Disclosing signatures of dark matter with astroparticle messengers

Silvia Manconi

Sorbonne University & LPTHE

December 5, 2024

FRIF Day 2024

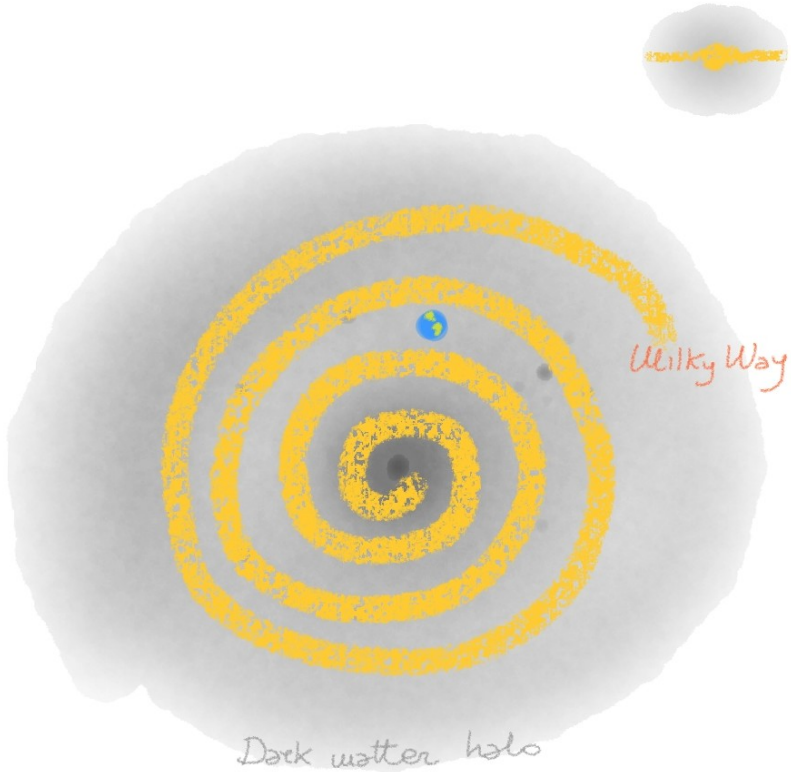
Silvia Manconi, Chaire de Professor Junior, started 1^{st} December 2024

Astroparticle physics and theory models of dark matter

Silvia Manconi, Chaire de Professor Junior, started 1^{st} December 2024

Astroparticle physics and theory models of dark matter

- Nature of **Dark Matter**: indirect searches
- **Astroparticles** origin: sources, propagation



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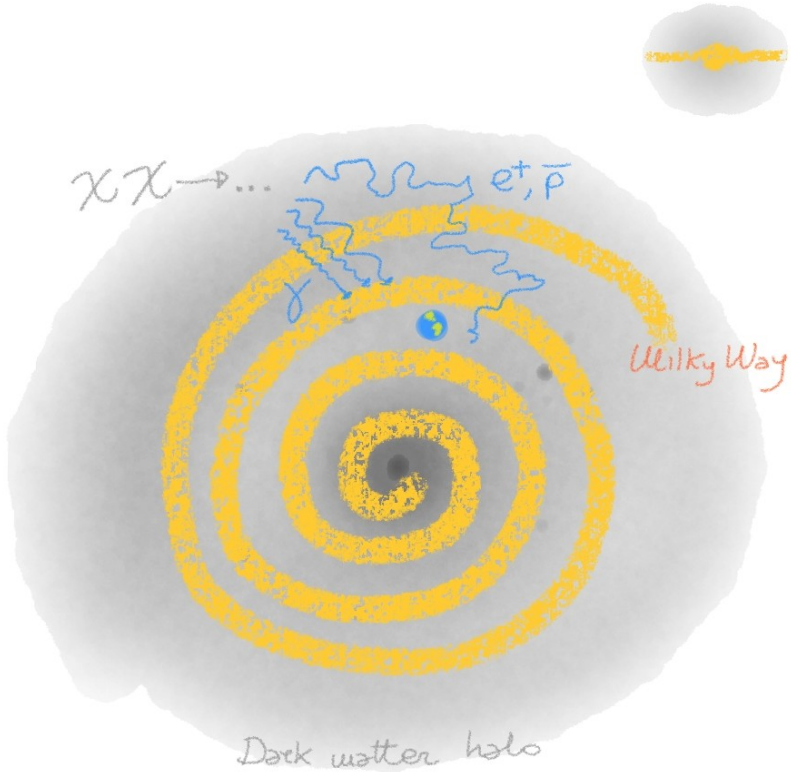

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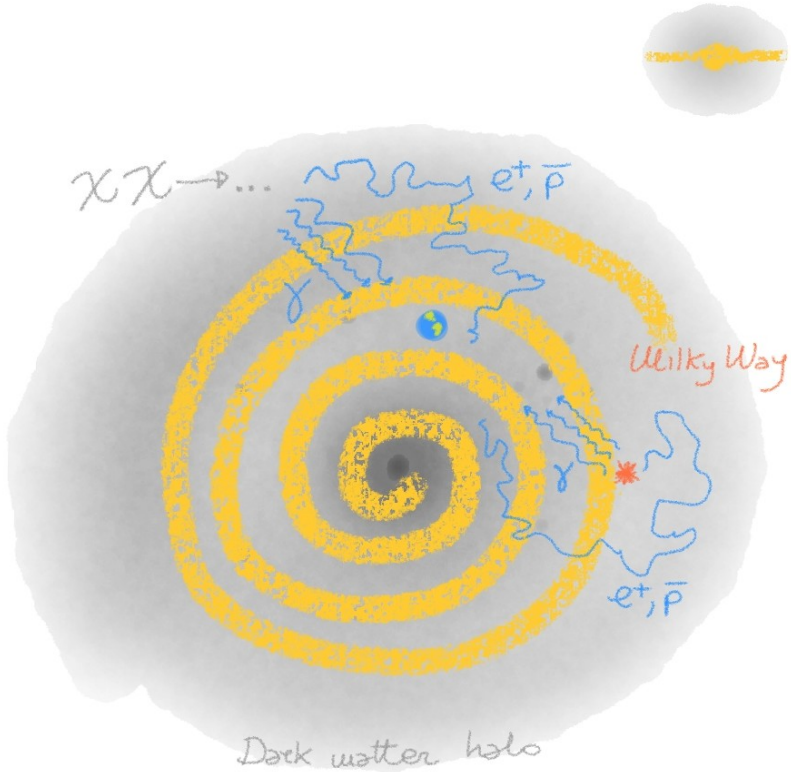

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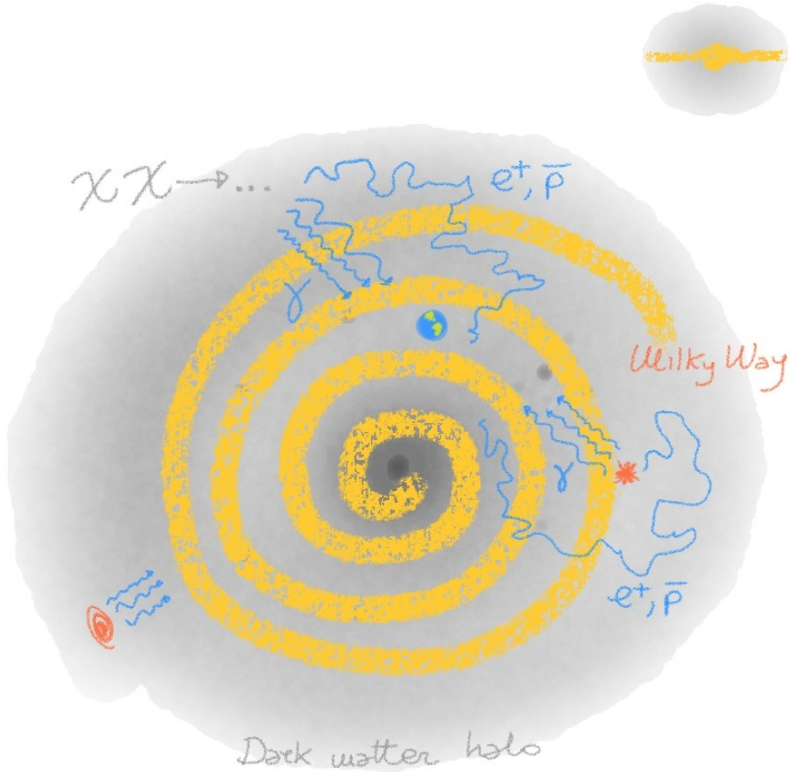

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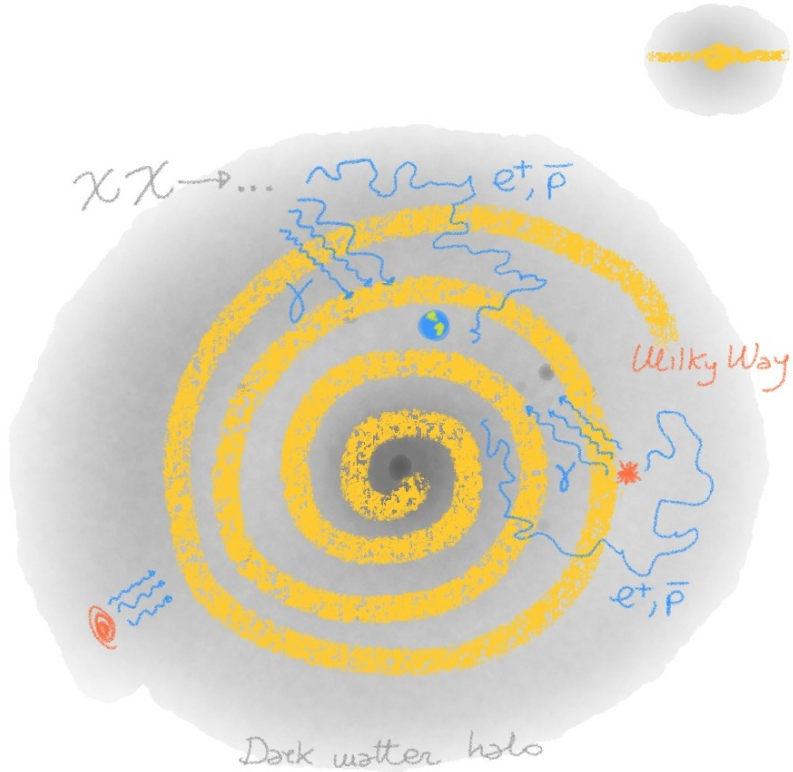


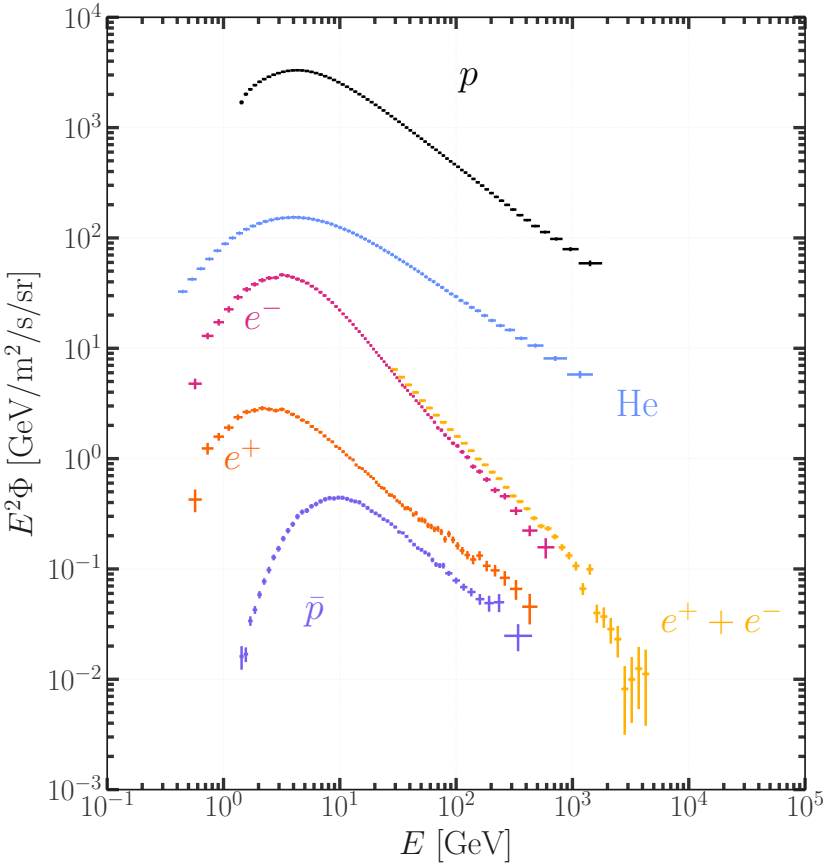
Phenomenology of high energy astroparticles (GeV-TeV)

in the Milky Way and beyond

from exotic and astrophysical sources

Astroparticle messengers: precision era

Local cosmic ray flux



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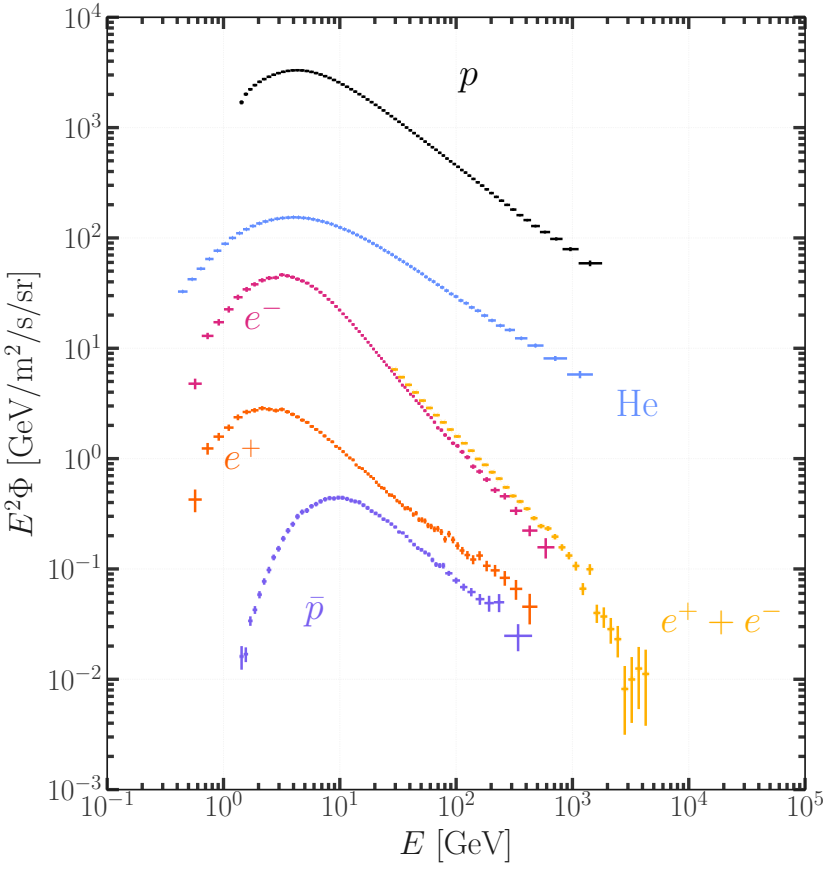

