



TEXAS A&M UNIVERSITY
Mitchell Institute



SANFORD
UNDERGROUND
RESEARCH
FACILITY

Cosmic Ray-Dark Matter scattering as a source of the GCE

CETUP* 2026
July 2, 2026



CELEBRATING
CETUP*
Center for Theoretical
Underground Physics
and Related Areas
OF COLLABORATIVE RESEARCH

Deepak Sathyan

[2605.08010] by Bhaskar Dutta, Debopam Goswami, Jason
Kumar, Mudit Rai, DS

Galactic Center Excess: an overview

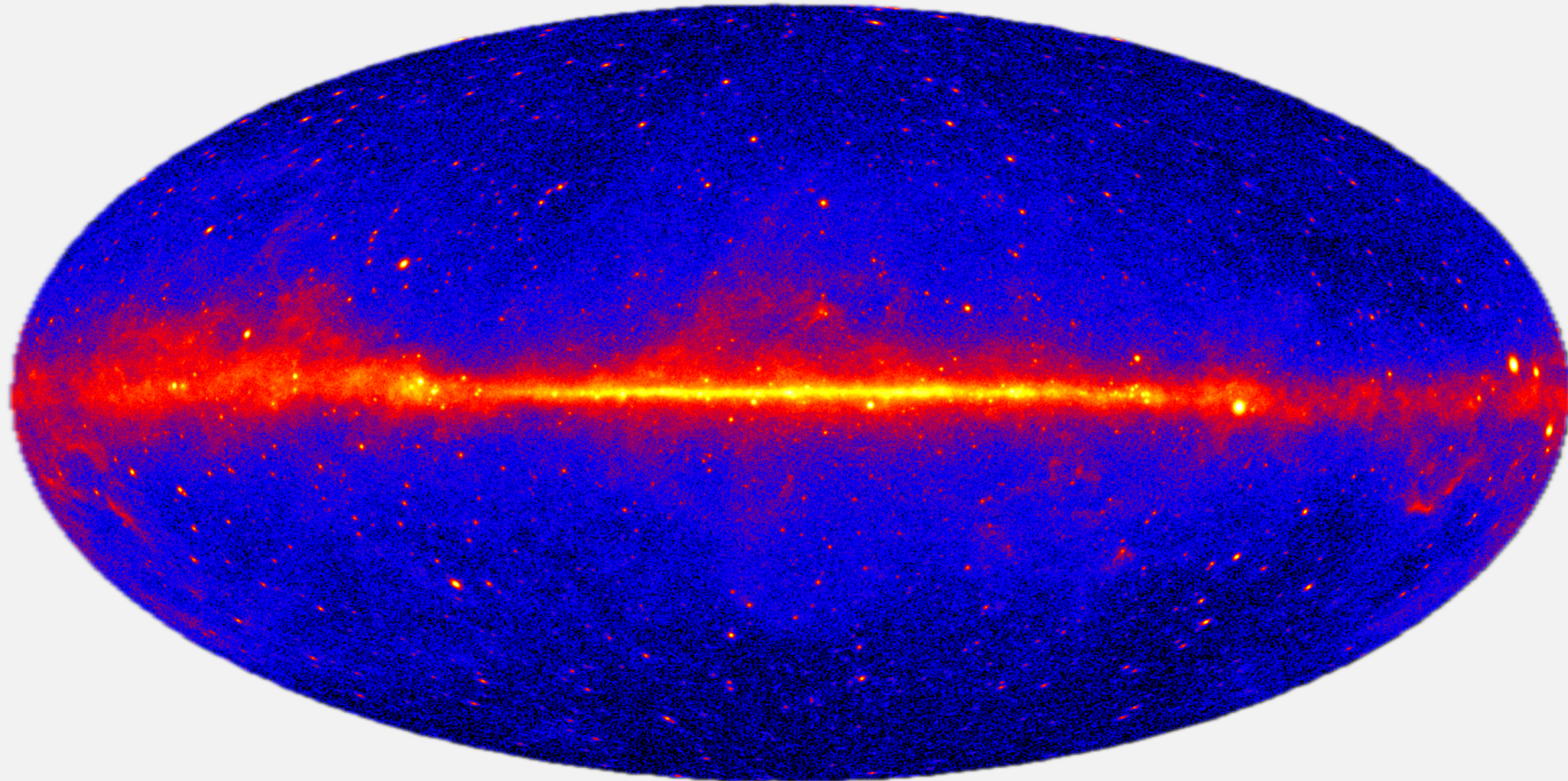
- Fermi Large Area Telescope measures gamma ray emission
[\[1012.2292\] A Morselli, B Canadas, V Vitale](#)

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Fermi-LAT 5 year data

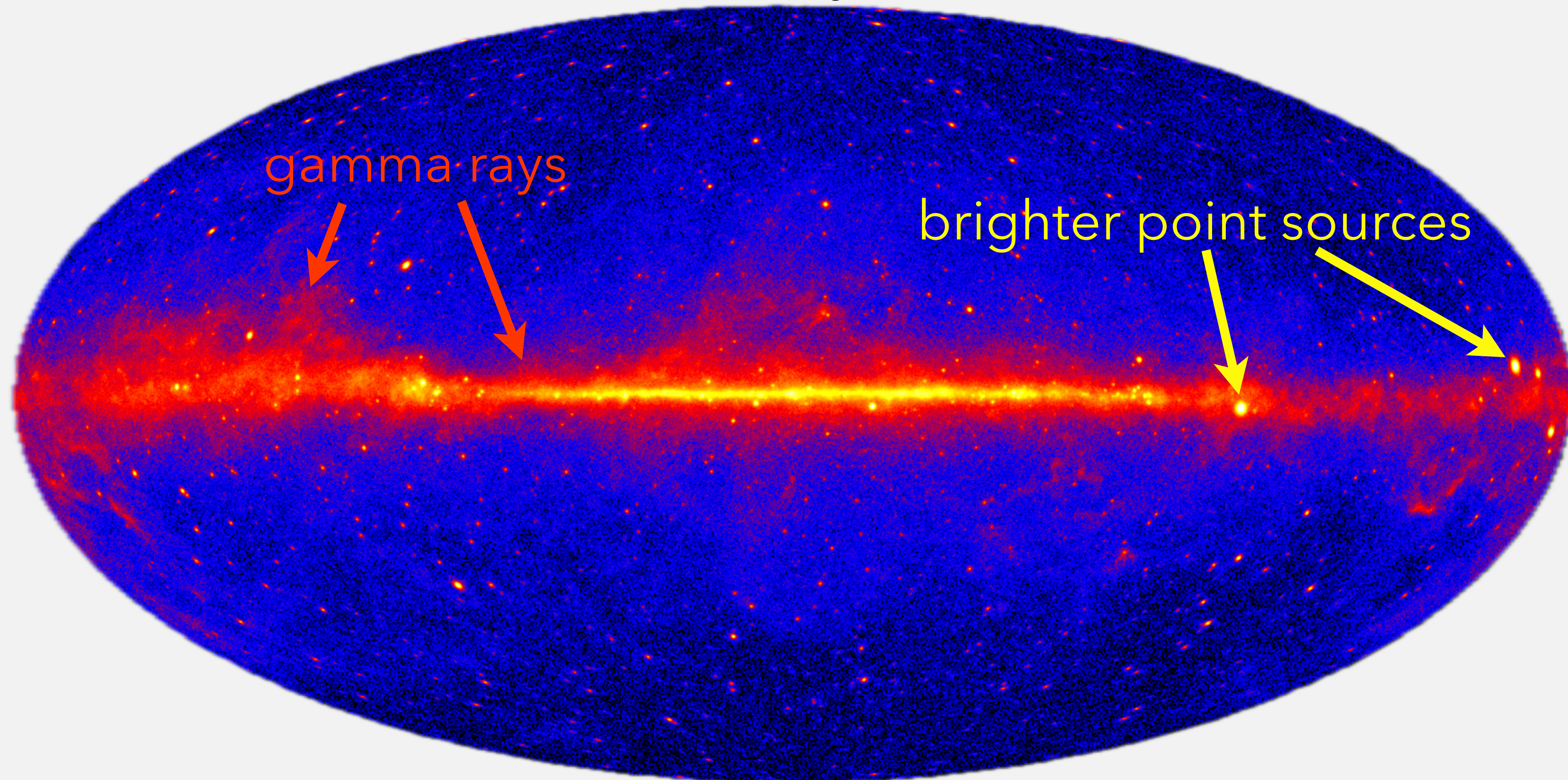


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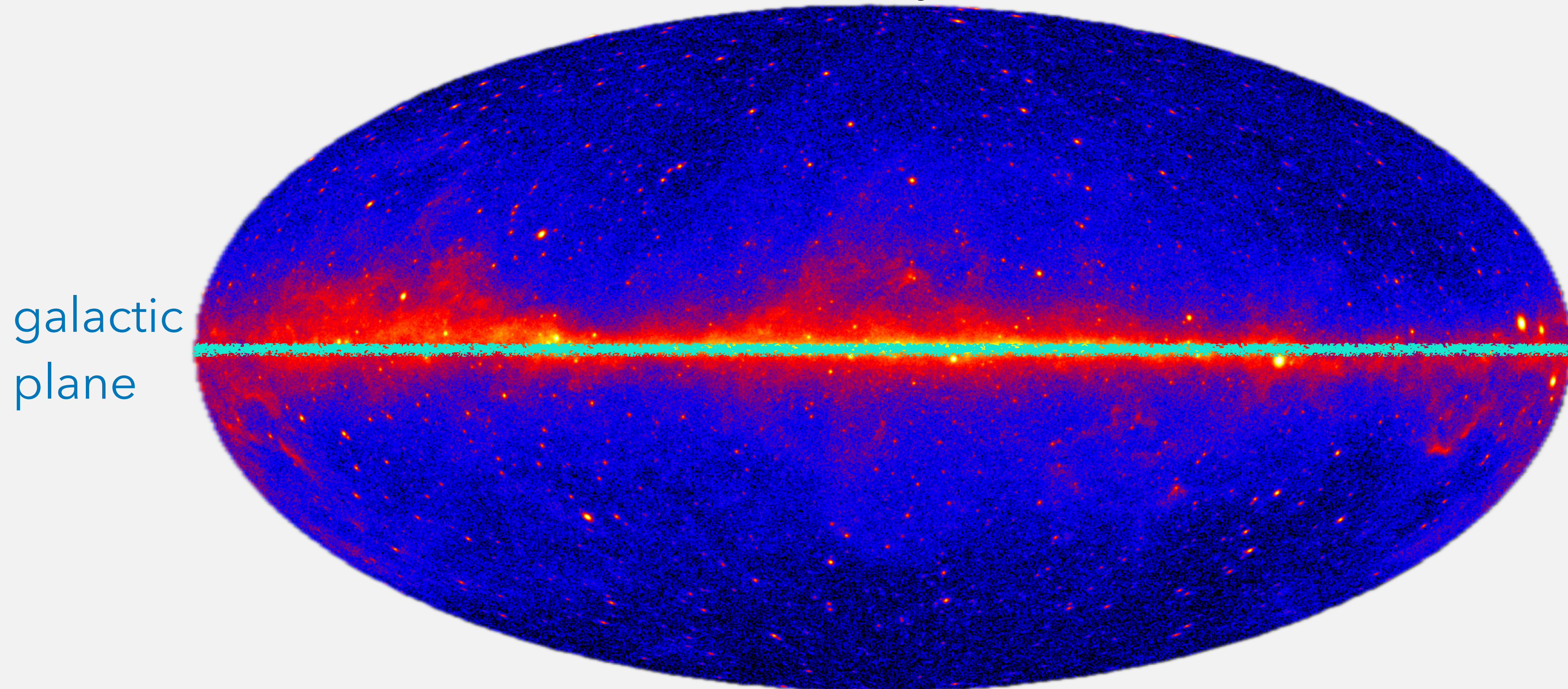


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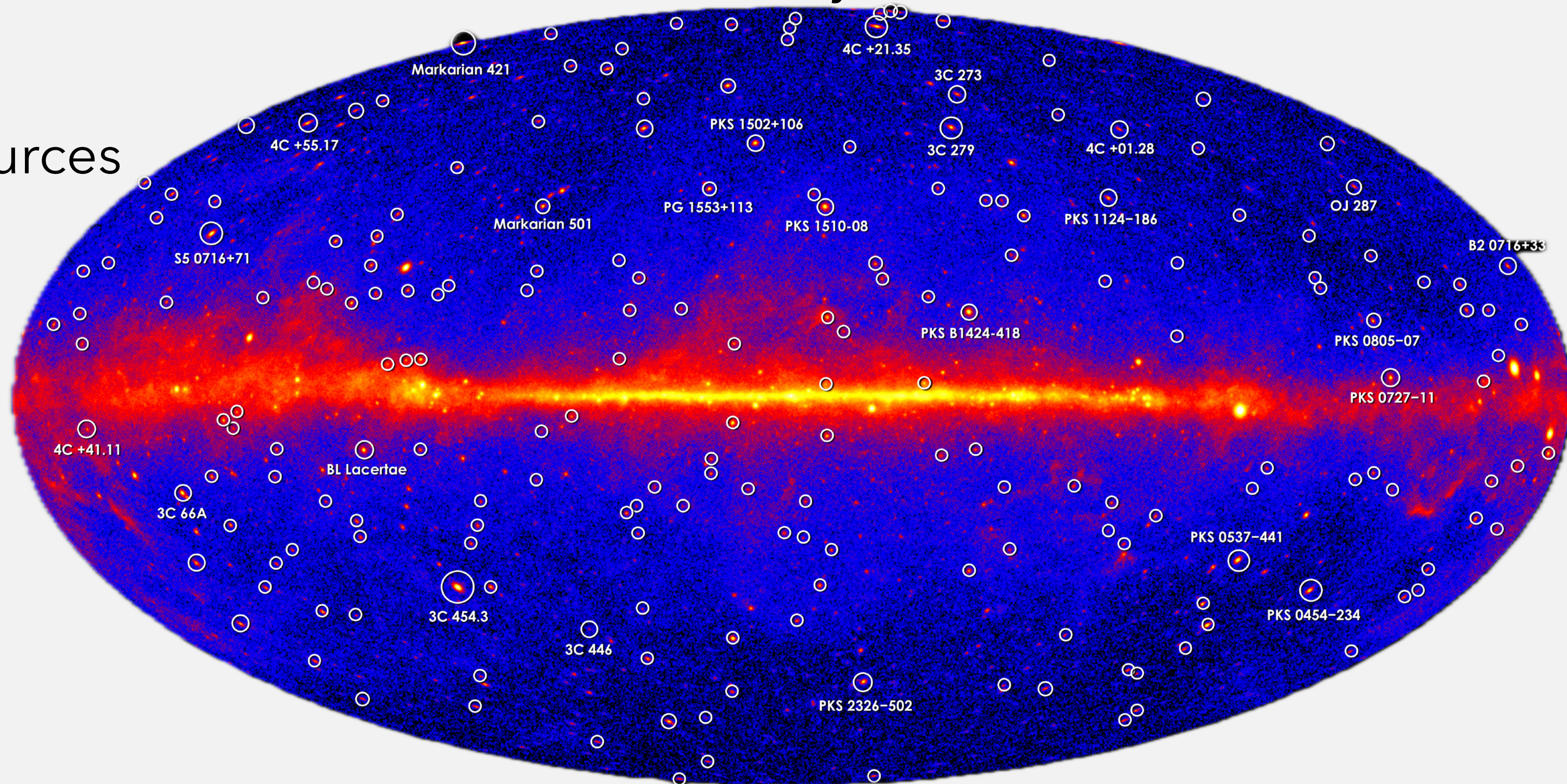
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blazar sources

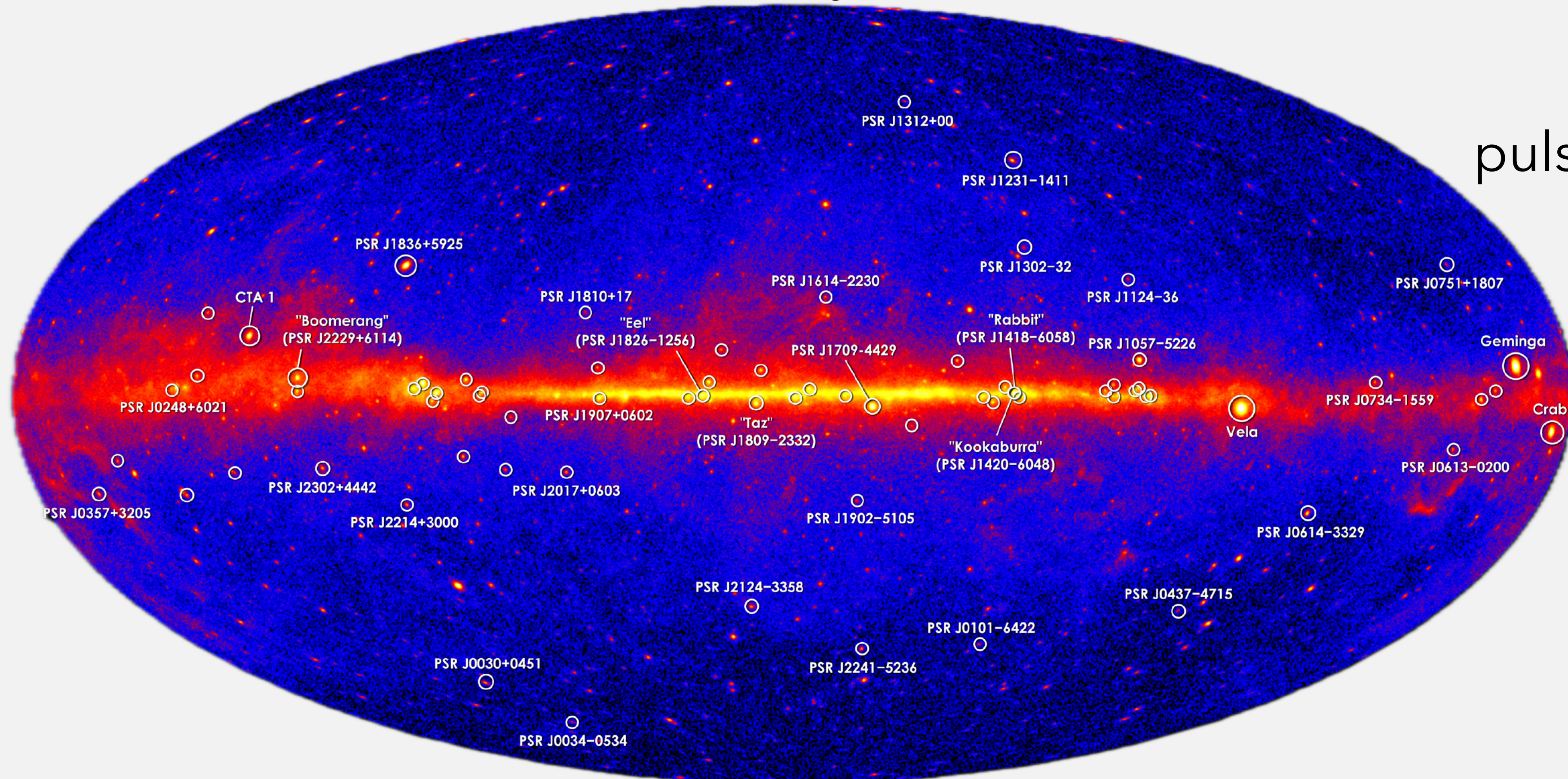


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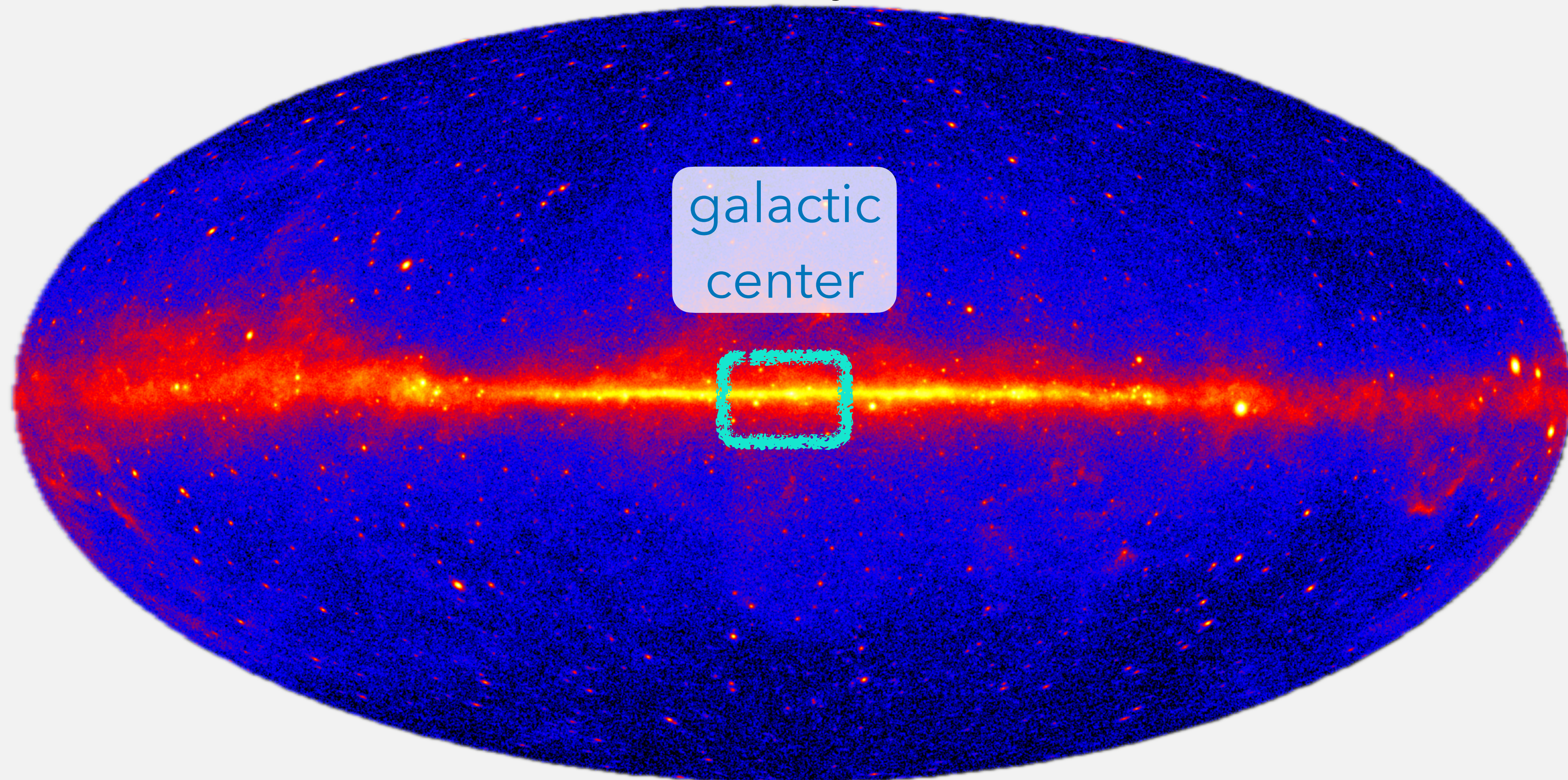
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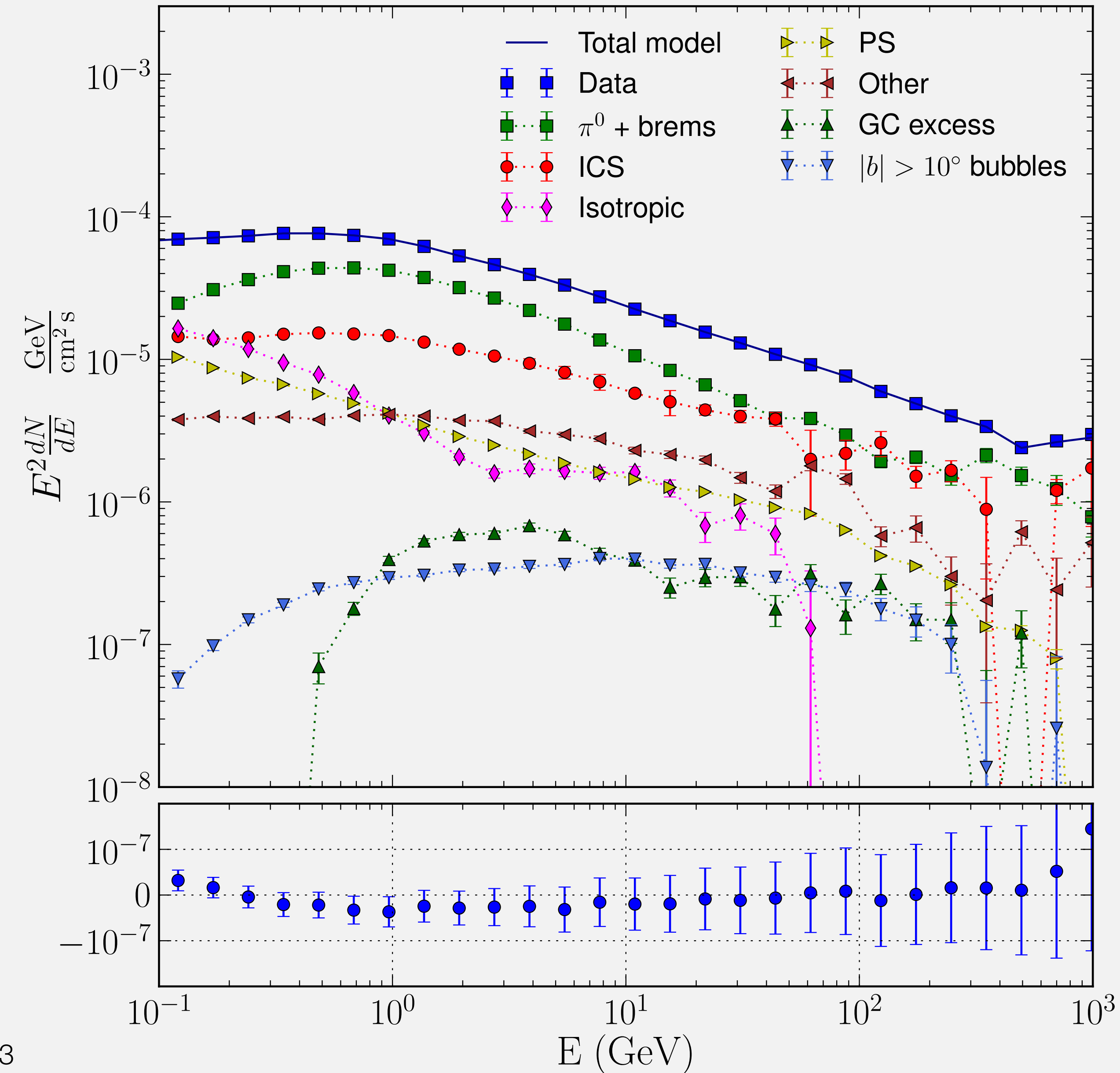


