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

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Nordita workshop 'What is Dark Matter?'

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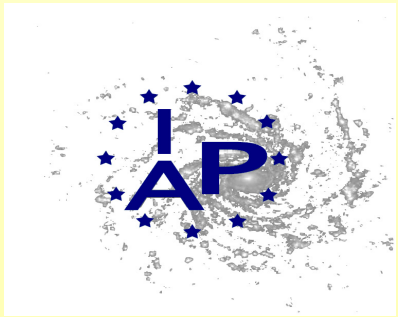
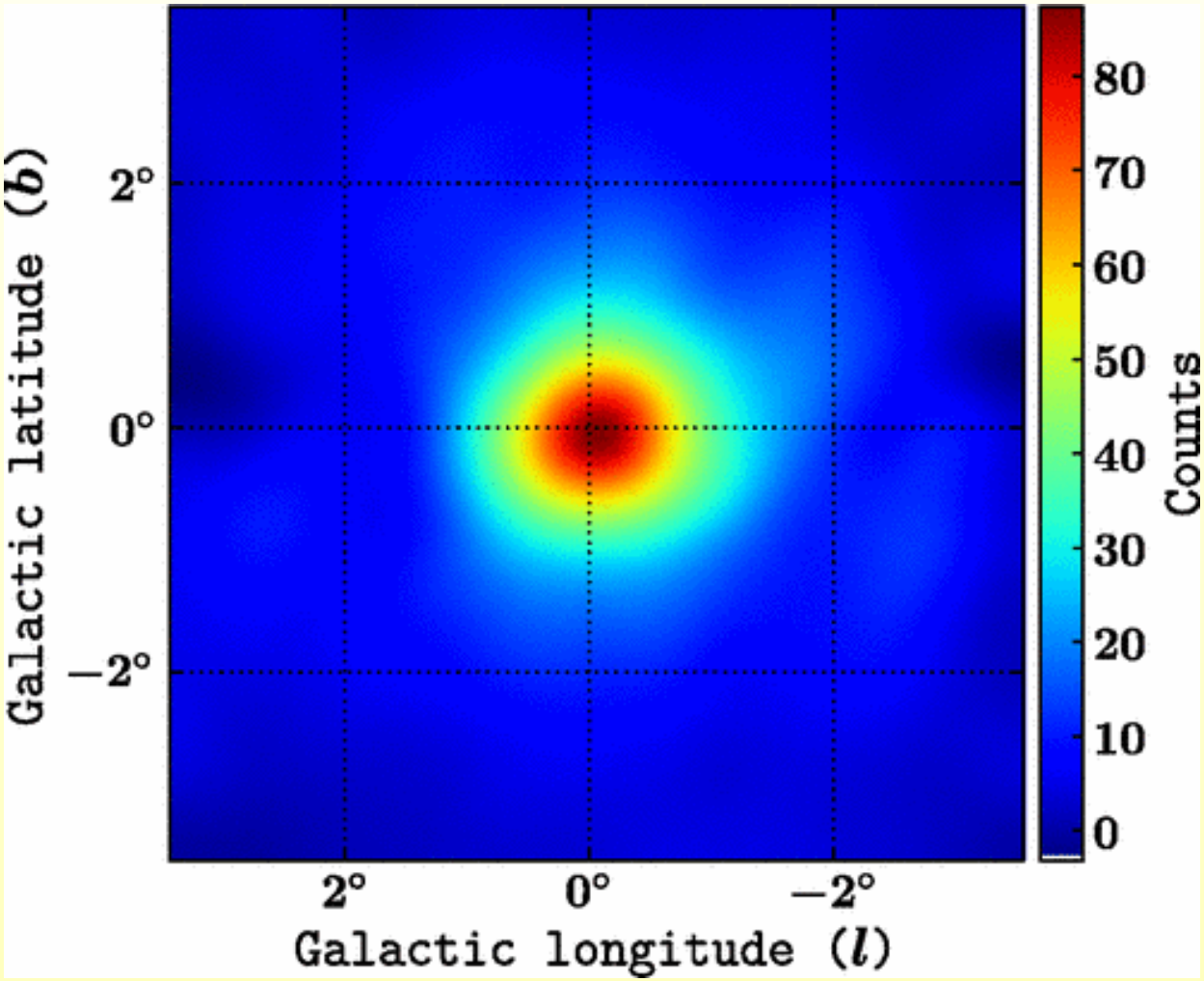
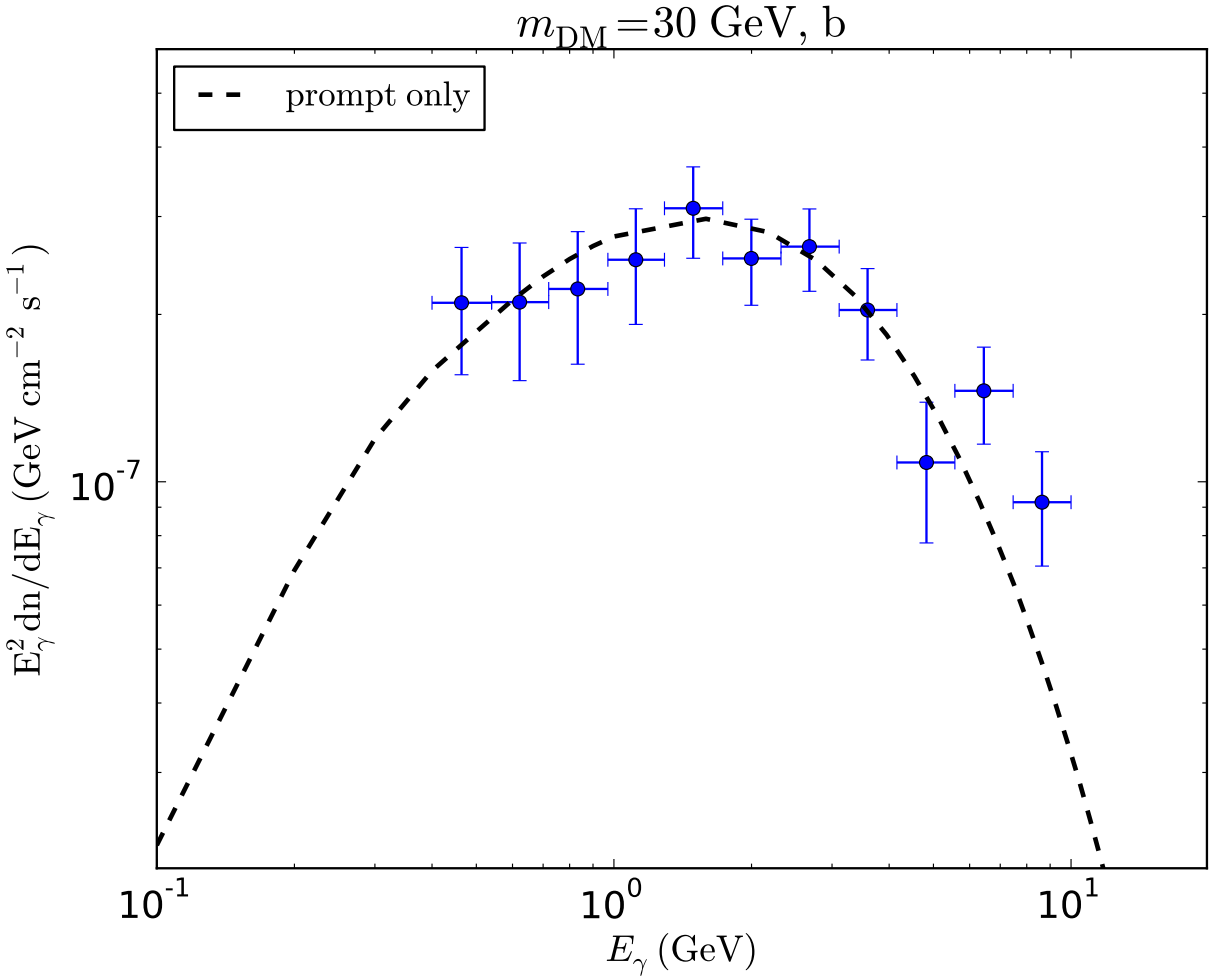


