Celestial-body focused dark matter annihilation throughout the galaxy

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Overview

1) Dark matter capture in compact objects

2) DM annihilation via long-lived mediators

3) DM signals from capture in Brown Dwarfs and Neutron Stars

Key idea of the talk

1) Indirect detections typically focus on DM annihilation in galactic halos.

2) We consider a scenario where celestial bodies ‘focus’ annihilations and increases the annihilation efficiency.

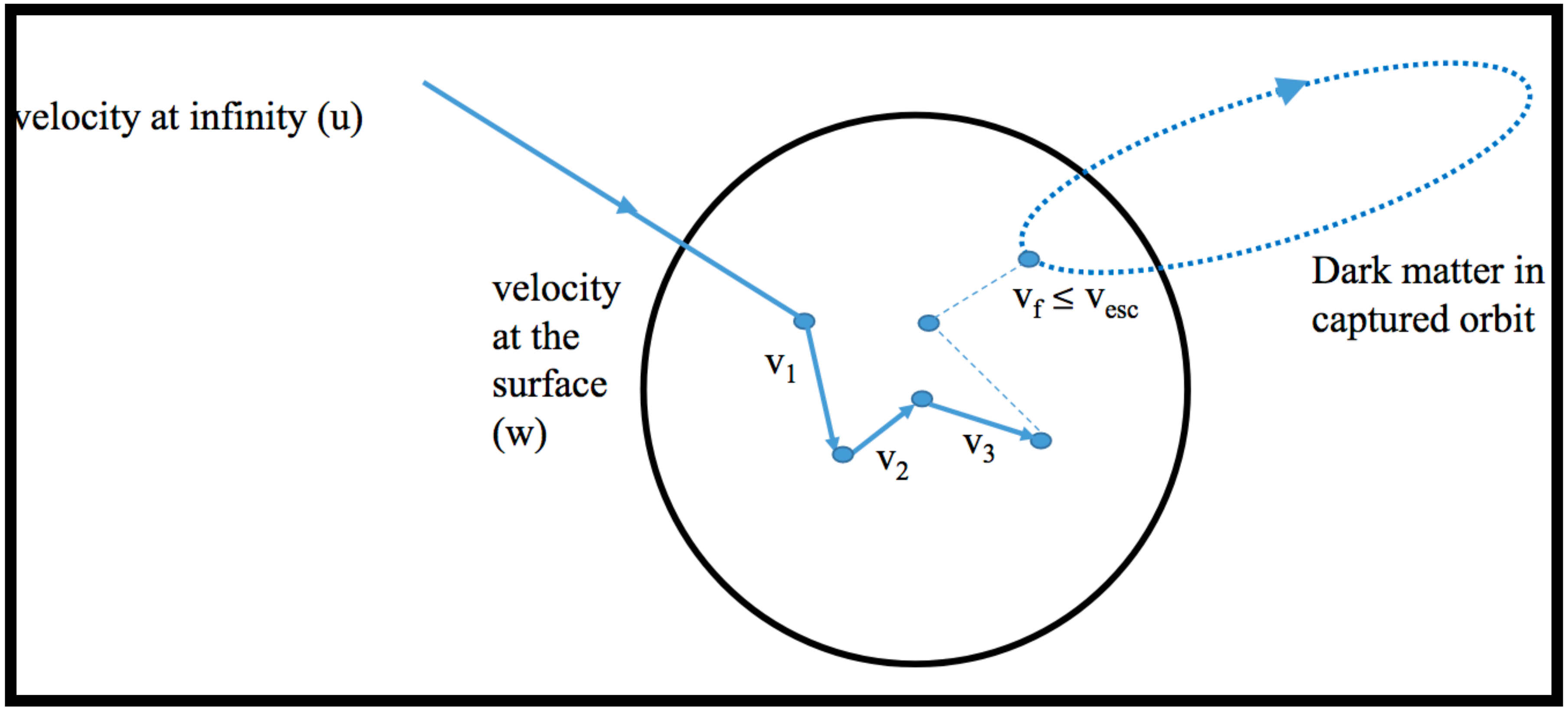
3) DM captured by Neutron Stars (NS) or Brown Dwarfs (BDs) and annihil- -ates within them.

4) Annihilation to long-lived mediators - decay outside of the celestial object.

5) Novel detection signatures.

6) Strong constraints on DM-nucleon scattering cross section.

