Celestial Objects as Dark Matter Colliders

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In collaboration with: **Tim Tait**[2] , *PRD*, arXiv:2212.12547
Tim Tait, and **Tim Linden**[3], in preparation

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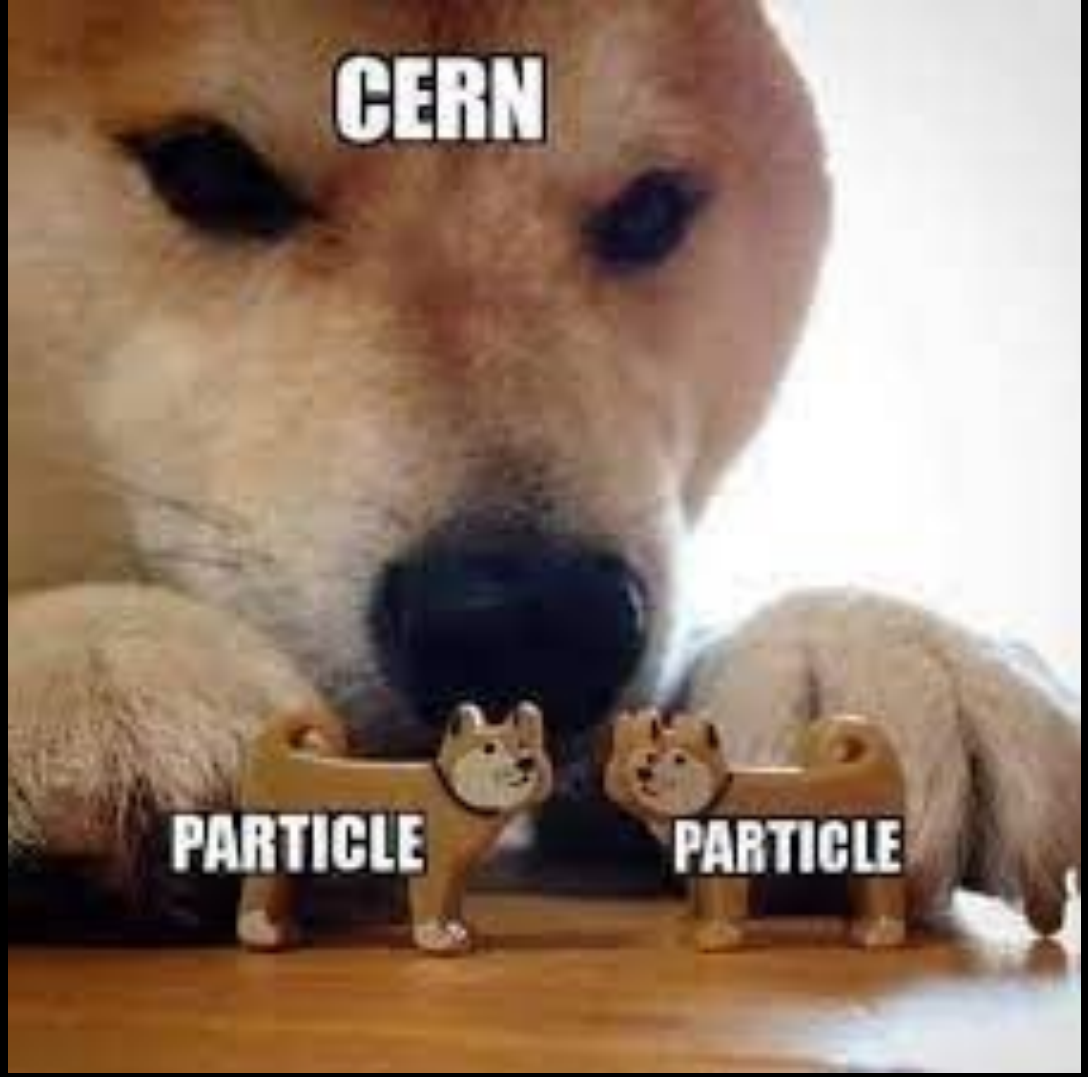
Windows on the Universe - 30th Anniversary of the Rencontres du Vietnam


