Dark Matter Multi-wavelenght/Multi-messengers constraints with synchrotron and Inverse Compton radiation

Based on
E.Borriello, A.Cuoco, G.Miele, PRD79:023518,2009
E.Borriello, A.Cuoco, G.Miele, ApJL.699:L59-L63,2009

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University of Aarhus,
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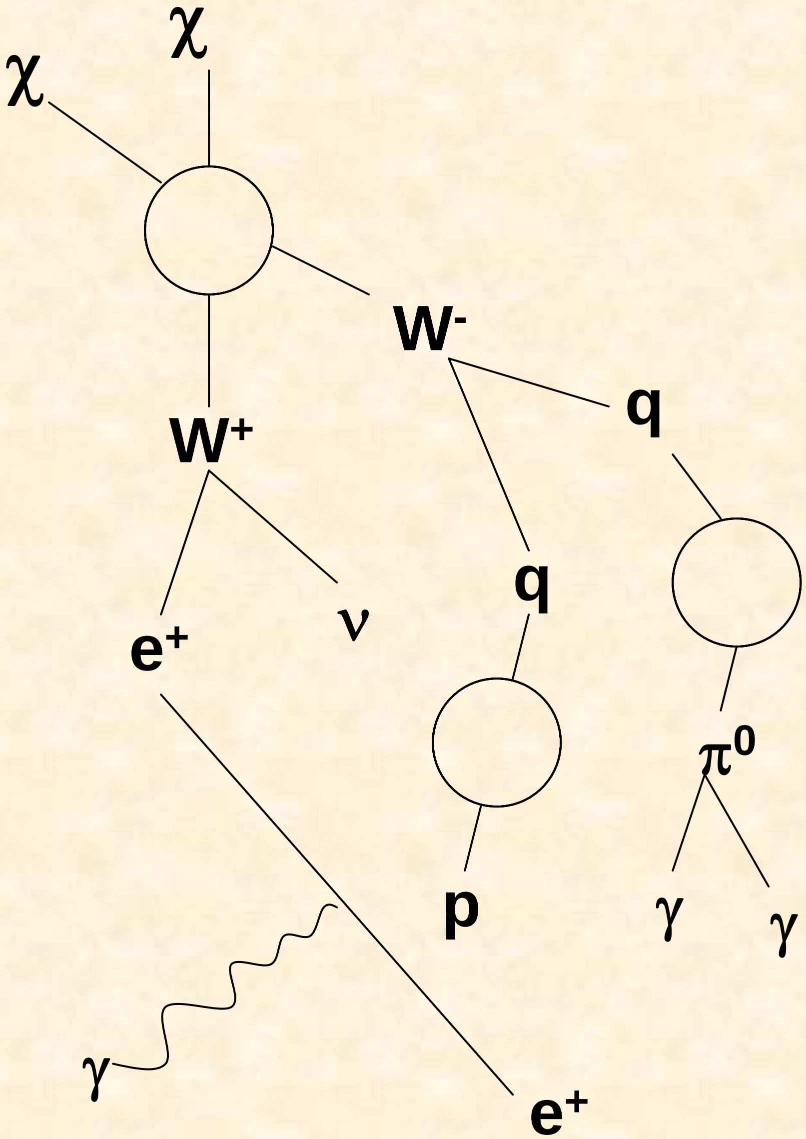
Stanford Linear Acceleration Center,
TeVPa09,
July 15st 2009

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

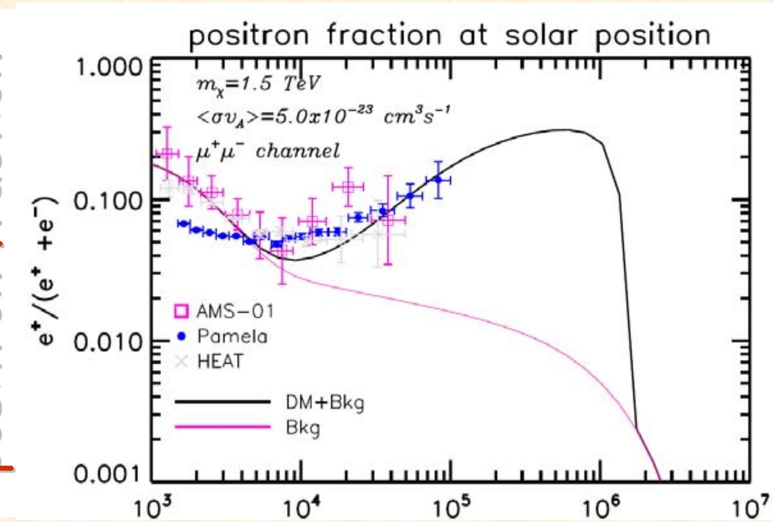


the Pamela/ATIC Anomalies: e+e- excesses w.r.t. the background

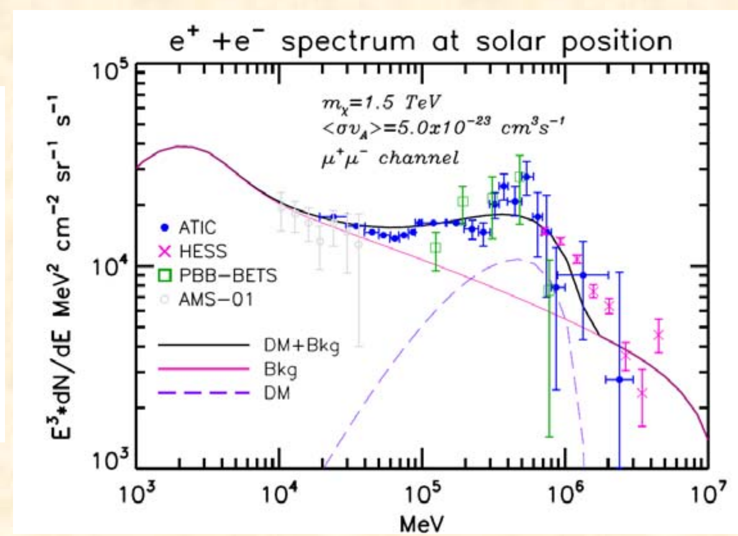
Both the signals seems to have the same origin:

- Astrophysical explanation?
- DM explanation?