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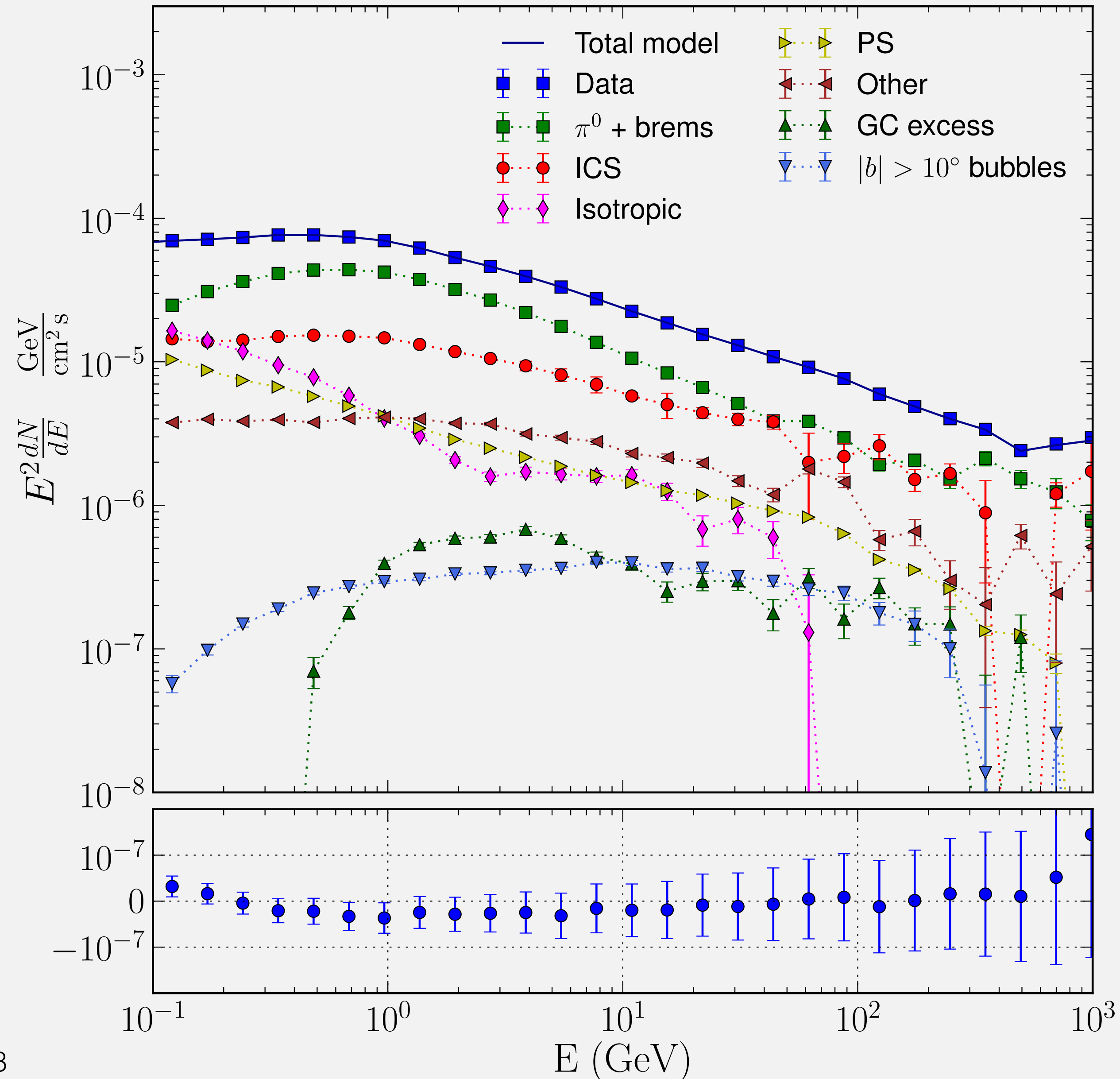
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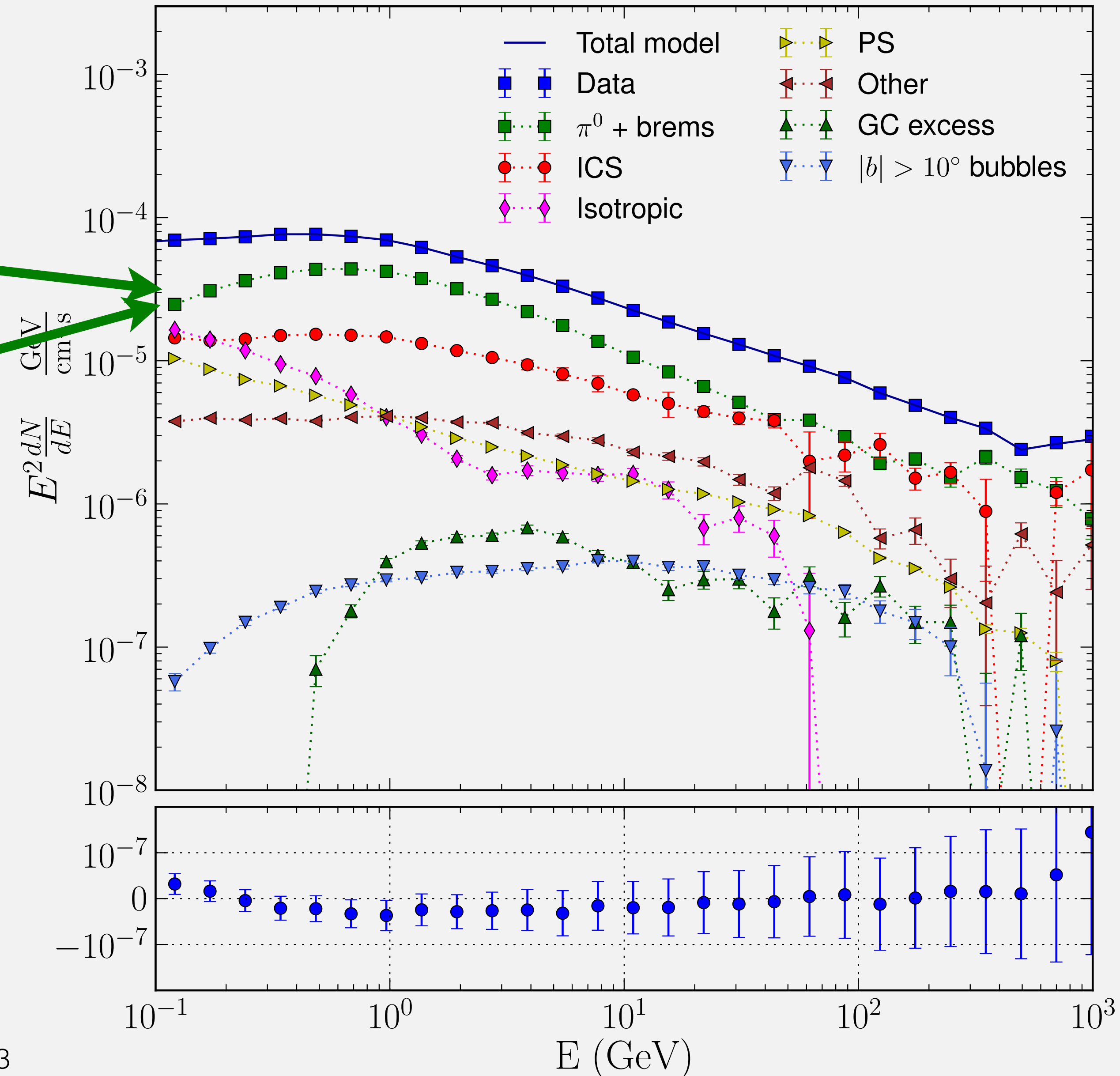
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[\[1704.03910\]](#) The Fermi-LAT Collaboration

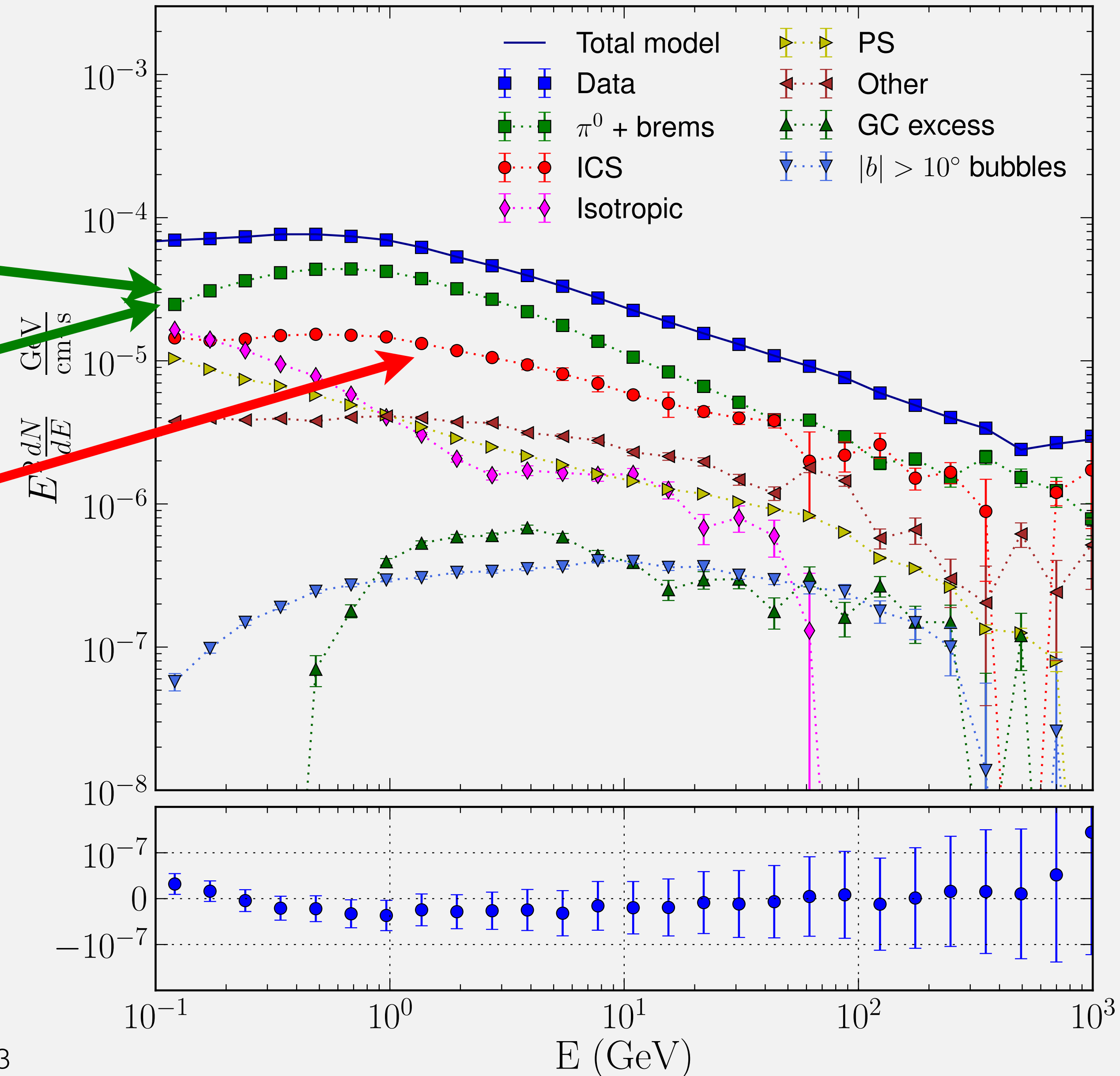
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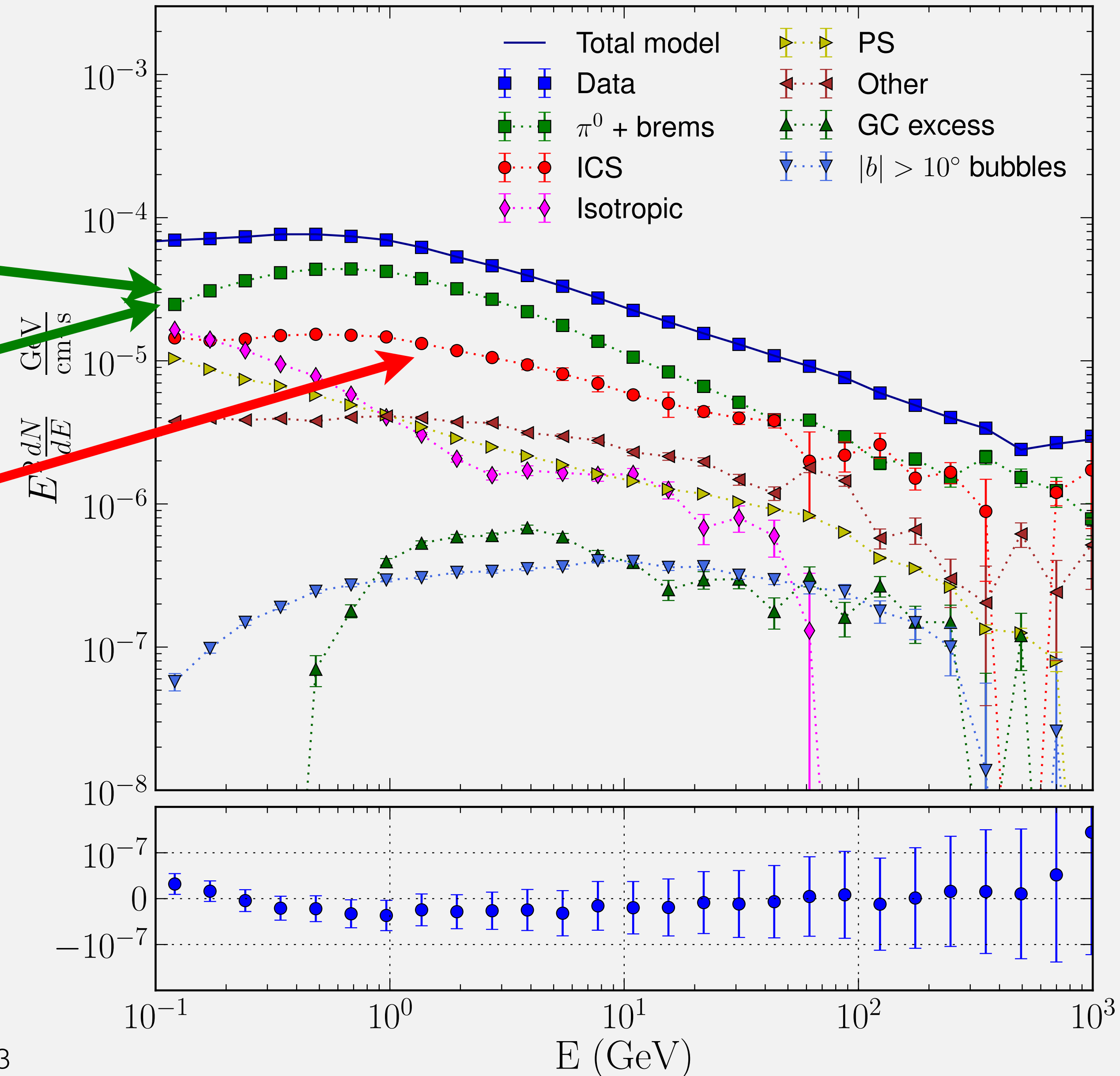
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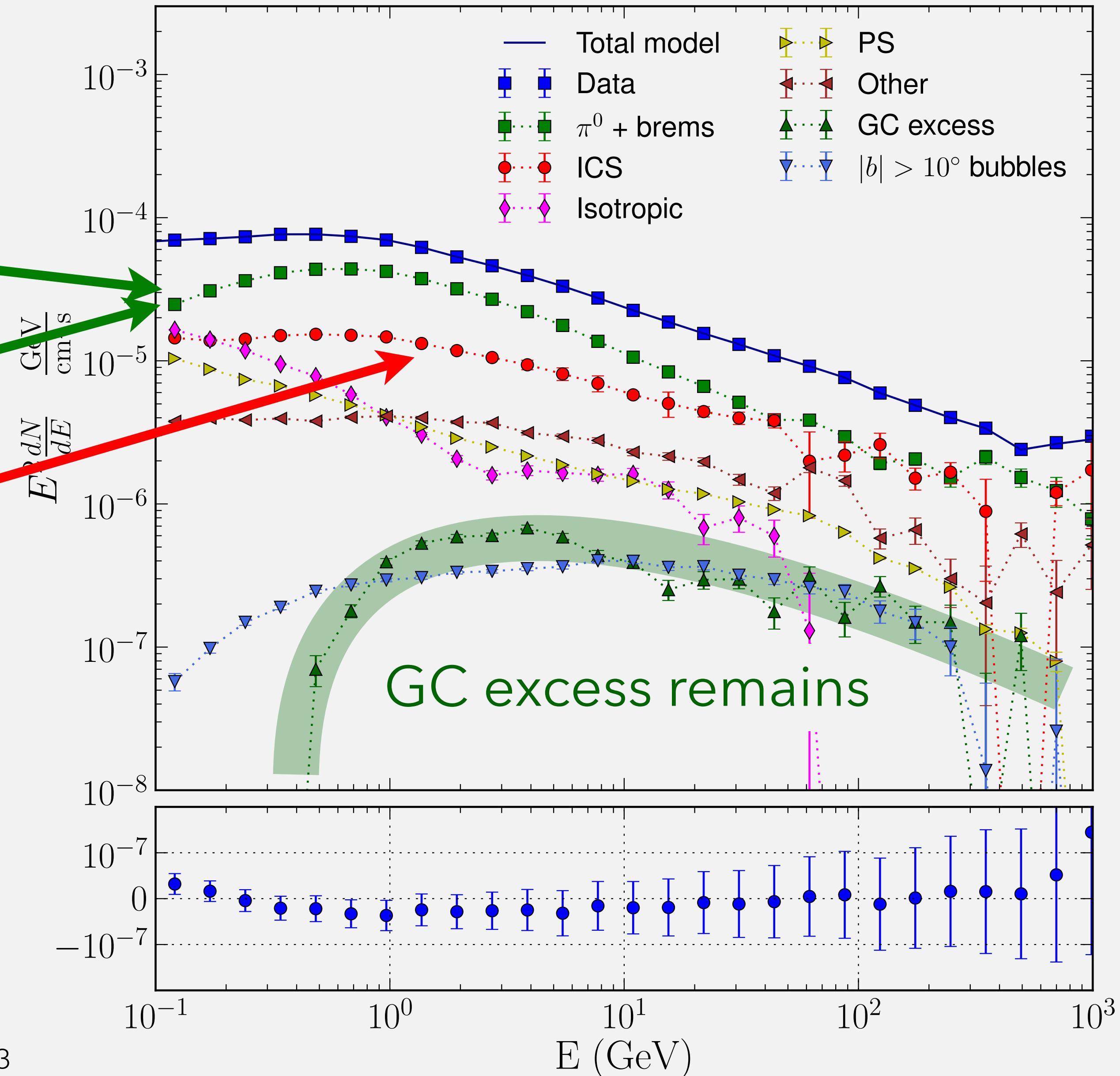
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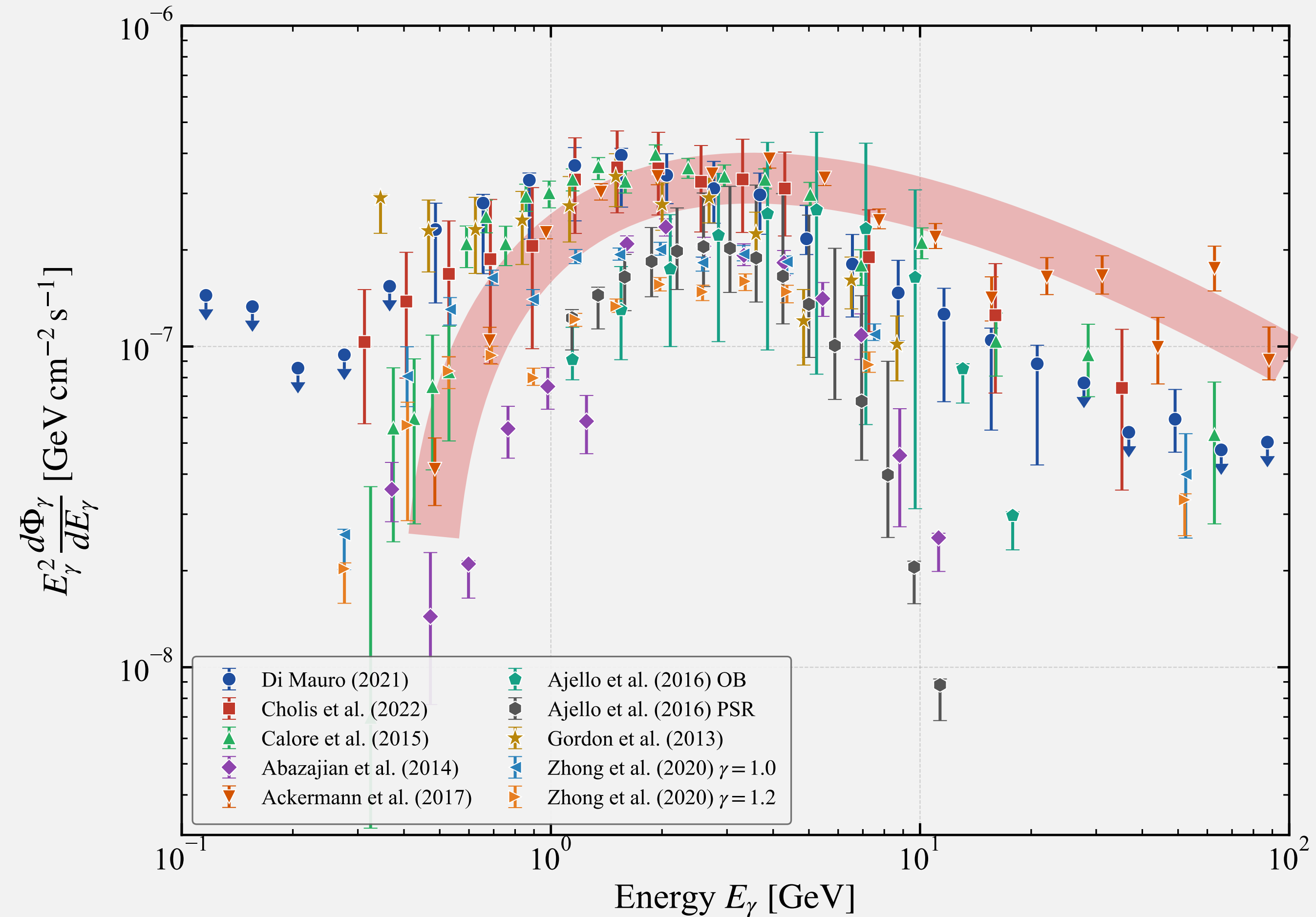


