Multi-wavelength Dark Matter constraints from radio observations and from diffuse Fermi-LAT gamma-ray observations

for the Fermi-LAT collaboration

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IDM2010,
Montpellier
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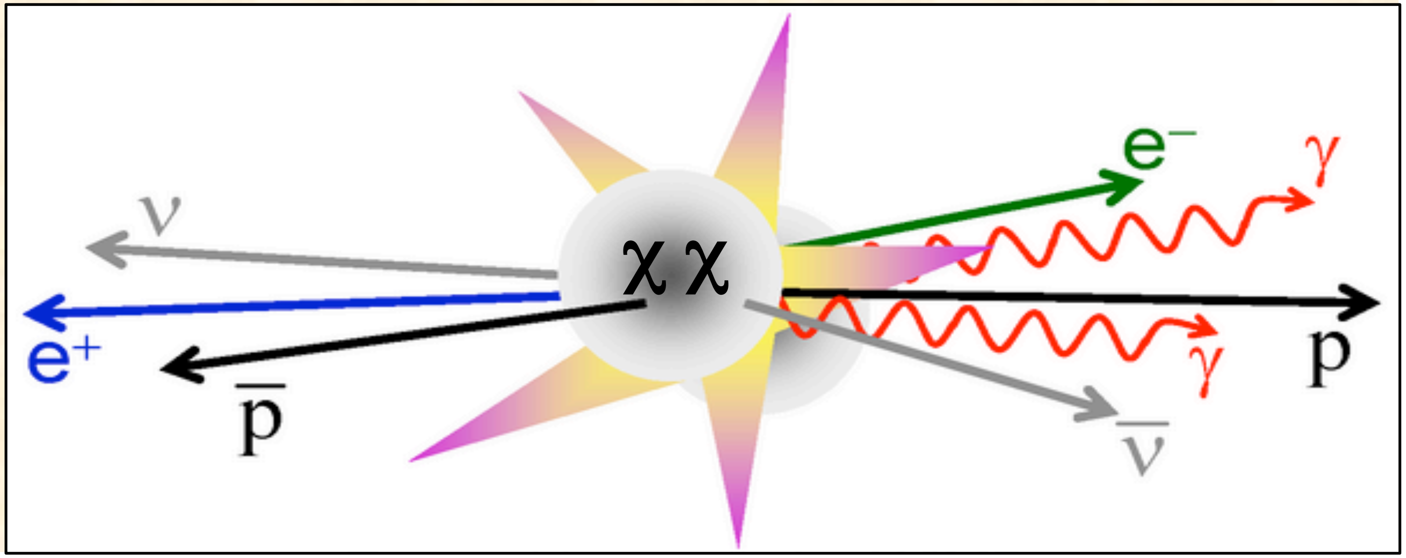
Indirect Detection of Dark Matter: the General Framework

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

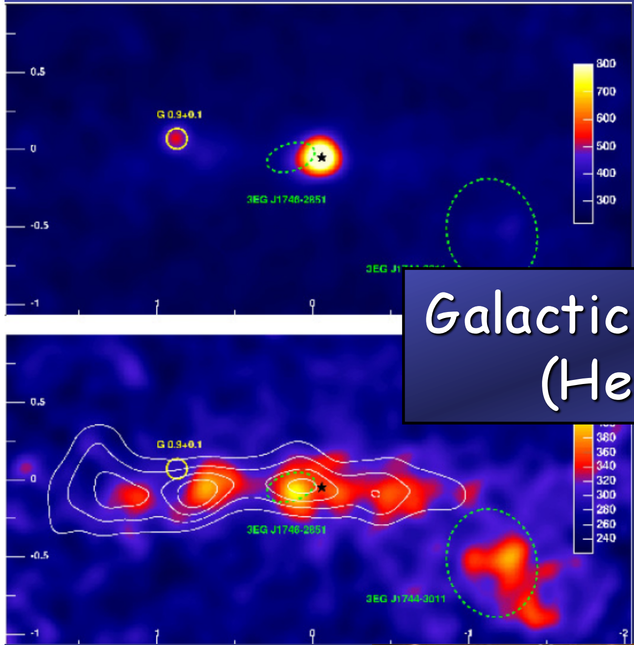
2) **Fragmentation/Decay** Annihilation products decay and/or fragment into some combination of electrons, protons, deuterium, neutrinos and gamma rays

3) **Synchrotron and Inverse Compton** Relativistic electrons up-scatter starlight to MeV-GeV energies, and emit synchrotron photons via interactions with magnetic fields



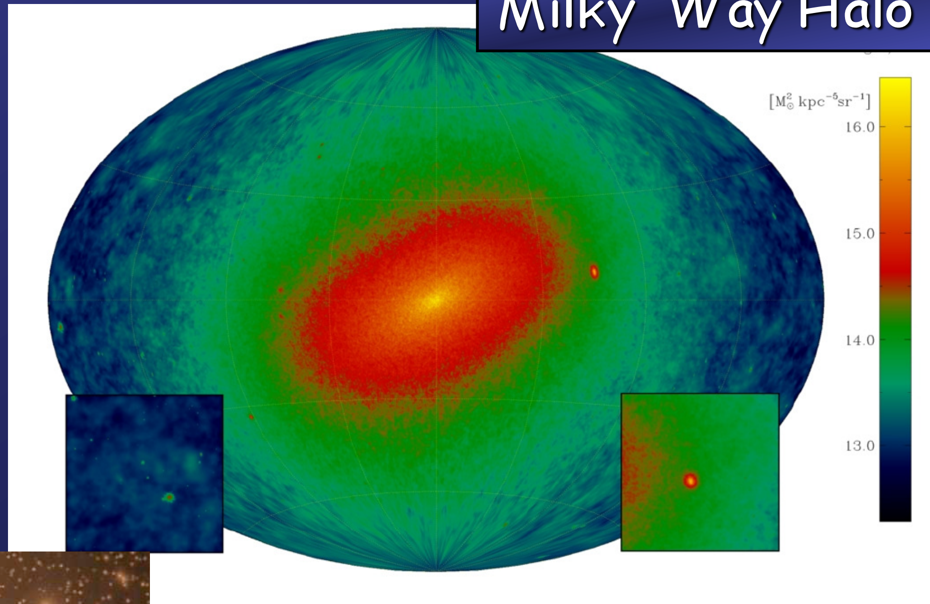
χ

Where to look

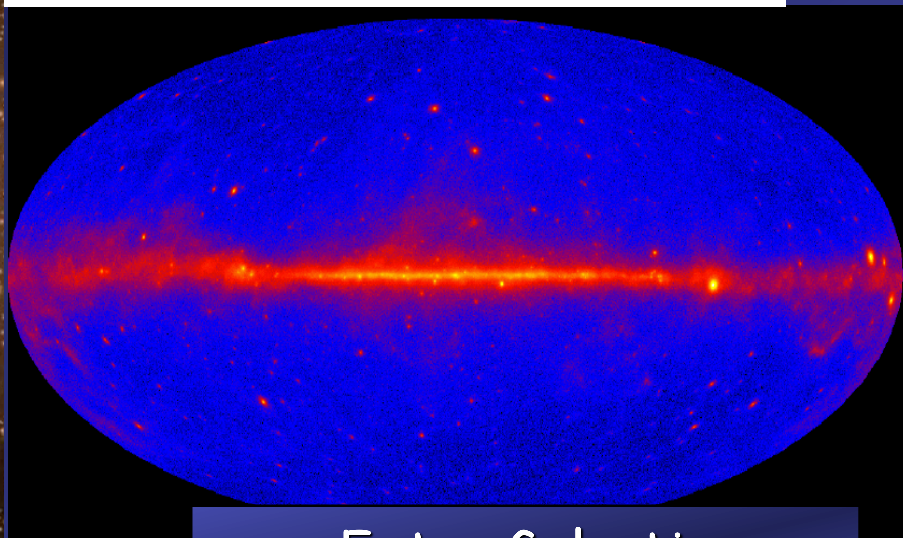


Galactic Center (Hess)

Milky Way Halo

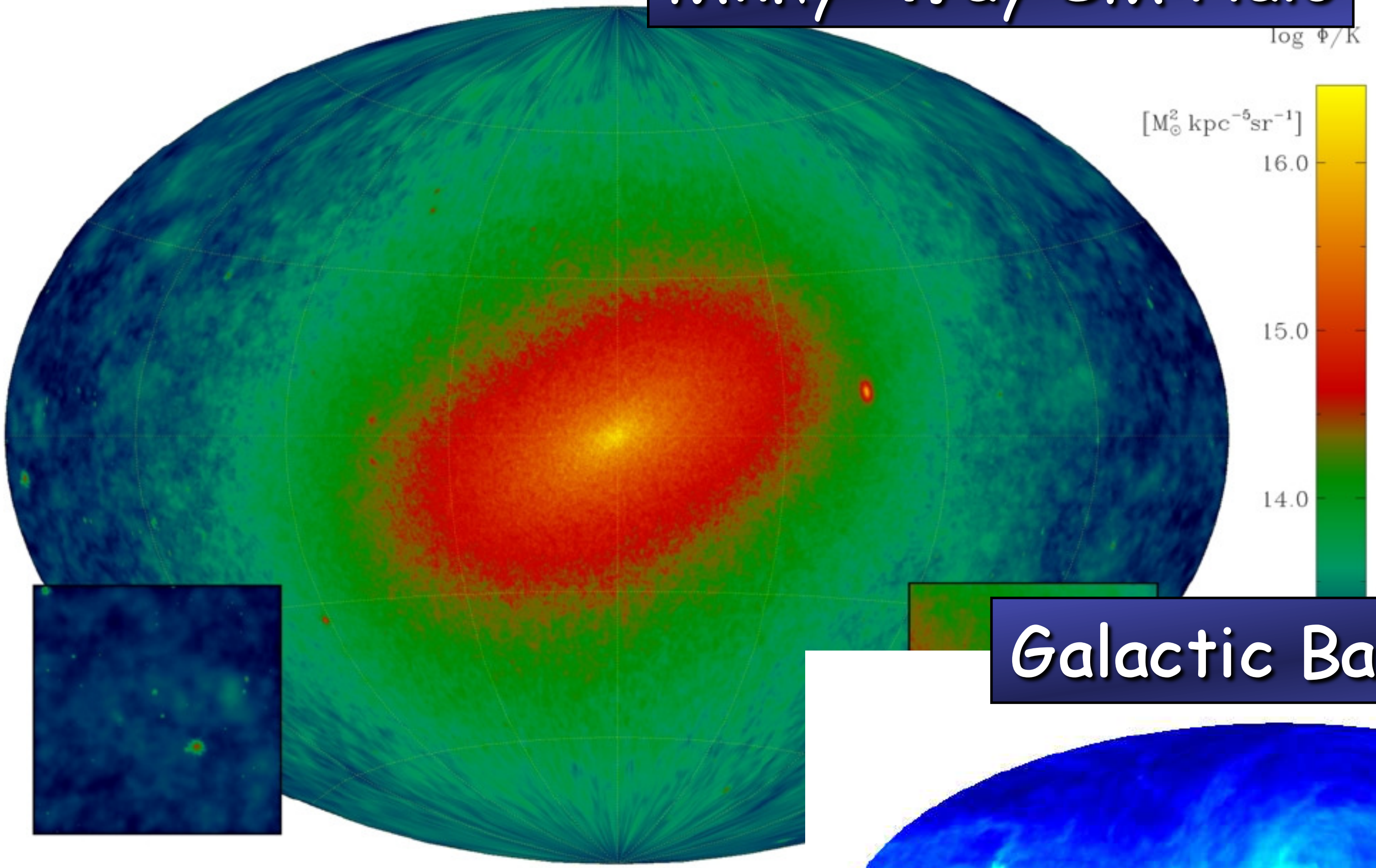


DM Clumps: Via Lactea Simulation Diemand et al.

