New Perspectives On High-Energy Neutrinos From the Sun

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... and some other Dark Matter Phenomenology

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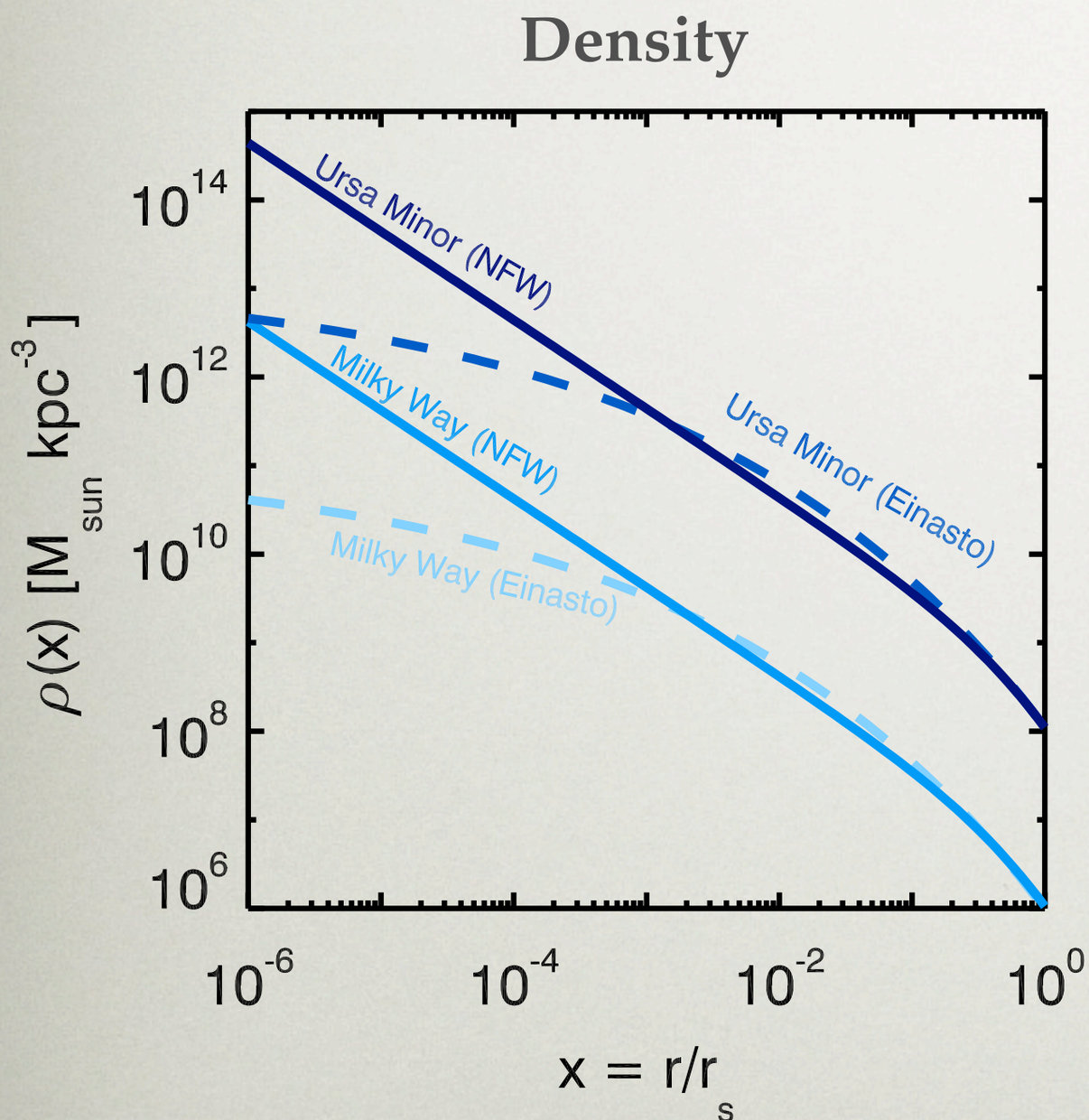
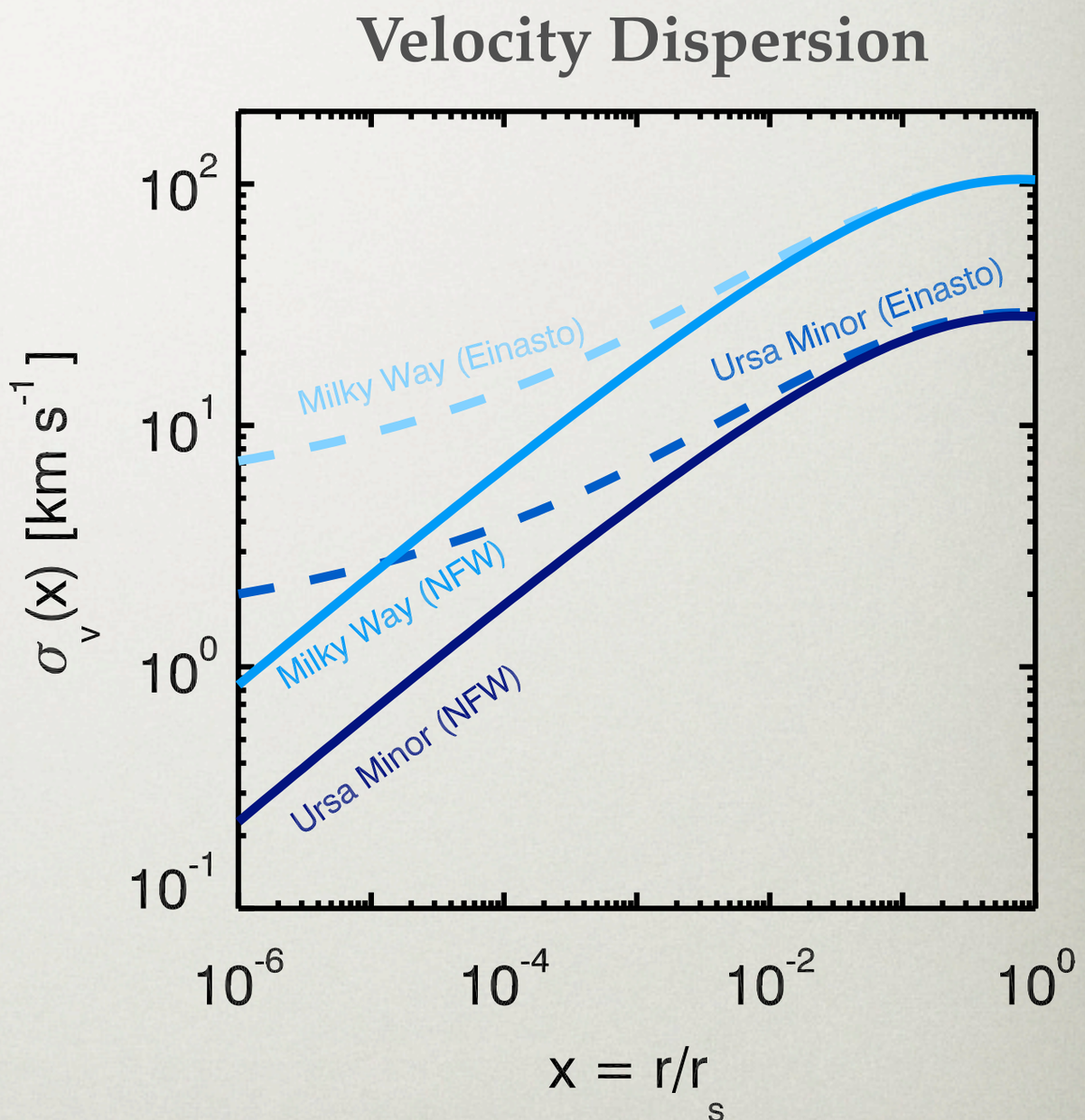
Outline