CERN
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Dark Matter
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Dark Matter
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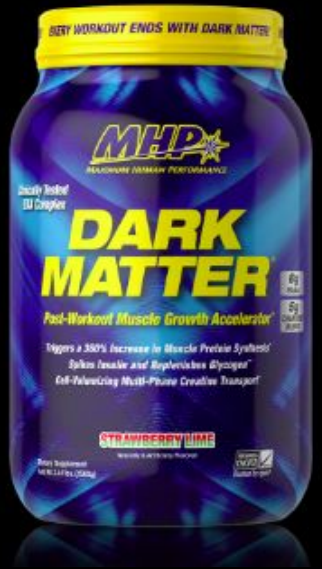
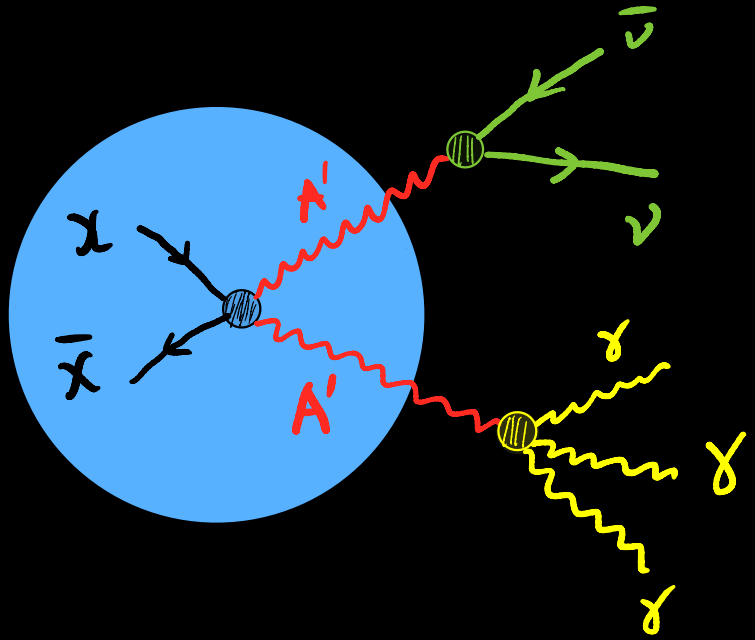
Outline


EVERY WORKOUT ENDS WITH DARK MATTER
MHP
DARK MATTER
Post-Workout Muscle Growth Accelerator
STRAWBERRY LIME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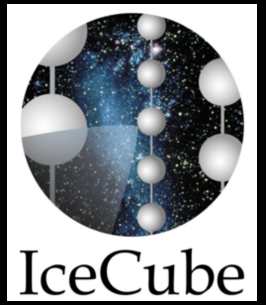
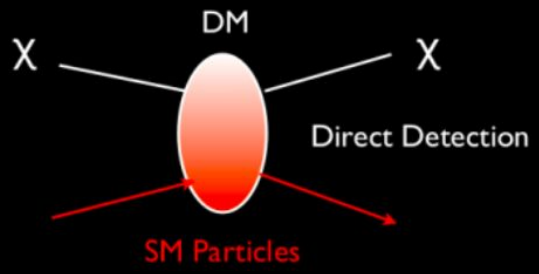
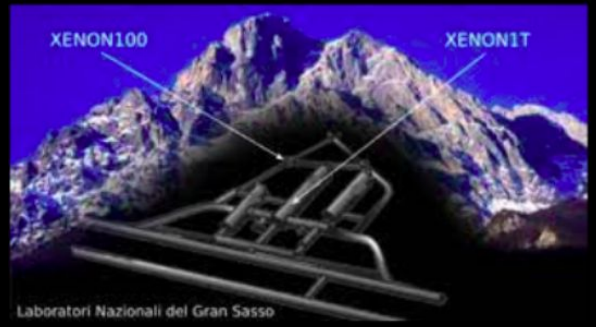

IceCube

General Dark Matter Detection Methods

Signature: recoiled energies.





More details in Prof. Fei Gao's talk!

