Fitting the Fermi-LAT GeV excess: on the importance of the propagation of electrons from dark matter

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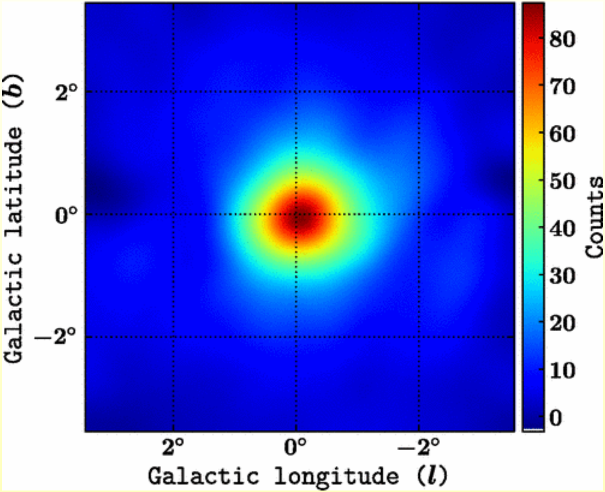
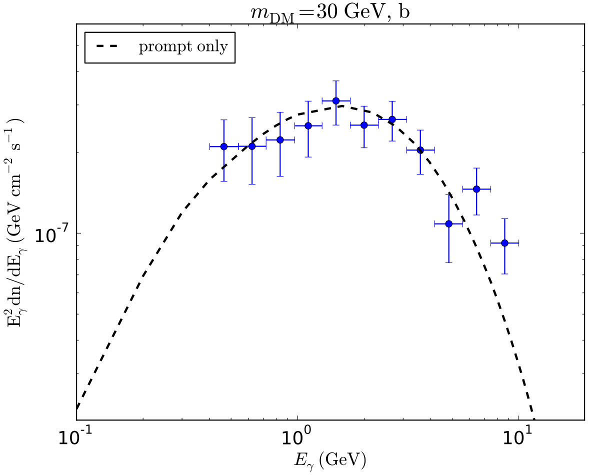
- GC excess in γ-rays between 0.1 and 10 GeV in Fermi data
  Fermi-LAT collaboration 2009
  Hooper & Linden 2011
  Gordon & Macias 2013
  Abazajian *et al.* 2014
  Daylan *et al.* 2014
- Within region smaller than $10^\circ \times 10^\circ$ around the GC
- Spherically symmetric
- Obtained by subtracting known sources and using Fermi models for diffuse emission
- Background modelling debated



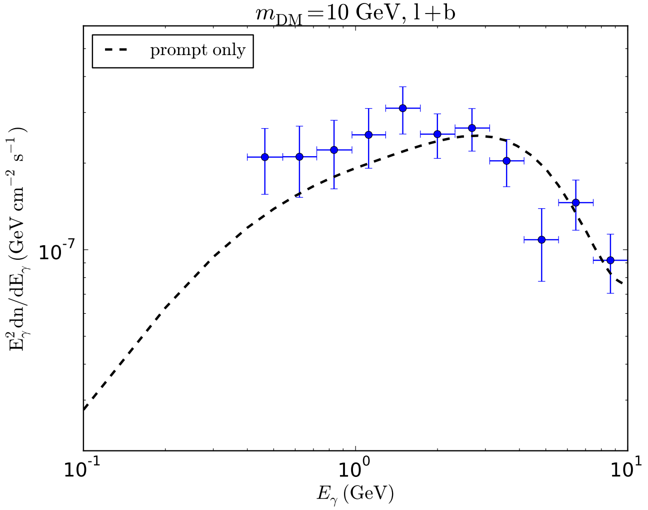
Gordon & Macias 2013

Best fit a priori for prompt emission only for $b\bar{b}$
$\rho \propto r^{-1.2}$, $\langle \sigma v \rangle \sim 2 \times 10^{-26}$ cm^3 s^{-1}