- GC excess in γ-rays between 0.1 and 10 GeV in Fermi data
  Fermi-LAT collaboration 2009
  Hooper & Linden 2011
  Gordon & Macias 2013
  Abazajian *et al.* 2014
  Daylan *et al.* 2014
- Within region smaller than $10^\circ \times 10^\circ$ around the GC
- Spherically symmetric
- Obtained by subtracting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



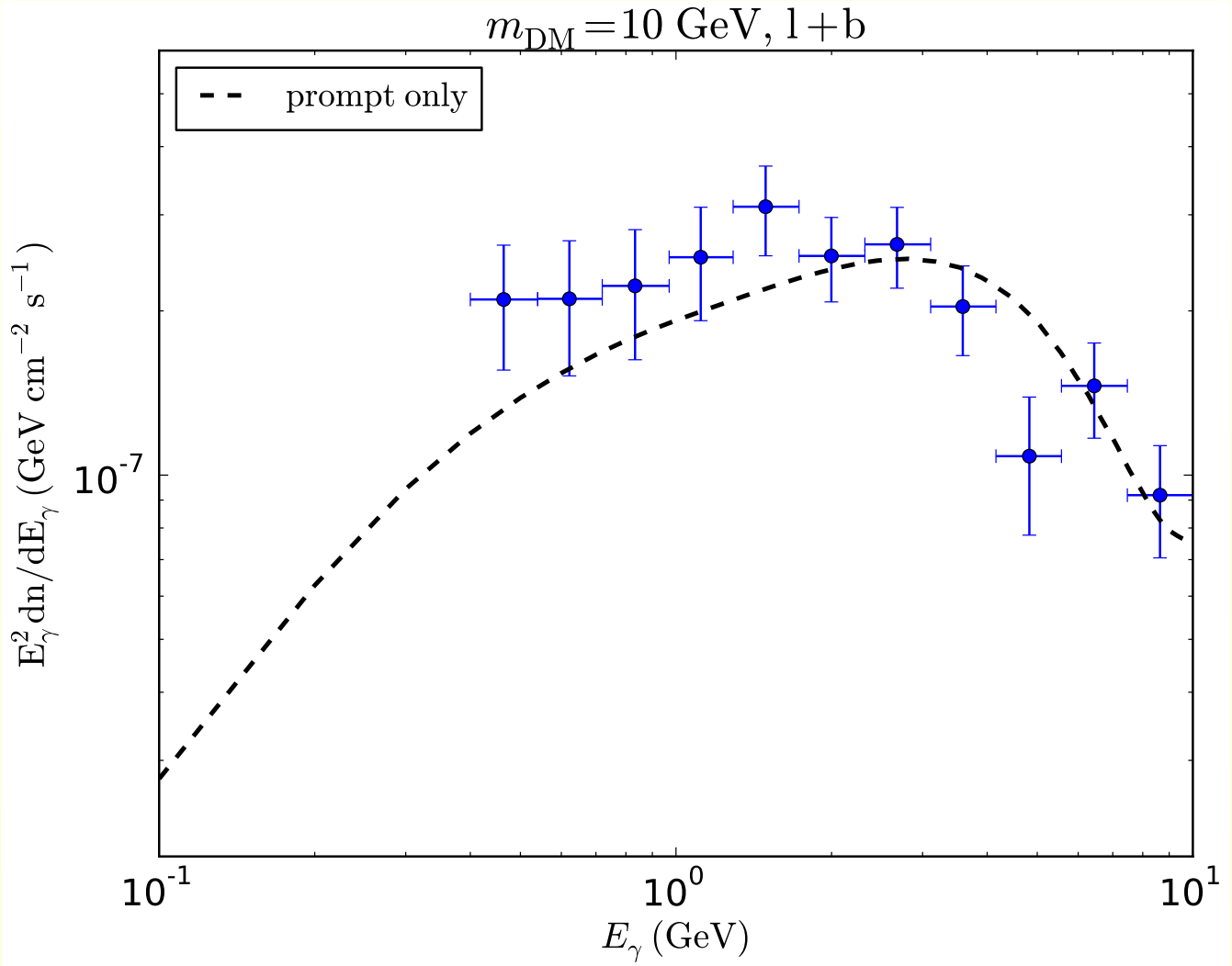
Gordon & Macias 2013

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}

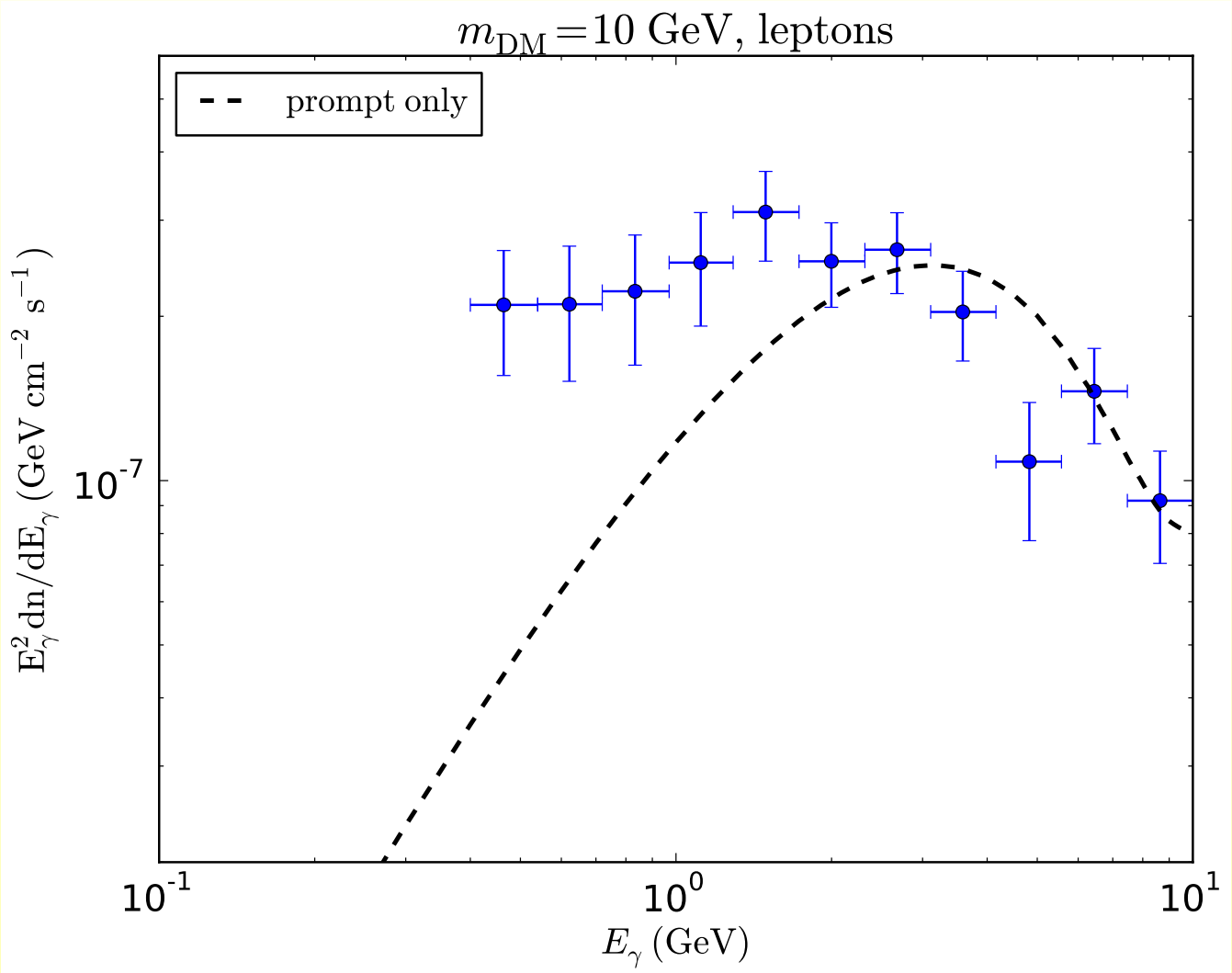


Data points from Gordon & Macias 2013

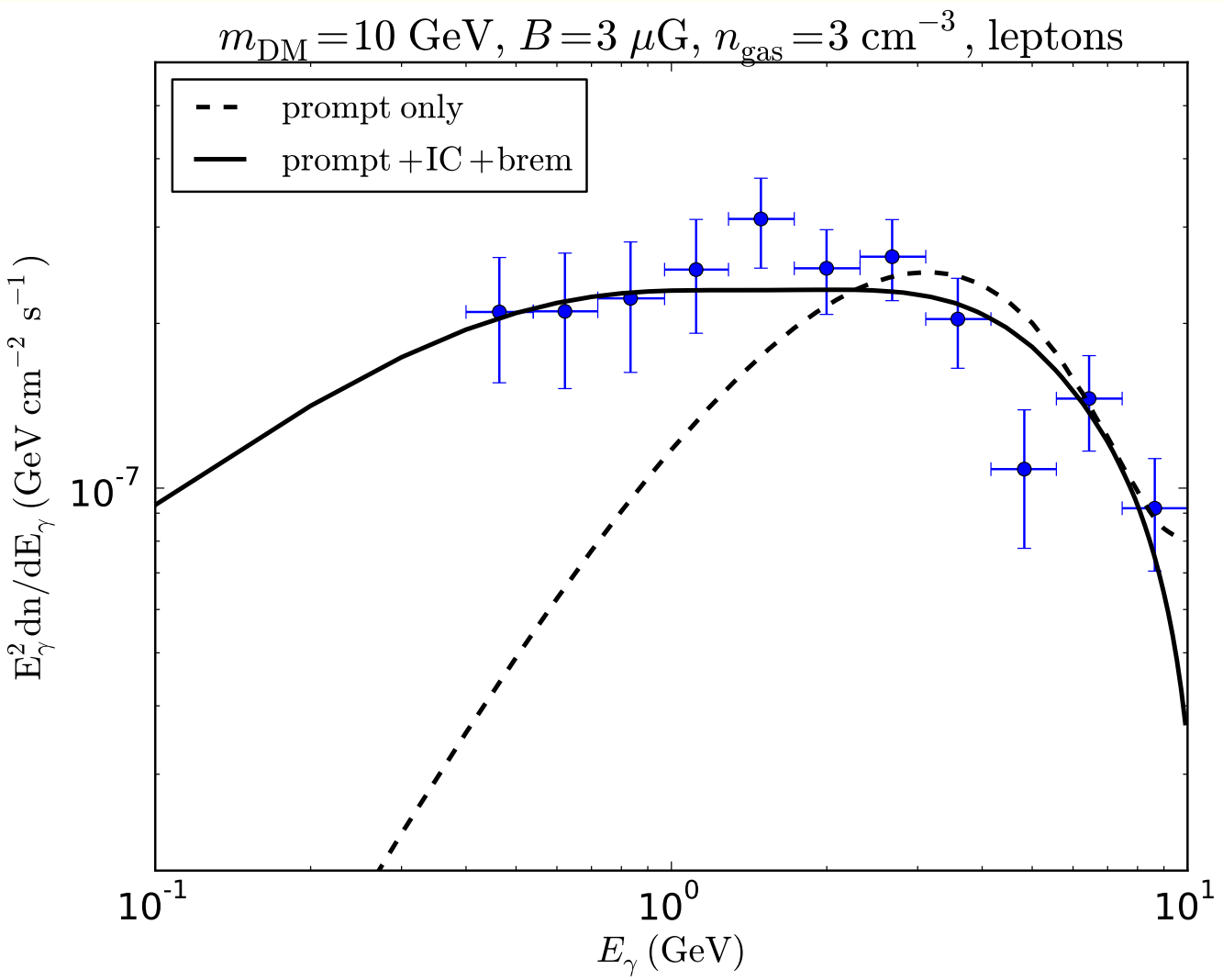
Relatively good fit with mixture of leptons and b quarks



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



Unless we include inverse Compton and Bremsstrahlung!