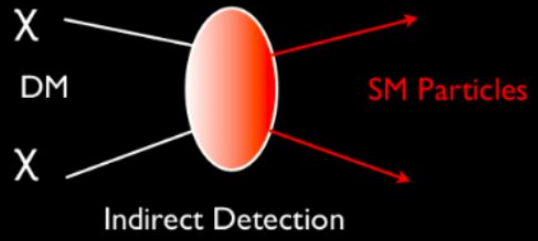
$\sigma_{\chi n}$

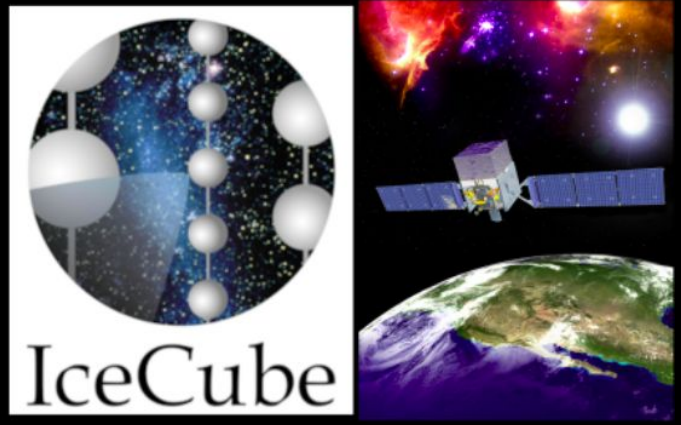
$\sigma_{\chi n}$

arXiv:2212.12547

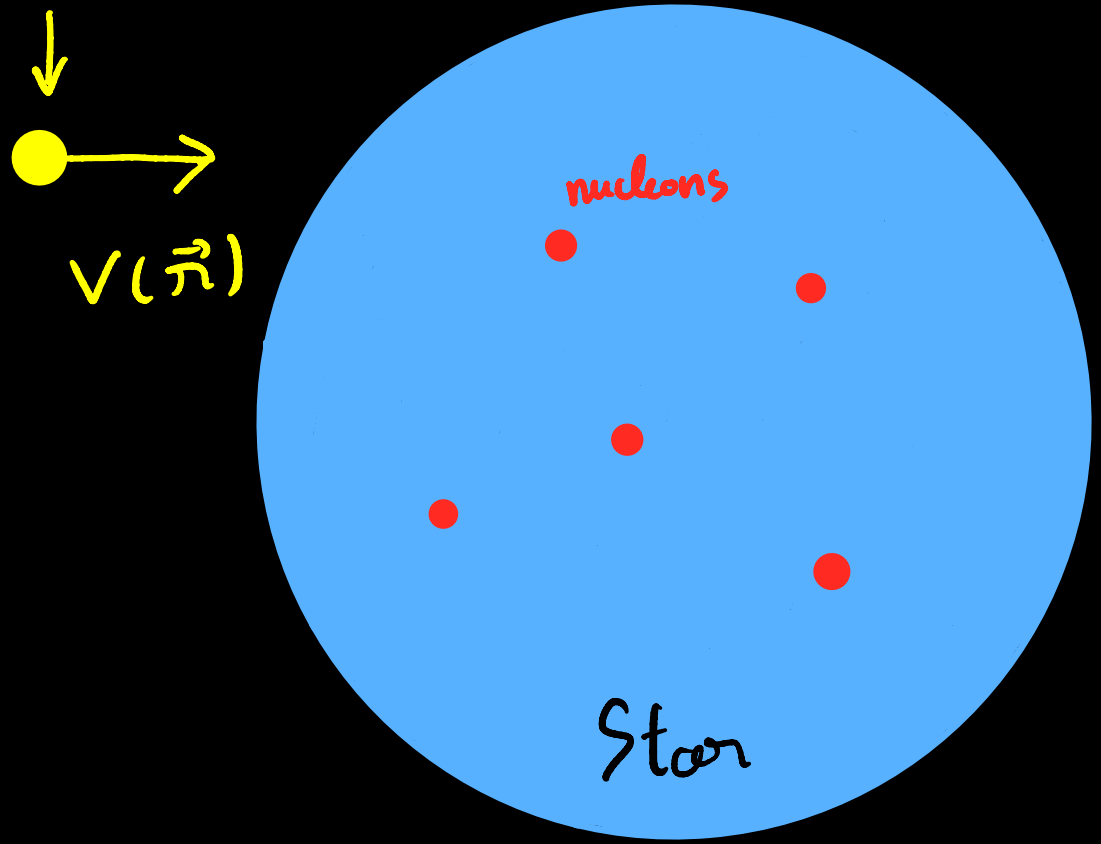
$\langle \sigma_{\chi\chi} \rangle$

Signature: stable SM $(e^+, p, \gamma, \nu, \ldots)$.





Dark Matter Capture



Scattering N^{th} times:

$v_N \leq v_{esc}$

Captured!

Capture Rate $[\ s^{-1}\ ]$

$$C \sim \frac{\rho_\chi}{m_\chi} \times P(\tau) \times F(v, v_{esc})$$

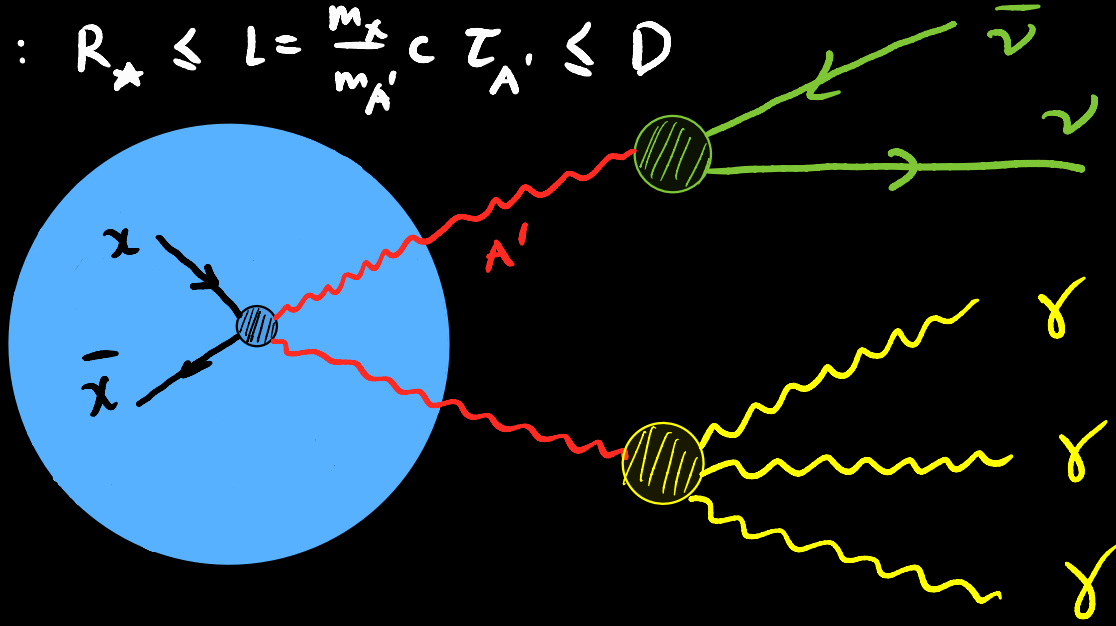
Optical depth : $\tau = 1.5\, \underline{\sigma_{\chi n}} \rightarrow$ DM model