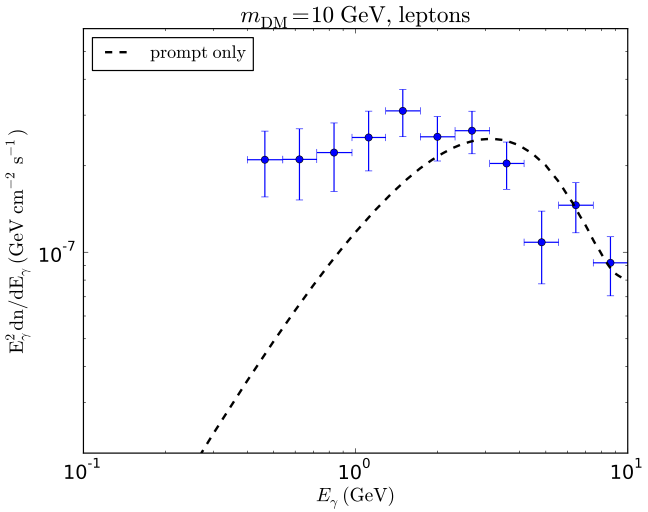


Data points from Gordon & Macias 2013

Relatively good fit with mixture of leptons and b quarks

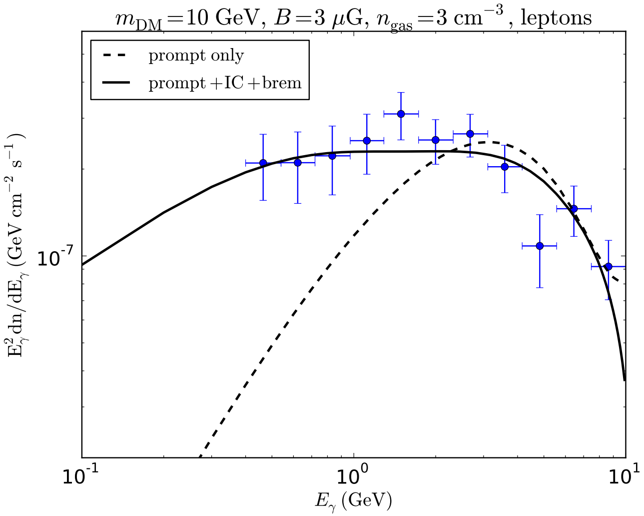


But we're nowhere near a priori with leptons only...

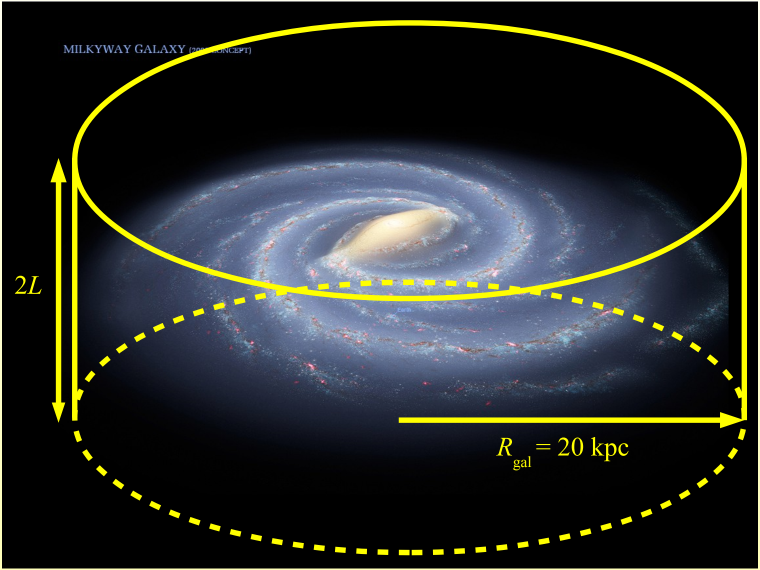


- But this is for prompt emission only
- Electrons also by-products of DM annihilations
- Inverse Compton and Bremsstrahlung emissions from e^+ and e^- produced in DM annihilations shouldn't be neglected (Ackermann *et al.* 2013, Cirelli *et al.* 2013) $\longrightarrow$ corrections
- Diffusion must be included to model these emissions $\Longrightarrow$ affects the interpretation of the data!

