Testing Cosmic Rays Anomalies with multi-wavelength secondary radiation

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CR Backgrounds for
DM Searches
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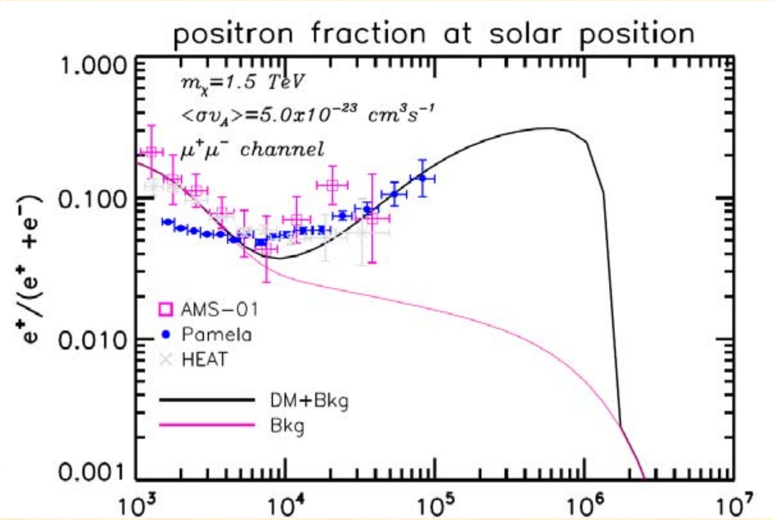
the Pamela/ATIC Anomalies: e+e- excesses w.r.t. the background

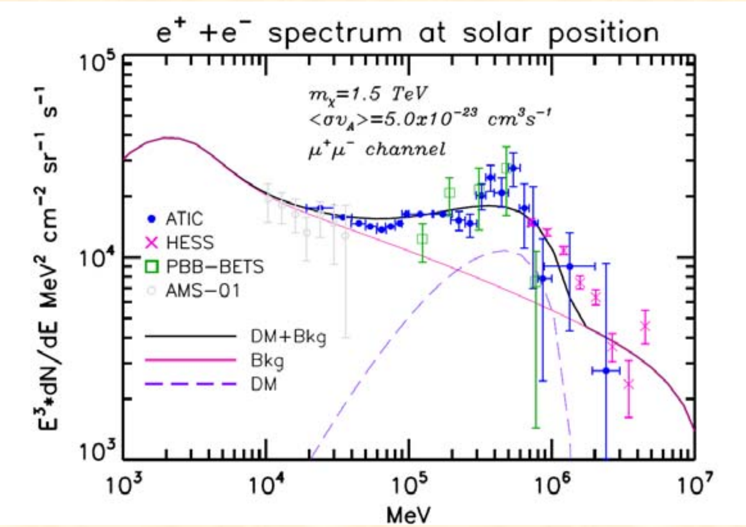
Both the signals seems to have the same origin:

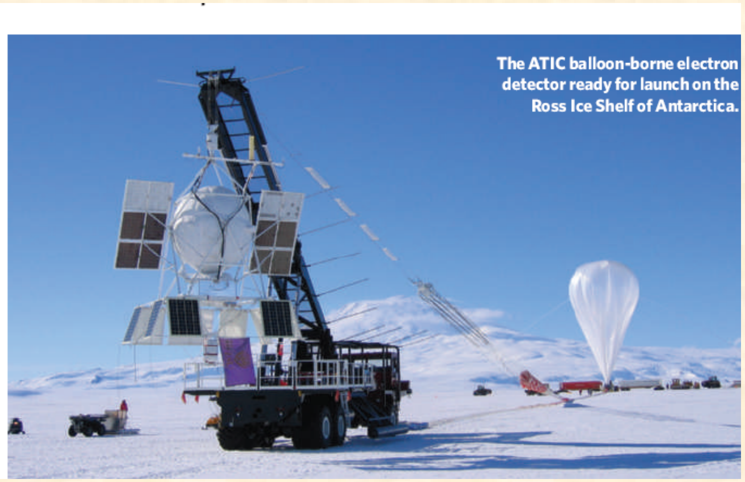
- Astrophysical explanation?
- DM explanation?