TL, C. Bœhm, J. Silk, arXiv:1403.1987

Diffusion-loss equation

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

- $\psi(\vec{x}, E)$ cosmic-ray spectrum after propagation
- K diffusion coefficient: $K(E) = K_0 \left(\frac{E}{E_0}\right)^{\delta}$ with $E_0 = 1$ GeV
- $b_{\rm tot}(E)$ 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

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

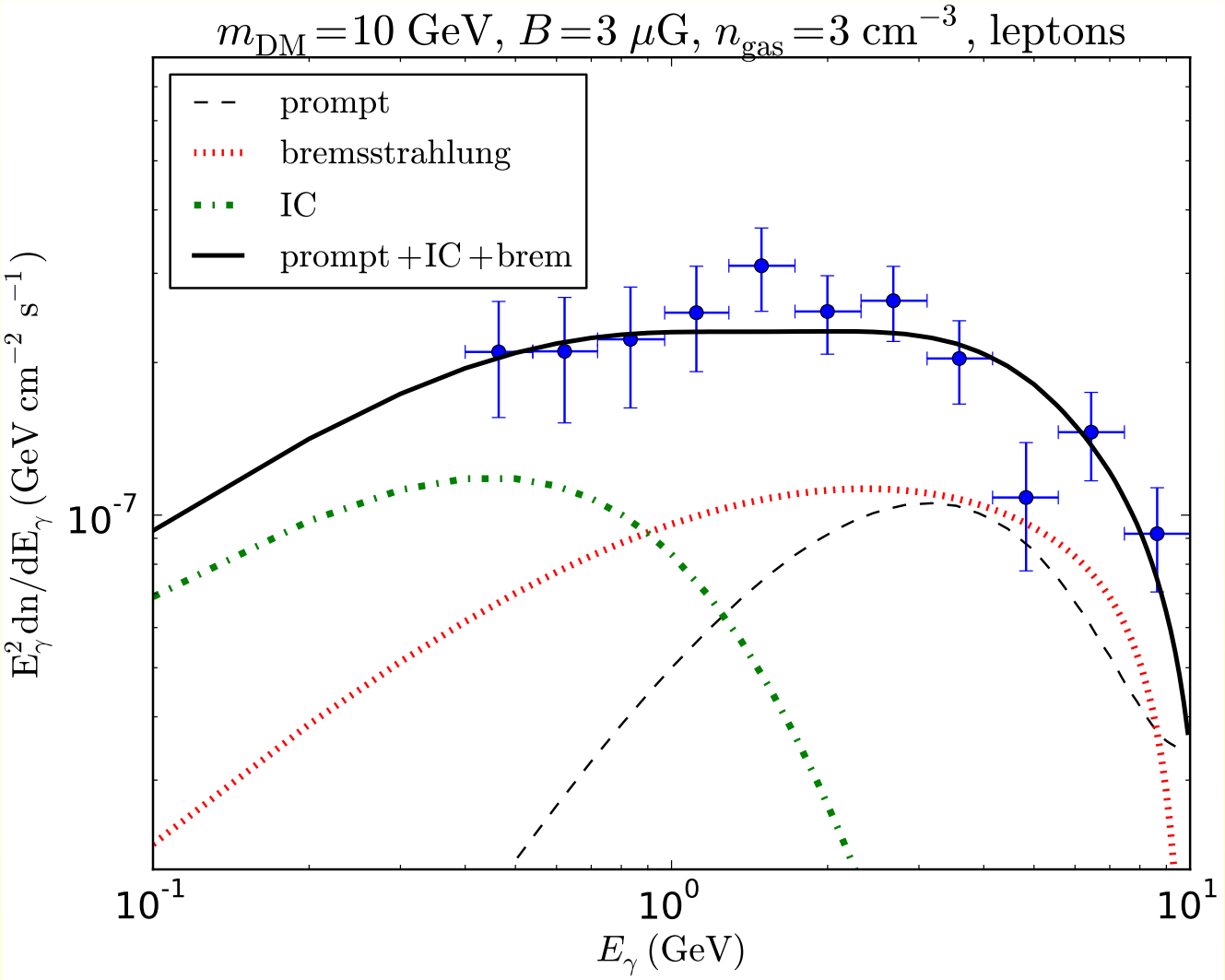
- κ normalization factor $\propto$ annihilation cross section
- $b_{\rm tot}(E)$ total energy loss rate
- $\tilde{I}_{\vec{x}}$ **halo function** $\longrightarrow$ fundamental quantity for diffusion
- $\lambda_{\rm D}(E, E_{\rm S})$ diffusion length
- $\frac{{\rm d}n}{{\rm d}E}$ injection spectrum

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

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

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

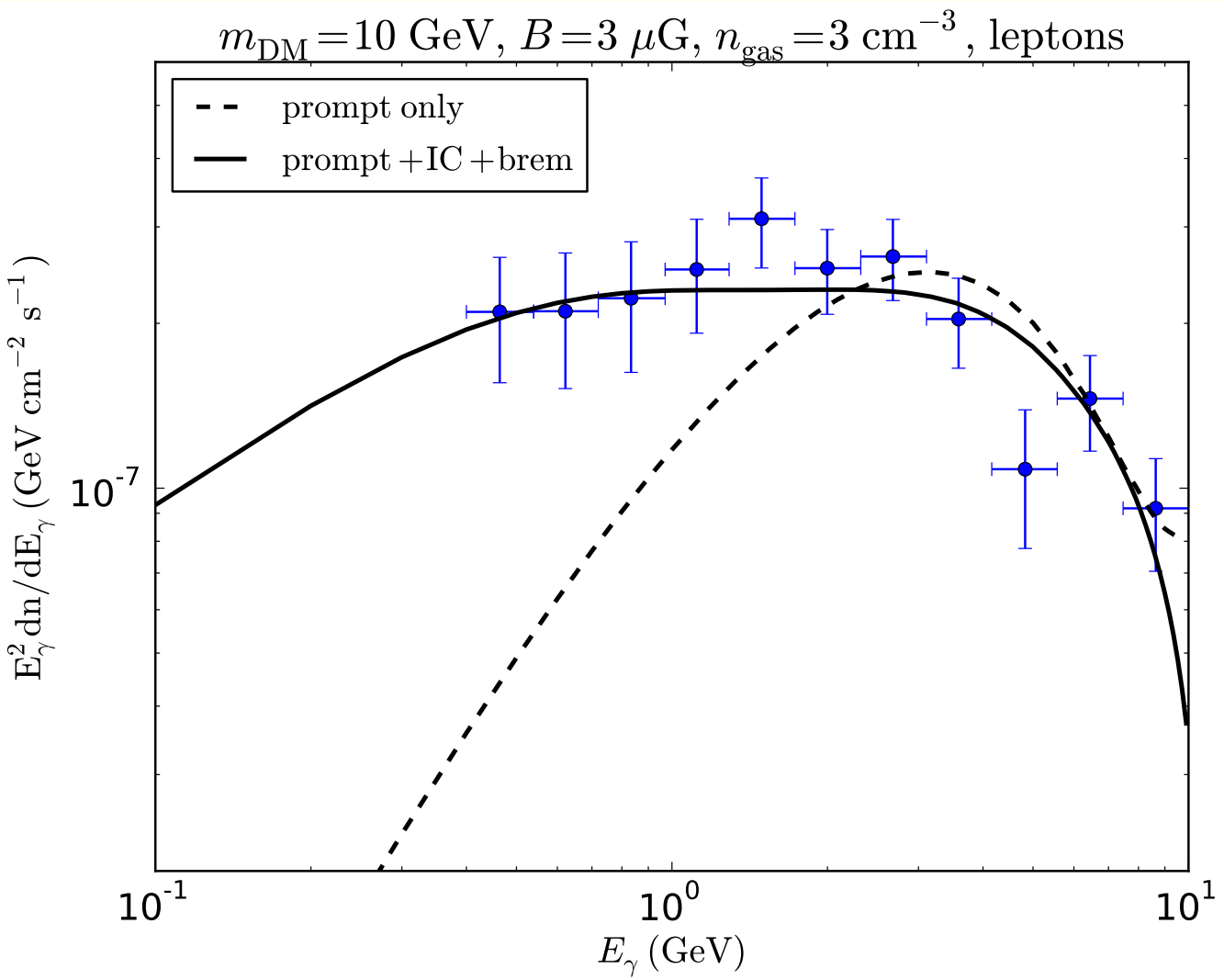
All contributions of the same order of magnitude