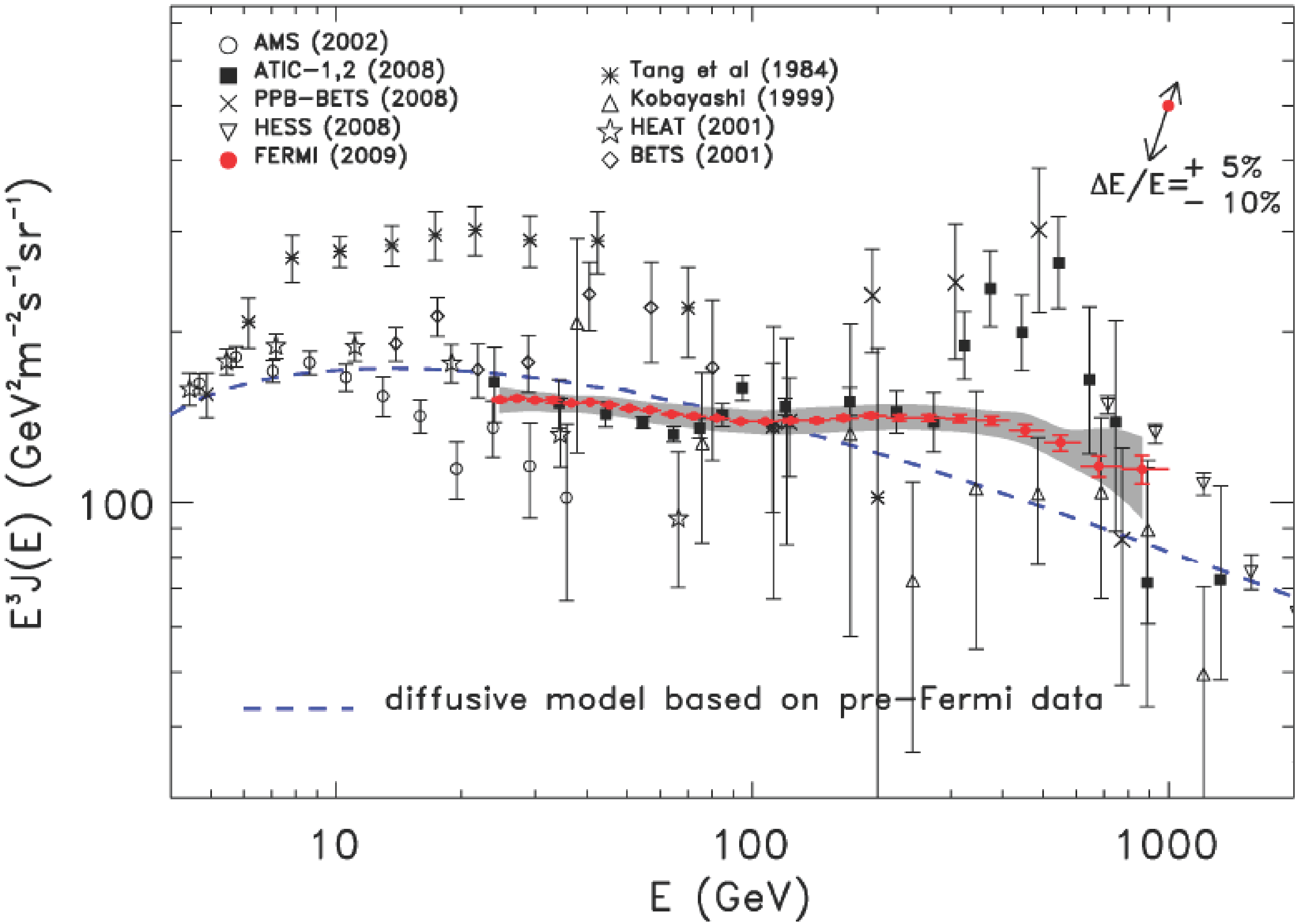
positron fraction



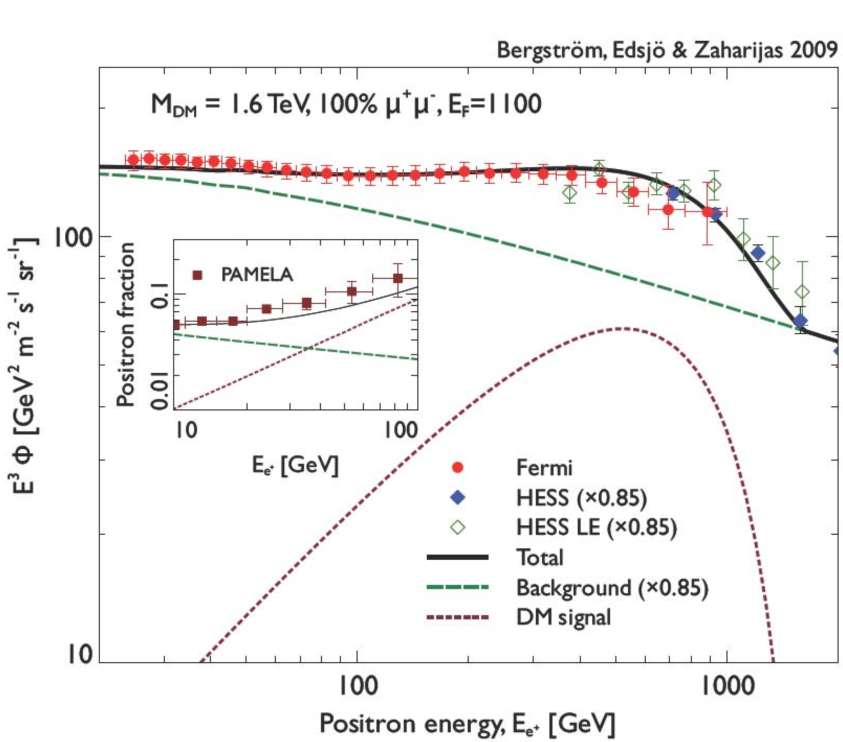
$e^+ + e^-$ flux



CRe Fermi spectrum from 20 GeV to 1 TeV

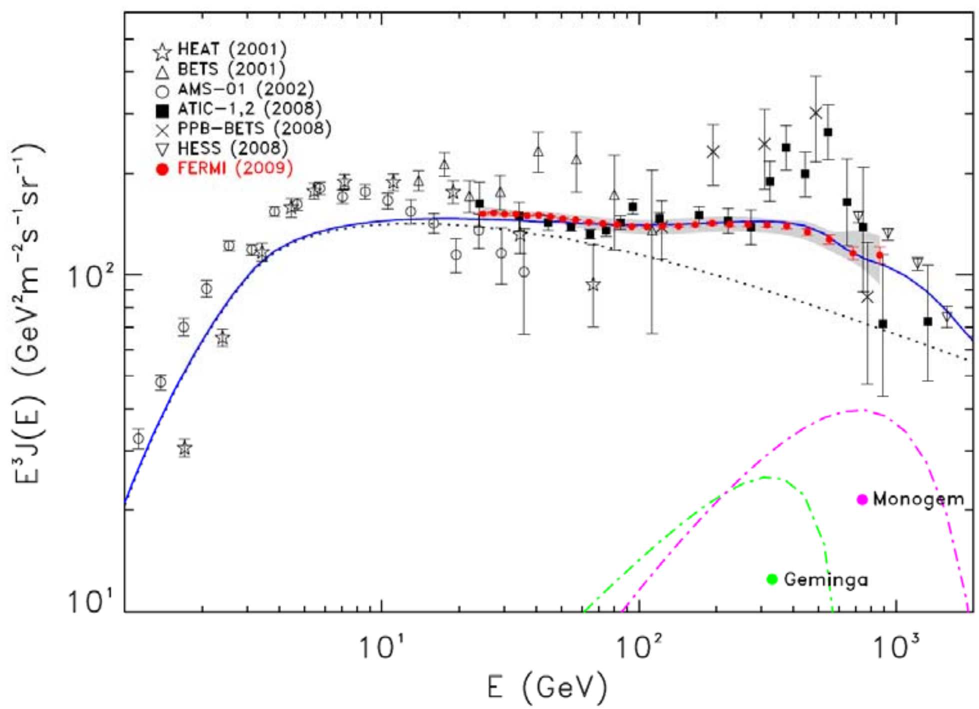


Astrophysical vs Dark Matter Fits