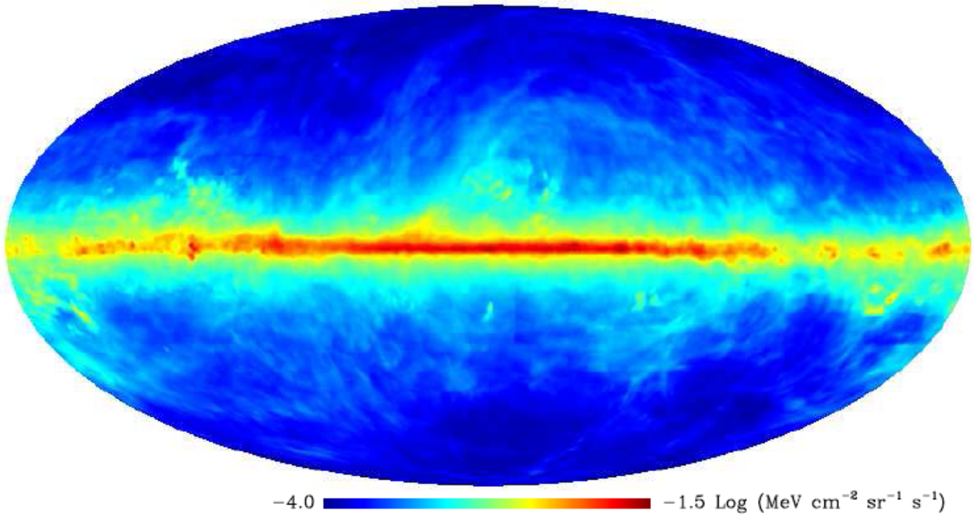


Extra Galactic Background

Milky Way DM Halo



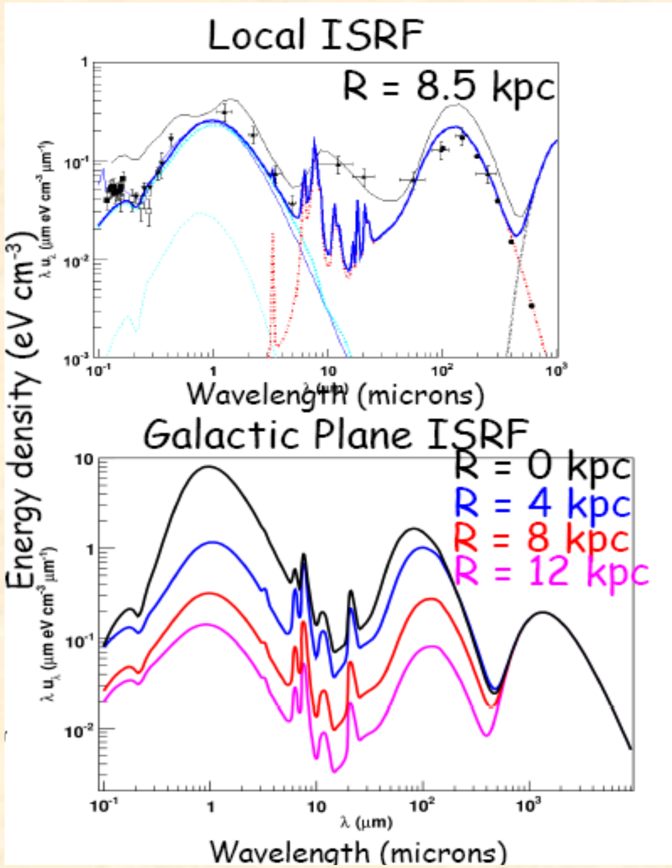
Galactic Backgrounds



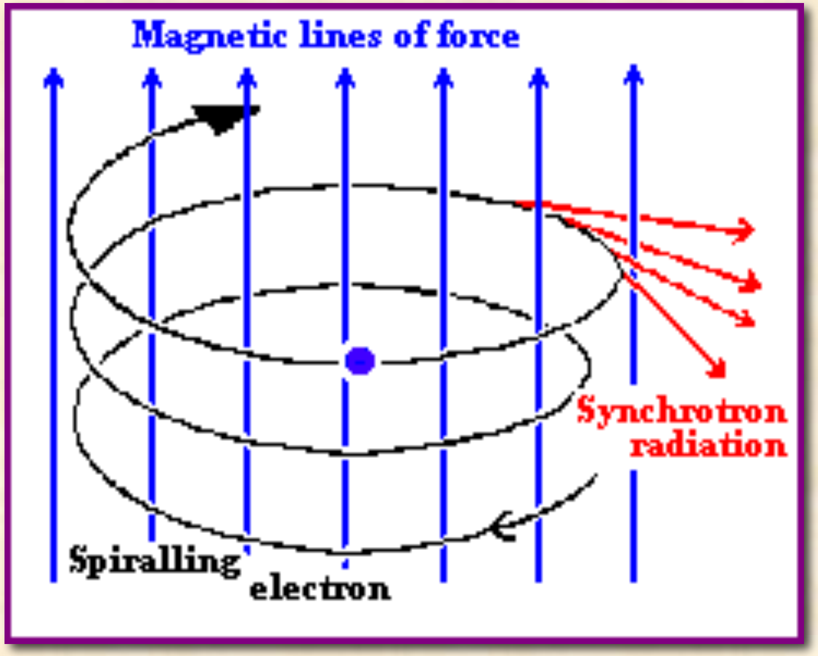
Different morphologies can be exploited to disentangle the DM signal from astrophysics

Indirect Detection With Synchrotron and Inverse Compton Radiation

ICS on the Galactic ISRF



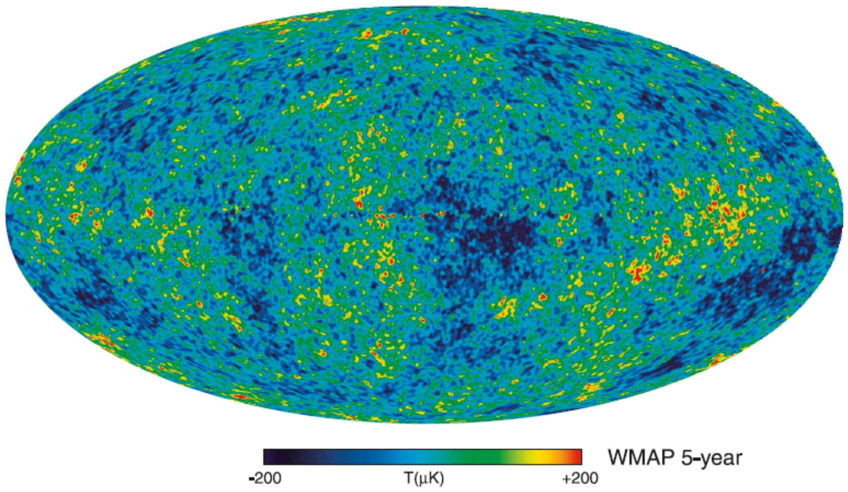
Synchrotron on the GMF



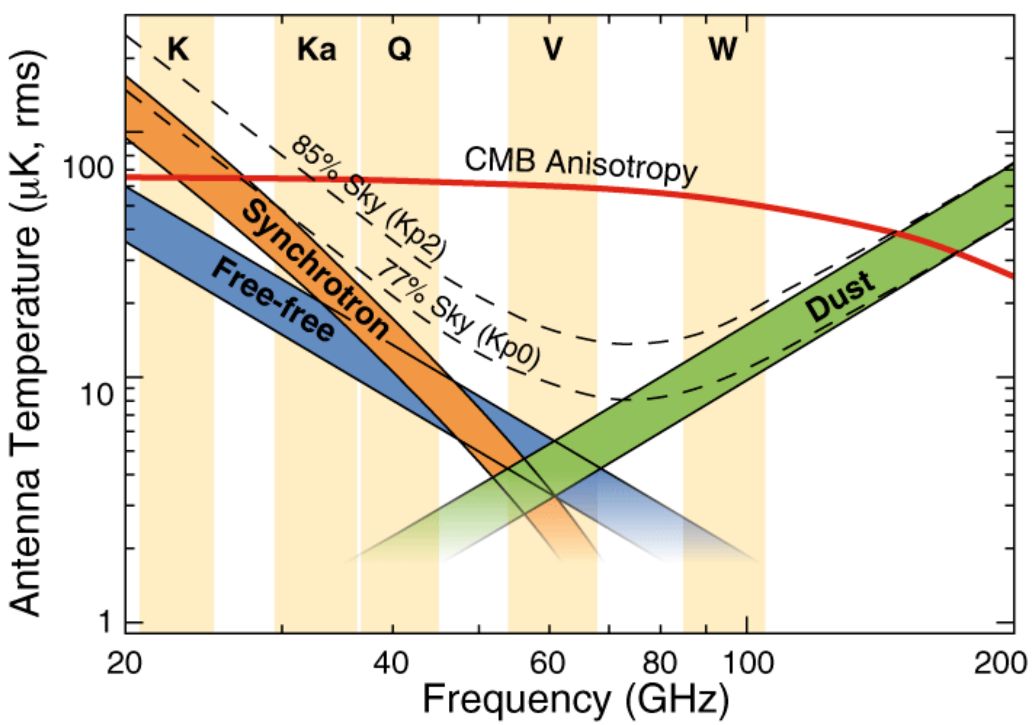
- Charged leptons and nuclei strongly interact with gas, Interstellar Radiation and Galactic Magnetic Field.
- During the process of thermalization HE e+e− release secondary low energy radiation, in particular in the radio and X-ray/soft Gamma band.

