Radio constraints on Galactic WIMP dark matter

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Based on:

Galactic synchrotron emission from WIMPs at radio frequencies / JCAP01(2012)005, 1110.4337

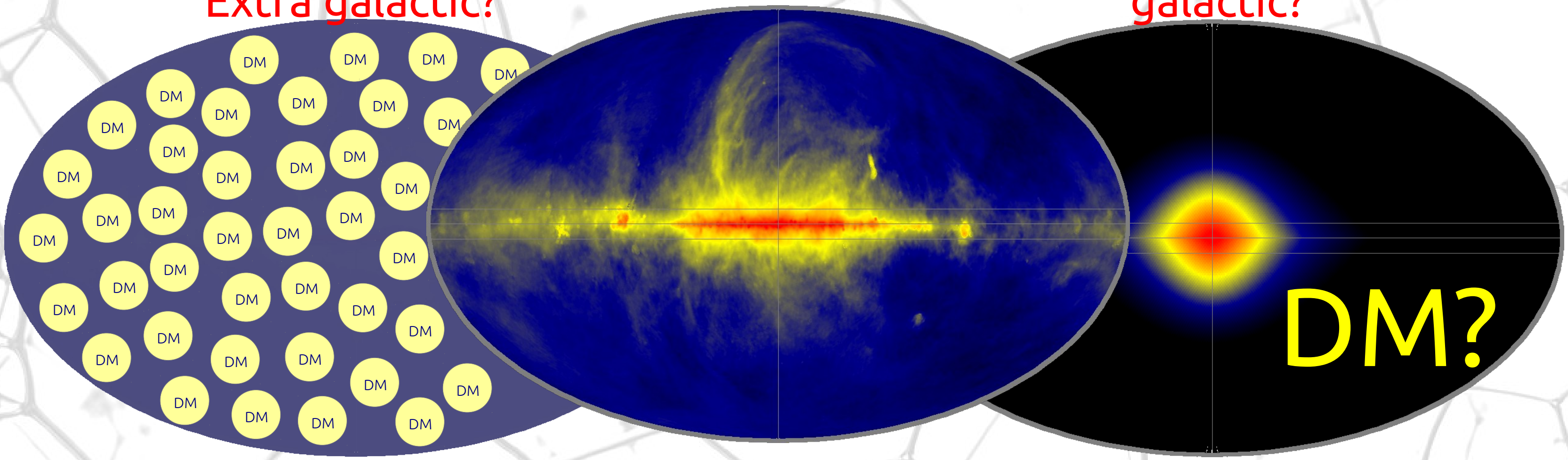
4th Roma International Conference on AstroParticle Physics
22 – 24 May, 2013

Motivation

Possible contribution to the radio sky from WIMP dark matter

Extra galactic?

galactic?

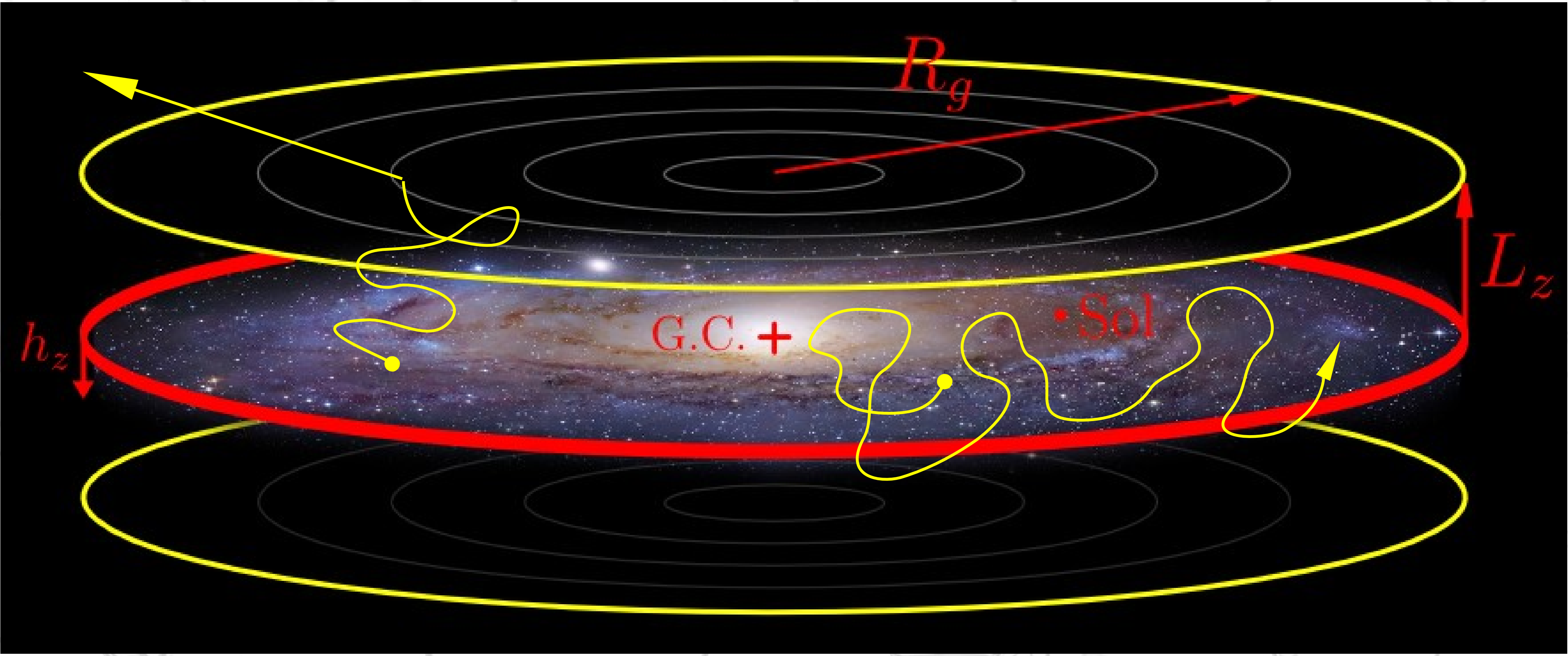


Haslam map @408MHz

The plan

- Cosmic rays propagation
- Synchrotron emission
- Synchrotron from Galactic Dark Matter
- Conclusions