Very good fit with leptons only (democratic scenario)



TL, C. Bœhm, J. Silk, arXiv:1403.1987


MILKYWAY GALAXY
2L
Earth
$R_{gal} = 20$ kpc

Diffusion-loss equation

$$K\nabla^2\psi + \frac{\partial}{\partial E}(b_{\mathrm{tot}}\psi) + q = 0 \quad (1)$$

- $\psi(\vec{x}, E)$ cosmic-ray spectrum after propagation
- K diffusion coefficient: $K(E) = K_0 \left(\frac{E}{E_0}\right)^{\delta}$ with $E_0 = 1$ GeV
- $b_{\mathrm{tot}}(E)$ total energy loss rate (IC, synchrotron, Bremsstrahlung...)
- $q(\vec{x}, E)$ source term $\propto \rho^2$ for DM annihilations

Spectrum of e^- and e^+ after propagation

$$\psi(\vec{x},E) = \frac{\kappa}{b_{\rm tot}(E)} \int_E^{\infty} \tilde{I}_{\vec{x}}(\lambda_{\rm D}(E,E_S)) \frac{\mathrm{d}n}{\mathrm{d}E}(E_S)\, \mathrm{d}E_S \tag{2}$$

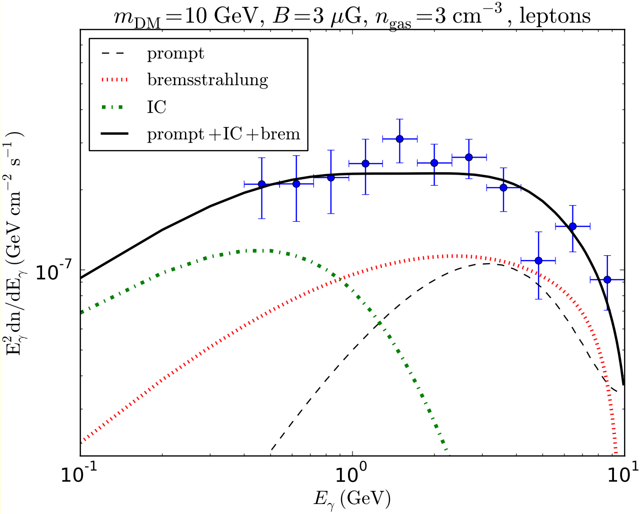
- κ normalization factor $\propto$ annihilation cross section
- $b_{\rm tot}(E)$ total energy loss rate
- $\tilde{I}_{\vec{x}}$ **halo function** $\longrightarrow$ fundamental quantity for diffusion
- $\lambda_{\rm D}(E, E_{\rm S})$ diffusion length
- $\frac{\mathrm{d}n}{\mathrm{d}E}$ injection spectrum

Computing $\tilde{I}$ with Green's functions

$$\tilde{I}_{\vec{x}}(\lambda_{\mathrm{D}}(E, E_S)) = \int_{\mathrm{DZ}} \mathrm{d}\vec{x}_{\mathrm{S}}\, G(\vec{x}, E; \vec{x}_{\mathrm{S}}, E_{\mathrm{S}}) \left(\frac{\rho(\vec{x}_{\mathrm{S}})}{\rho_{\odot}}\right)^2 \quad (3)$$

- $G(\vec{x}, E; \vec{x}_{\mathrm{S}}, E_{\mathrm{S}}) \equiv G(\vec{x}, \vec{x}_{\mathrm{S}}, \lambda_{\mathrm{D}}(E, E_S))$ Green's function
- Trick for steepness of ρ: logarithmic steps
- G becomes infinitely peaked for $\lambda_{\mathrm{D}} \to 0$ (i.e. $E \to E_{\mathrm{S}}$)
  $\Longrightarrow$ trick: defining different regimes for G
  (TL, C. Bœhm, J. Silk, arXiv:1311.0139)

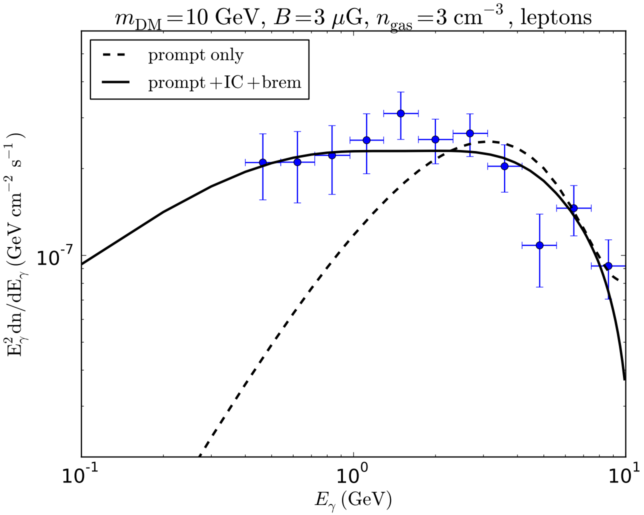
All contributions of the same order of magnitude



