AstroTH: Hands-on

Francesca Calore

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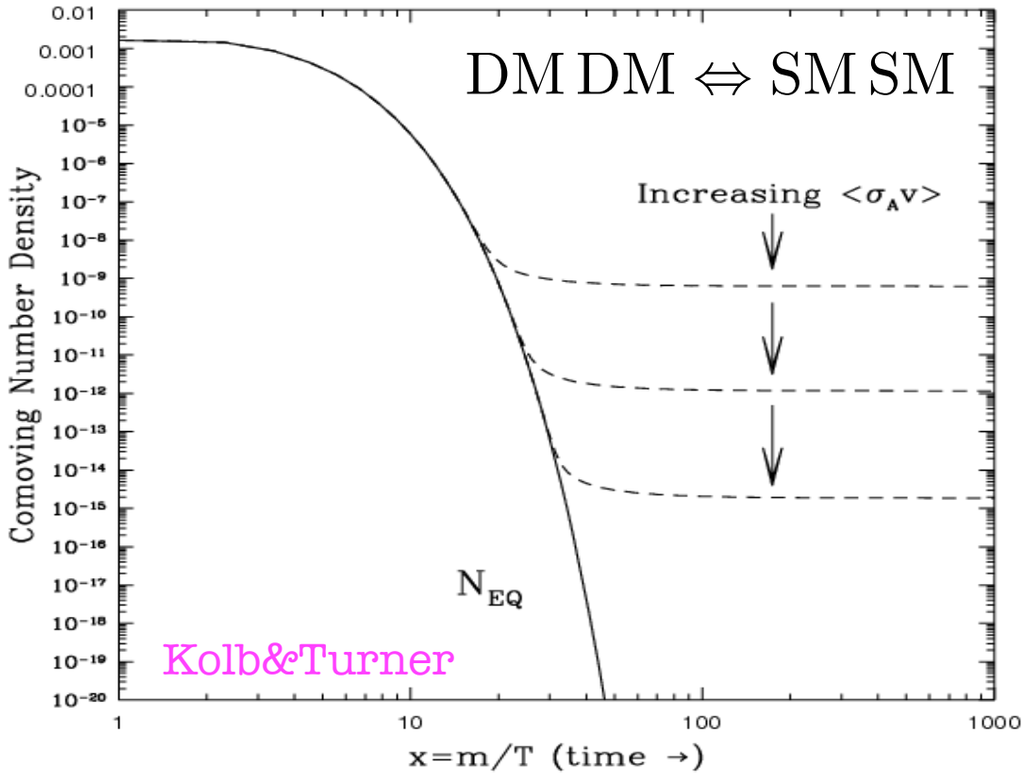
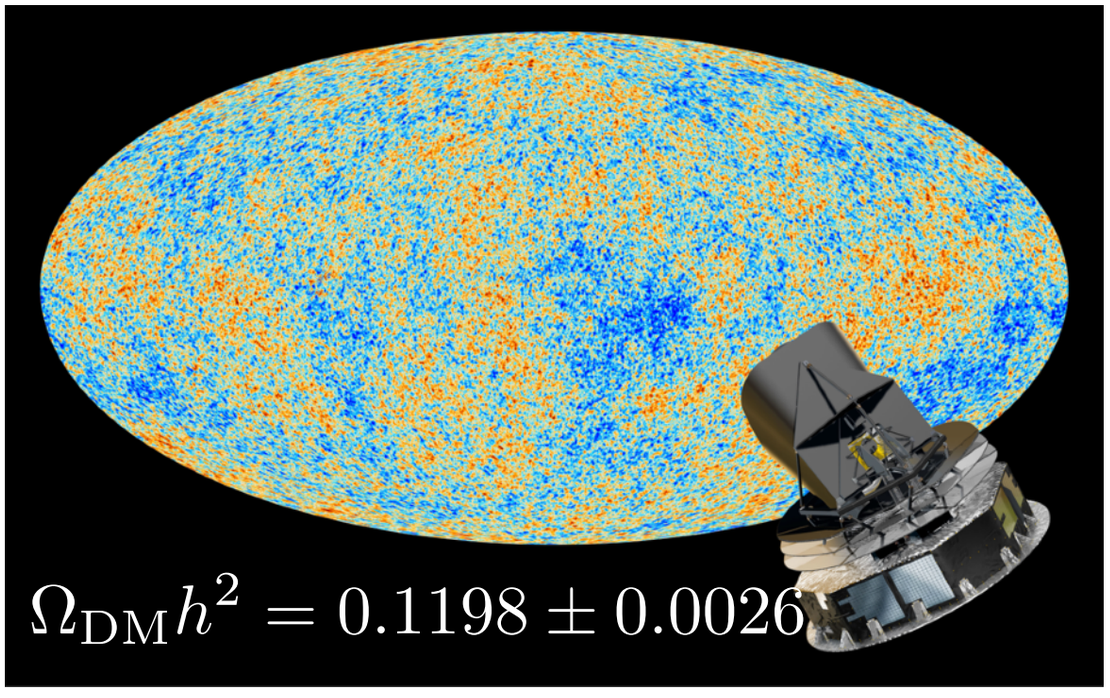
Weakly Interacting Massive Particles (WIMP)

The dark matter landscape

Freeze-out production mechanism



CMB temperature anisotropy

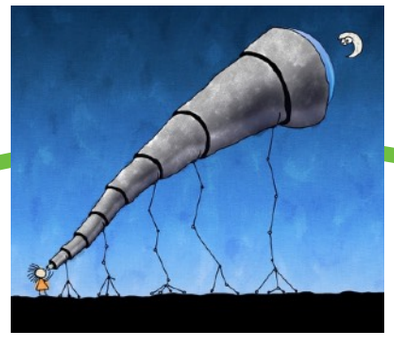


$$\Omega_{\rm DM}h^2 \sim \frac{10^{-27}{\rm cm}^3/{\rm s}}{\langle\sigma({\rm DM\,DM} \to {\rm SM\,SM}){\rm v}\rangle}$$

$$\langle\sigma({\rm DM\,DM} \to {\rm SM\,SM}){\rm v}\rangle \sim 3\times10^{-26}{\rm cm}^3/{\rm s}$$