1. Velocity-Dependent Annihilation Cross-Sections (Sommerfeld Effect) & Halo Structure
2. The Phenomenology of High-Energy Neutrinos from the Sun in Models of self-interacting Dark Matter
3. Halo Substructure & Indirect Signals

Sommerfeld Effect & Halo Structure

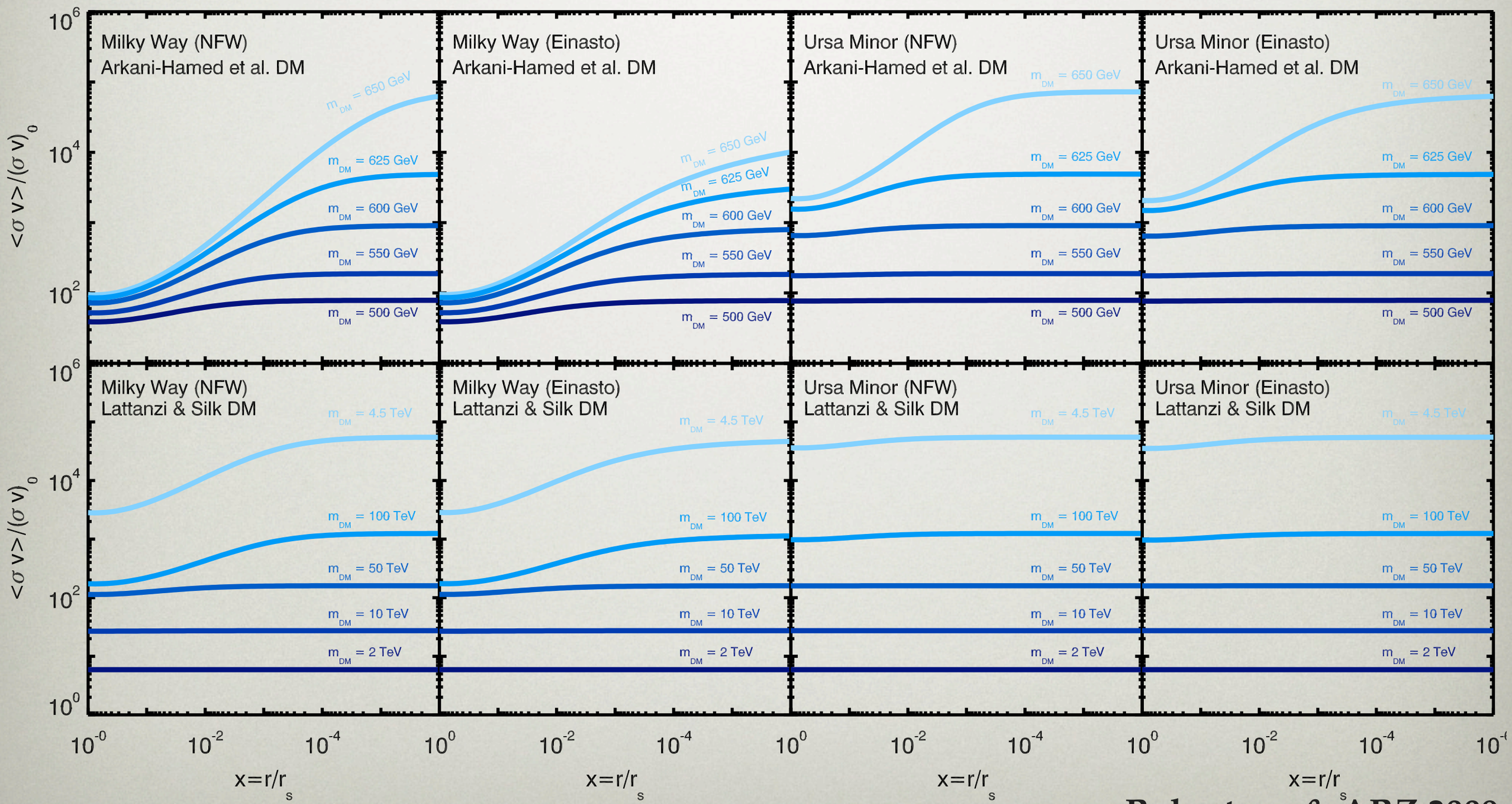




Robertson & ARZ 2009

Sommerfeld Effect & Halo Structure

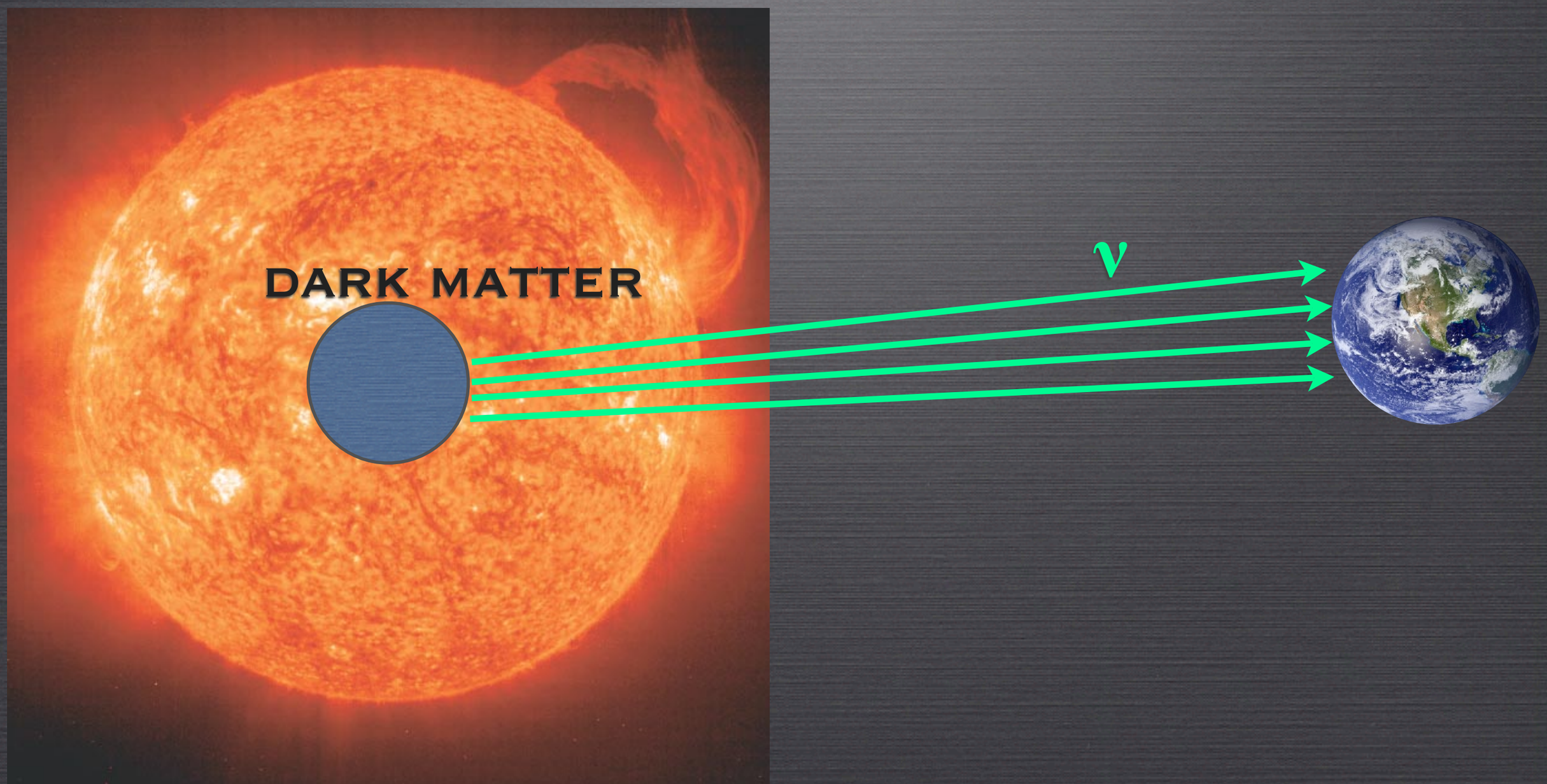
"Anomalous Gradient" in Annihilation Products Due To Velocity Dep.