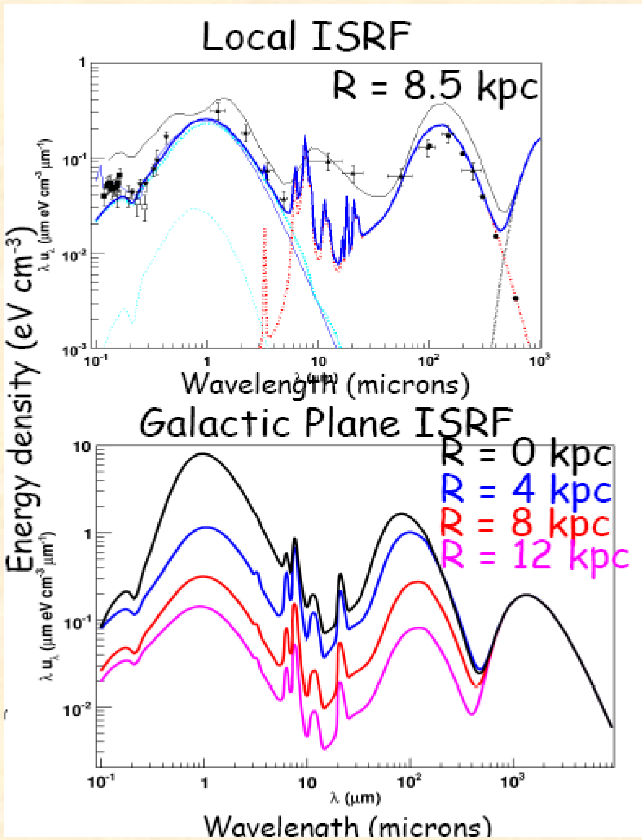
Bergstrom, Edsjo & Zaharias 2009

Grasso et al. 2009

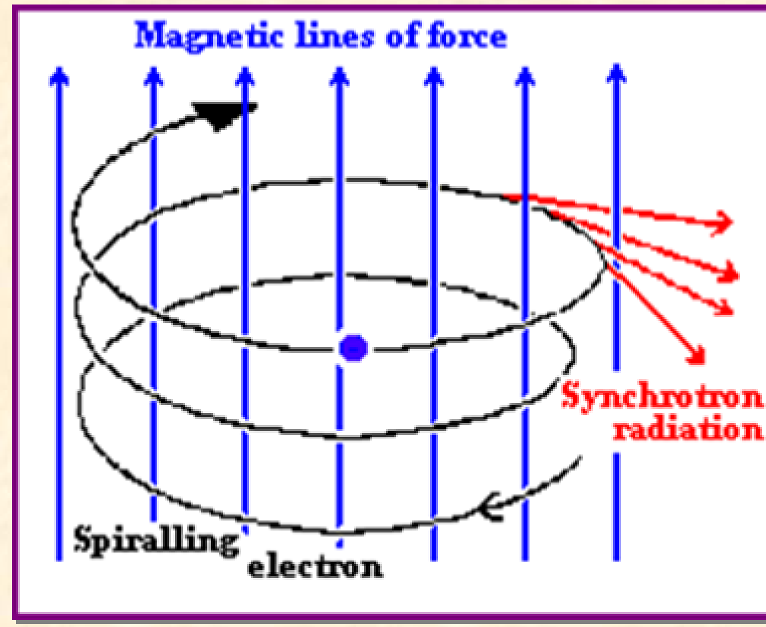


Indirect Detection With Synchrotron and Inverse Compton Radiation

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.

