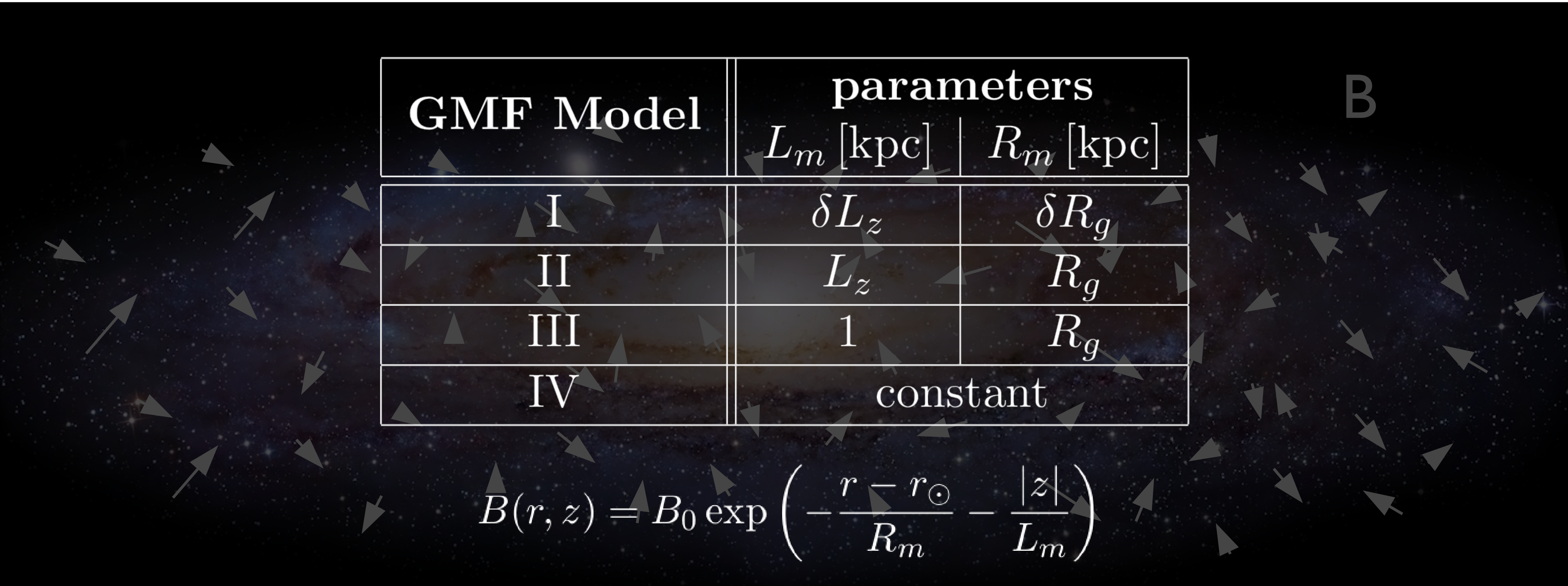
Synchrotron emission



Electrons propagates and interact with the Galactic Magnetic Field

For *O*(μG) and MeV—GeV electrons, synchrotron emission falls in the MHz—GHz frequency range.

Synchrotron radiation



GMF Model	parameters	
	L_m [kpc]	R_m [kpc]
I	δL_z	δR_g
II	L_z	R_g
III	1	R_g
IV	constant	

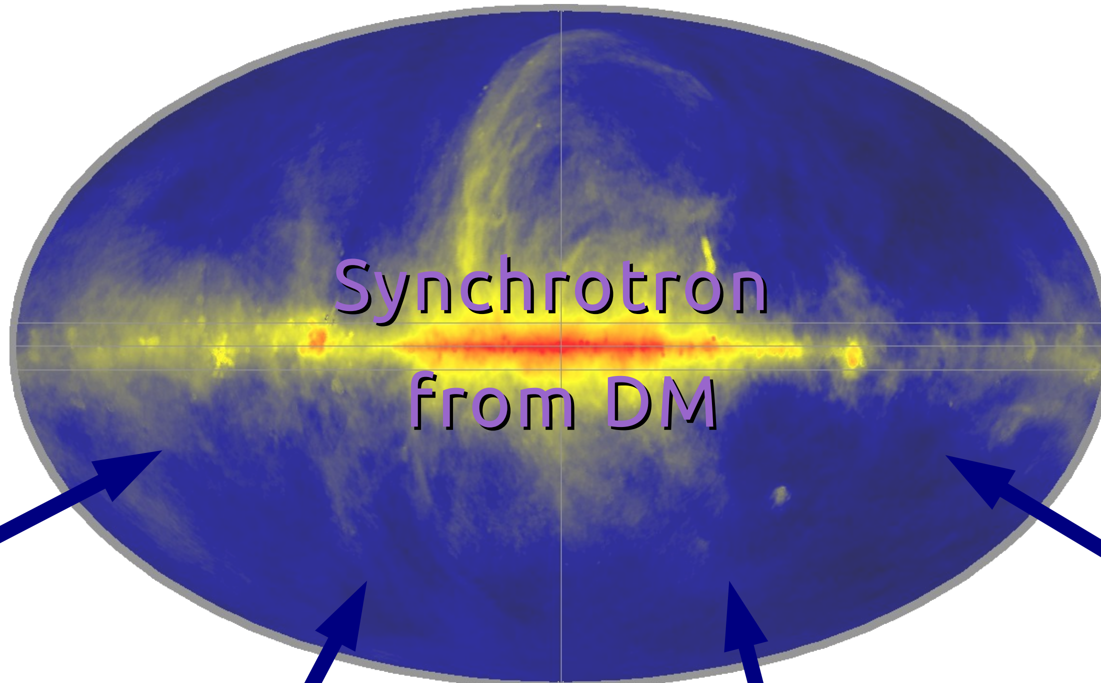
$$B(r,z) = B_0 \exp\left(-\frac{r - r_\odot}{R_m} - \frac{|z|}{L_m}\right)$$

The GMF distribution is poorly known specially outside of the Galactic plane

There are some parameterization based on RM
(see: Han et al. Astro-ph/0601357, Jansson et al. 0905.2228, Sun et al. 0908.3378)

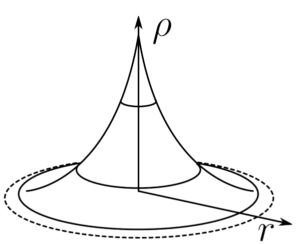
The average intensity goes ~ 1—10 μG

Uncertainties in the Galactic DM case



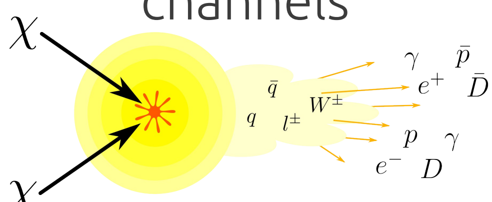
DM distribution

Isothermal
NFW



DM properties

Mass: 1-1000 GeV
5 annihilation channels



CR propagation

min/med/max

Mod.	prop. parameters		
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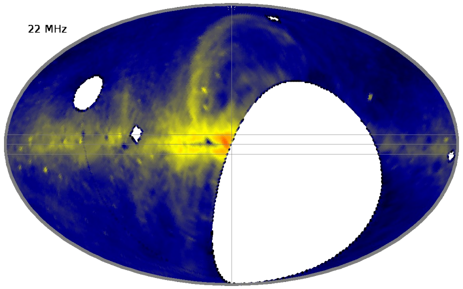
max	15	0.0765	0.46