Figure made by Debopam Goswami, inspired by

[\[2509.08043\]](#) Y Hu, C Cesarotti, T Slatyer

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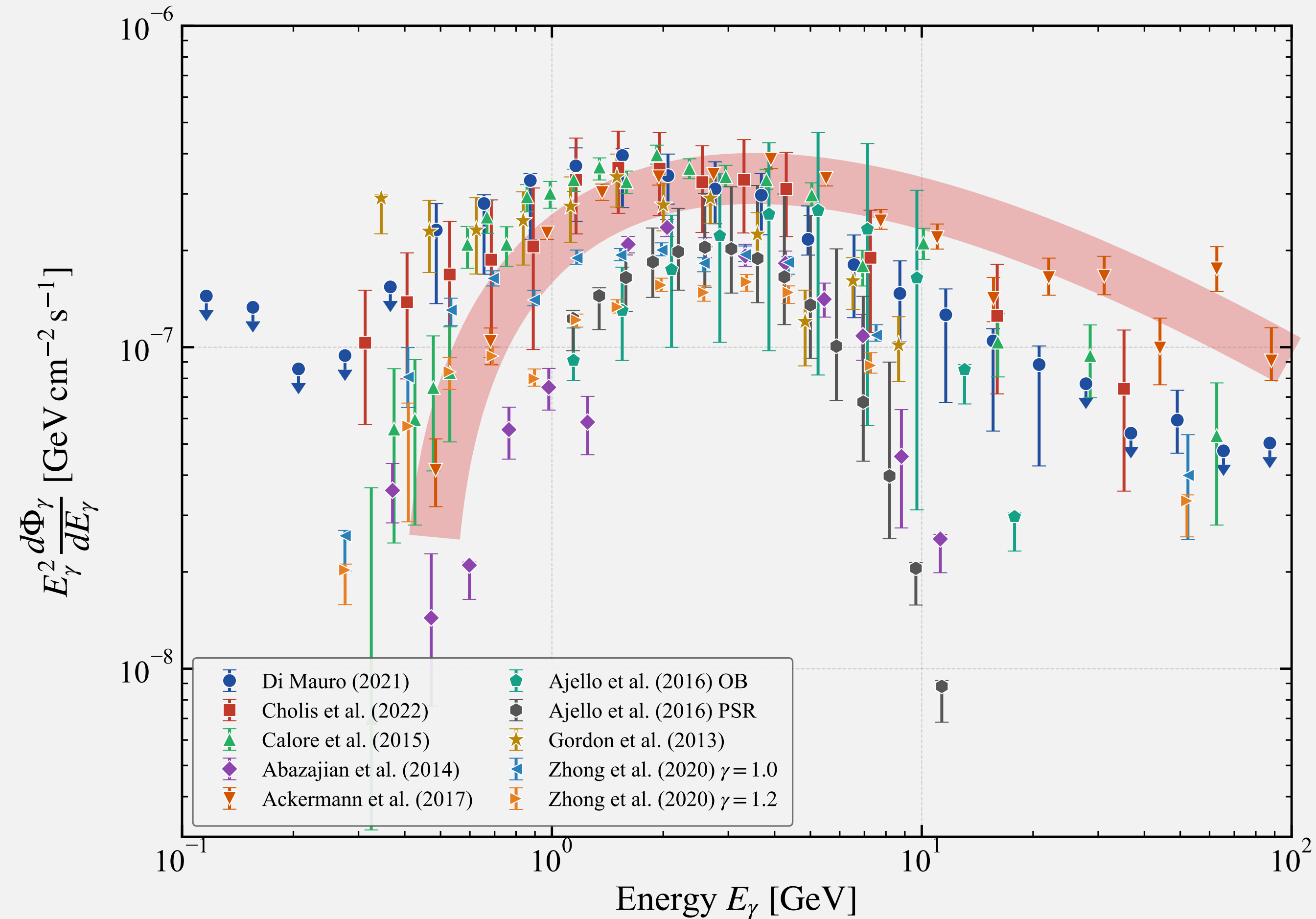


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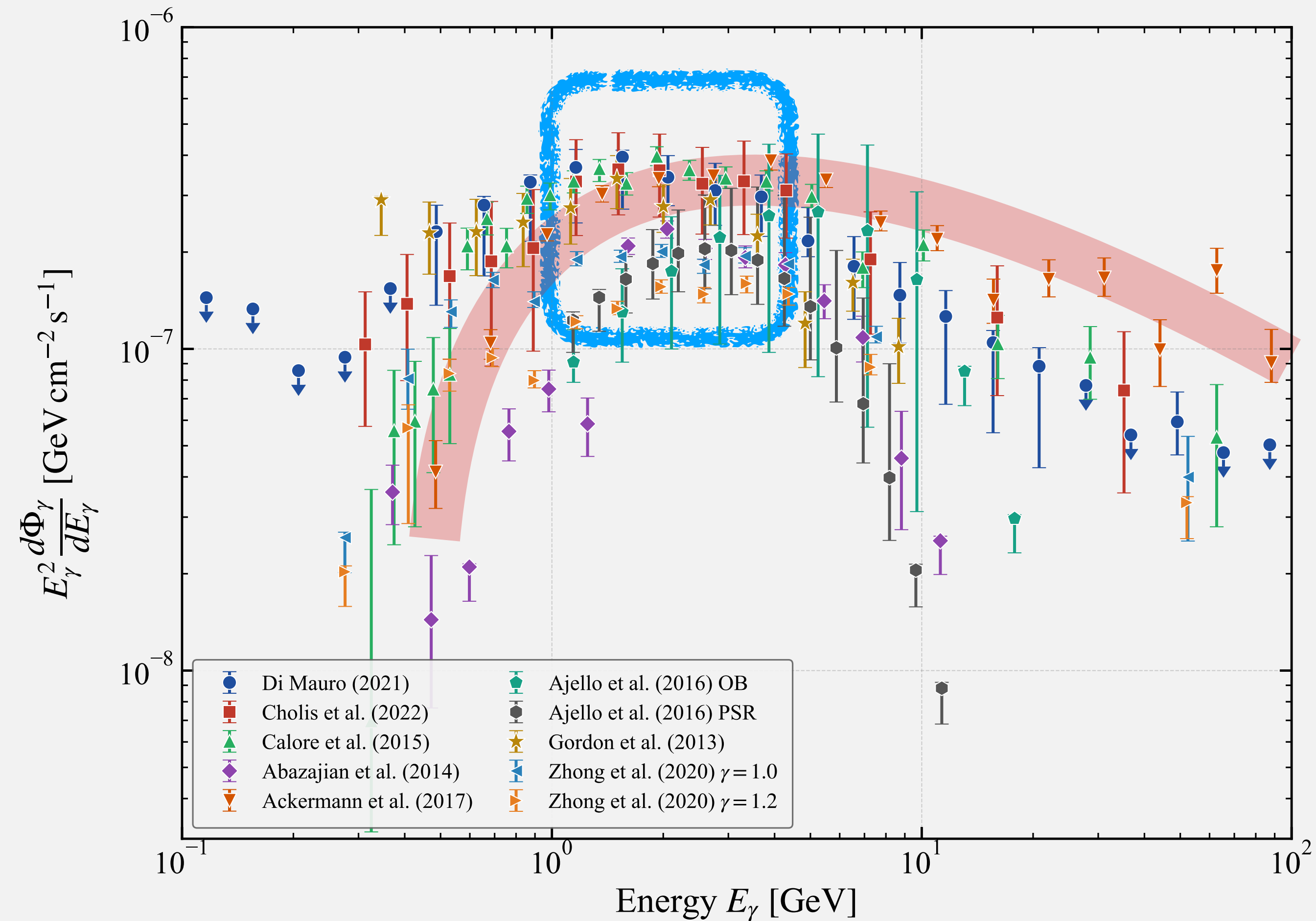


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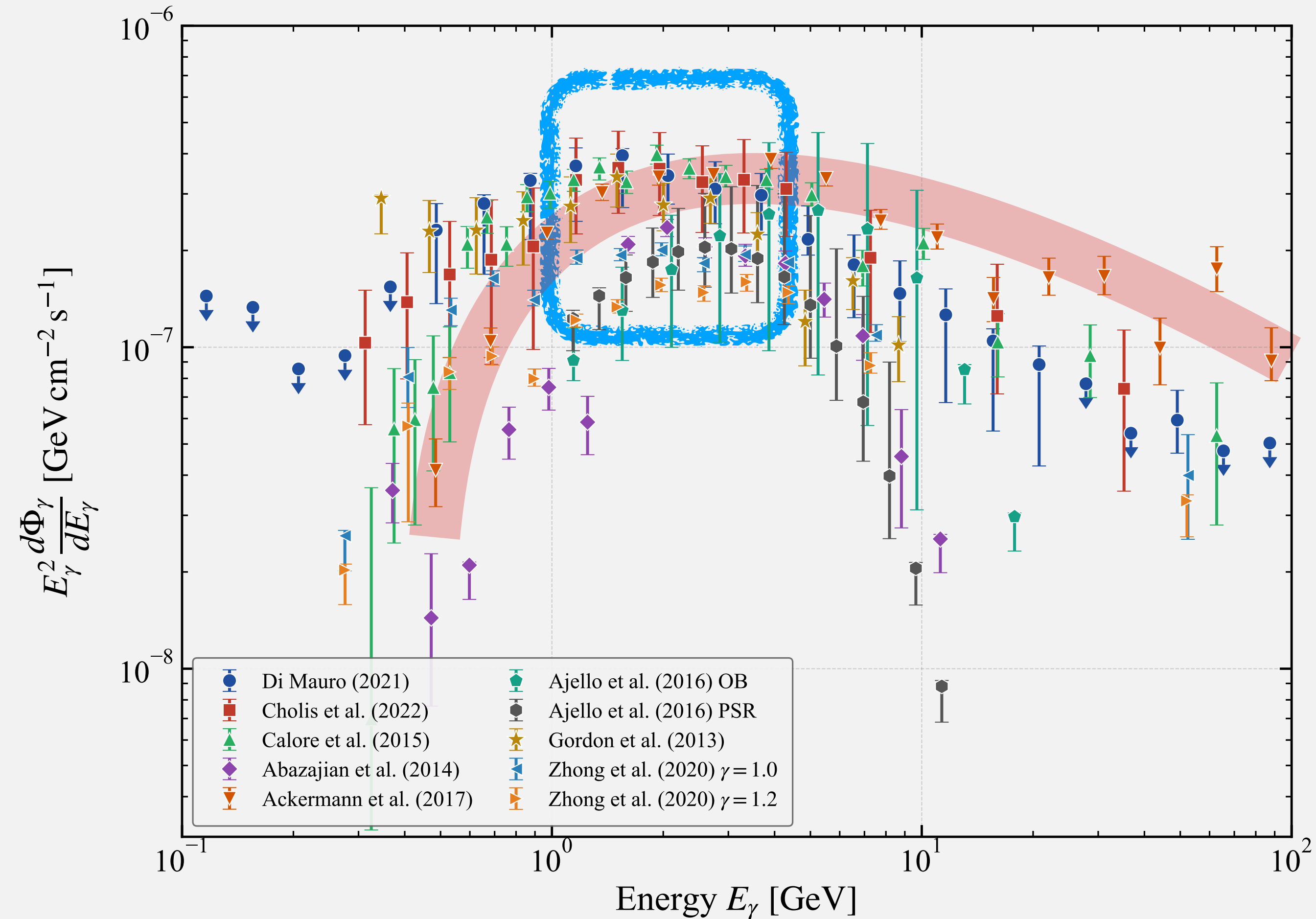


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- dark matter? BSM?
- additional astrophysical processes?

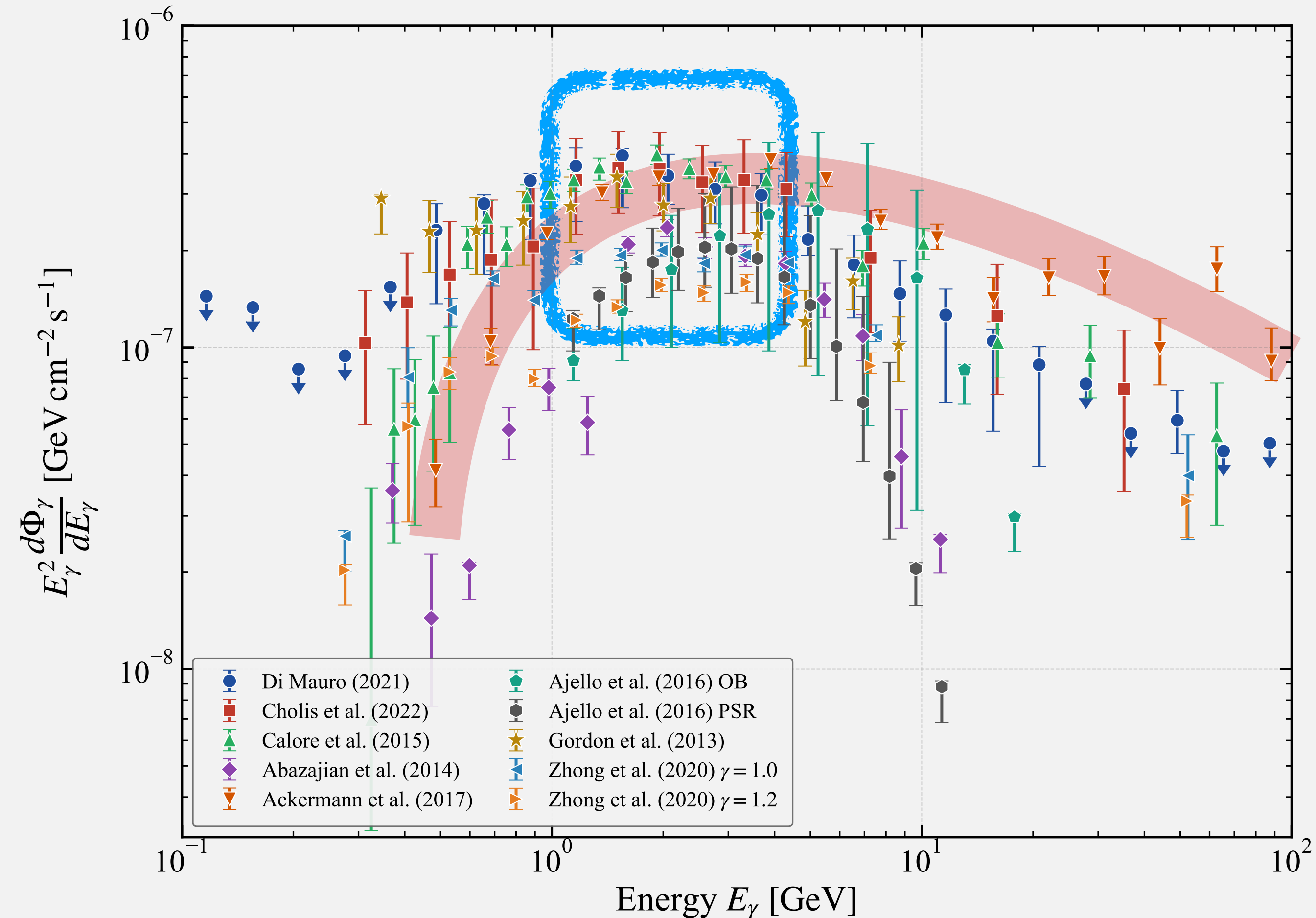


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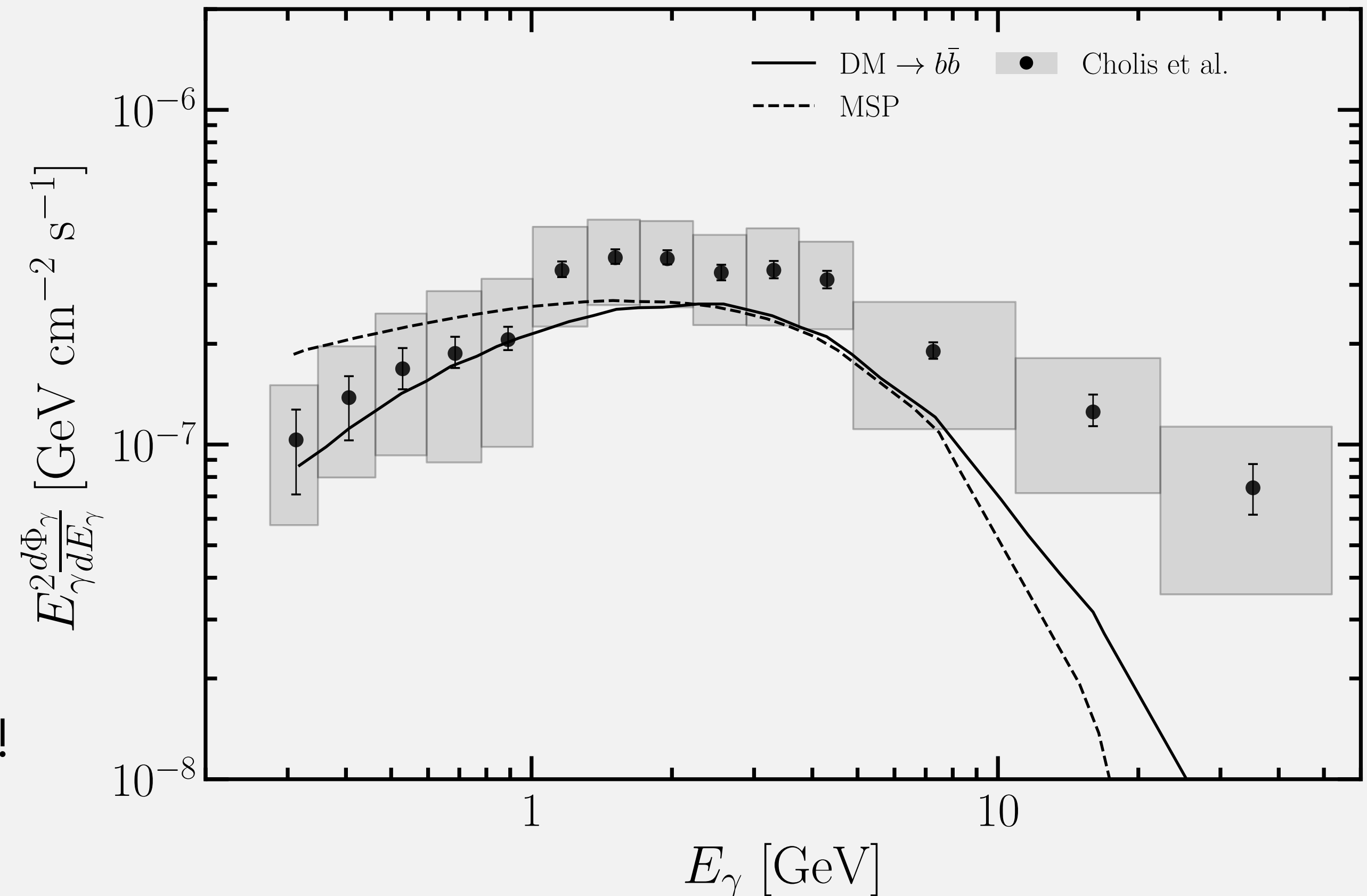
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[\[2112.09706\]](#) I Cholis, Y Zhong, S McDermott, J Surdutovich

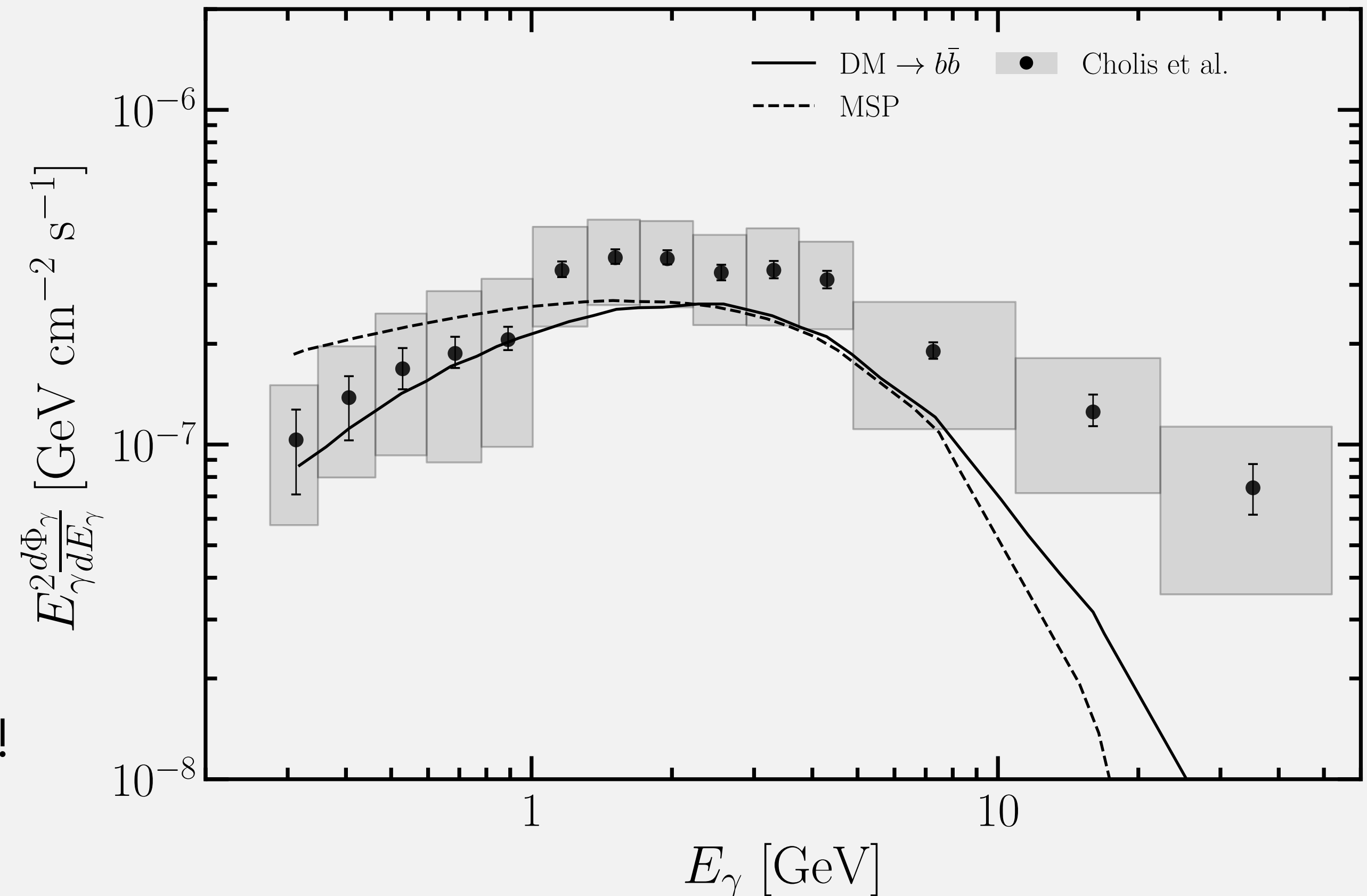
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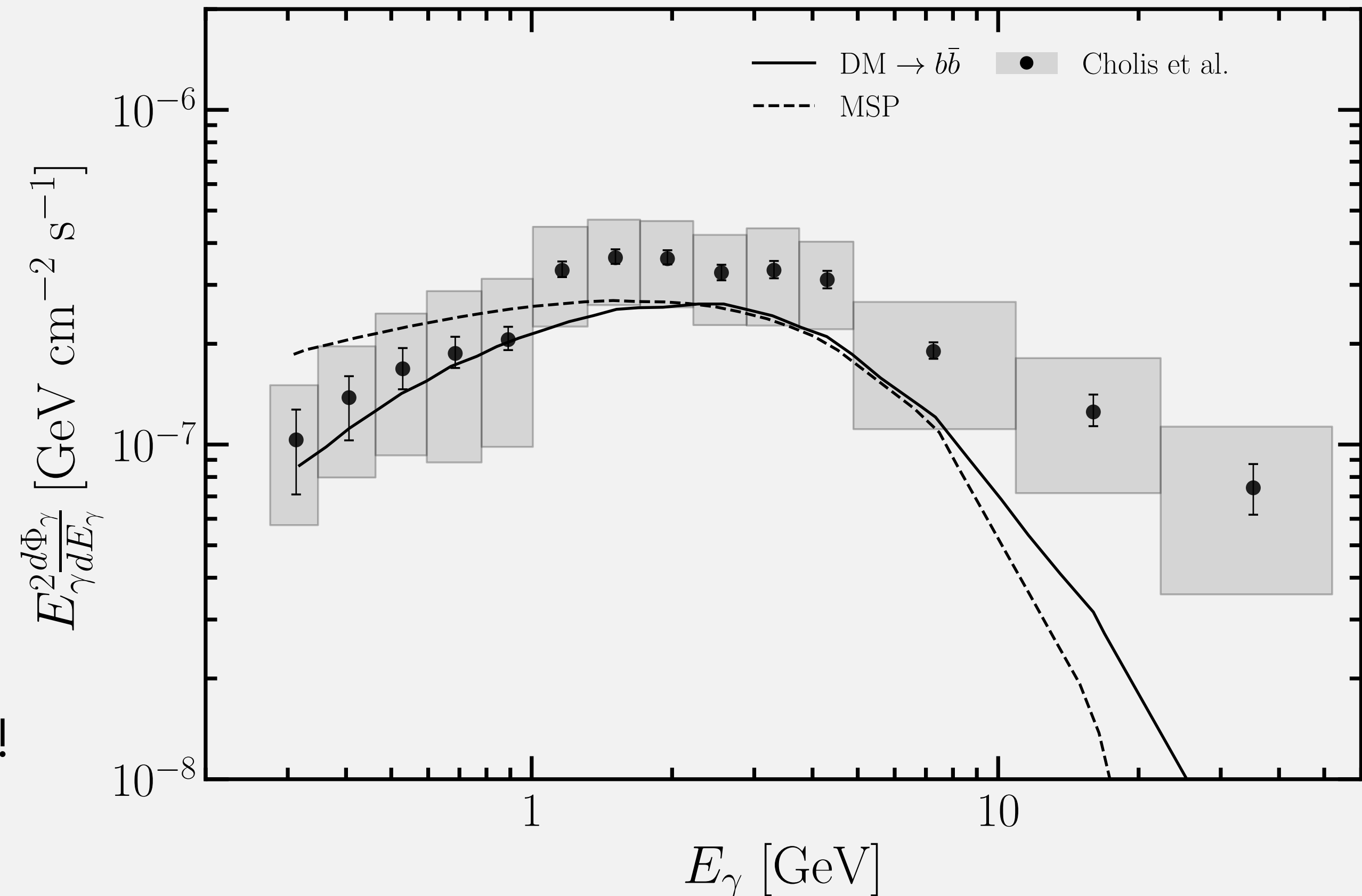
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- SMBH sourcing additional gamma rays
 - [\[1510.04698\]](#) E Carlson, T Linden, S Profumo
 - [\[1603.06584\]](#) E Carlson, T Linden, S Profumo