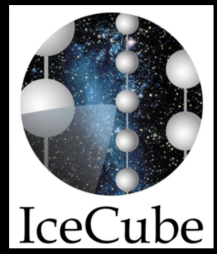
$\sigma_{sat} \rightarrow$ Compact Object

Dark Matter density (Generalized NFW) : $\rho_{NFW}(r) = \dfrac{\rho_0}{\left(\frac{r}{r_s}\right)^{\gamma}\left(1+\frac{r}{r_s}\right)^{3-\gamma}}$

Dark Matter Annihilation in Compact Objects

Limits: $R_\star \lesssim L = \frac{m_\chi}{m_{A'}} c\,\tau_{A'} \lesssim D$

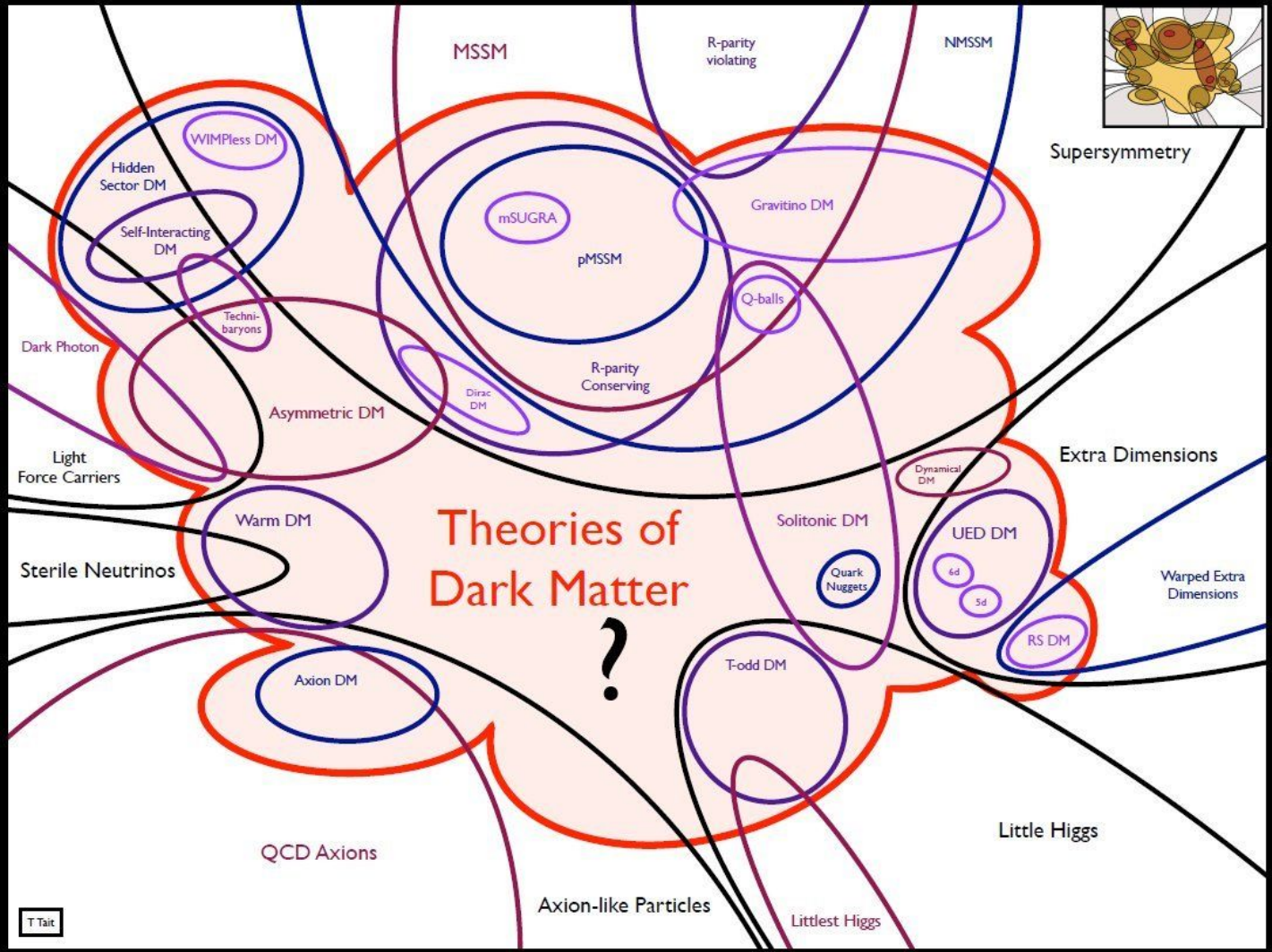




Energy Flux: $E^2 \frac{d\Phi}{dE} \sim \frac{C(\tau)}{D^2} BR(A' \to SM)$

Which DM model?