positron fraction

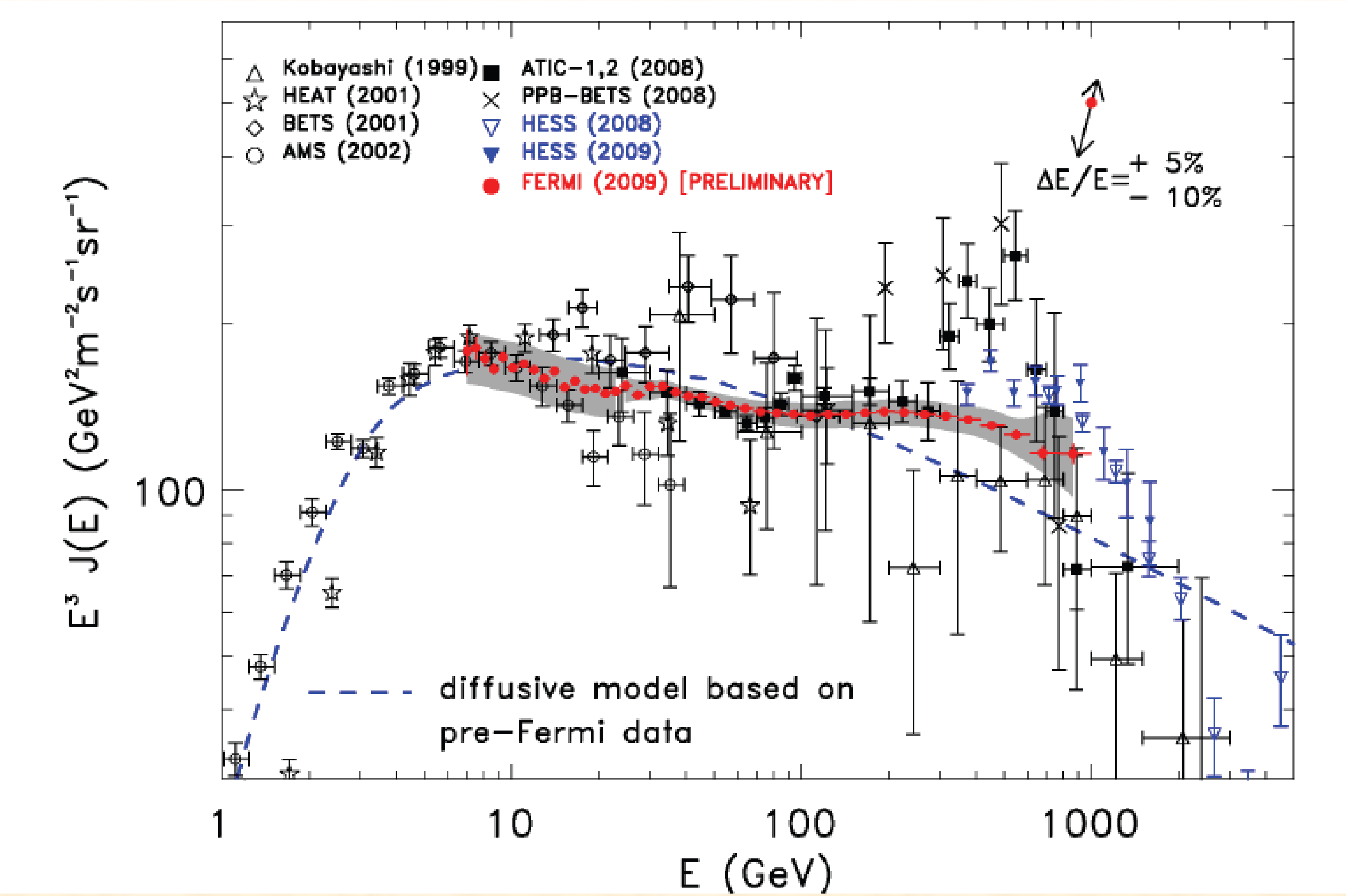


e^++e^- flux



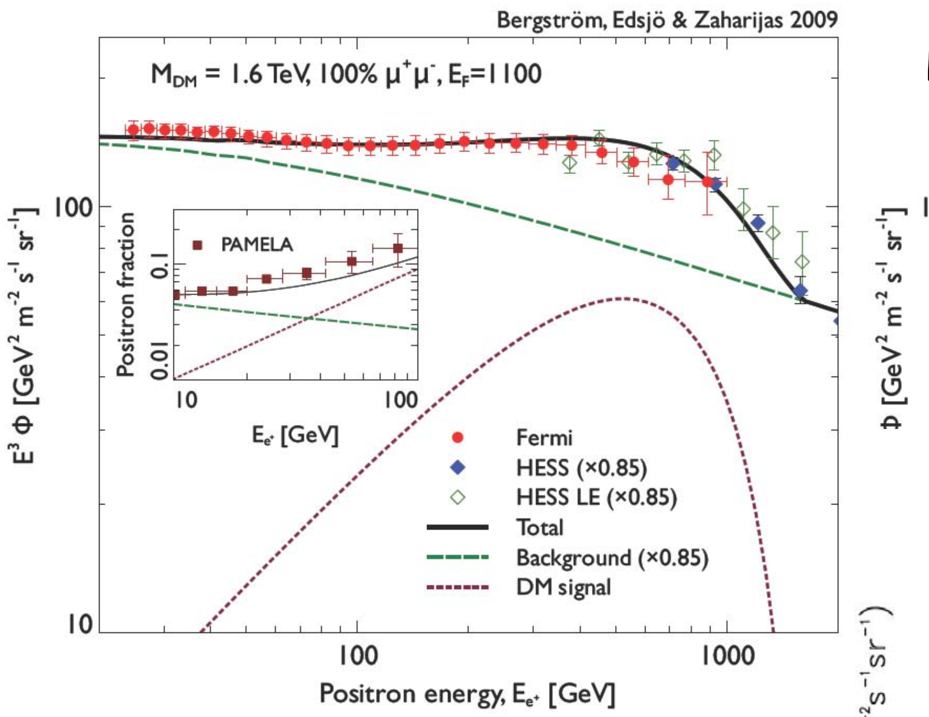


CRe Fermi spectrum from 7 GeV to 1 TeV



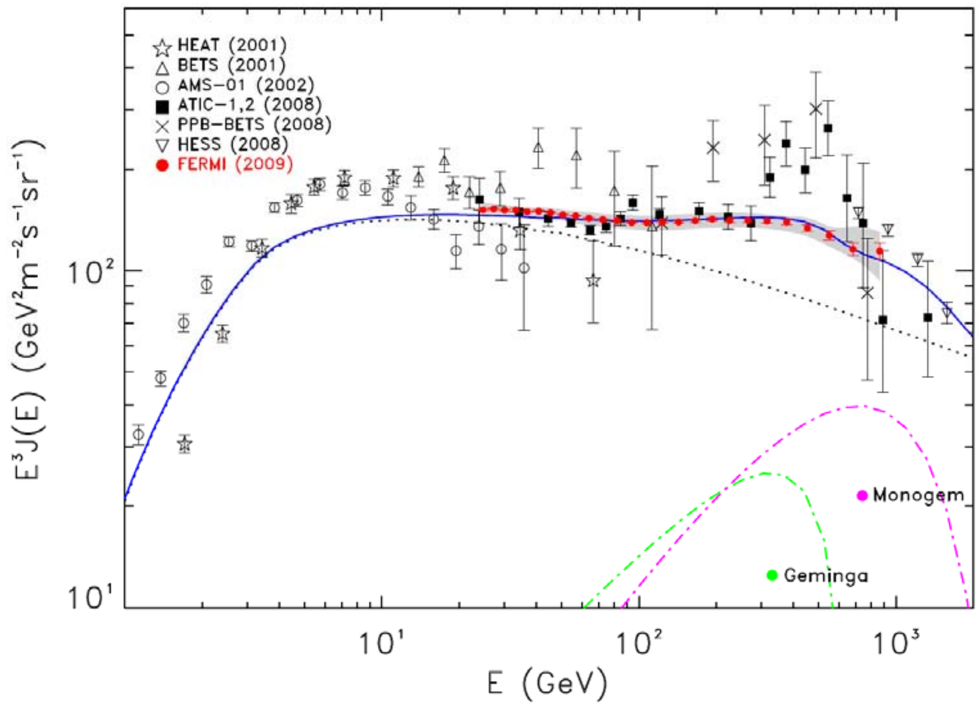
See Latronico's and Gaggero's Talk

Astrophysical vs Dark Matter Fits



Bergstrom, Edsjo & Zaharias 2009

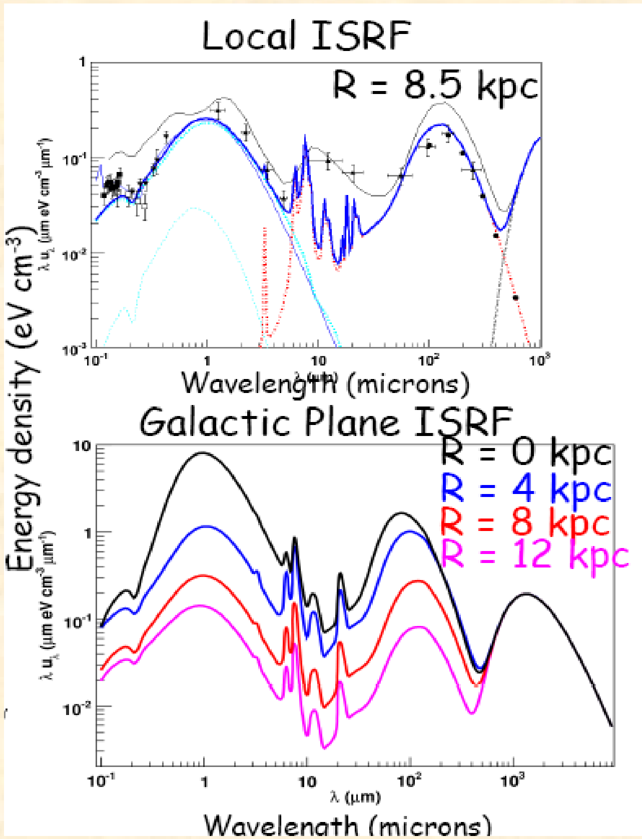
Grasso et al. 2009



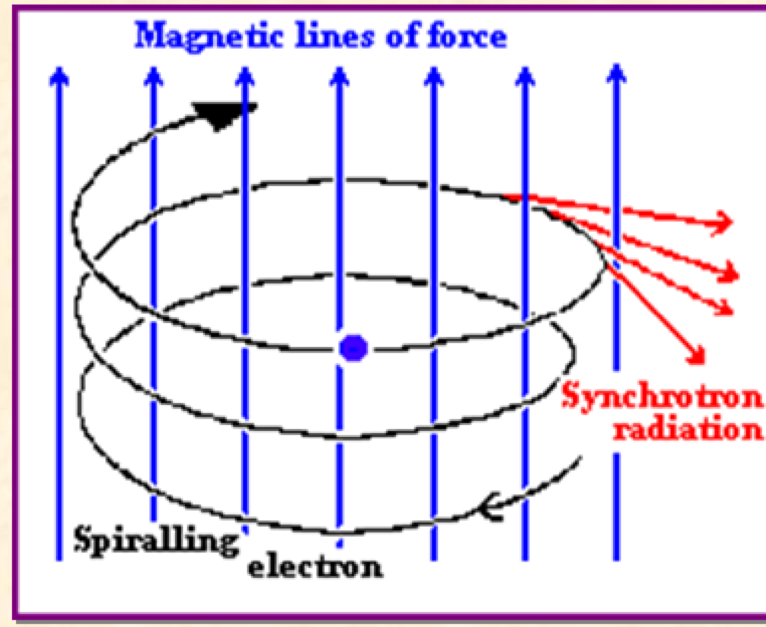
How to test in a way as model independent as possible?

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.

Diffusion and Energy Losses

Propagation equation for e+e-

$$\frac{\partial}{\partial t}\frac{dn_e}{dE_e} = \vec{\nabla}\cdot\left[K(E_e,\vec{r})\vec{\nabla}\frac{dn_e}{dE_e}\right] + \frac{\partial}{\partial E_e}\left[b(E_e,\vec{r})\frac{dn_e}{dE_e}\right] + Q(E_e,\vec{r}), \quad (13)$$

=0 Steady State Solution

Source Term: Injection Spectrum

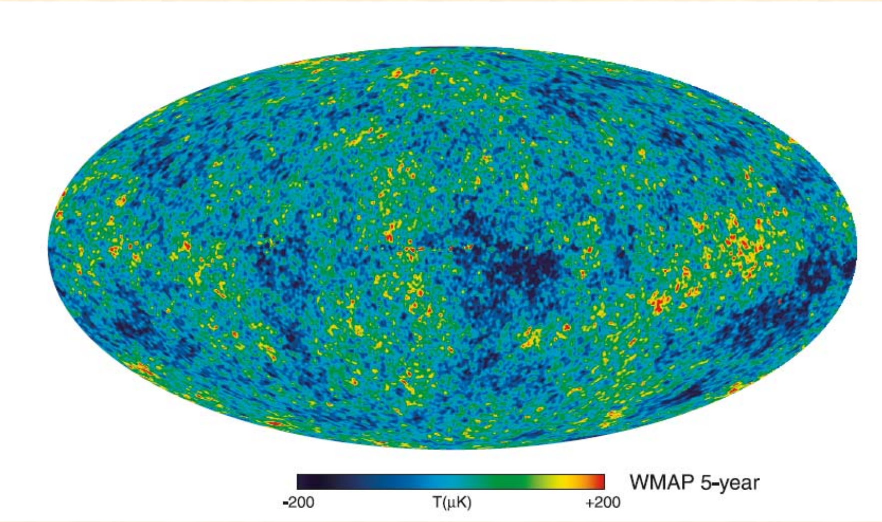
Diffusion

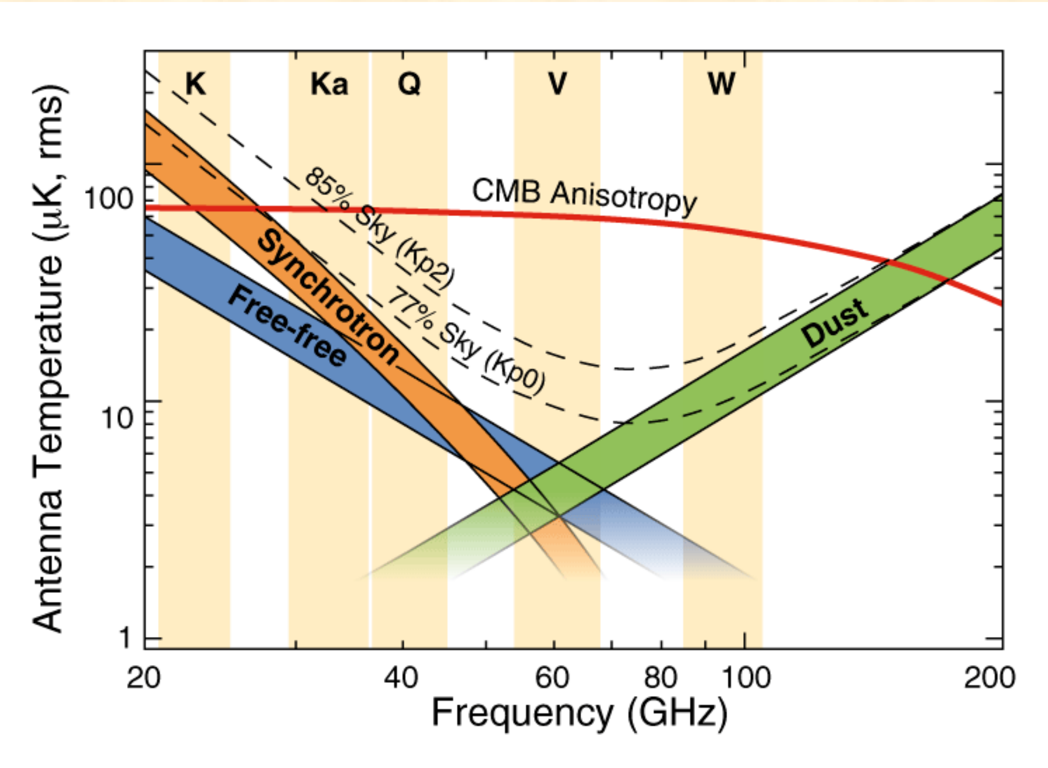
Energy Losses: ICS and Synchrotron

$$Q(r,E) = \rho^2 \langle\sigma_A v\rangle / 2m_\chi^2 \times dN_e/dE.$$

full numerical approach employing **Galprop**, or **Dragon** (see related talks)