Milky Way Halo and Secondary Radiation: synchrotron

The Microwave sky



•In addition to CMB photons, WMAP data is “contaminated” by a number of galactic foregrounds that must be accurately subtracted



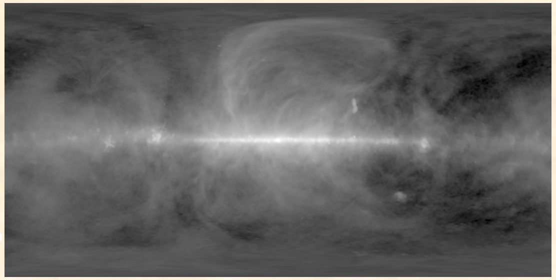
•The WMAP frequency range is well suited to minimize the impact of foregrounds

•Substantial challenges are involved in identifying and removing foregrounds

•Possible technique: Template fitting: see below

Template fitting

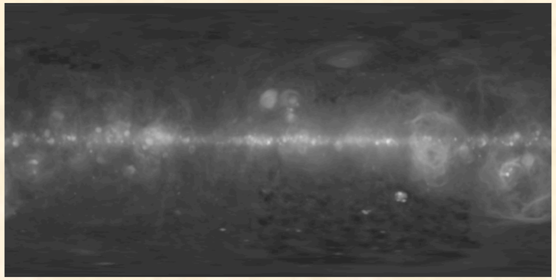
Synchrotron



Synchrotron: Template: C.G.T. Haslam et al., A&A **100 (1981) 209.**

+

Free-free



Freefree: Template: D.P. Finkbeiner, ApJS **146 (2003) 407.**

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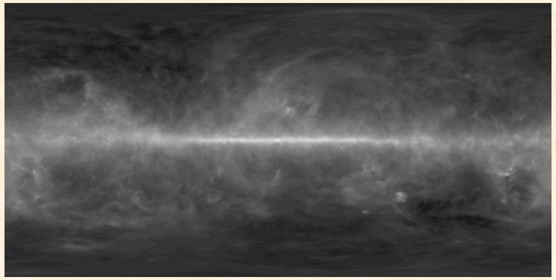
T & S Dust

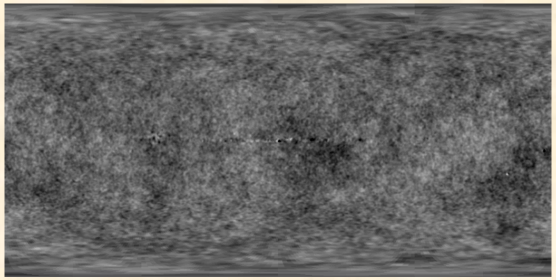


Dust: Template: D.P. Finkbeineret al., ApJ **524 (1999) 867.**

WMAP

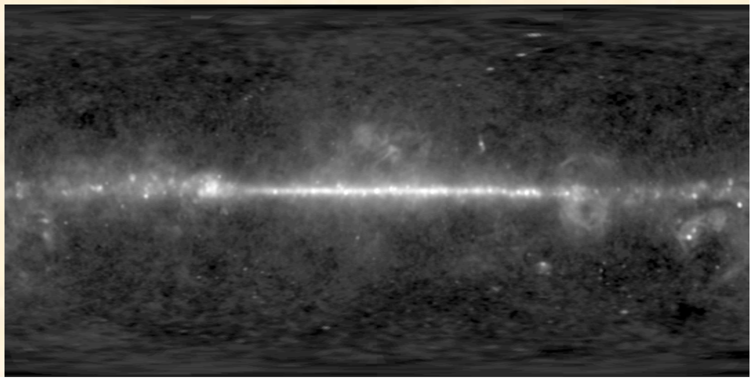
+

CMB

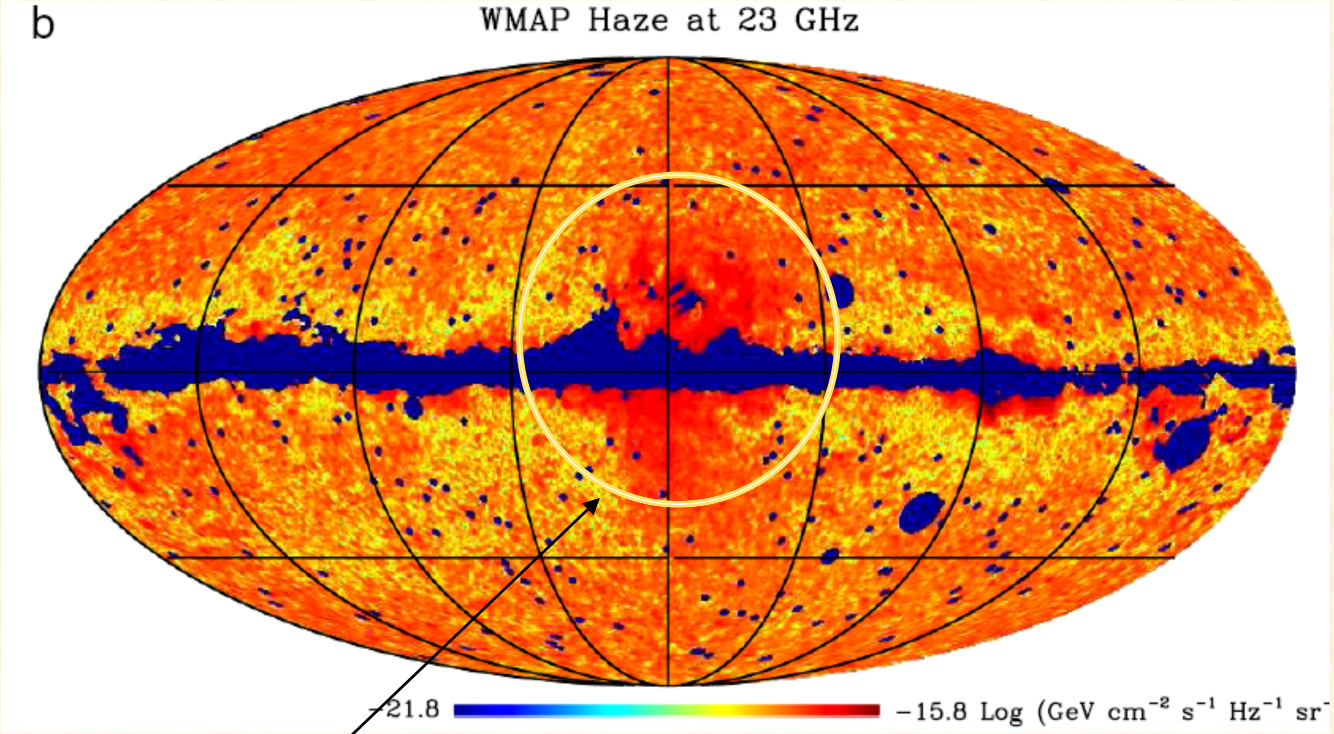


CMB: Gold et al., arXiV:1001.4555.

TOTAL



Residuals of the radio template fitting: The "WMAP Haze"

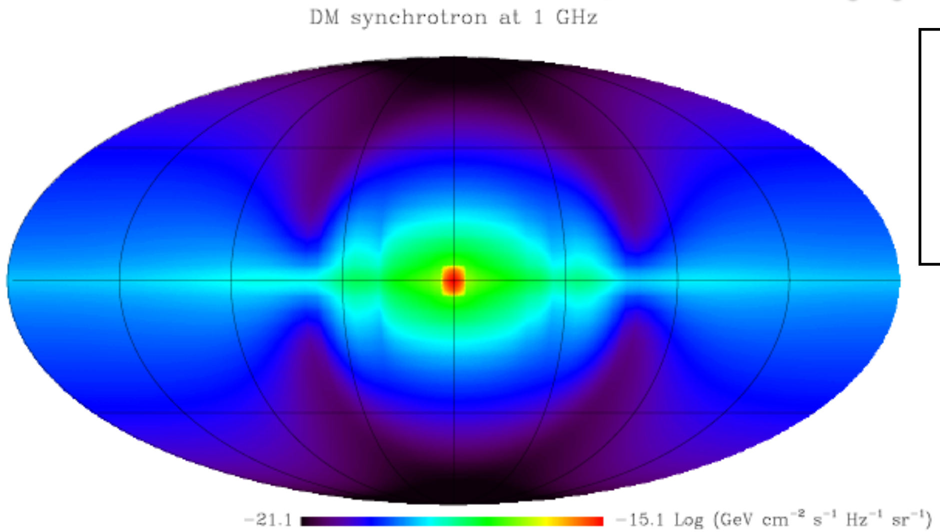


The residual map after the foregrounds template subtraction shows an excess within the inner ~20° around the Galactic Center

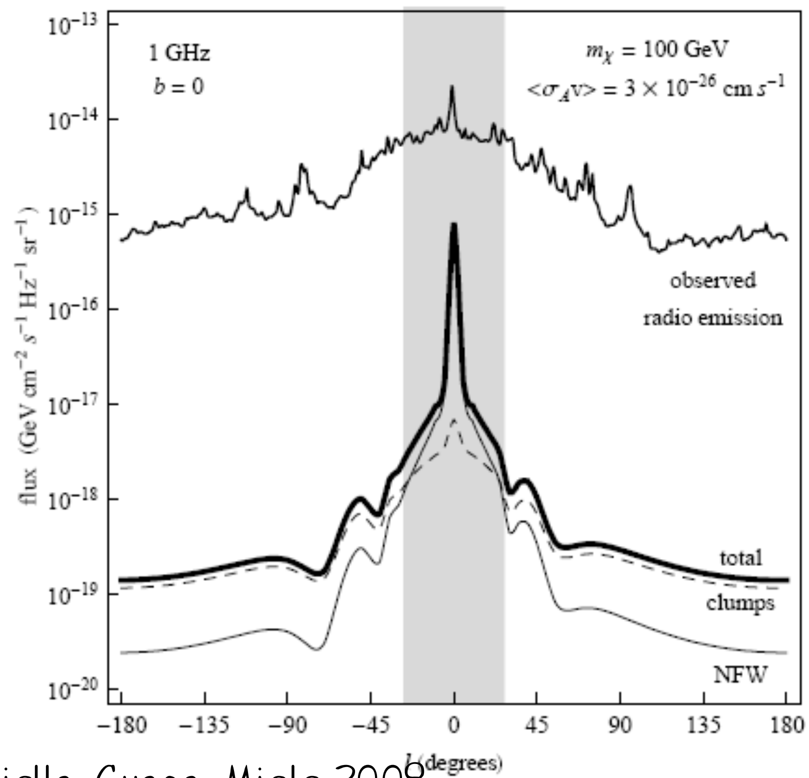
Not clear if physical or artifact of the template fitting procedure…

D. P. Finkbeiner, Astrophys. J. 614 (2004) 186
G. Dobler and D. P. Finkbeiner, arXiv:0712.1038 [astro-ph].

DM diffuse signal



Pattern of the DM synchrotron emission at 1 GHz. The characteristic pattern is given by the line of sight projection of the galactic magnetic field.