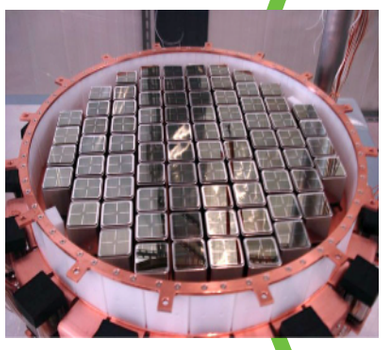
Natural candidates at the weak scale

WIMP detection strategies

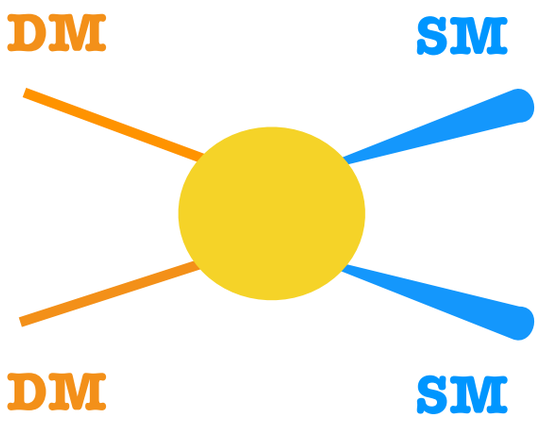


F. Donato, M. Ahlers
M. Vogelsberger

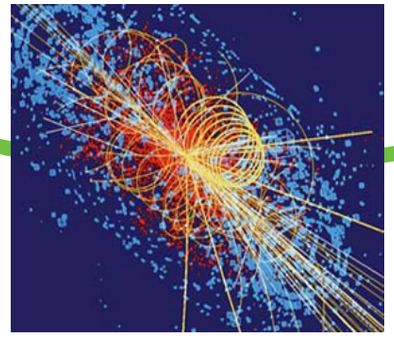
Indirect Searches



Direct
Searches



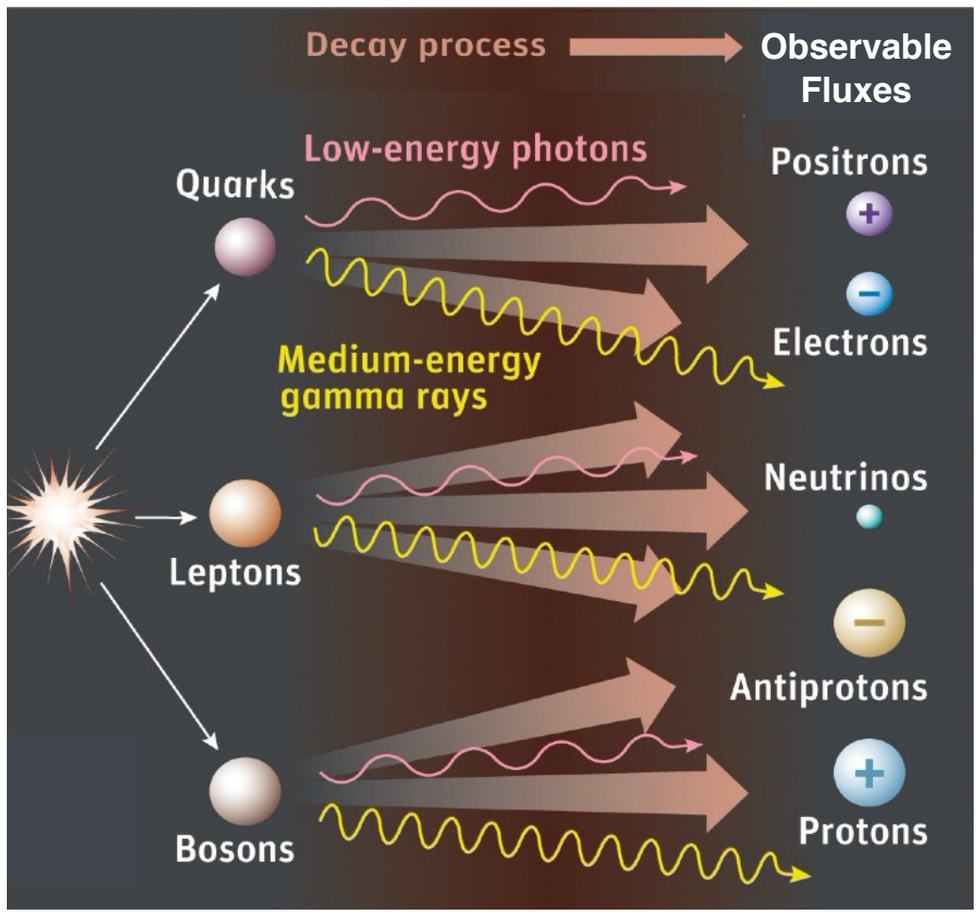
Collider Searches



S. Caron

Indirect dark matter detection

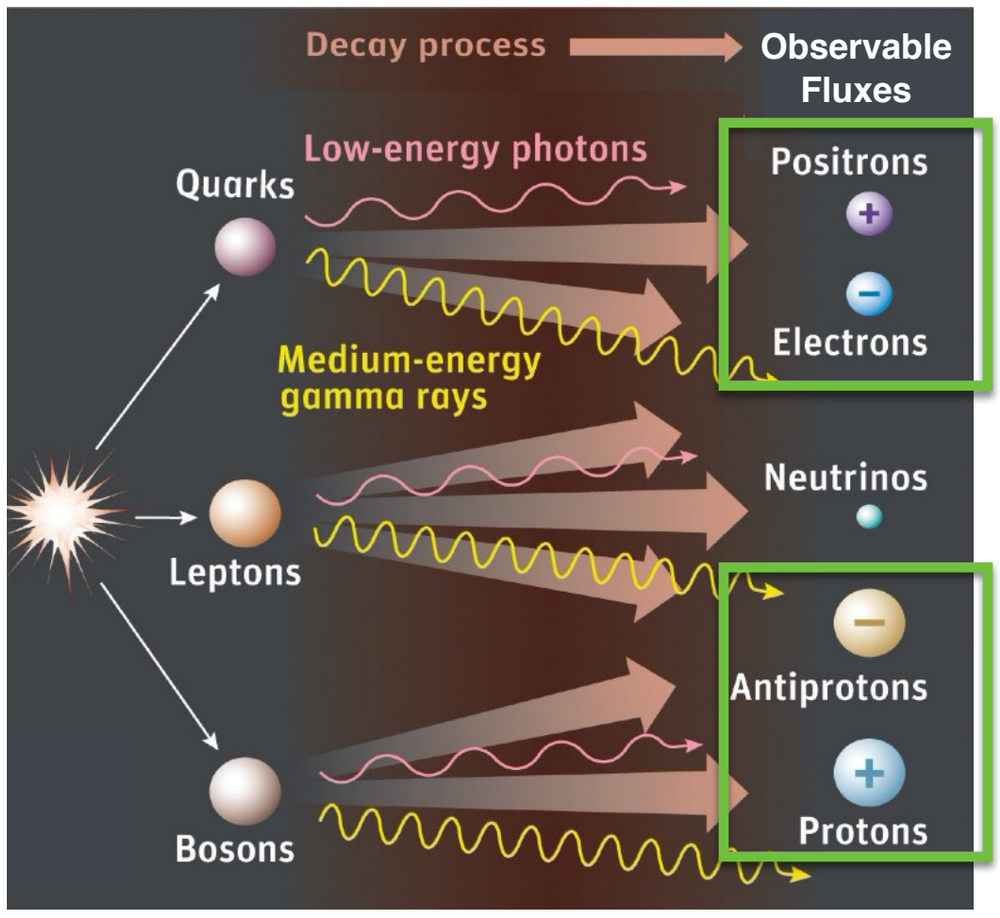
DM annihilation/decay



Indirect searches
for stable dark matter annihilation (or decay) products.

Indirect dark matter detection

DM annihilation/decay



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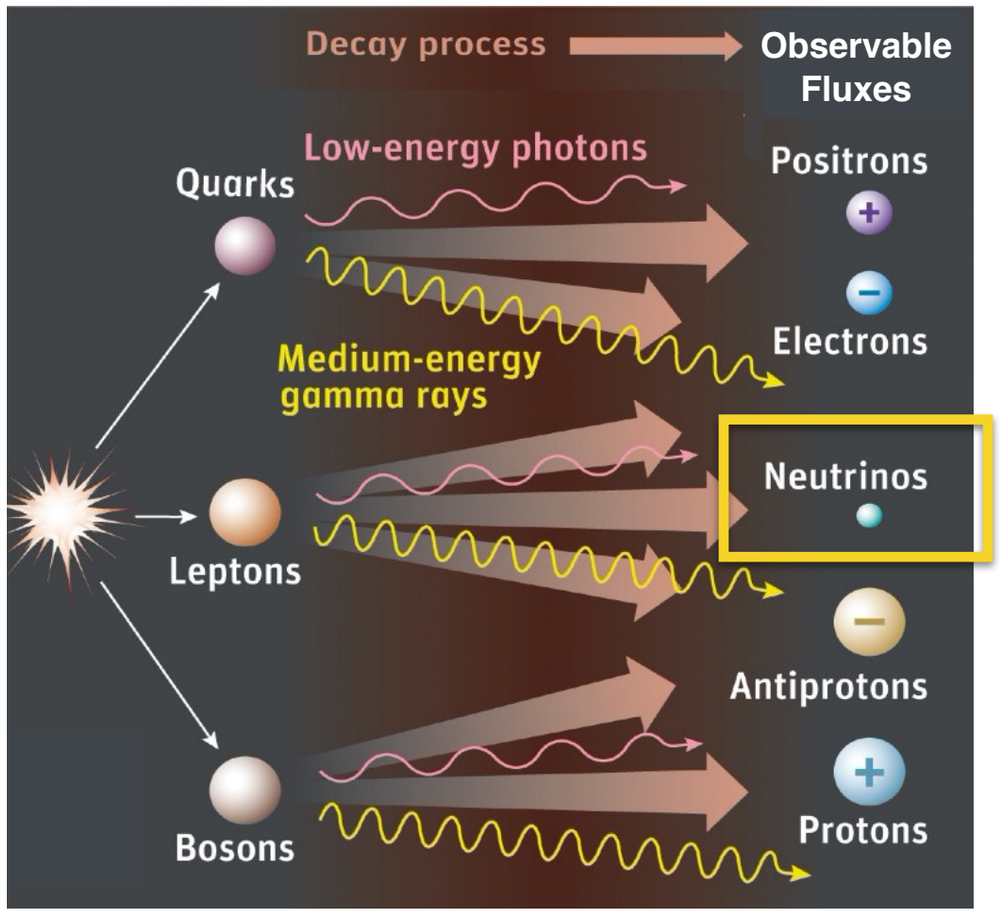
DM annihilation/decay