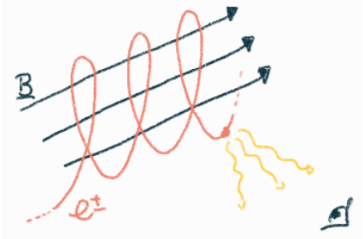

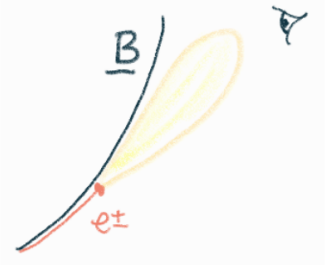

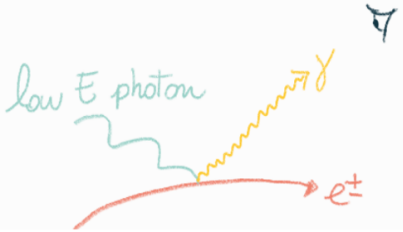

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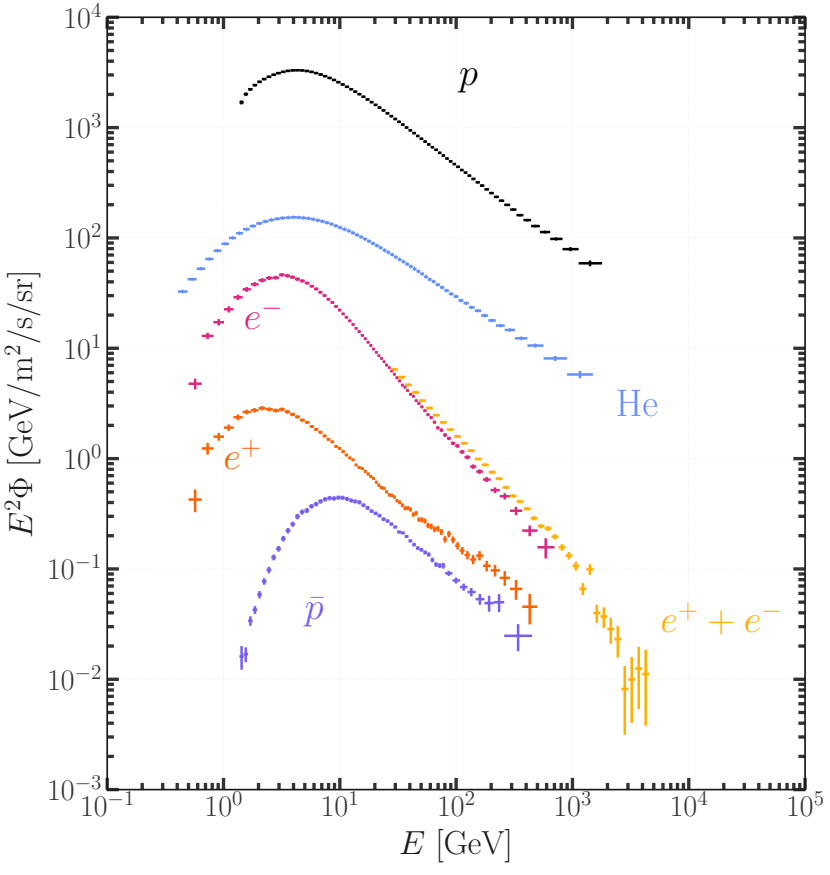
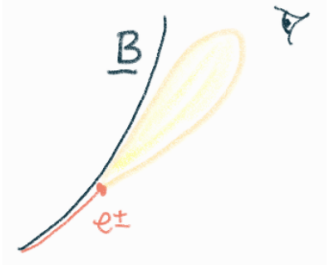
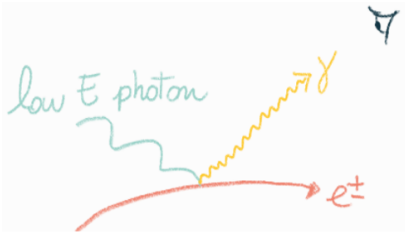
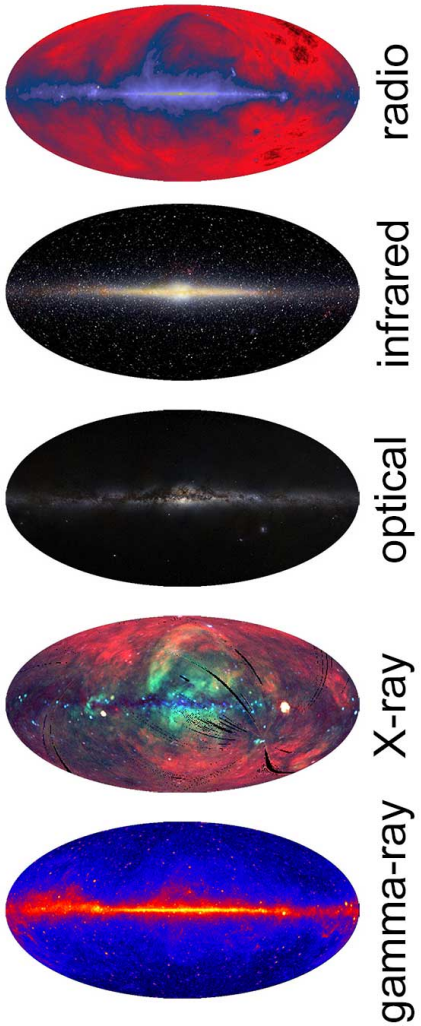






Multiwavelength photons



[NASA]

Astroparticle messengers: precision era

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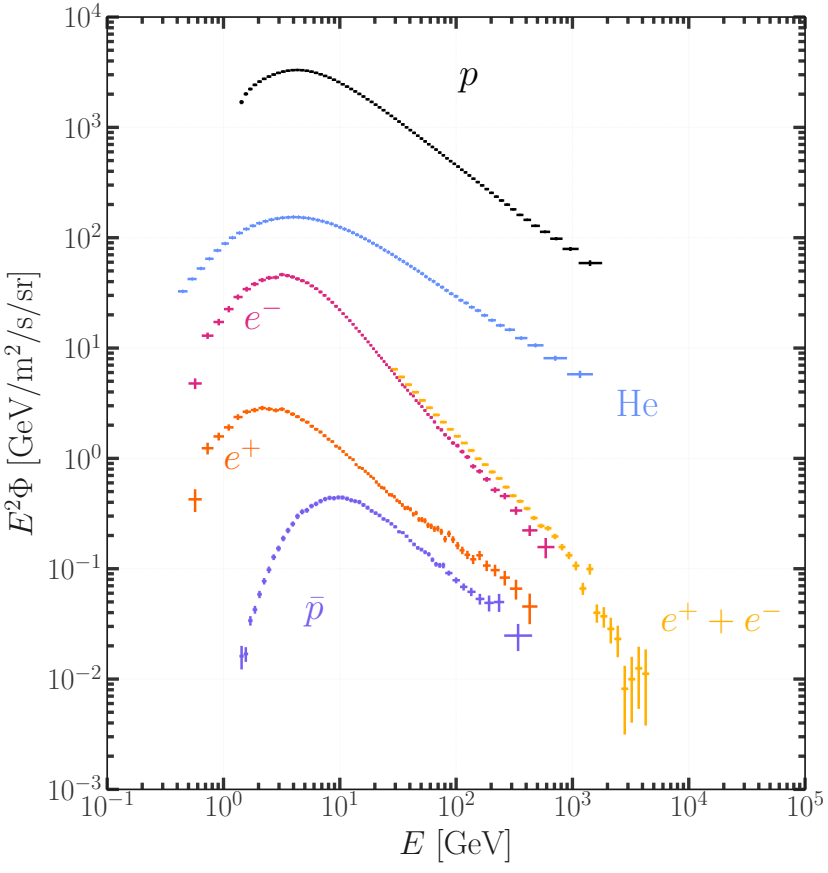

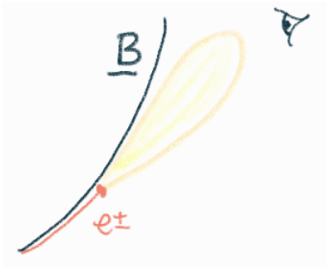

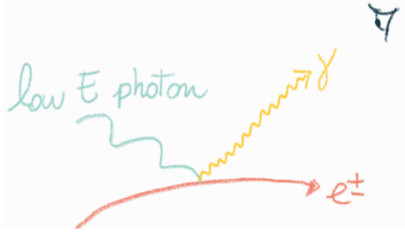

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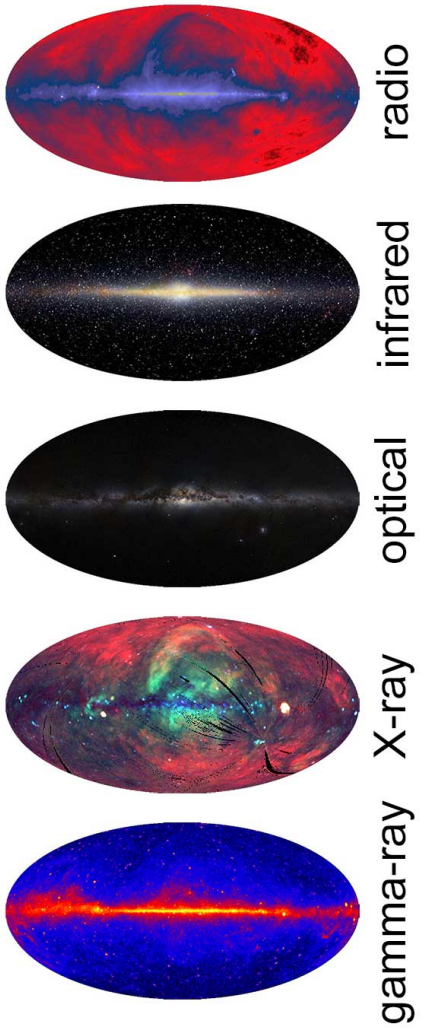

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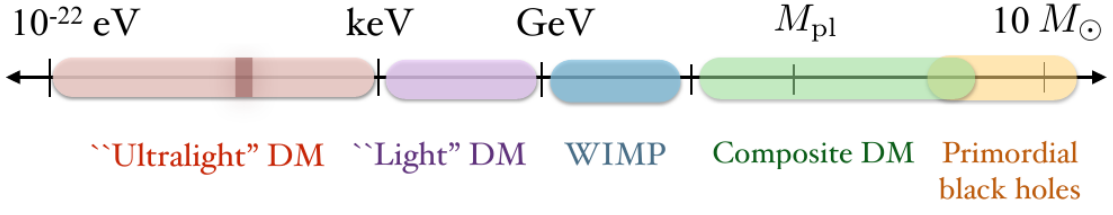

[1904.07915]

Astroparticle messengers: precision era

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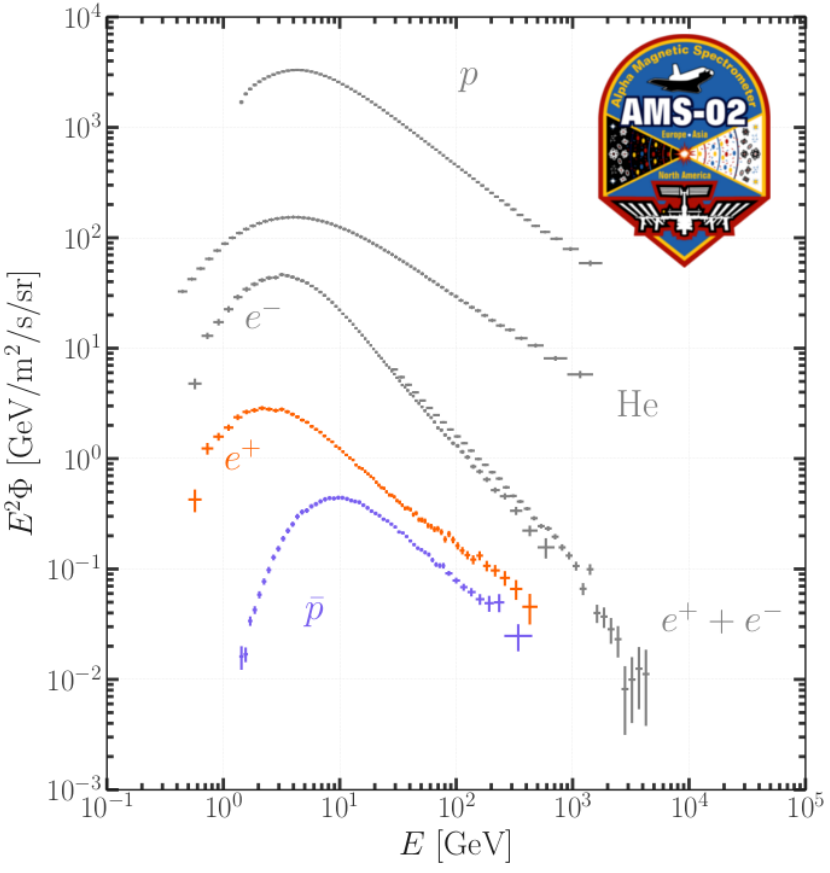