GMF distribution

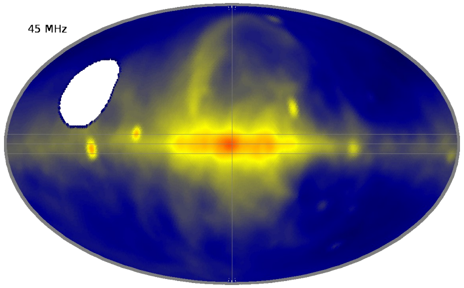
4 models

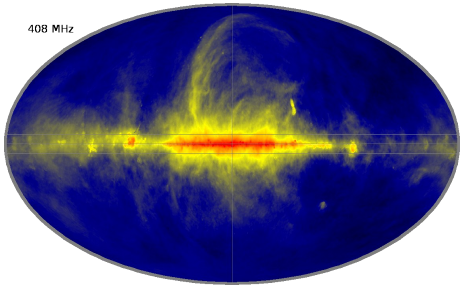
Observations from 22 to 1420 MHz



← @22MHz DRAO: Roger et al. 1999

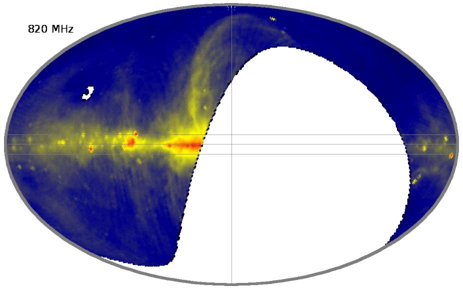
@45MHz Guzmán et al. 2010 →

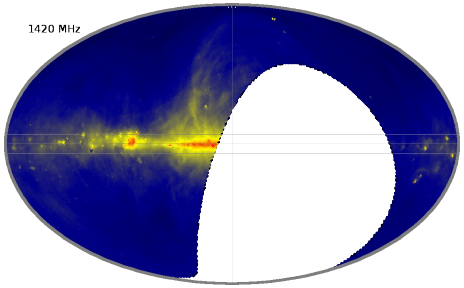




← @408MHz Haslam et al. 1982

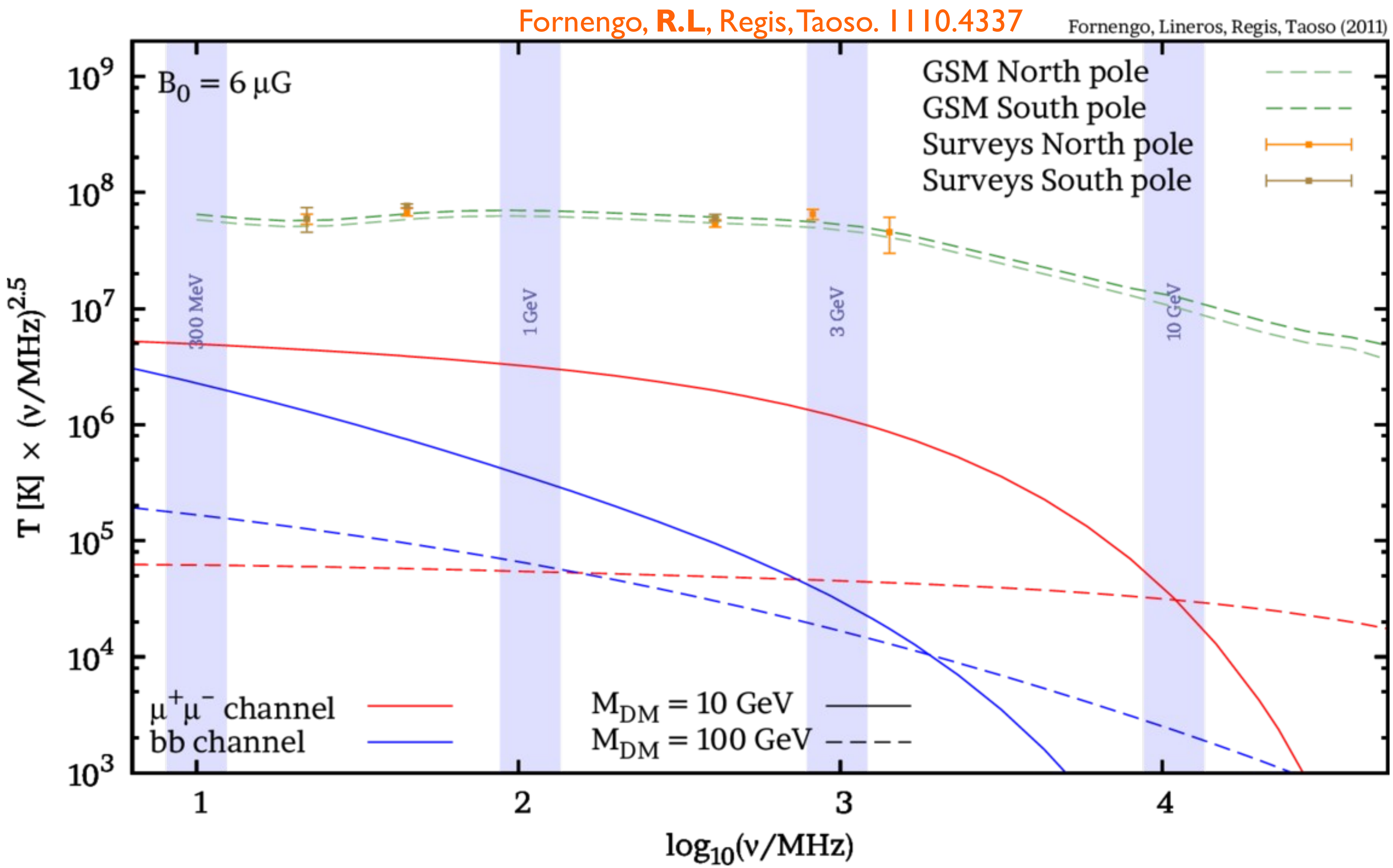
@820MHz Berkhuijsen et al. 1972 →





← @1420MHz Reich and Reich et al. 1986

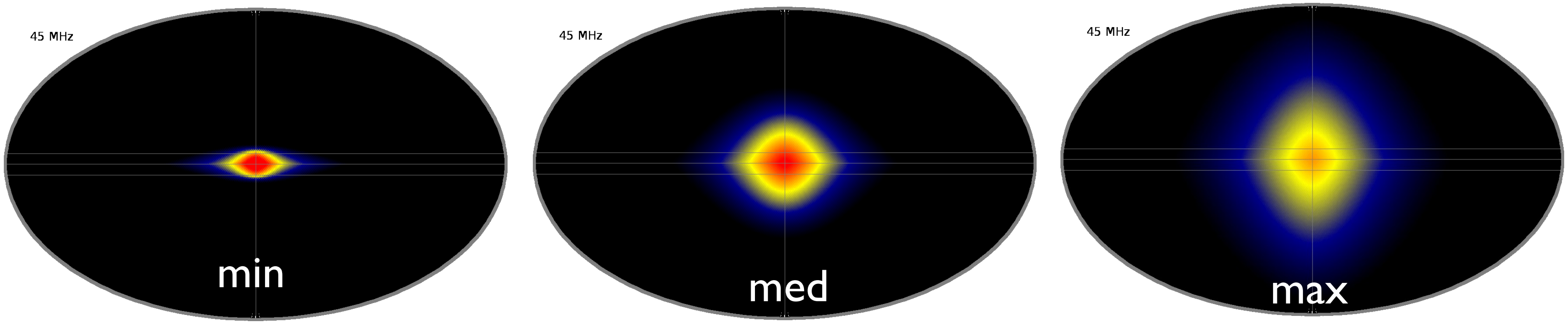
Frequency spectrum



Lower frequencies are better for testing light DM.
The frequency spectrum depends on the annihilation channel and mass value