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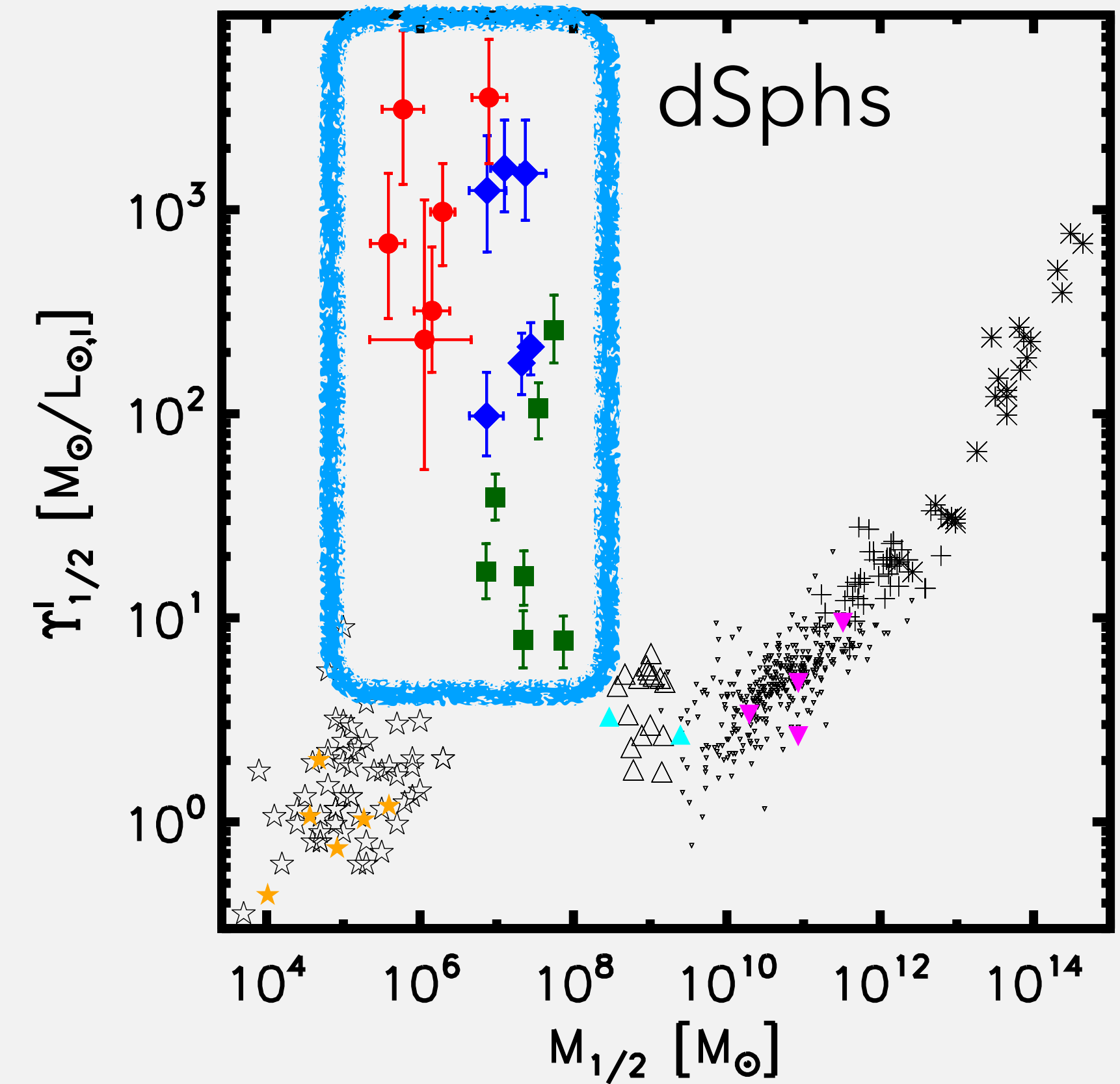
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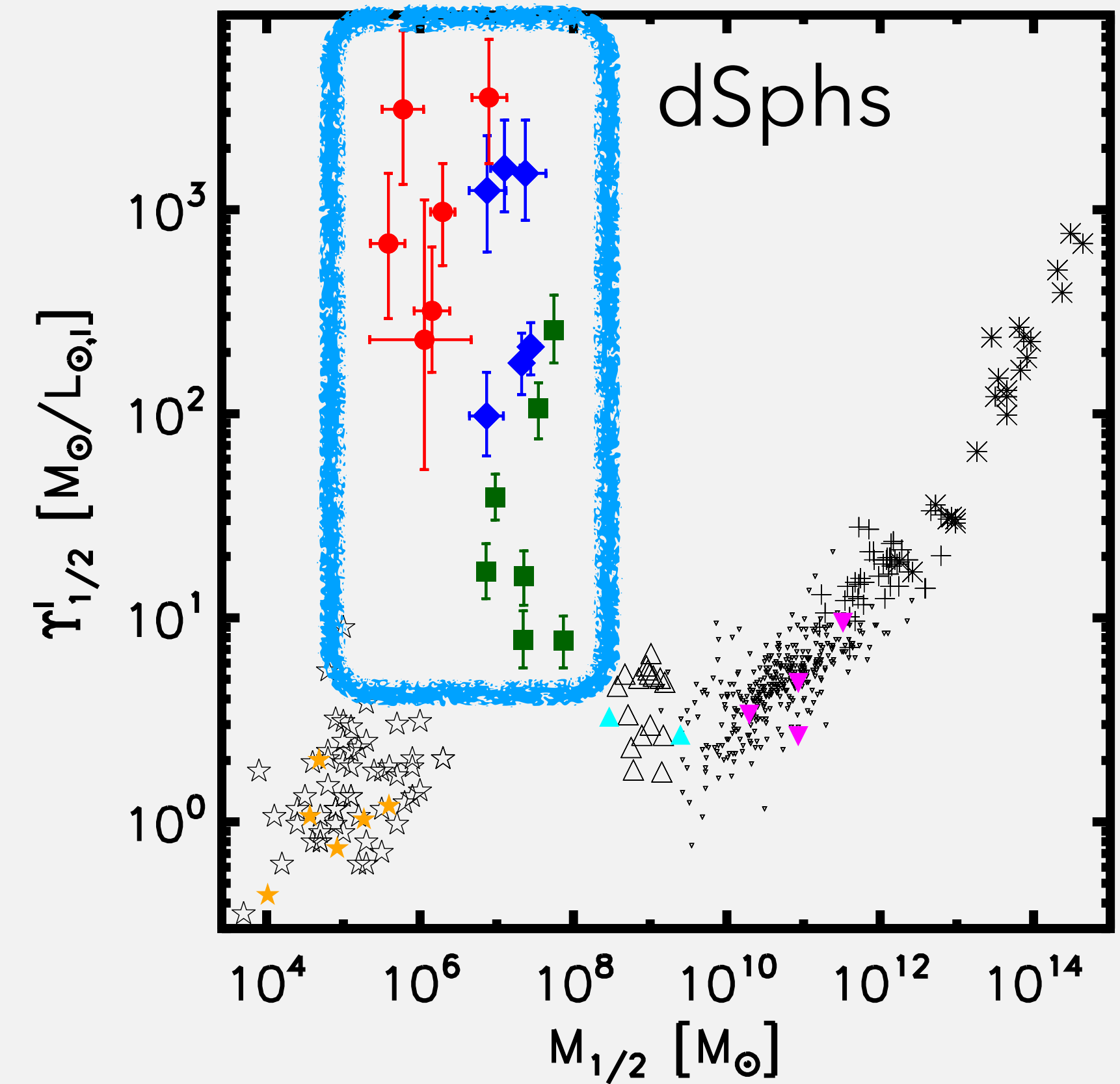
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[\[0908.2995\] J Wolf et al.](#)

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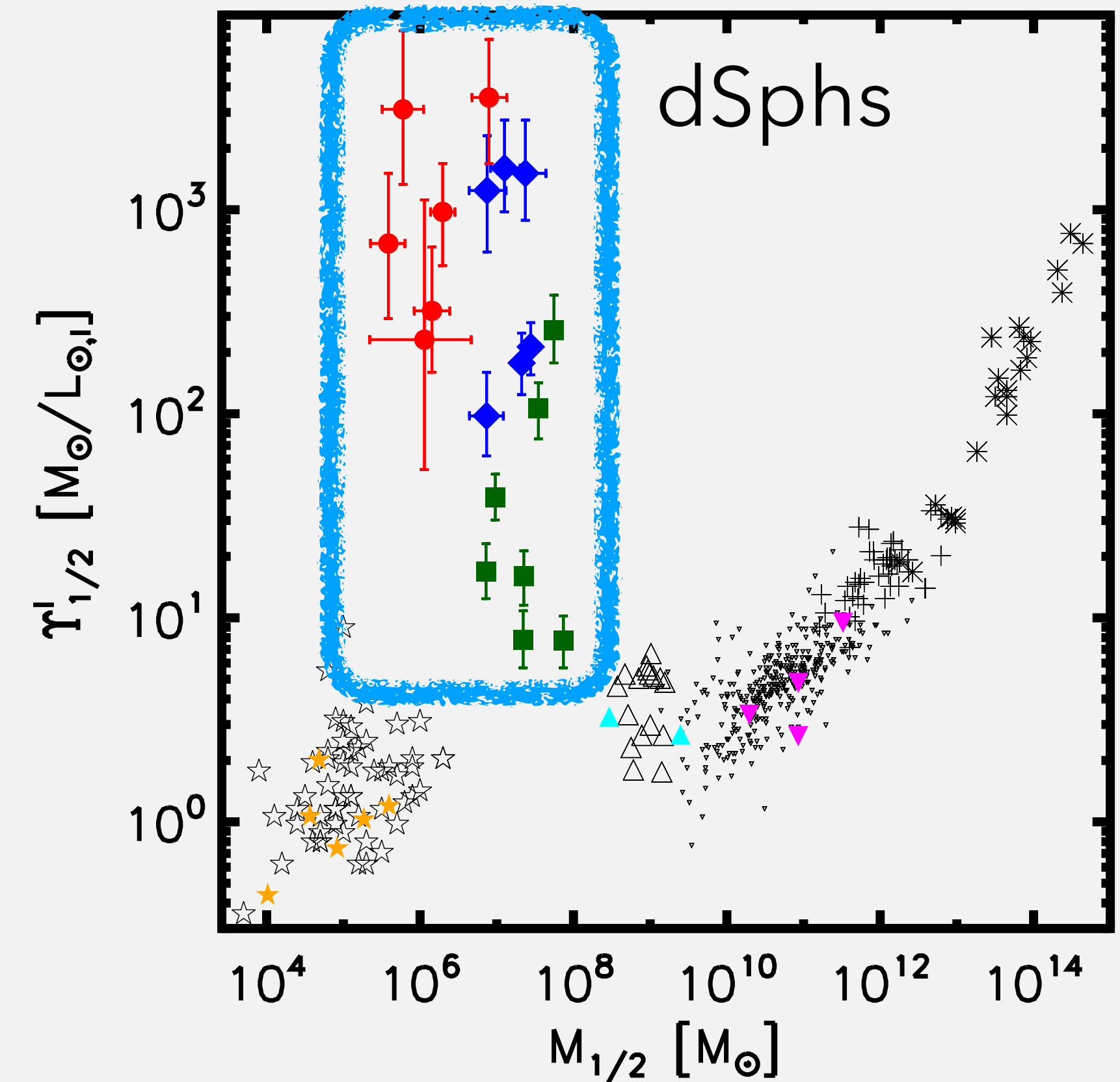
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- cosmic ray outbursts could produce additional gamma rays along the galactic disk

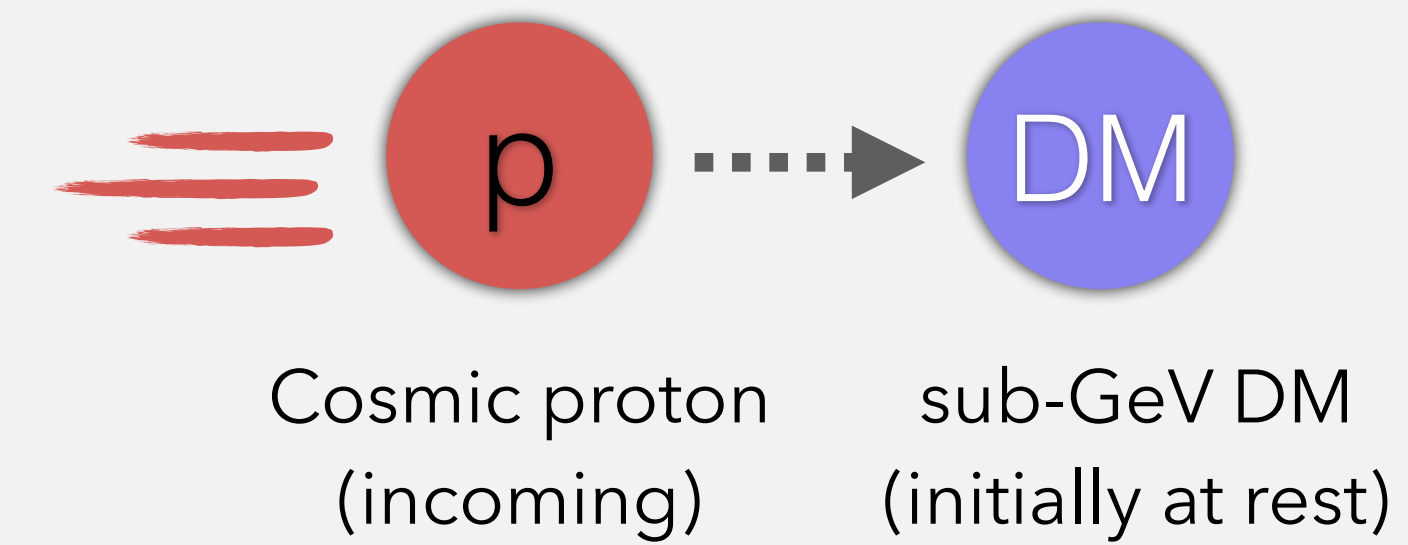


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our proposal: cosmic ray-dark matter scattering

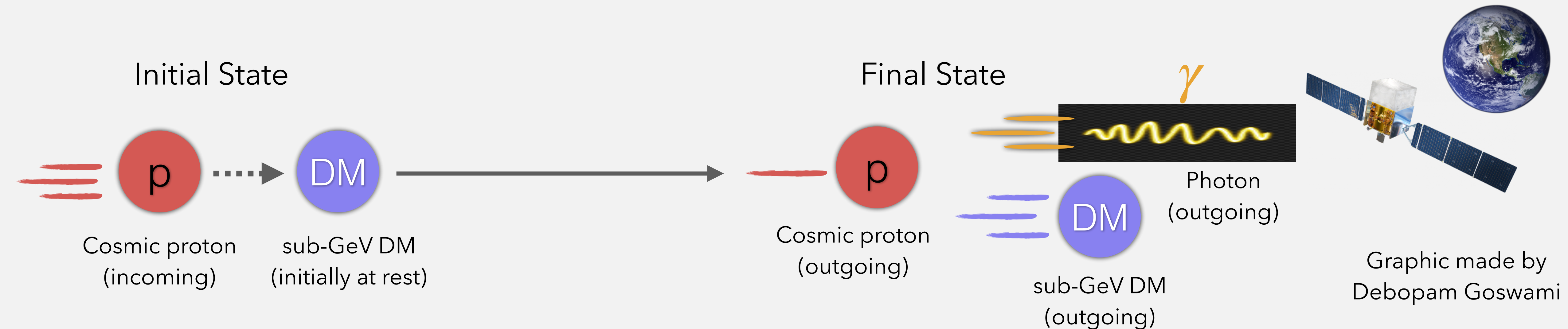
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Initial State



Graphic made by
Debopam Goswami

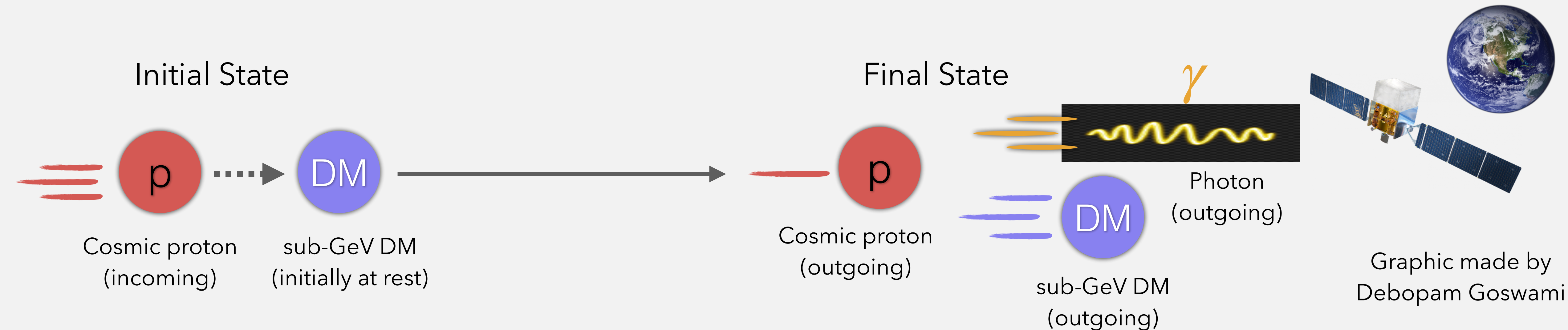
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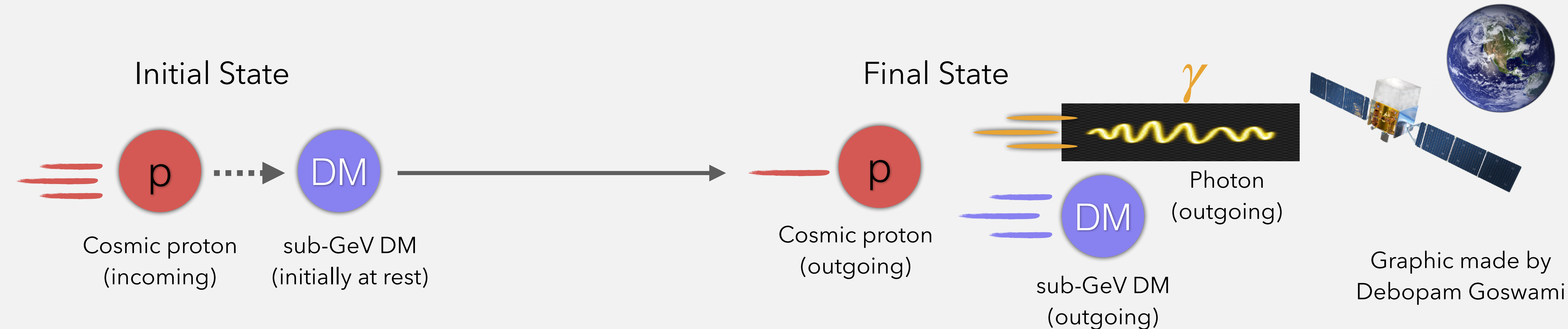
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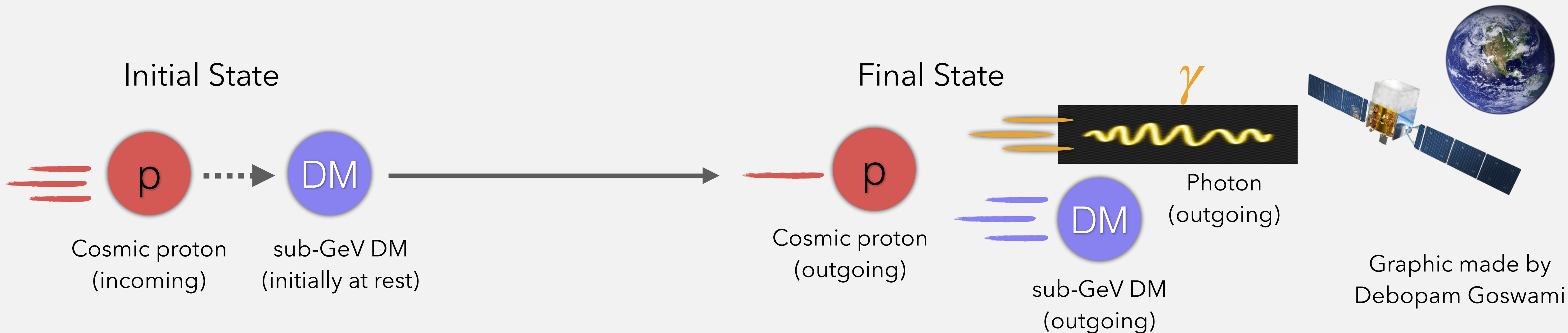
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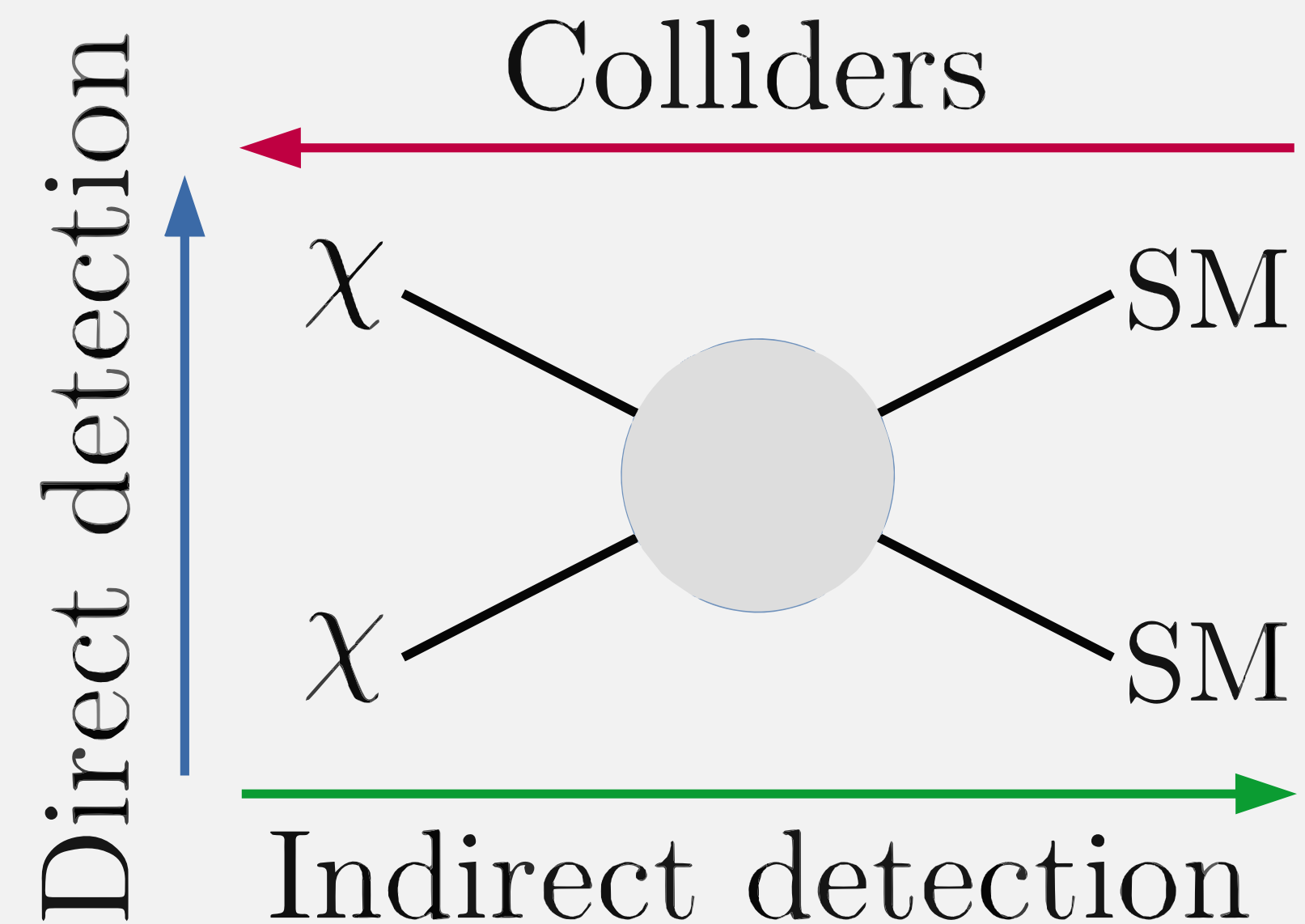