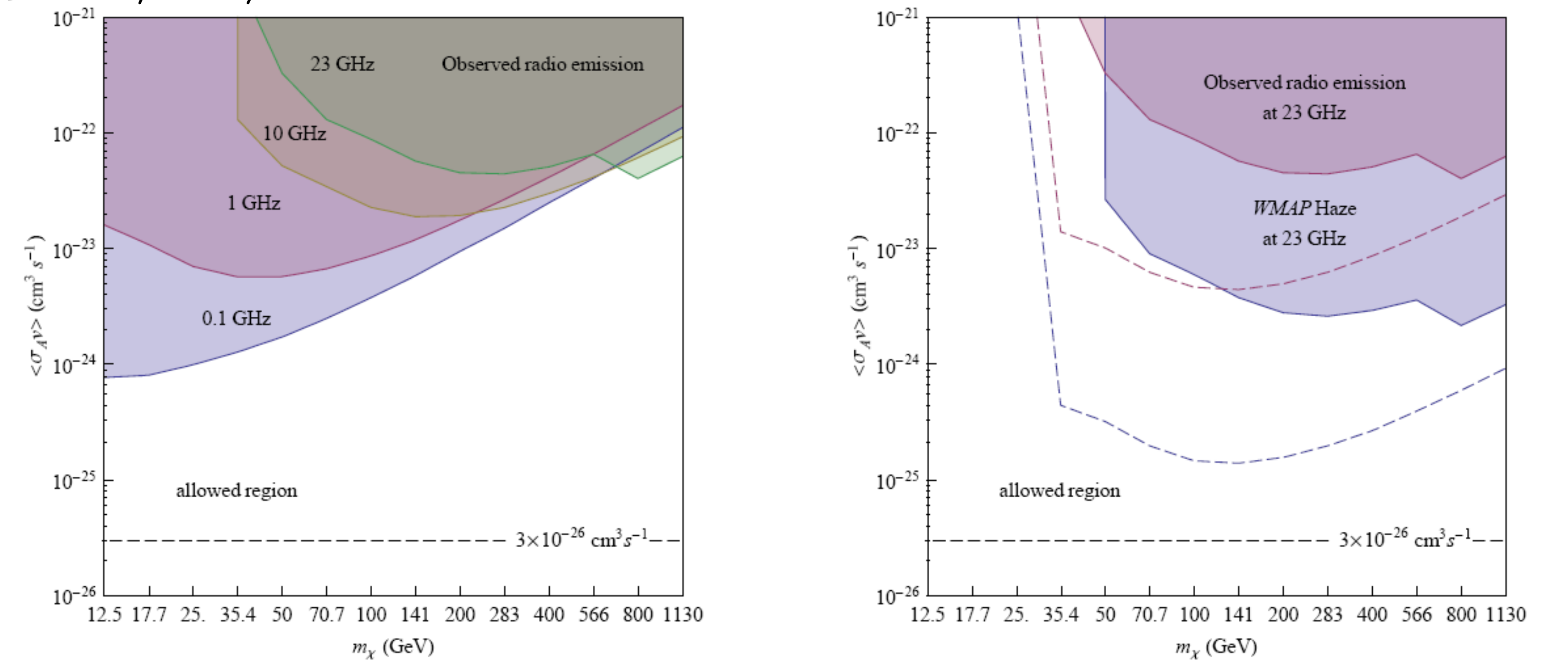
Requiring that the DM signal does not exceed the observed radio emission (CMB cleaned, but not foreground cleaned) DM constraints in the m_χ - $\langle\sigma_A v\rangle$ plane can be derived. The region around the GC (15°x15°) is excluded from the analysis.

DM synchrotron profile for the halo and unresolved substructures and their sum at 1 GHz. The astrophysical observed emission at the same frequency is also shown. The gray band indicates the angular region within which the DM signal from the host halo dominates over the signal from substructures

Borriello, Cuoco, Miele 2008

DM constraints in the m_χ-<$\sigma_A v$> plane

Borriello, Cuoco, Miele 2008

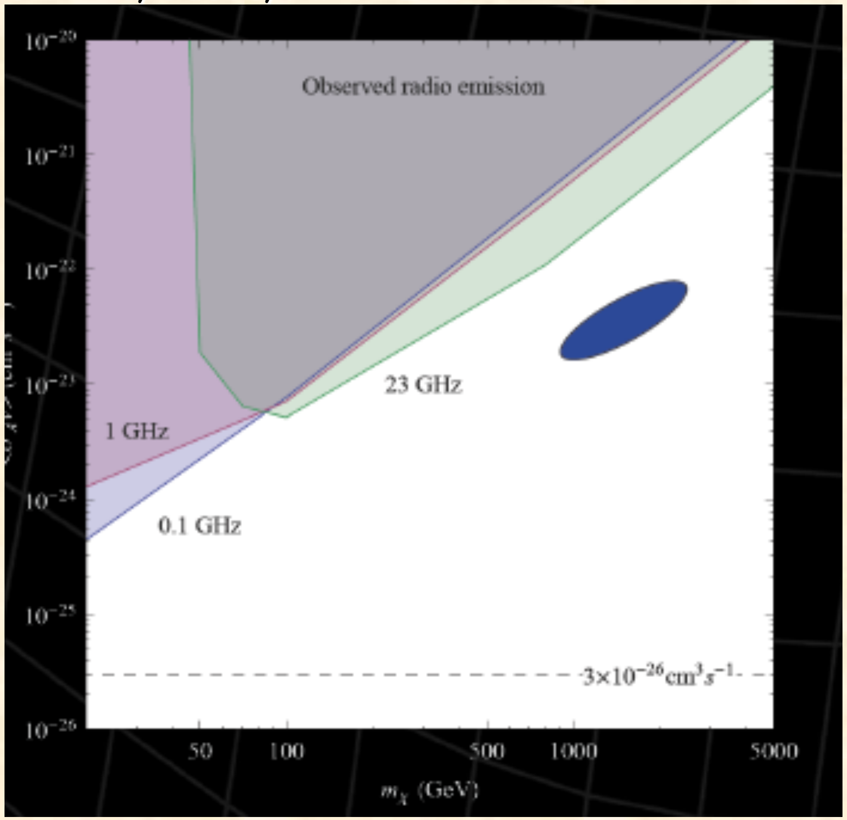


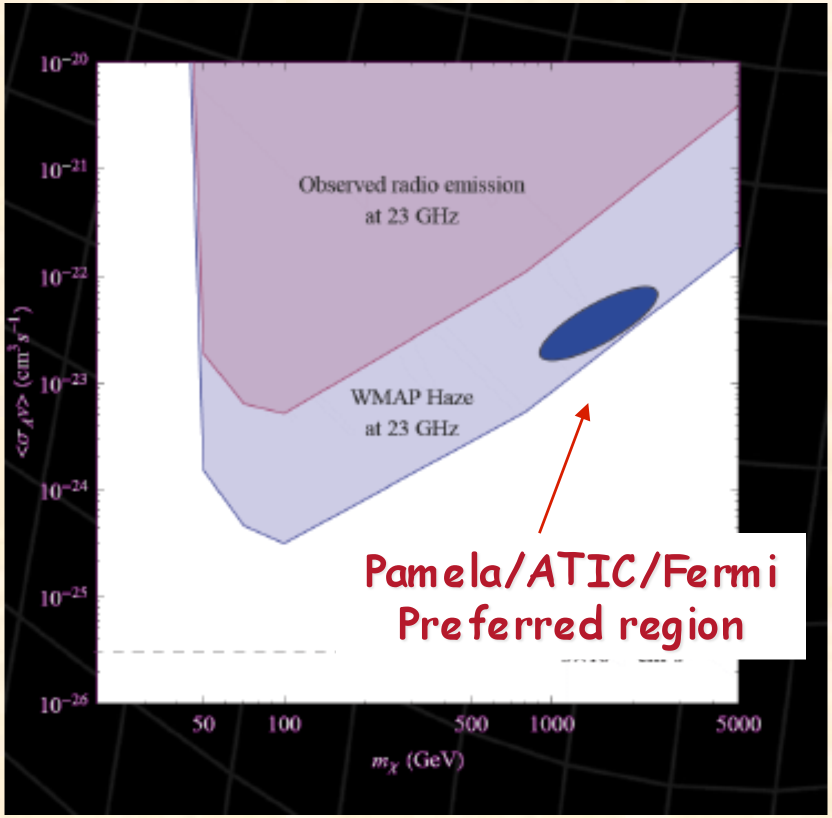
- Constraints in the m_χ- <$\sigma_A v$> plane for various frequencies, without assuming synchrotron foreground removal.
- DM spectrum is harder than background, thus constraints are better at lower frequencies.

- Constraints from the WMAP 23 GHz foreground map and 23 GHz foreground cleaned residual map (the WMAP Haze) for the TT model of magnetic field (filled regions) and for a uniform 10 μG field (dashed lines).
- With a fine tuning of the MF is possible to adjust the DM signal so that to match the Haze, like in Hooper et al.

Same for μ+μ- channel

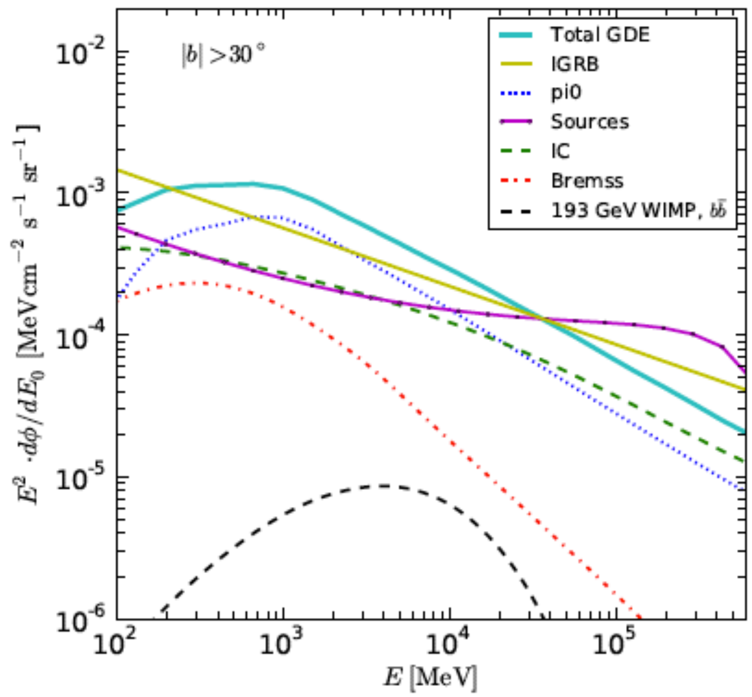
Borriello, Cuoco, Miele 2008





Milky Way Halo and Secondary Radiation: Inverse Compton and Final State radiation