Cosmic rays propagation

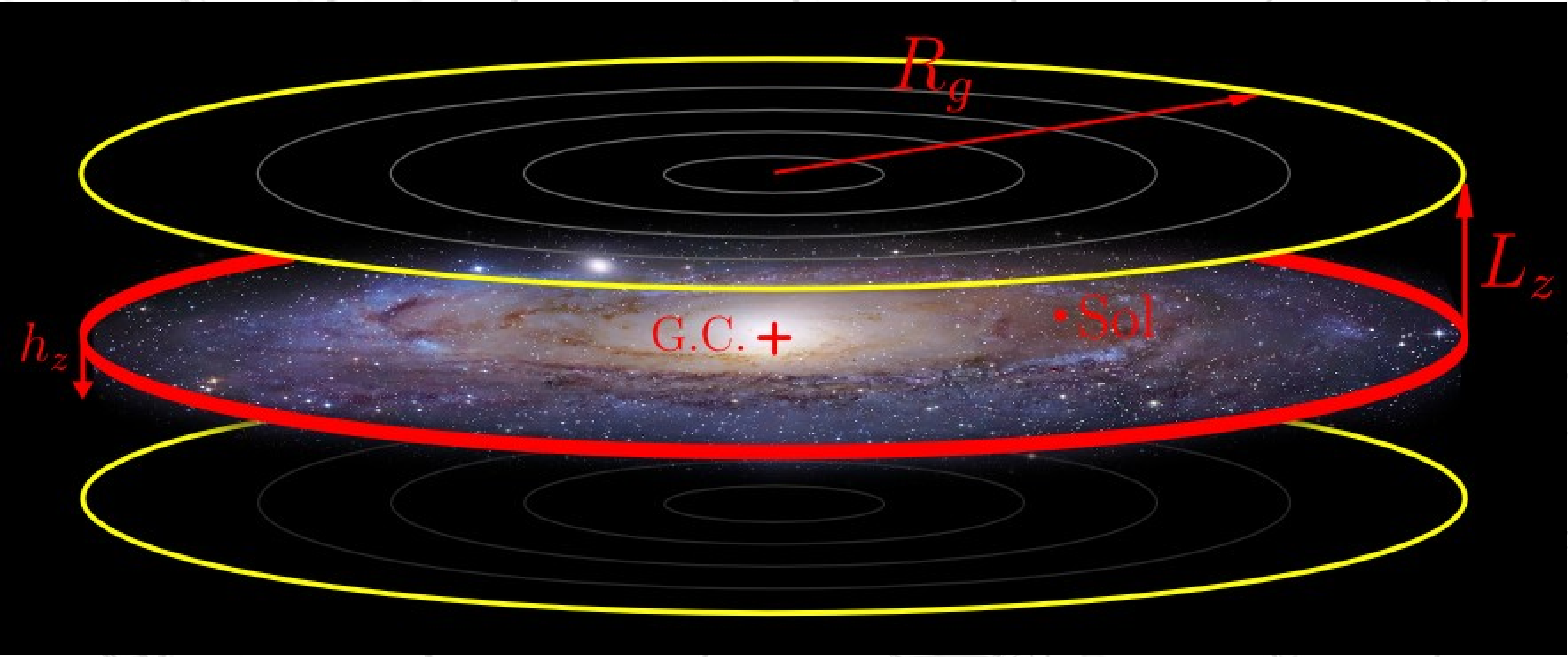


Ginzburg and Syrovatskii. 1964

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

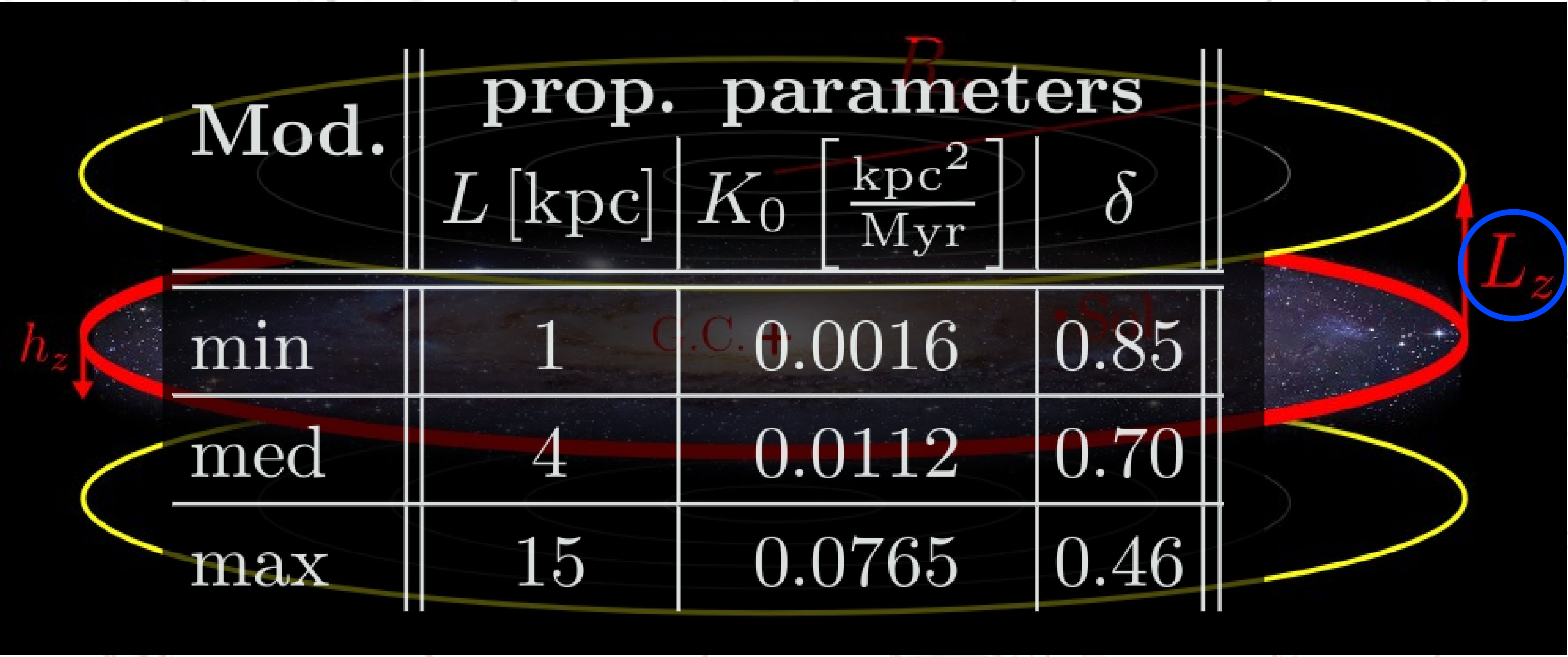


The transport equation describes the evolution of the density of cosmic rays

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

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

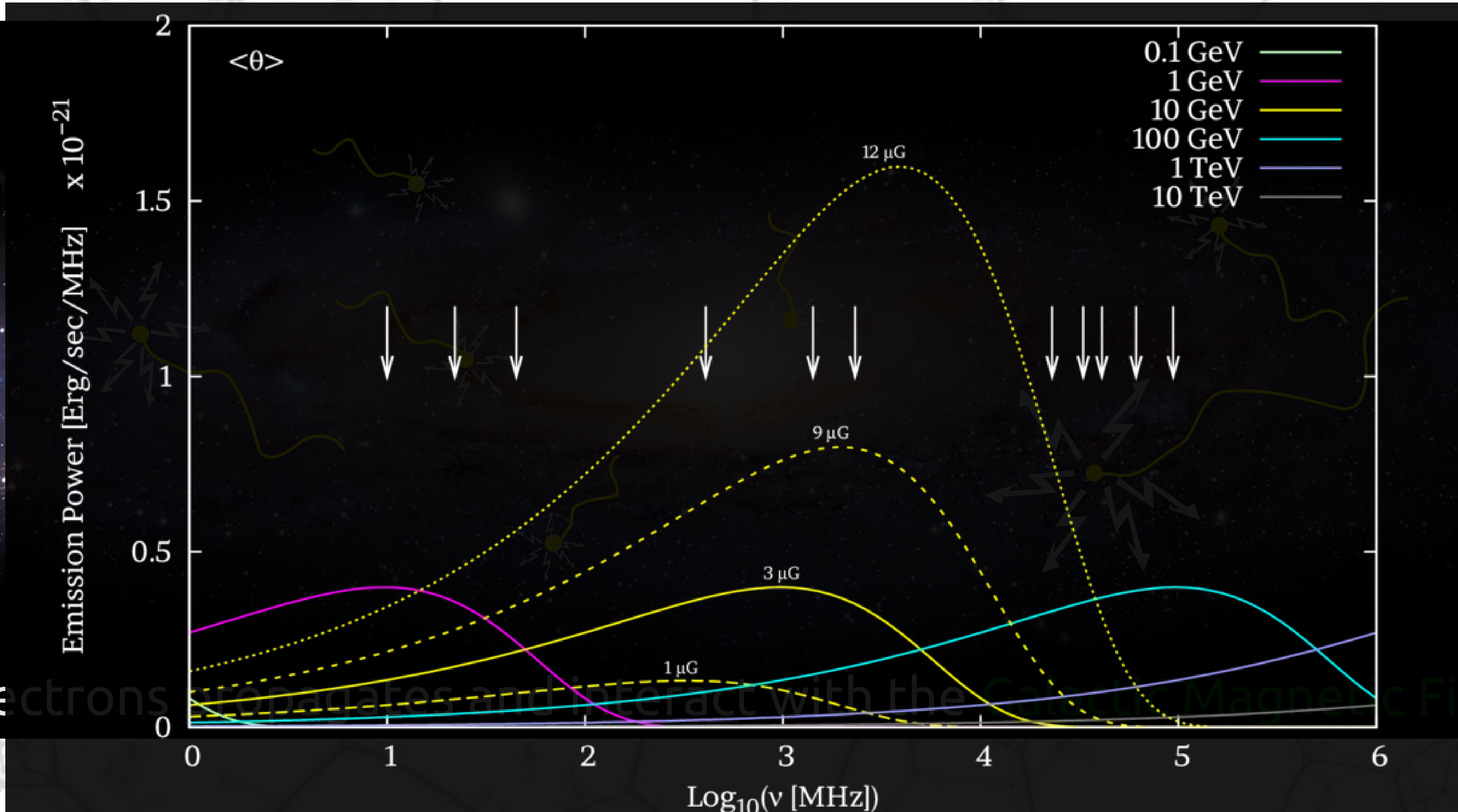
$$\frac{\partial \psi}{\partial t} + \nabla \cdot \left(-K_0 \epsilon^\delta \nabla \psi + \mathbf{V}_c \psi \right) + \frac{\partial J_\epsilon}{\partial \epsilon} = q_{\mathrm{src}}$$

Sources

Synchrotron emission

Electrons propagates and interact with the Galactic Magnetic Field

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.