DM capture in compact objects



$$C_N = \underbrace{\pi R^2}_{\text{area of the object}} \times \underbrace{p_N(\tau)}_{\text{probability for } N \text{ collisions}}$$
$$\times \underbrace{n_{\rm DM} \int \frac{f(u)du}{u} (u^2 + v_{\rm esc}^2)}_{\text{DM flux}}$$
$$\times \underbrace{g_N(u)}_{\text{probability that } v_f \leq v_{\rm esc} \text{ after } N \text{ collisions}} .$$

$$C = \sum_{N=1}^{\infty} C_N,$$

$$C_{\max} = \pi R^2 n_\chi(r) v_0 \left(1 + \frac{3}{2} \frac{v_{\rm esc}^2}{\overline{v}(r)^2}\right) \xi(v_p, \overline{v}(r)),$$

DM Capture and annihilation in Celestial Bodies

$$\frac{dN(t)}{dt} = C_{\rm tot} - C_A N(t)^2$$

$$N(t) = \sqrt{\frac{C_{tot}}{C_A}}\ \tanh(\frac{t}{t_{eq}})$$

$$t_{eq} = 1/\sqrt{C_A C_{tot}}$$

Equilibrium Condition :

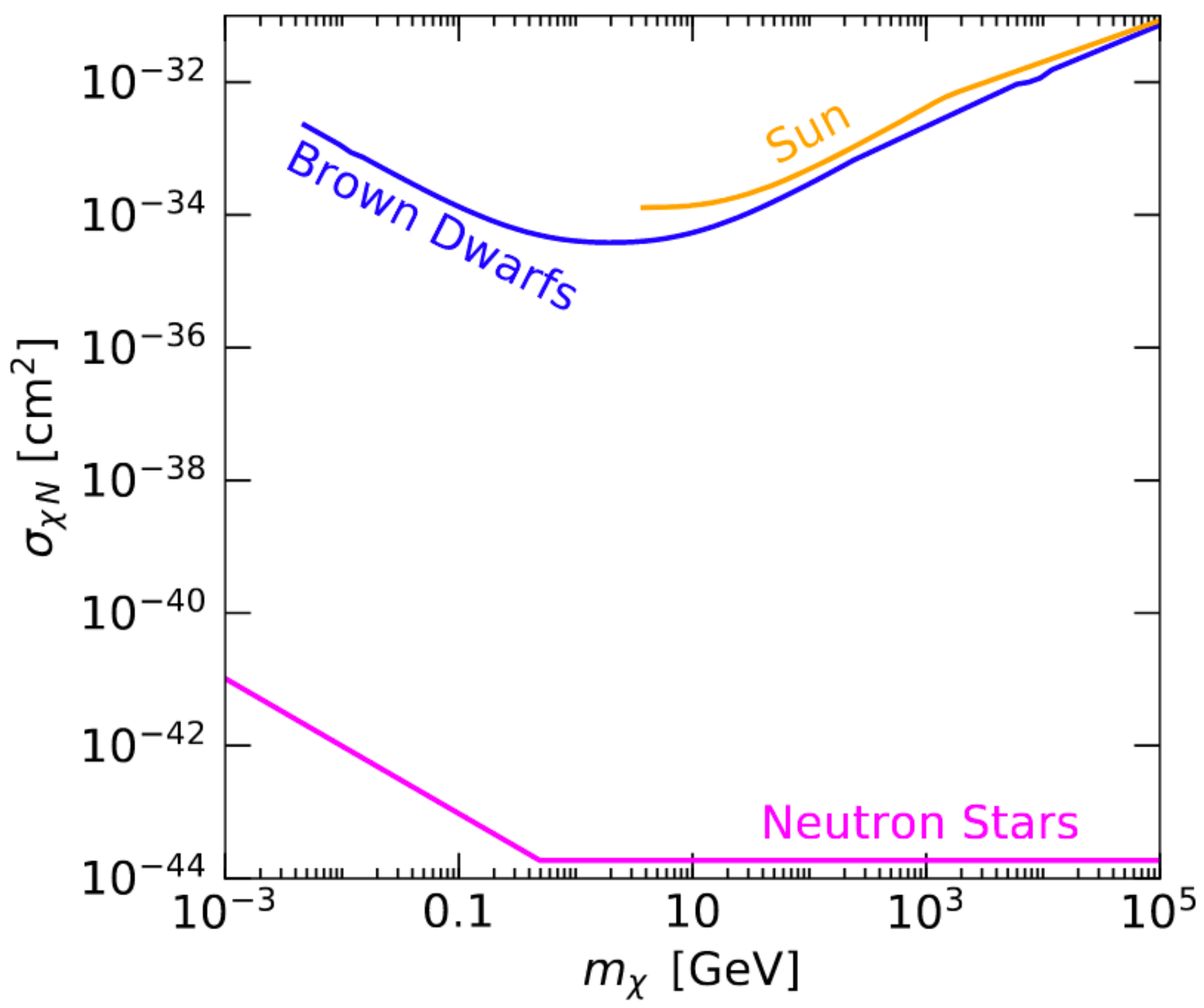
$$\Gamma_{ann} = \Gamma_{cap}/2 = C_{tot}/2 \propto n_\chi$$