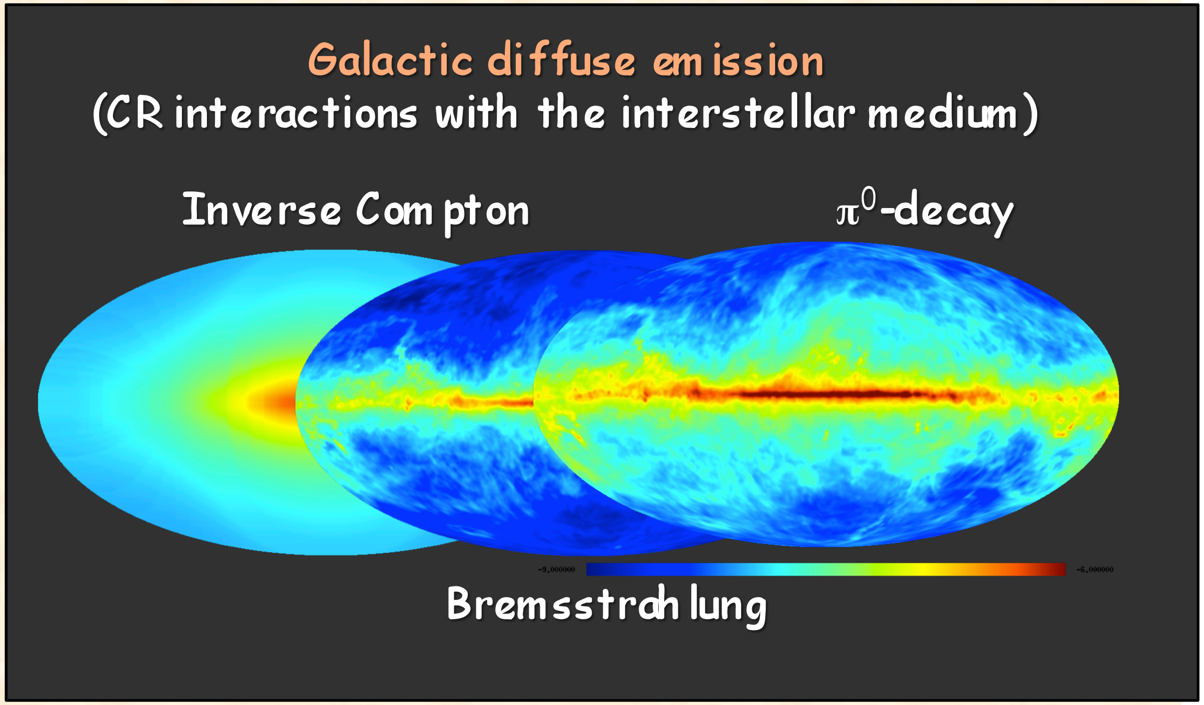
The Gamma Sky



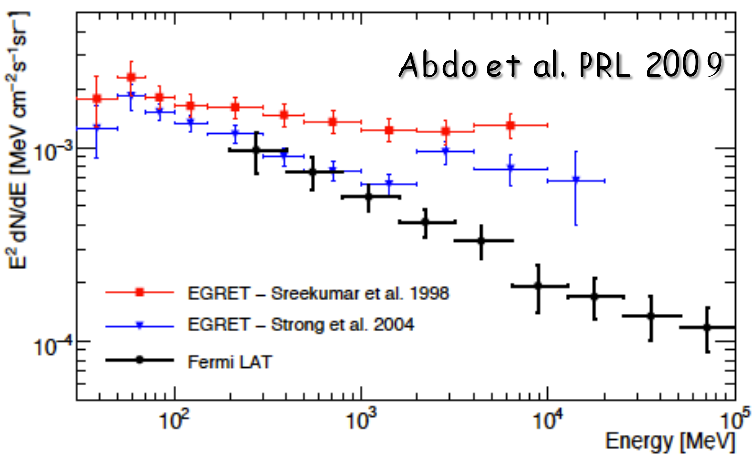
Galactic Contribution from:

1. Pion Decay
2. Inverse Compton
3. Electron Bremsstrahlung

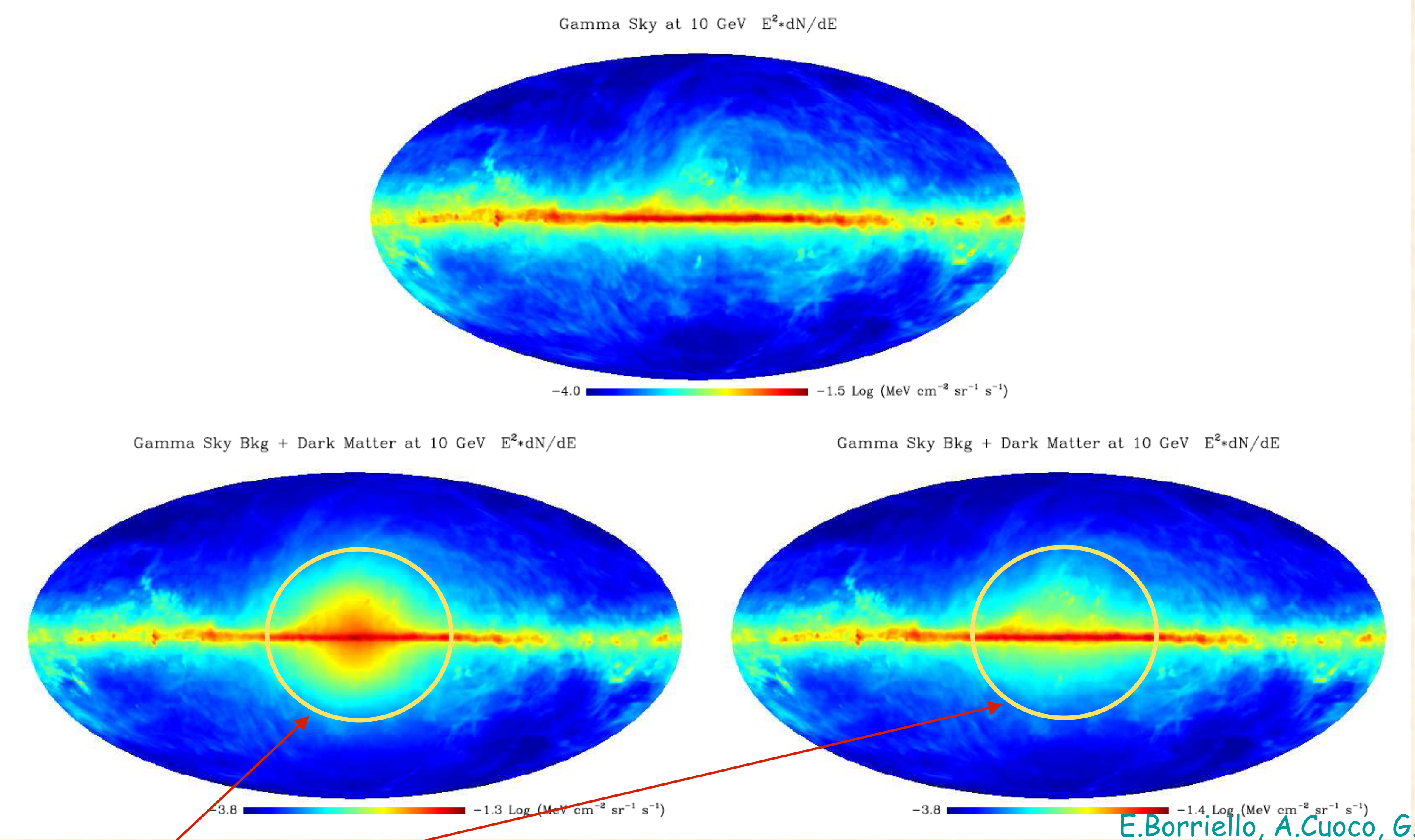
Galprop Foregrounds Model:



4. IGB



The "ICS Haze"

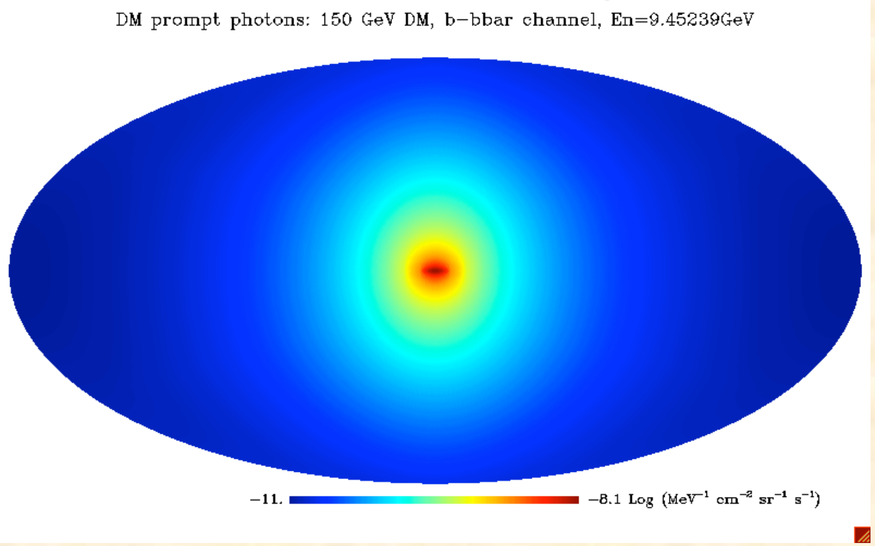


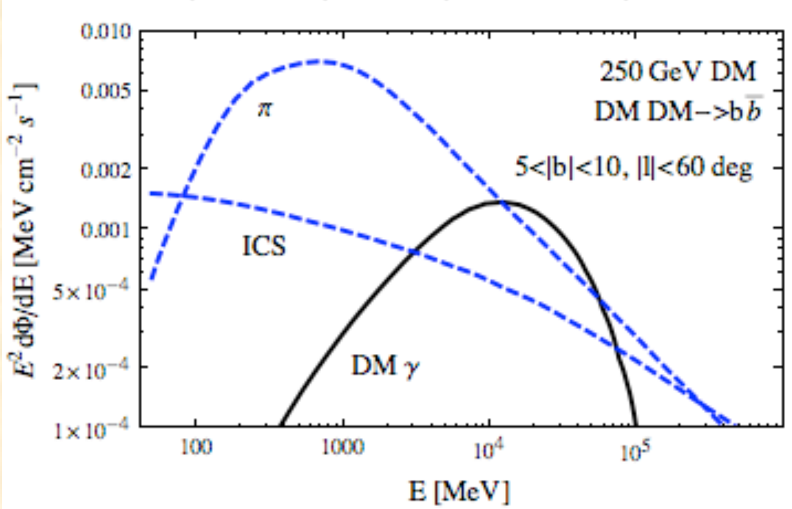
E.Borriello, A.Cuoco, G.Miele
Ap.J.699:L59-L63,2009

Similarly to the synchrotron case, IC signal produces an extremely peculiar "ICS Haze" peaking around 10-100 GeV which provides a further mean to discriminate the DM signal from the astrophysical backgrounds and/or to check for possible systematics.

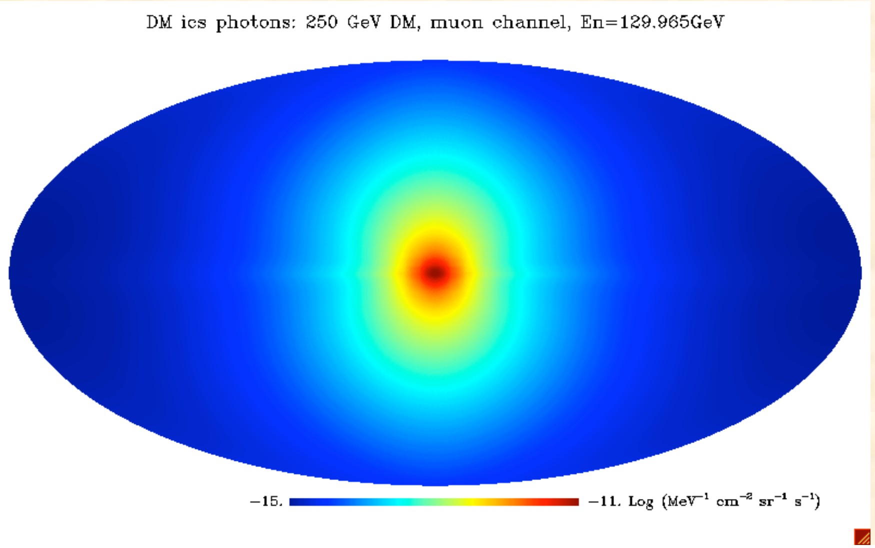
DM gamma components for ICS and FSR

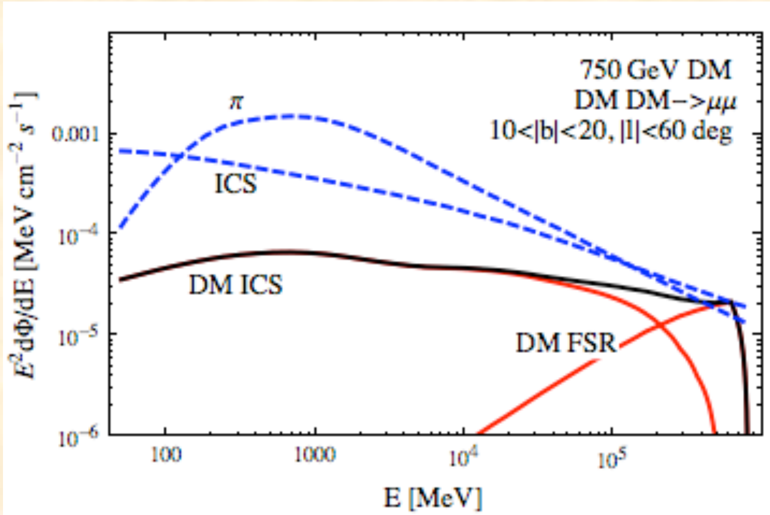
Final state radiation only (b-bar case): compact Haze morphology and peaked spectrum