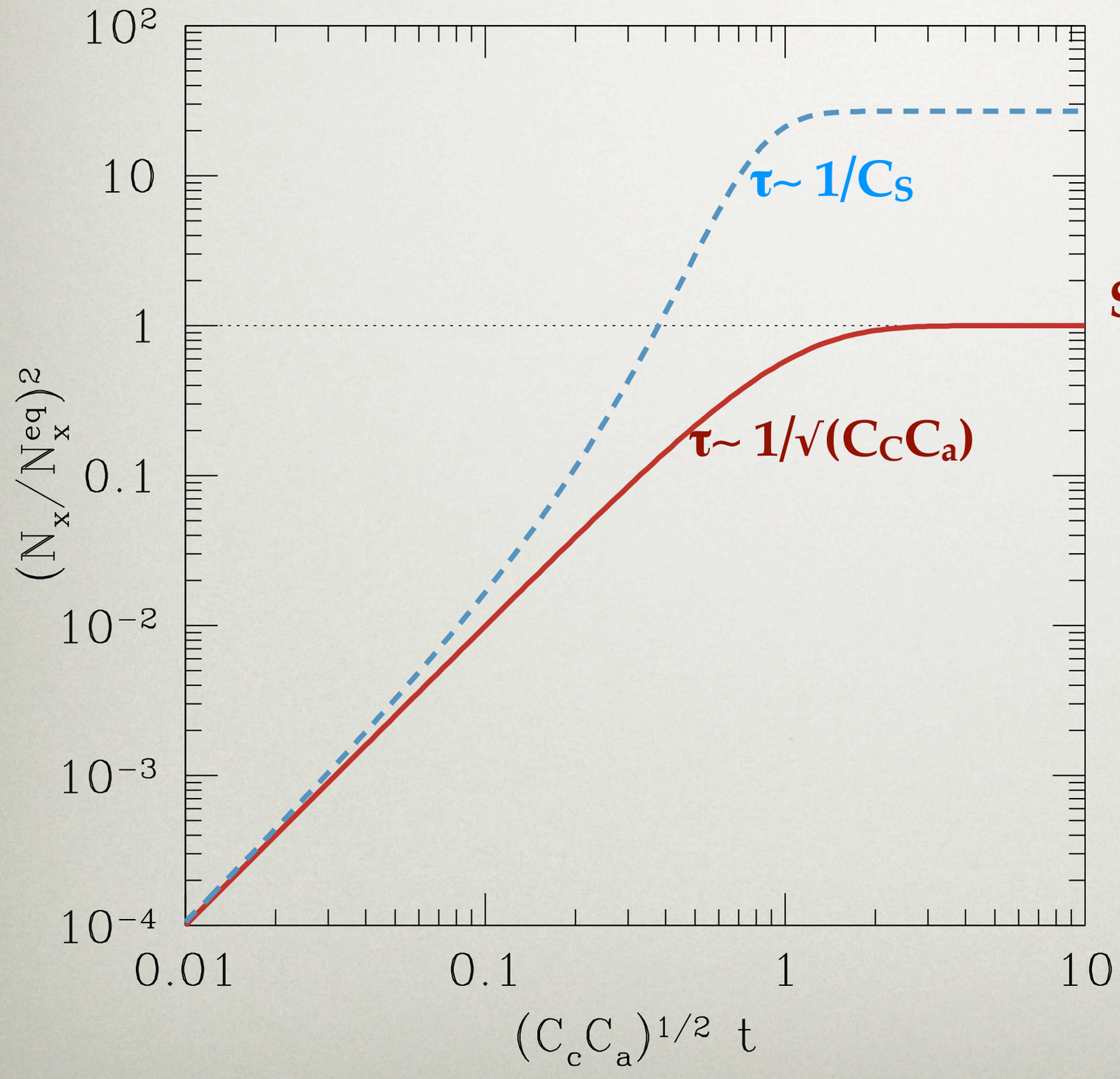
But see, Slatyer et al. 2009...

Robertson & ARZ 2009

High-Energy Neutrinos From The DM In The Sun



When Can DM Self-Capture Matter?