TL, C. Bœhm, J. Silk, arXiv:1403.1987

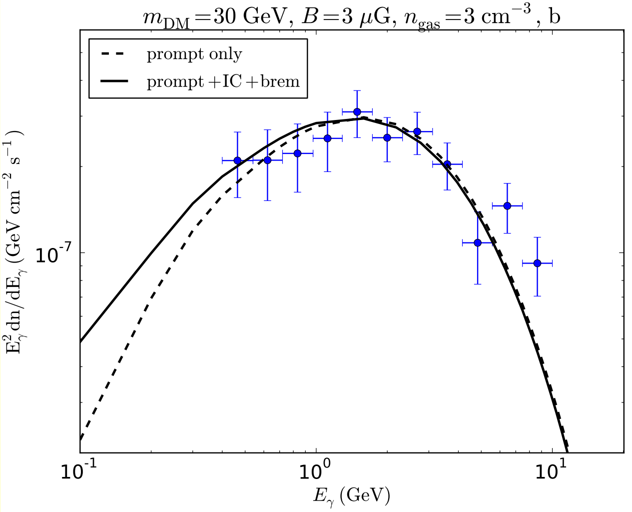
Best fit for democratic annihilation into leptons!

$\langle \sigma v \rangle = 0.86 \times 10^{-26}\ \mathrm{cm}^3\ \mathrm{s}^{-1}$



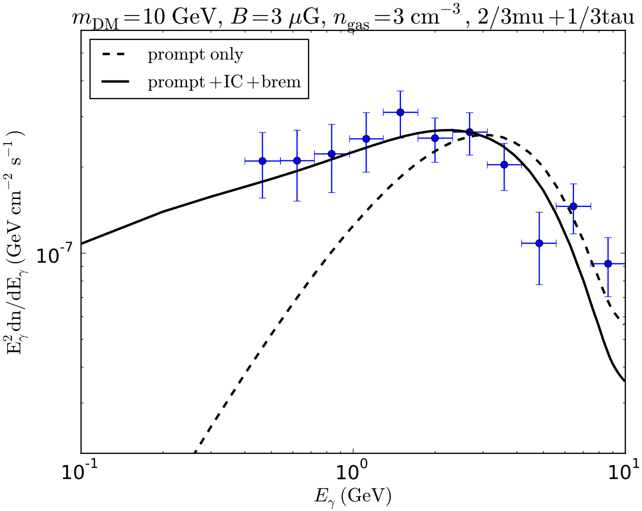
TL, C. Bœhm, J. Silk, arXiv:1403.1987

Fit for $b\bar{b}$ only slightly affected

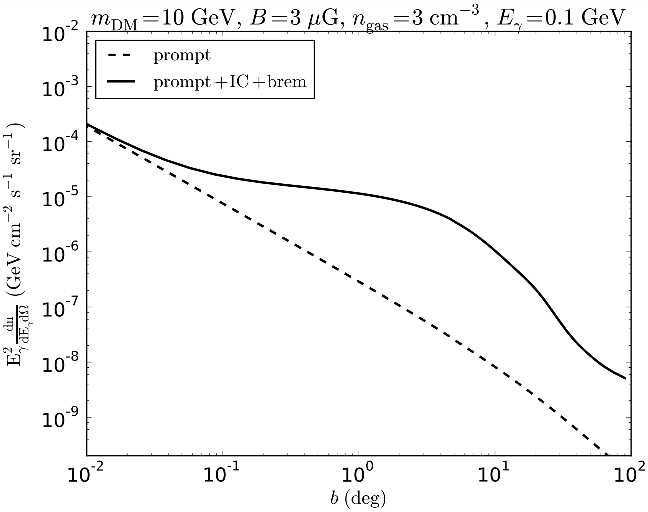


TL, C. Bœhm, J. Silk, arXiv:1403.1987

Very good fit with only muons and taus (cf. AMS limits on e^+e^-, Bergström *et al.* 2013, Ibarra *et al.* 2014)