TL, C. Bœhm, J. Silk, arXiv:1403.1987

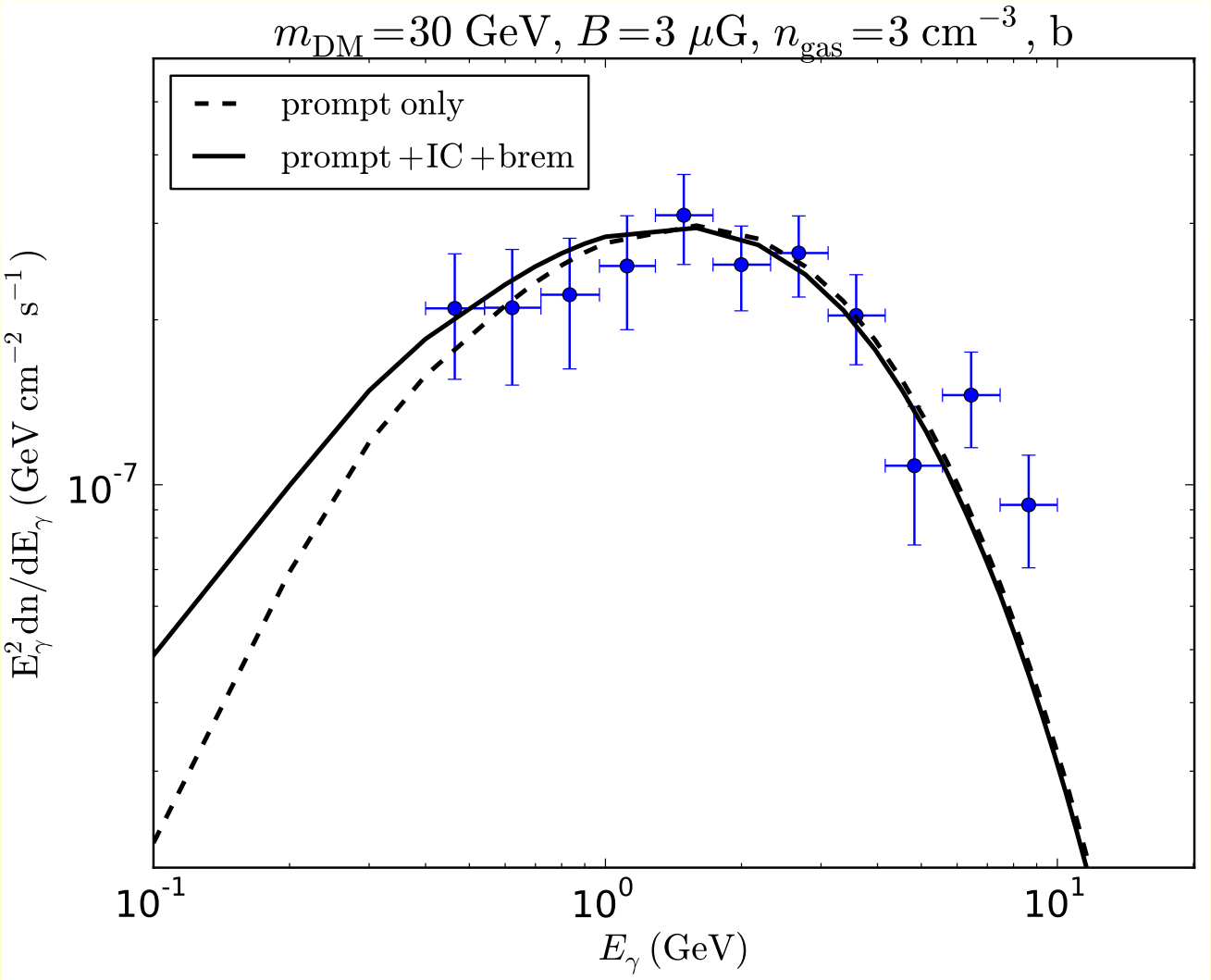
Best fit for democratic annihilation into leptons!