Self-Interacting Dark Matter, flux ≈ $C_S^2/2C_a$

Standard Dark Matter Model, flux ≈ $C_C/2$

Define, $R_S = C_S^2/(C_C\ C_A)$

Zentner 2009

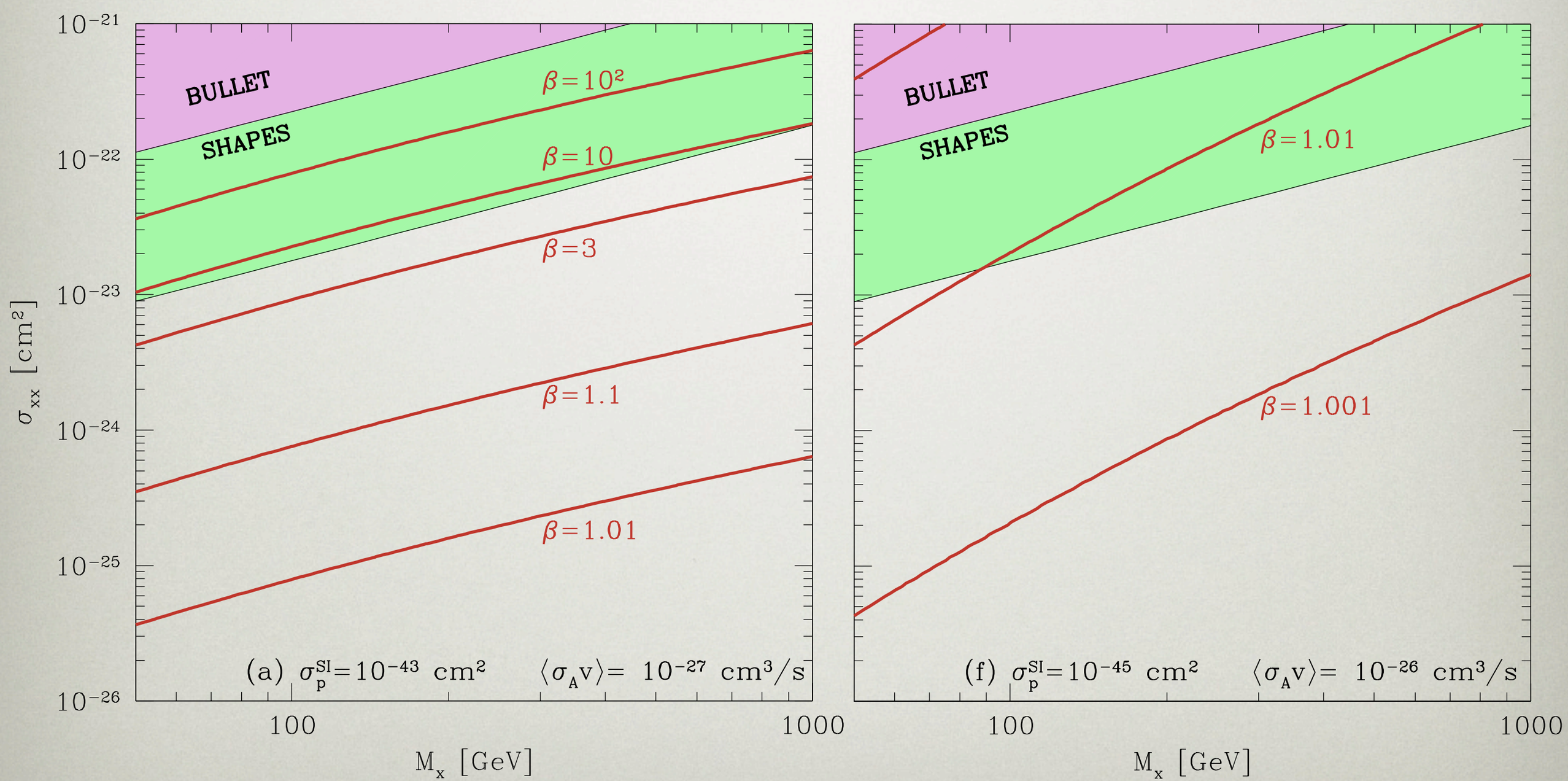
Neutrino Capture In The Sun

Capture Rates: $$C = \sqrt{\frac{3}{2}}\, n_{\mathrm{x}} \sigma v_{\mathrm{esc}}(\mathrm{R}_\odot)\, \frac{v_{\mathrm{esc}}(\mathrm{R}_\odot)}{\bar{v}} N \langle \hat{\phi} \rangle$$