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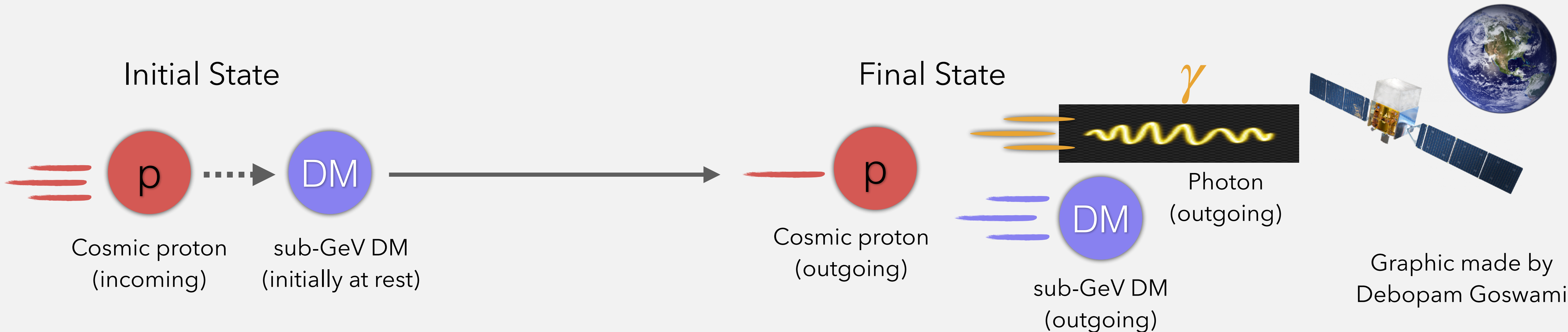
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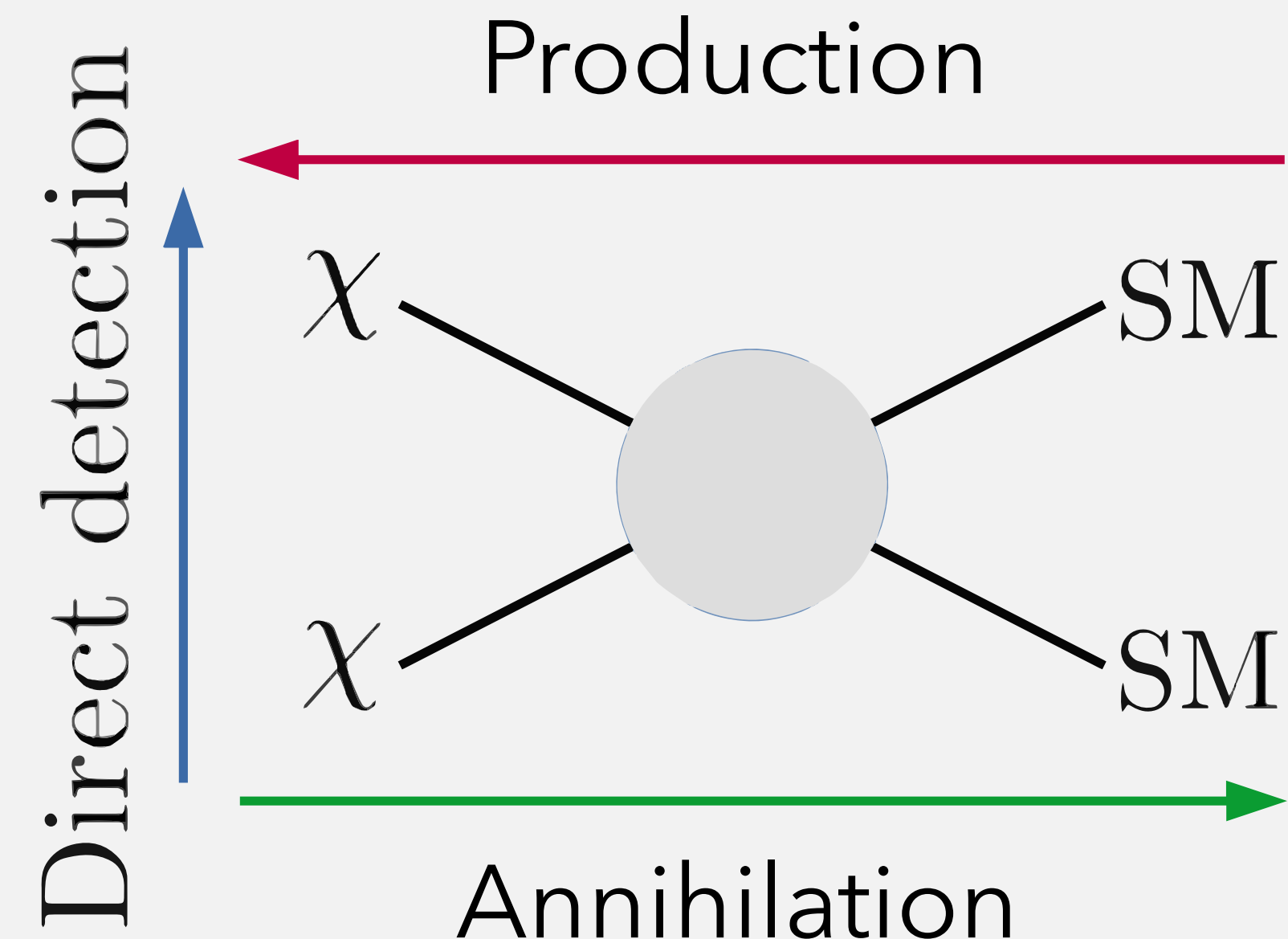
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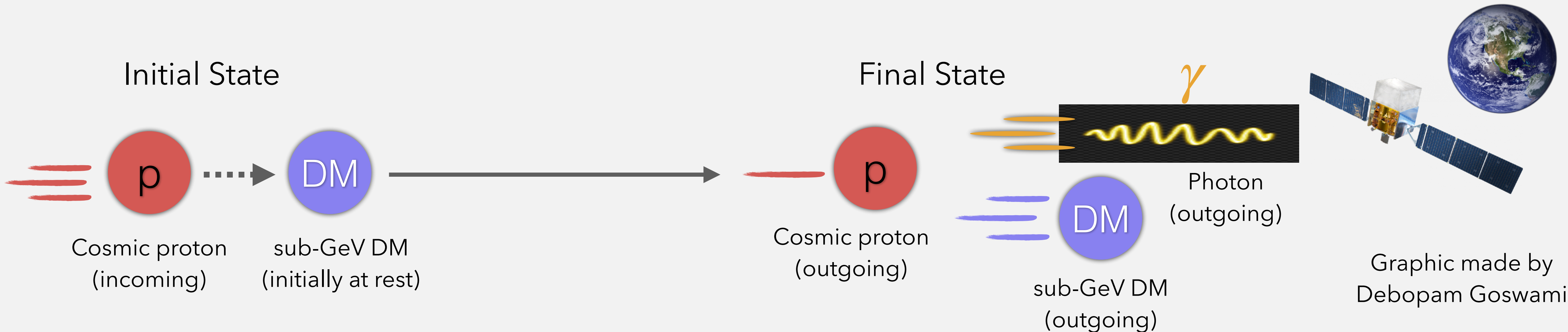
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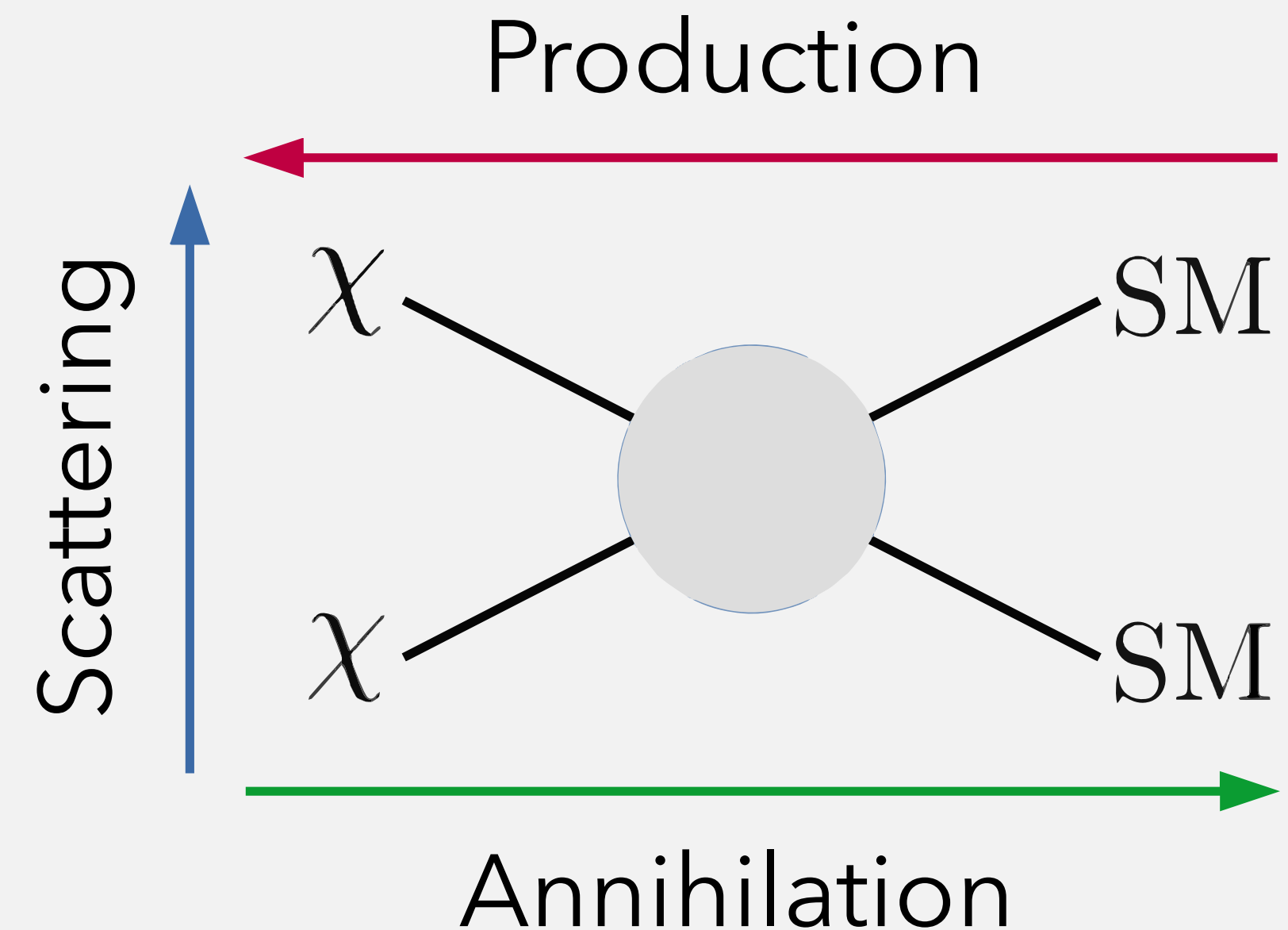
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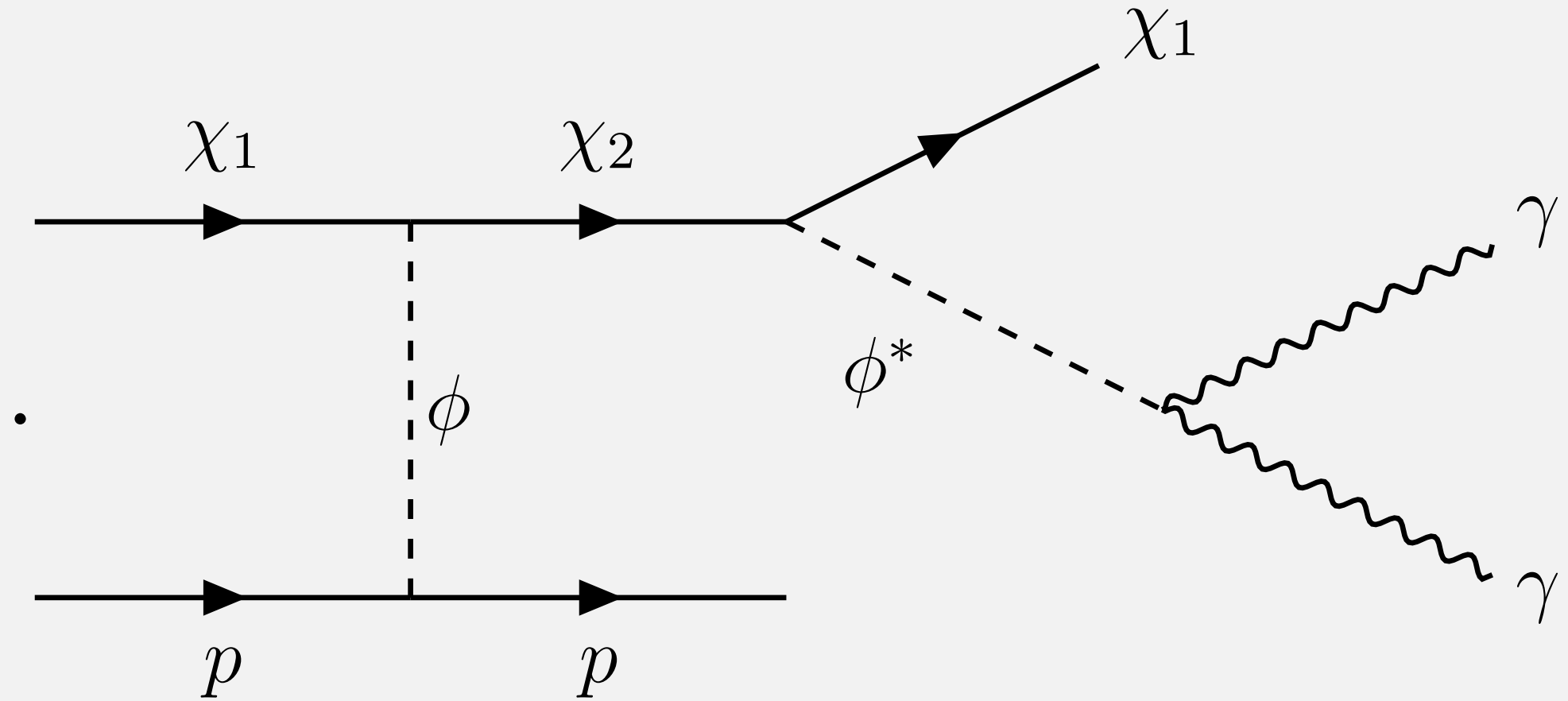
cosmic ray-(inelastic) dark matter scattering

[\[hep-ph/0101138\]](#) D Smith, N Weiner

cosmic ray-(inelastic) dark matter scattering

- upscattering of dark matter into heavier unstable state, decay producing photons via off-shell scalar mediator

$$\mathcal{L}_{\text{inelastic}} \supset g_{12} \bar{\chi}_1 \chi_2 \phi + g_{\phi pp} \phi \bar{p} p - \frac{1}{2} g_{\phi \gamma \gamma} \phi F_{\mu\nu} F^{\mu\nu} + \text{h.c.}$$



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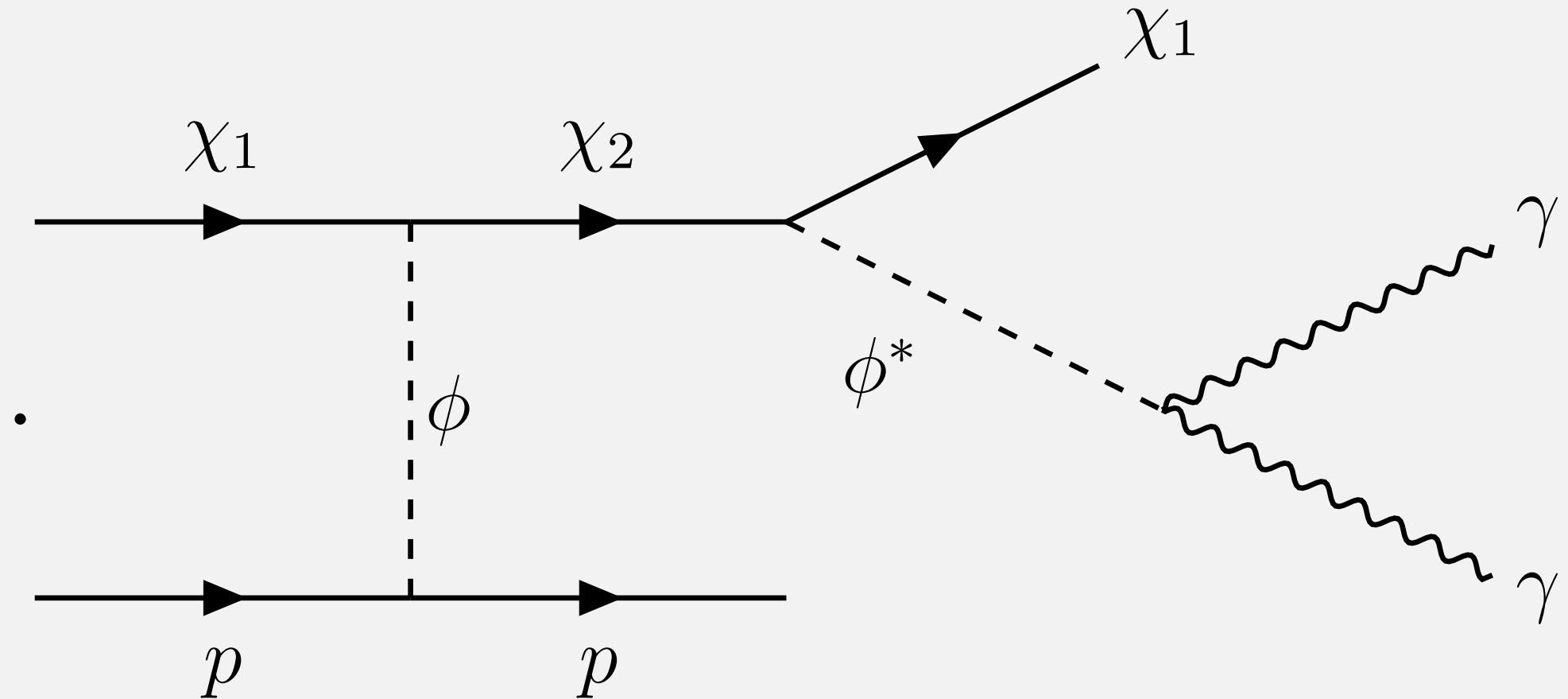
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$$m_{\chi_1} \sim 100 \text{ MeV}$$

$$\Delta = m_{\chi_2} - m_{\chi_1} \sim 2 m_{\chi_1}$$

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Inelastic DM Model						
BP	m_{χ_1} [GeV]	Δ [GeV]	m_ϕ [GeV]	g_{12}	$g_{\phi pp}$	$g_{\phi \gamma \gamma}$ [GeV ⁻¹]
iDM BP1	0.08	0.24	0.25	0.80	0.04	1.0×10^{-5}
iDM BP2	0.16	0.31	0.32	1.00	0.05	1.0×10^{-5}

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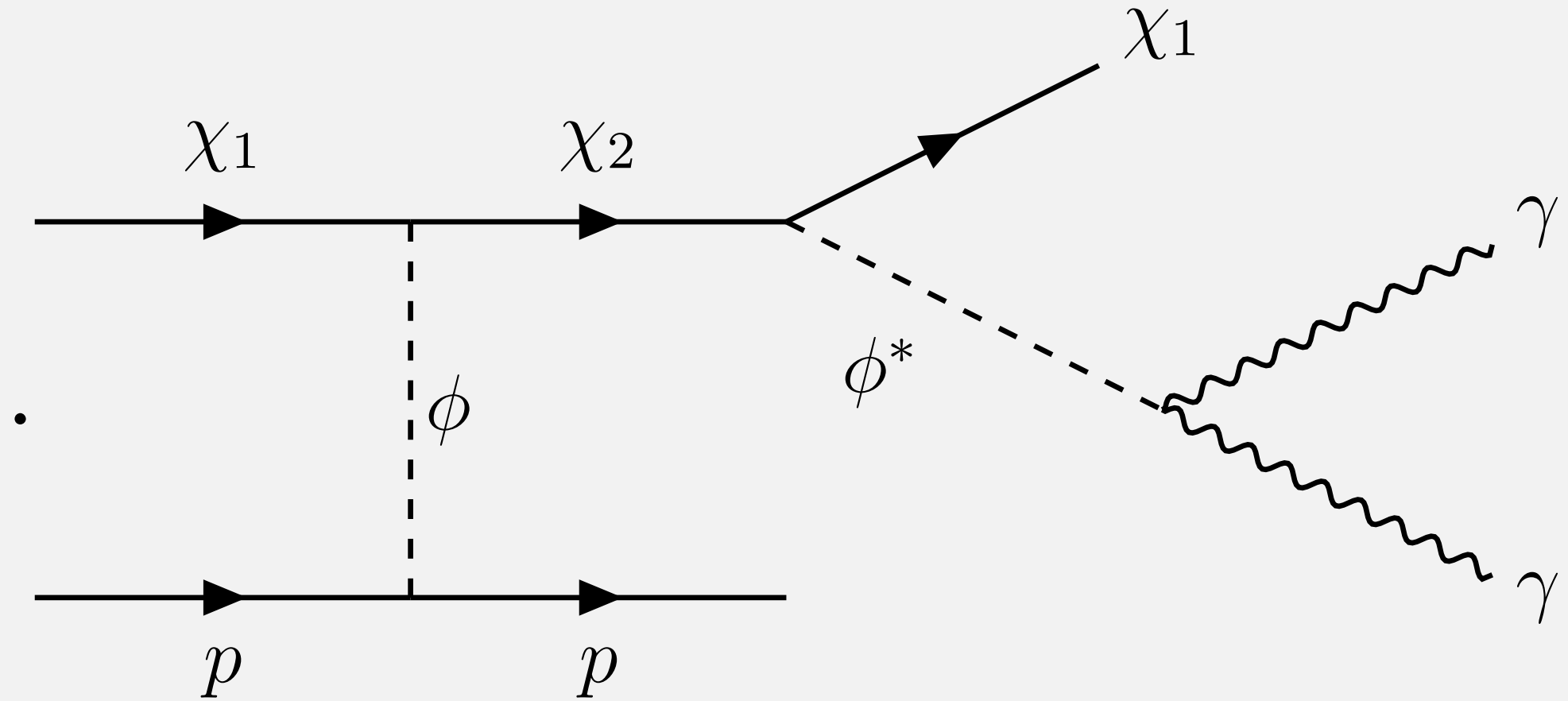
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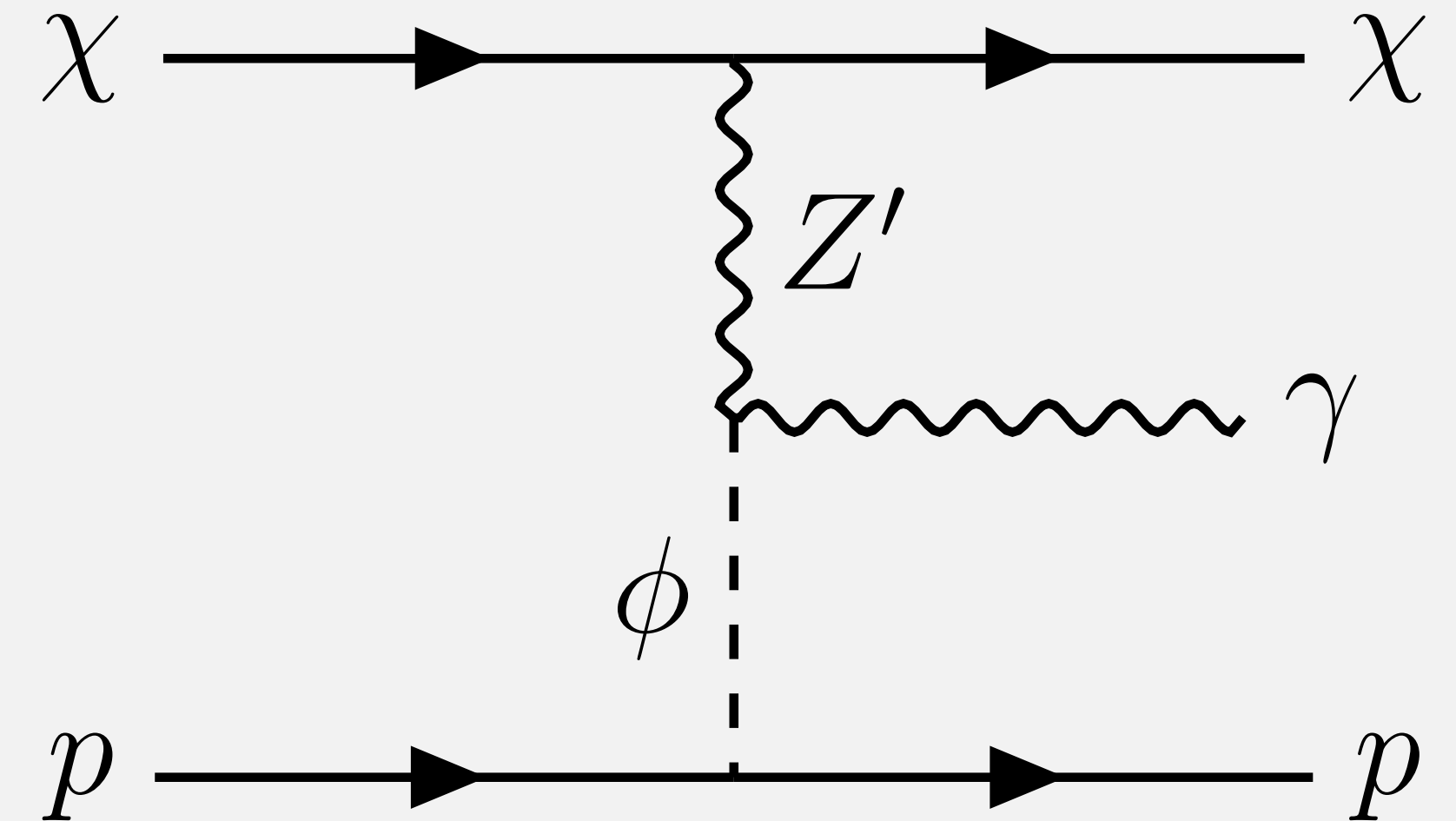
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[2504.08071] B Dutta, A Karthikeyan, D Kim, A Thompson, R Van de Water