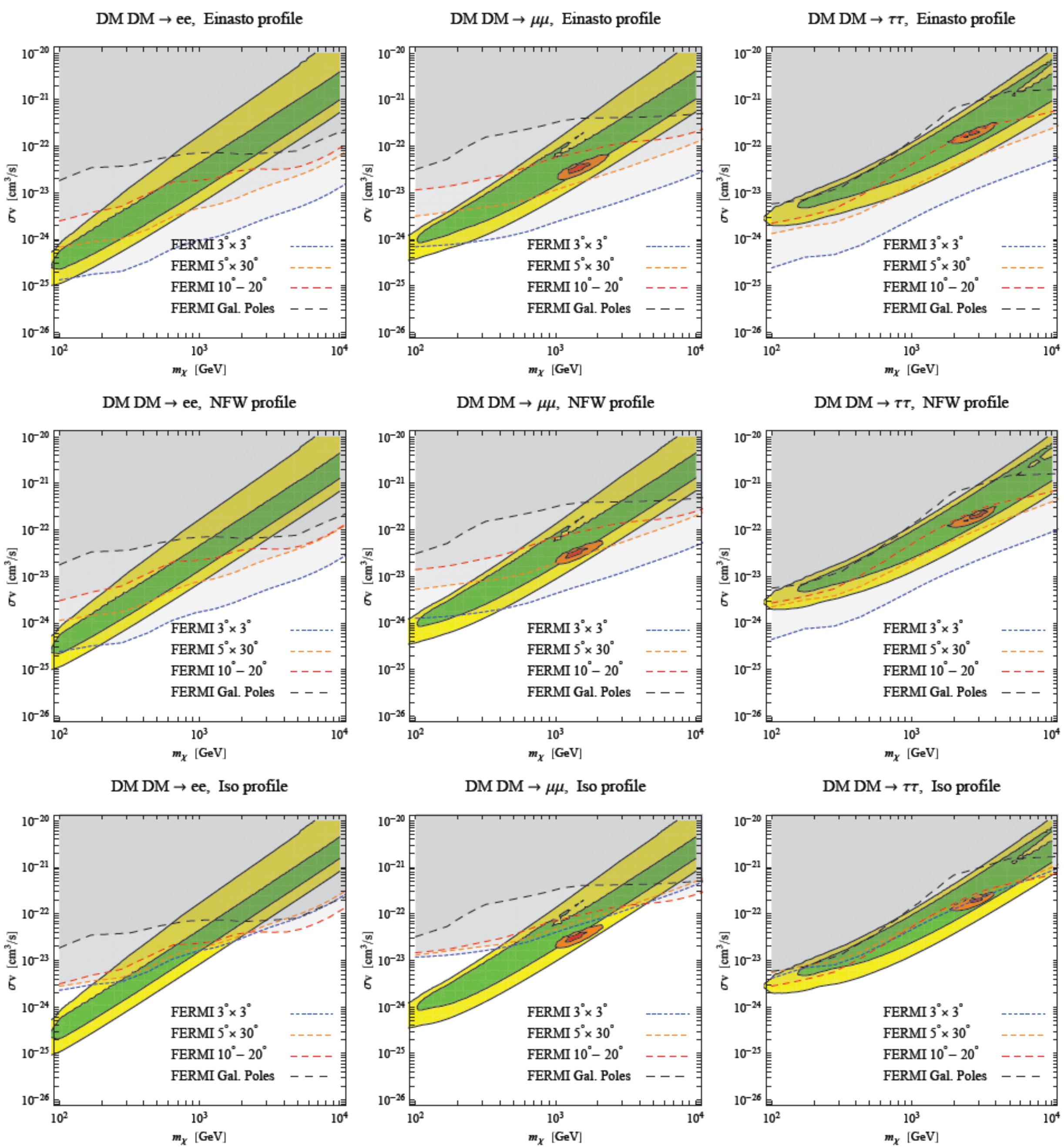


ICS +FSR (μ+μ- case): extended Haze morphology and hard spectrum





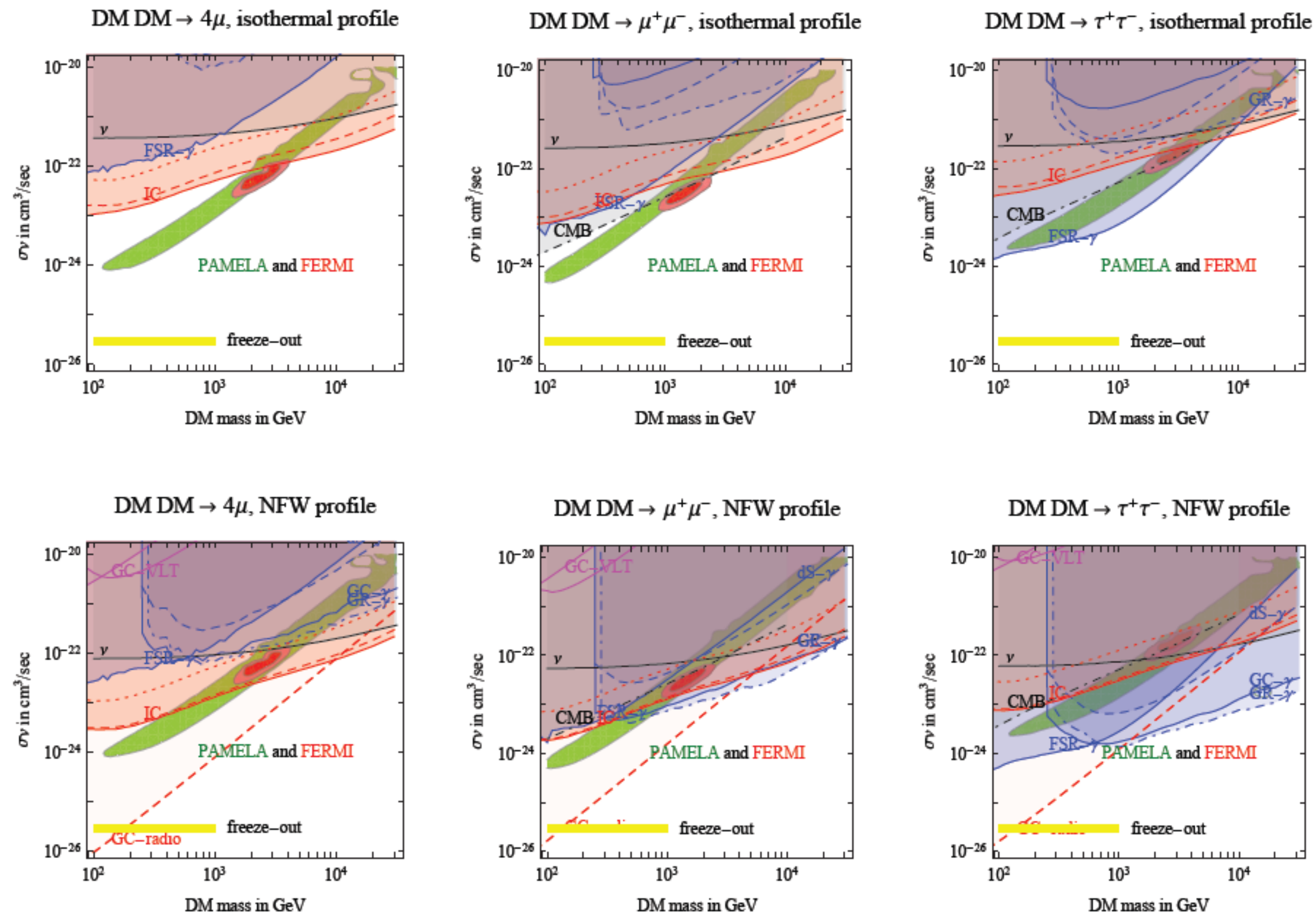
DM constraints from ICS and Fermi data



Conservative constraints can be set requiring that the DM signal does not exceed the observed gamma flux. No Background modeling

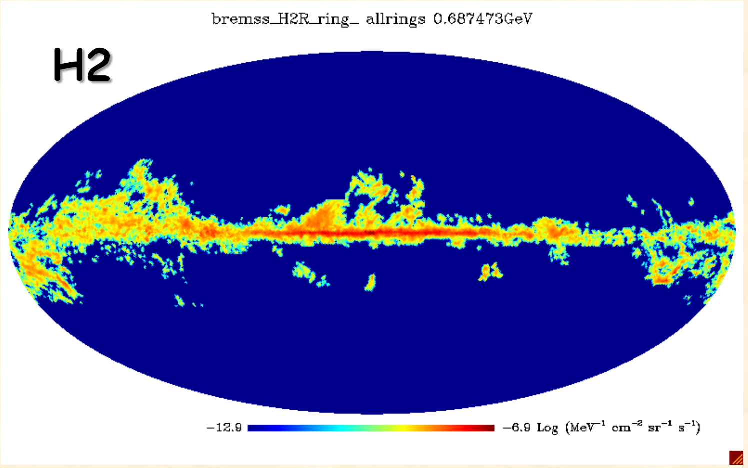
M. Cirelli, P. Panci, P. D. Serpico, arXiv:0912.0663