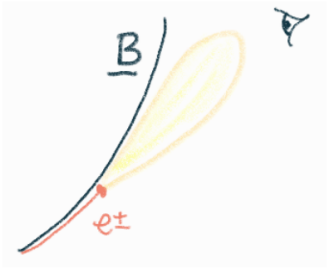

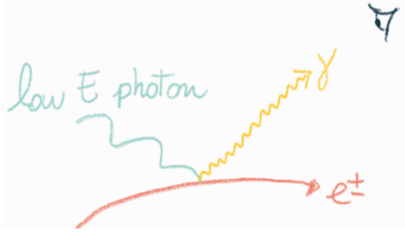

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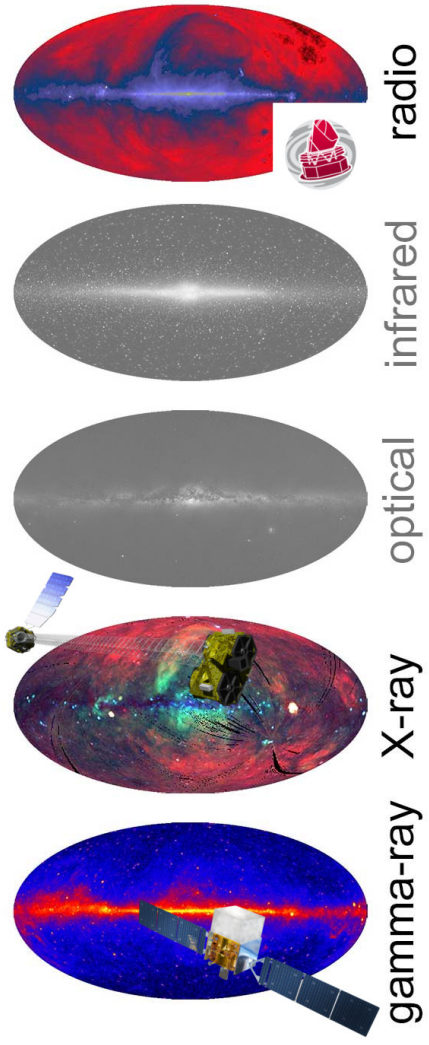

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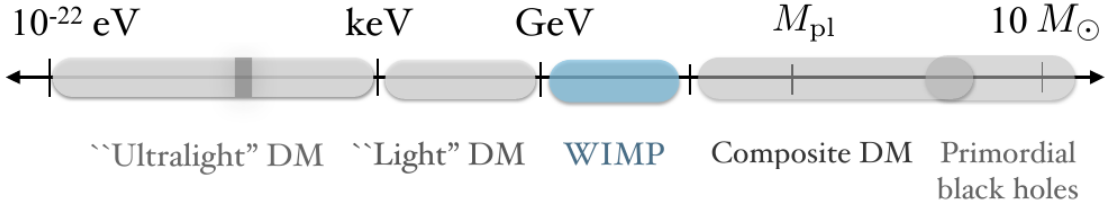


[1904.07915]

Trajectory

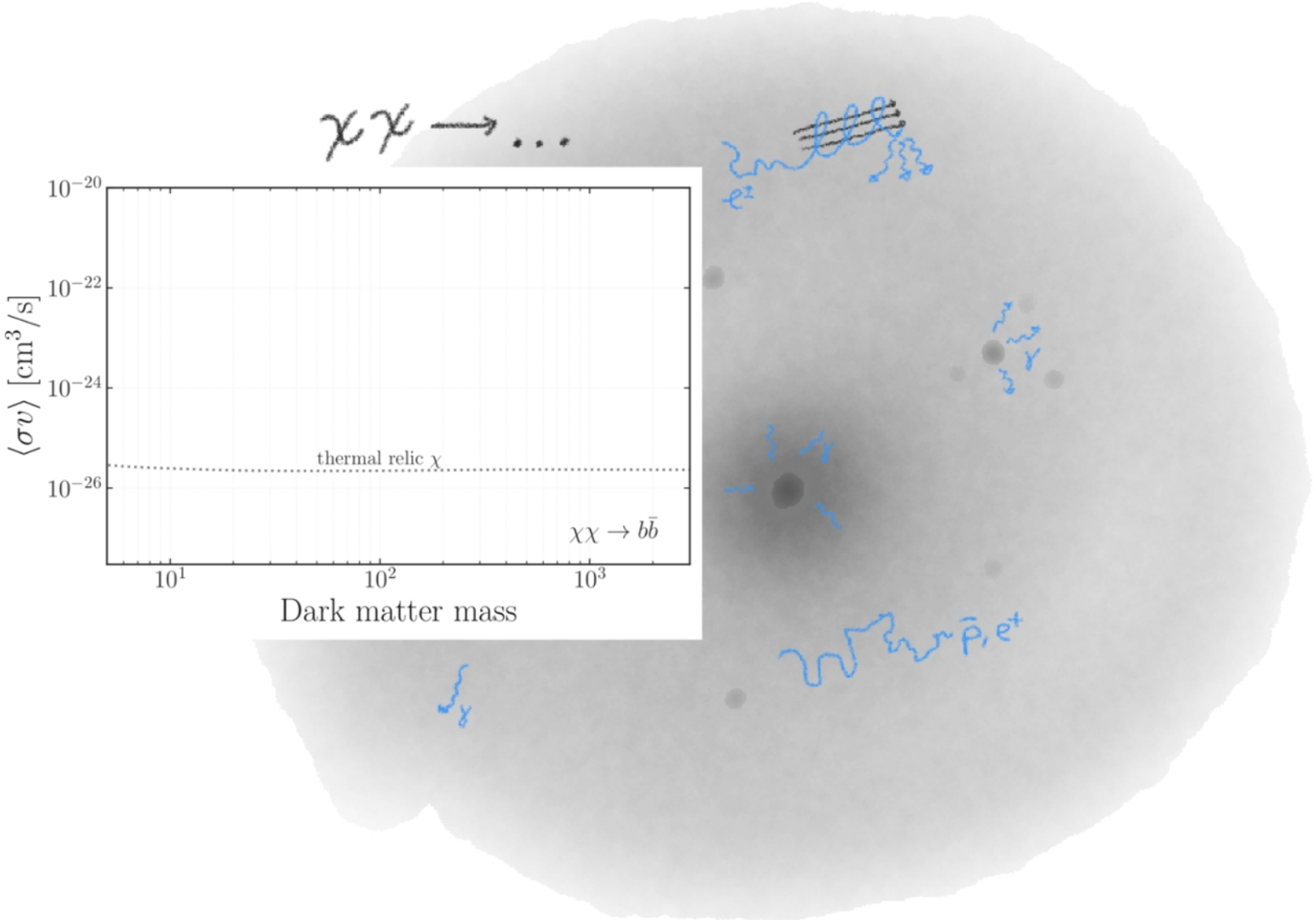
Undergrad Cagliari/Turin (IT) + CERN
Theoretical physics of fundamental interactions

PhD Turin + SLAC (US) [defended Jan'19]
F. Donato, N. Fornengo

Postdoc TTK RWTH Aachen (DE) [Oct'19-Nov'22]
M. Kraemer, F. Kahlhoefer, J. Lesgourges

Postdoc LAPTh Annecy (FR) [Dec'22-Nov'24]
F. Calore, P. Serpico, Y. Genolini
Marie Skłodowska-Curie fellowship: Signatures of cosmic rays and new fundamental particles in the Very high energy sky (VerSi)

I search for dark matter...



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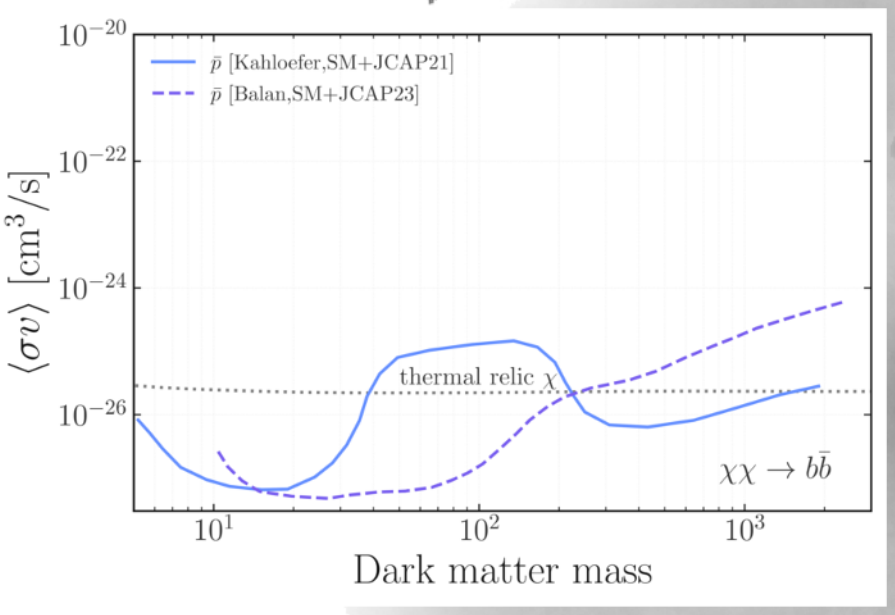

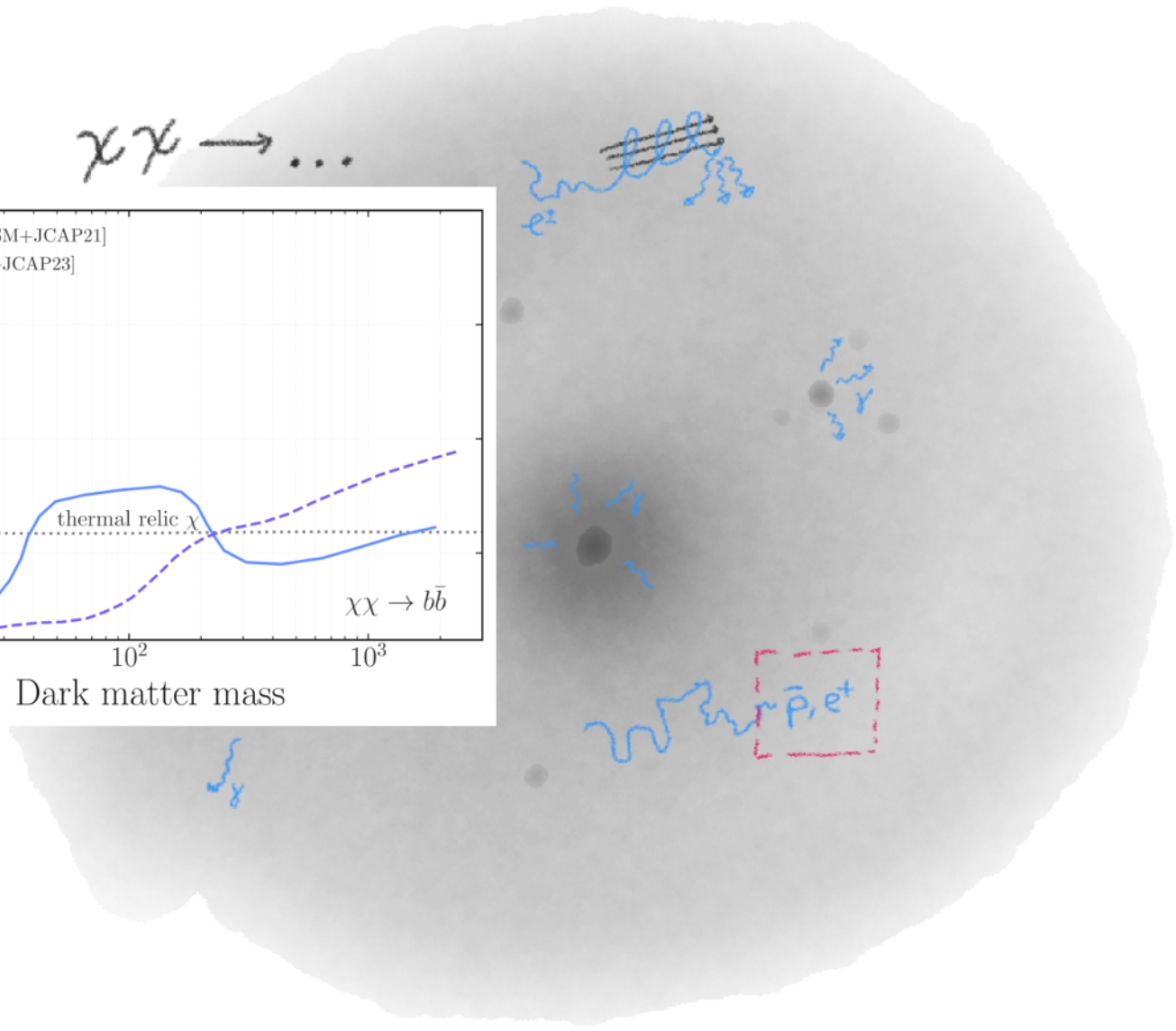

Cosmic antimatter

[Kahloefer,SM+JCAP'21]