Synchrotron DM @45MHz

(σv) = 3 x 10^{26} cm^3/sec; DM DM → μμ; NFW



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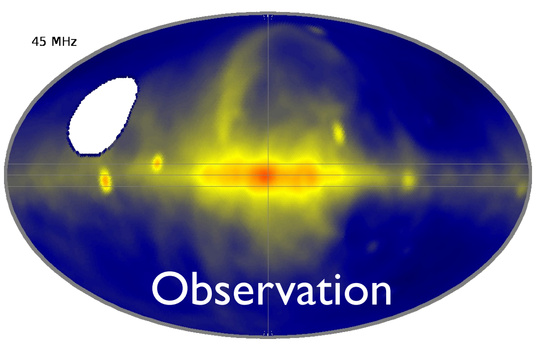
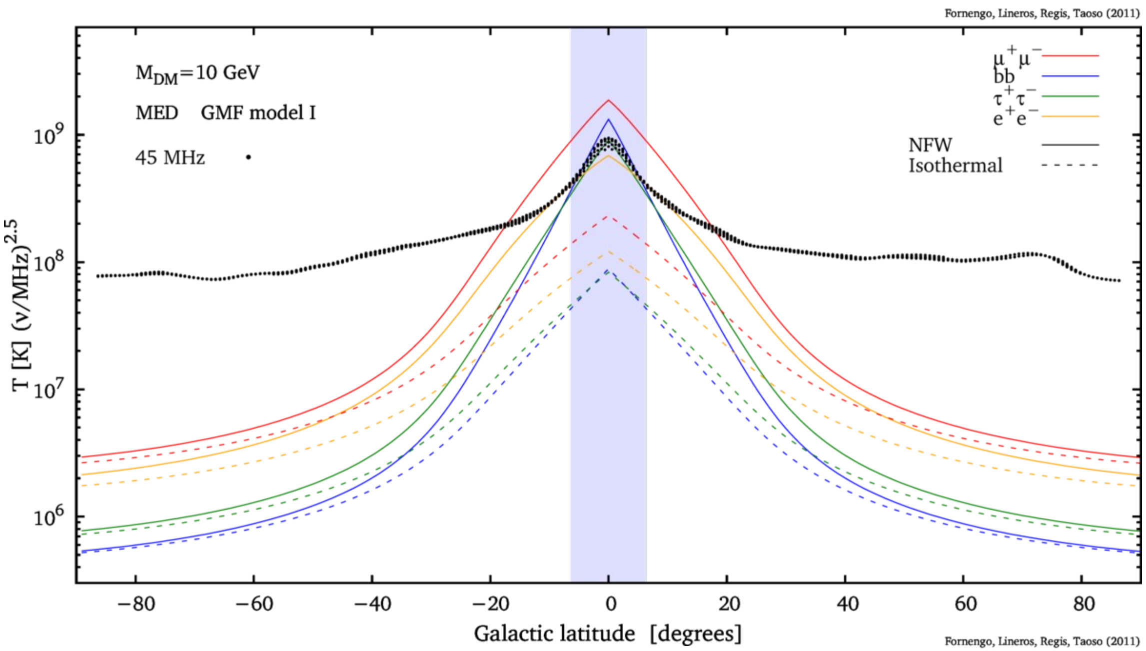
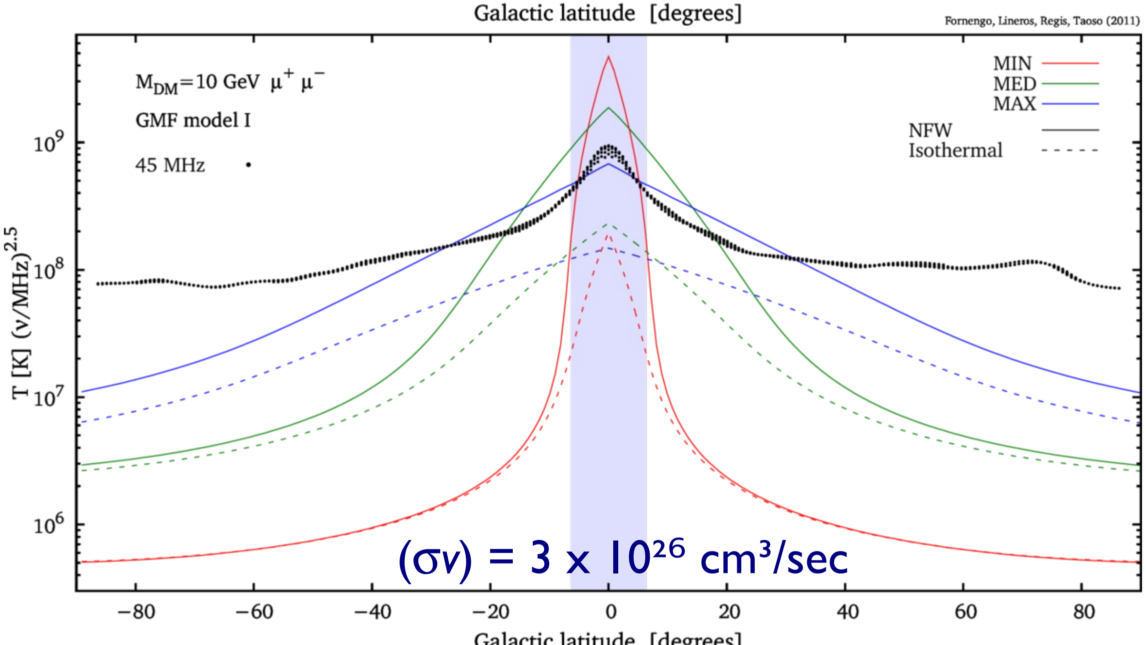


DM annihilation with thermal cross section produce radio waves as intense as the observations

* same color scale

Synchrotron DM @45MHz





The morphology depends on:

Annihilation channel
DM distribution

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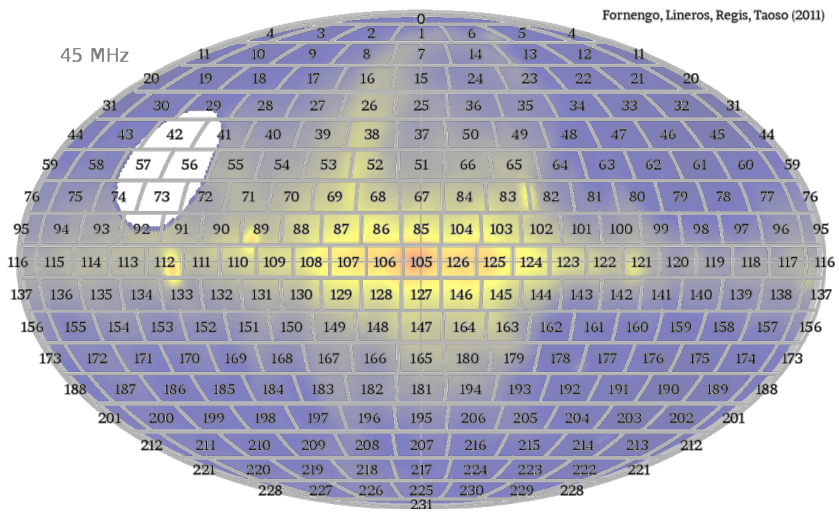
Also depends on:

Propagation model

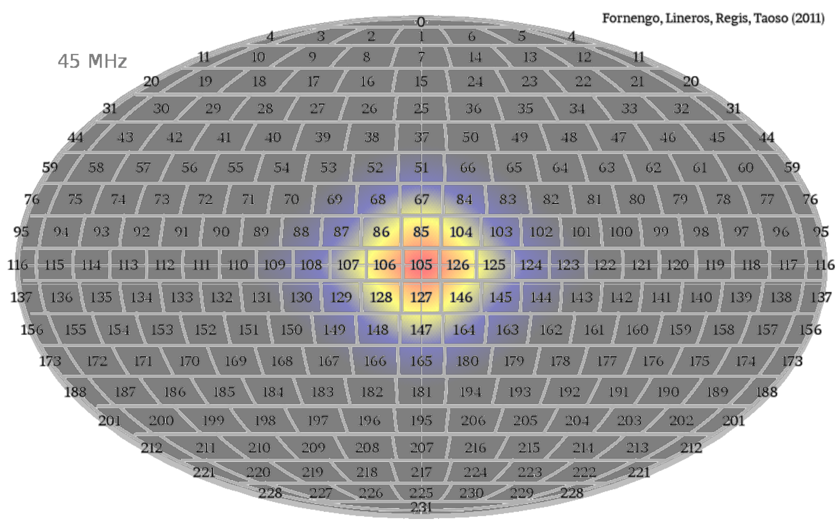
$|b|<30^o$ region is promising

Constraining Galactic DM



We divide Obs/DM skymaps into several patches ~10ºx10º

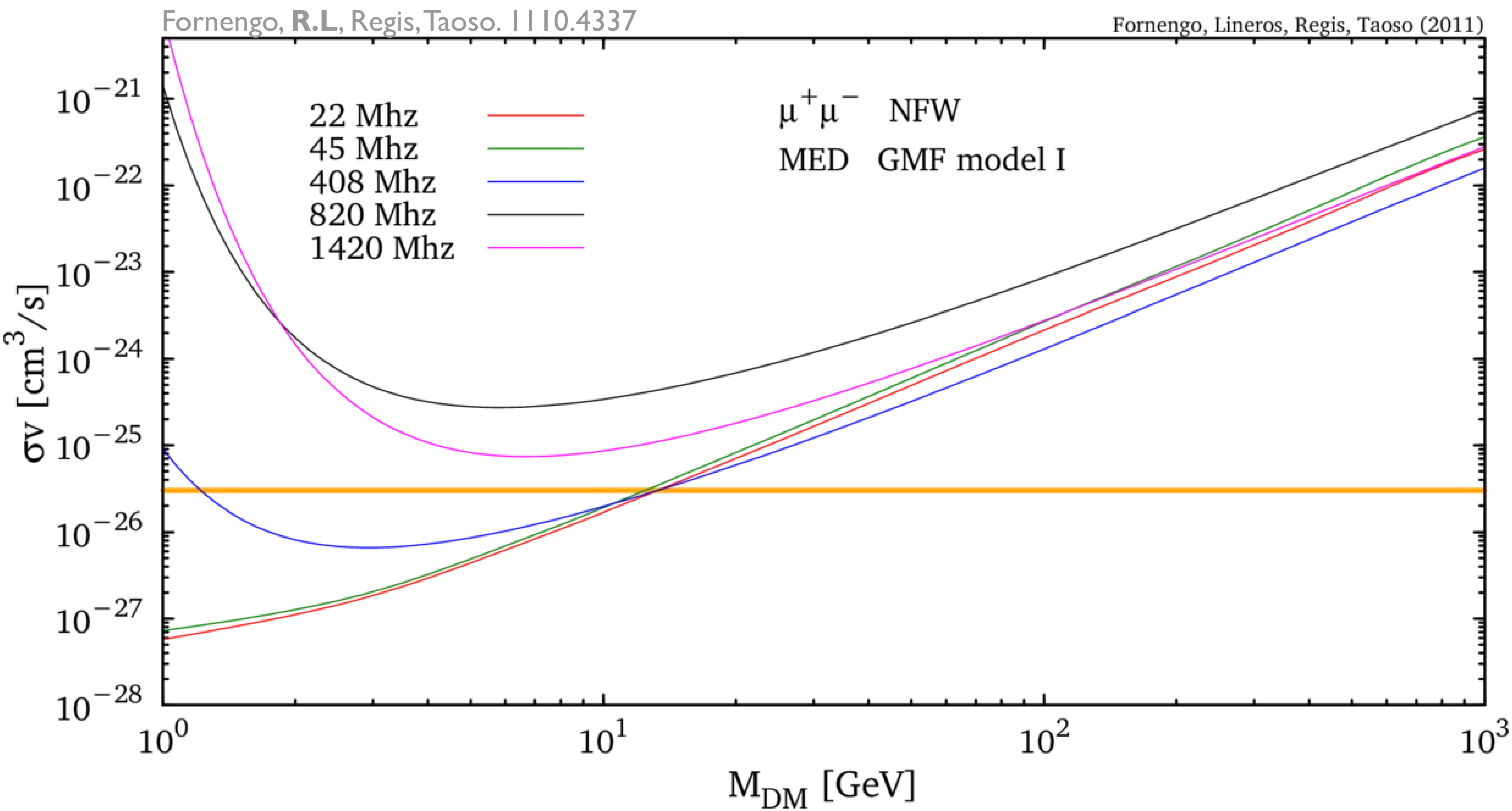
$$T_{\rm DM} \leq T_{\rm obs} + 3\sigma$$



We calculate an upper bound for (σv)