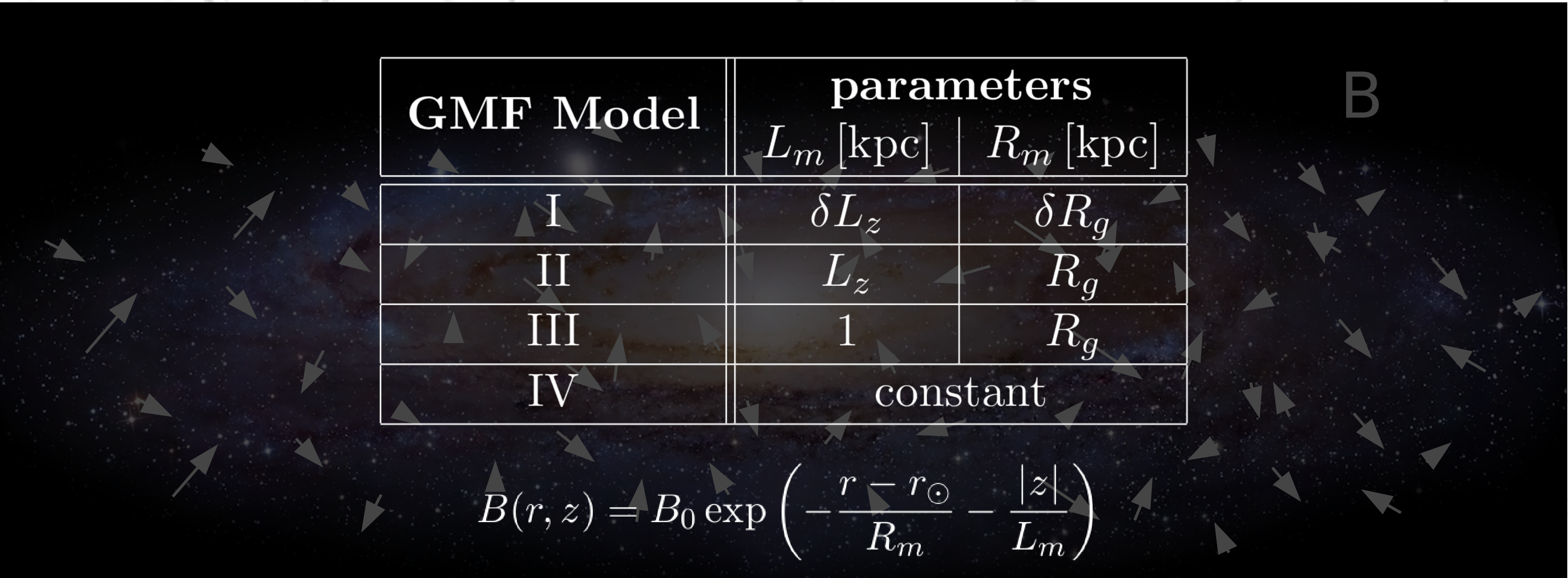
Synchrotron radiation

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

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	

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

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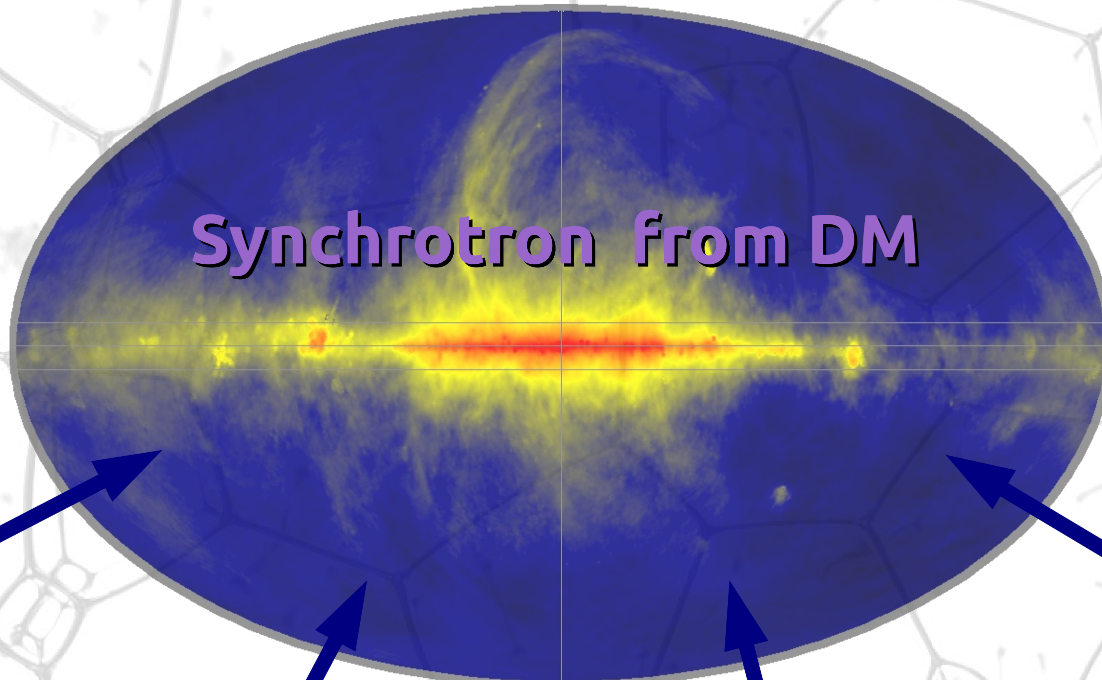
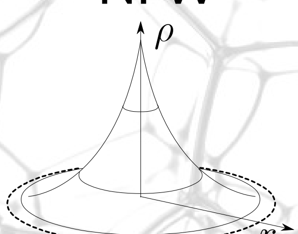
Uncertainties in synchrotron emission



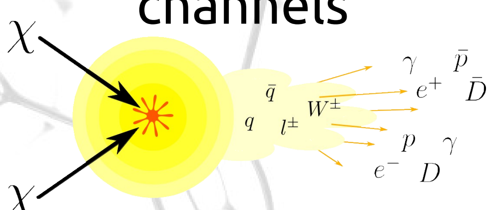
DM distribution

Isothermal
NFW



DM properties

Mass: 1-1000 GeV
5 annihilation channels



CR propagation

min/med/max

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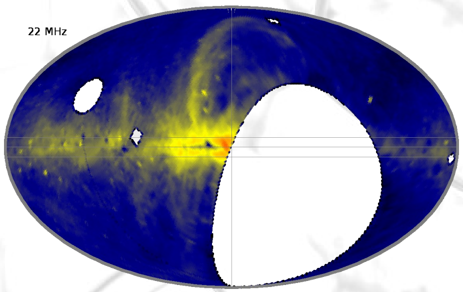
GMF distribution