Emission from diffusion extends to $\sim 10^\circ$



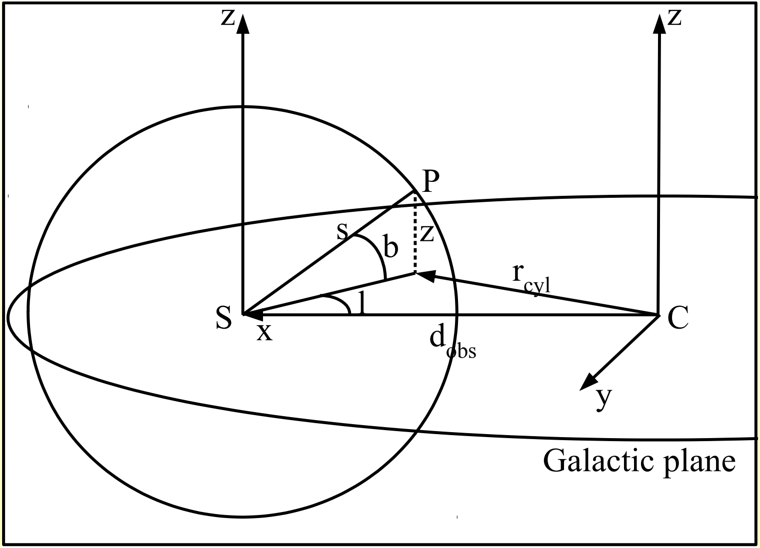
TL, C. Bœhm, J. Silk, arXiv:1403.1987

- Morphology of total signal between 3° and 12° close to that of prompt emission
  $\Longrightarrow$ compatible with the literature
- Flux much flatter below 3 degrees at 0.1 GeV
  $\Longrightarrow$ may allow one to discriminate between scenario with $b\bar{b}$ and scenario with leptons
- But discrepancies between slopes of the DM profile depending on whether inner 1° is included or not (1.2 vs 1.4) in Daylan *et al.* 2014

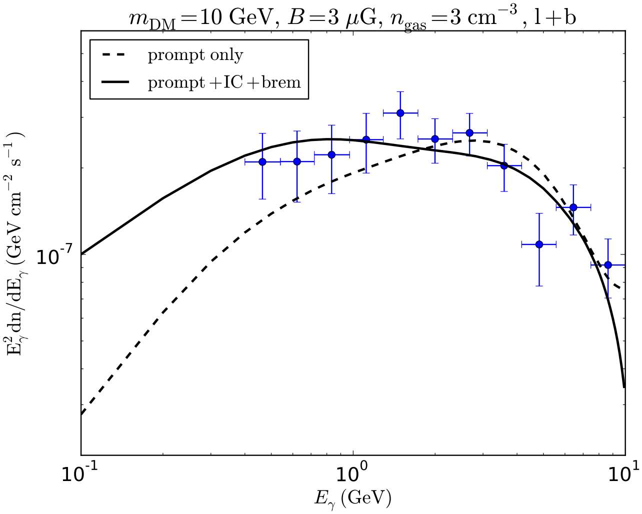
Conclusion

- Strong case for DM
- $b\bar{b}$ and prompt emission simplest set-up a priori
- But very important to include all relevant emission processes and diffusion
- $b\bar{b}$ and 30 GeV is not the only possibility: DM can be 10 GeV and annihilate into leptons
- Including emissions of diffused electrons changes interpretation of the excess in terms of DM
- Morphology below $\sim 1^\circ$ can help to discriminate

Thank you for your attention!


z
z
P
s
b
z
r_{cyl}
l
S
x
C
d_{obs}
y
Galactic plane

Data from Gordon *et al.*, arXiv:1306.5725



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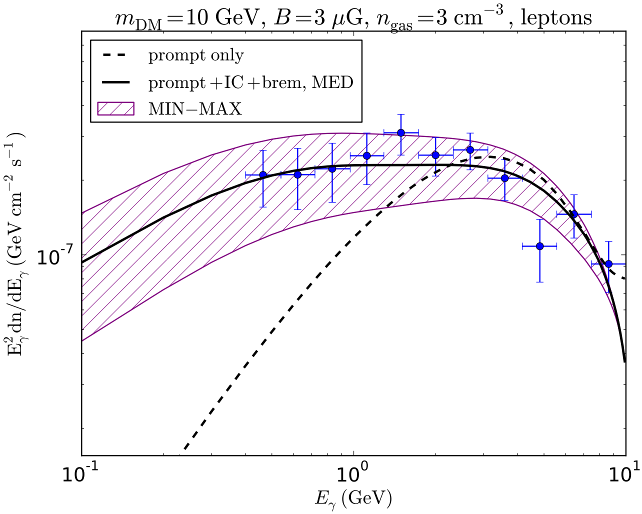

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