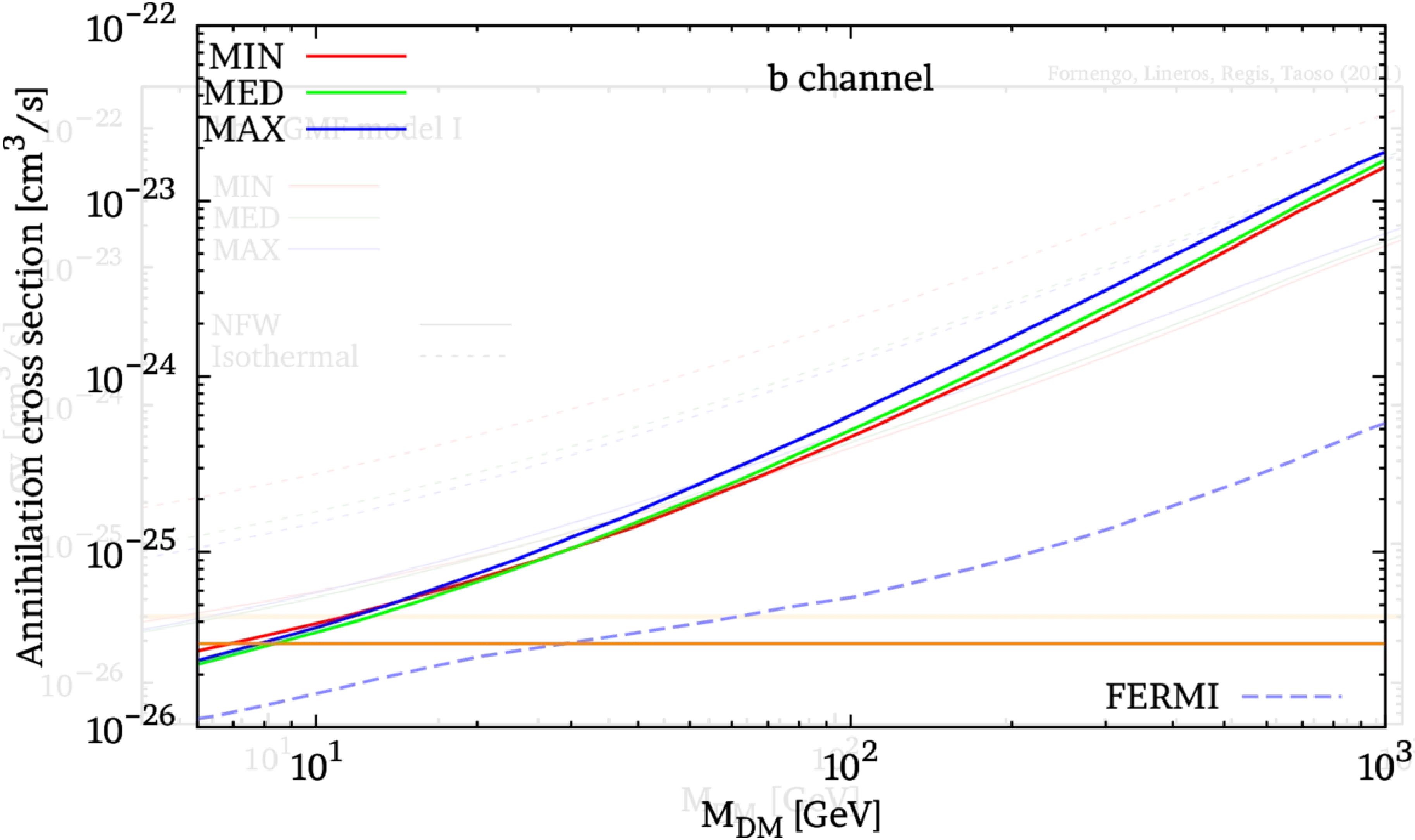
using the most stringent patch in every skymap

Constraining Galactic DM



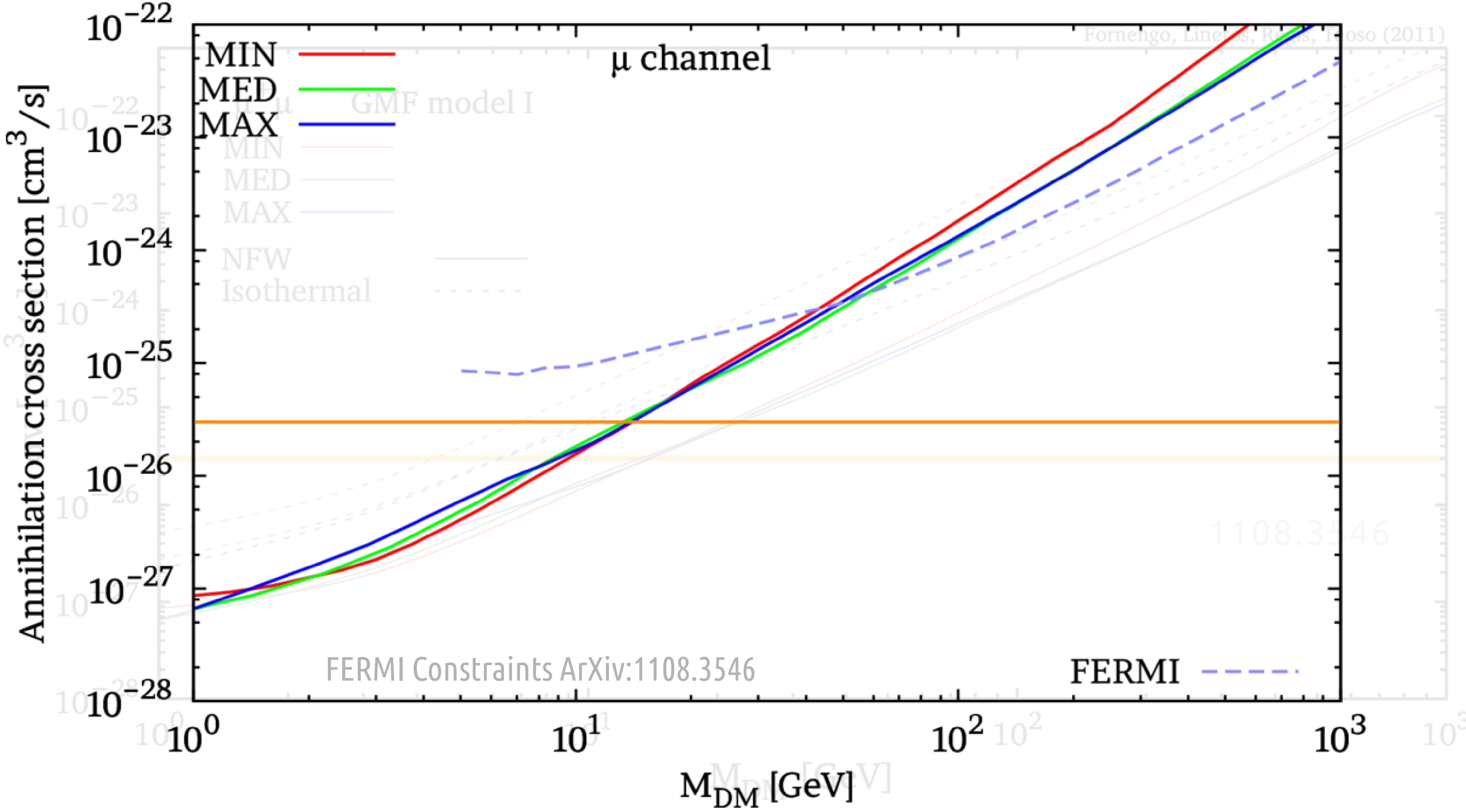
As we expect, the constraints depends also on the DM mass and the frequency