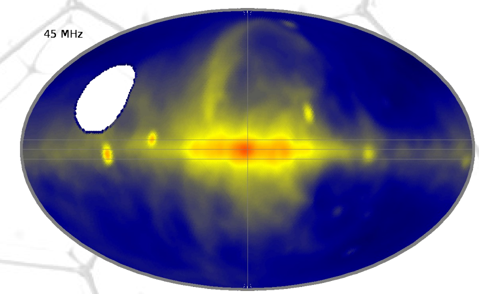
4 models

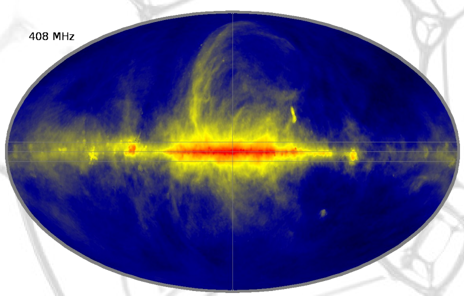
Observations from 22 to 1420 MHz



← @22MHz DRAO: Roger et al. 1999

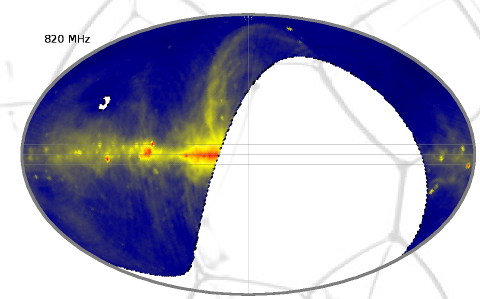
@45MHz Guzmán et al. 2010 →

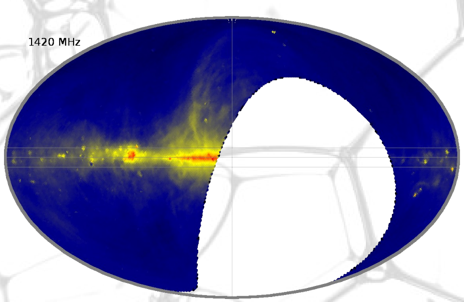




← @408MHz Haslam et al. 1982

@820MHz Berkhuijsen et al. 1972 →

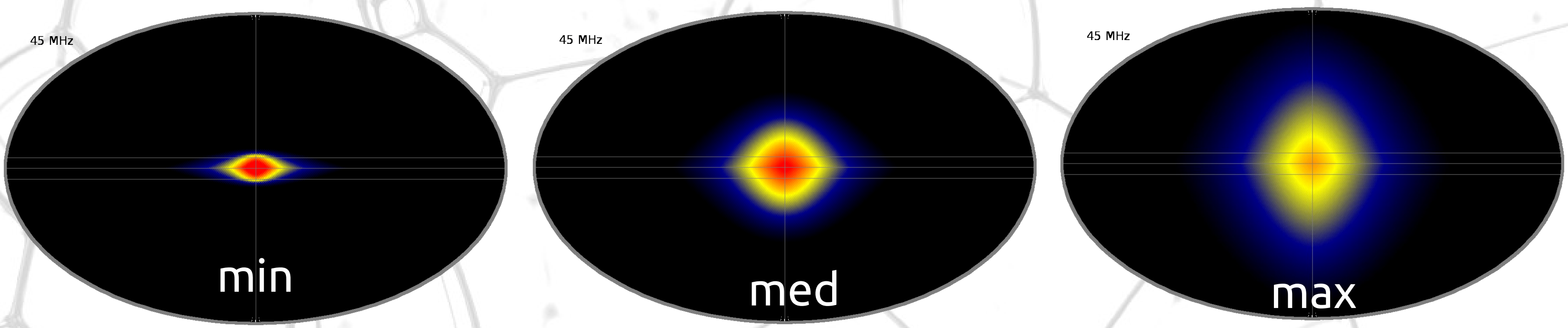




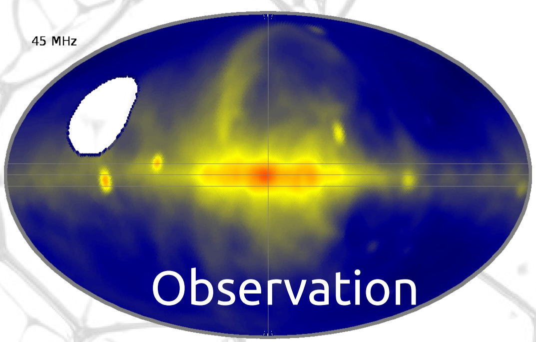
← @1420MHz Reich and Reich et al. 1986

Synchrotron DM @45MHz

$(\sigma v) = 3 \times 10^{26}$ cm^3/sec; DM DM $\rightarrow \mu\mu$; NFW

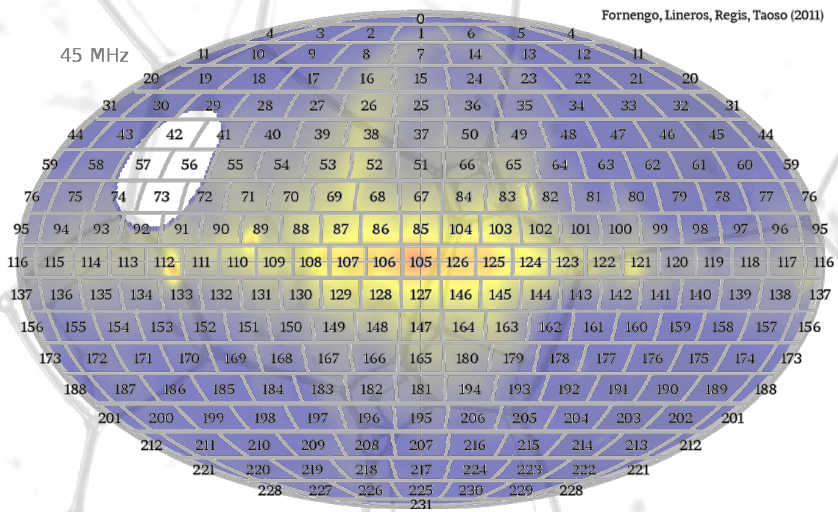


Fornengo, **R.L**, Regis, Taoso. 1110.4337



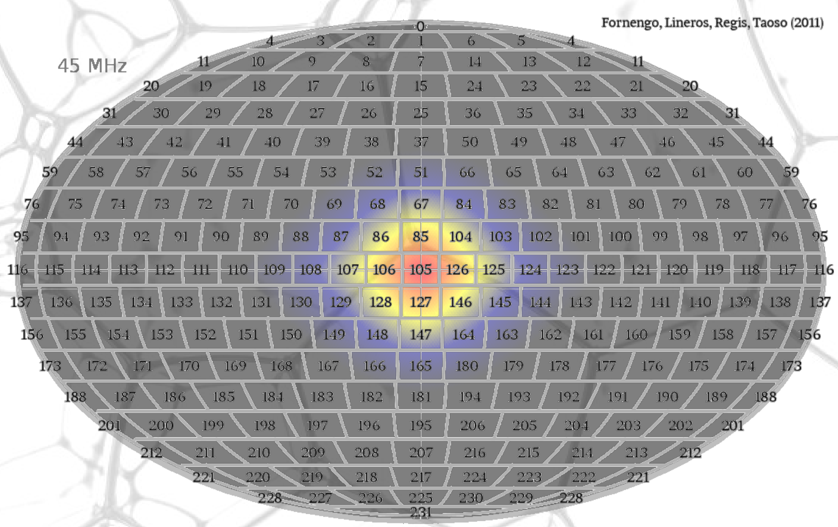
DM annihilations with thermal cross section produce synchrotron emission as intense as the observations!

Constraining Galactic DM



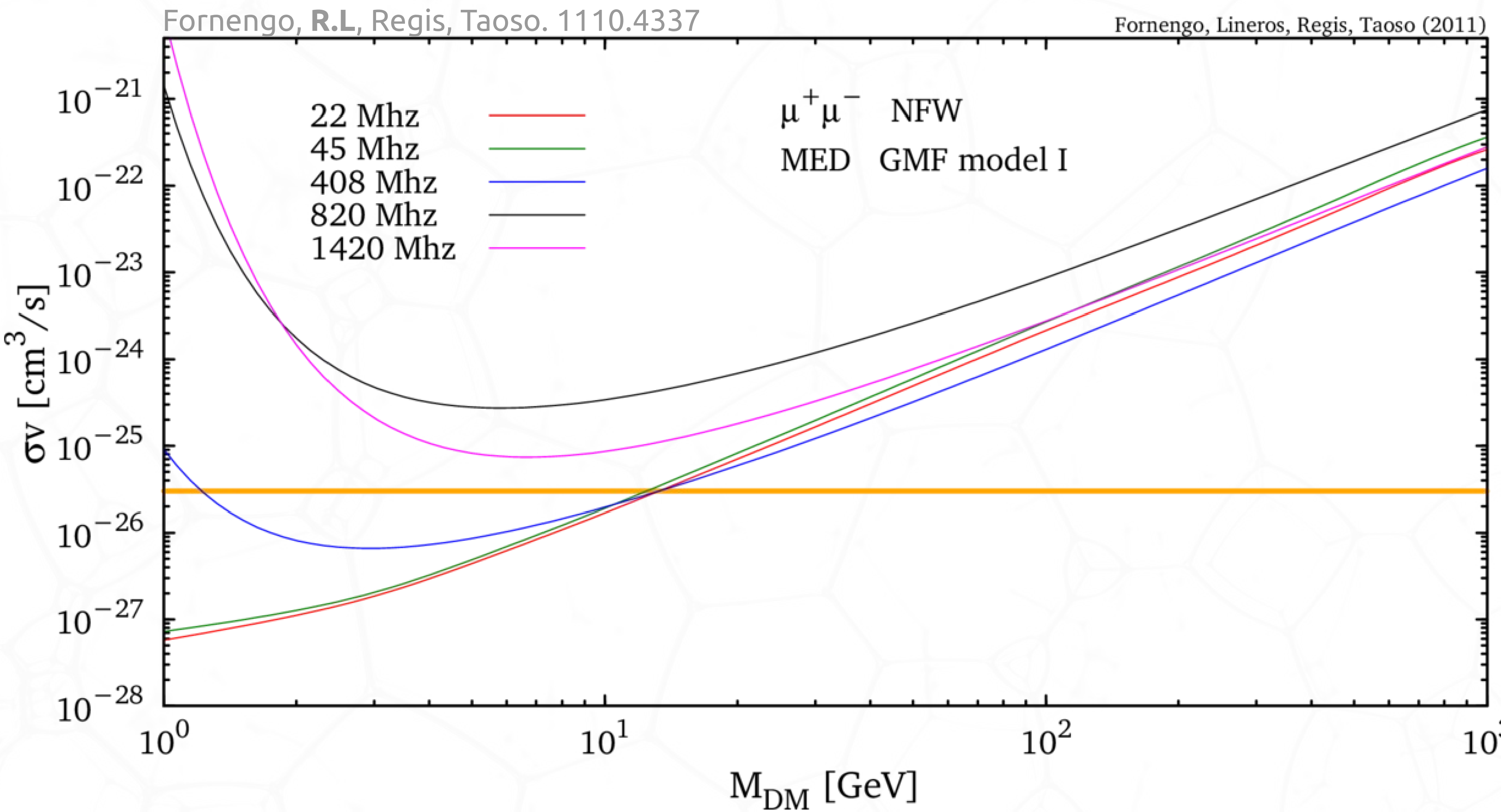
We divide Obs & DM skymaps into several patches ~10º x10º

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



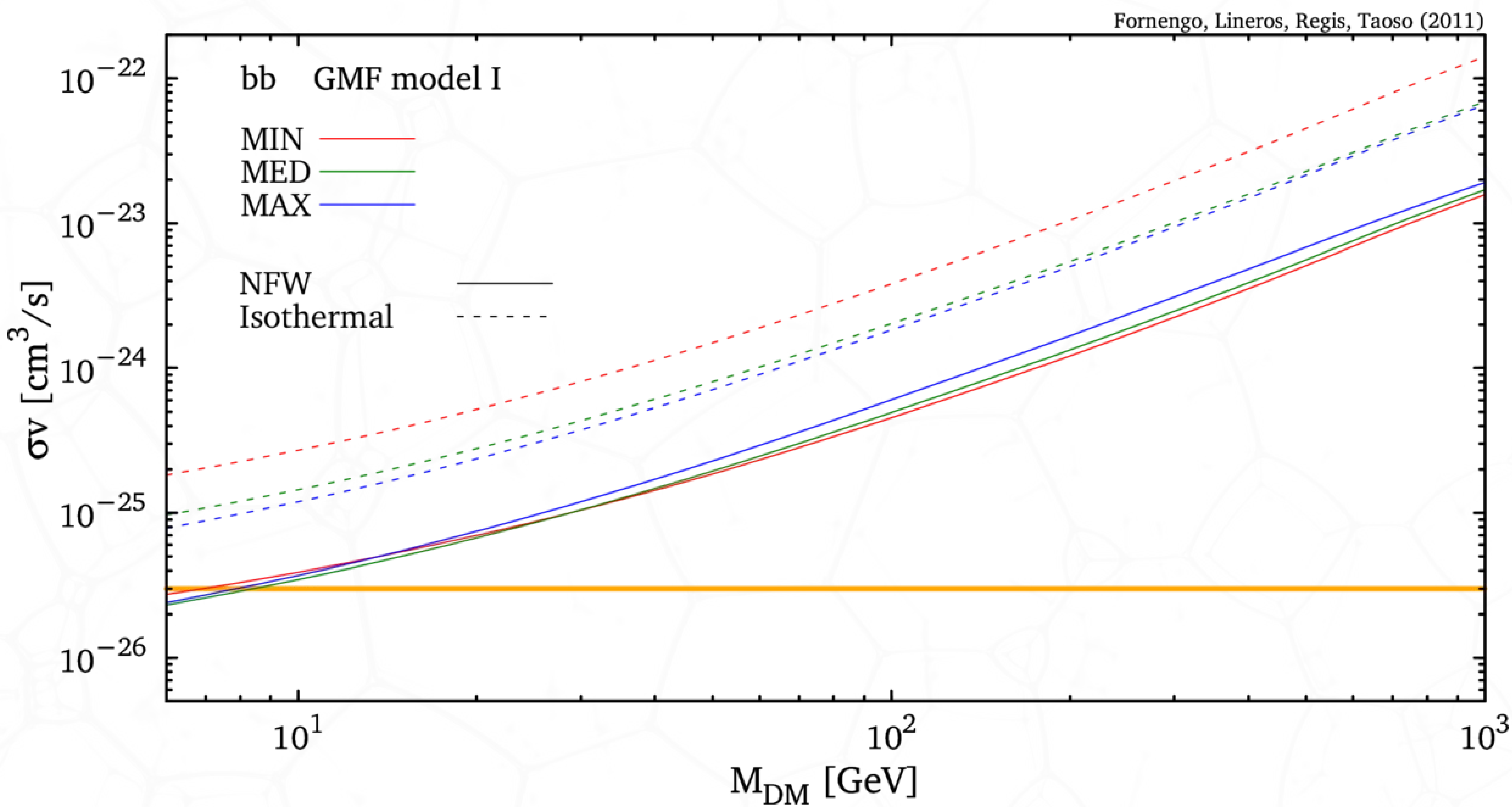
We calculate an upper bound for (σv) using the most stringent patch in each skymap