The Microwave sky



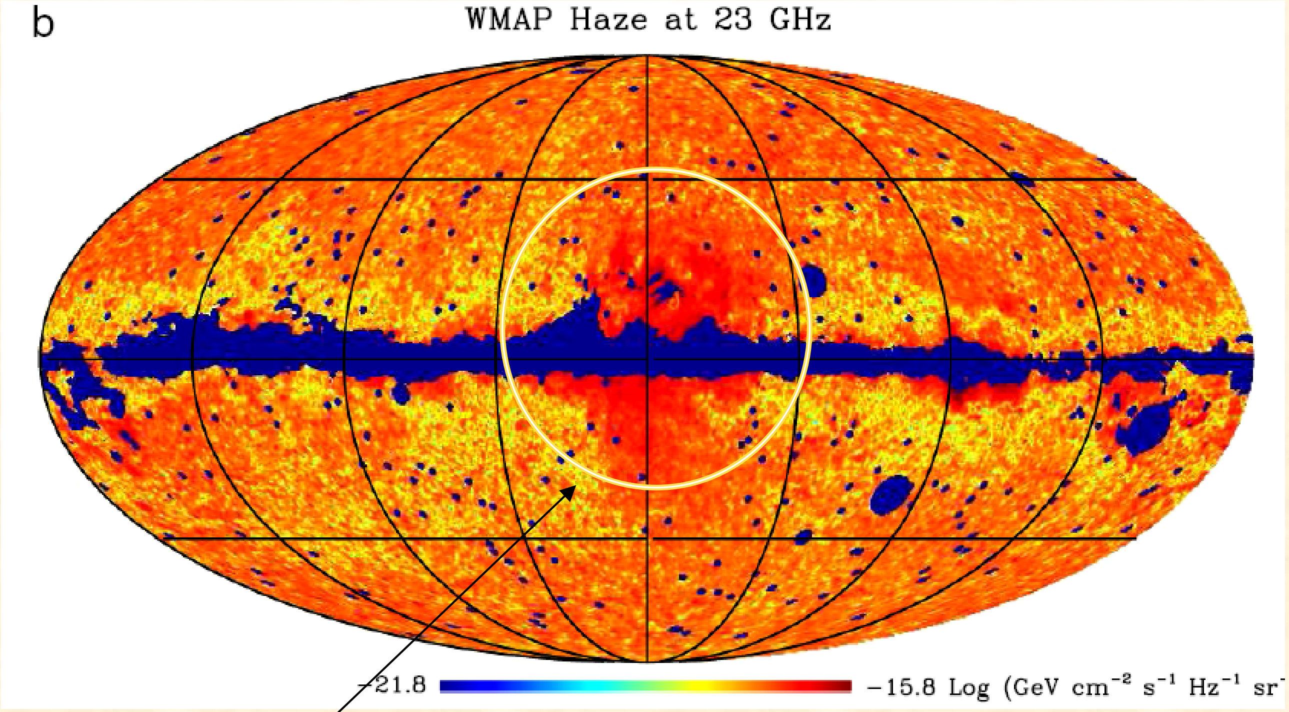


- In addition to CMB photons, WMAP data is "contaminated" by a number of galactic foregrounds that must be accurately subtracted

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

- Substantial challenges are involved in identifying and removing foregrounds

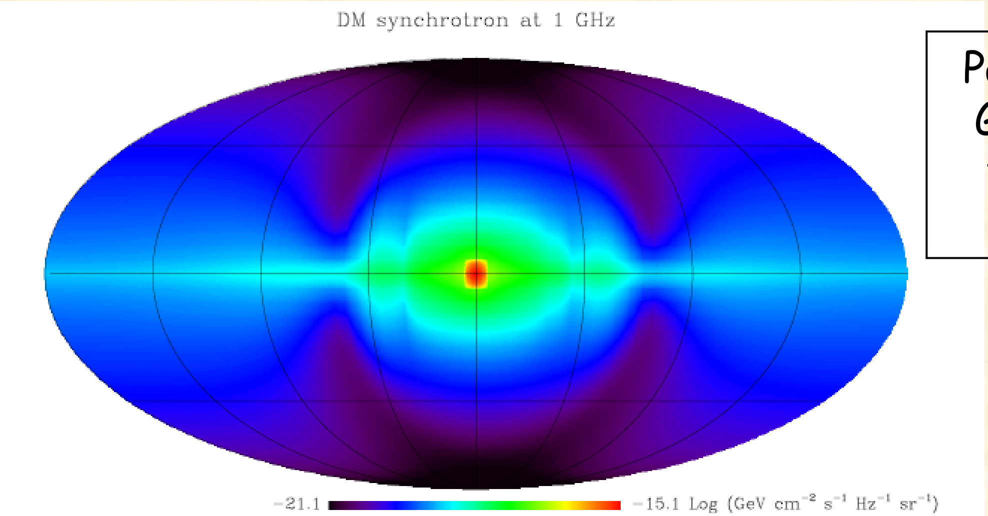
The "WMAP Haze"



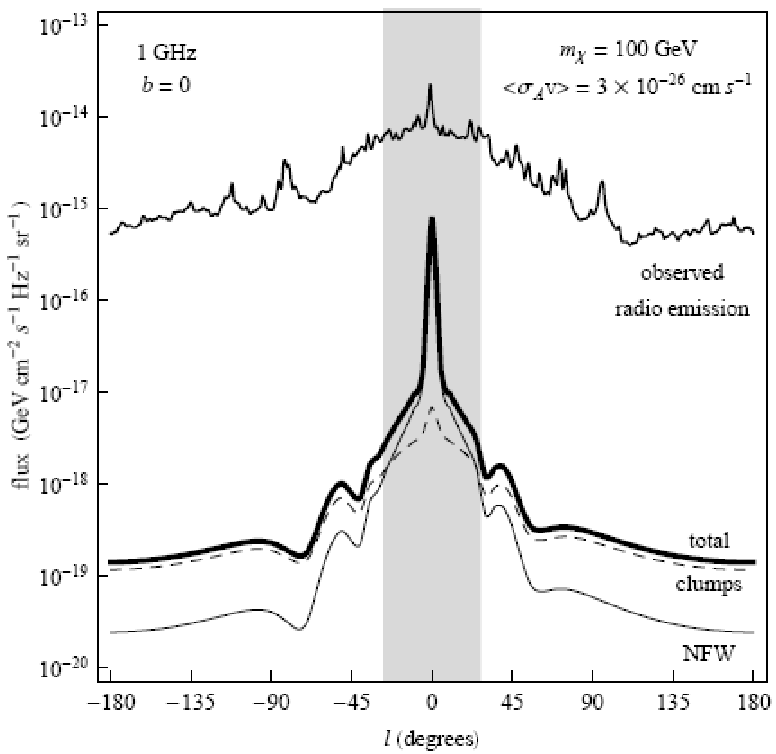
After known foregrounds are subtracted, an excess appears in the residual maps within the inner ~20° around the Galactic Center

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.

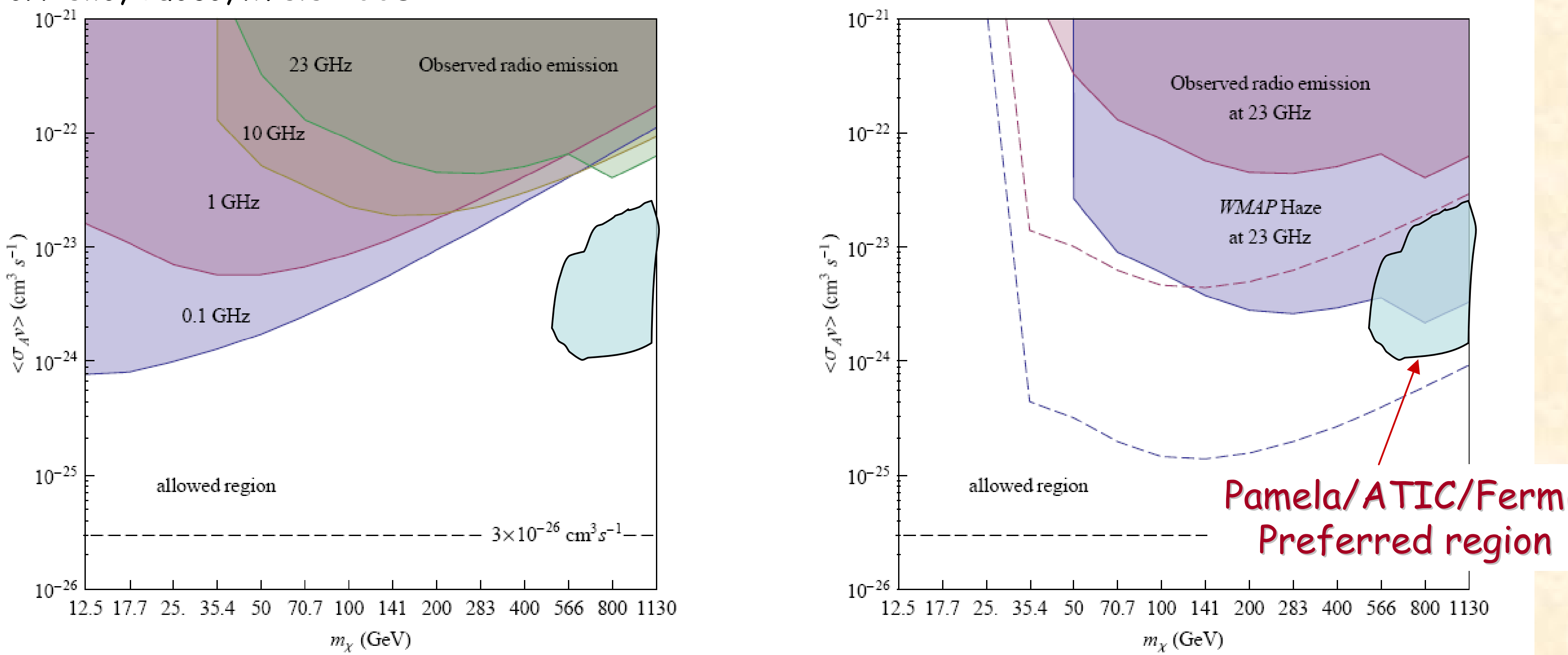


Requiring that the DM signal does not exceed the observed radio emission (CMB cleaned, but not foreground cleaned) DM constraints in the m_χ - $<\sigma Av>$ plane can be derived. The region around the GC (15°x15°) is excluded from the analysis.