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



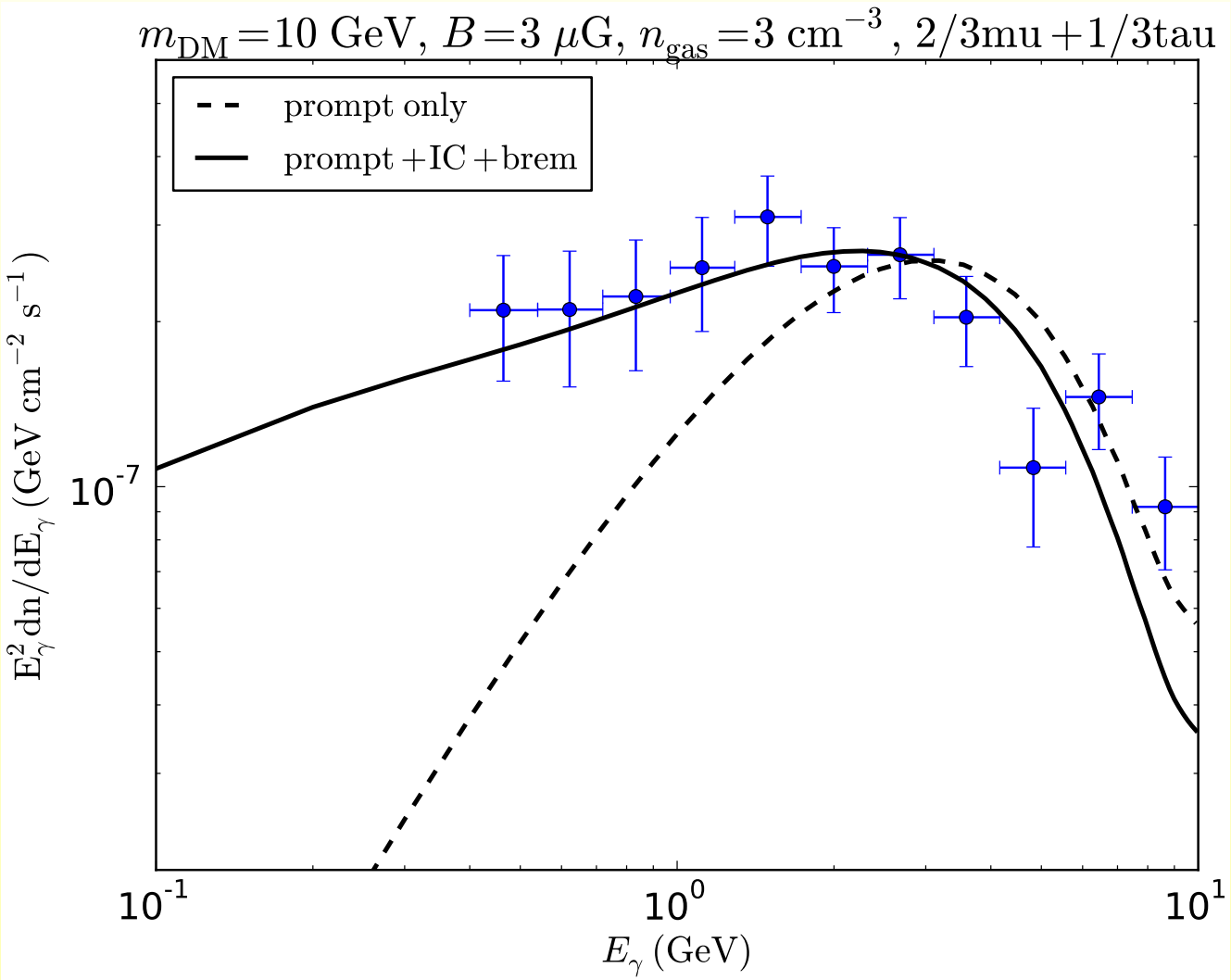
TL, C. Bœhm, J. Silk, arXiv:1403.1987

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

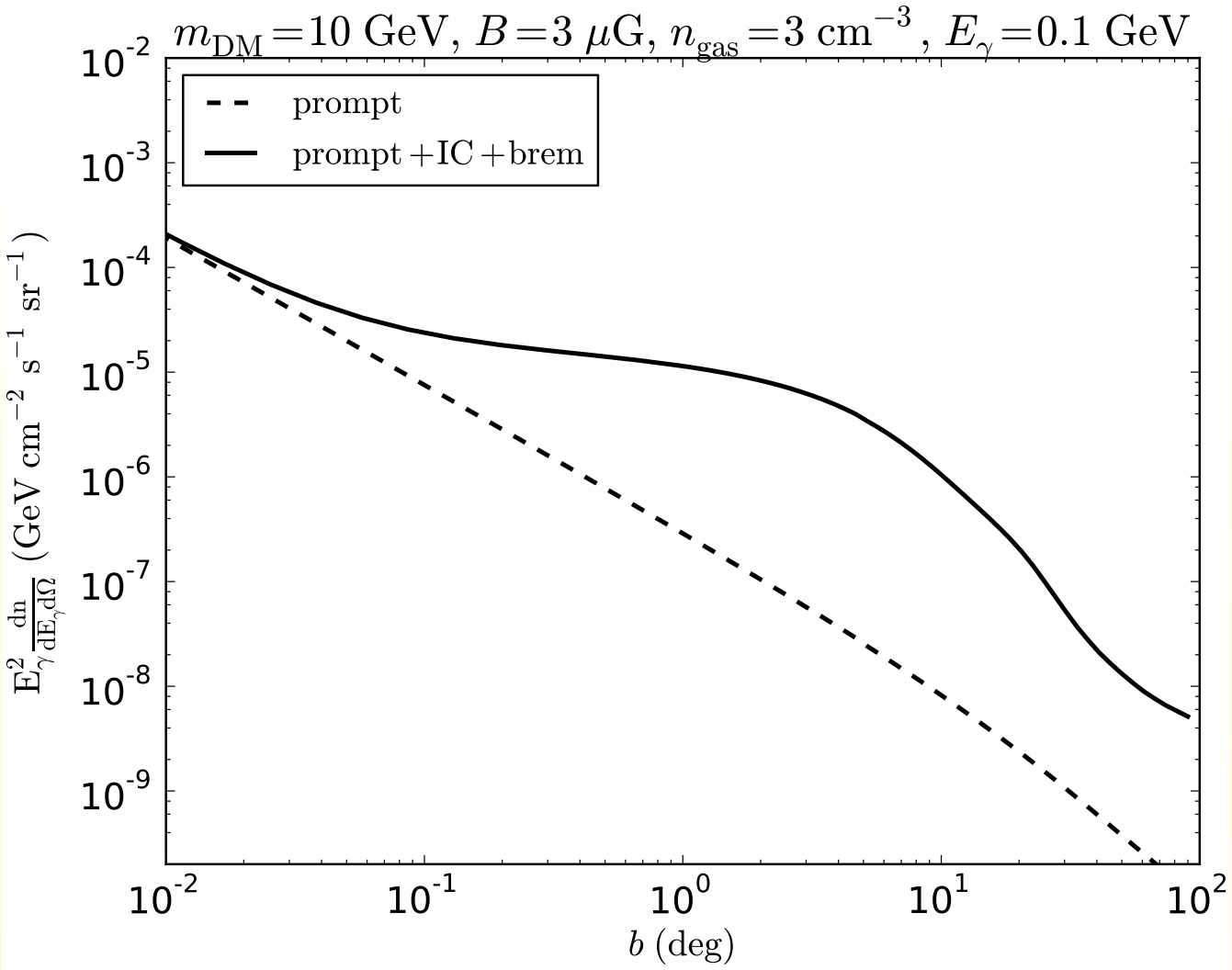


TL, C. Bœhm, J. Silk, arXiv:1403.1987