$\Gamma_{tot} \propto n_\chi n_{\rm BD/NS}$ **(annihilation proportional to n_χ and $n_{\rm BD/NS}$)**

$\Gamma_{ann,halo} \propto n_\chi^2$ **(Standard halo annihilation $\propto n_\chi^2$)**

Model : DM decays to long-lived mediators and can escape the celestial object

Cross-Section reach



Galactic Center Calculations

BDs in GC: Mass range - 0.01 - 0.07 $M_\odot$

$$n_{\rm BD} = 7.5 \times 10^4 r_{\rm pc}^{-1.5} {\rm pc}^{-3},$$ **(Using Kroupa IMF)**

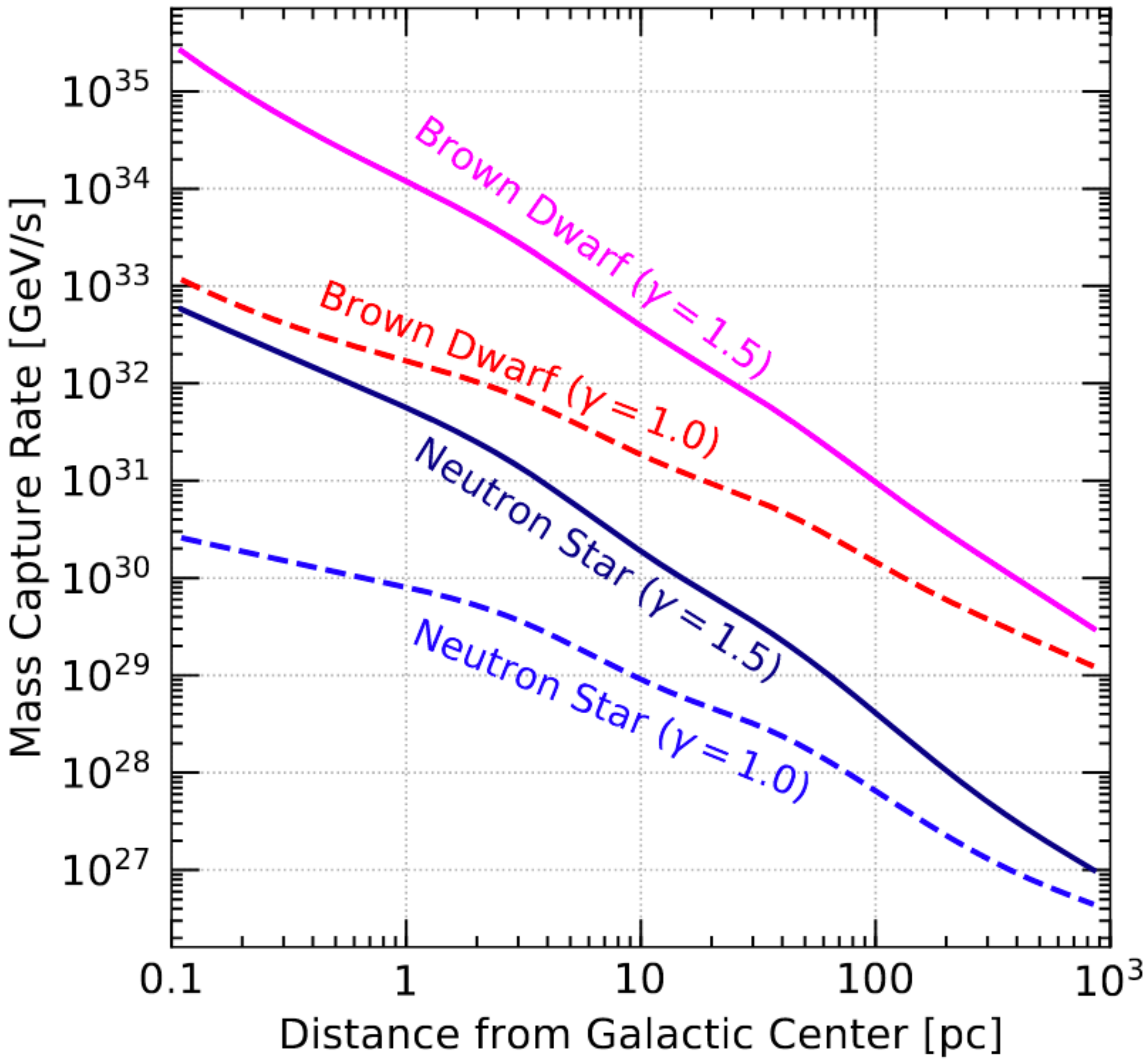
NSs in GC- Nuclear Cluster Models

$$n_{\rm BD} = 7.5 \times 10^4 r_{\rm pc}^{-1.5} {\rm pc}^{-3},$$

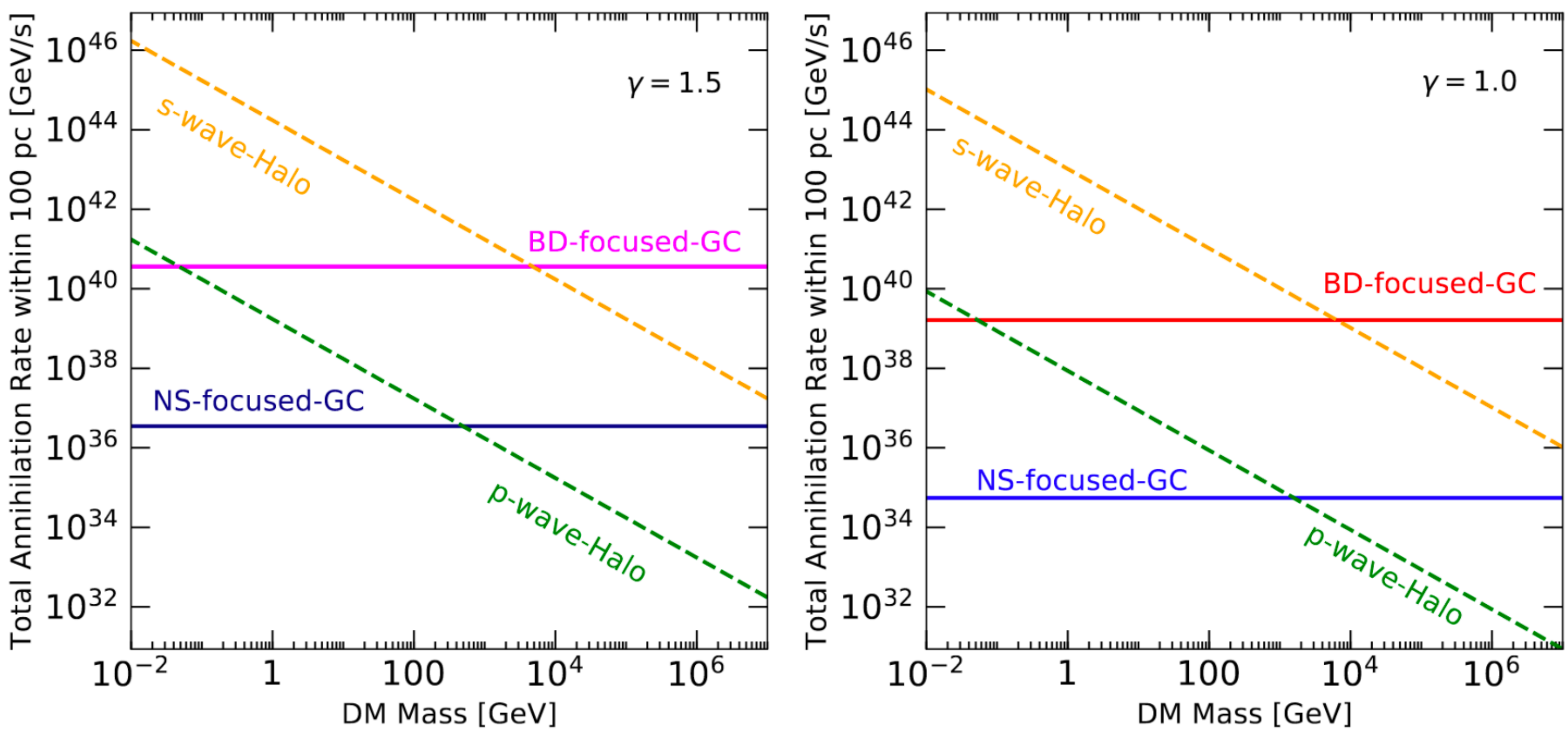
Standard Generalized NFW for DM density