[Balan,SM+JCAP'23]

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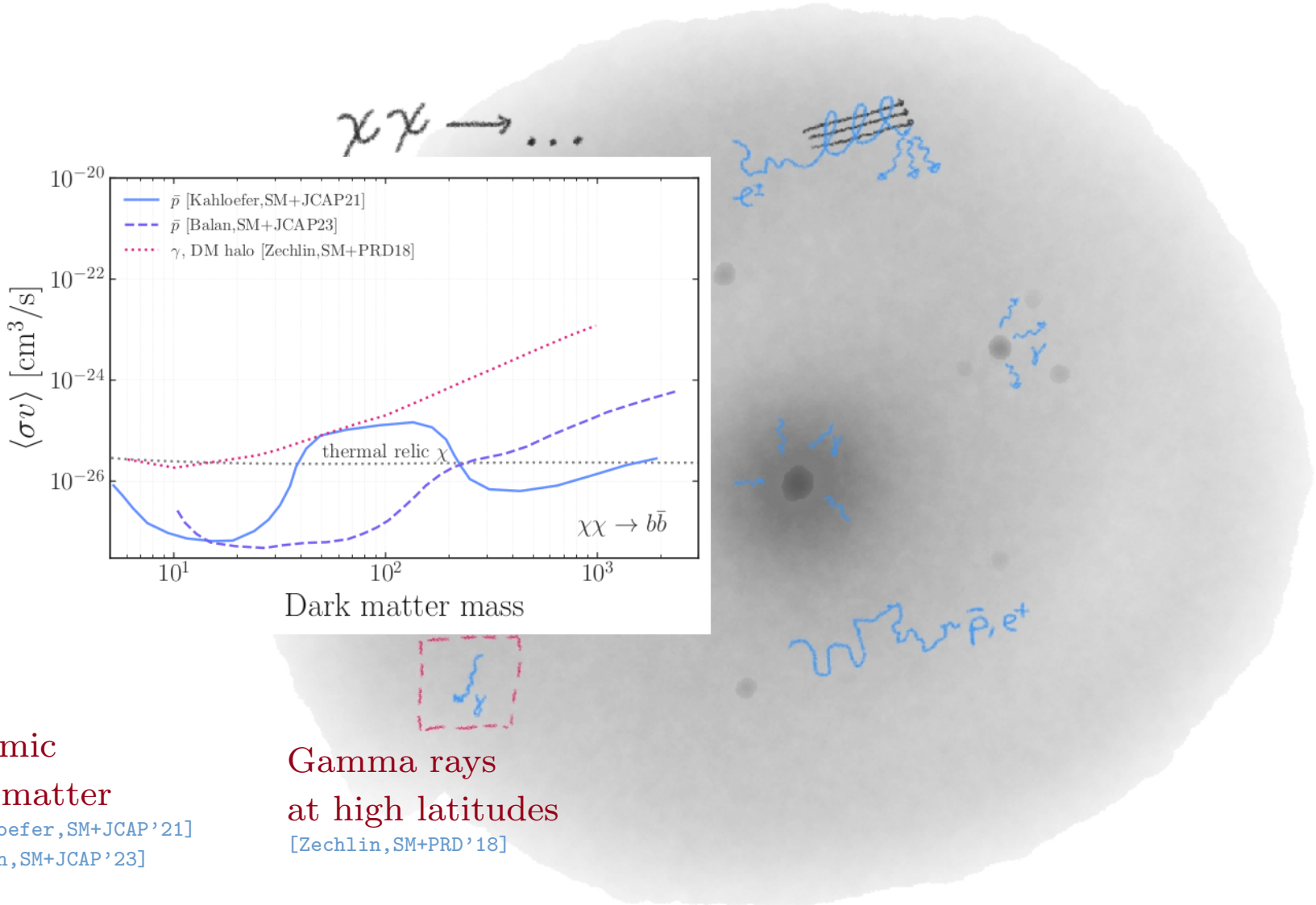

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Gamma rays at high latitudes

[Zechlin,SM+PRD'18]

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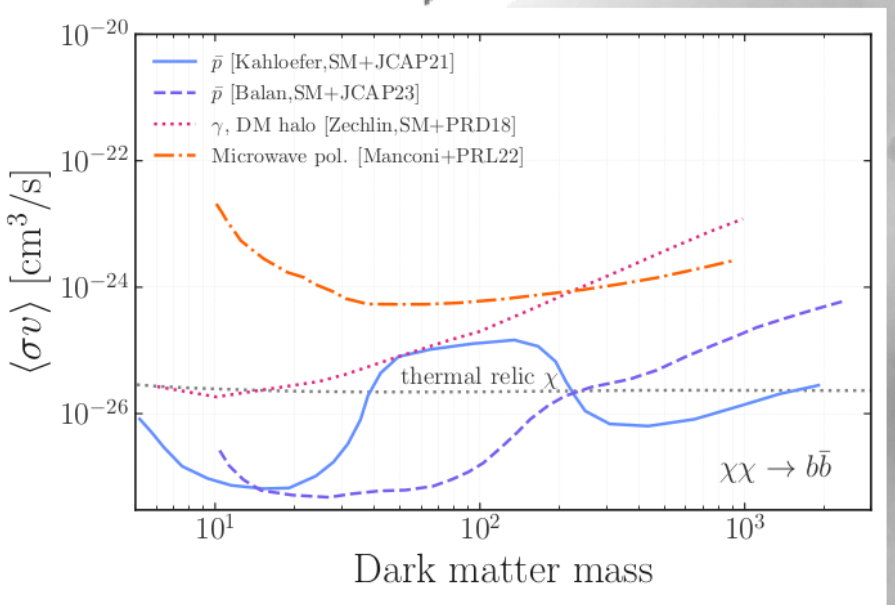

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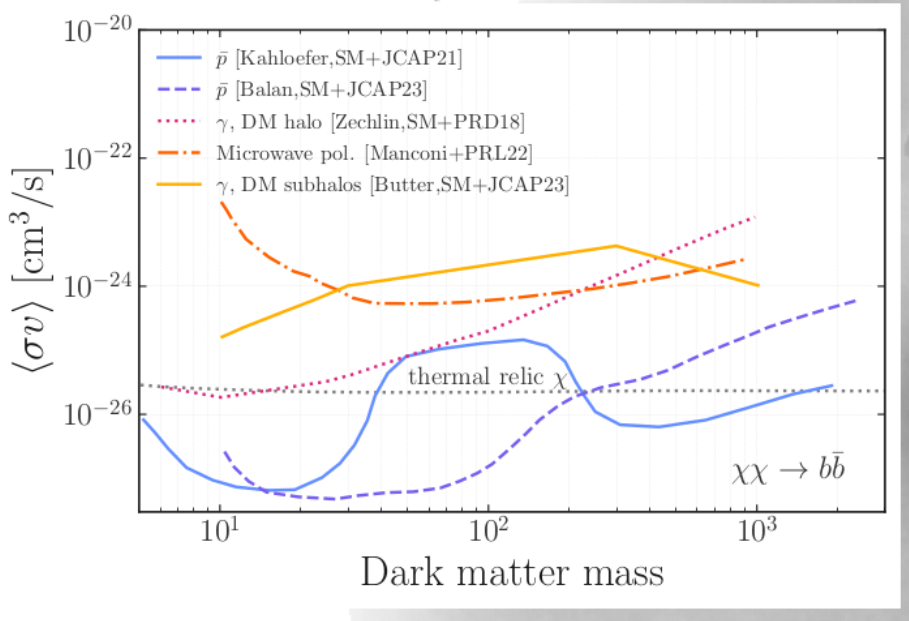

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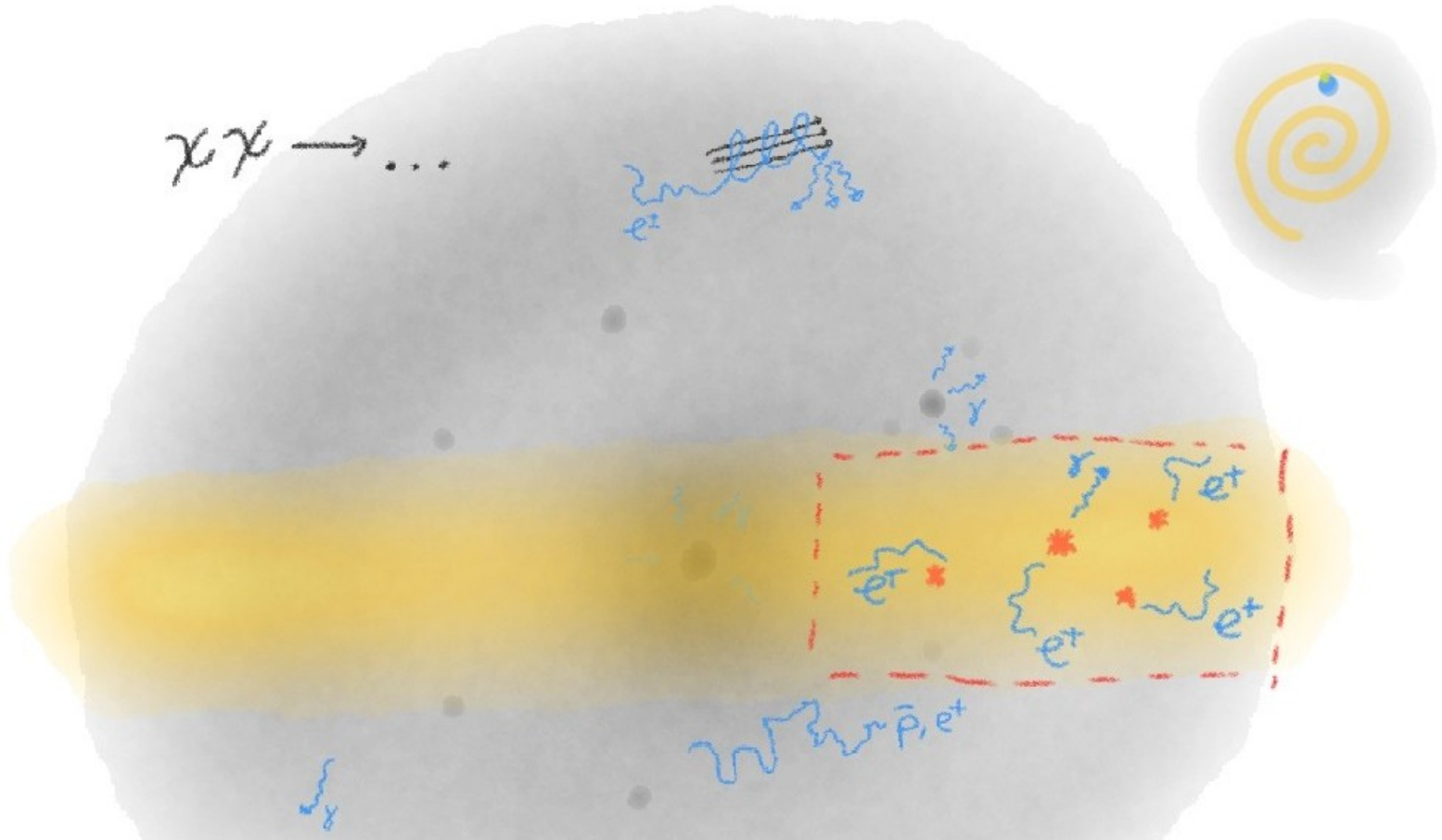
Gamma rays from subhalos & machine learning
[Butter,SM+JCAP'23]

...on top of astrophysical backgrounds



Stellar populations ($e^{\pm}$, radio to TeV)

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[DiMauro,SM+ApJ'17]
[Manconi+JCAP'19]
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[Manconi+PRD'20]

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[Recchia,SM+PRD'21]
[Orusa,SM+JCAP'21]
[DiMauro,SM+PRD'23]
[Manconi+A&A'24]
[Orusa,SM+24]