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 $\sim 10^\circ$

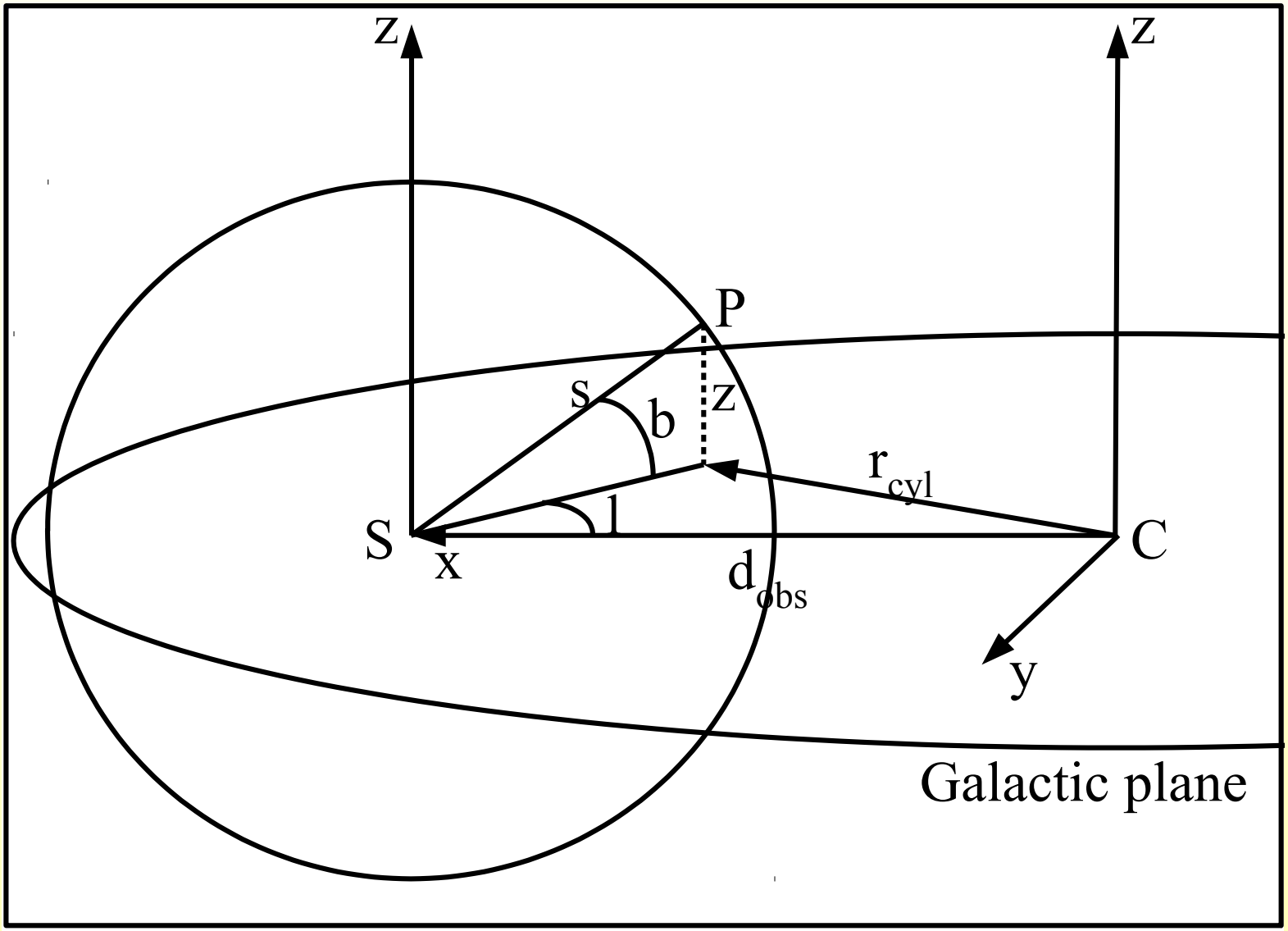


TL, C. Bœhm, J. Silk, arXiv:1403.1987

Conclusion

- Pretty strong case for DM
- But very important to include all relevant processes