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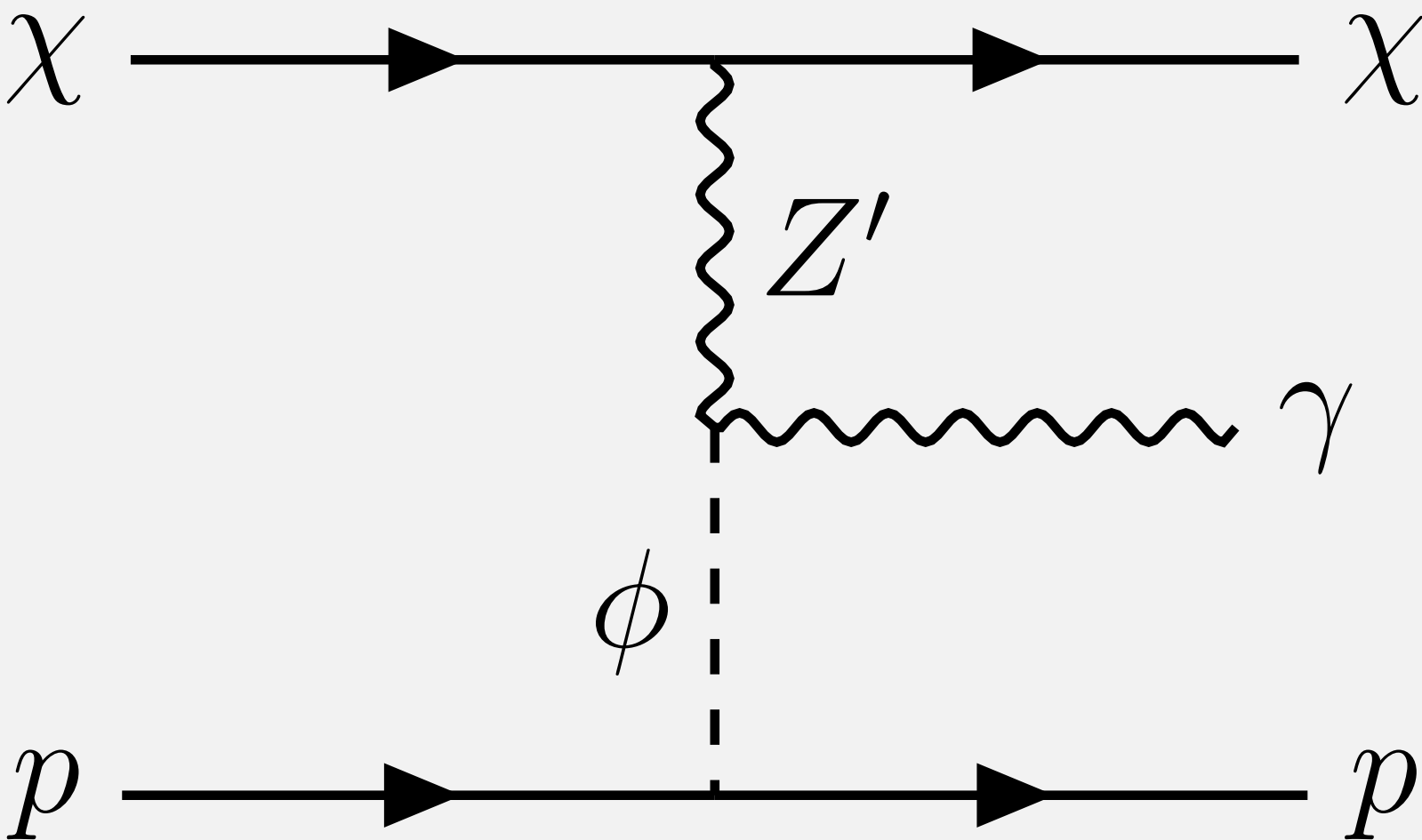
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- Mass scales:

$$m_\chi \sim 1 \text{ GeV}$$

$$m_{Z'} \sim m_\phi < m_\chi$$



[2504.08071] B Dutta, A Karthikeyan, D Kim, A Thompson, R Van de Water

Elastic DM Model					
BP	m_χ [GeV]	$m_{Z'}$ [GeV]	m_ϕ [GeV]	α_D	$g_{\phi Z' \gamma} g_{\phi pp}$ [GeV ⁻¹]
eDM BP1	1.00	0.19	0.20	0.16	1.96
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cosmic ray-(elastic) dark matter scattering

- 2-to-3 internal brem to produce energetic photon

$$\mathcal{L}_{\text{elastic}} \supset g_D \bar{\chi} \gamma^\mu \chi Z'_\mu - \frac{1}{2} g_{\phi Z' \gamma} \phi F_{\mu\nu} Z'^{\mu\nu} + g_{\phi pp} \phi \bar{p} p$$

- Mass scales:

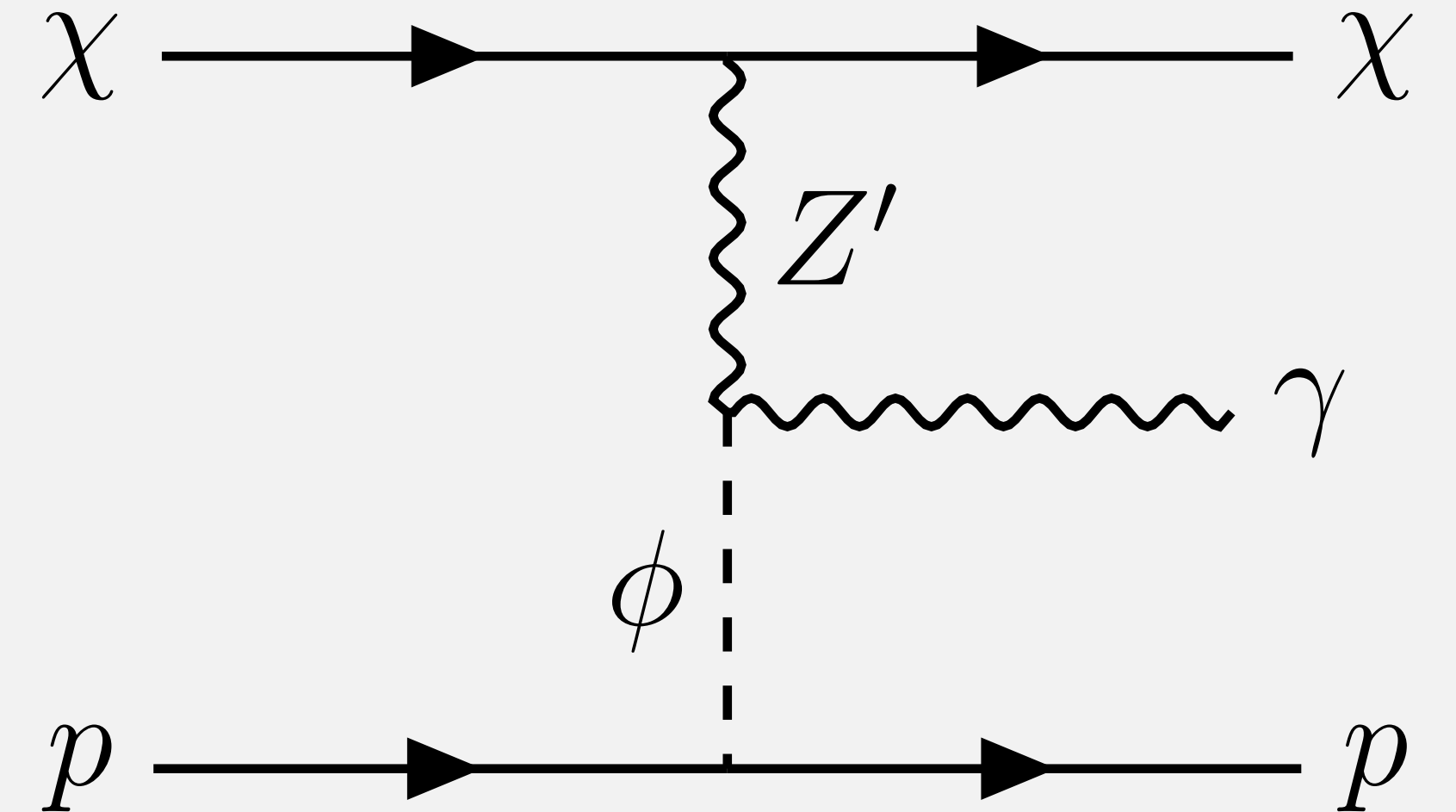
$$m_\chi \sim 1 \text{ GeV}$$

$$m_{Z'} \sim m_\phi < m_\chi$$

- asymmetric DM at ~GeV mass can be related to baryon/DM energy density ratio

- asymmetric DM cannot produce GCE via annihilation, avoids SIDM constraints

[\[0901.4117\]](#) D Kaplan, M Luty, K Zurek



[\[2504.08071\]](#) B Dutta, A Karthikeyan, D Kim, A Thompson, R Van de Water

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photon flux from CR-DM scattering

photon flux from CR-DM scattering

$$\frac{d\Phi_\gamma}{dE_\gamma} = \frac{D_{\text{ROI}}}{4\pi m_{\text{DM}}} \int dE_p \frac{d\Phi_p}{dE_p} \frac{d\sigma(E_p, E_\gamma)}{dE_\gamma}$$

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[\[2008.12137\] G Guo, Y Tsai, M Wu, Q Yuan](#)

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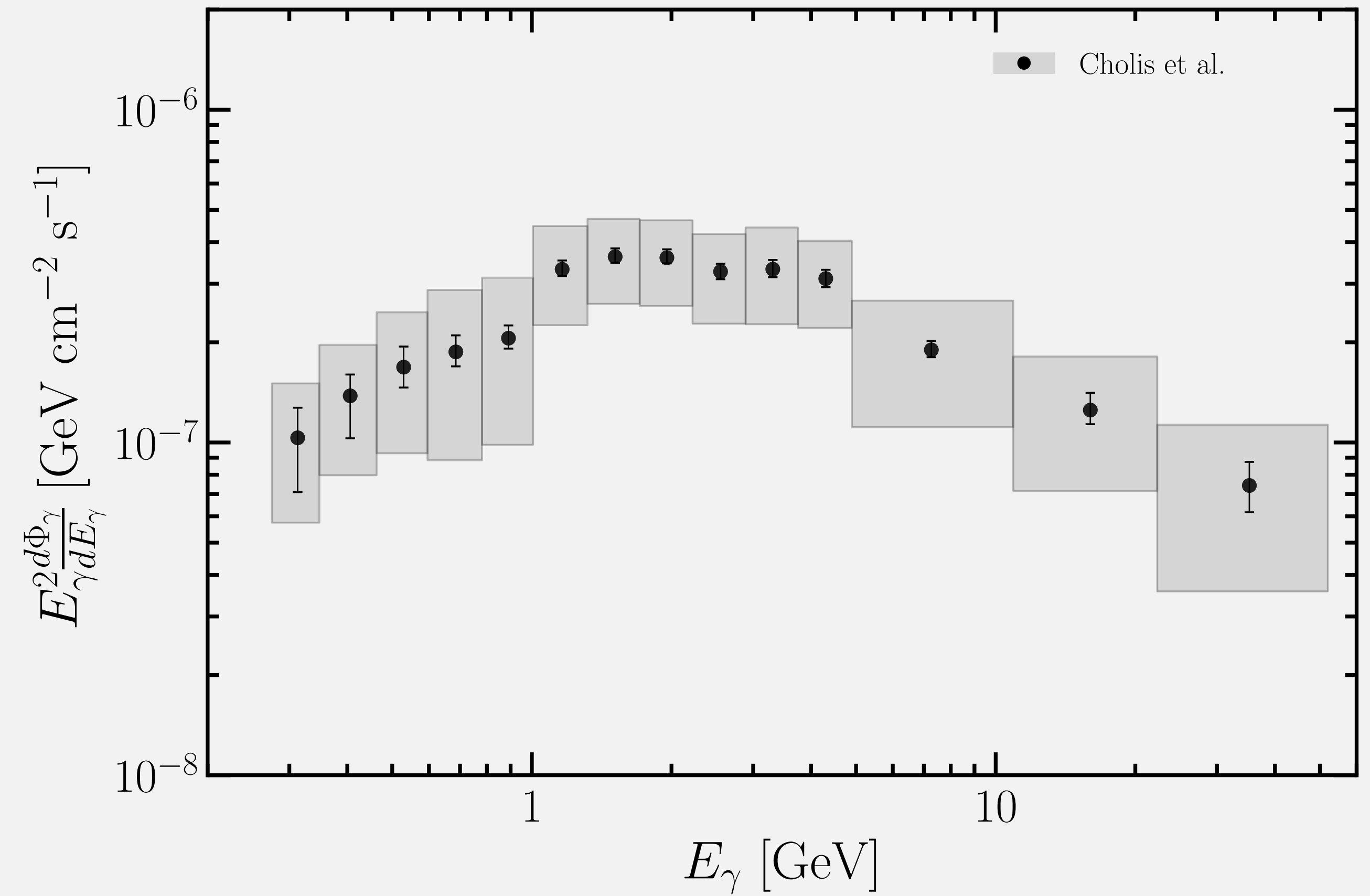
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[\[2008.12137\] G Guo, Y Tsai, M Wu, Q Yuan](#)
- consistent with GALPROP CRF used in background modeling
[\[astro-ph/9807150\] A Strong, I Moskalenko](#)

results

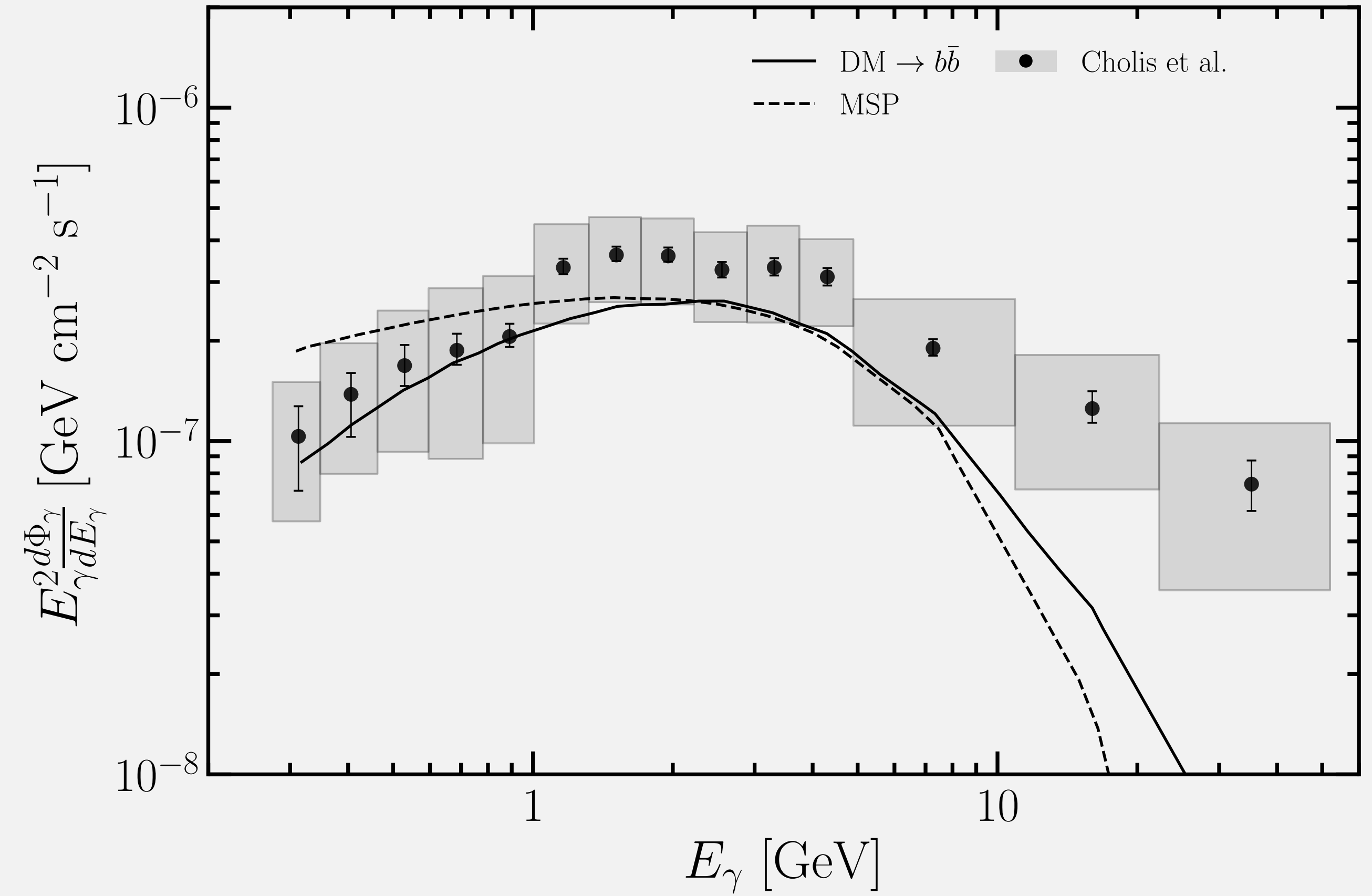
results

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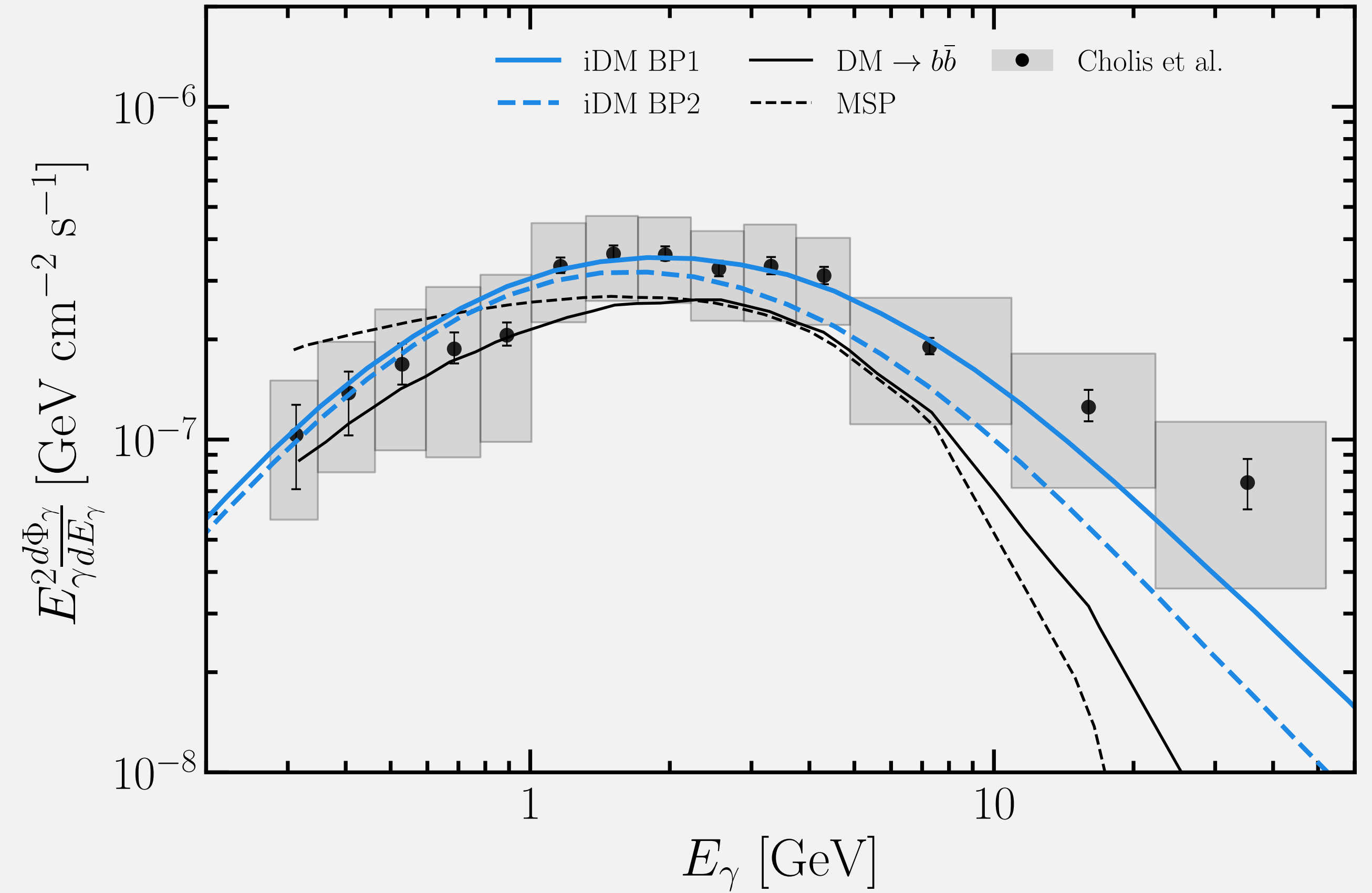
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results