Details of the Calculations

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

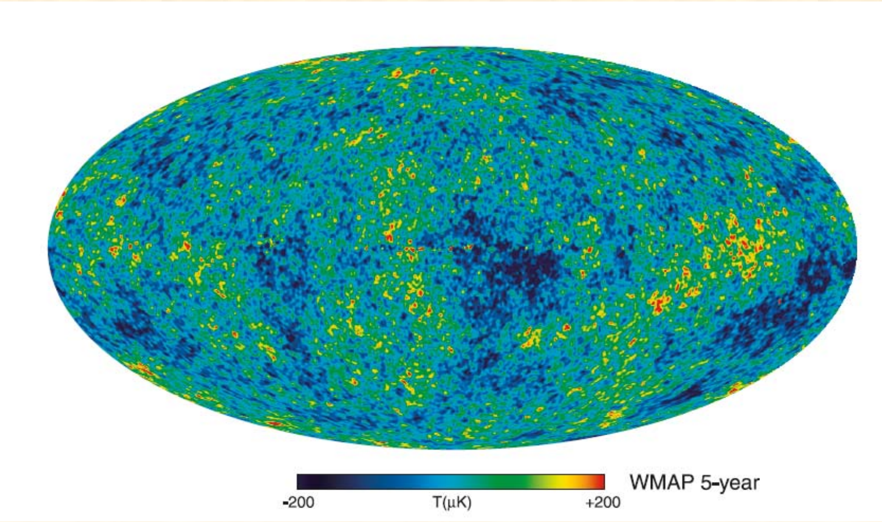
Diffusion

Energy Losses: ICS and Synchrotron

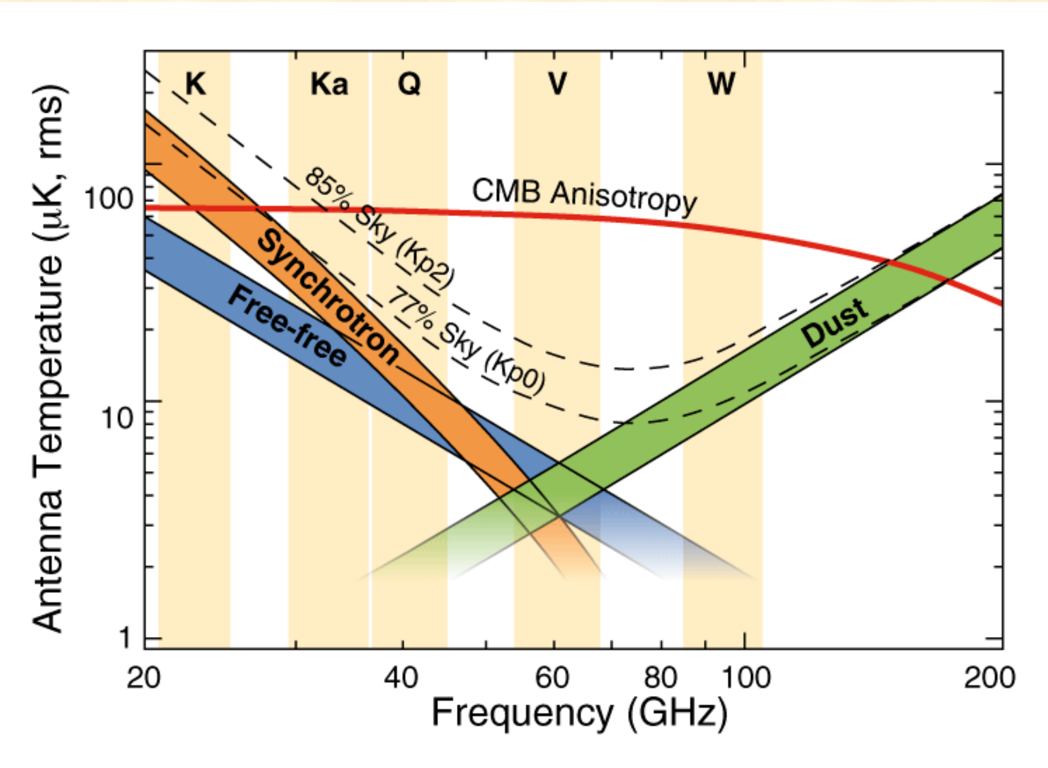
$$Q(r,E) = \rho^2 \langle\sigma_{\rm A} v\rangle / 2m_\chi^2 \times dN_e/dE.$$

full numerical approach employing **Galprop**, Moskalenko & Strong 98-08

The Microwave sky



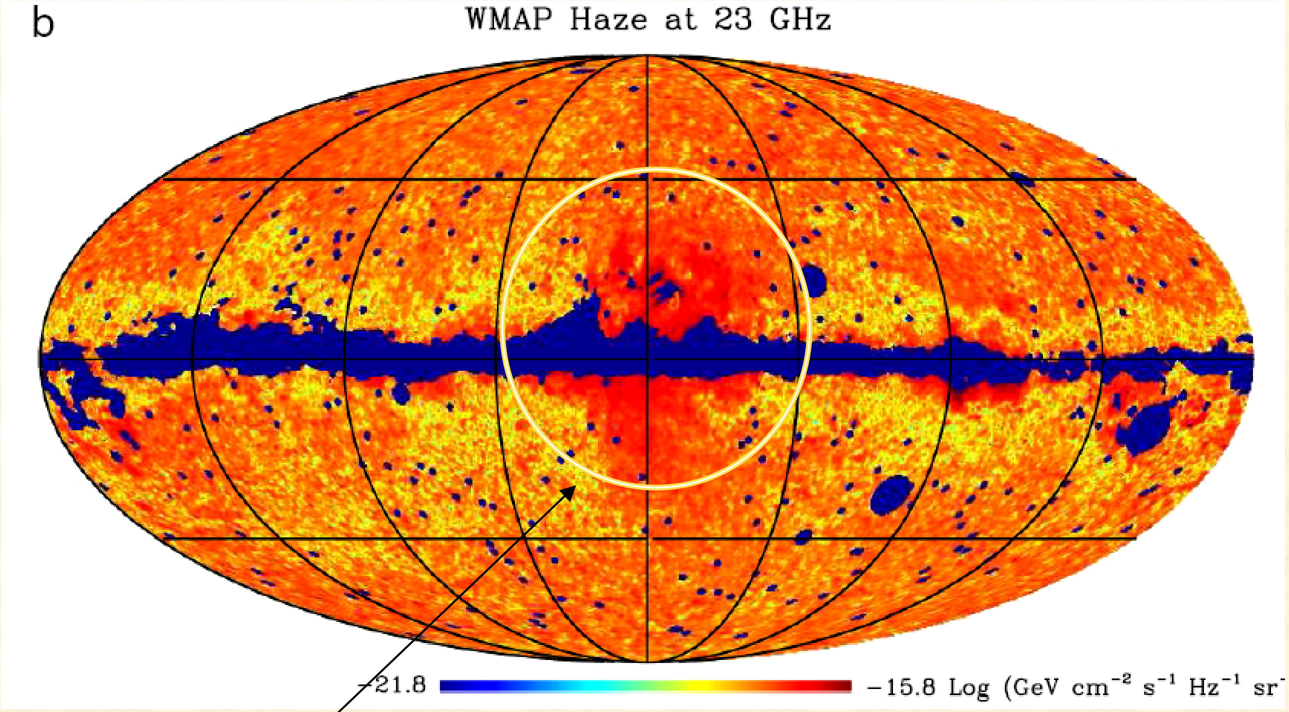
•In addition to CMB photons, WMAP data is “contaminated” by a number of galactic foregrounds that must be accurately subtracted



•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"