- $b\bar{b}$ and 30 GeV is not the only possibility: DM can be 10 GeV and annihilate into leptons

Thank you for your attention!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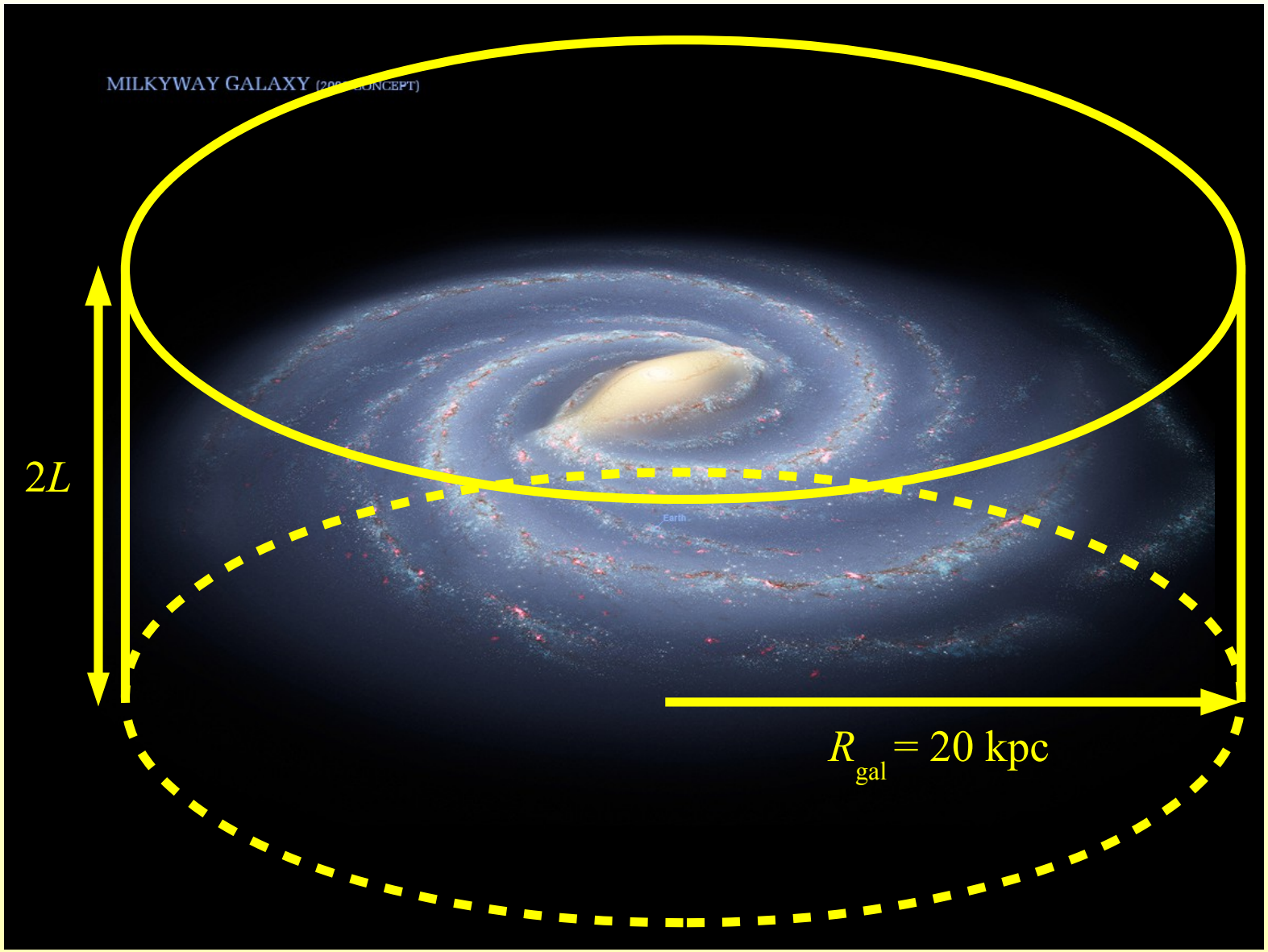
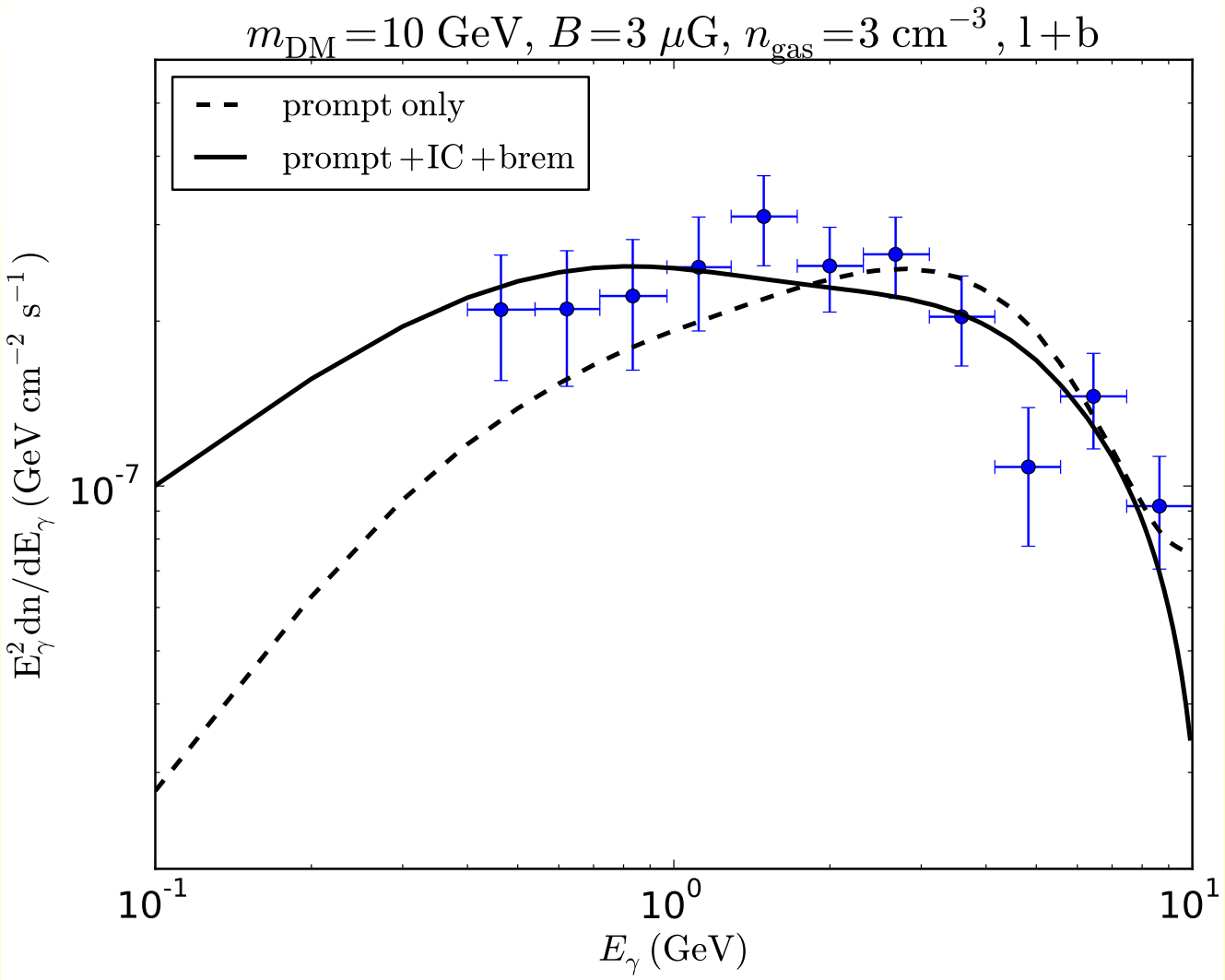
Galactic plane