Constraining Galactic DM



Constraints depends also on the DM mass and the frequency

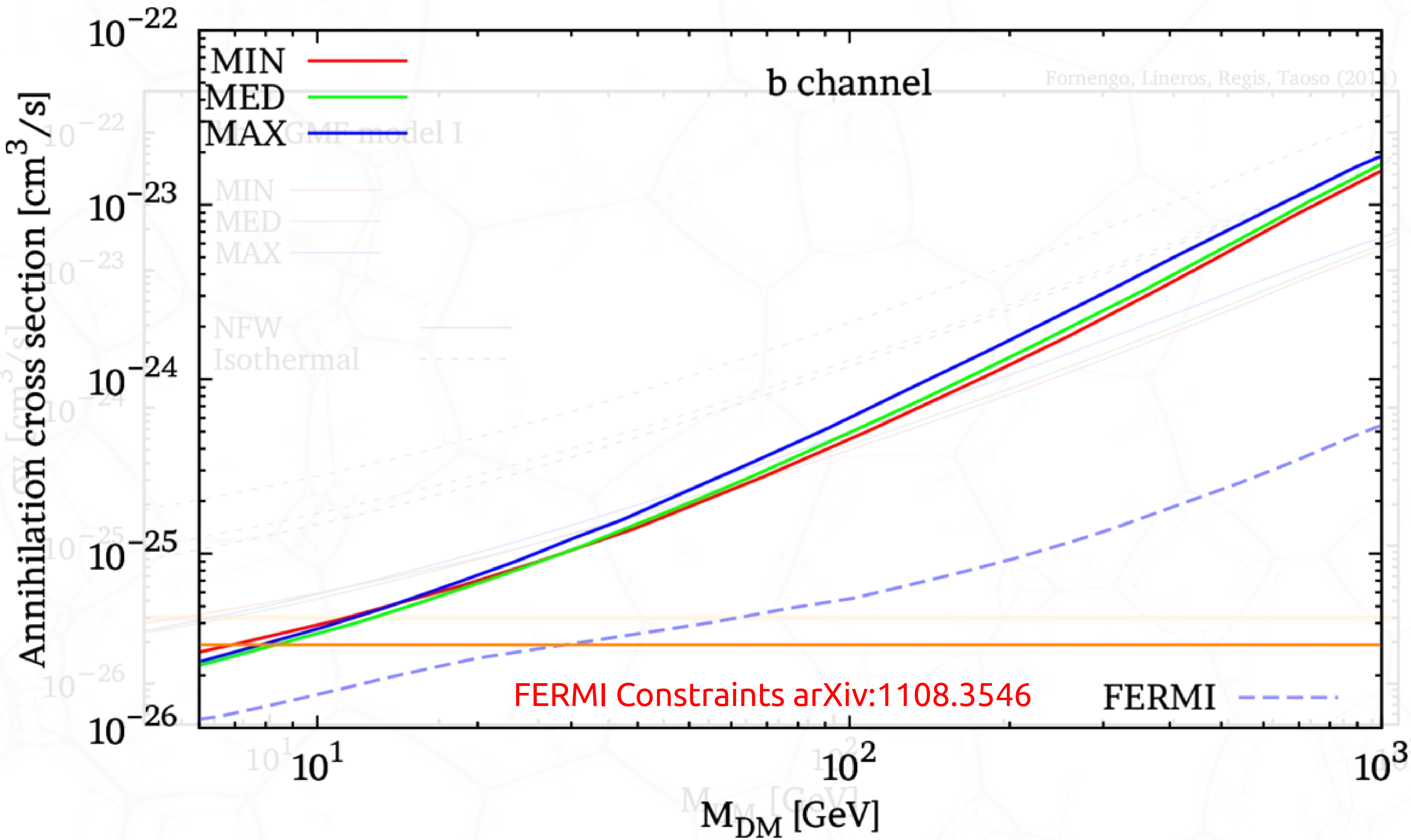
Constraining Galactic DM



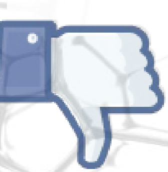
Light DM (< 10GeV) can be constrained

the thermal cross section is reached ~10GeV

Constraining Galactic DM

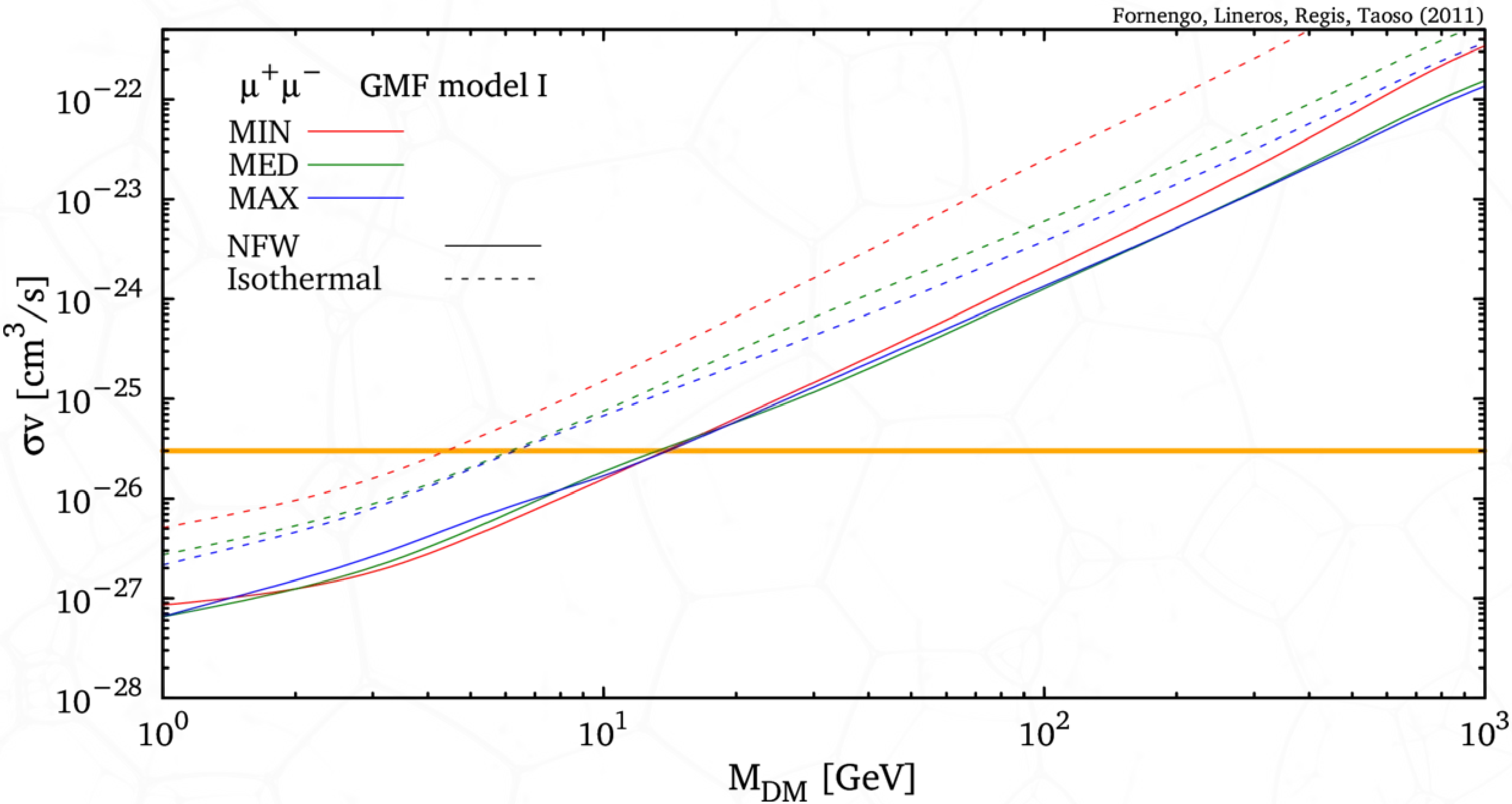


Light DM (< 10GeV) can be constrained