Our choice

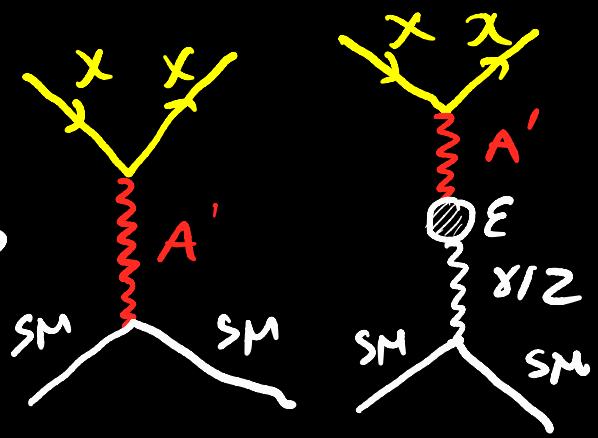


Dark Photon model: $SU(2)_L \times U(1)_Y \times U(1)_X$

$$\mathcal{L} \supset \bar{X}\left(i\not{\partial}_{U(1)_X} - m_X\right)X$$

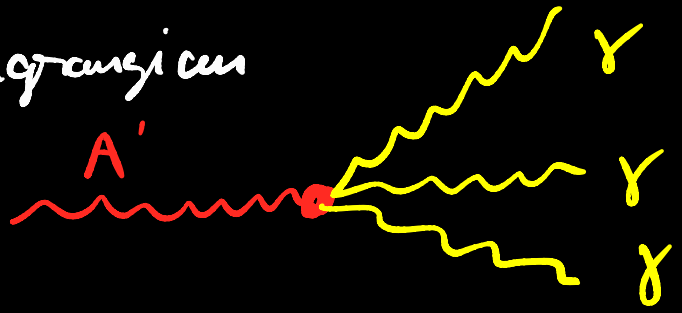
$$- \frac{1}{2} m_{A'}^2 A'_\mu A'^\mu - \frac{\varepsilon}{2} B'_{\mu\nu} B^{\mu\nu}$$