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

DM constraints in the m_χ-$\langle\sigma_A v\rangle$ plane

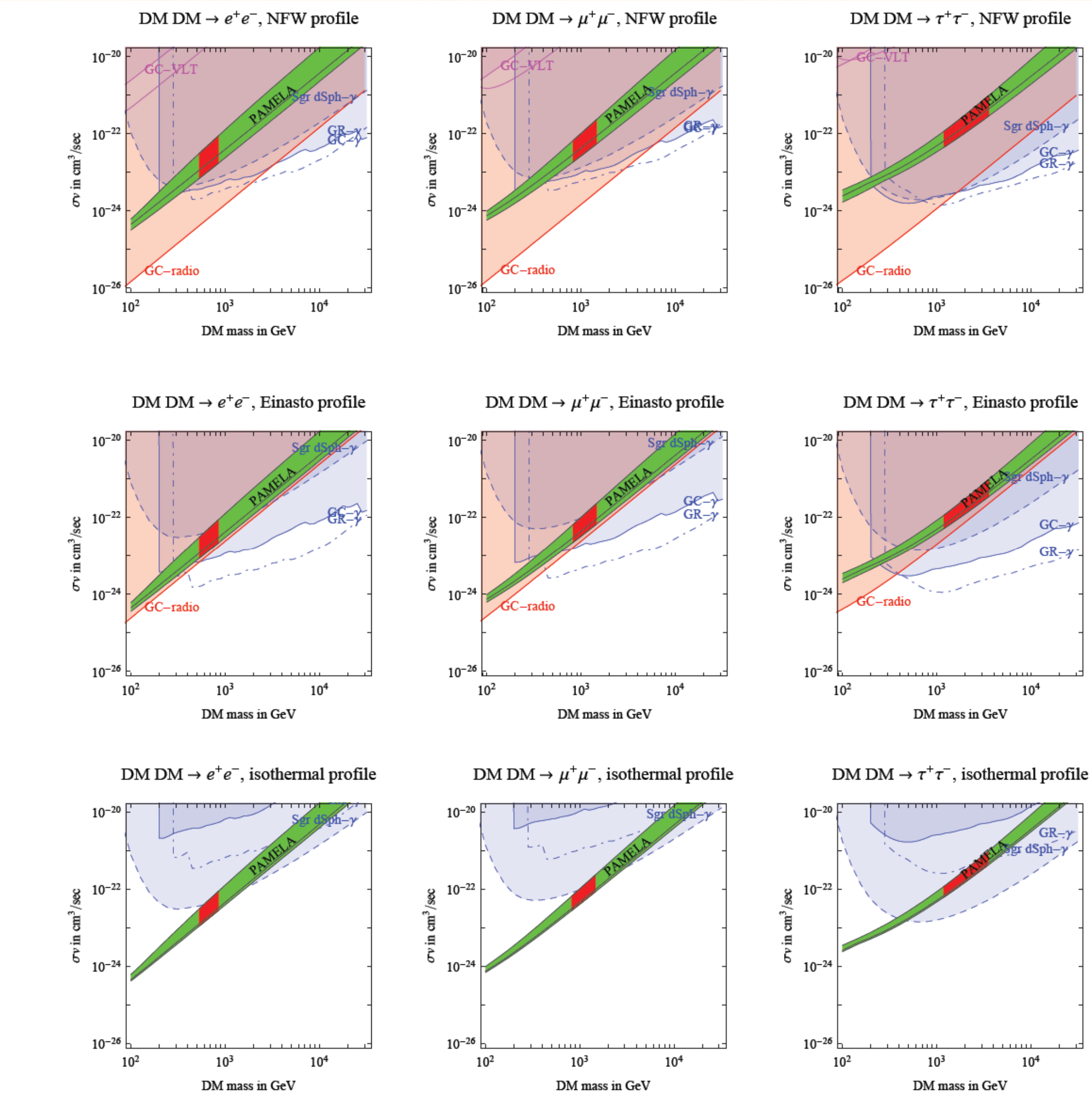
Borriello, Cuoco, Miele 2008



- Constraints in the m_χ - $\langle\sigma_A v\rangle$ 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.

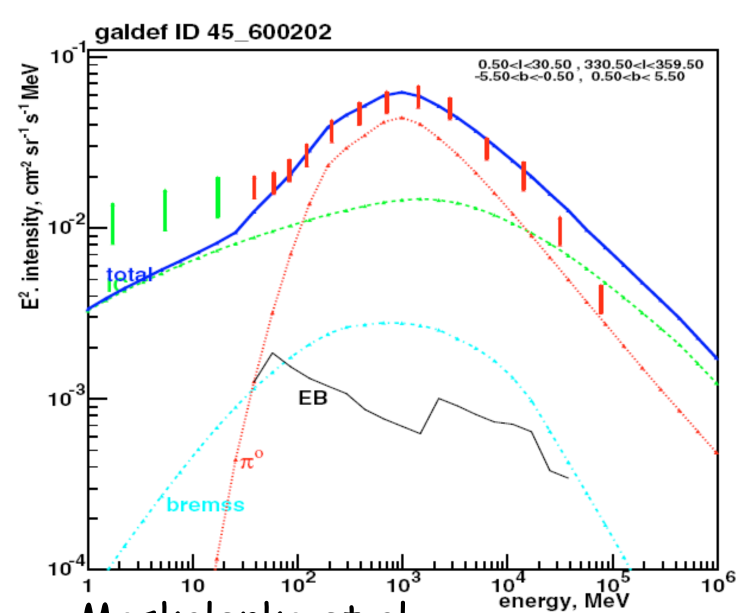
DM constraints from the Galactic Center



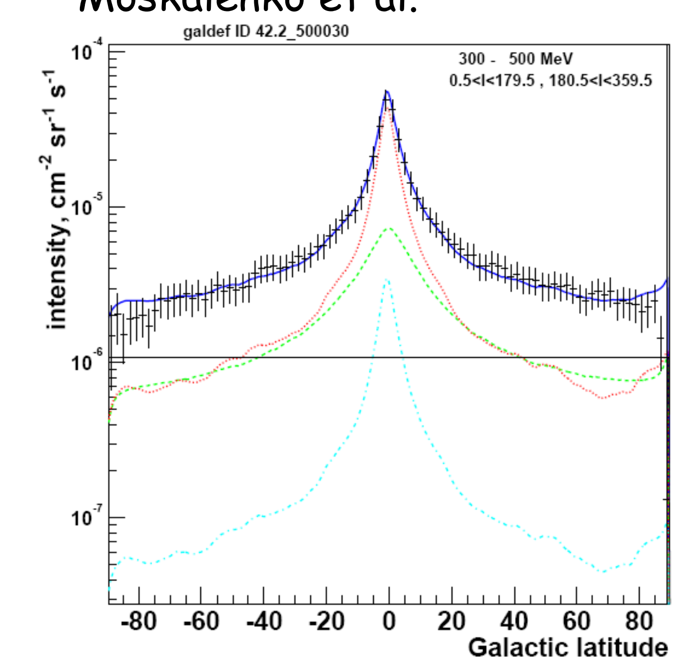
More stringent constraints but more model dependent on the DM profile and magnetic field in the GC

G.Bertone, M.Cirelli, A.Strumia, M.Taoso, JCAP 2009, arXiv:0811.3744

The Gamma Sky



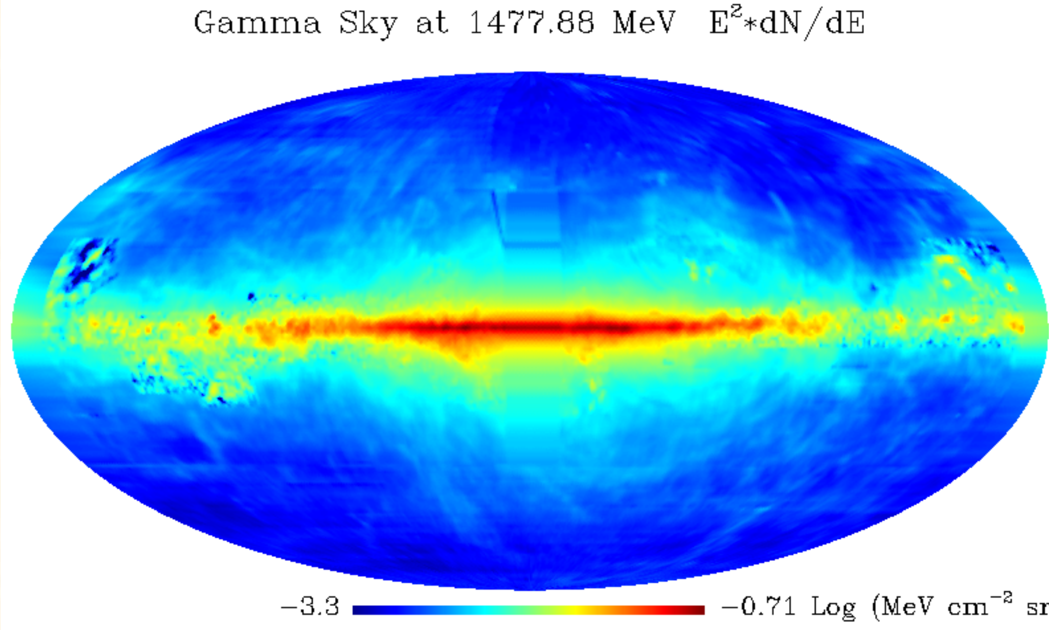
Moskalenko et al.