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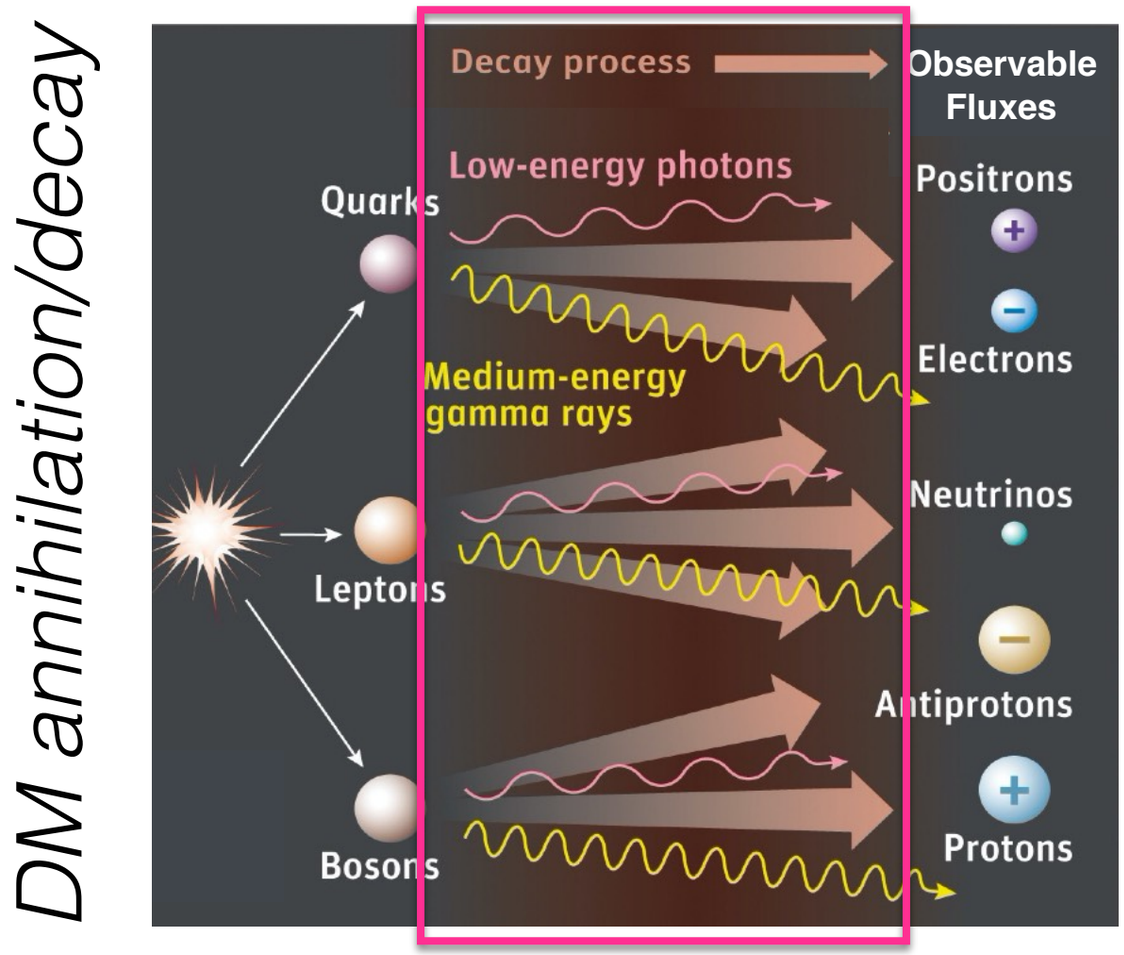

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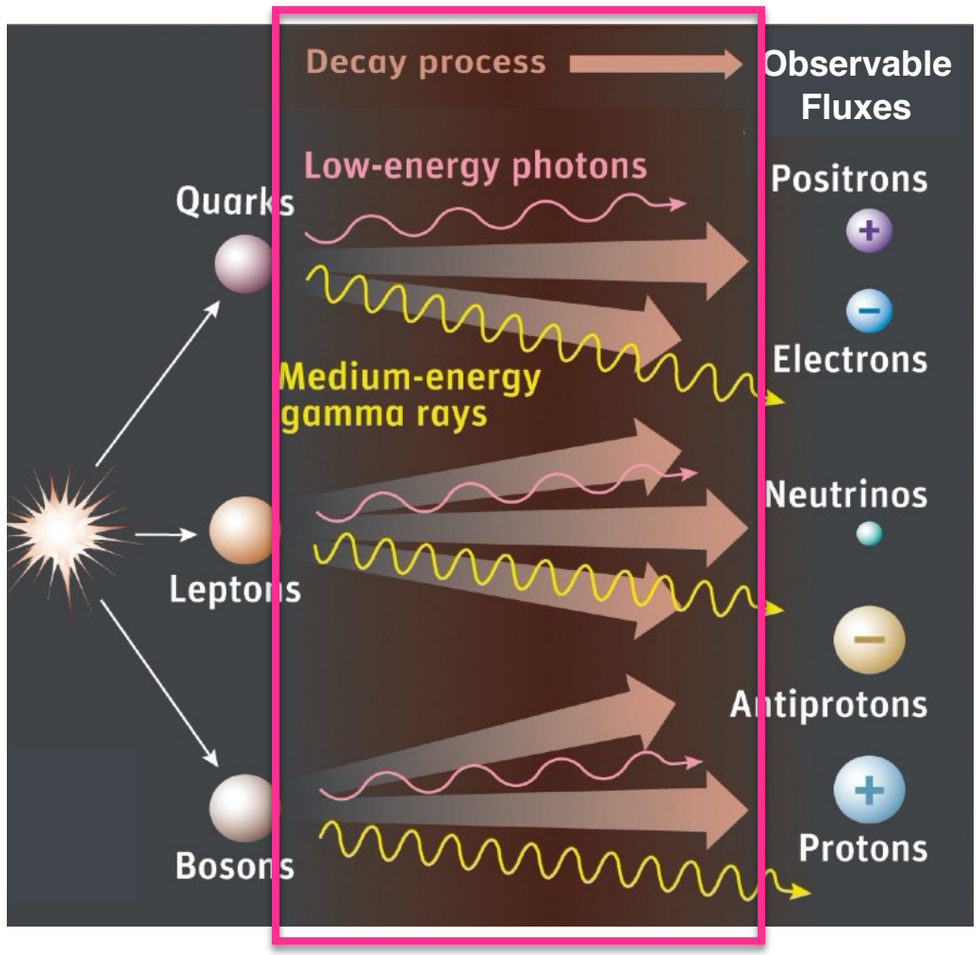
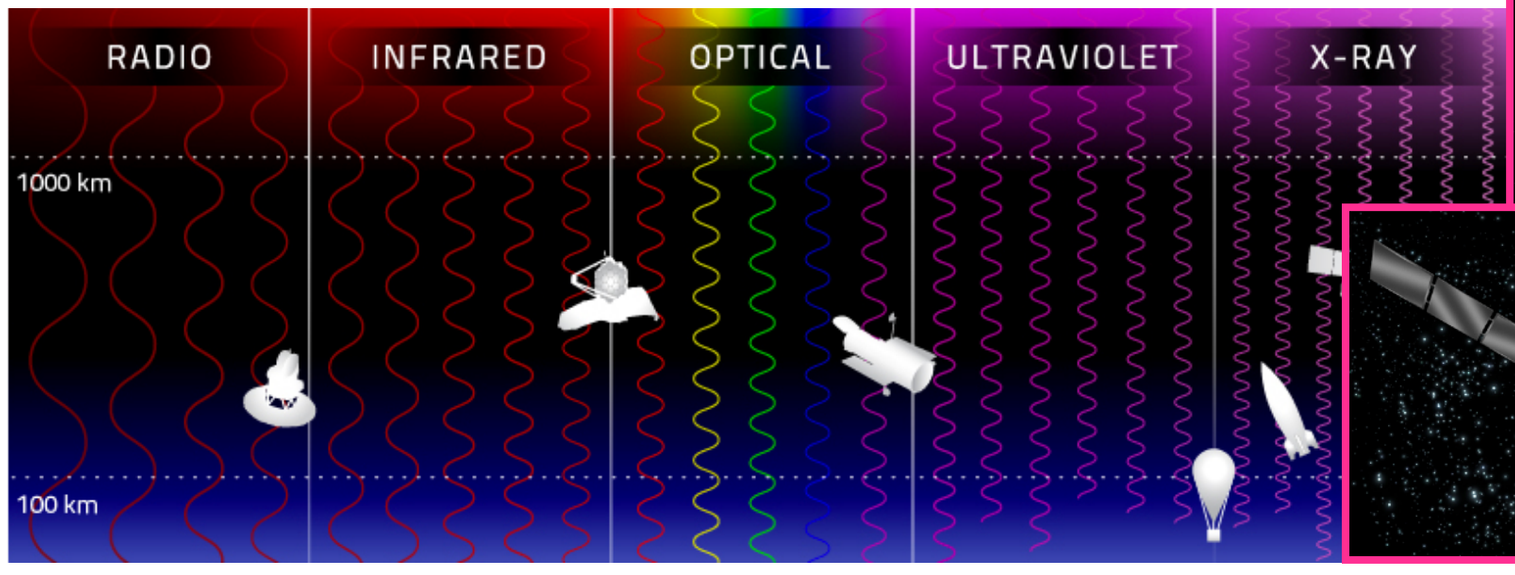