$$\rho_\chi(r) = \frac{\rho_0}{(r/r_s)^\gamma (1 + (r/r_s))^{3-\gamma}},$$

NS and BD capture rates

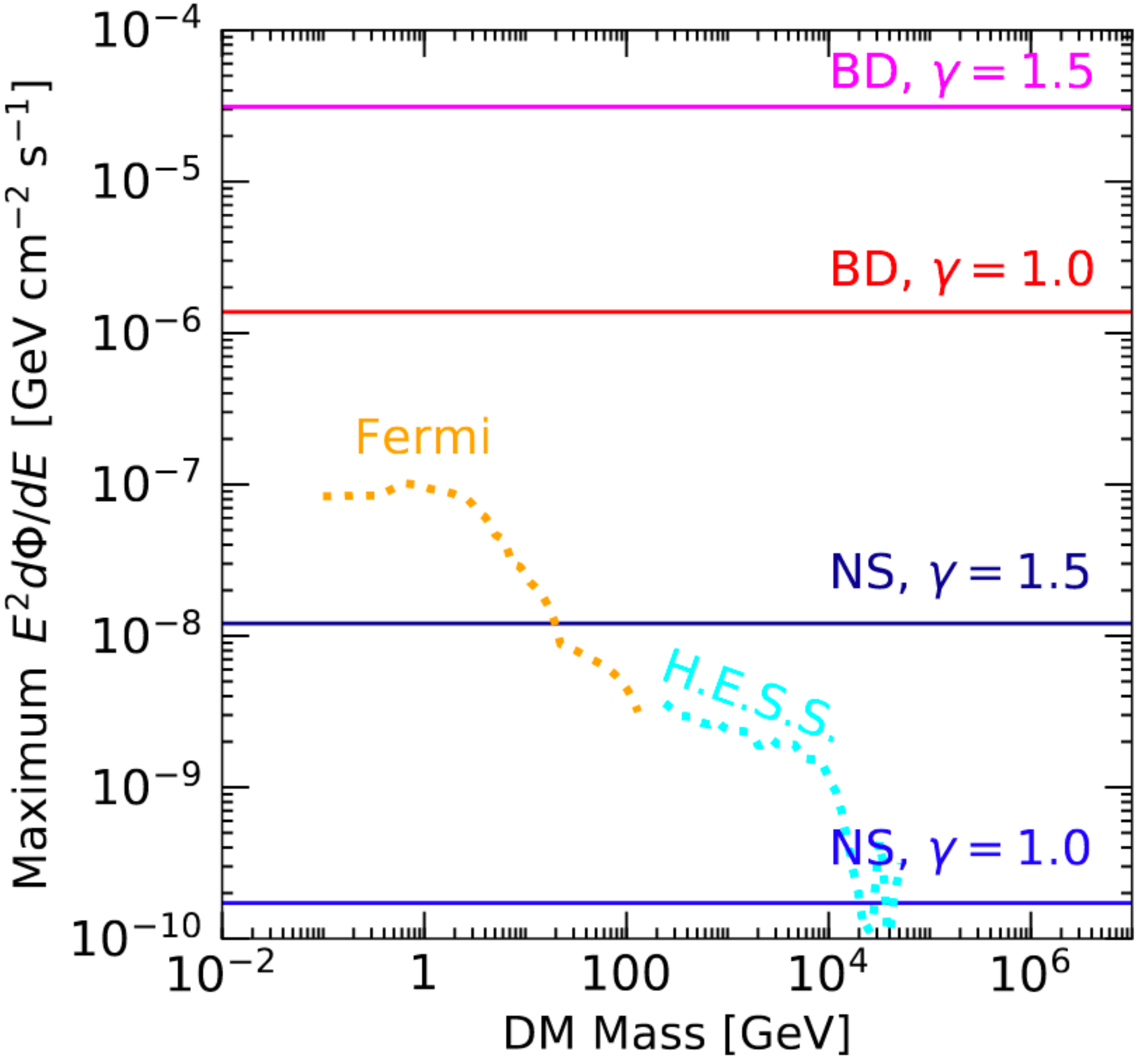


‘focused’ annihilation vs. Halo annihilation

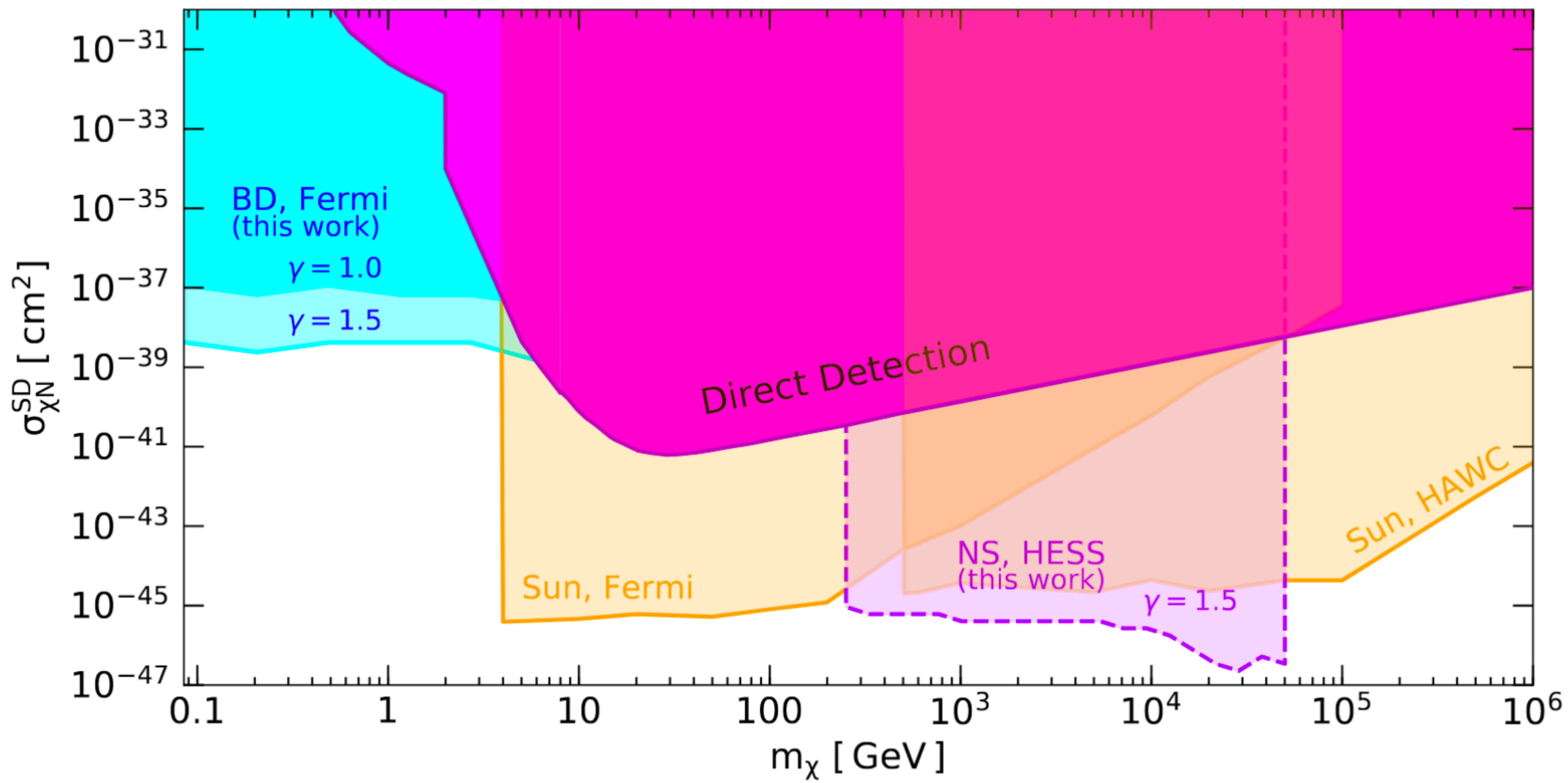


Maximum capture rate assumed for this plot

Galactic Center NS and BD fluxes



Constraints



Conclusions

1) Novel DM signatures from celestial bodies in models of annihilation to long-lived mediators explored.

2) Celestial-Body ‘focused’ annihilation can be stronger than standard halo annihilation.

3) The signal will have a novel morphology scaling like the number density of celestial bodies.

4) Strong constraints derived in the sub-GeV with state-of-the art telescope measurements.

Thanks for your attention !