Constraining Galactic DM



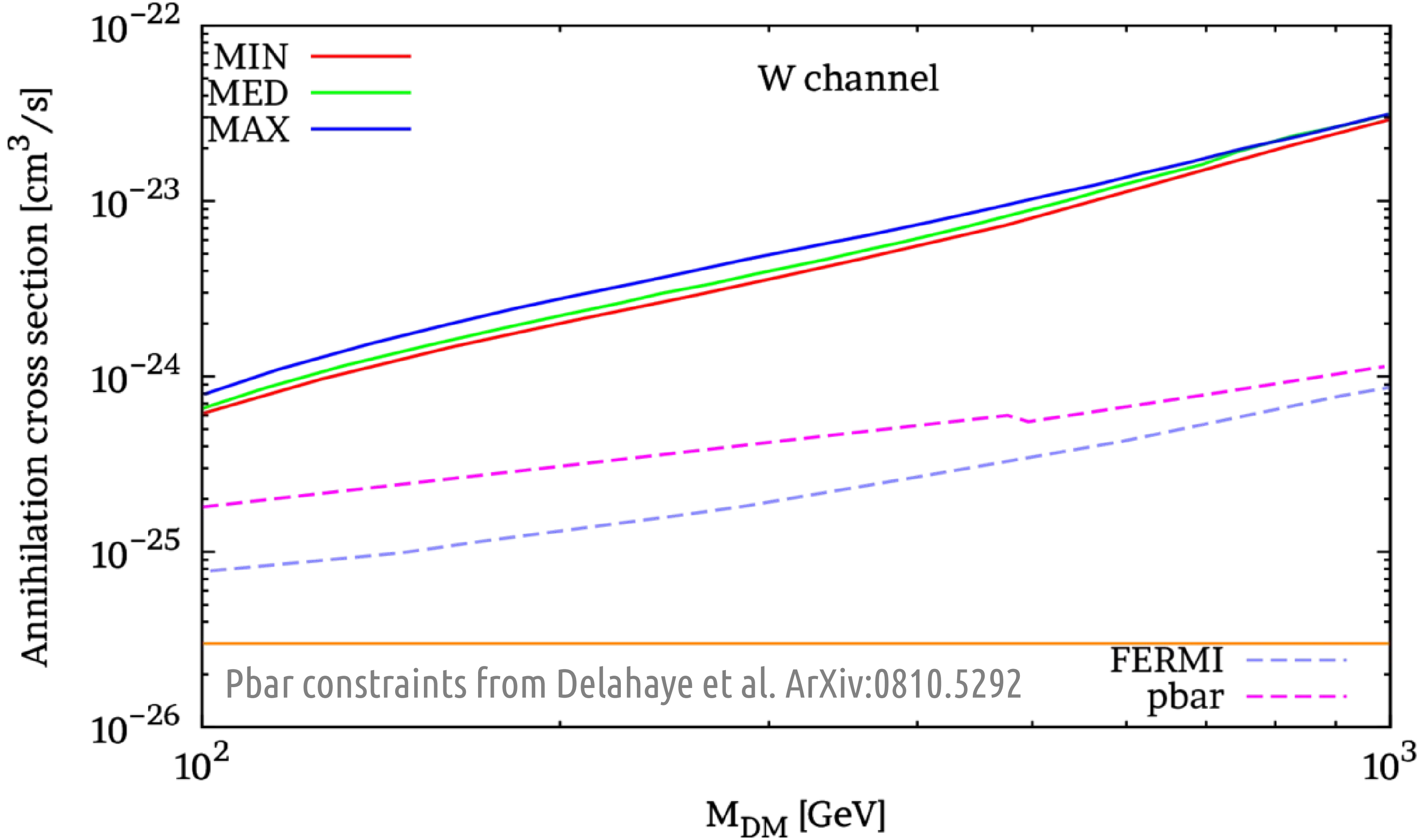
Light DM (< 10GeV) can be constrained
the thermal cross section is reached ~10GeV

Constraining Galactic DM



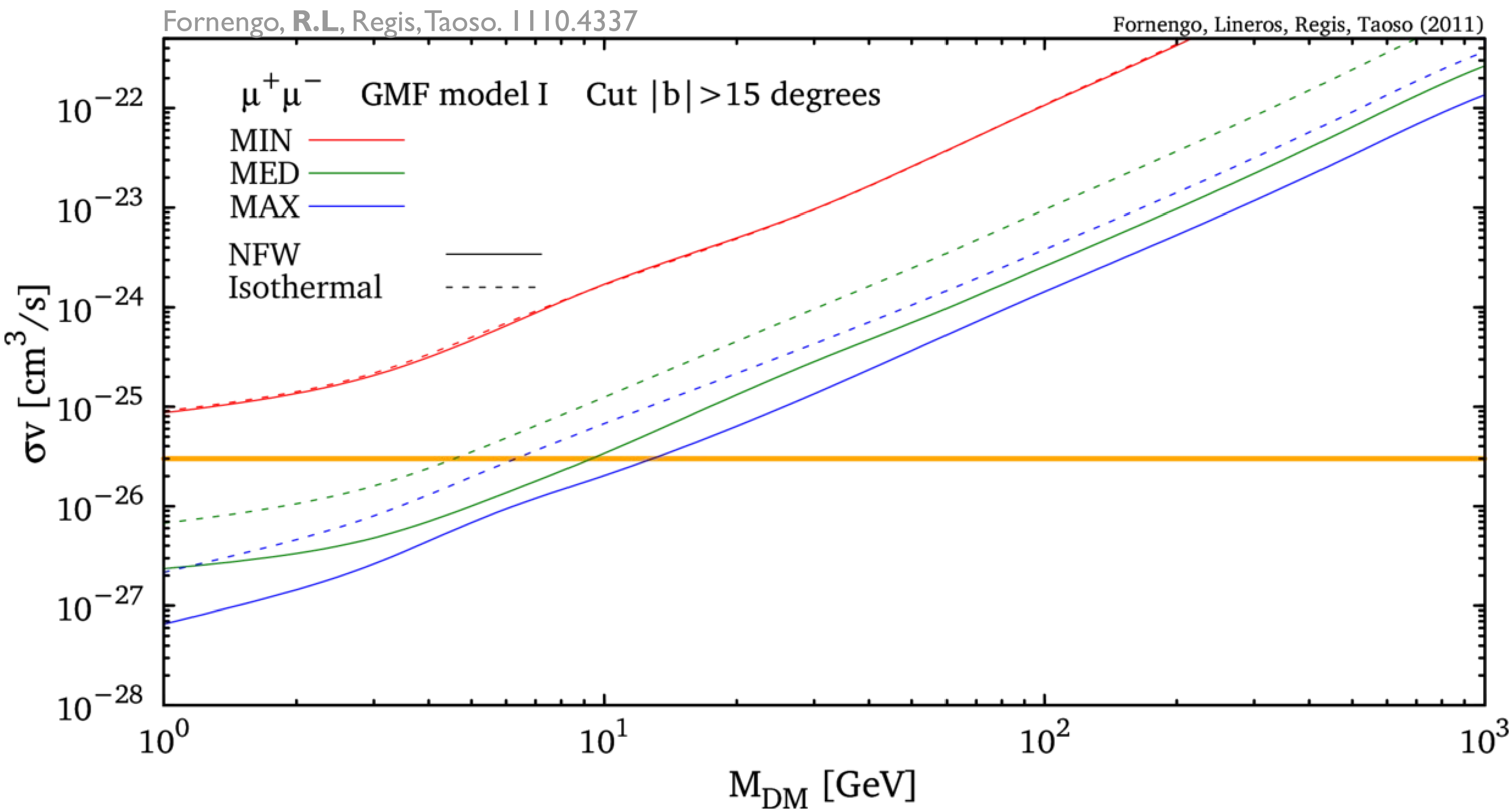
Constraints can reach the thermal cross section
For case of μ: Radio can do better than FERMI