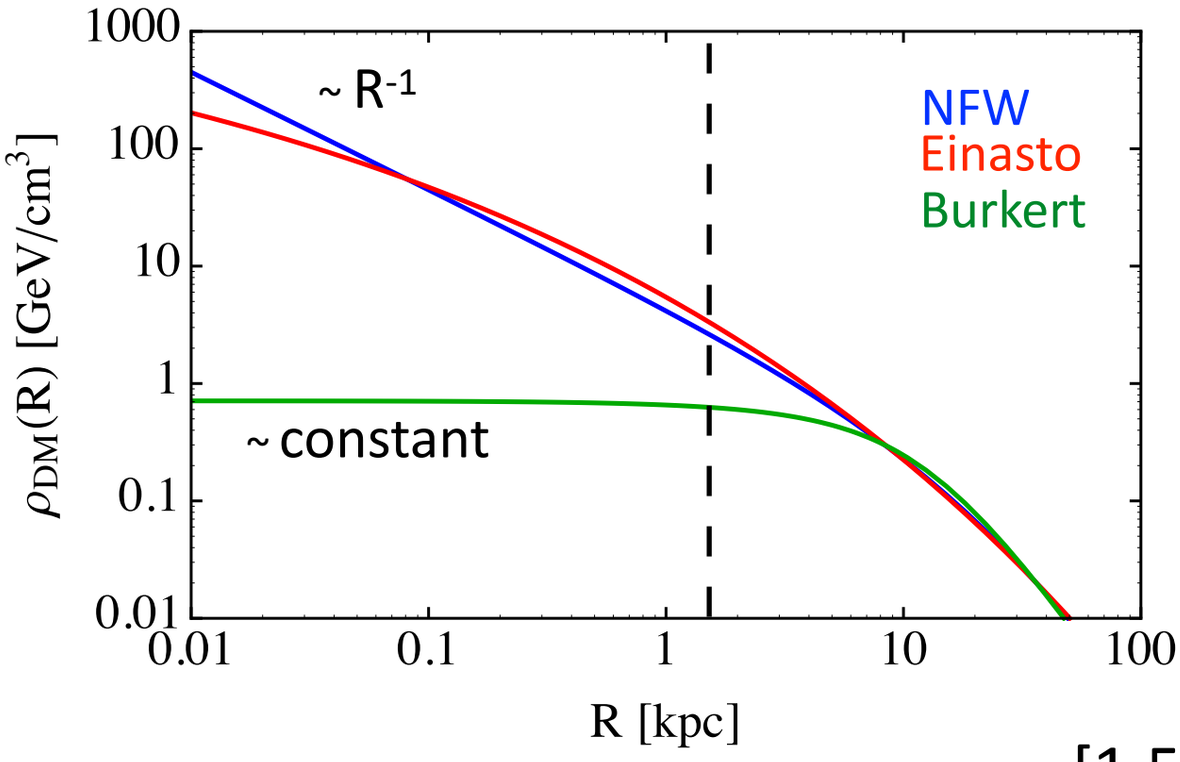


The WIMP gamma-ray flux

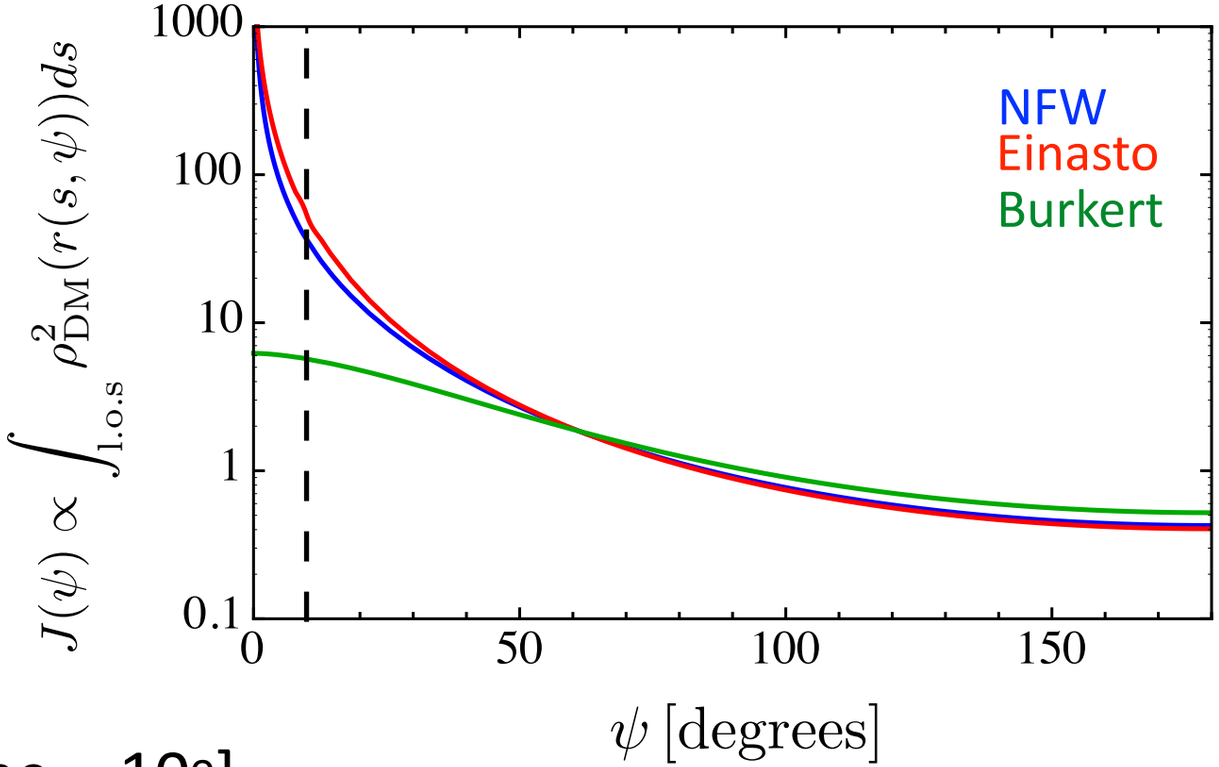
E.g: gamma-ray differential flux from spatial distribution $\rho_{\rm DM}$

$$\frac{d\Phi_\gamma}{dE_\gamma}(E_\gamma, s, \Delta\Omega) \propto \frac{\langle\sigma v\rangle}{2m^2_{\rm DM}} \sum_i B_i \frac{dN^i_\gamma}{dE_\gamma} \frac{1}{4\pi} \int_0^{\Delta\Omega} d\Omega \int_{\rm l.o.s} \rho^2_{\rm DM}(s) ds$$

Dark matter density profiles:



Spatial distribution of the signal:

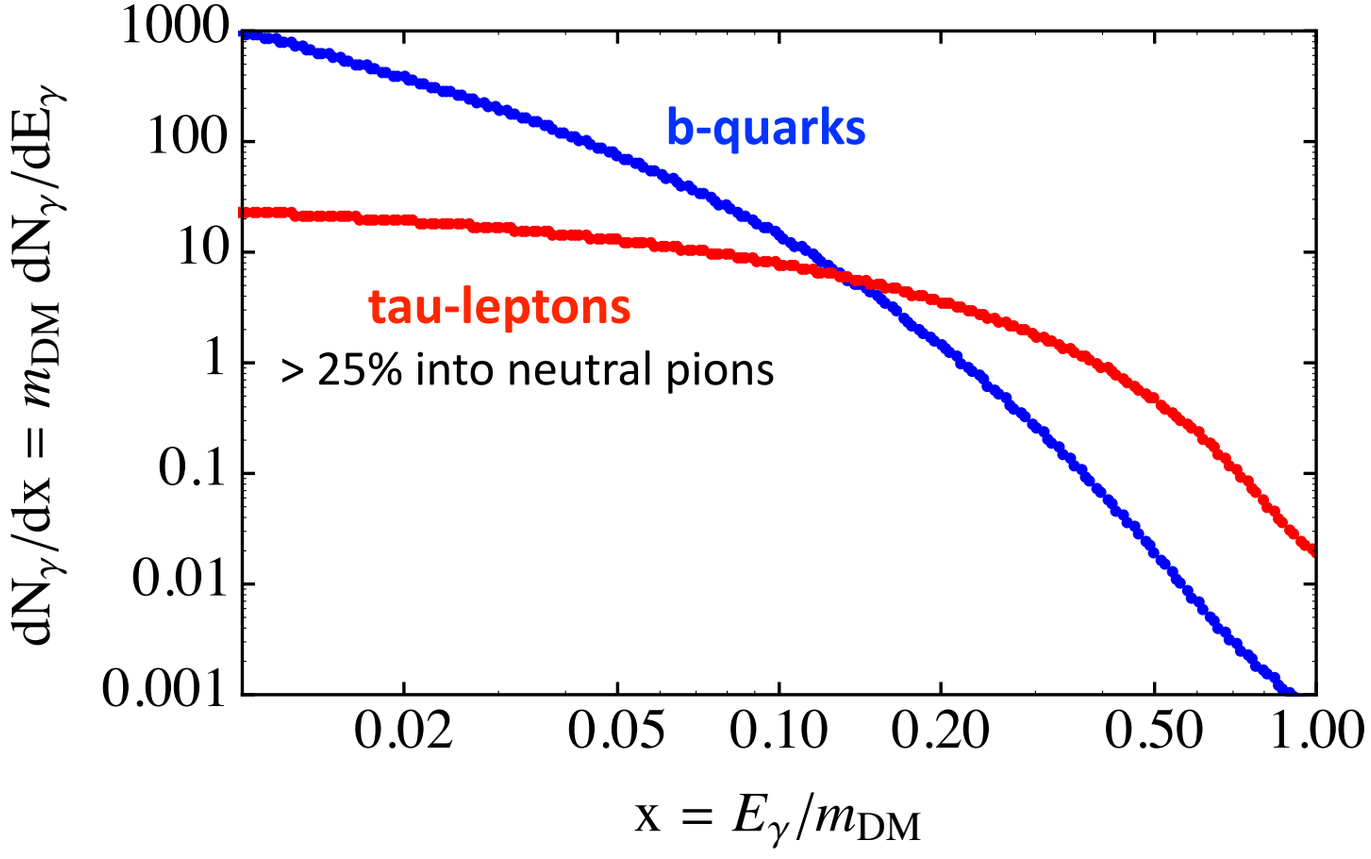


[1.5 kpc ≃ 10º]

Spectra of prompt “secondary” photons

$$\frac{d\Phi_\gamma}{dE_\gamma}(E_\gamma, s, \Delta\Omega) = \frac{\langle\sigma v\rangle}{2m^2_{\rm DM}} \sum_i B_i \frac{dN^i_\gamma}{dE_\gamma} \frac{1}{4\pi} \int_0^{\Delta\Omega} d\Omega \int_{\rm l.o.s} \rho^2_{\rm DM}(s) ds$$

100% Branching ratio (independent on PP model)



$$x \equiv \frac{E_X}{m_\chi}$$

$$\frac{dN_X}{dx} \equiv m_\chi \frac{dN_X}{dE}$$

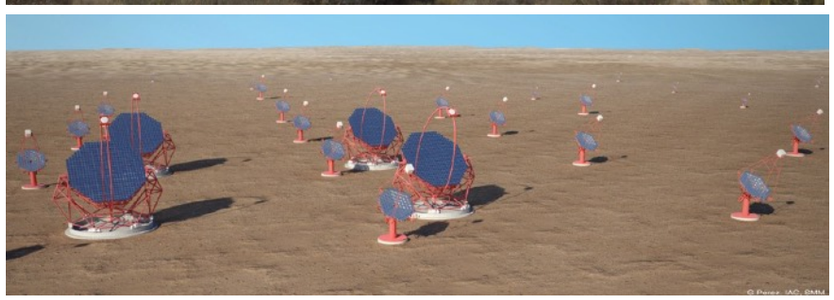
Gamma-ray instruments

D. Maurin's lectures

Space-based telescopes
(aboard satellites)

Fermi-LAT
AGILE
AMS-02
Gamma-400
…

Ground-based telescopes
(Cherenkov telescopes)