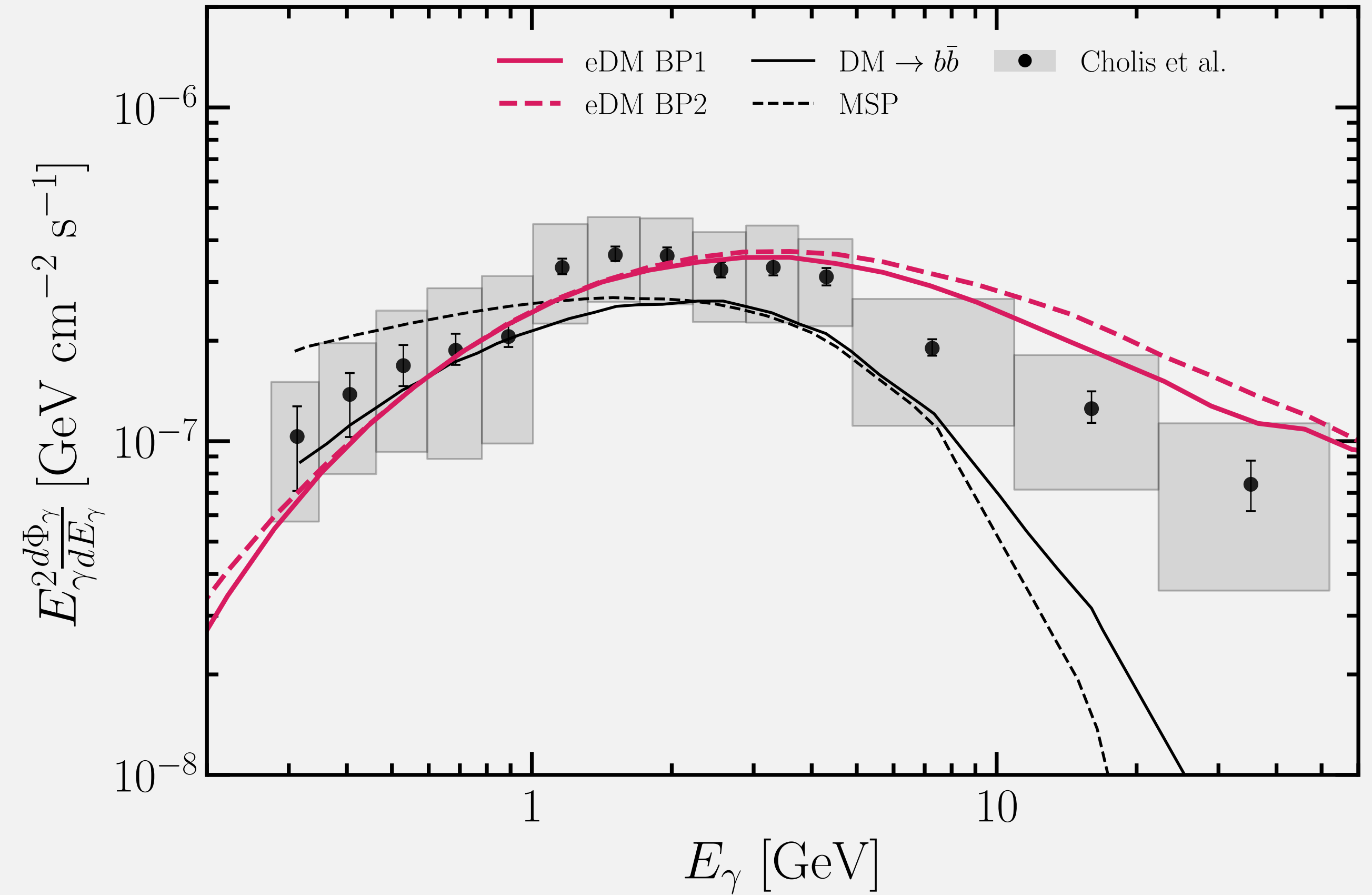
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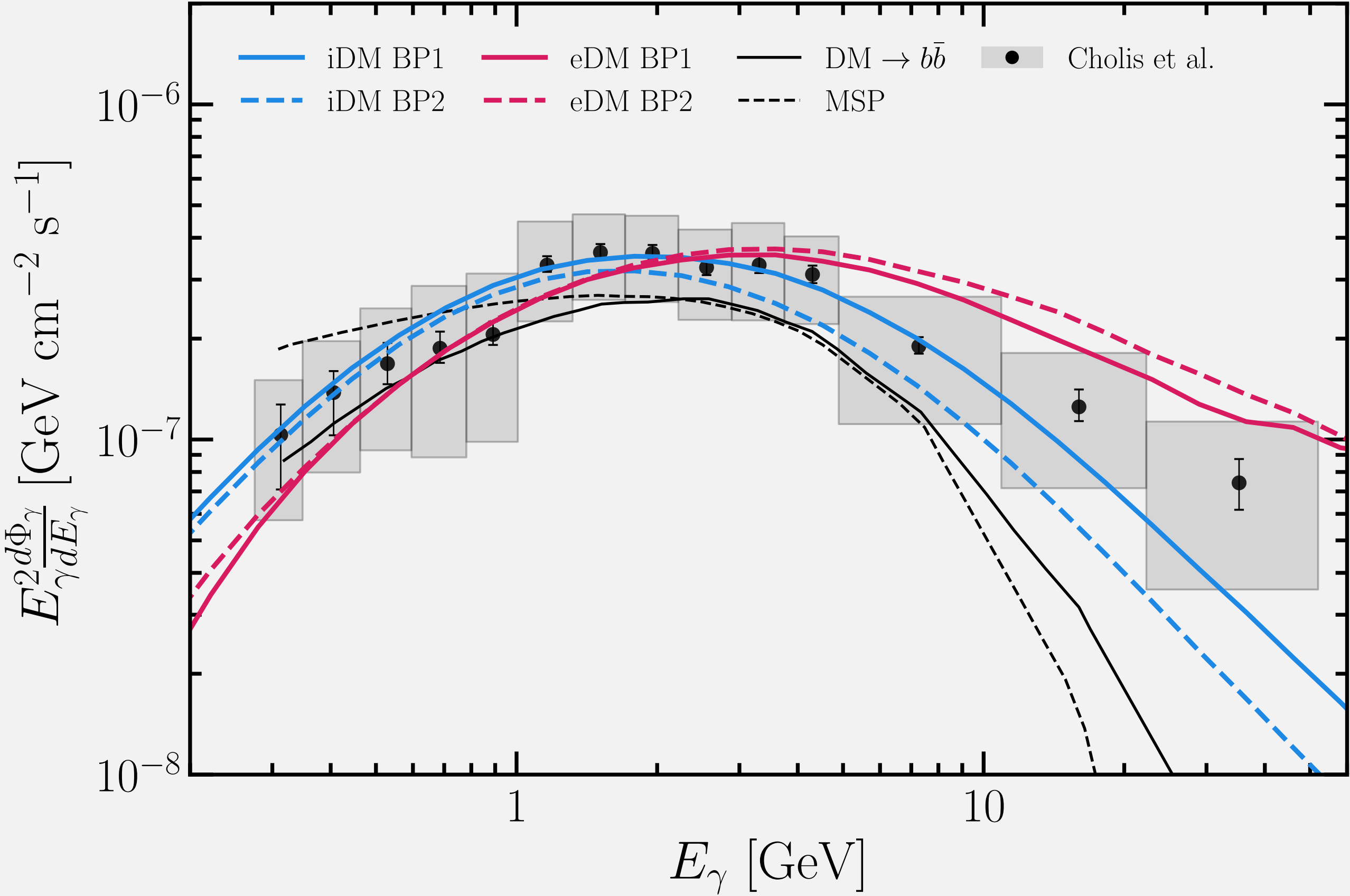
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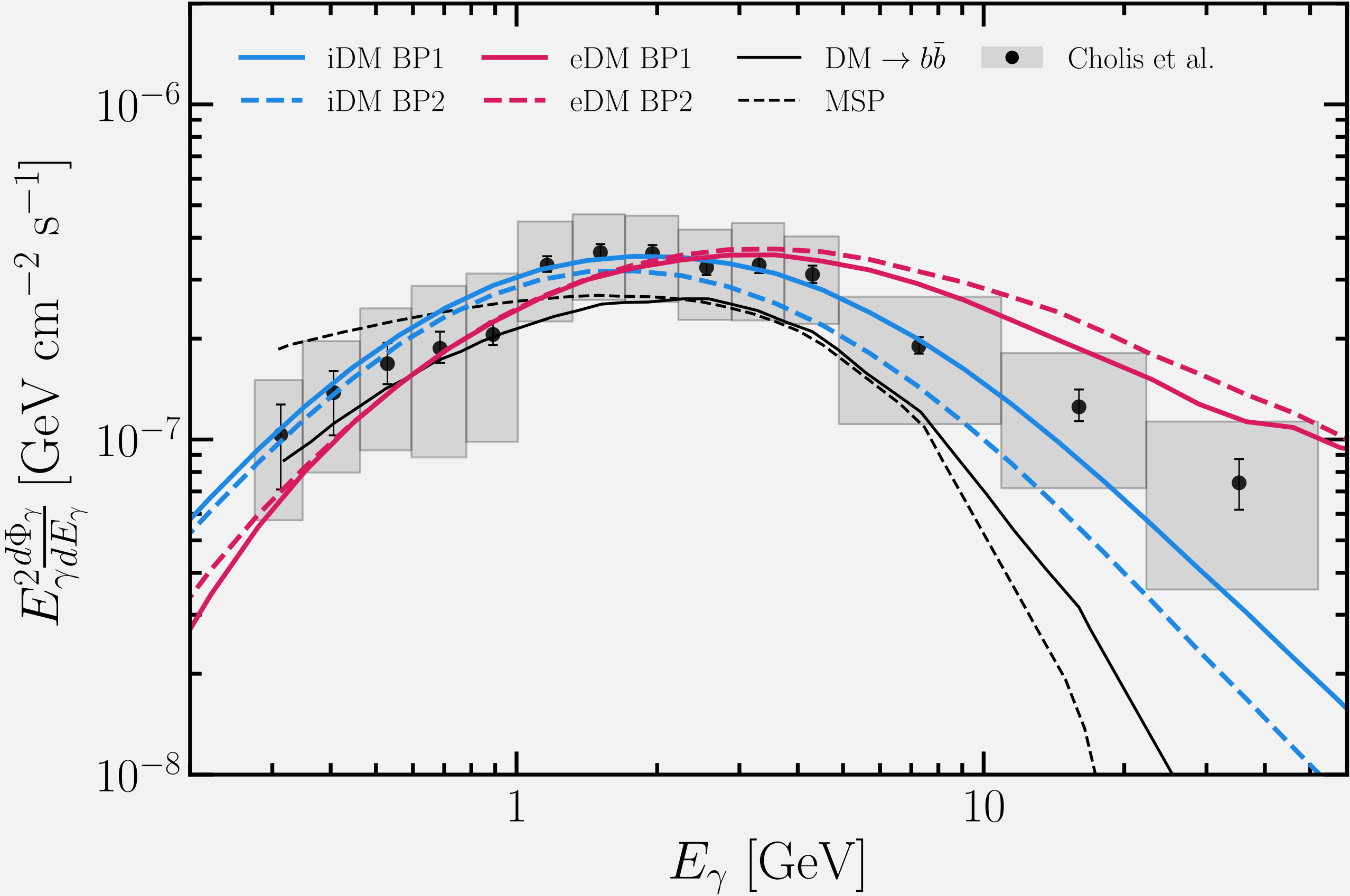
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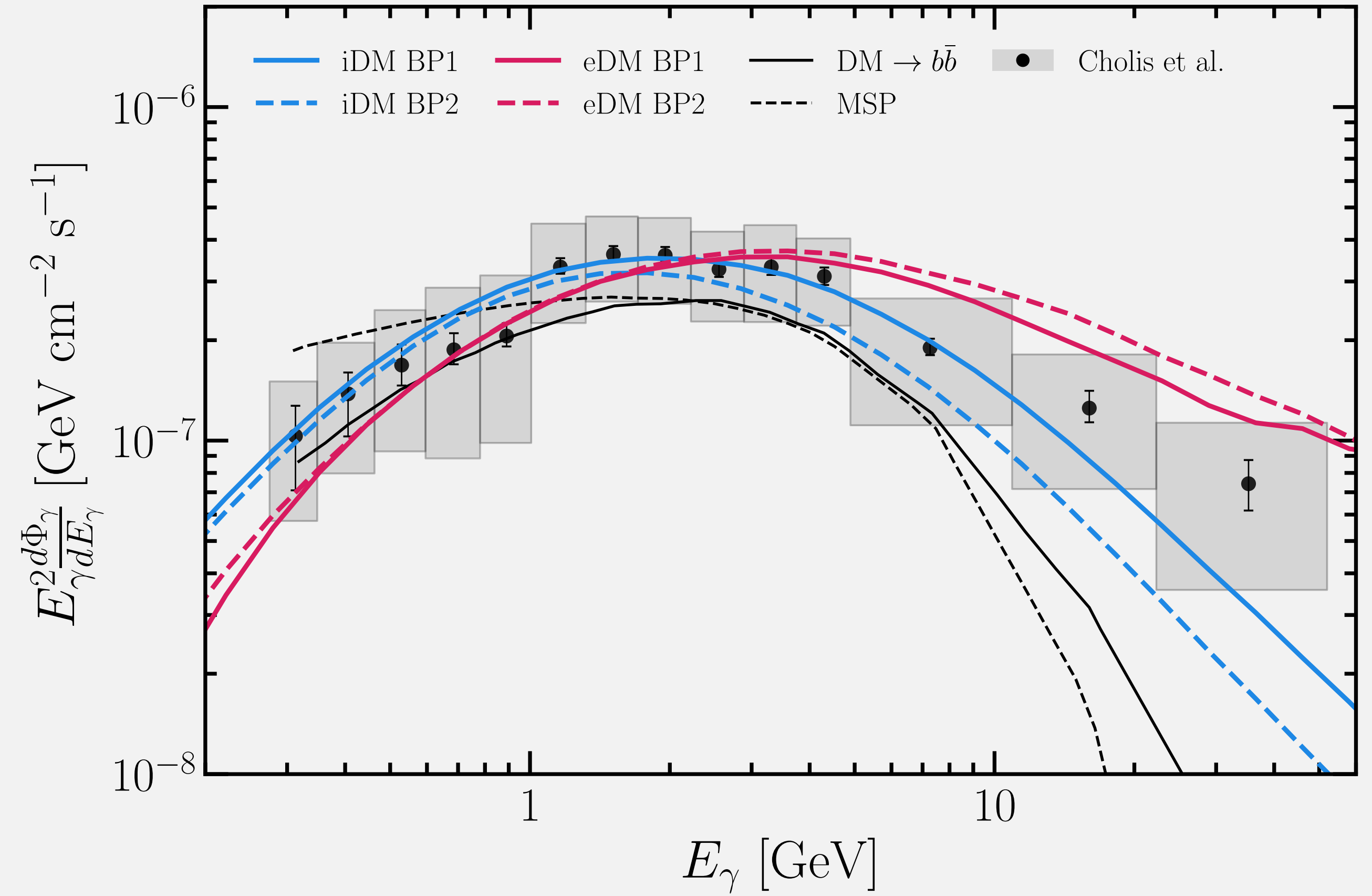
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- quantitative measure: compute χ^2 using truncated covariance matrix



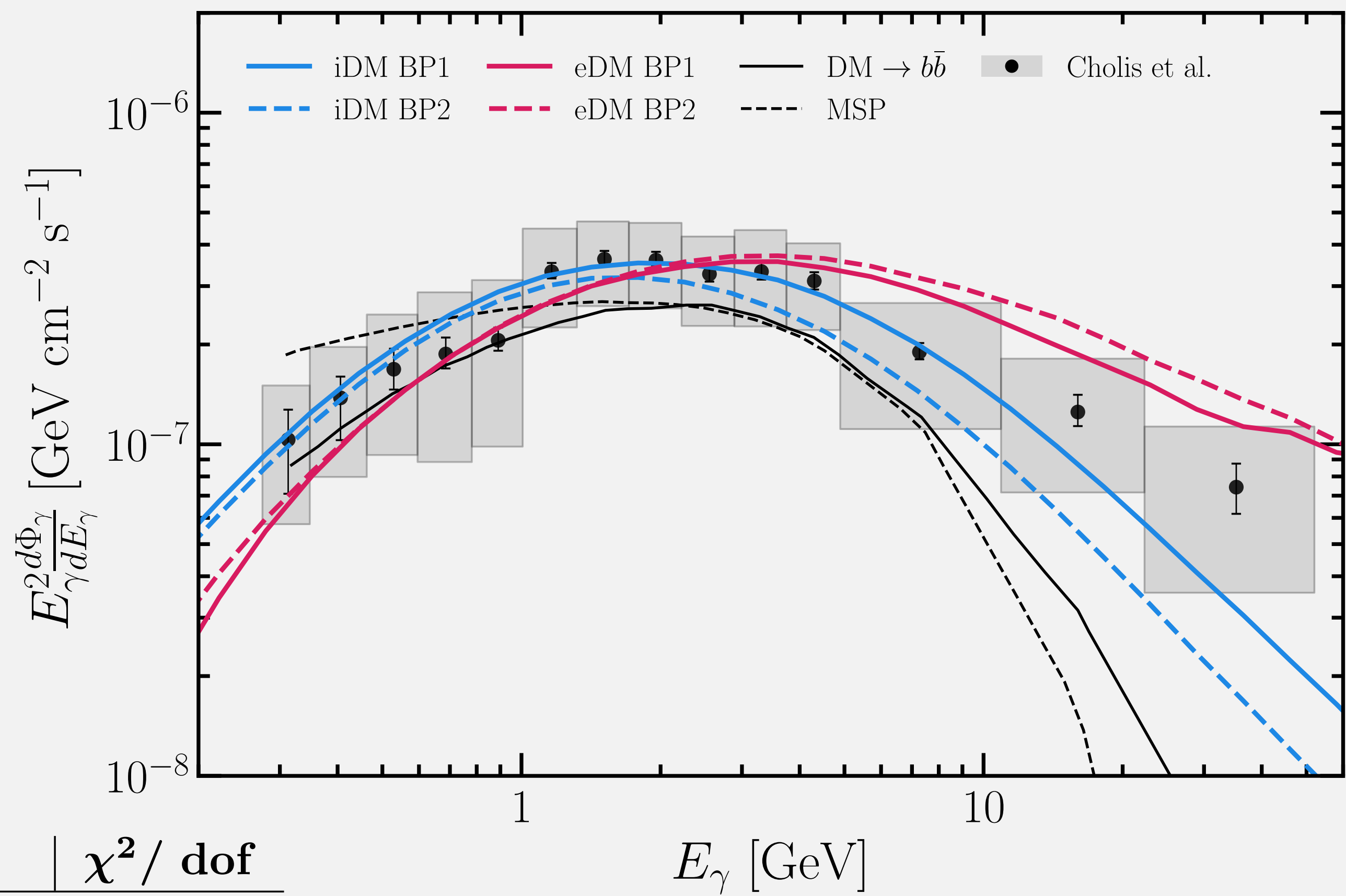
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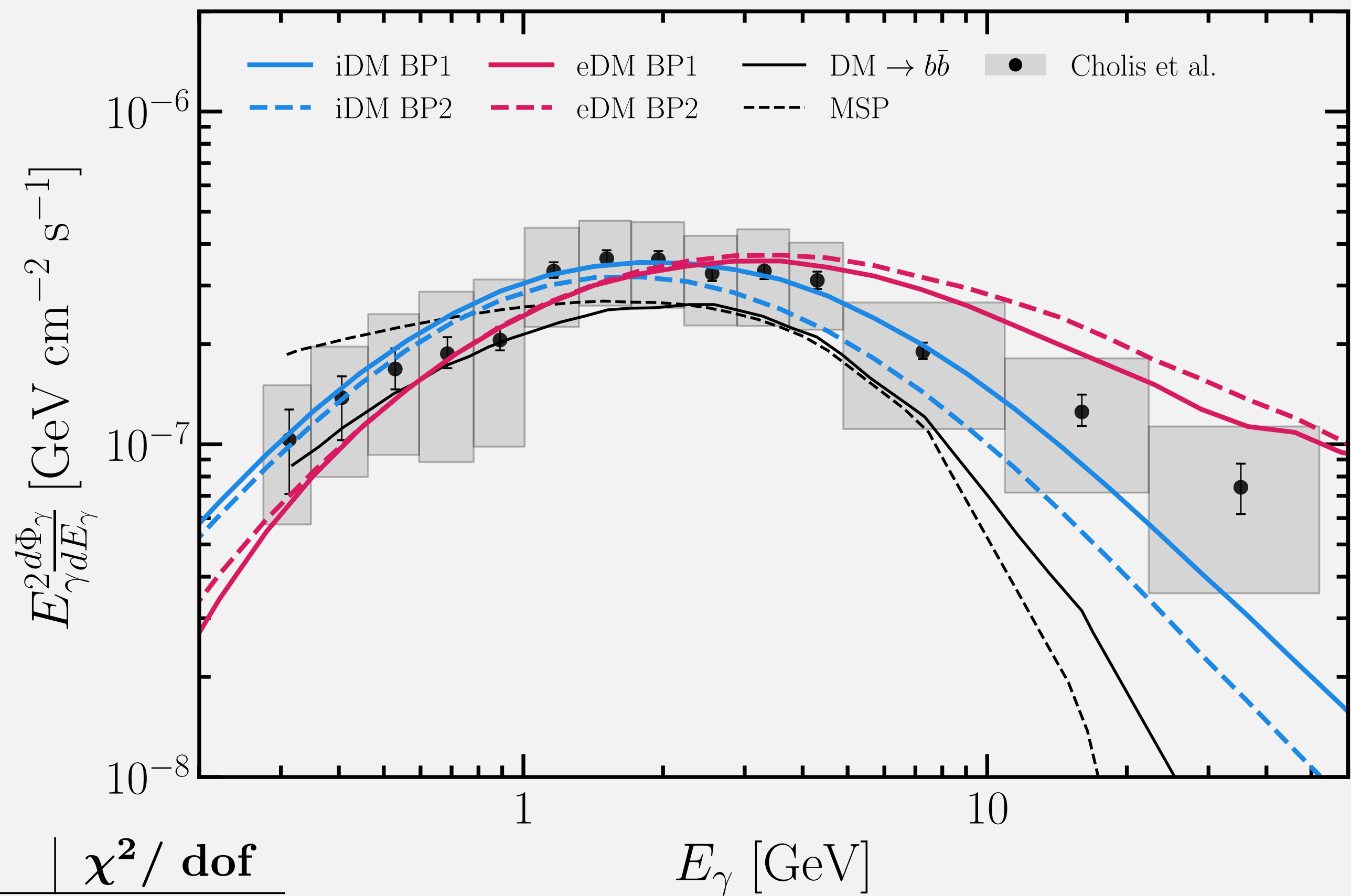
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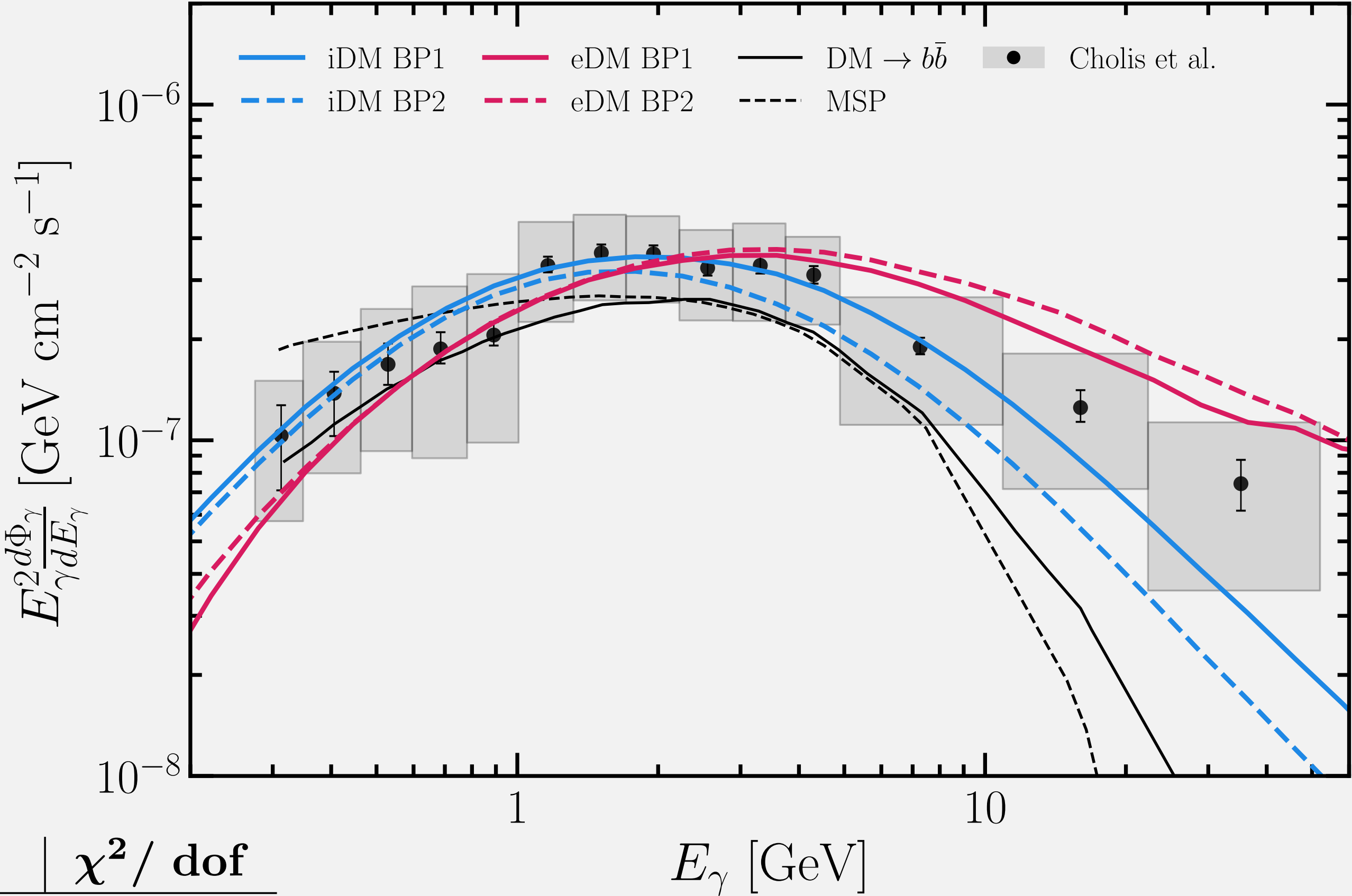
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reproduced literature
results to within ~5%

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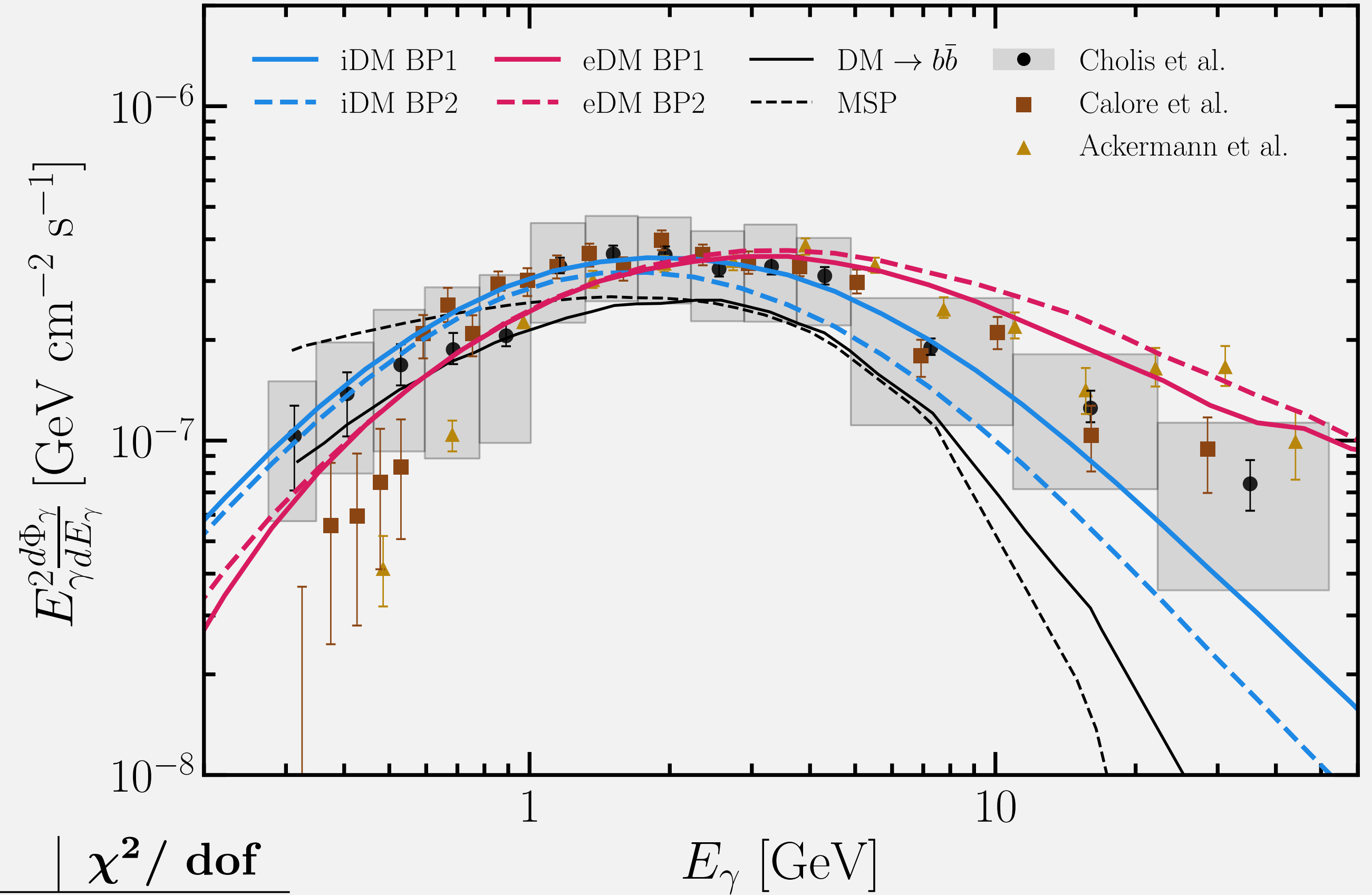