Galactic Contribution from:

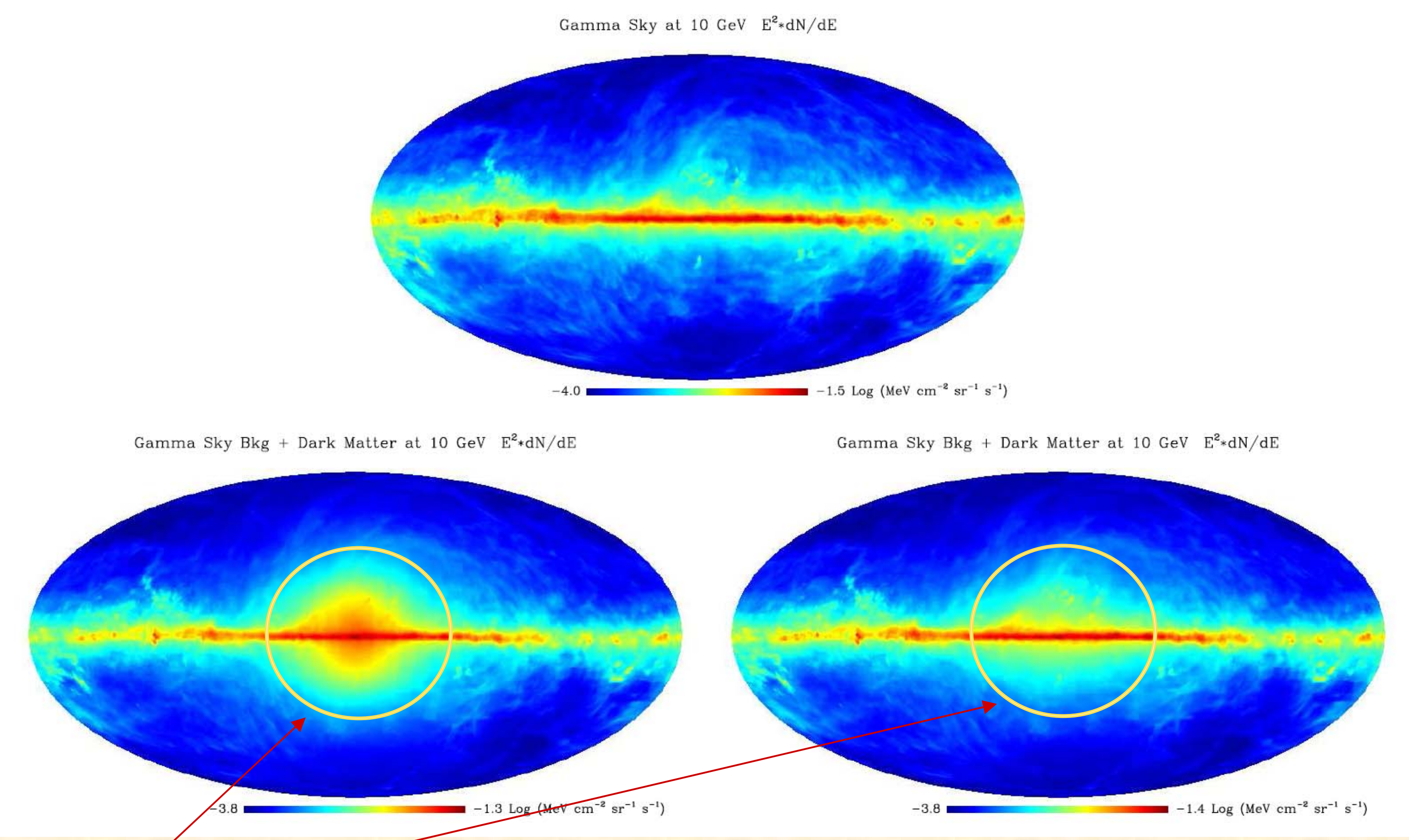
1. Pion Decay
2. Inverse Compton
3. Electron Bremsstrahlung

Galprop Foregrounds Model:



Also, detector resolution, charged particle background…

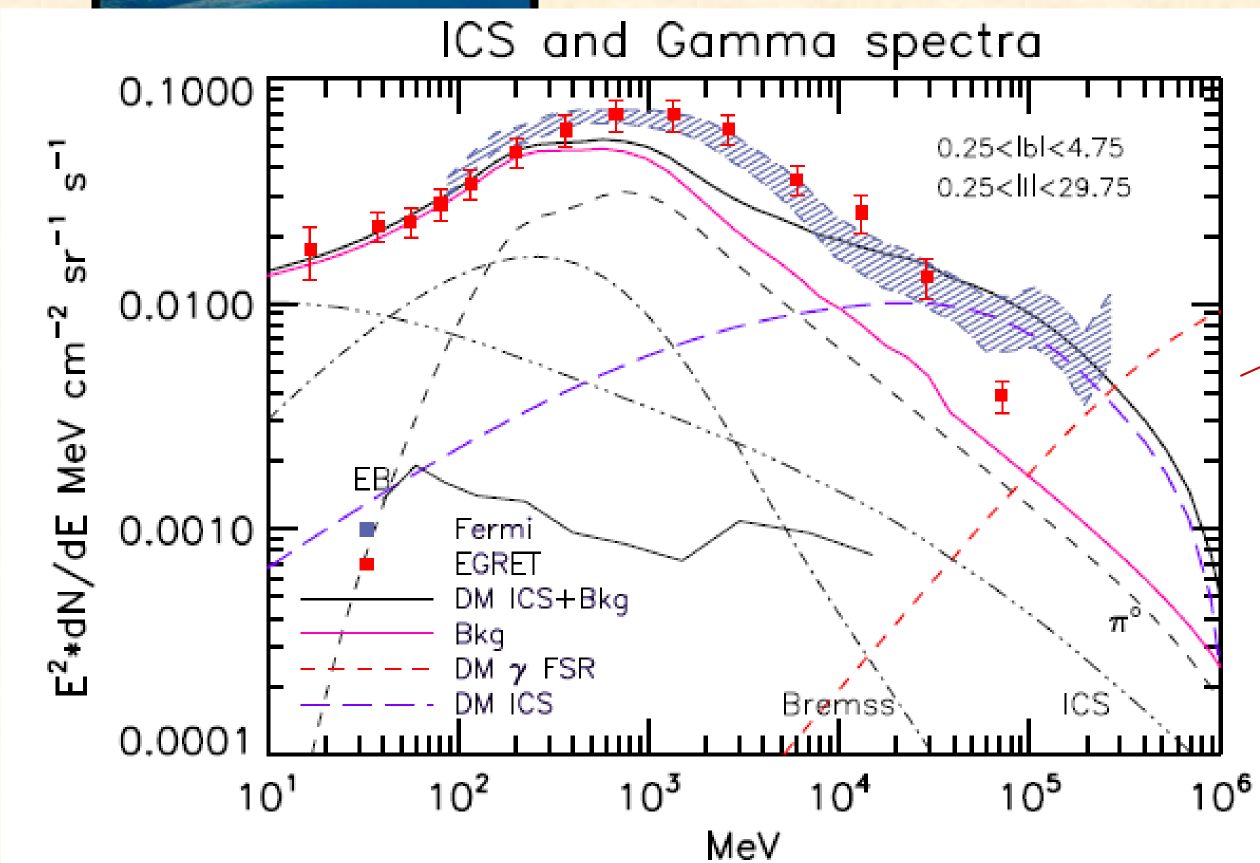
The "ICS Haze"

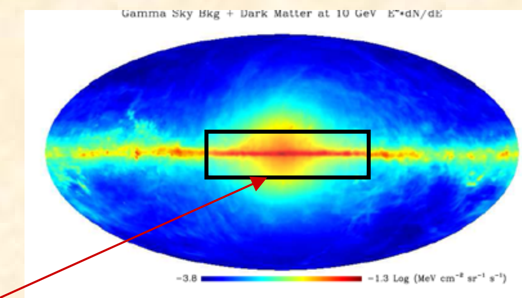


Similarly to the synchrotron case, IC signal produces an extremely peculiar "ICS Haze" peaking around 10-100 GeV which provides a further mean to discriminate the DM signal from the astrophysical backgrounds and/or to check for possible systematics.

ICS and background Spectra from Pamela/ATIC and forecast for Fermi

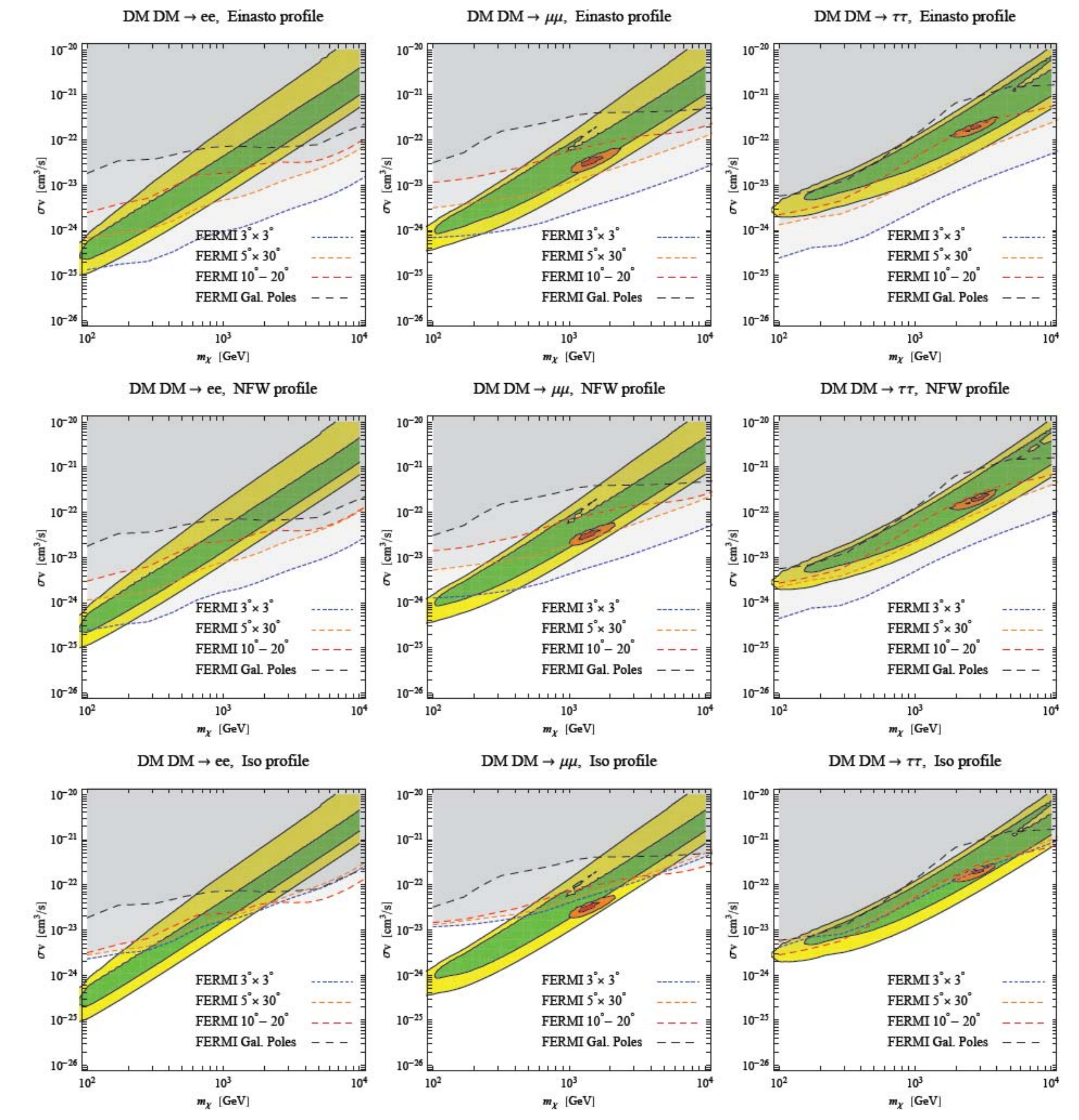
- The Pamela/Atic electrons produce a large excess of Inverse Compton Radiation w.r.t to the galactic backgrounds
- EGRET somewhat disfavors the excess. Fermi can say more, but care is needed with the systematics