HESS
MAGIC
VERITAS
CTA
…

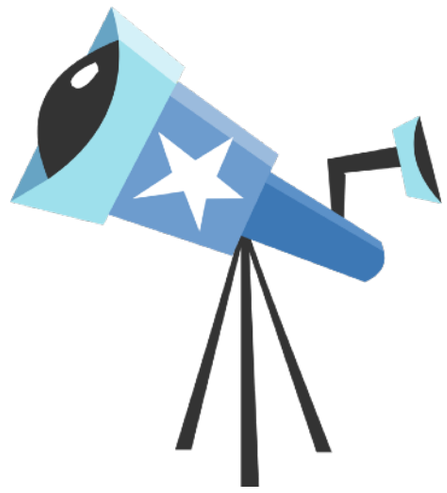
General about DM searches

Observed Flux

$$\Phi_{\mathrm{Obs}}$$

Expected Flux

$$\Phi_{\mathrm{Th}}$$



General about DM searches

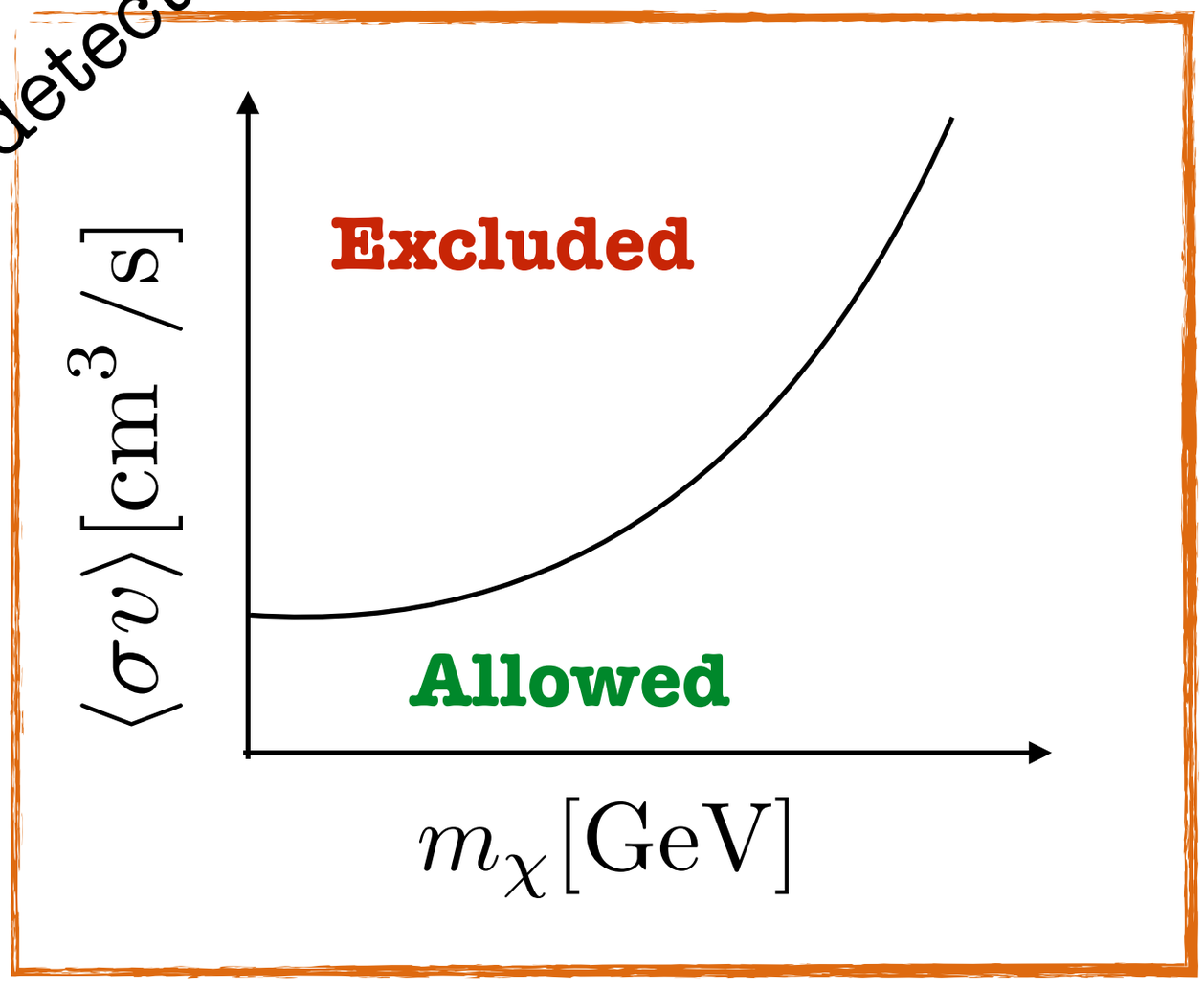
Observed Flux

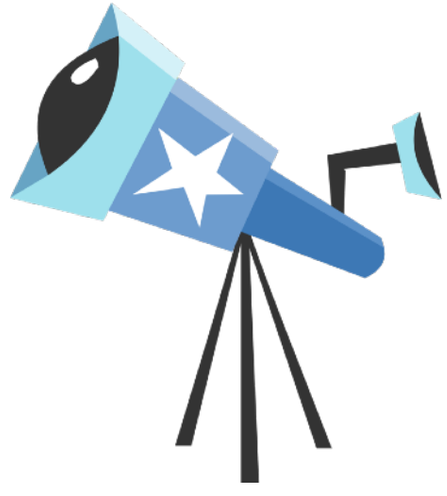
$$\Phi_{\mathrm{Obs}}$$

Expected Flux

$$\Phi_{\mathrm{Th}}$$

No signal detection





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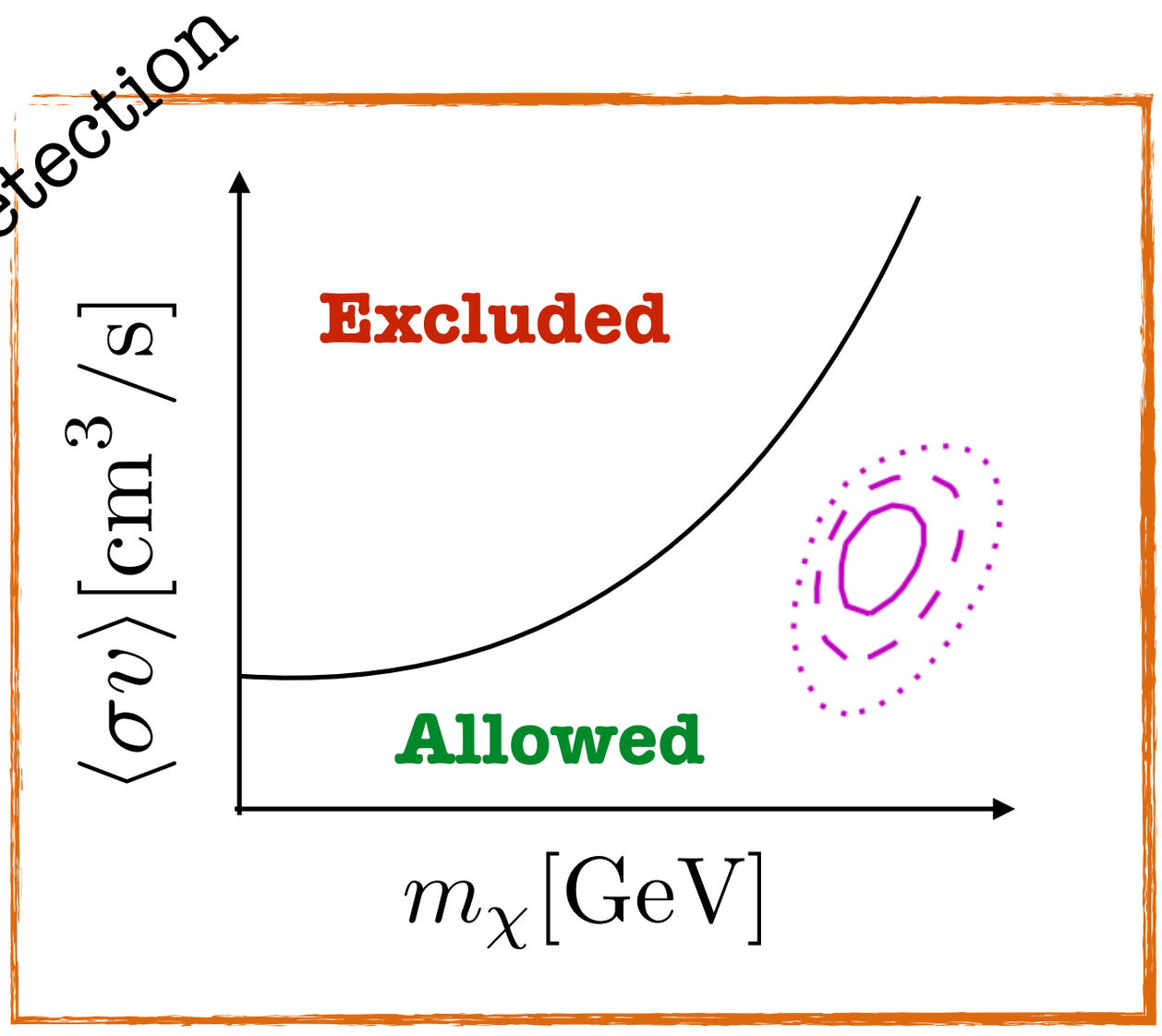
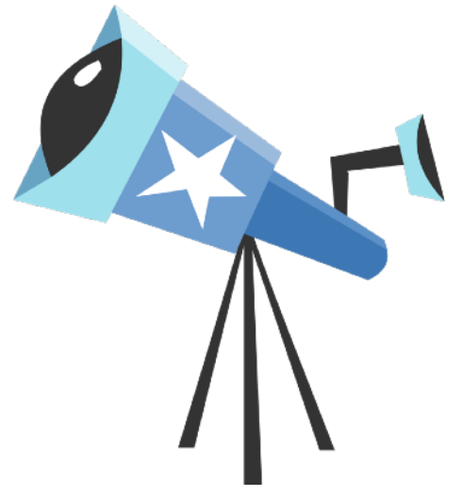
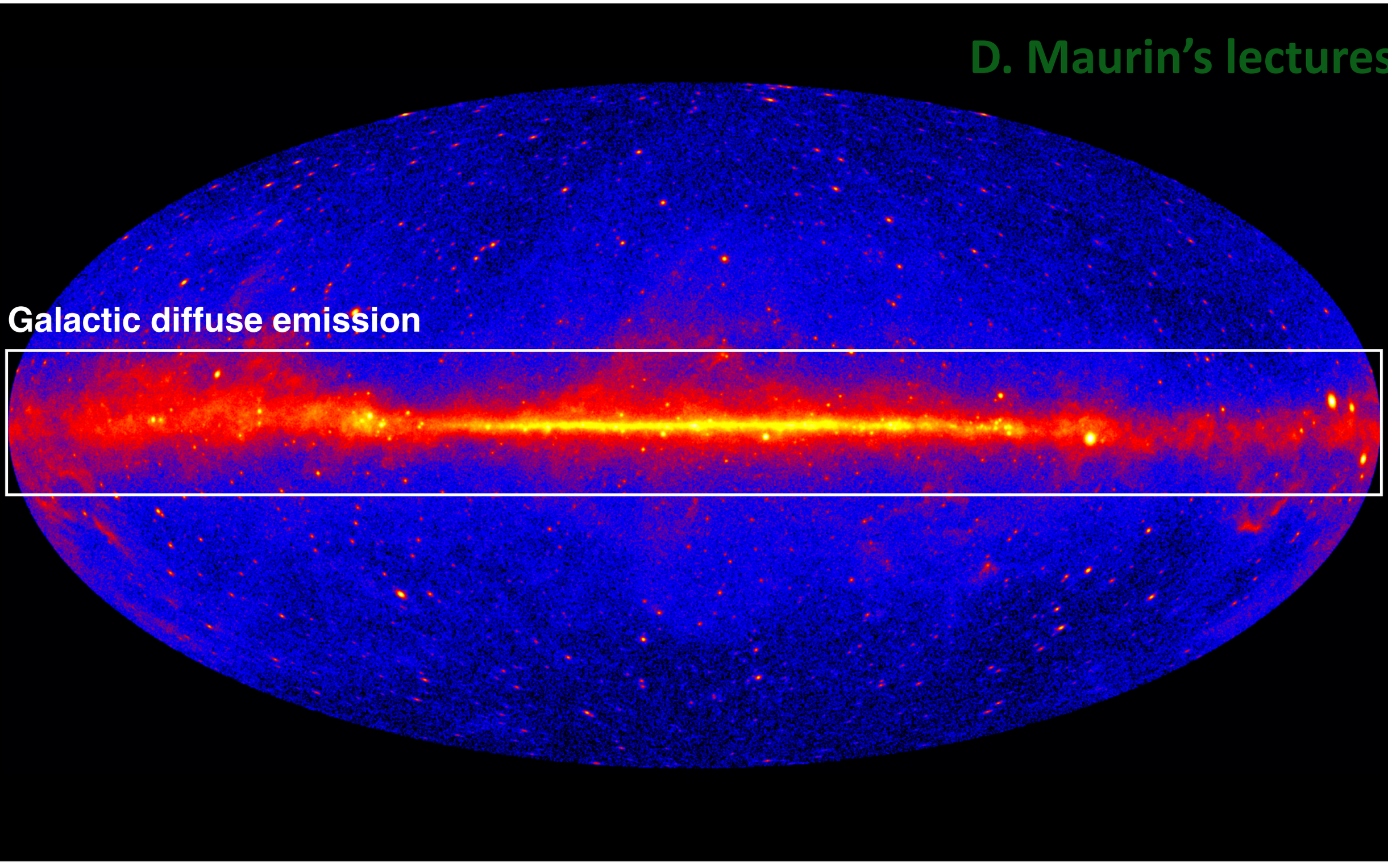




The Fermi-LAT gamma-ray sky

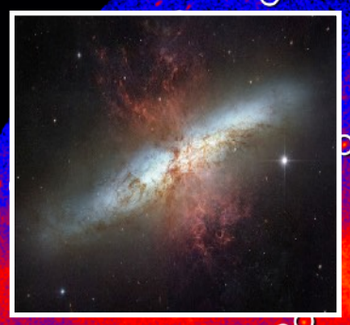
Astrophysical components: The Galactic diffuse emission