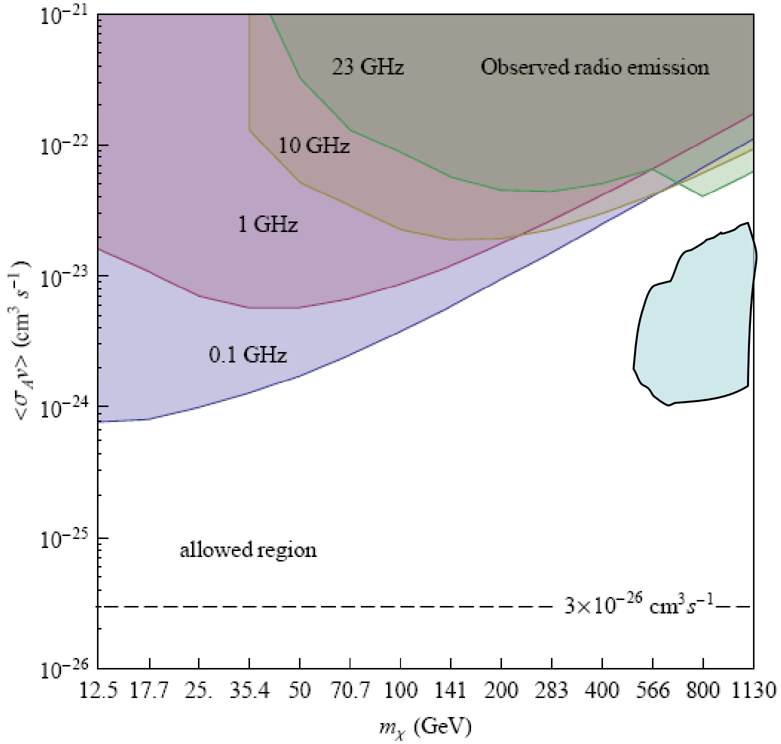


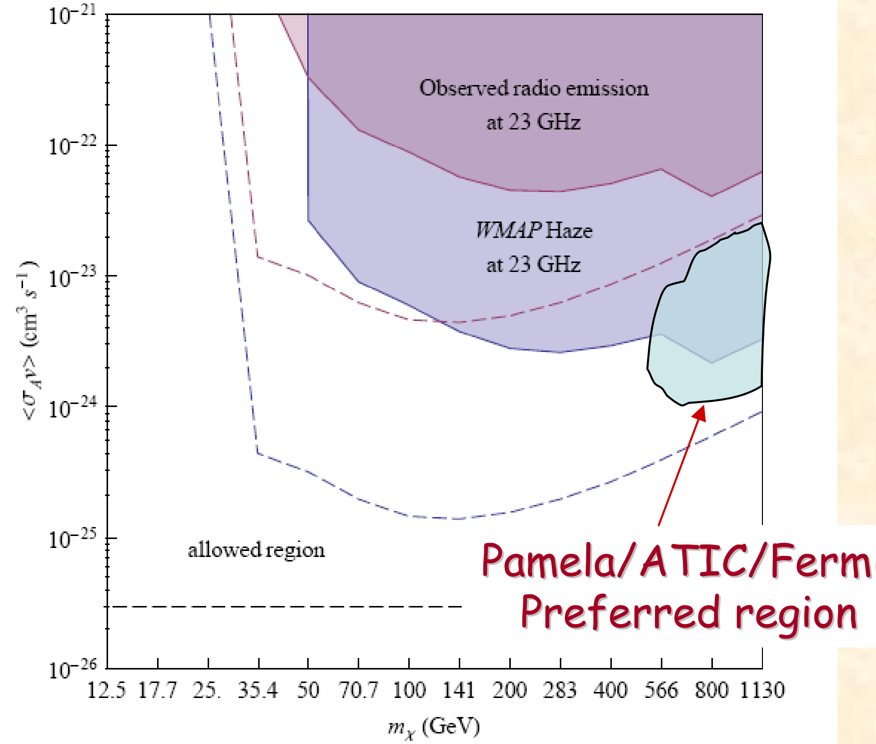
After known foregrounds are subtracted, an excess appears in the residual maps within the inner ~20° around the Galactic Center

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

DM constraints in the m_χ-<σ_Av> plane

Borriello, Cuoco, Miele 2008

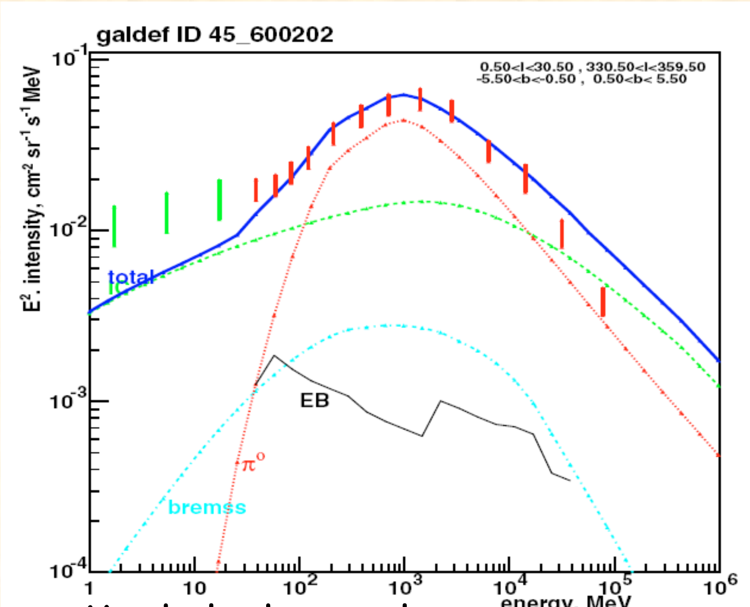




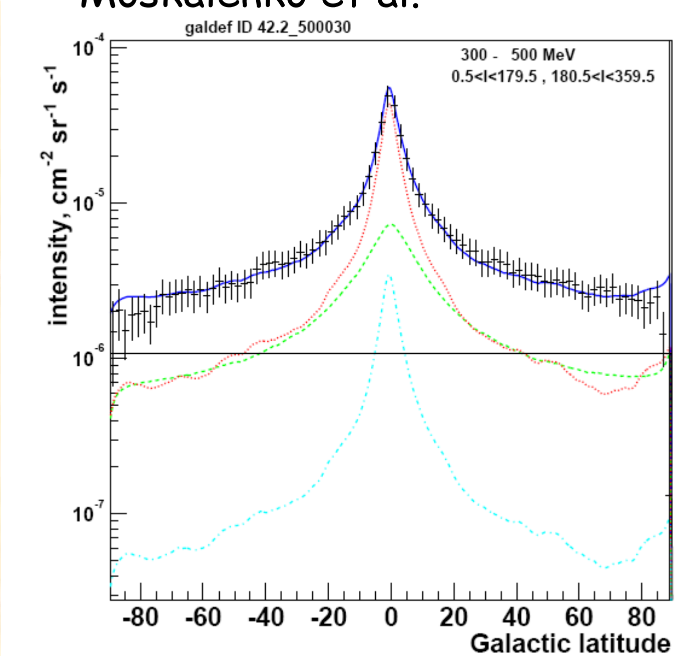
- Constraints in the m_χ - <σ_Av> plane for various frequencies, without assuming synchrotron foreground removal.
- DM spectrum is harder than background, thus constraints are better at lower frequencies.

- 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.

The Gamma Sky



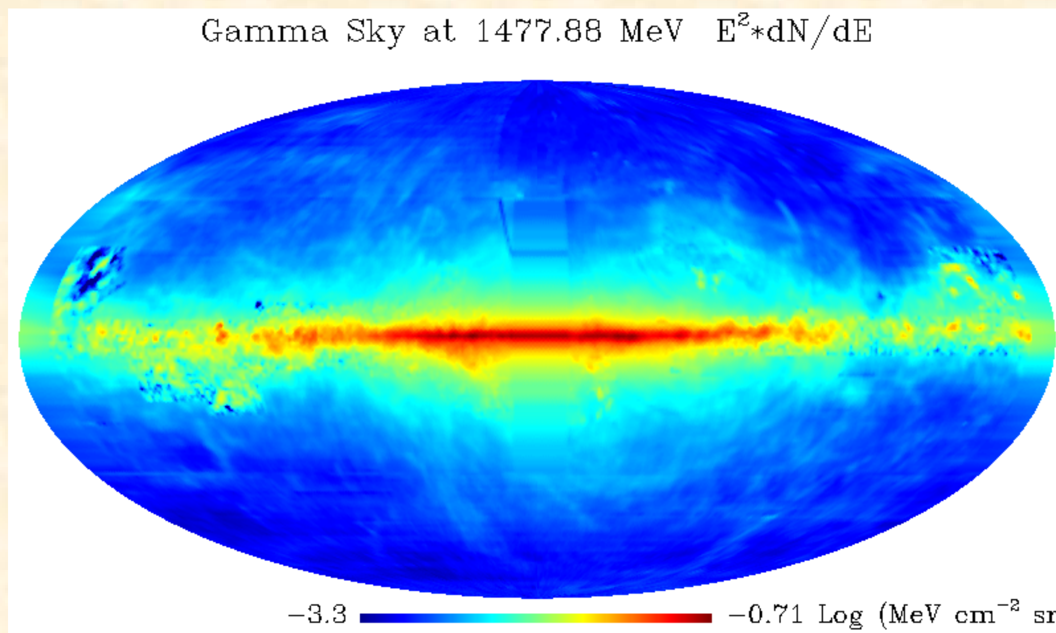
Moskalenko et al.