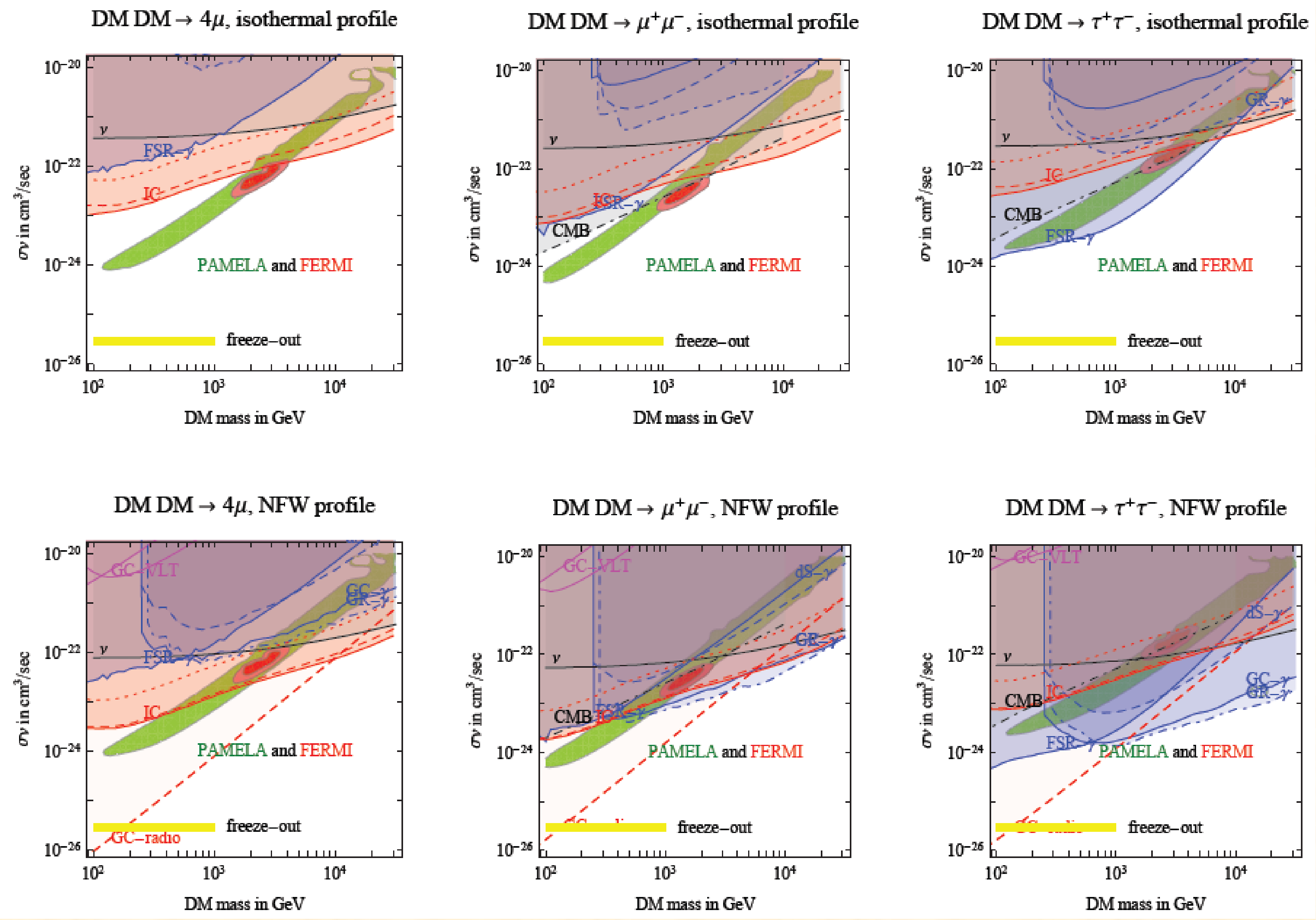
E.Borriello, A.Cuoco, G.Miele
Ap.J.699:L59-L63,2009

DM constraints from ICS and Fermi data



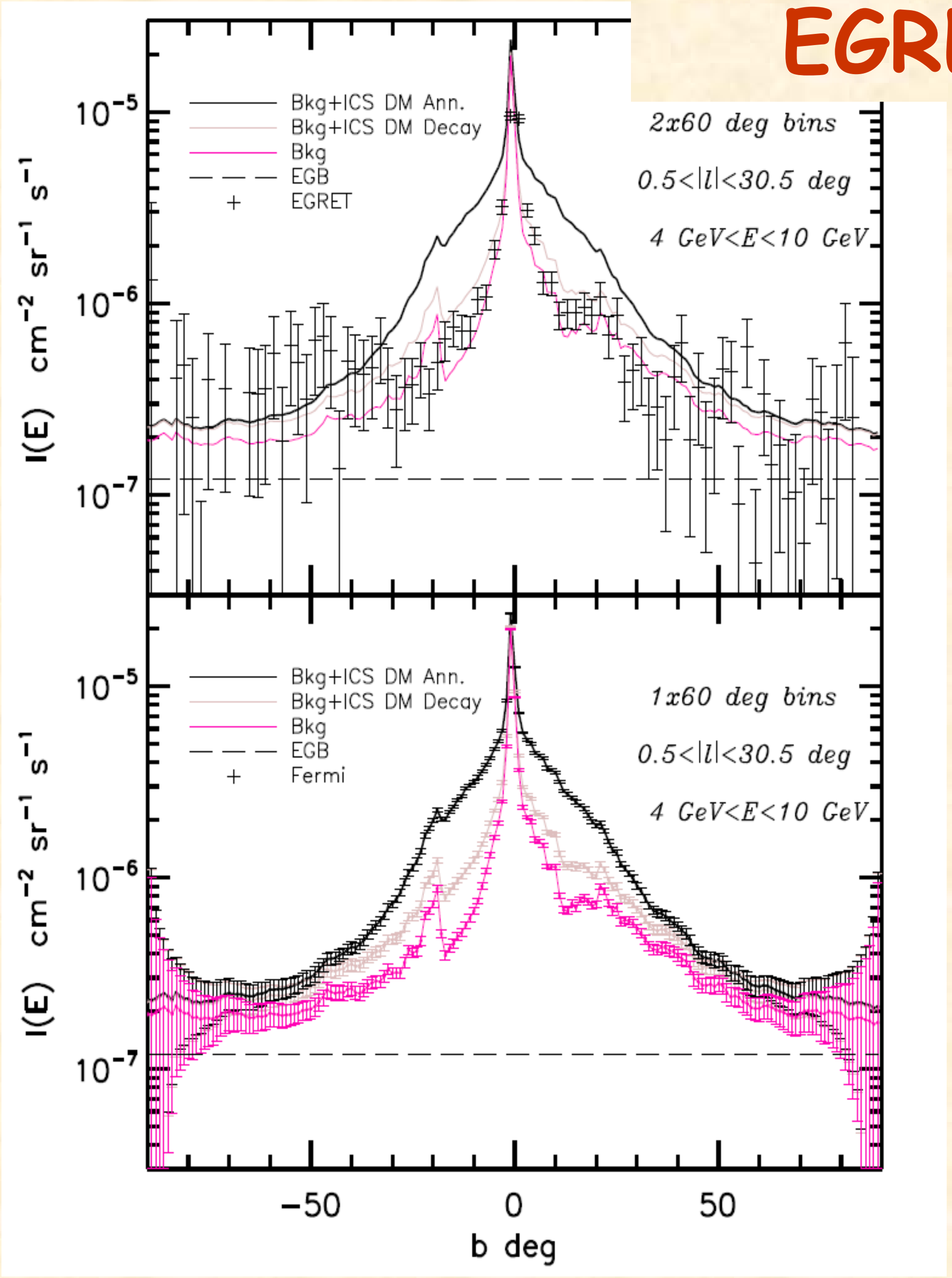
M. Cirelli, P. Panci, P. D. Serpico, arXiv:0912.0663

DM constraints from ICS and Fermi data



M. Papucci, A. Strumia, arXiv:0912.0742

Profiles and Comparison of EGRET/Fermi Statistic



- Upper panel: EGRET data compared the annihilation model and the decaying model. Annihilating DM produces a too much broad peak to fit the data, beside producing an excessively high normalization.

- Lower Panel: forecast of the Fermi ability to discriminate among the astrophysical and annihilating DM scenario. Also shown is the Decaying DM scenario.

Sytematics:

- Uncertainties in the exposure
- Residual charged particle contamination.
- Foreground modeling

A Fermi Haze?