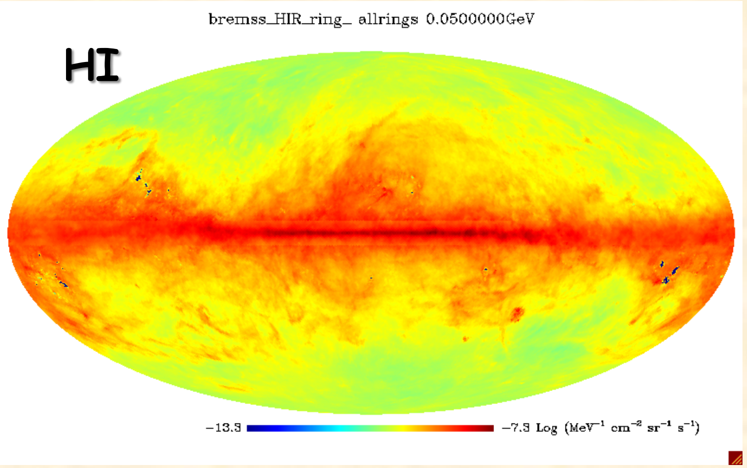
DM constraints from ICS and Fermi data

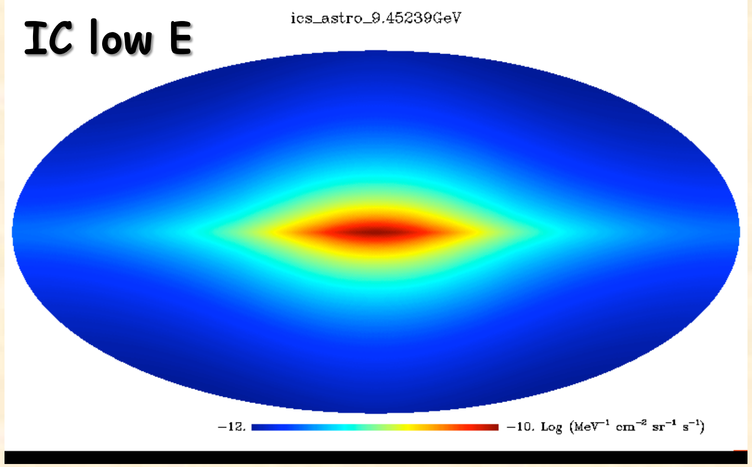


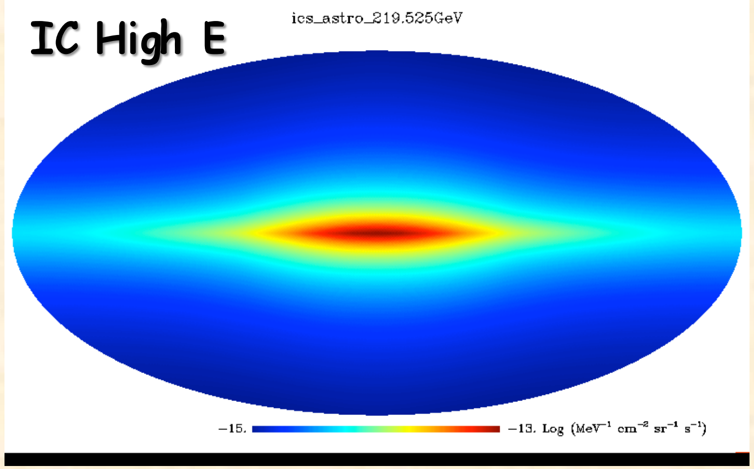
M. Papucci, A. Strumia, arXiv:0912.0742

Modeling the background: template fitting (2)

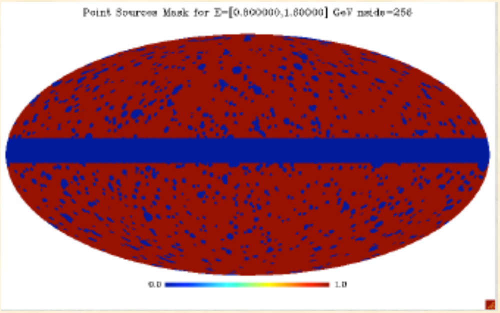






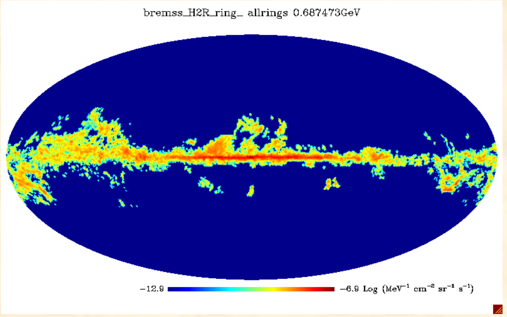


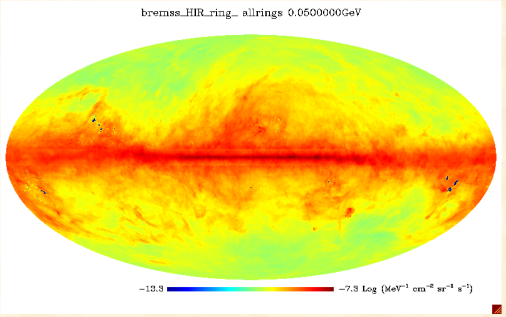
X

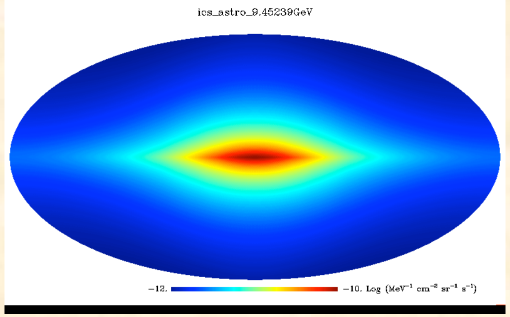


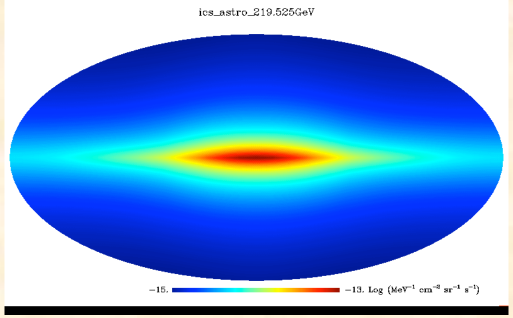
Galactic Plane
and point source
mask

DM vs background morphology

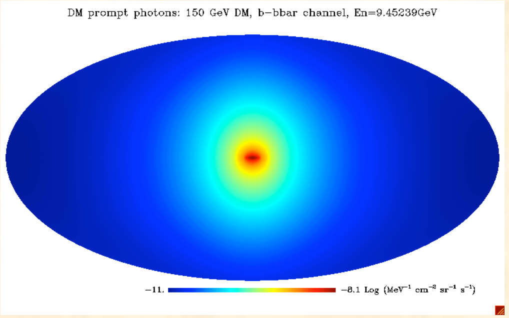


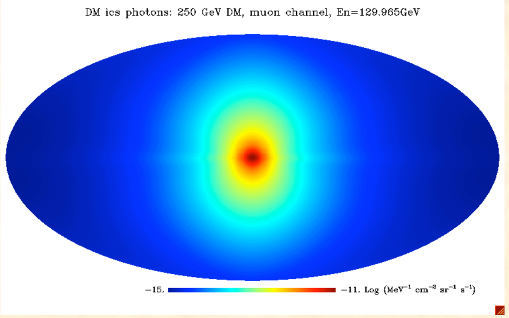






VS



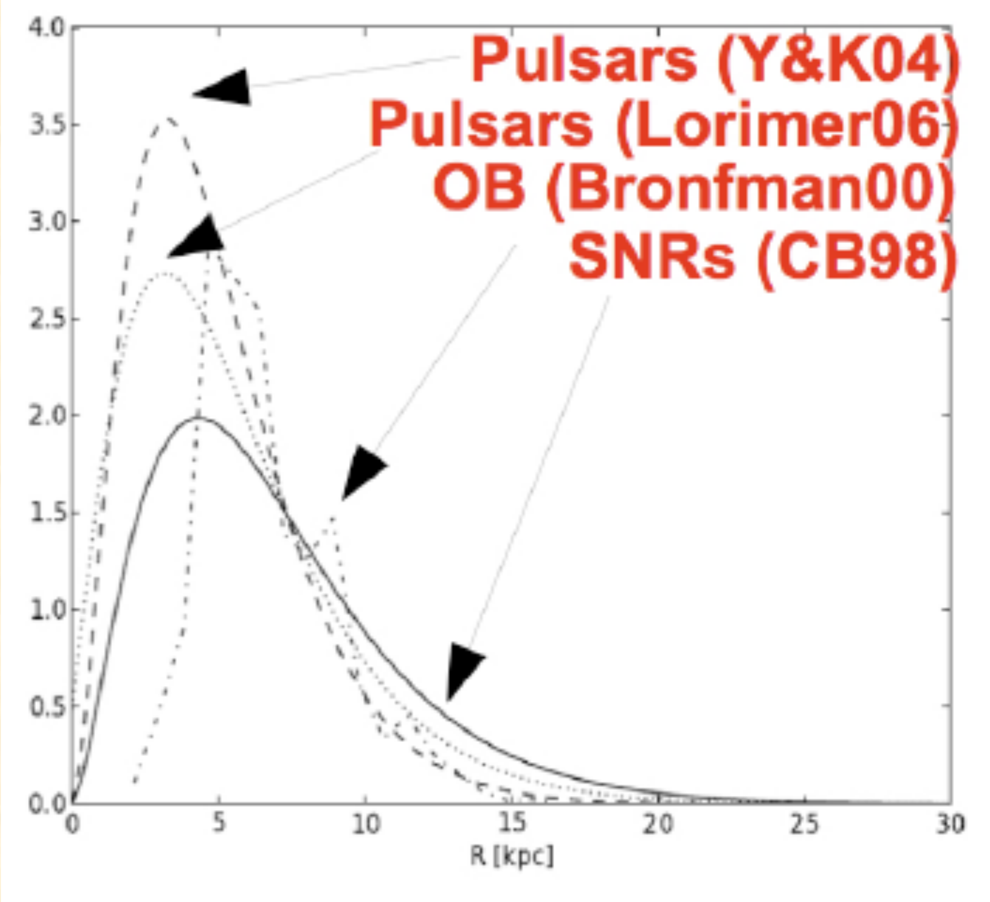


A global likelihood fit can be performed to find the contribution of each component

Cosmic Ray sources distribution

We use the SNR model (Case & Bhattacharya 1998) for the distribution of CRs sources. This model has a very low gradient within few kpc's from the GC giving a very low astrophysical signal and thus a conservative DM constrain.

We use an halo size of z=4kpc, while the other parameters (D, Va) are tuned to match the CR data.



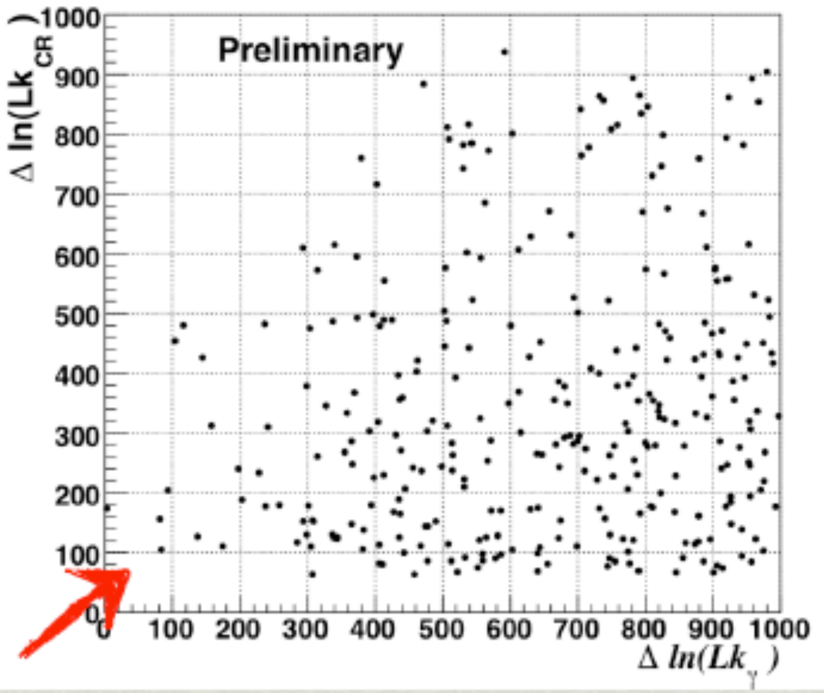
Current work on quantifying the effect of the astrophysical model choice

Difficulty:
likelihood varies by a huge amount among astrophysical models

✦-> DM *limit is effectively determined by a single diffuse model even in this approach,* rather than many models contributing to ln Lk profile - it is ***currently hard to quantify the effect of the uncertainty in the choice of a diffuse model on the dark matter limits.***
Work in progress...