Galactic Contribution from:

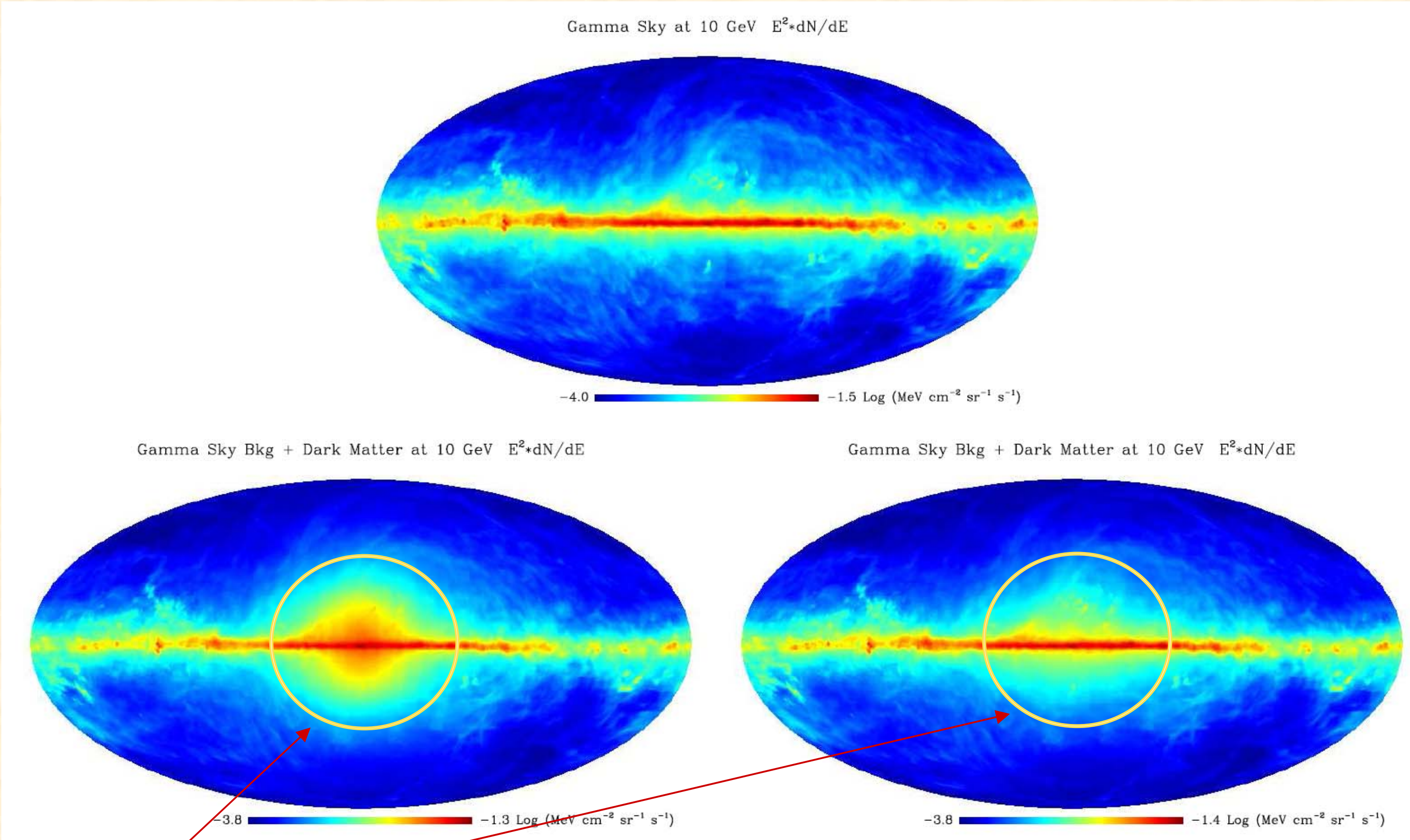
1. Pion Decay
2. Inverse Compton
3. Electron Bremsstrahlung

Galprop Foregrounds Model:



Also, detector resolution, charged particle background…

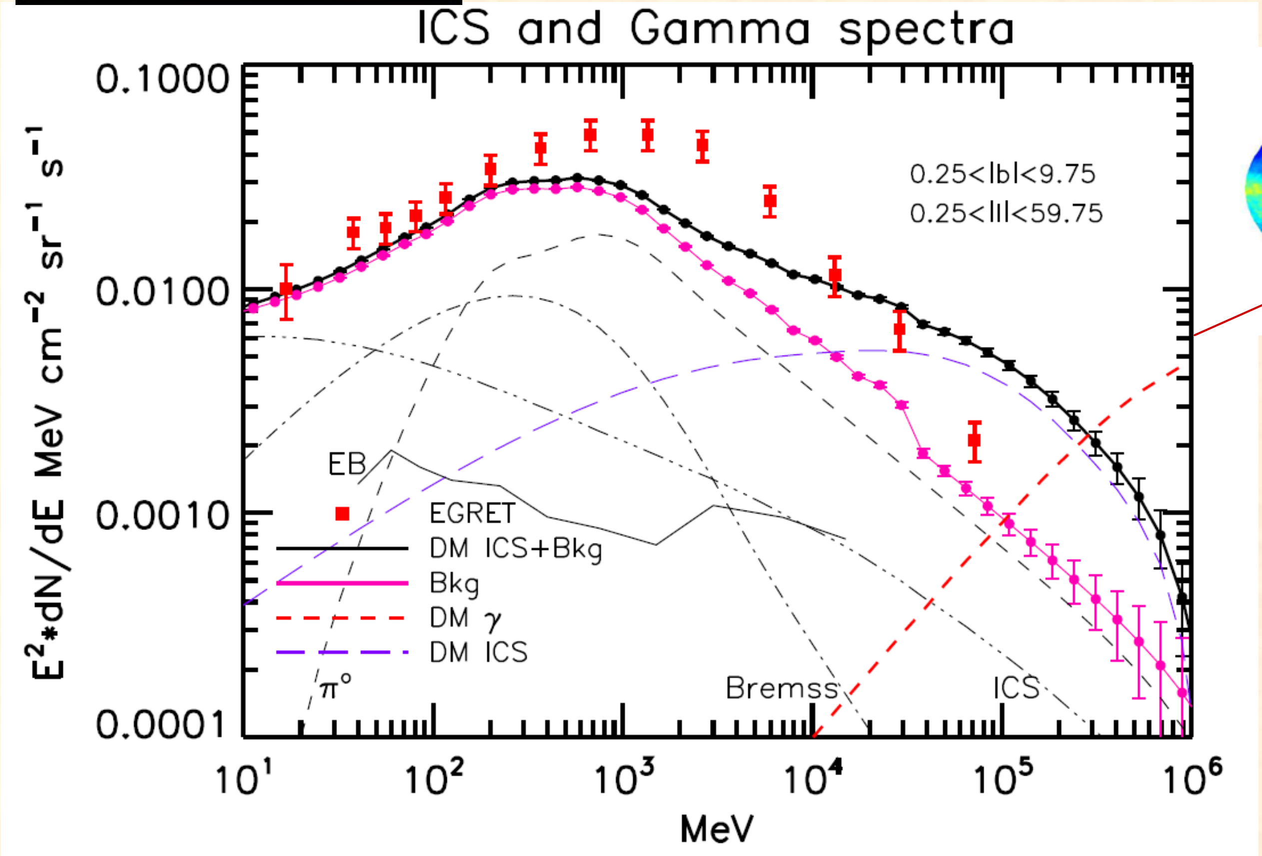
The "ICS Haze"