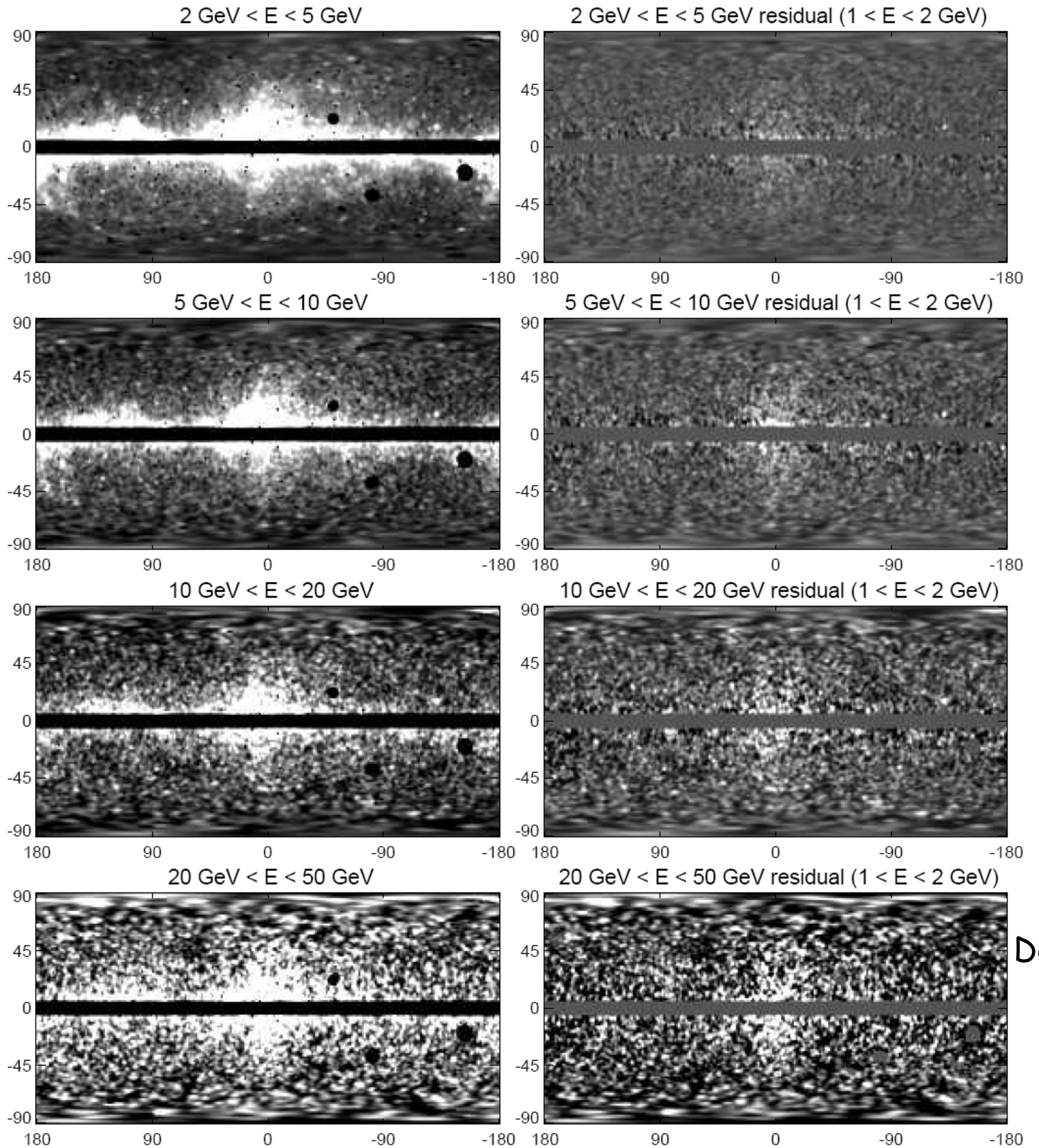
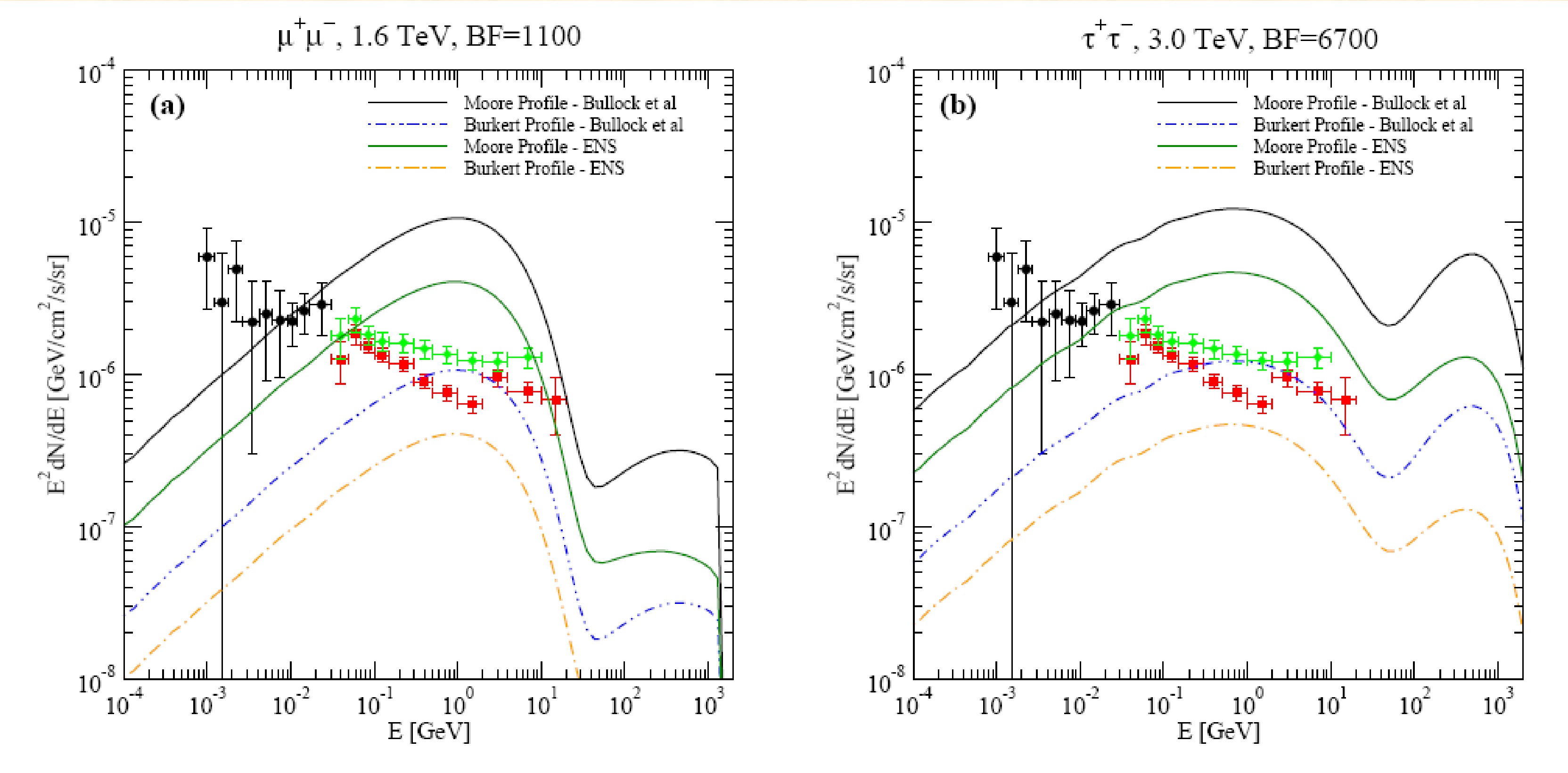


FIG. 5.— The same as Figure 3 but using the *Fermi* 1-2 GeV map for cross-correlations instead. Unlike the SFD dust map which should trace π^0 emission only, the low energy *Fermi* map includes the soft ICS and bremsstrahlung associated with lower energy electrons. In fact comparing the residuals in this figure with those in Figure 3, it is clear that the disky component has been subtracted leaving only the ICS haze. Furthermore, the ICS haze is more prominent in the high energy maps indicating a harder spectrum than π^0 emission which is the dominant emission mechanism at $\sim$1 GeV energies.

Dobler, Finkbeiner et al. 2009

Comparison with the Extra-Galactic Inverse Compton



Jeltema & Profumo 2009

- Constraints from the Extra-Galactic Inverse Compton can be in principle stronger than the galactic ones but are generally more model dependent.

Belikov & Hooper 2009

Hütsi, Hektor, Raidal 2009

What other signatures?