the thermal cross section is reached ~10GeV

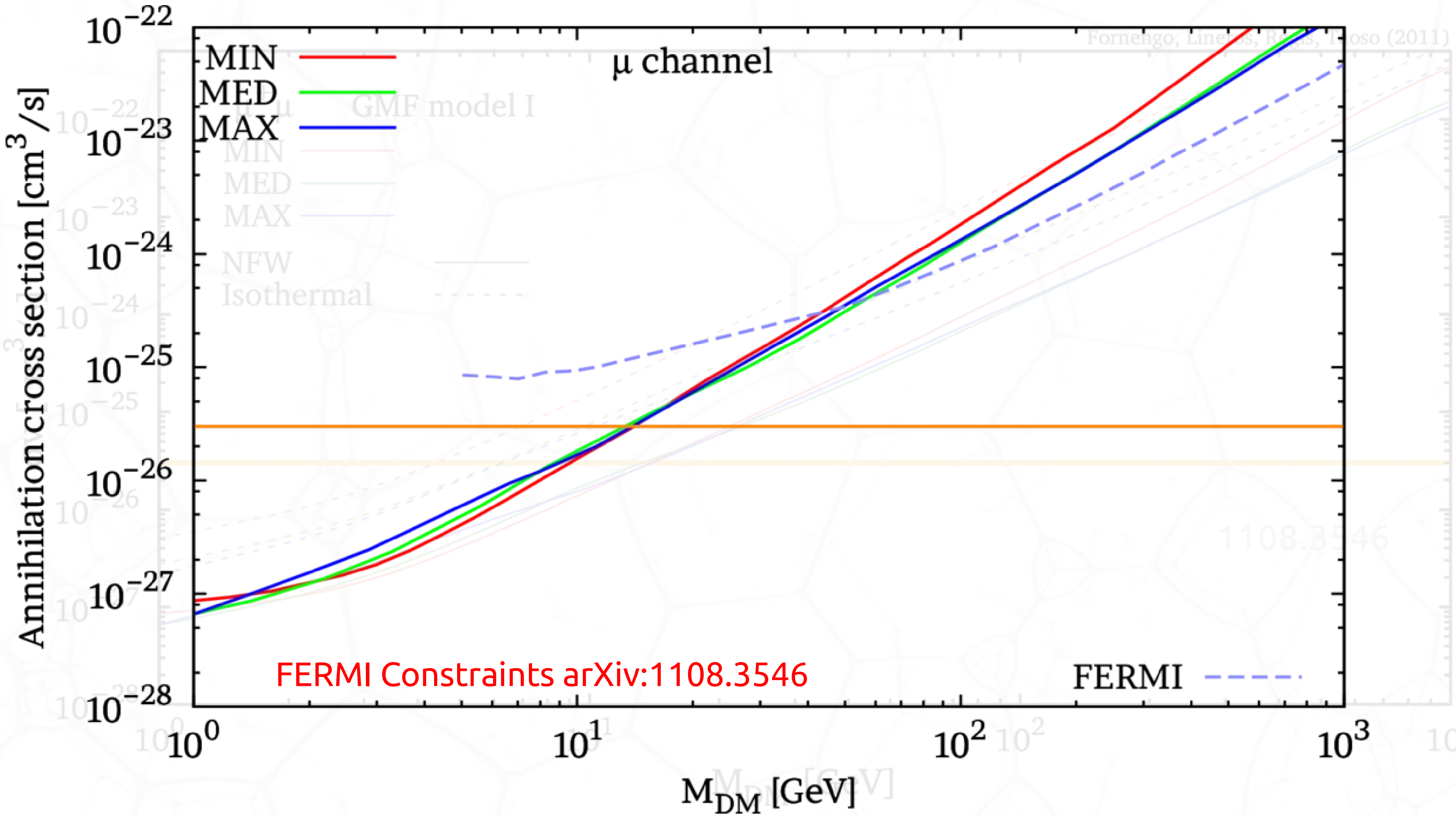
Constraining Galactic DM



Constraints touch the thermal cross section

For case of μ: Radio can do better than FERMI

Constraining Galactic DM



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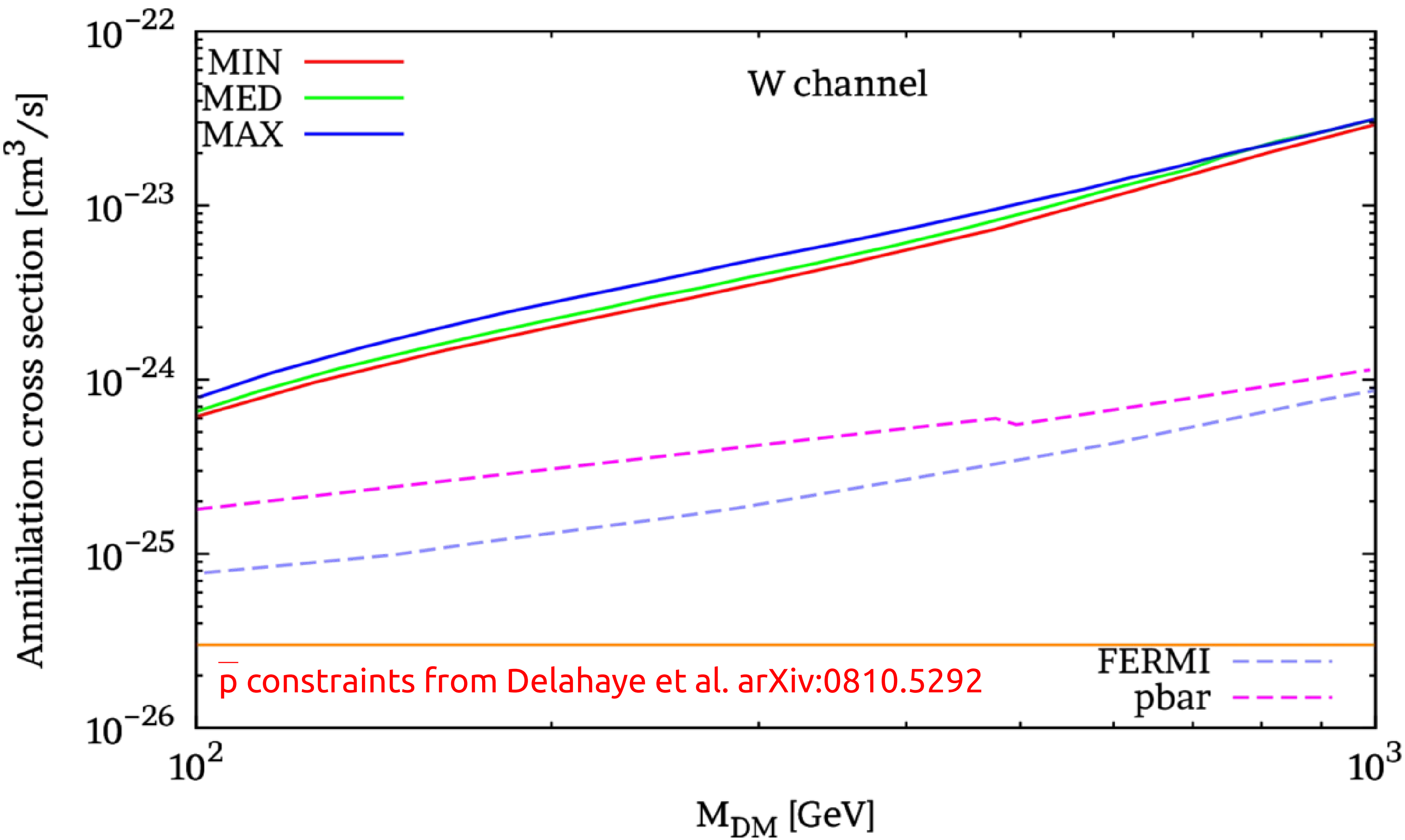
Constraining Galactic DM