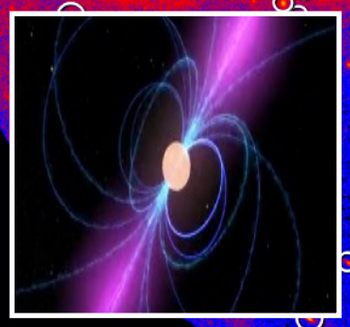
D. Maurin's lectures

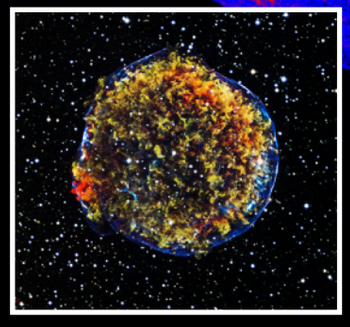


Astrophysical components: Detected sources and Fermi bubbles

Detected sources



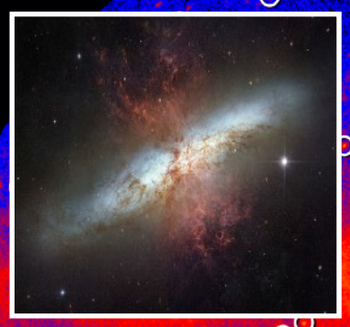


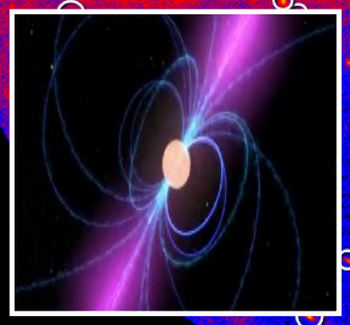


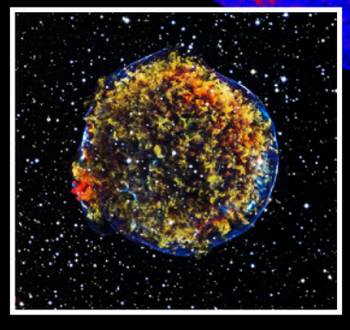
3FGL

Astrophysical components: Detected sources and Fermi bubbles

Detected sources





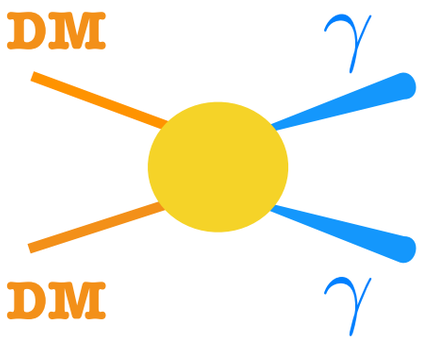


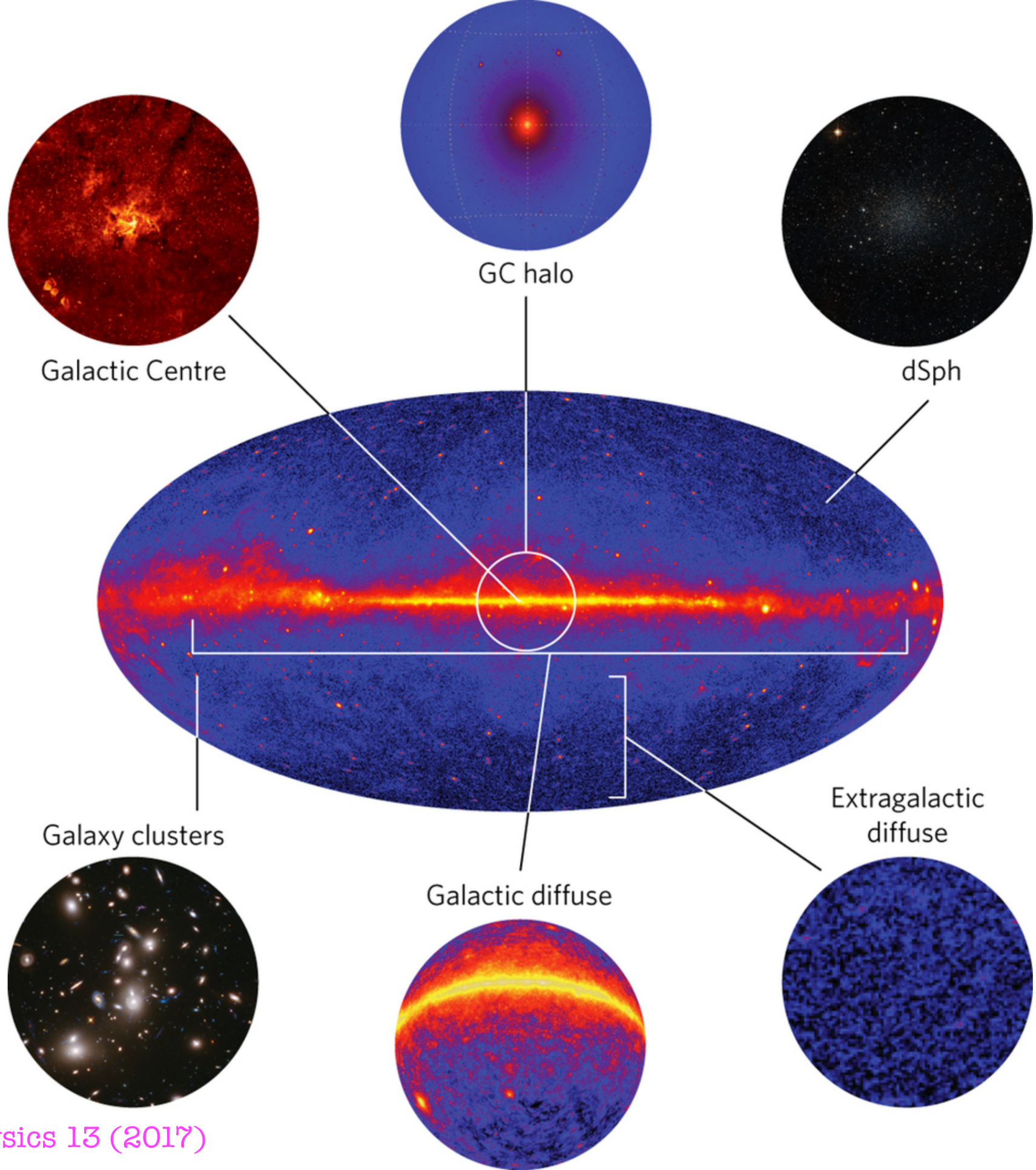
3FGL

Fermi bubbles

Su+ ApJ'10;
Fermi-LAT Coll. ApJ'14

Targets for dark matter searches





+ dedicated searches for gamma-ray lines

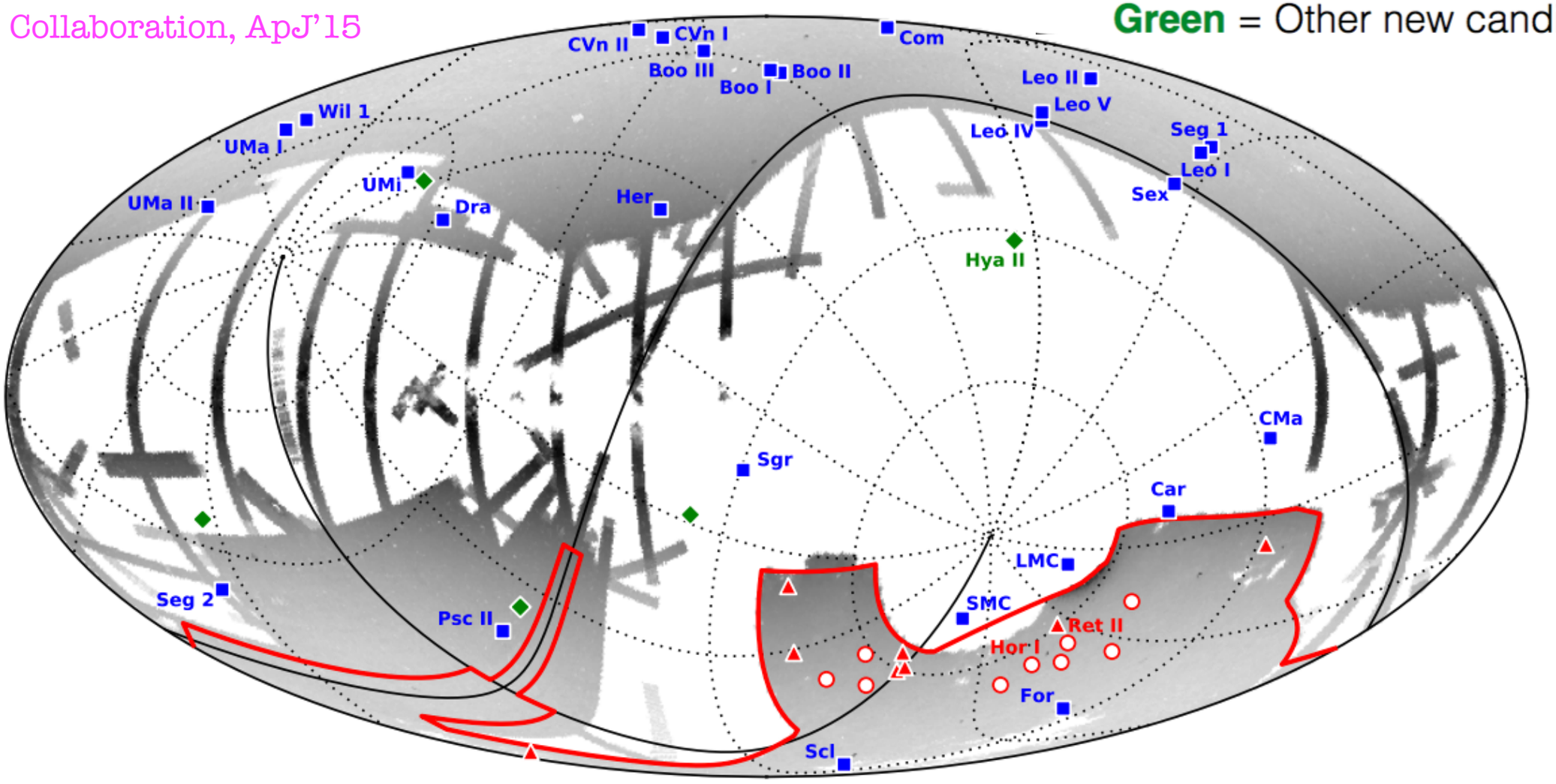
Conrad & Reimer Nature Physics 13 (2017)