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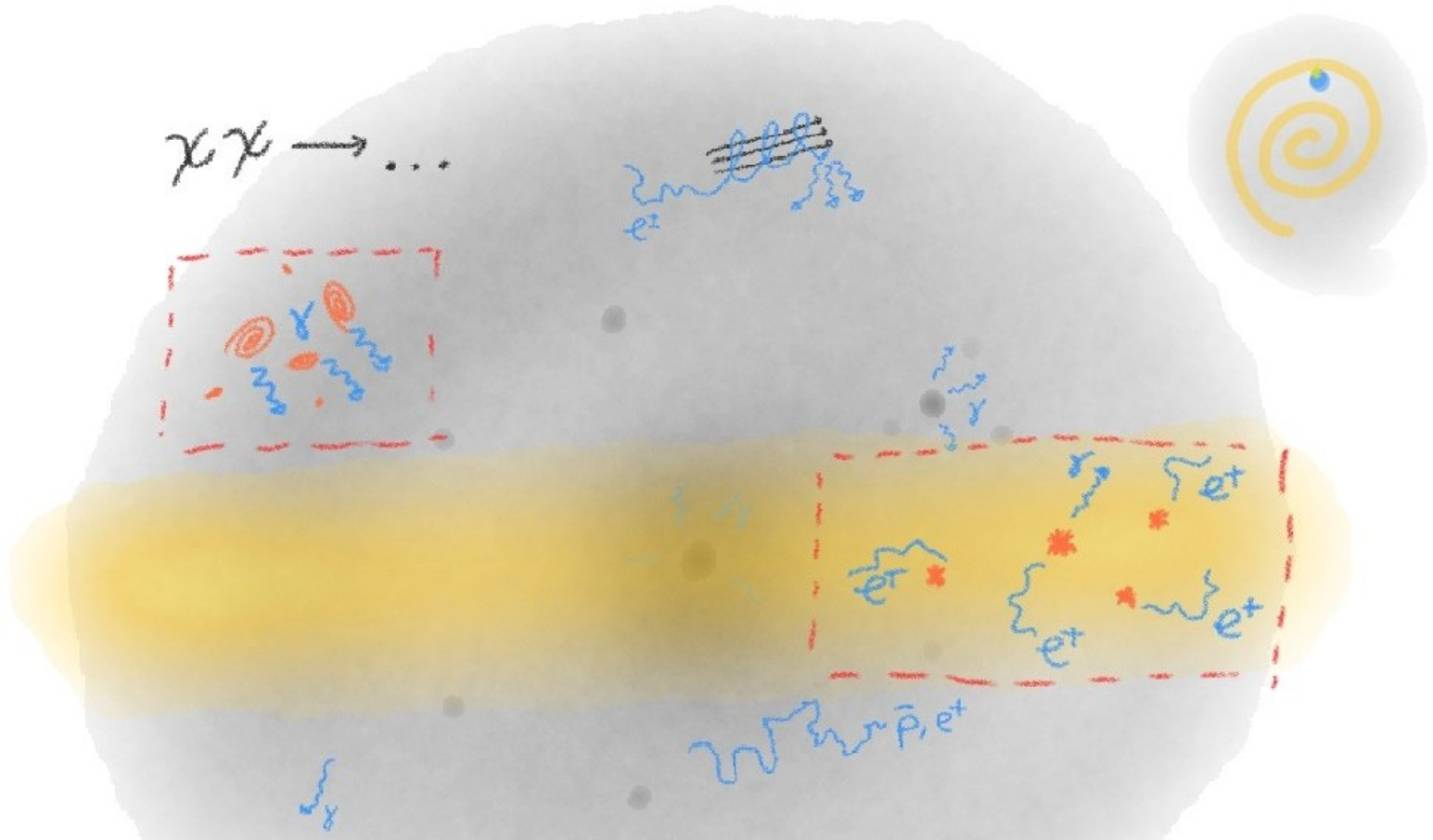

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Extragalactic

[Manconi+PRD'20]
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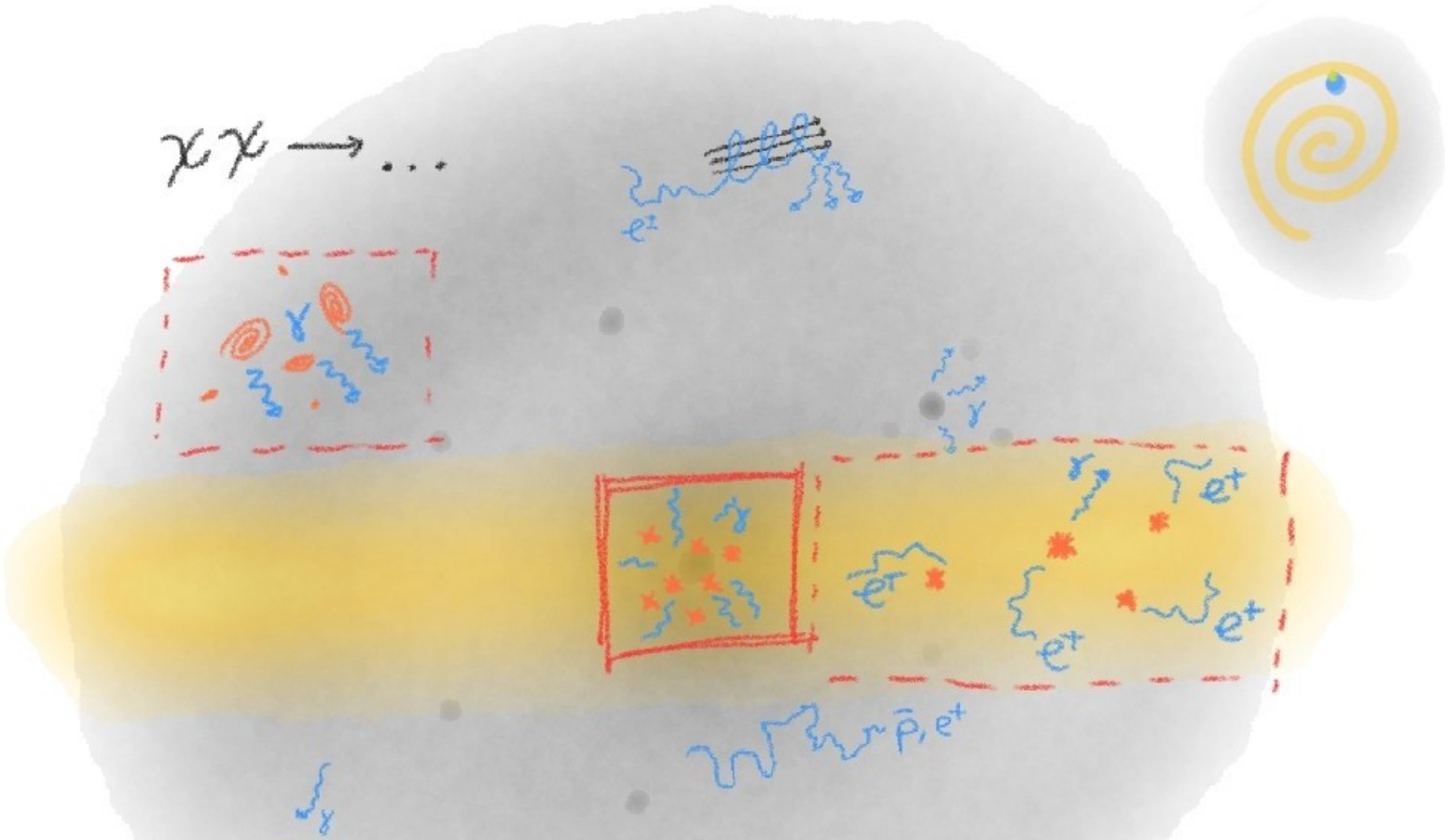

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Galactic center

[Calore,SM+PRL'21]
[Manconi+PRD'24]

Extragalactic

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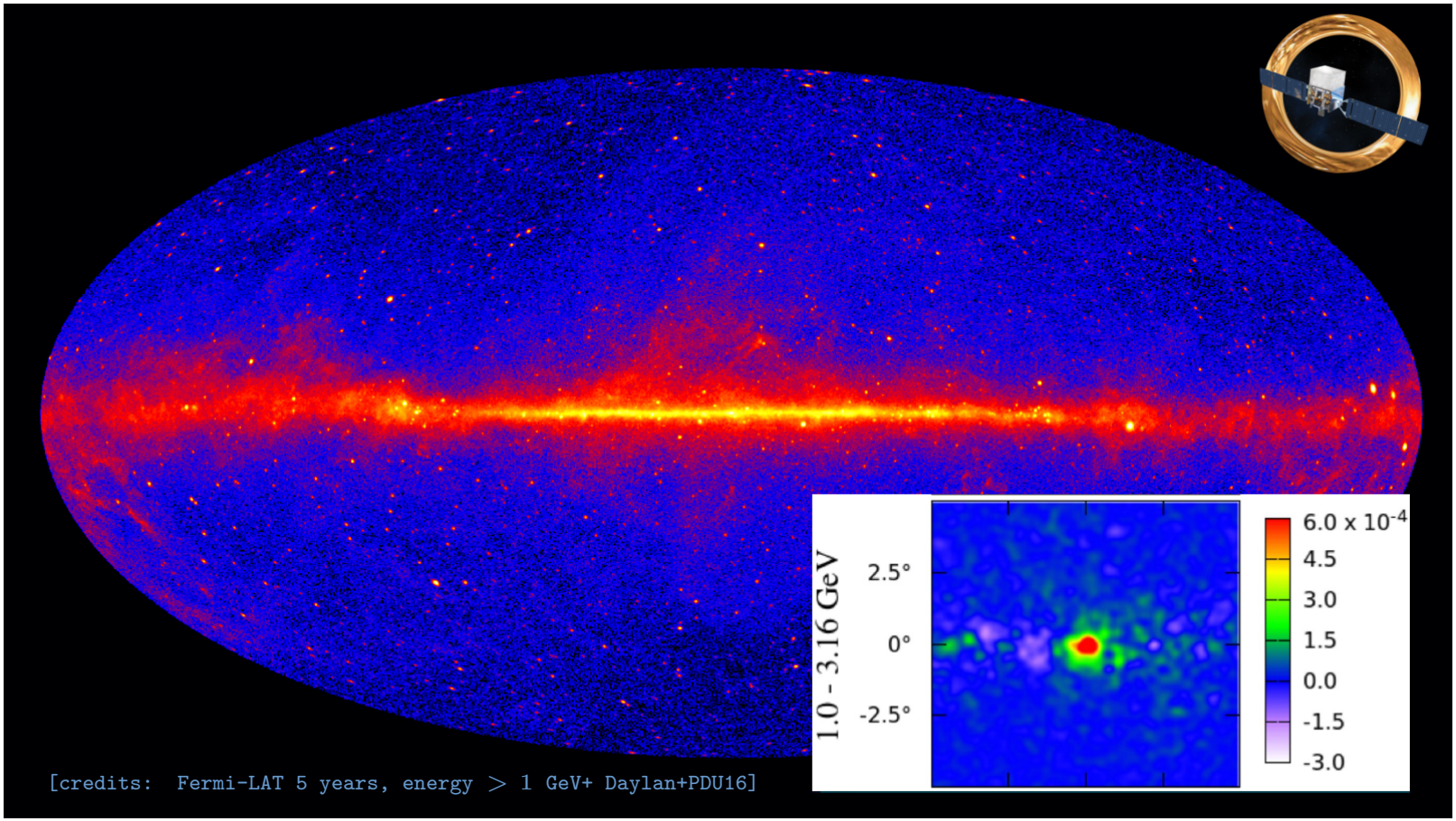
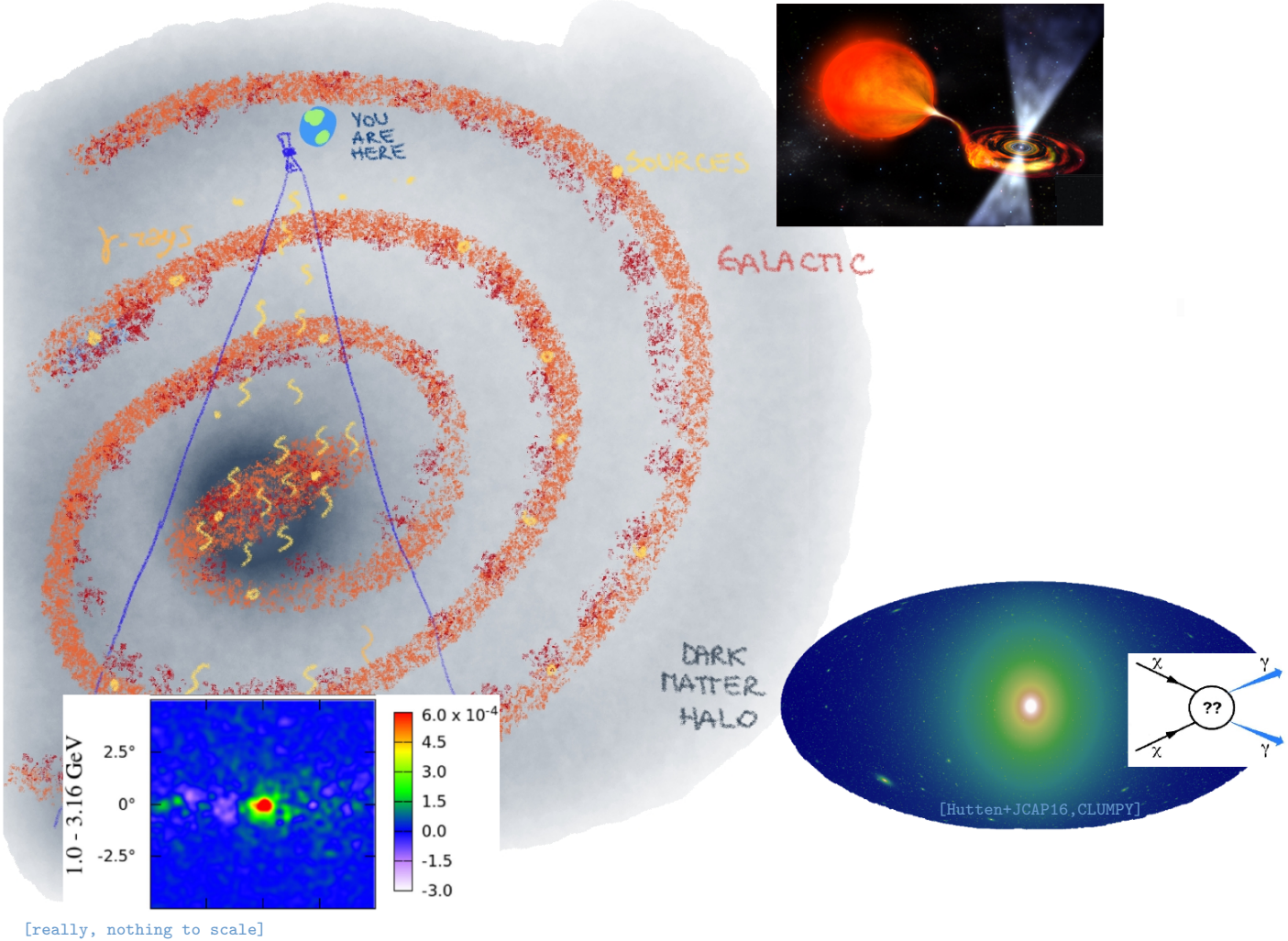
The Galactic Center Excess



Statistically significant excess in Fermi-LAT data
with respect to diffuse emission and resolved astrophysical sources
few % of 2-20 GeV inner Galaxy flux [hot topic... N+1 papers]

Dark matter or stellar populations?