$$m_{A'} < m_e$$

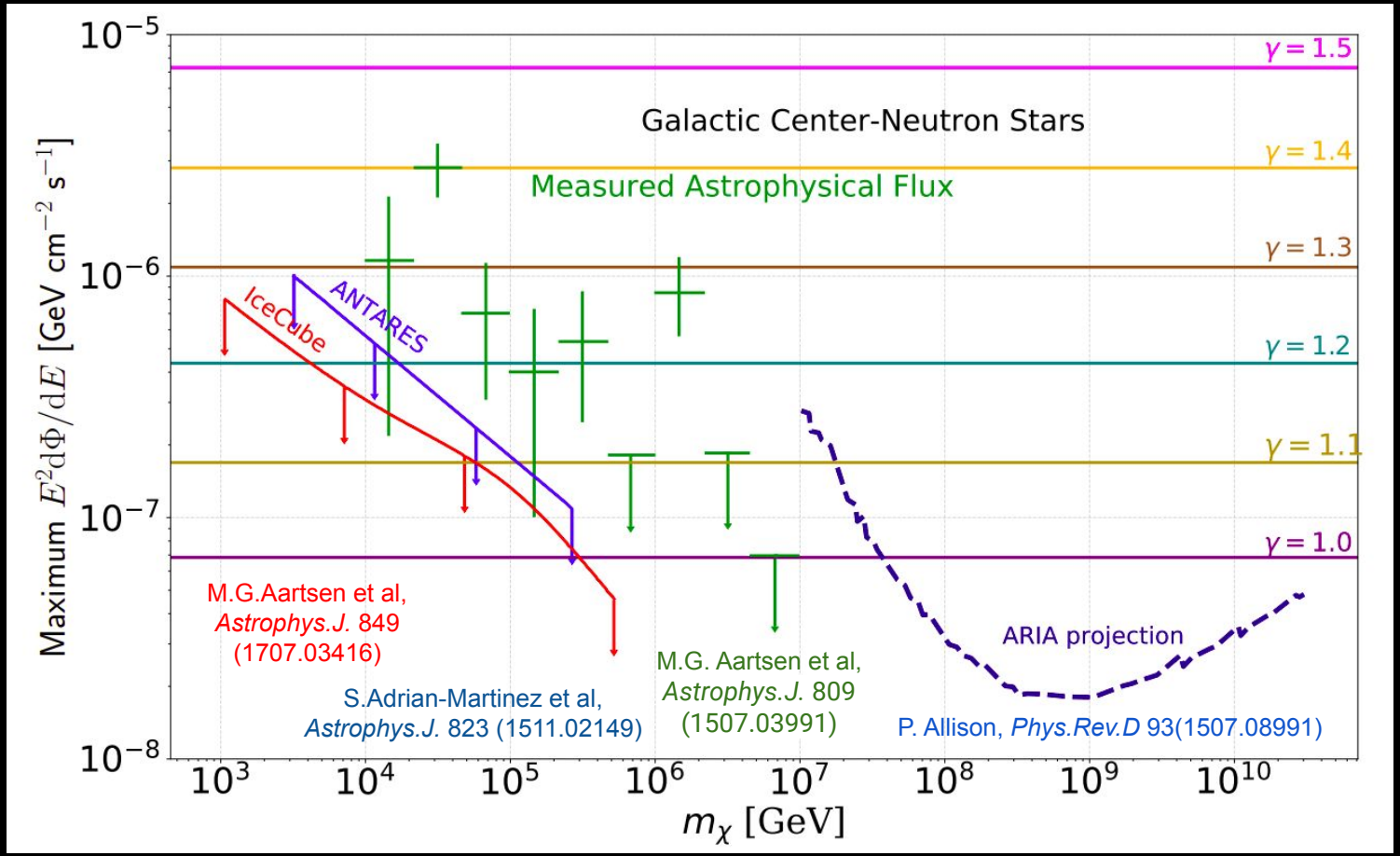


Euler - Heisenberg Lagrangian

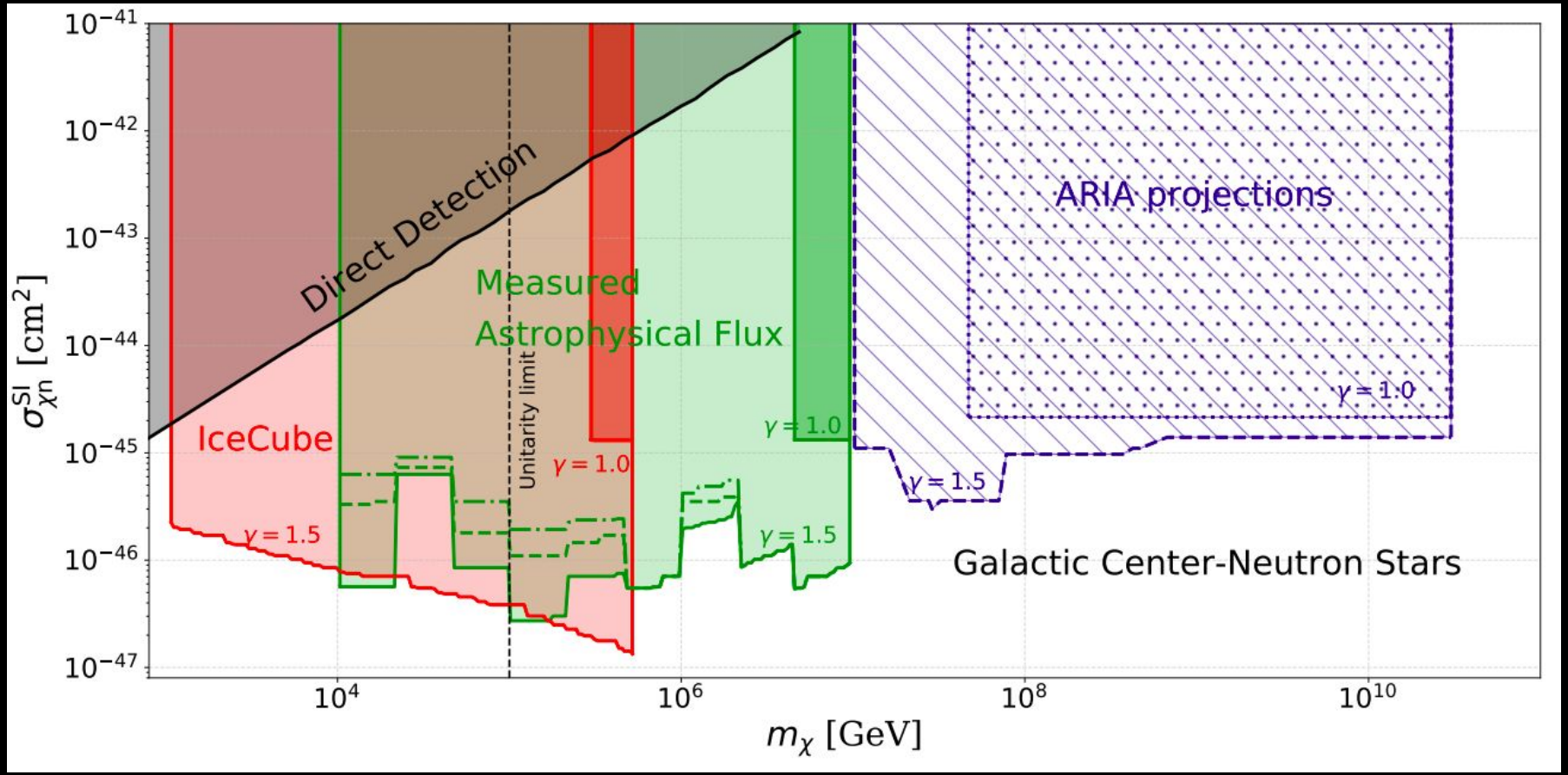
$$\mathcal{L}_{EH}^{Dark} \longrightarrow$$