Known dwarf spheroidal galaxies

Stellar density field from SDSS and DES

DES Collaboration, ApJ'15

Blue = Known prior to 2015
Red triangles = DES Y2Q1 candidates
Red circles = DES Y1A1 candidates
Green = Other new candidates

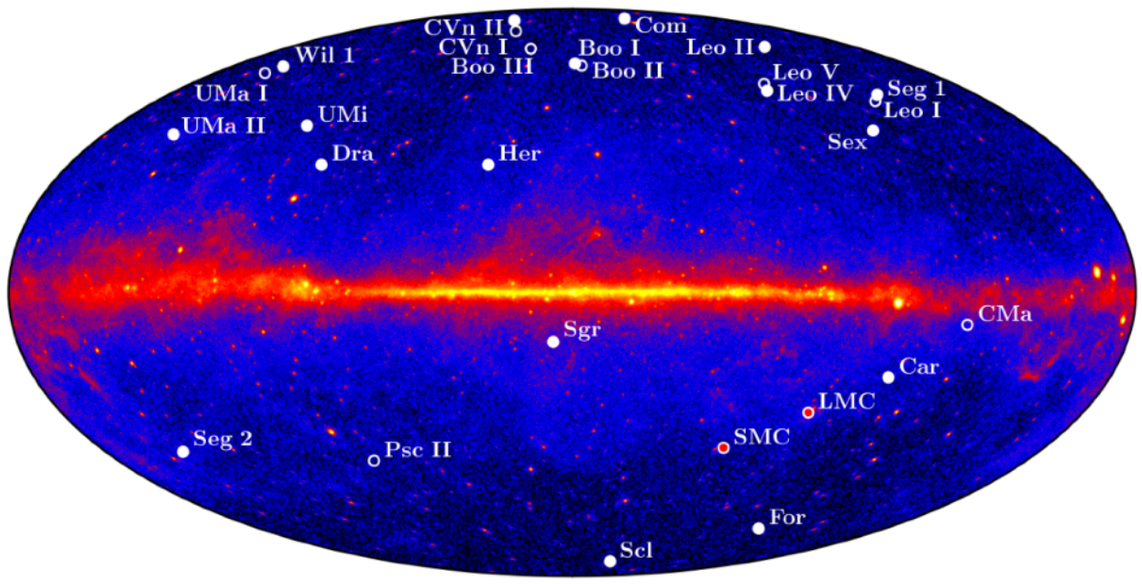


SDSS northern hemisphere, classical + ultra-faint dwarfs

DES southern hemisphere, 17 new dwarfs

Pan-STARRS, 3 new candidates

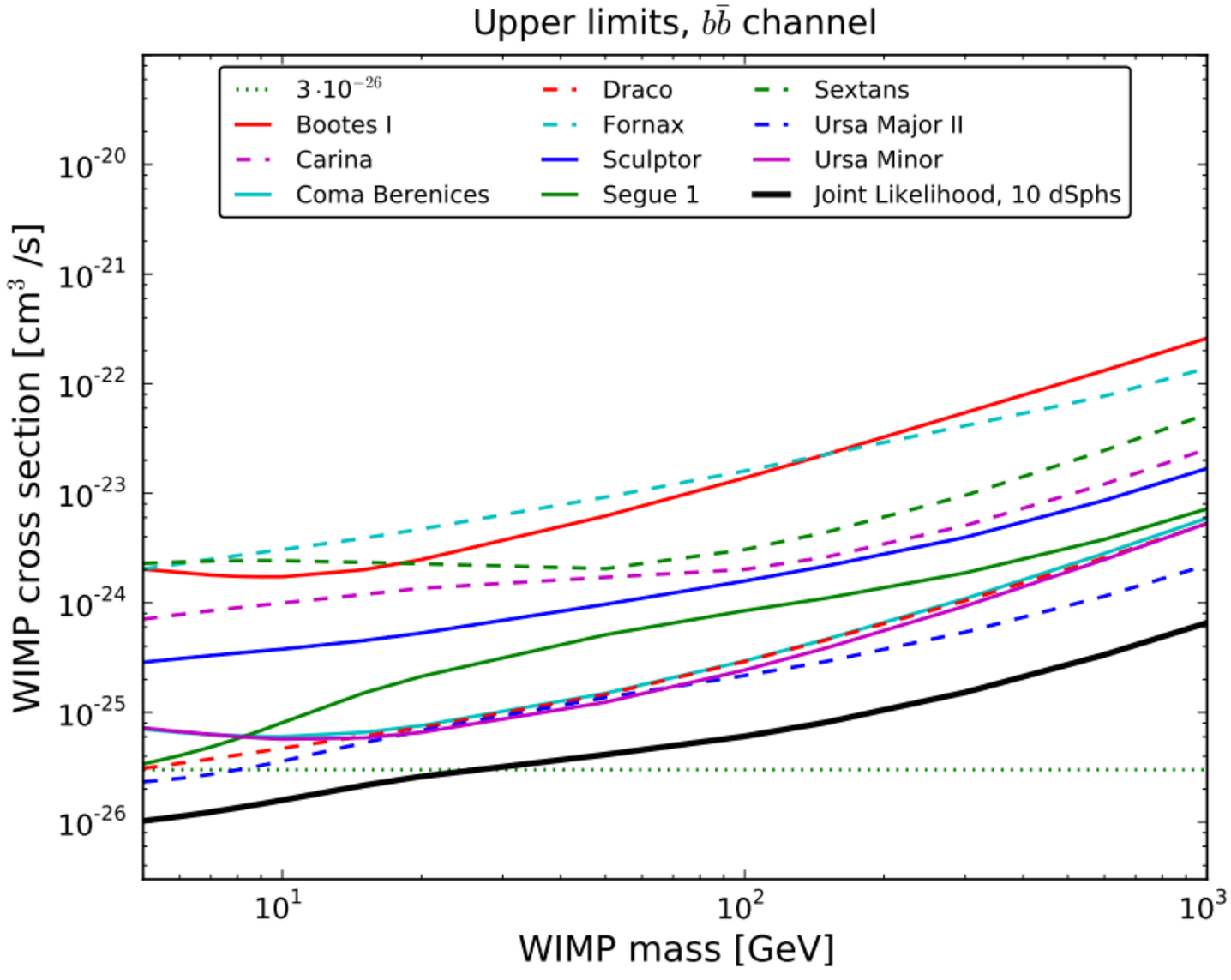
Gamma-ray limits from dSphs



$$L(D|\mathbf{pw},\{\mathbf{p}\}_i) = \prod_i L_i^{\mathrm{LAT}}(D|\mathbf{pw},\mathbf{p}_i) \times \frac{1}{\ln(10)\, J_i \sqrt{2\pi}\sigma_i} e^{-\left[\log_{10}(J_i)-\overline{\log_{10}(J_i)}\right]^2/2\sigma_i^2}$$

Analysing dSphs as a group results in sensitivity competitive with other targets —> **Stacking technique**.

Fermi-LAT Collaboration, PRL'11



Tutorial: dark matter limits from Draco

Link to Tutorial instructions