[really, nothing to scale]

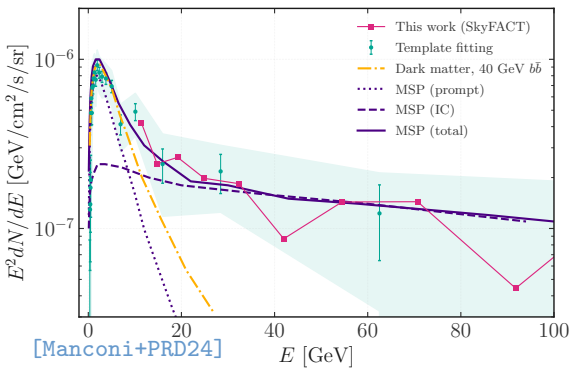
New physics phenomena:

+ **Dark Matter**: annihilation in Galactic halo
+ **Stellar**: population of new, faint sources

Debated, likely stellar

Significant community effort & debate: developing new methods, tackling bias from background diffuse emission mis-modeling

Energy spectrum



[Manconi+PRD24]

- High energy tail $E > 10$ GeV

  [Linden+PRD'16,Manconi+PRD'24]

- Naturally explained by inverse Compton of $e^{\pm}$ in stellar population
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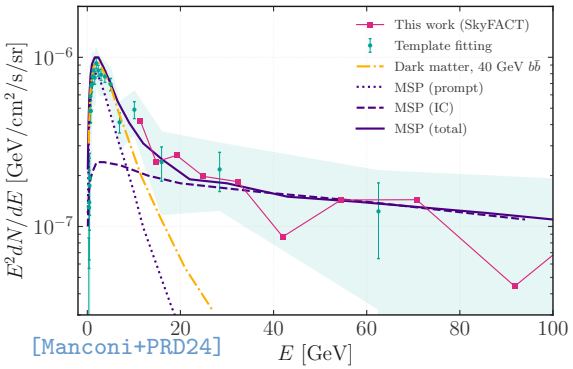

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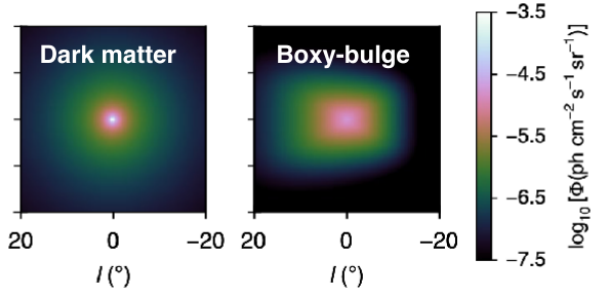
Morphology



- Longitudinal asimmetry at ~ 10 deg
- Stellar-like: independent evidence

  [Bartels+NA'18,Macias+NA'18,JCAP'19,

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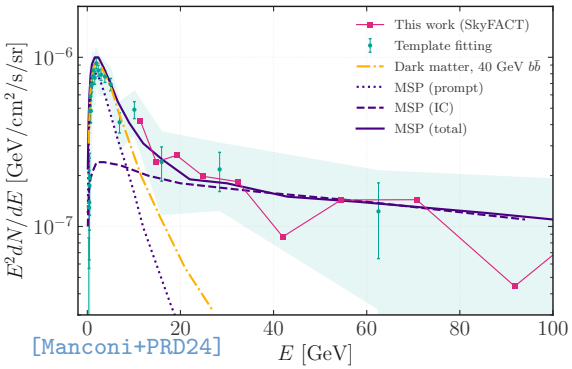

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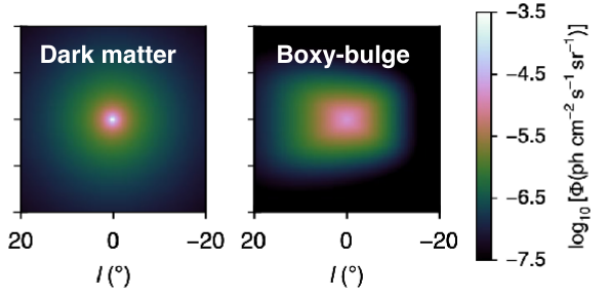

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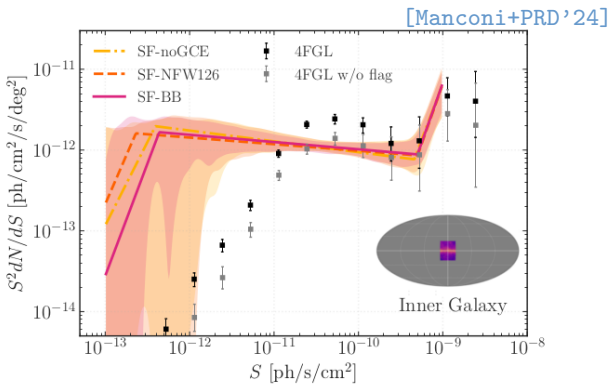
Statistics of photon counts

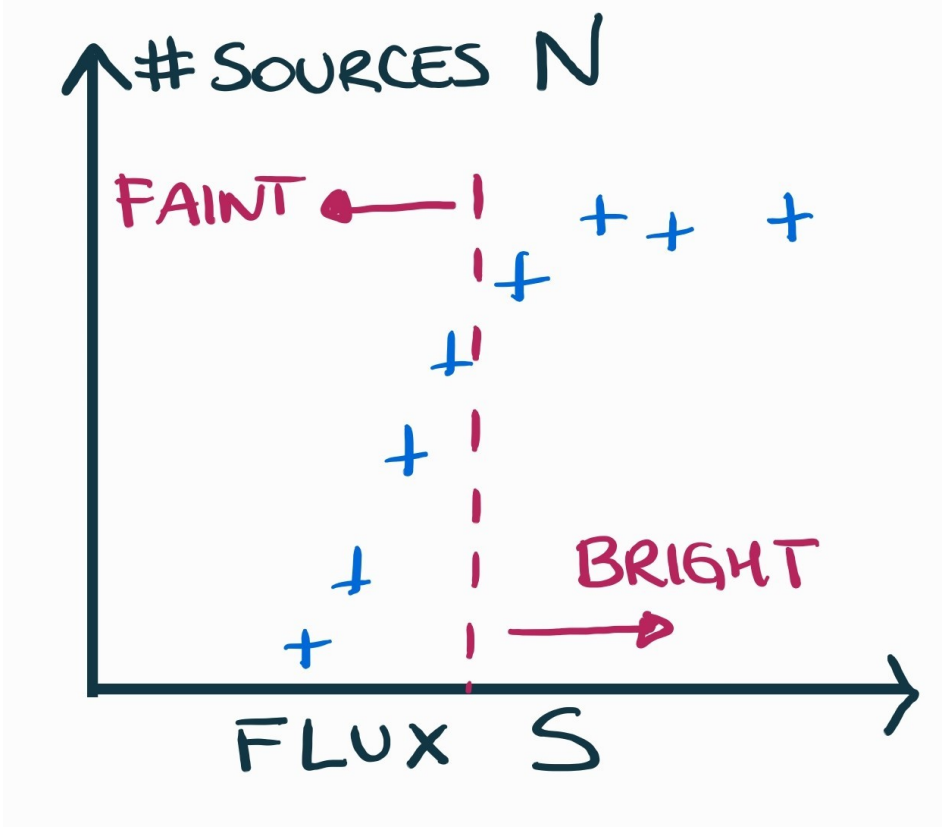


- Unresolved point sources: independent evidences
  [Buschmann+PRD'20,Calore,SM+PRL'21,
  List+PRD'21,Manconi+'PRD'24]
- Source number depends on luminosity function [Dinsmore+JCAP'22]

Corroborating an (at least) partial stellar origin of the excess

Dissecting the Galactic center GeV excess

Photon count statistics: advanced methods to interpret Fermi-LAT data extracting crucial observables



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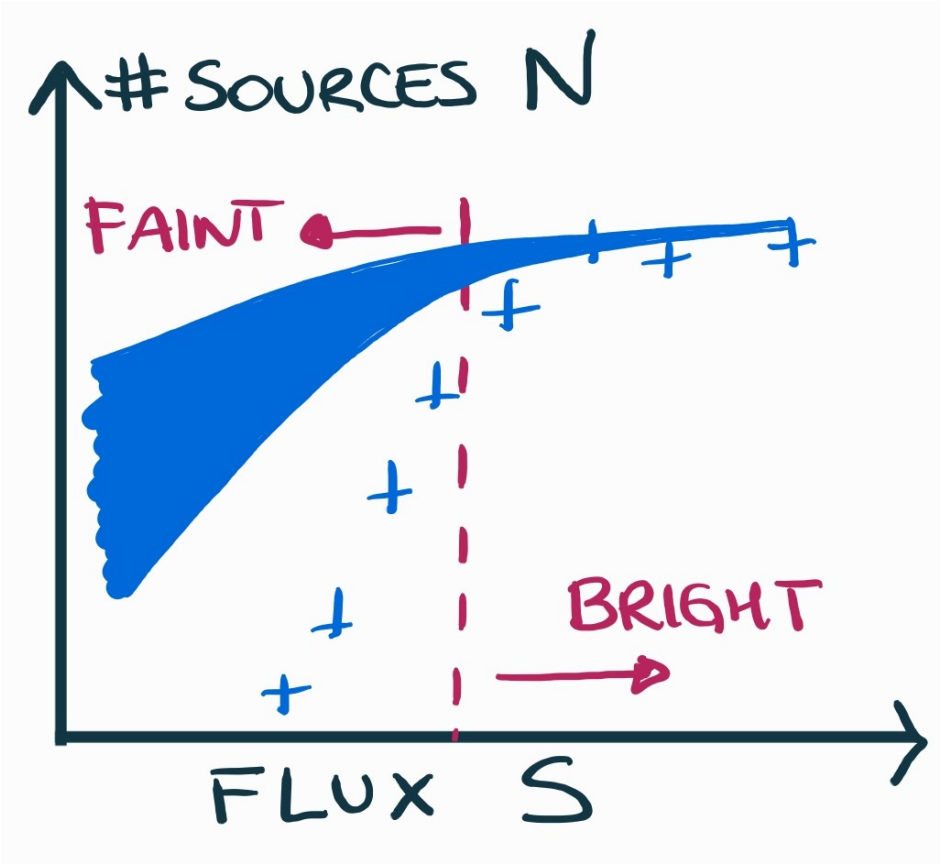

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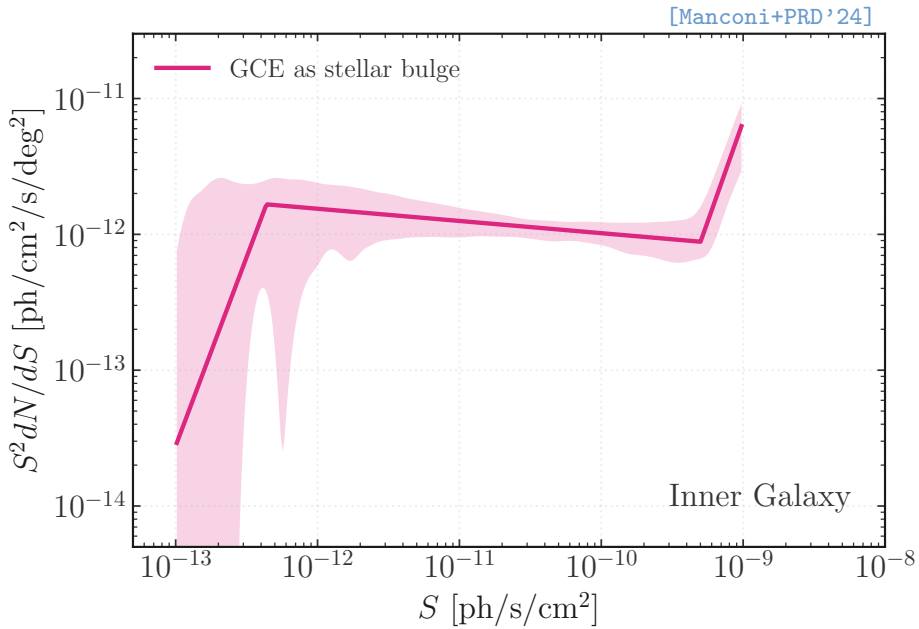