Neutrino Experimental limits



SI Cross section bounds above TeV

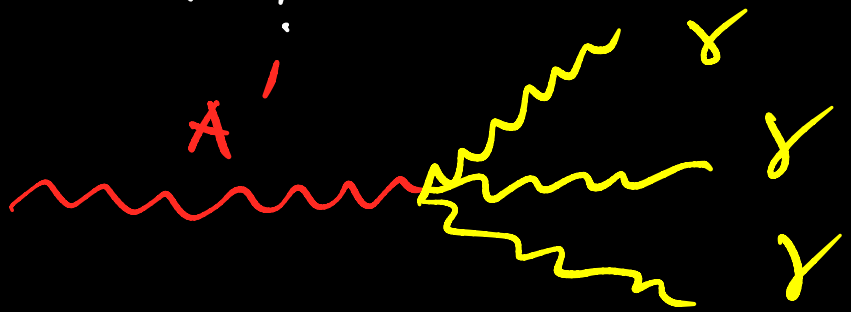


Ongoing work: Photon tridents

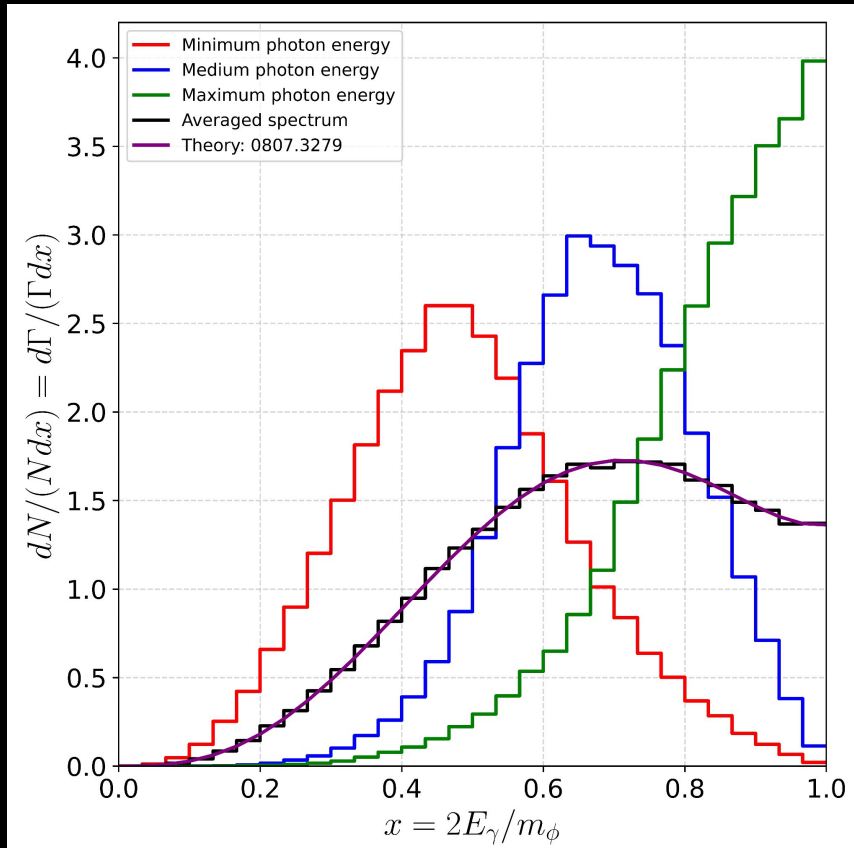
$$m_{A'} \ll m_e$$

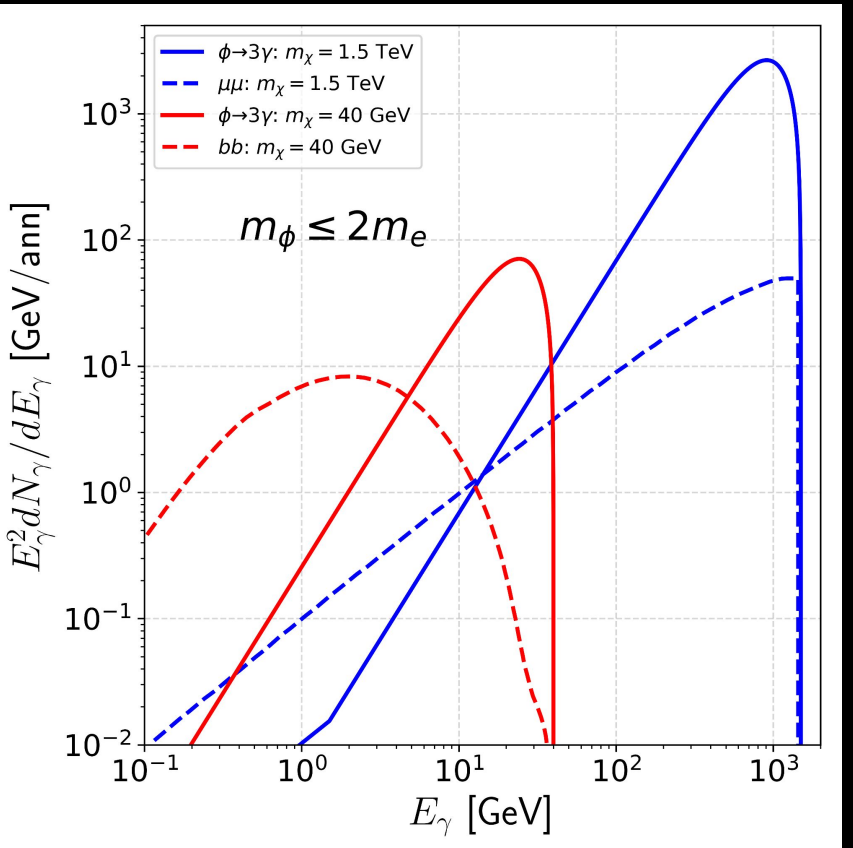
$$\mathcal{L}_{EH}^{dark} = \frac{\varepsilon \alpha^2}{45 m_e^4} \left(14 F'_{\mu\nu} F^{\nu\lambda} F_{\lambda\rho} F^{\rho\mu} - 5 F'_{\mu\nu} F^{\mu\nu} F_{\alpha\beta} F^{\alpha\beta} \right)$$

(+ FeynRuls) Voila!



Preliminary results: triple photons decay