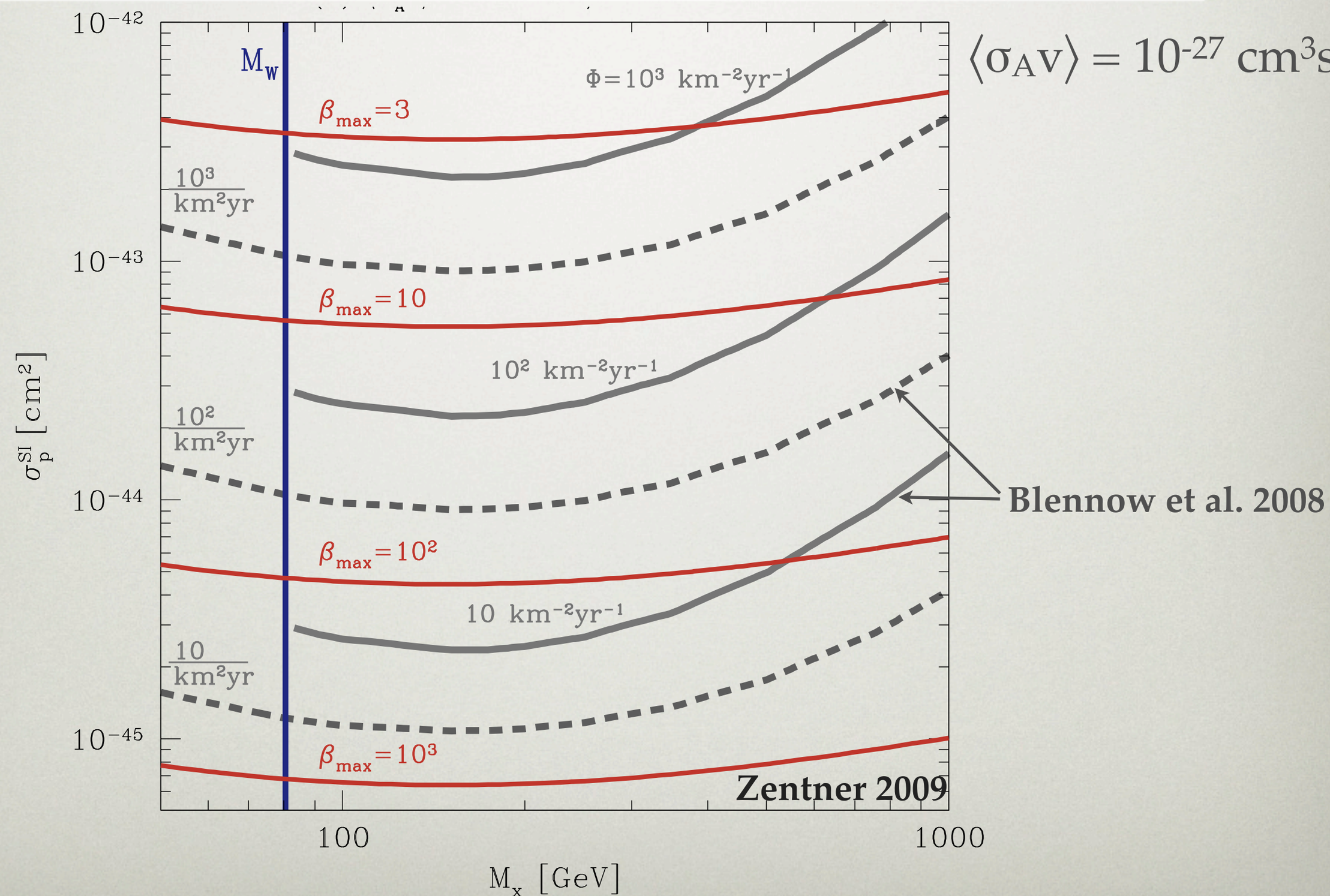
$$R_{\mathrm{s}} \approx \sqrt{\frac{3}{2}} \frac{\sigma_{\mathrm{xx}}^2 v_{\mathrm{esc}}(\mathrm{R}_\odot)}{\sigma_{\mathrm{N}} \langle \sigma_{\mathrm{A}} v \rangle} \frac{v_{\mathrm{esc}}(\mathrm{R}_\odot)}{\bar{v}} \frac{\langle \hat{\phi}_{\mathrm{x}} \rangle^2}{\langle \hat{\phi}_{\mathrm{N}} \rangle} \frac{V_1}{V_2} \frac{n_{\mathrm{x}}\ M_{\mathrm{N}} V_1}{f_{\mathrm{N}} \mathrm{M}_\odot}$$

$$R_{\mathrm{s}} \approx 0.4 \left(\frac{\sigma_{\mathrm{xx}}}{10^{-24}\ \mathrm{cm}^2} \right)^2 \left(\frac{10^{-42}\ \mathrm{cm}^2}{\sigma_{\mathrm{N}}} \right) \left(\frac{10^{-27}\ \mathrm{cm}^3 \mathrm{s}^{-1}}{\langle \sigma_{\mathrm{A}} v \rangle} \right) \left(\frac{100\ \mathrm{GeV}}{M_{\mathrm{x}}} \right)^{5/2}$$