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

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



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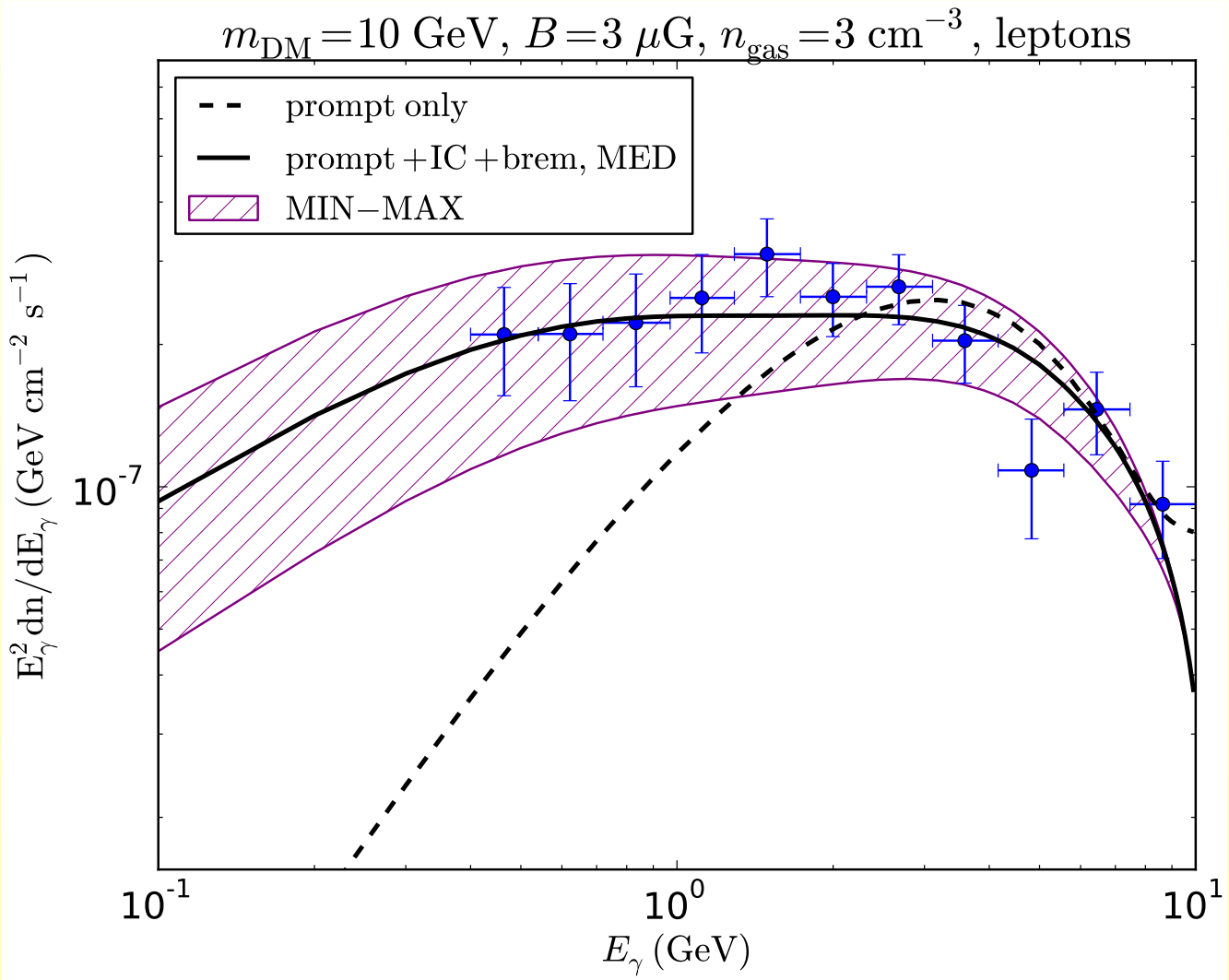

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