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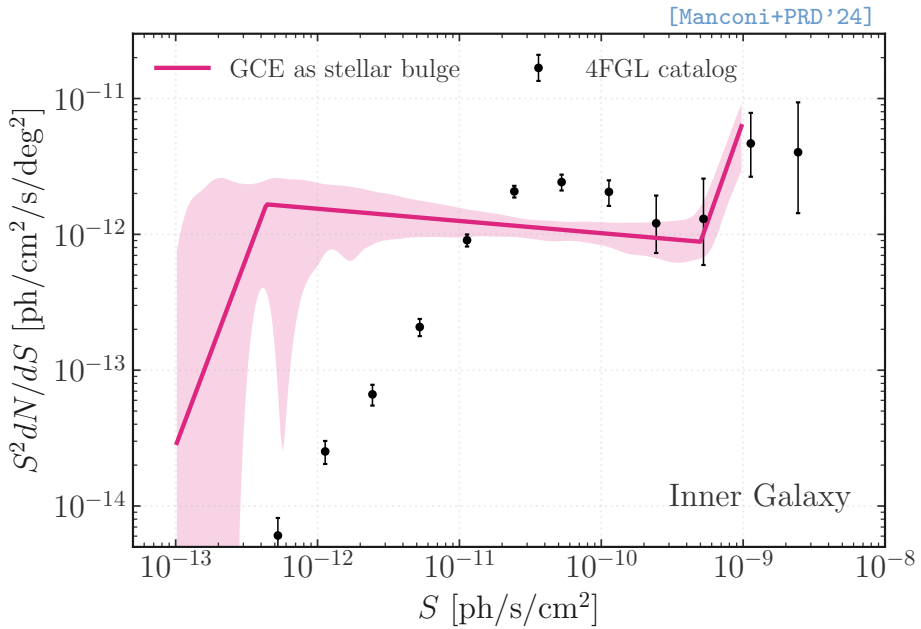
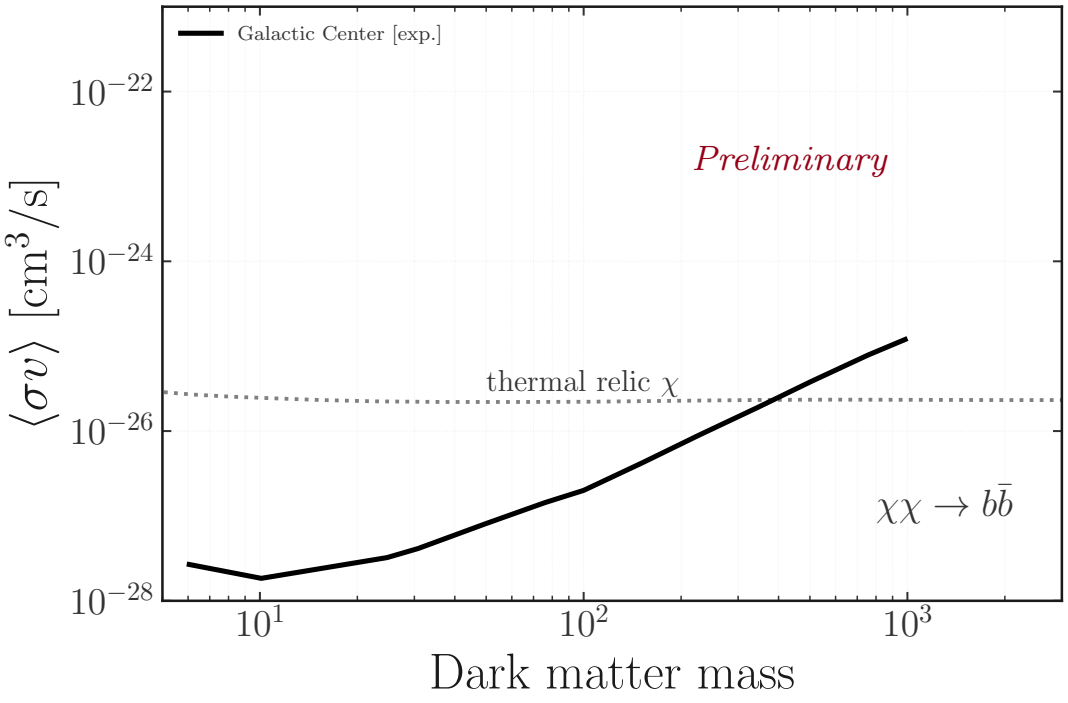


- Robustly addressing diffuse mismodeling, we revealed flux and spatial distribution of faint sources in the inner Galaxy [Calore,SM+PRL'21]
- Highest energy: energy spectrum, morphology & photon counts **support (partial) stellar origin** [Manconi+PRD'24]

Work in progress

Constraints to GeV dark matter: potentially strongest in GeV mass range



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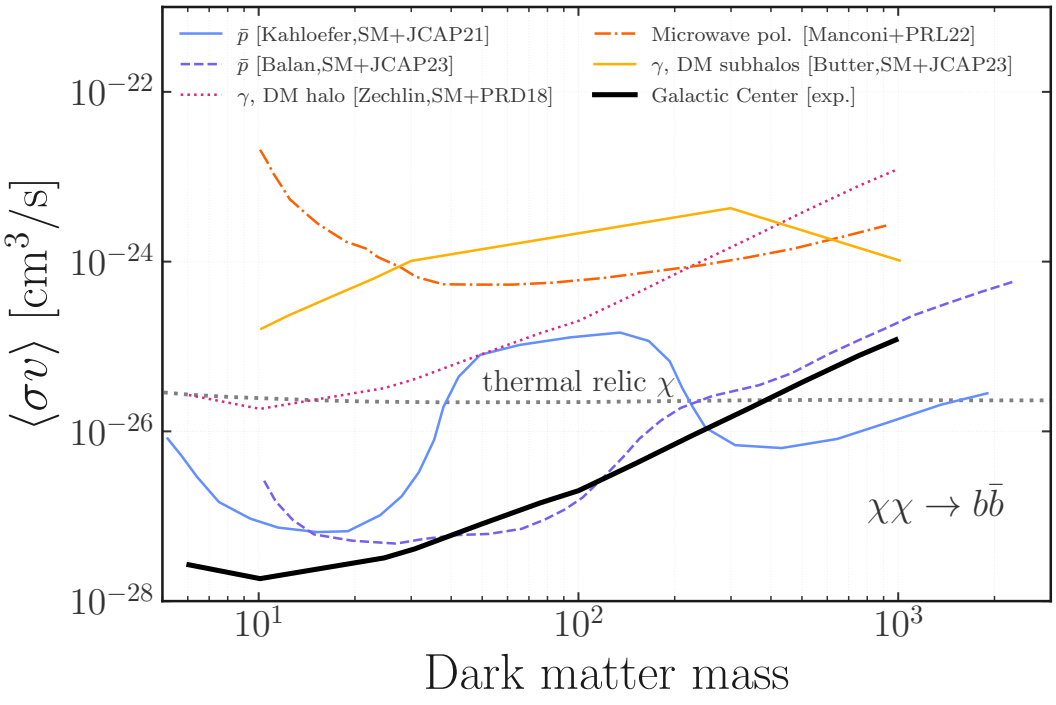

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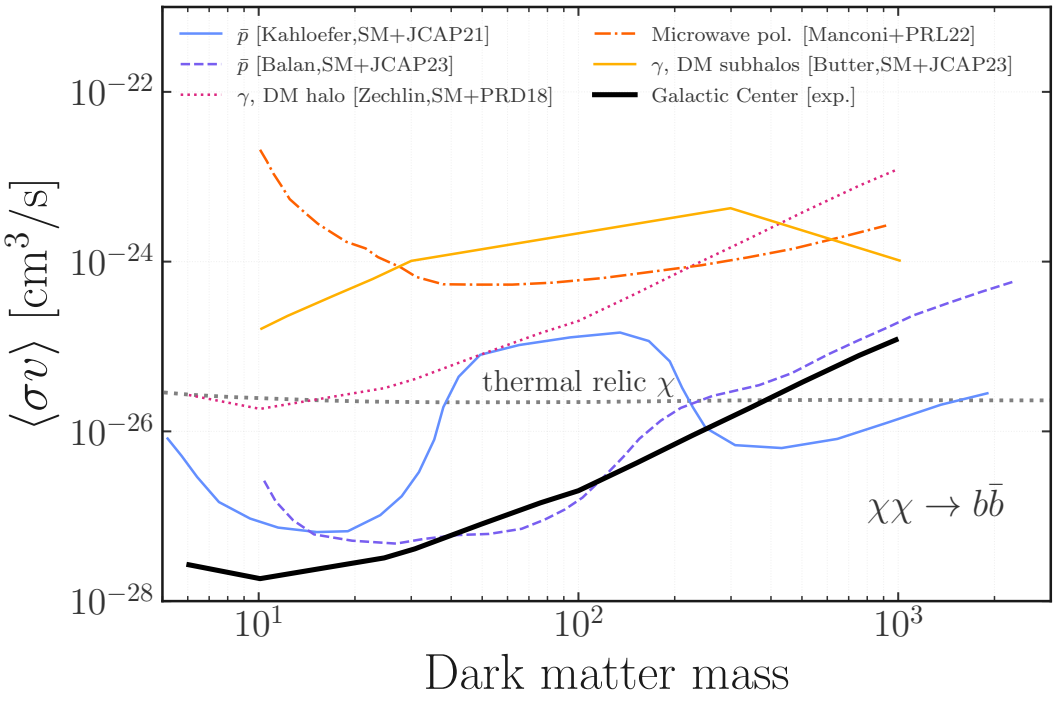
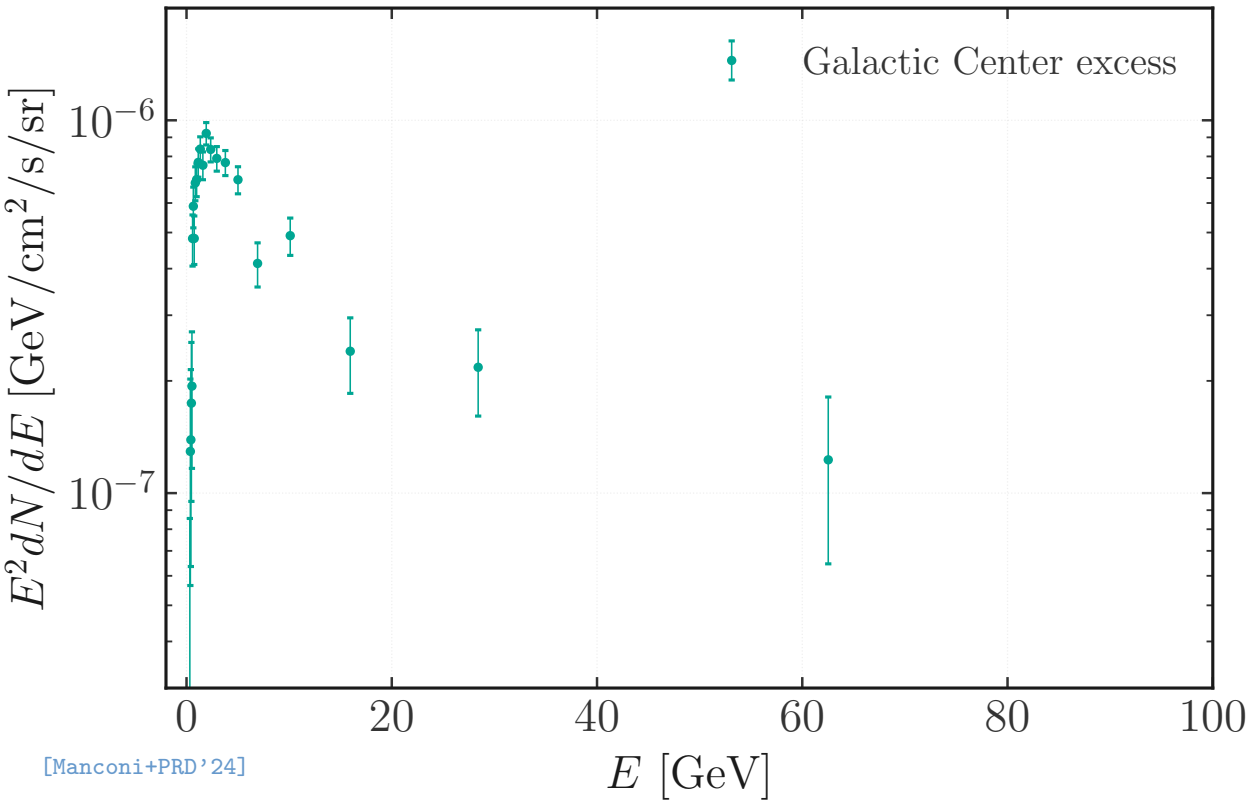


Next:

- Extend to nearby Galaxy (dwarf spheroidal, M31, LMC)
- Exploit X-ray and TeV current and forthcoming telescopes (eRosita, ART-XC, LHAASO, Cherenkov Telescope Array (CTA),...)

Work in progress

Nature of > 10 *GeV gamma ray emission at the Galactic Center*



[Manconi+PRD'24]

Work in progress

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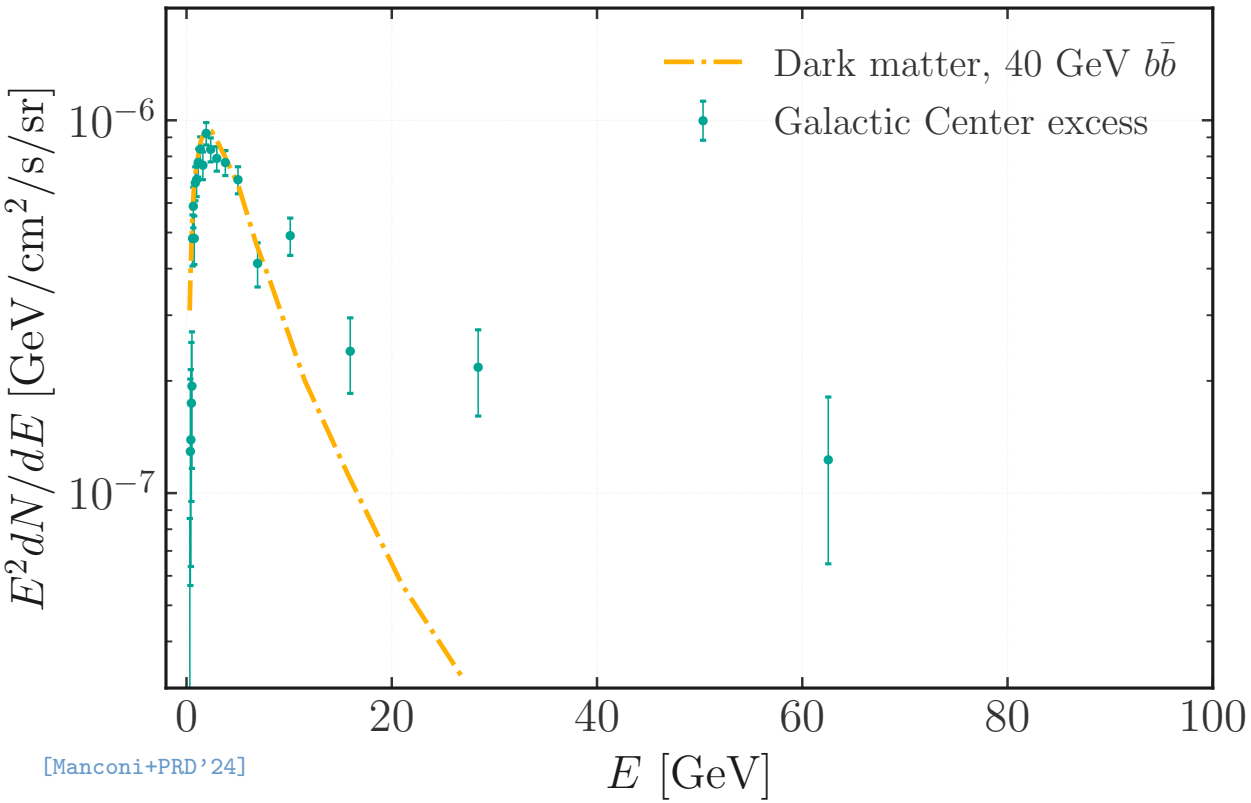