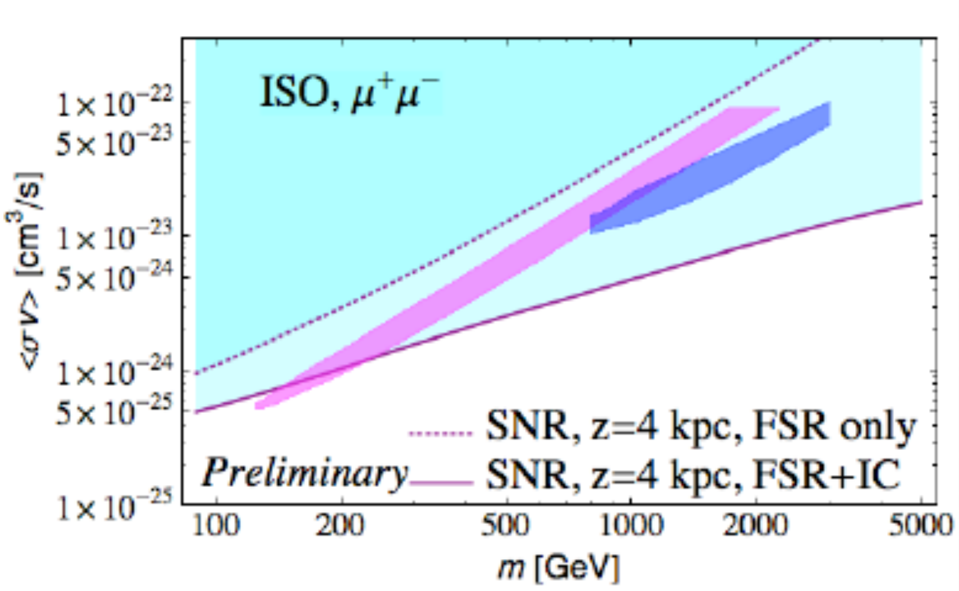
Sparse Sampling

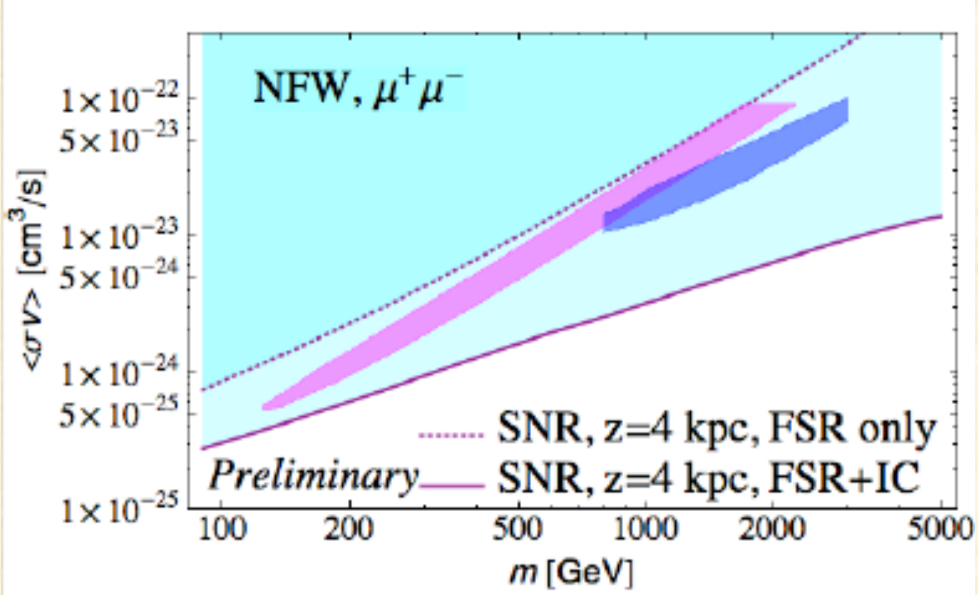
Including χ^2 from the CR data in the Likelihood makes it difficult (naively sampling) to populate the region that satisfies both CR and gamma rays. This important region is currently dominated by a couple of models.



See Talk of B.Anderson, next

DM exclusion limits

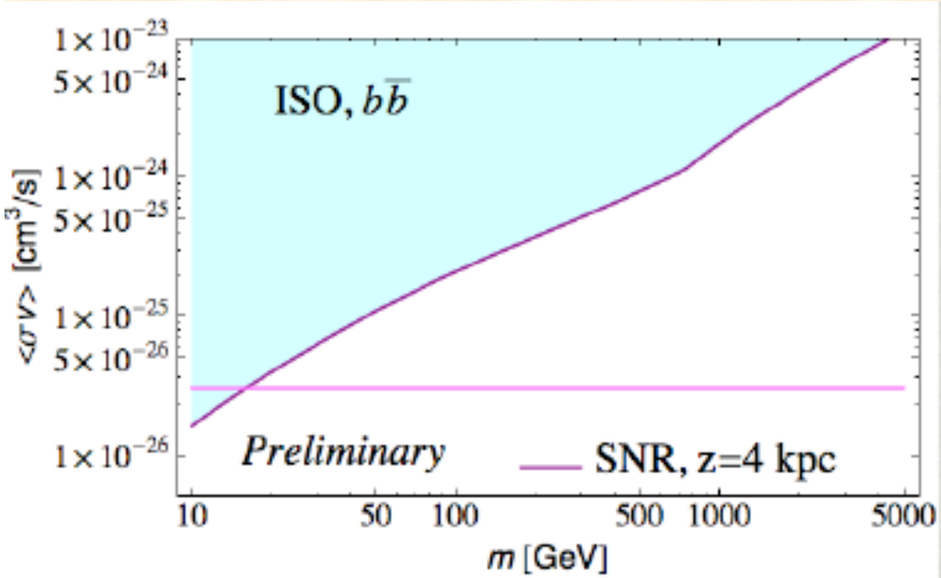


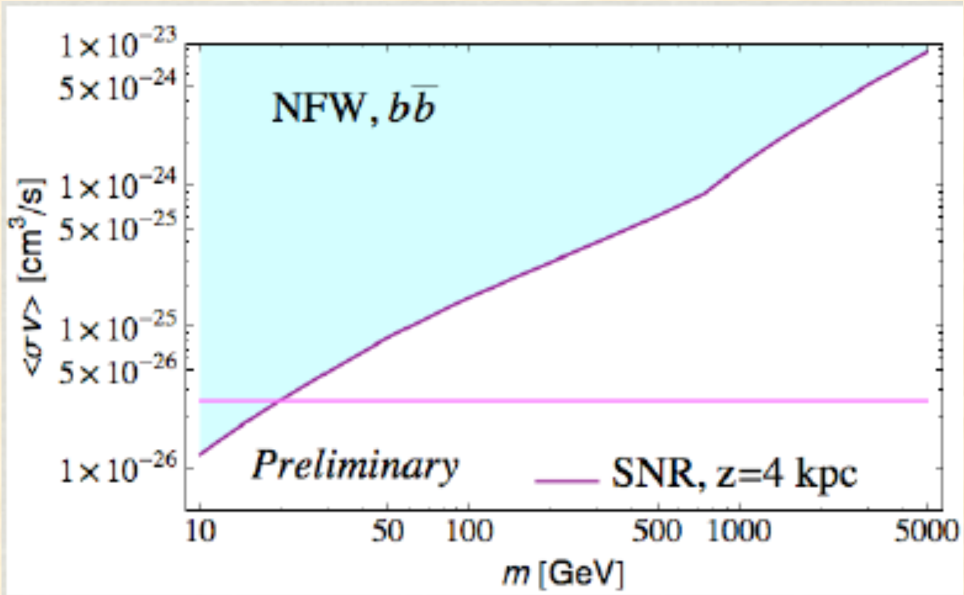


- FSR limits only comes from data up to 100 GeV and are quite weak.

- With FSR+ICS the Pamela/Fermi region is excluded independently of the DM profile.

DM exclusion limits (2)

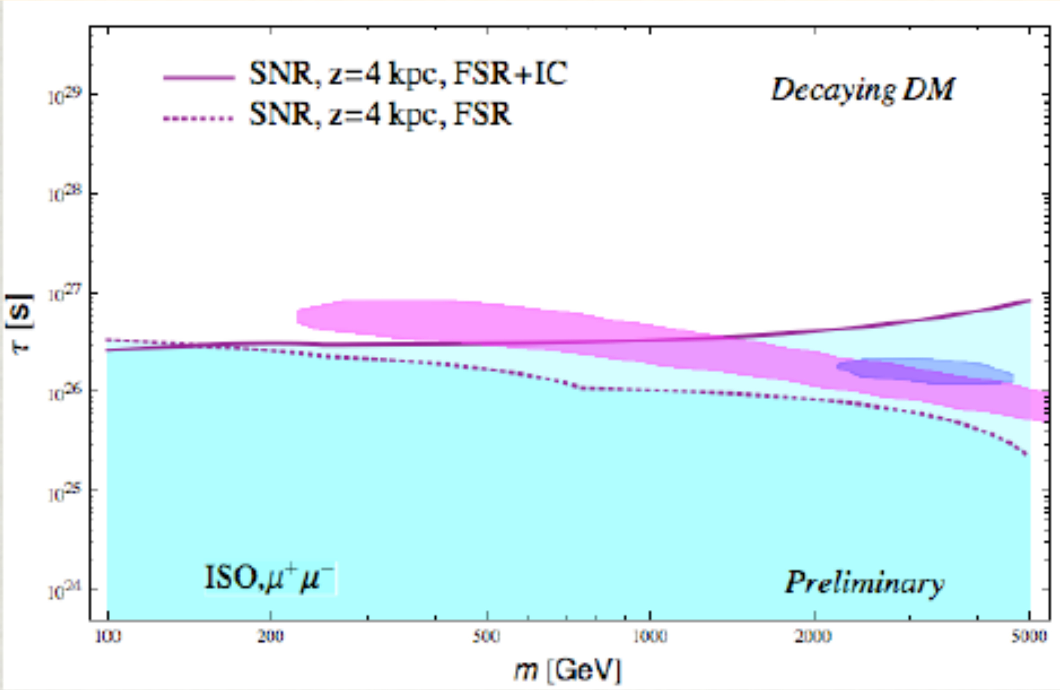




- bbar constrain are also weakly dependent from the DM profile

- Thermal freeze-out cross section probed for low DM wimp masses.

DM exclusion limits (3)



•Also the Decaying DM scenario is incompatible with the DM interpretation of the PAMELA/Fermi CR excesses

Summary and Conclusions

•Secondary radiation provides a complentary mean to test/find possible DM signatures.

•Limits coming from the galactic Halo, in particular from gamma rays together with a modeling of the known galactic background, are quite strong and do not confirm the DM interpretation of the PAMELA/Fermi CR excesses.

•Still uncertainties in the galactic diffuse model. Modeling improvements and thus better DM constraints are expected in the near future…