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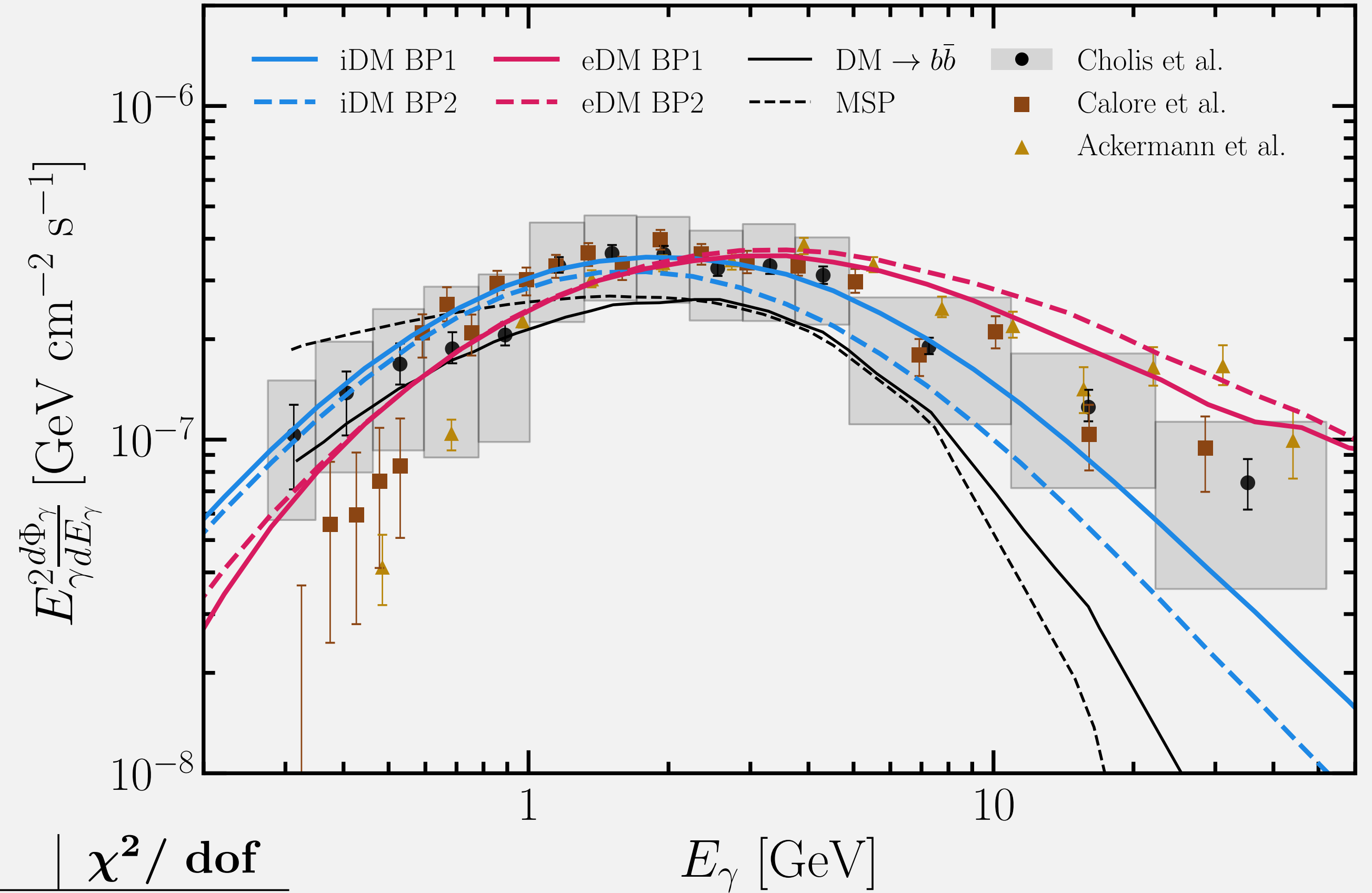


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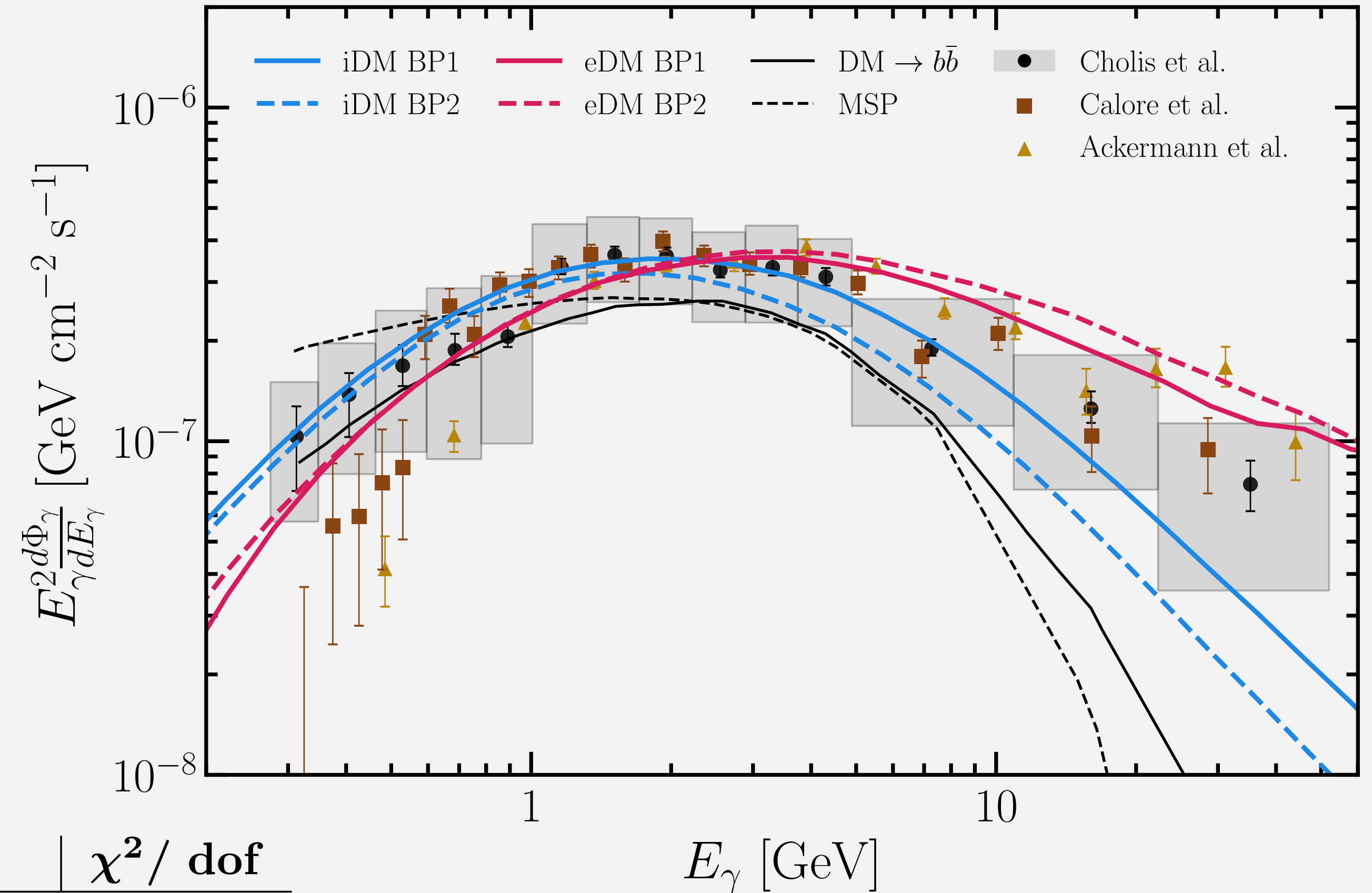
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CR-DM scattering fits the GCE comparably to best fitting DM annihilation and MSP spectra



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[\[2003.10416\] K Abazajian, S Horiuchi, M Kaplinghat, R Keeley, O Macias](#)

[\[2203.11626\] M Pohl, O Macias, P Coleman, C Gordon](#)

[\[2209.00006\] S McDermott, Y Zhong, I Cholis](#)

[\[2402.05449\] D Song et al.](#)

[\[2508.06314\] M Muru, J Silk, N Libeskind, S Gottloeber, Y Hoffman](#)

... and many more!

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- morphology arguments alone do not exclude CR-DM scattering as an explanation for the GCE

bounds on our CR-DM models

- bounds on both models:
 - direct detection of ambient or boosted DM (XENON1T, Panda-X, LZ)
 - for inelastic, large Δ weakens bounds for ambient DM upscattering
 - for elastic, 2-to-3 suppression and photon carries energy, so boosted DM is inefficient
 - bounds on the coupling of scalar mediator to protons $g_{\phi pp}$
 - checked consistency with monojet, NA62, PIENU, MAMI, etc.

[\[2504.08071\]](#) B Dutta, A Karthikeyan, D Kim, A Thompson, R Van de Water

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- only elastic DM model:
 - coupling $g_{\phi\gamma Z'}$ constrained by fixed target & beam dump experiments, as well as $(g - 2)_{e,\mu}$ [\[1806.00757\] P deNiverville, H Lee, M Seo](#)
 - small mass gap between Z' and ϕ , both with mass ~ 100 MeV, relaxes these constraints [\[2504.08071\] B Dutta, A Karthikeyan, D Kim, A Thompson, R Van de Water](#)
 - coupling g_D constrained by Bullet Cluster observations of self-interacting dark matter

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- further dedicated analysis on CR-DM scattering, since the process itself can modify CR flux used in background modeling

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- complementary signals of CR-DM scattering
 - DUNE/Hyper-K/JUNO sensitivity?
 - direct detection experiments will improve sensitivity to these interactions
 - signals at higher energies?

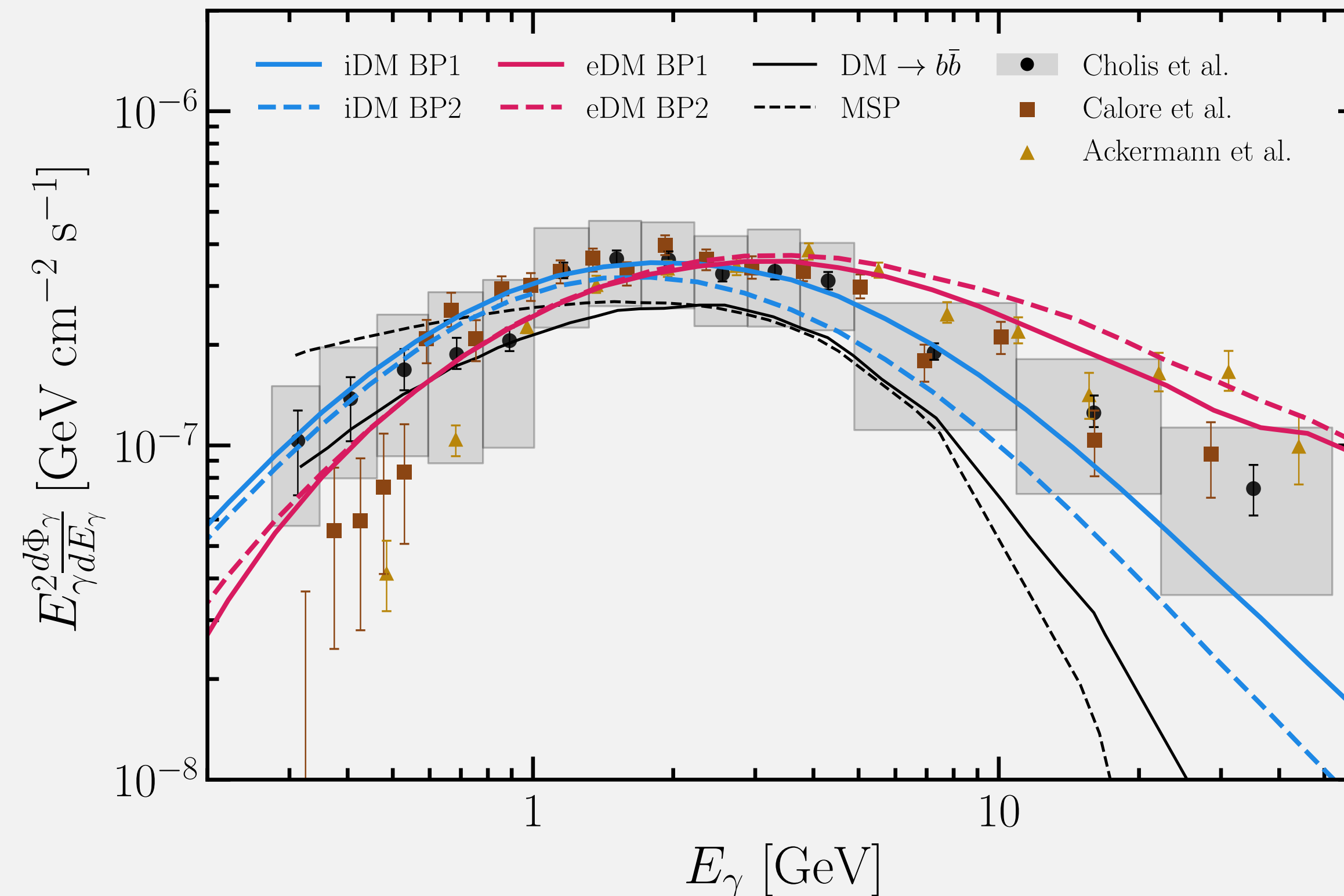
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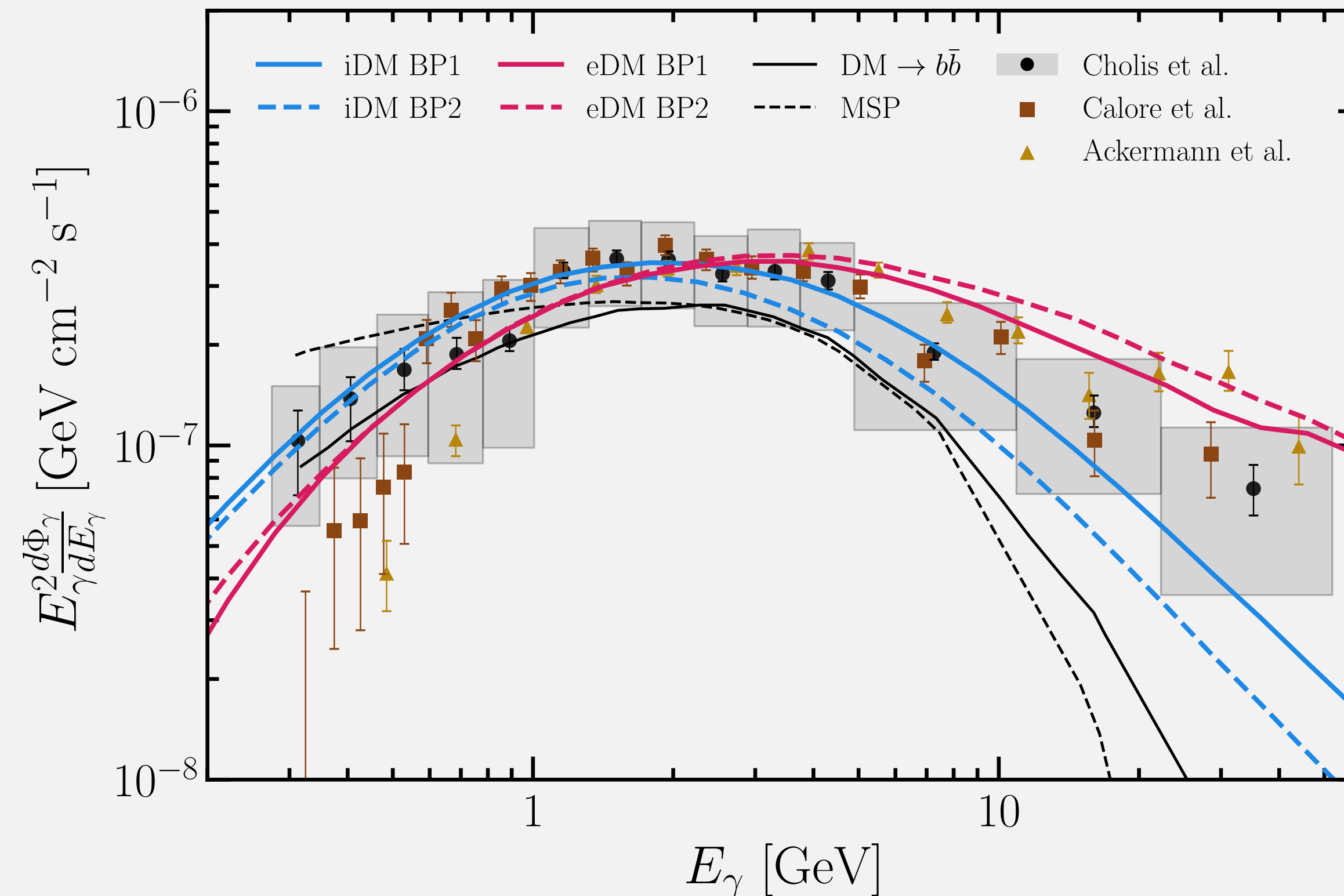
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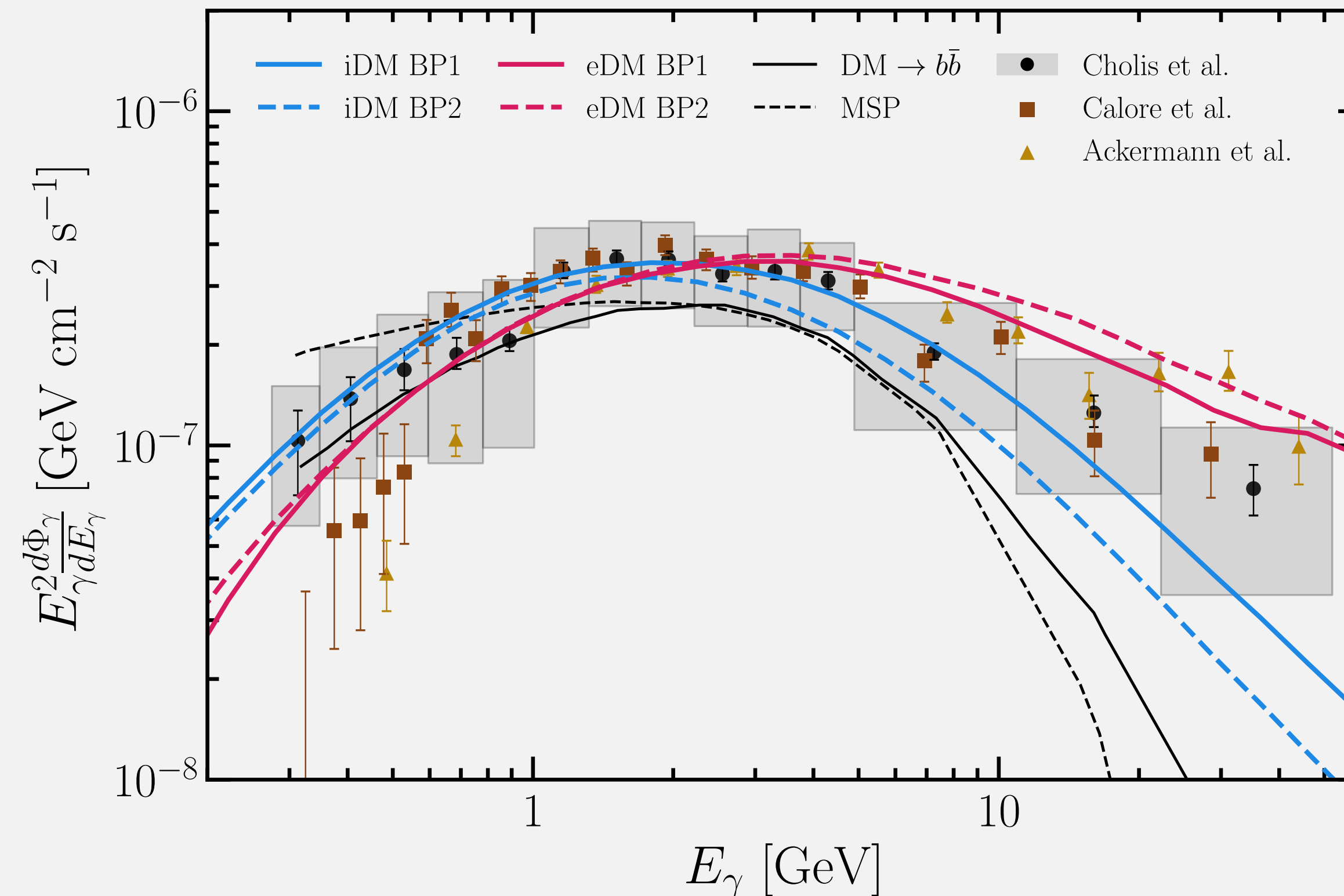
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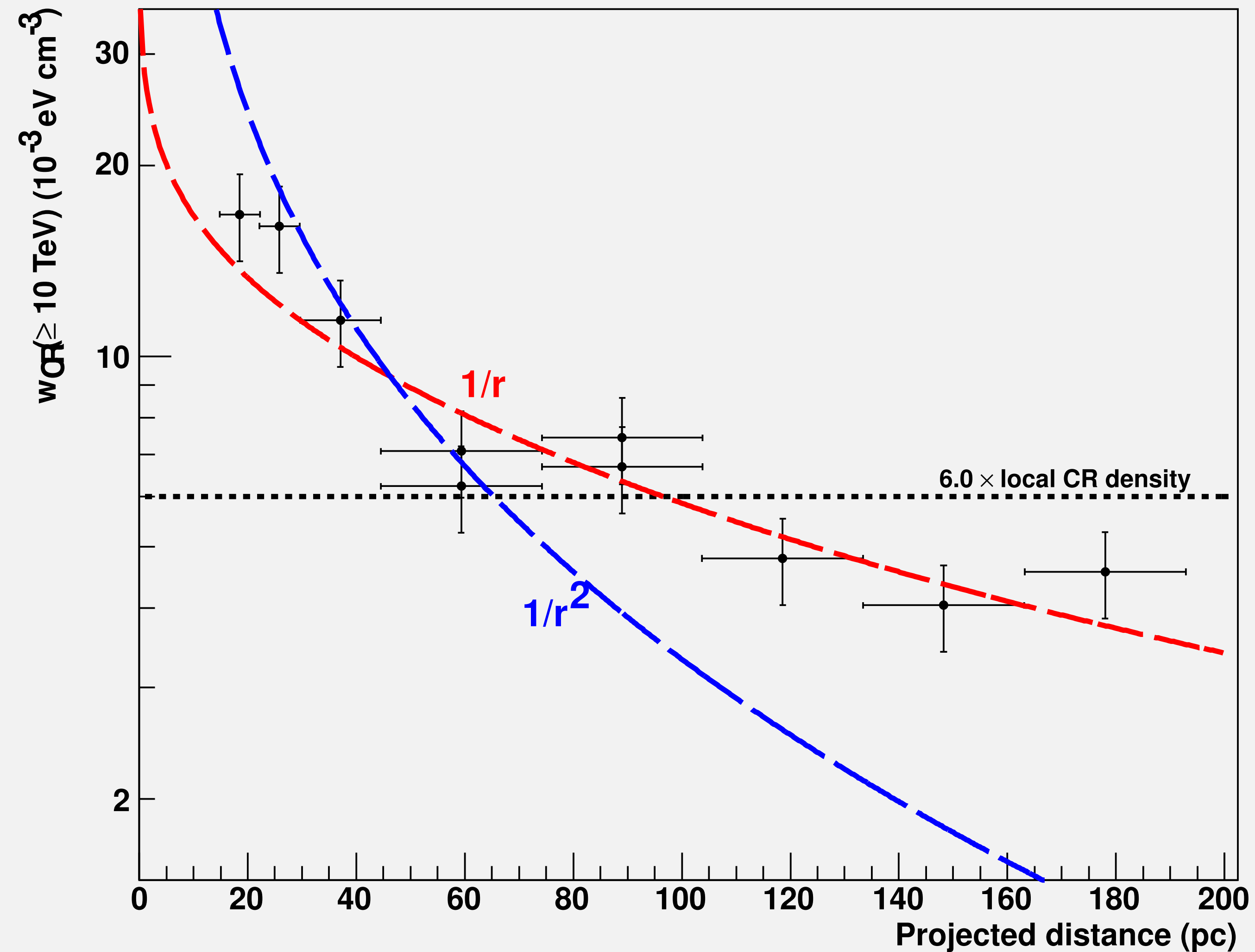
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- morphology still under debate within the community, does not rule out CR-DM scattering
- CR-DM models satisfy constraints by existing searches and can be probed by upcoming observations



backup slides

H.E.S.S. observations of UHE CRF

- for $r < 200$ pc, UHE CRs appear to follow $\sim 1/r$



[\[1603.07730\] H.E.S.S. collaboration](#)

CR-DM in the literature

- CR-DM signatures considered at AGNs [\[astro-ph/9706085\]](#) E Bloom, J Wells
- CR-DM scattering generating gamma rays [\[1106.4568\]](#) S Profumo, L Ubaldi
 - WIMP DM and EW scale mediators (SUSY motivated)
 - photon produced by ISR/FSR or internal brem off s-channel mediator, not from DM decay
 - they find scattering does not produce enough gamma rays to explain GCE for their parameter space