Bound for $W^{+}W^{-}$ and < 100 GeV DM are not so stringent

Constraining Galactic DM

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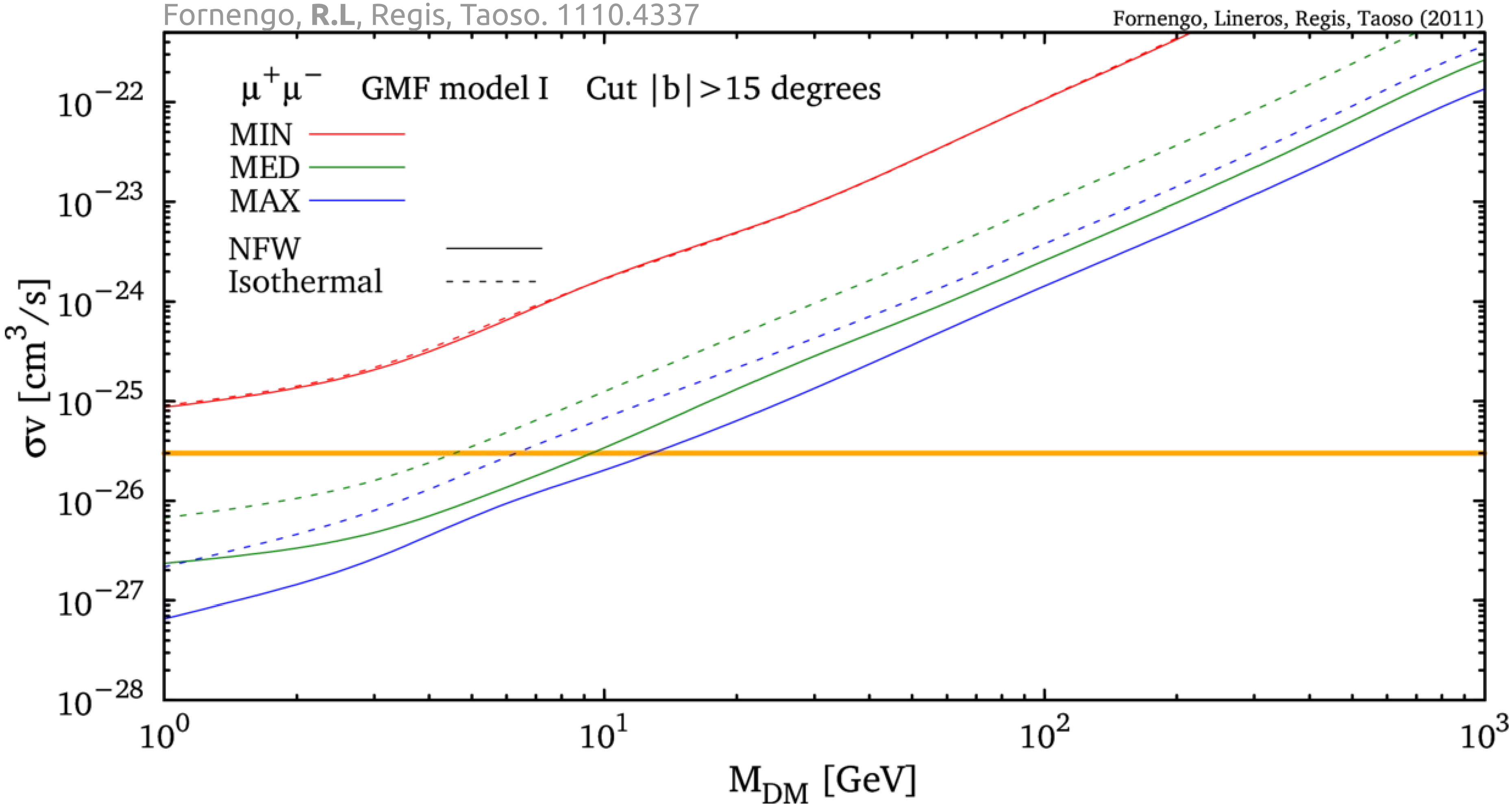

Regions outside of the Galactic plane give less stringent results.

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

Conclusions

- Searches of Dark Matter imprints on the (extra) galactic radio maps provide a very interesting tool for constraining it

- DM radio searches are able to explore regions with thermal cross section $(\sigma v) = 3 \times 10^{-26}\ \mathrm{cm}^3\ \mathrm{s}^{-1}$

- Lower frequencies are more suitable to explore light DM candidates, however cross correlation with other observables are required (!)

Thanks for your attention

Further details ...

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

Extra slides

Frequency spectrum

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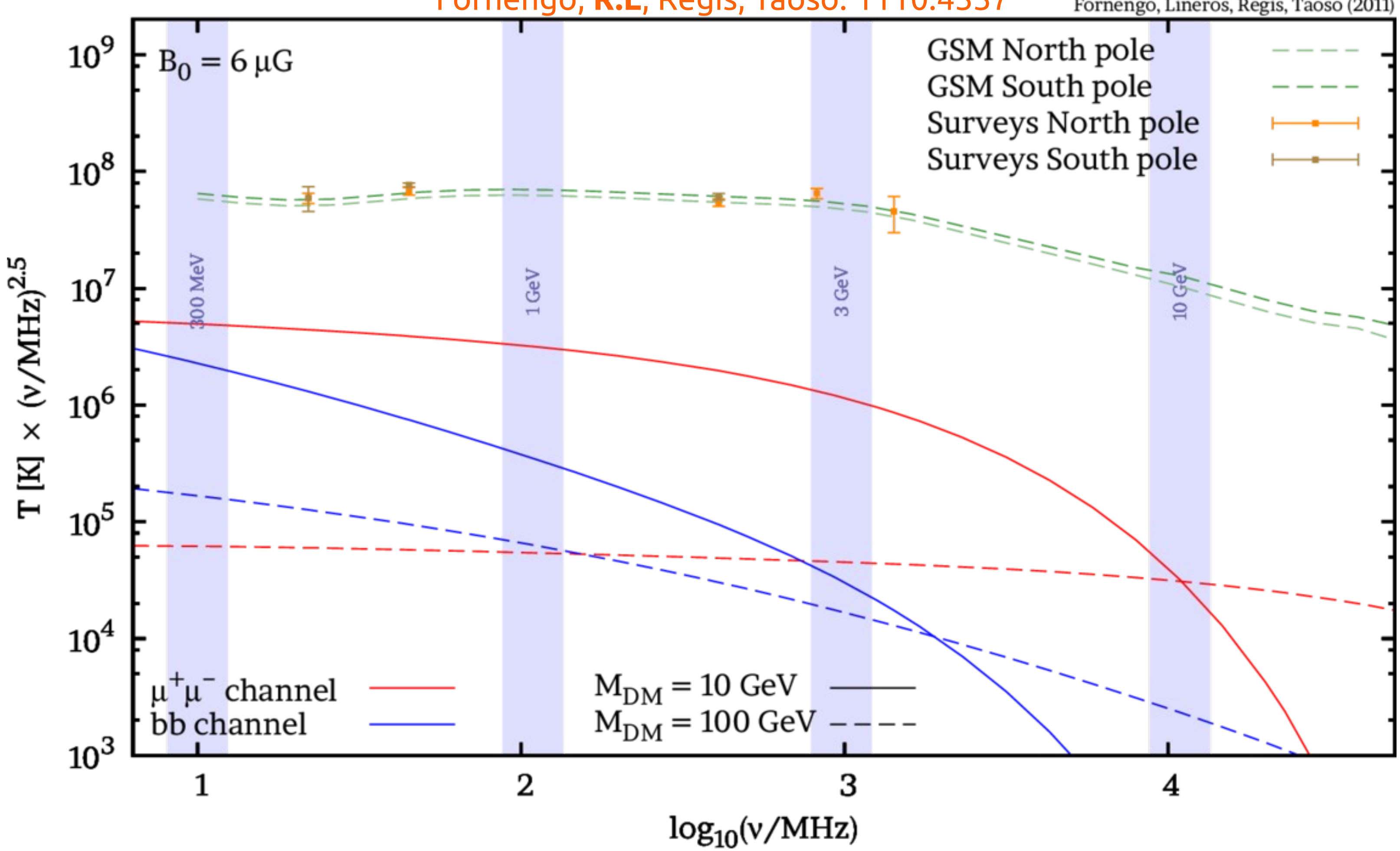
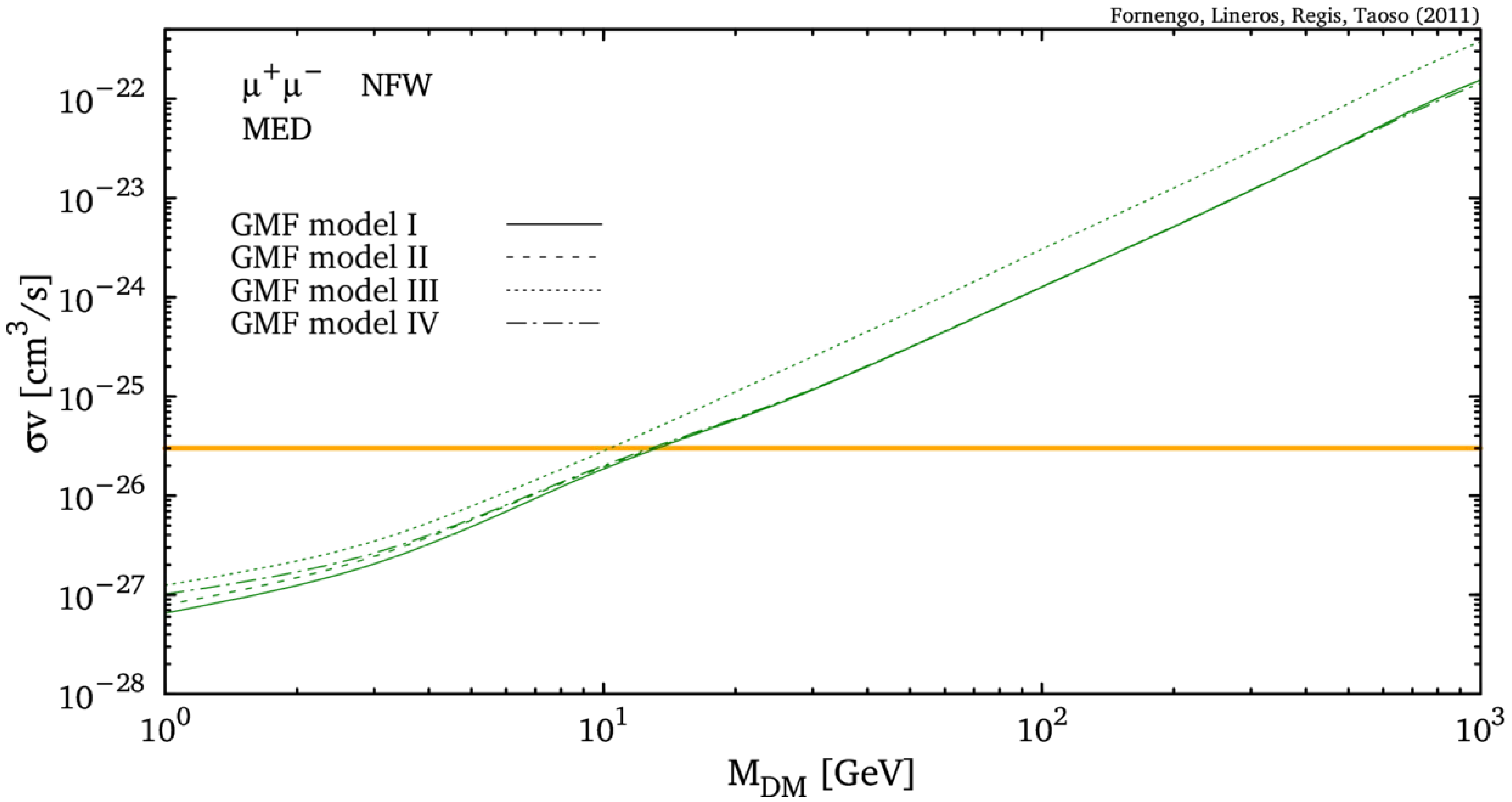