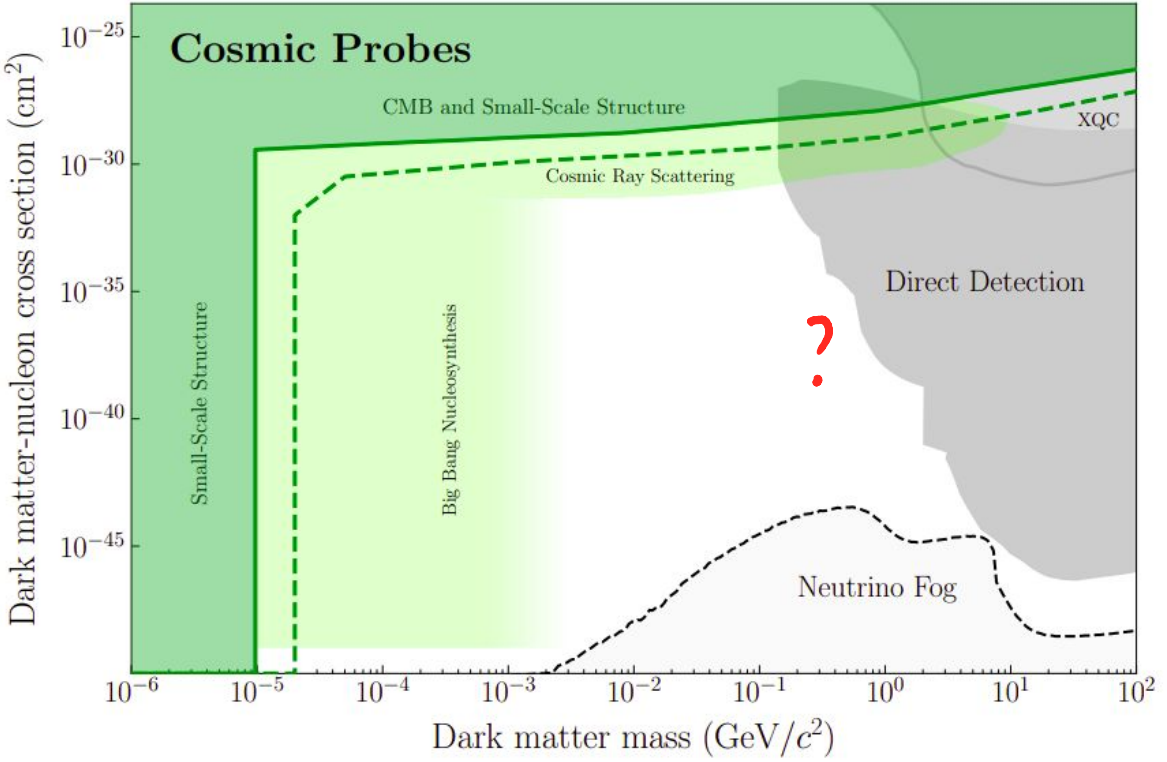




Why?

Fermi Gamma-ray Space Telescope

HAWC
High Altitude Water Cherenkov
Gamma-Ray Observatory



Take home message

High Energy Physics

- Can play with other models
- Improvement on the limits: IceCube-Gen2, Auger, ANITA, KM3Net, …
- (Extreme) Long-lived particle models.
- Probing neutrino-fog region.

Astrophysics

- JWST!!!
- Halo mass modelling.
- Different celestial objects: Brown Dwarfs, Magnetars, Pulsars, Exoplanets, ...

Thank you for listening!