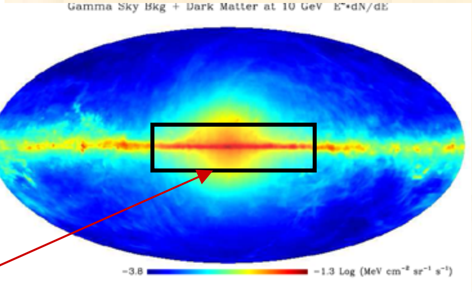


Similarly to the synchrotron case, IC signal produces an extremely peculiar "ICS Haze" peaking around 10-100 GeV which provides a further mean to discriminate the DM signal from the astrophysical backgrounds and/or to check for possible systematics.

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 already disfavor the excess, while Fermi can easily detect it





See also:
Meade et al. 2009,
Panci & Cirelli 2009,
Regis & Ullio 2009,
Cholis et al. 2008,
Zhang et al. 2008.

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

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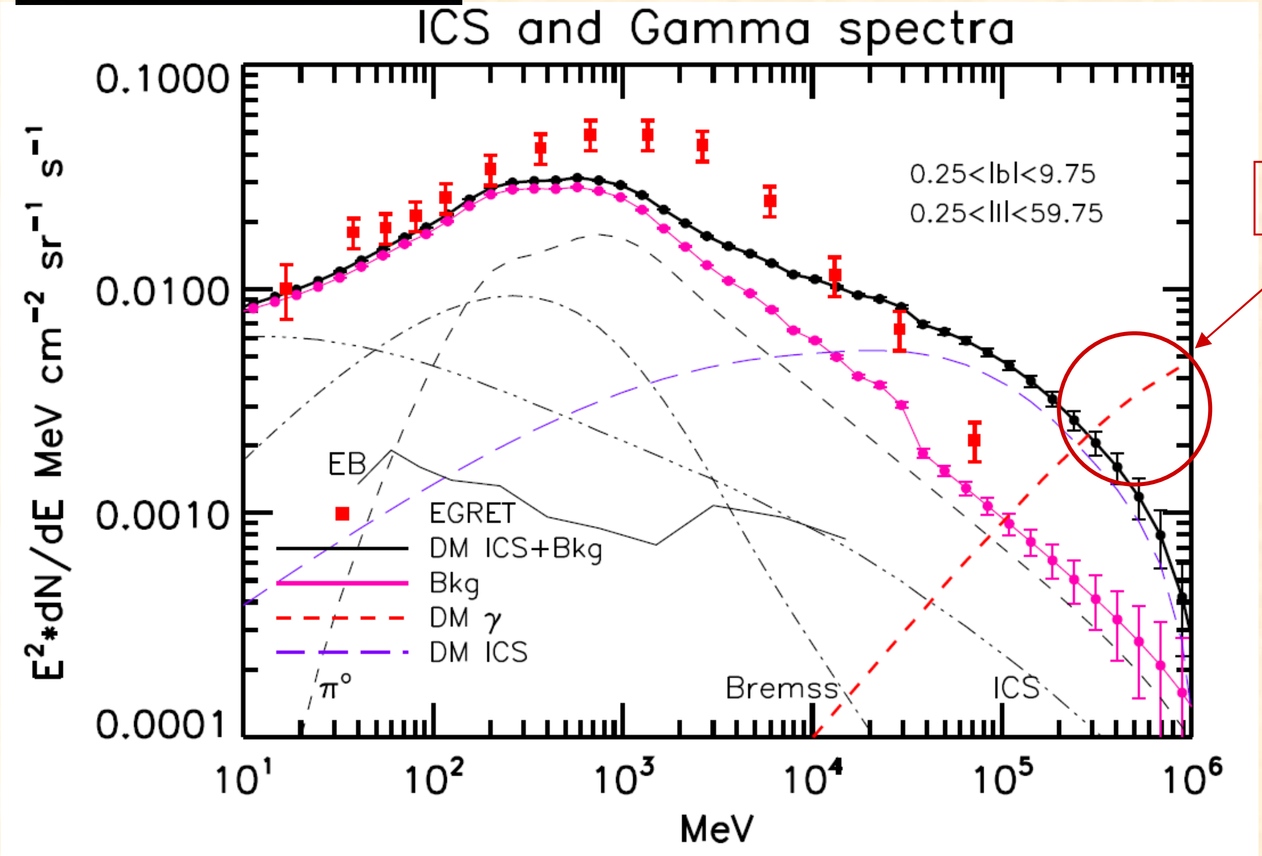