Constraining Galactic DM



Bound for WW and < 100 GeV DM are not so stringent

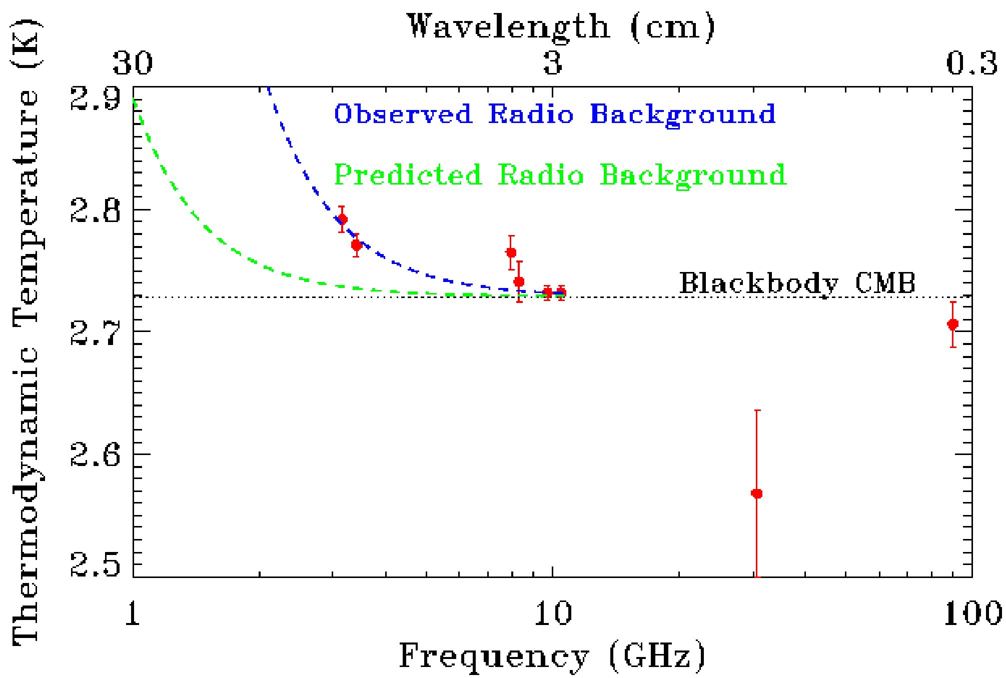
Constraining Galactic DM



Patches out of the Galactic plane give less stringent results.

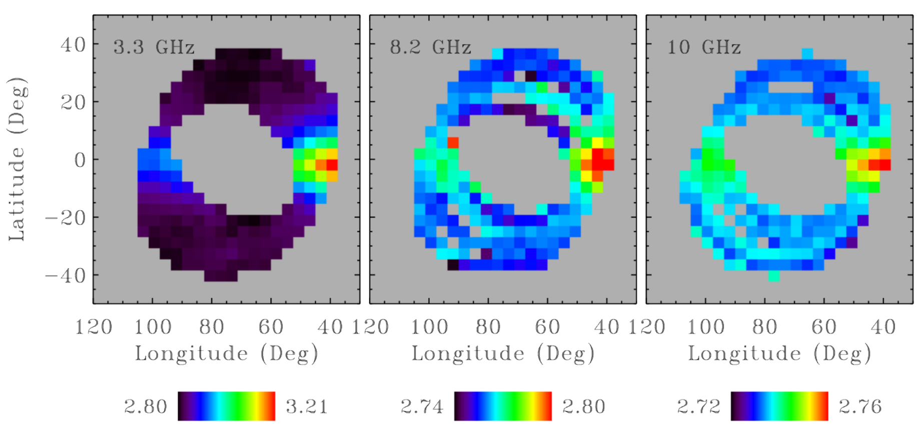
Cutting the disk has big impact on min (L_z=1kpc) propagation model.

Extragalactic background: ARCADE 2 excess



They have reported an excess in the radio background which is bigger that the expected with known sources

$$T_{sky}(\nu,\alpha,\delta) = T_{cmb}(\nu) + T_{gal}(\nu,\alpha,\delta) + T_{UERS}(\nu)$$