ICS and background Spectra from Pamela/ATIC and forecast for Fermi

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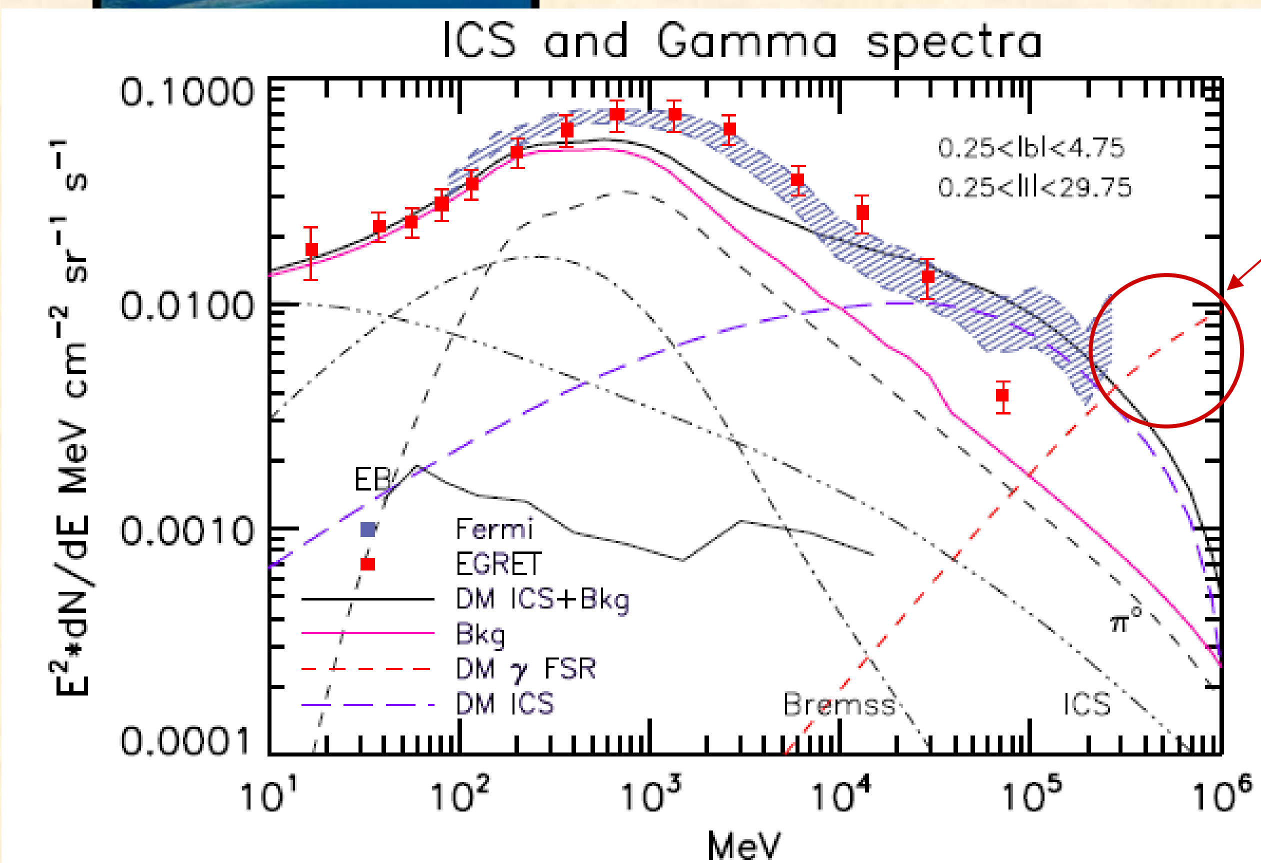
- EGRET somewhat disfavors the excess. Fermi can say more, but care is needed with the systematics



FSR Excess

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

Final State Radiation

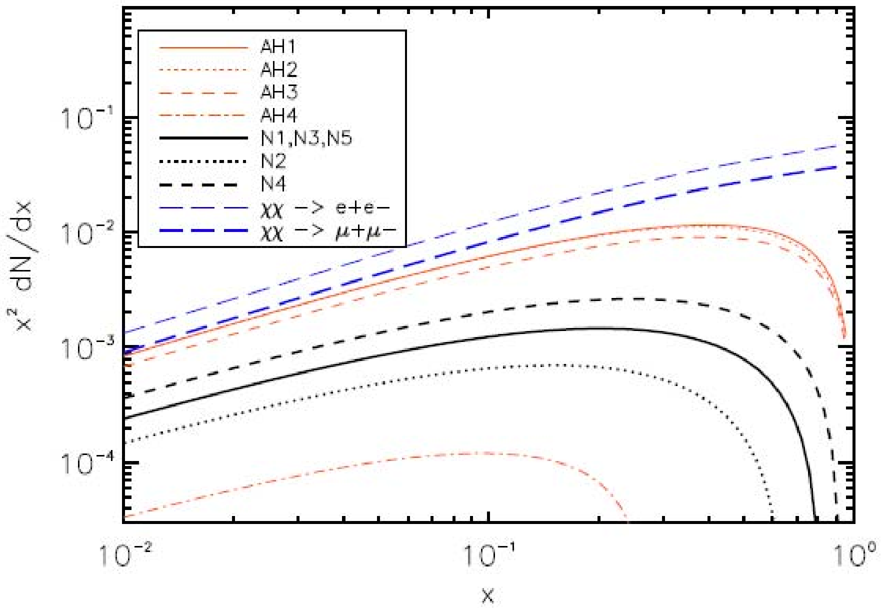


FIG. 1: The various possible photon spectra that can arise from DM annihilating to new light particles which in turn decay into charged leptons. For the models $N1 - N5$, we neglect here the decay of s to tau-leptons or bottom quarks – see Fig. 2 for an example of how this changes the spectra. For comparison, we also indicate the spectrum from DM directly annihilating to charged leptons.

Bergstrom et al.

PRD 2009. arXiv:0812.3895

Sommerfeld Enhancement

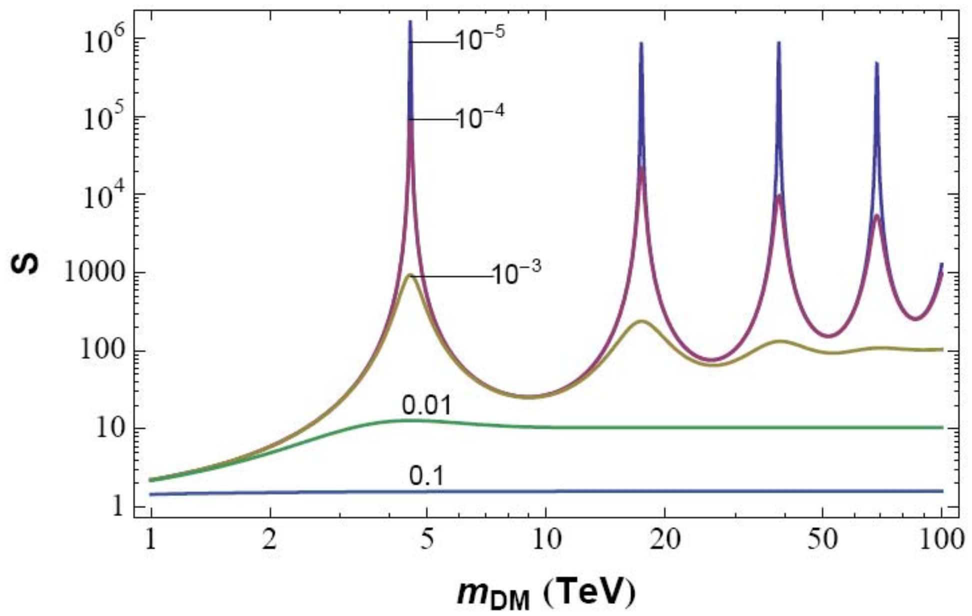
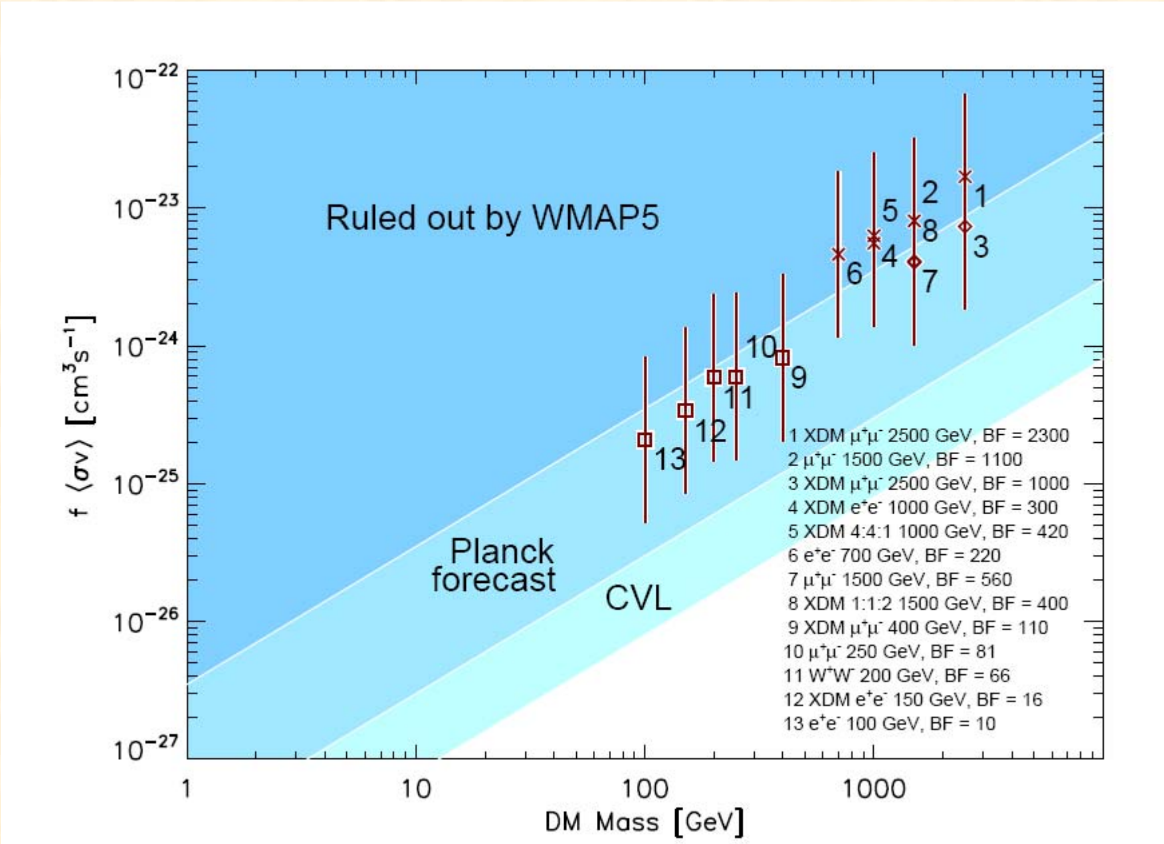


FIG. 2: Sommerfeld enhancement S as a function of the dark matter particle mass m, for different values of the particle velocity. Going from bottom to top $\beta = 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}$.

Lattanzi and Silk, arXiv:0812.0360

Sommerfeld Enhancement?



$v \sim 10^{-3}$ in DM halos today but $v \sim 10^{-7}$ at the time of CMB recombination! Sommerfeld effect is strongly saturated.

T. R. Slatyer, N. Padmanabhan, D. P. Finkbeinerer, arXiv:0906.1197

S. Galli, F. Iocco, G. Bertone, A. Melchiorri, arXiv:0905.0003

Summary and Conclusions

•Secondary Radiation provides a fairly model independent test of the origin of the PAMELA/ATIC/FERMI electrons.

•Fermi data provide already interesting constraints on the DM interpretation of the CR anomalies. More statistics and a study of the foregrounds can further pin down the limits.

•More in general Inverse Compton and Synchrotron Radiation provide a complementary mean to test/find possible DM signatures.

•Further complementary signatures given by Final State Radiation and CMB constraints.