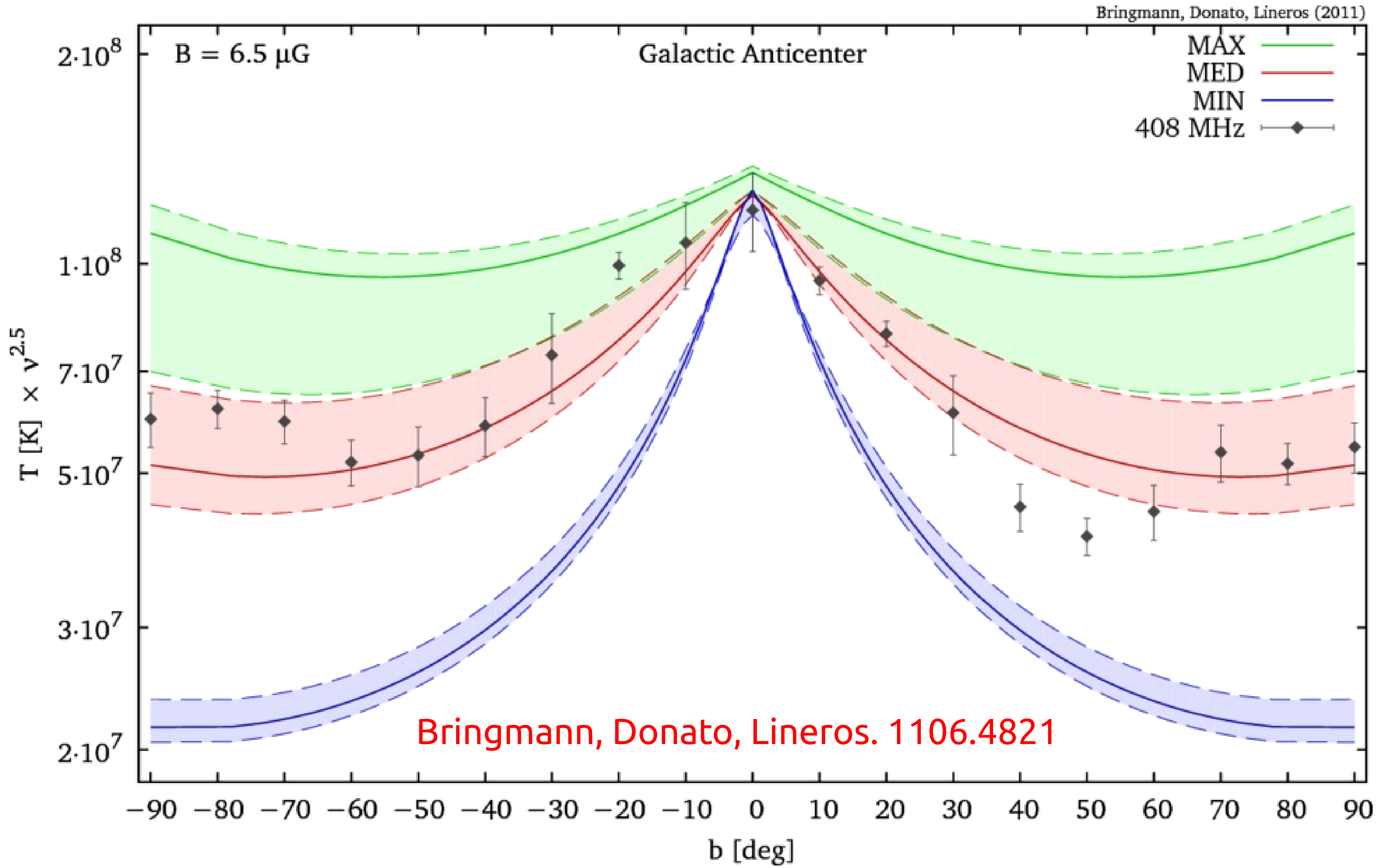
Lower frequencies are better for testing light DM.
The frequency spectrum depends on the annihilation channel and mass value

Constraints using different GMFs



Different GMFs do not change too much the constraints

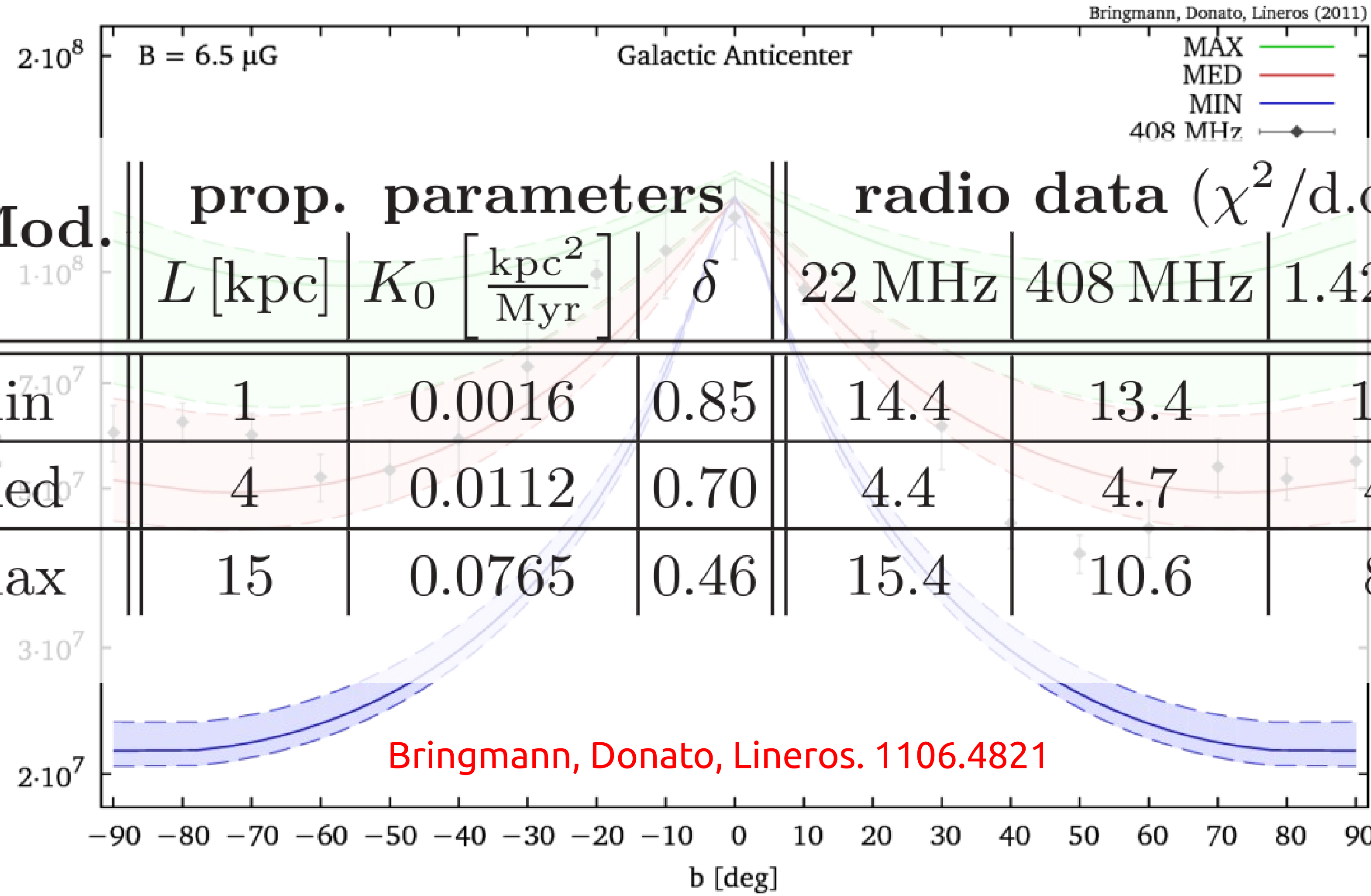
Synchrotron emission at 408 MHz



MAX, MED, and MIN models produce different morphologies

Disfavoured *L* > 15 kpc (or < 1 kpc) configurations

Synchrotron emission at 408 MHz



Mod.	prop. parameters			radio data (χ^2/d.o.f.)		
	L [kpc]	K_0 $\left[\frac{\text{kpc}^2}{\text{Myr}}\right]$	δ	22 MHz	408 MHz	1.42 GHz
min	1	0.0016	0.85	14.4	13.4	13.5
med	4	0.0112	0.70	4.4	4.7	4.7
max	15	0.0765	0.46	15.4	10.6	8.7

MAX, MED, and MIN models produce different morphologies
Disfavoured L > 15 kpc (or < 1 kpc) configurations