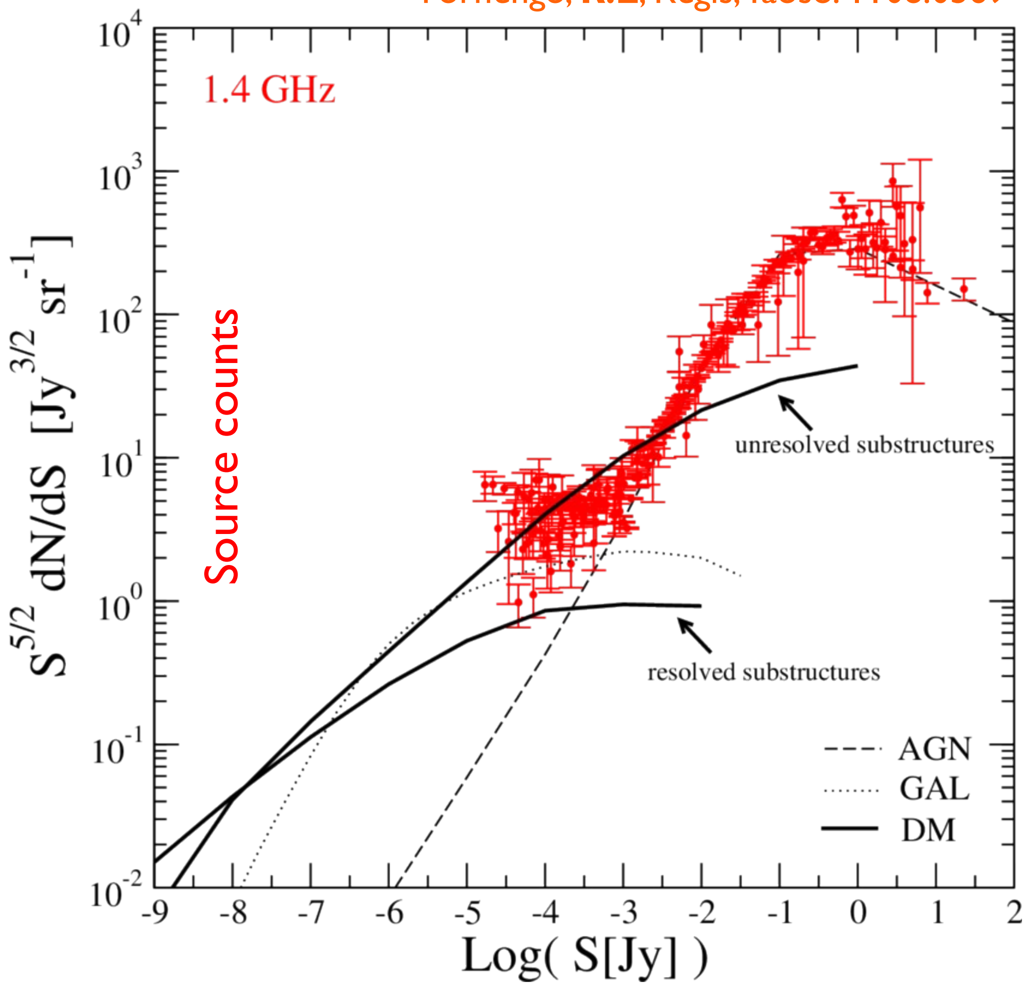


More details:
Firxen et al. arXiv:0901.0555
Seiffert et al. arXiv:0901.0559

http://arcade.gsfc.nasa.gov

ARCADE 2 excess

Fornengo, **R.L**, Regis, Taoso. 1108.0569



intensity

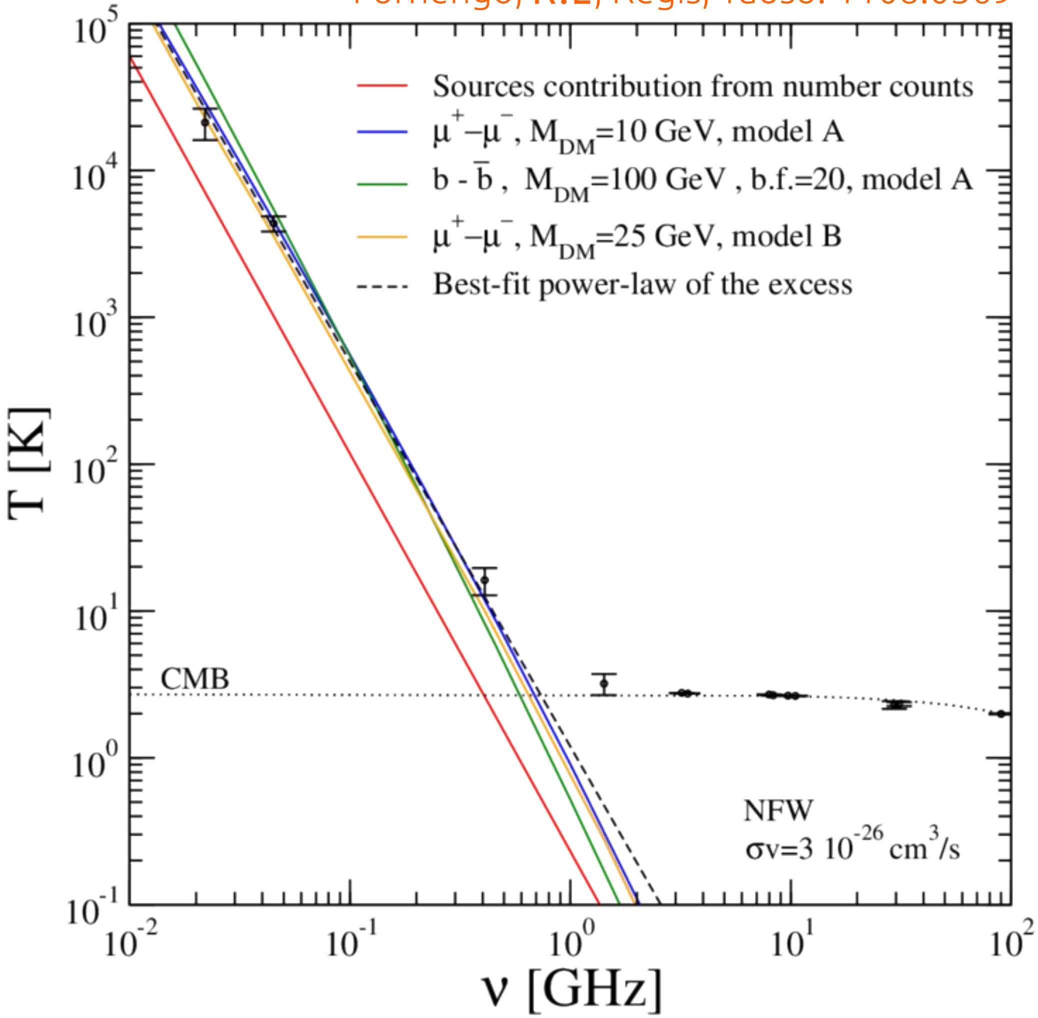
The source counts is the key to understand the excess

The ARCADE excess needs of a extragalactic population of sources that dominates at low luminosity and have a steep spectrum

Could the DM do the job?

ARCADE 2 excess

Fornengo, **R.L**, Regis, Taoso. 1108.0569



In principle, DM could provide the missing signal.

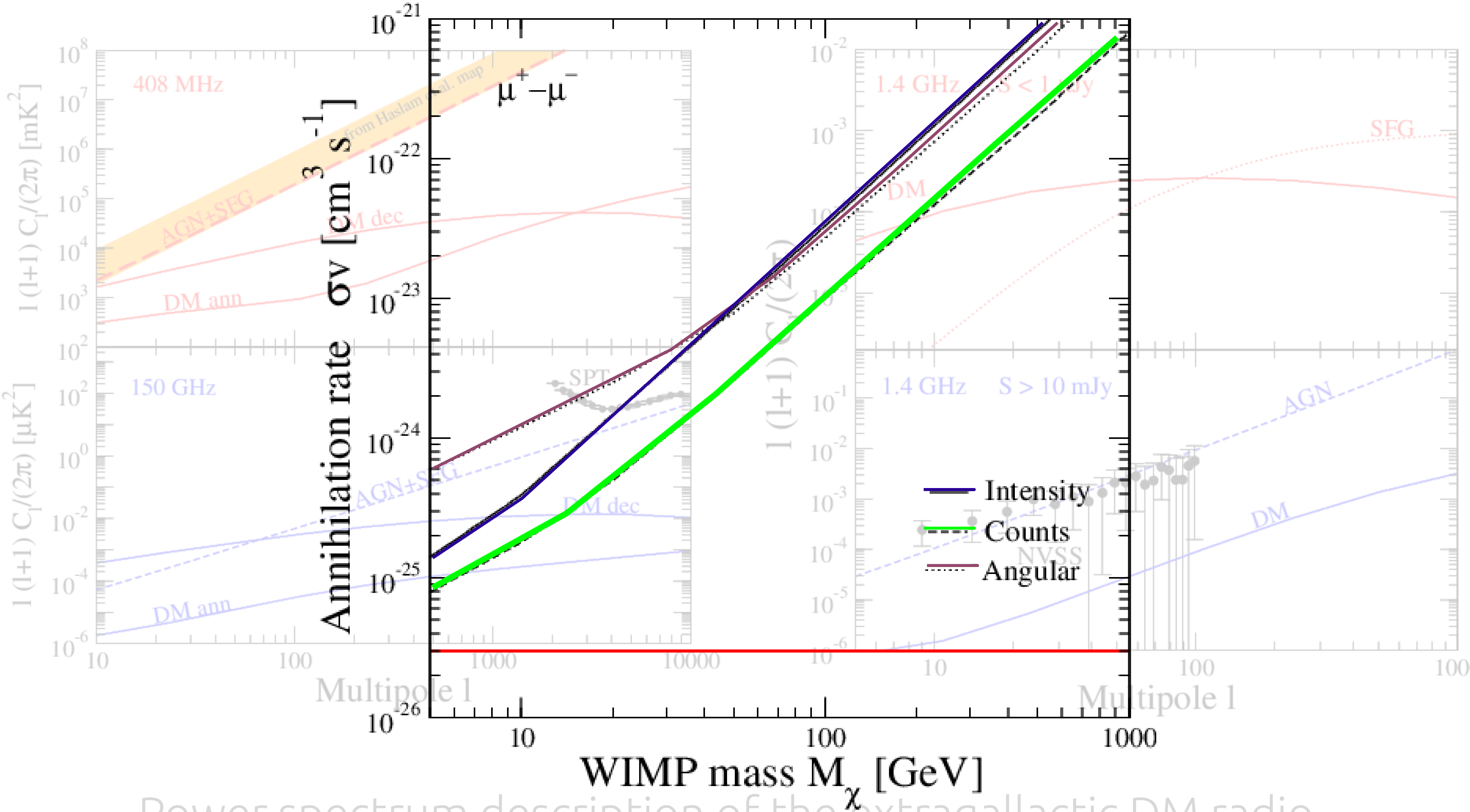
However, it is not unique.

Alternative explanations:

Faint quasars, radio-quite AGNs, star forming galaxies, unresolved galactic sources(?)

More details:
Gervasi et al. 0803.4138
Singal et al. 0909.1997

Beyond the extragalactic background



Power spectrum description of the extragallactic DM radio.
A full analysis and forecast are very challenging

Conclusions

- Searches of Dark Matter imprints on the (extra)Galactic radio maps gives a very interesting tool to constrain it

- DM radio searches would be able to touch the DM region with thermal value of (σv)

- Lower frequencies are more suitable to test light DM candidates, however cross correlation with other observables are required

- ARCADE 2 excess *would* have a DM explanation which is compatible with many other observations

Thanks for your attention