FSR Excess

See also:
Meade et al. 2009,
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Regis & Ullio 2009,
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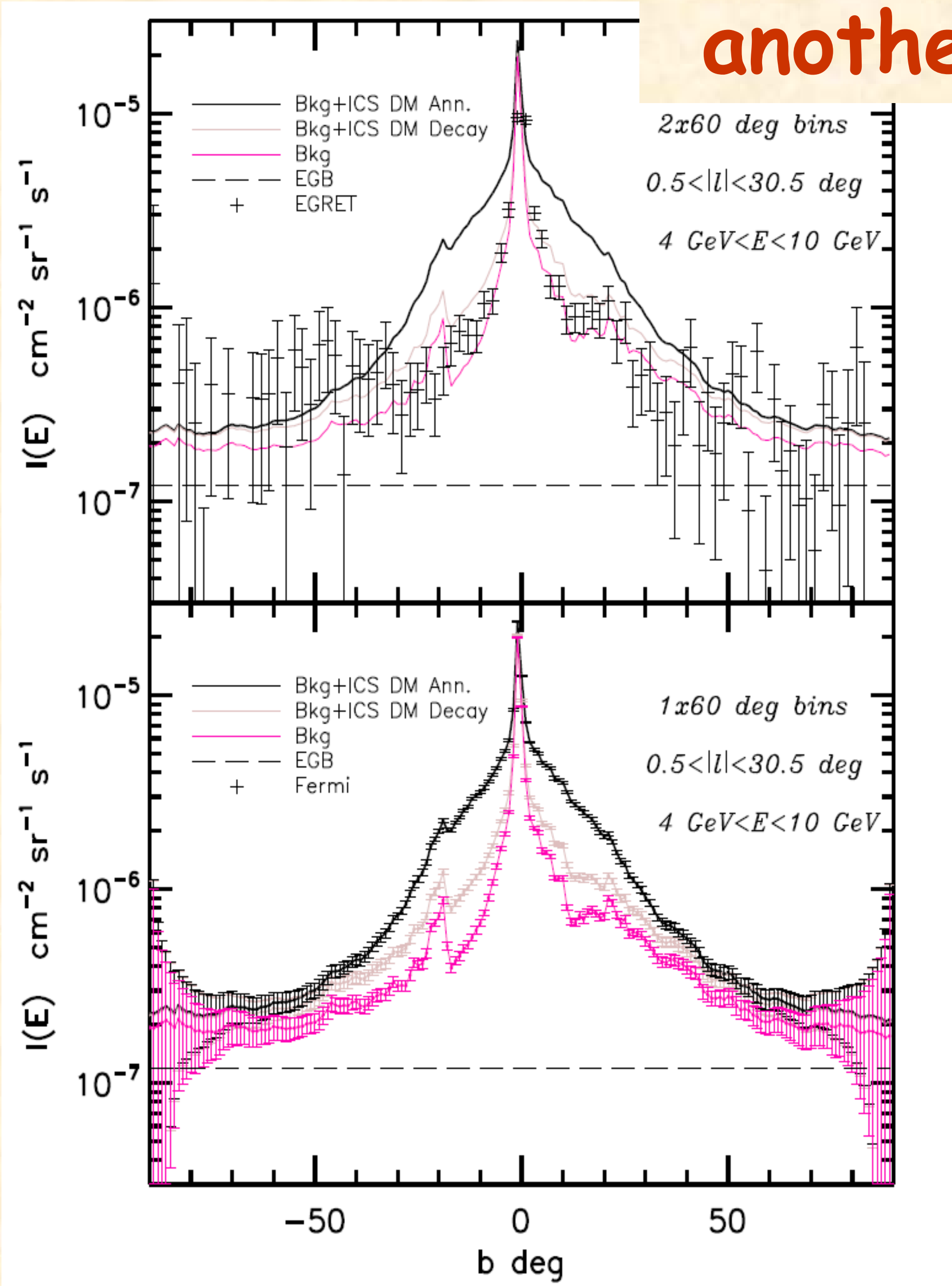
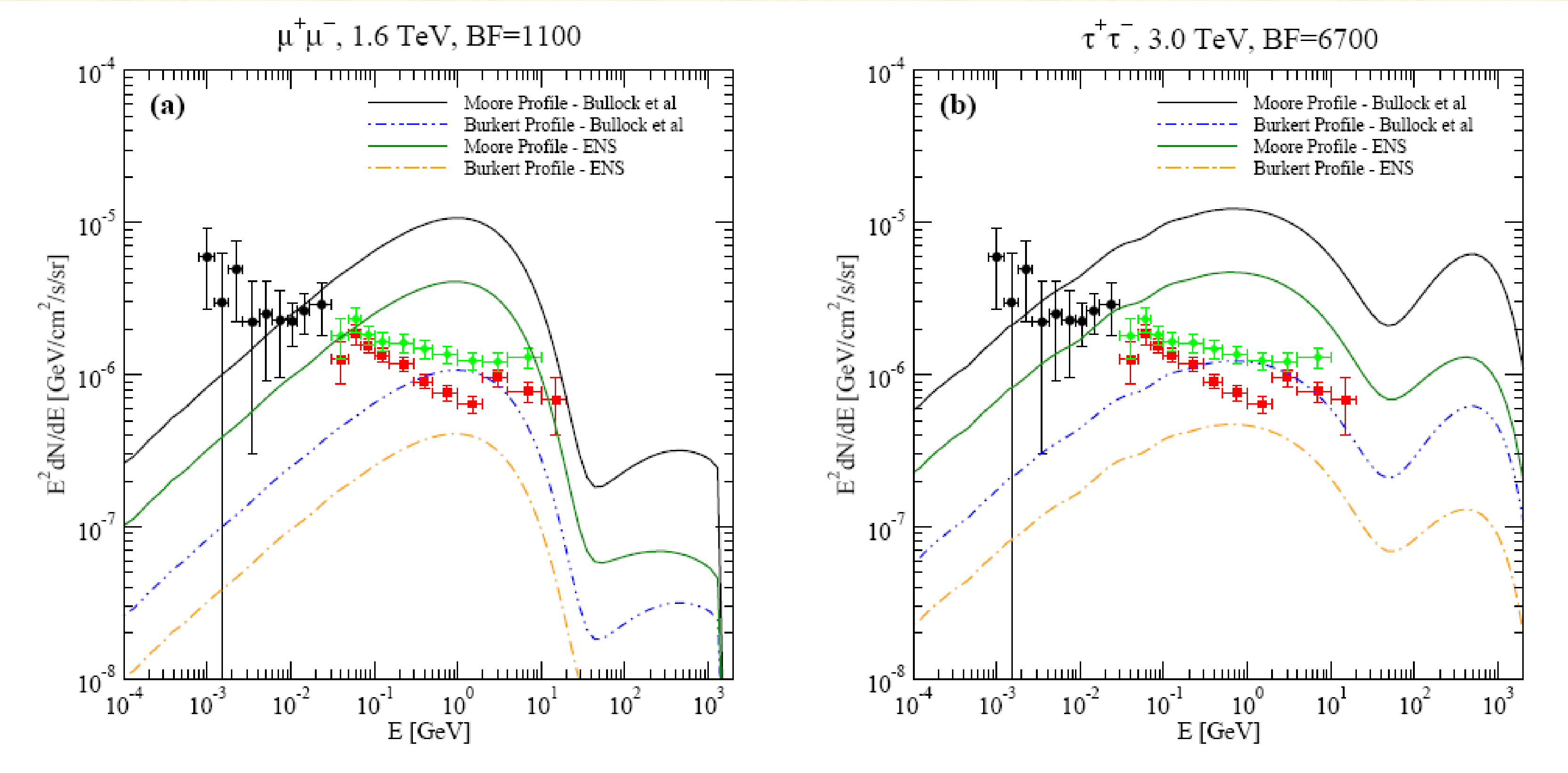
Comparison with EGRET and another forecast for Fermi



- 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.

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

See also Zaharias's Talk

Summary and Conclusions

•Inverse Compton and Synchrotron Radiation provide a model independent test of the origin of the PAMELA/ATIC/FERMI electrons.

•Data from Egret already disfavor significantly the DM interpretation of the signal, while data of the diffuse from Fermi can definitely rule out/confirm the DM interpretation.

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

•So, check your model against secondary radiation constraints!