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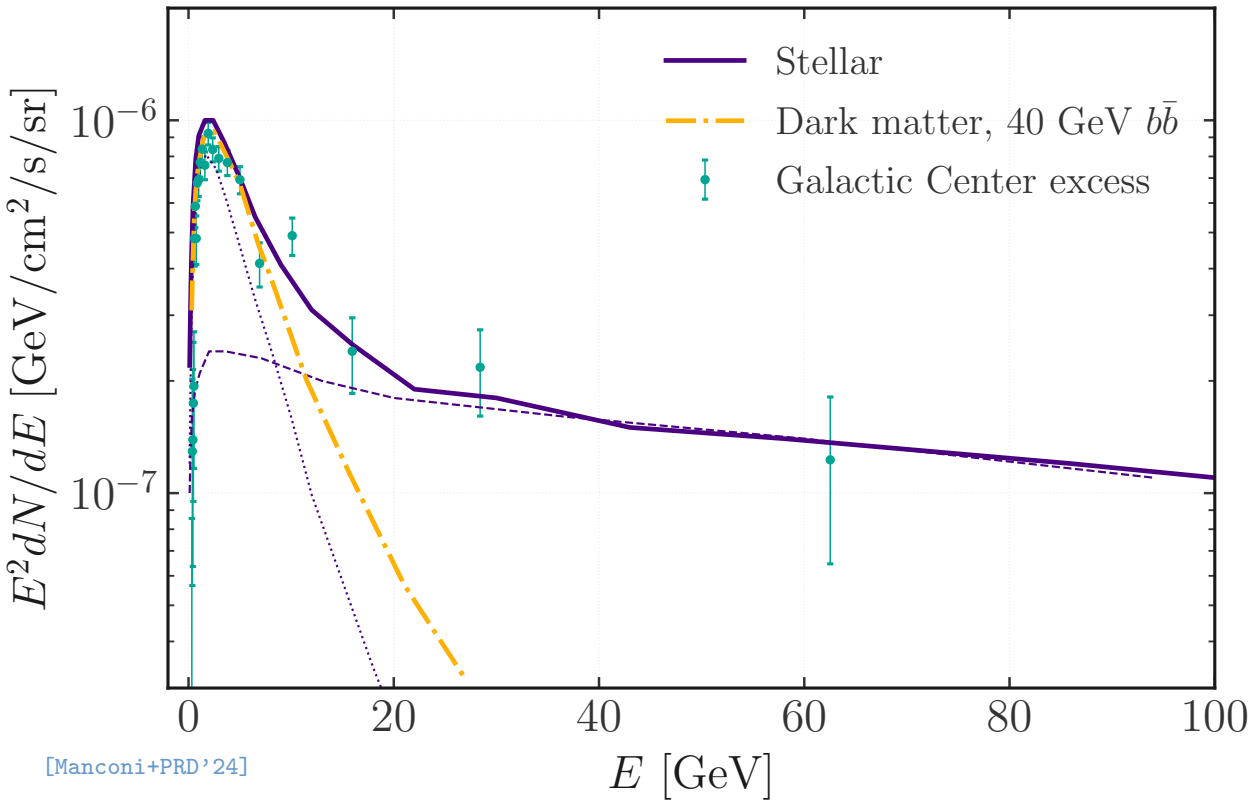

[Manconi+PRD'24]

1. Stellar population models: particle ($e^{\pm}$, p?), multiwavelength
2. Consequences for dark matter in the Milky Way and in nearby galaxies

Work in progress

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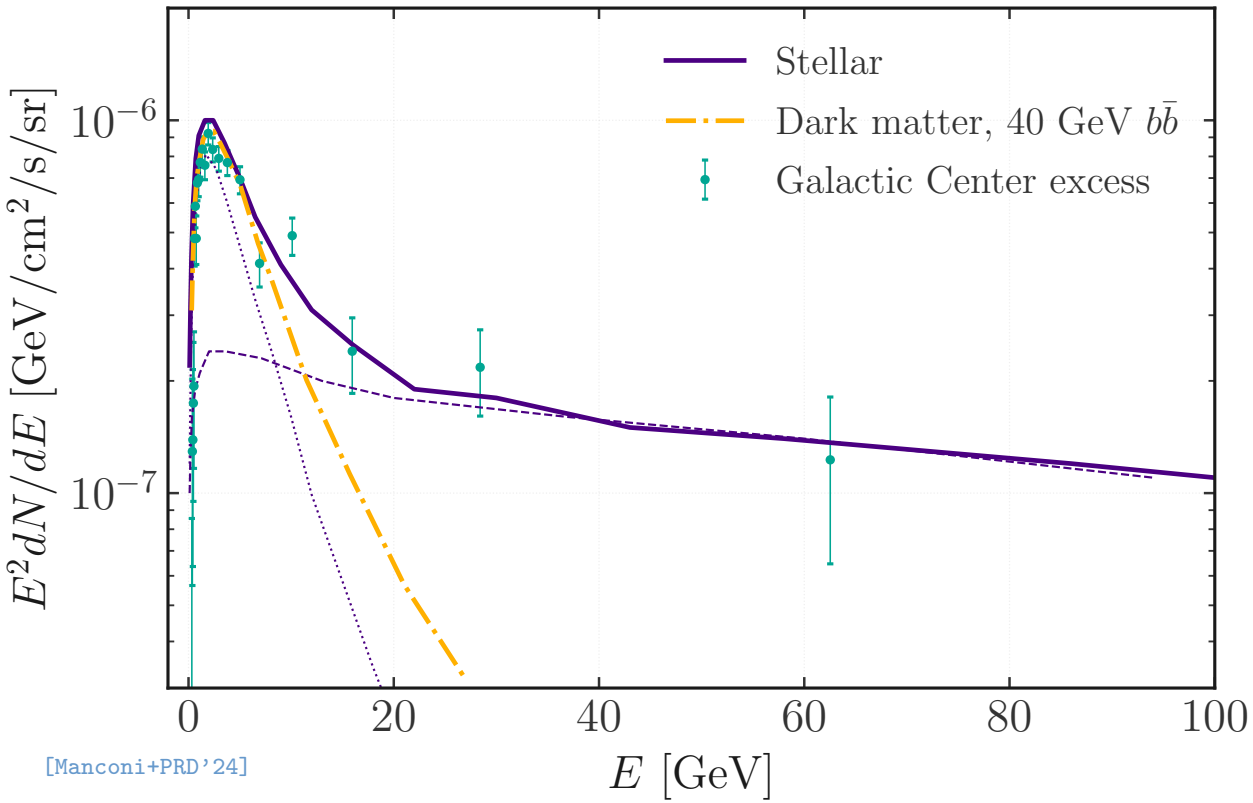

[Manconi+PRD'24]

1. Stellar population models: particle ($e^{\pm}$, p?), multiwavelength
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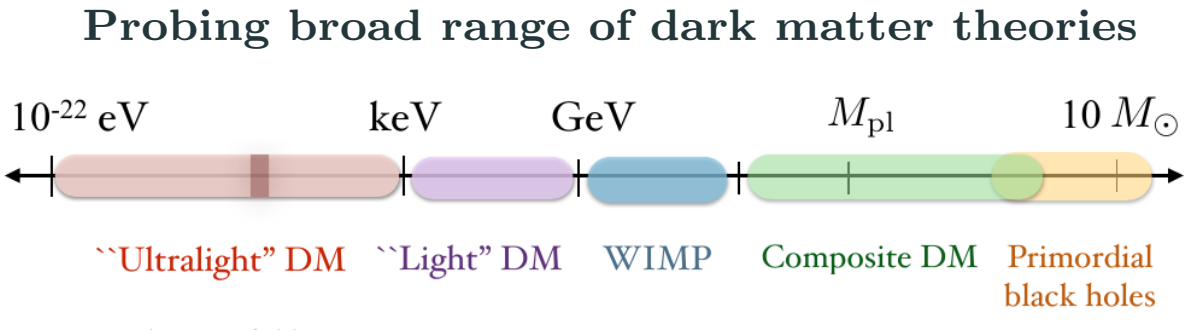
using current and upcoming X-ray and TeV telescopes
(eRosita, HAWC, Cherenkov Telescope Array (CTA),...)

Further interests



Axion-like particles

CTA: signatures in TeV γ-ray spectra

Machine learning signal processing

[Manconi,Nippel,Kraemer, in prep]

Global fits of theories Beyond SM

legacy of GeV astroparticles

GAMBIT, including astro uncertainties

e.g. [Kahloefer,SM+21,Balan,SM+23]

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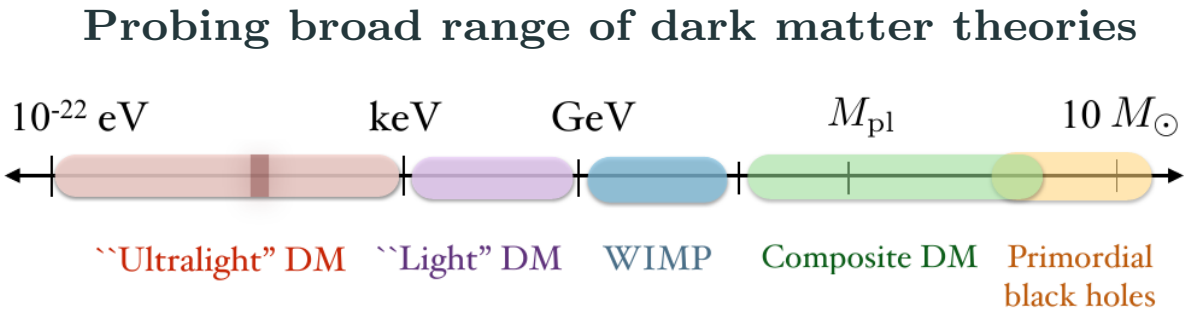

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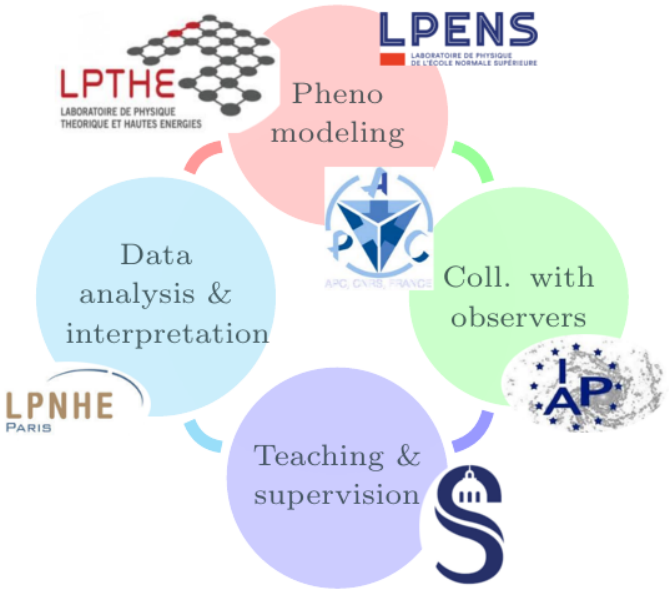
e.g. [Kahloefer,SM+21,Balan,SM+23]

Antimatter asymmetry; X-rays, MeV to probe sub-GeV dark matter

Summary

Phenomenology of dark matter & astroparticles with multi-messenger, multi-wavelength and machine learning methods



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open to collaborate to future courses in astroparticles

Supervision: Postdoc opening (deadline 16/12)+ M2-PhD with M.Cirelli

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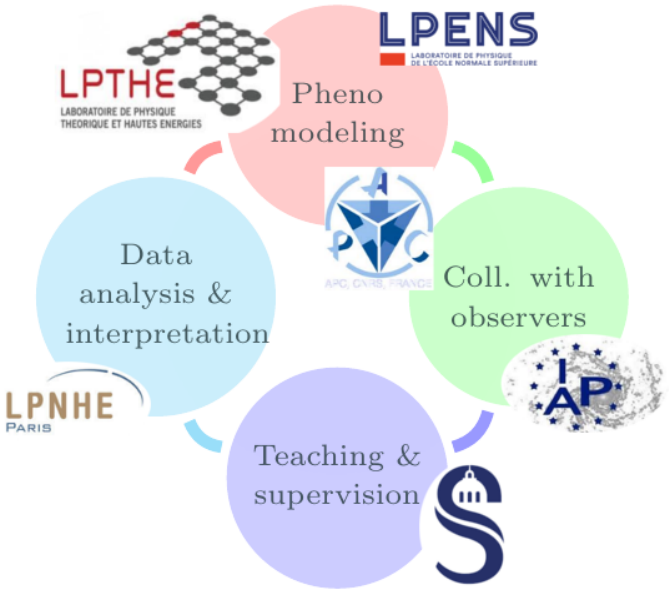

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Merci!