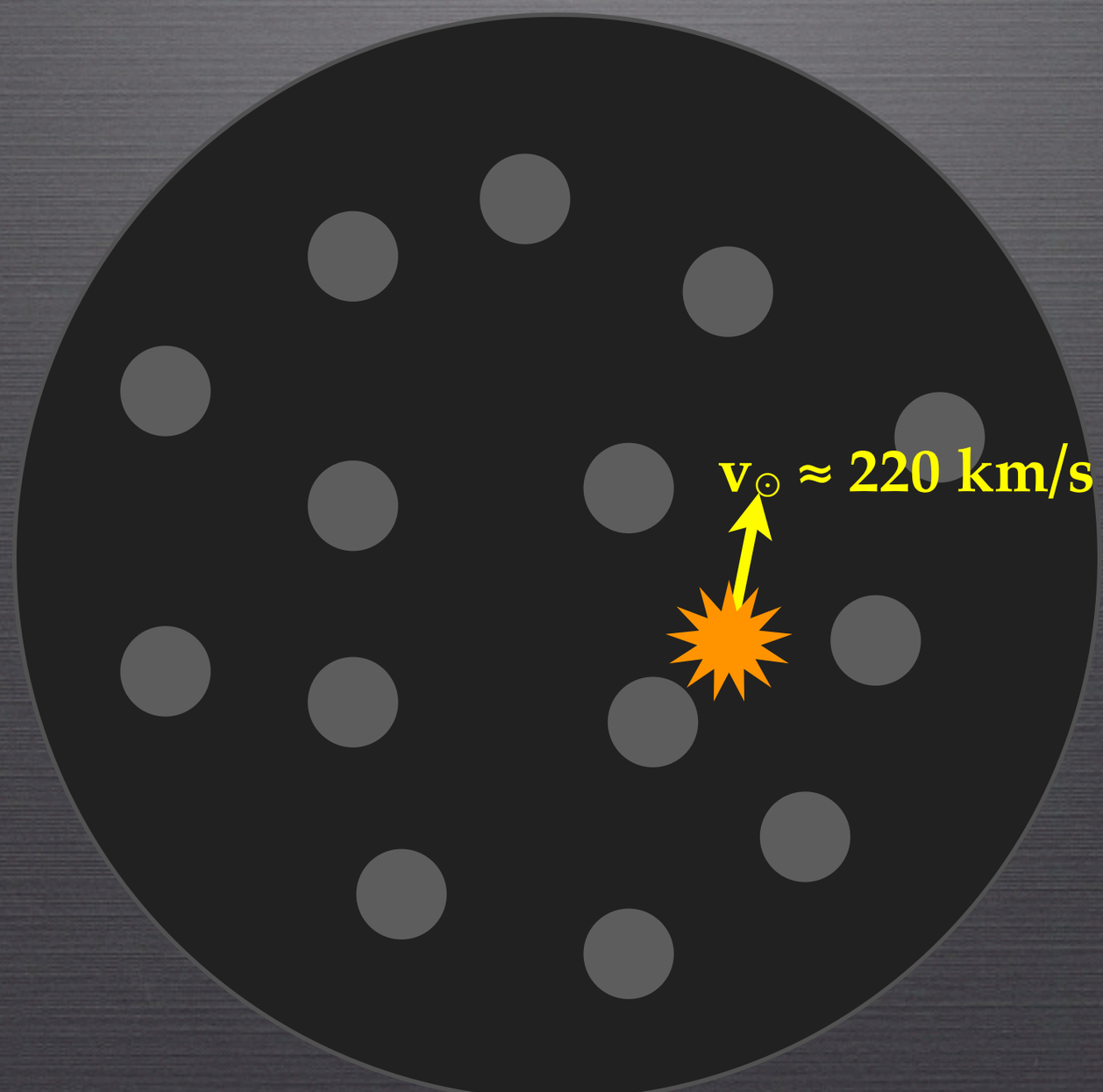
Relative Flux From Self-Captured DM



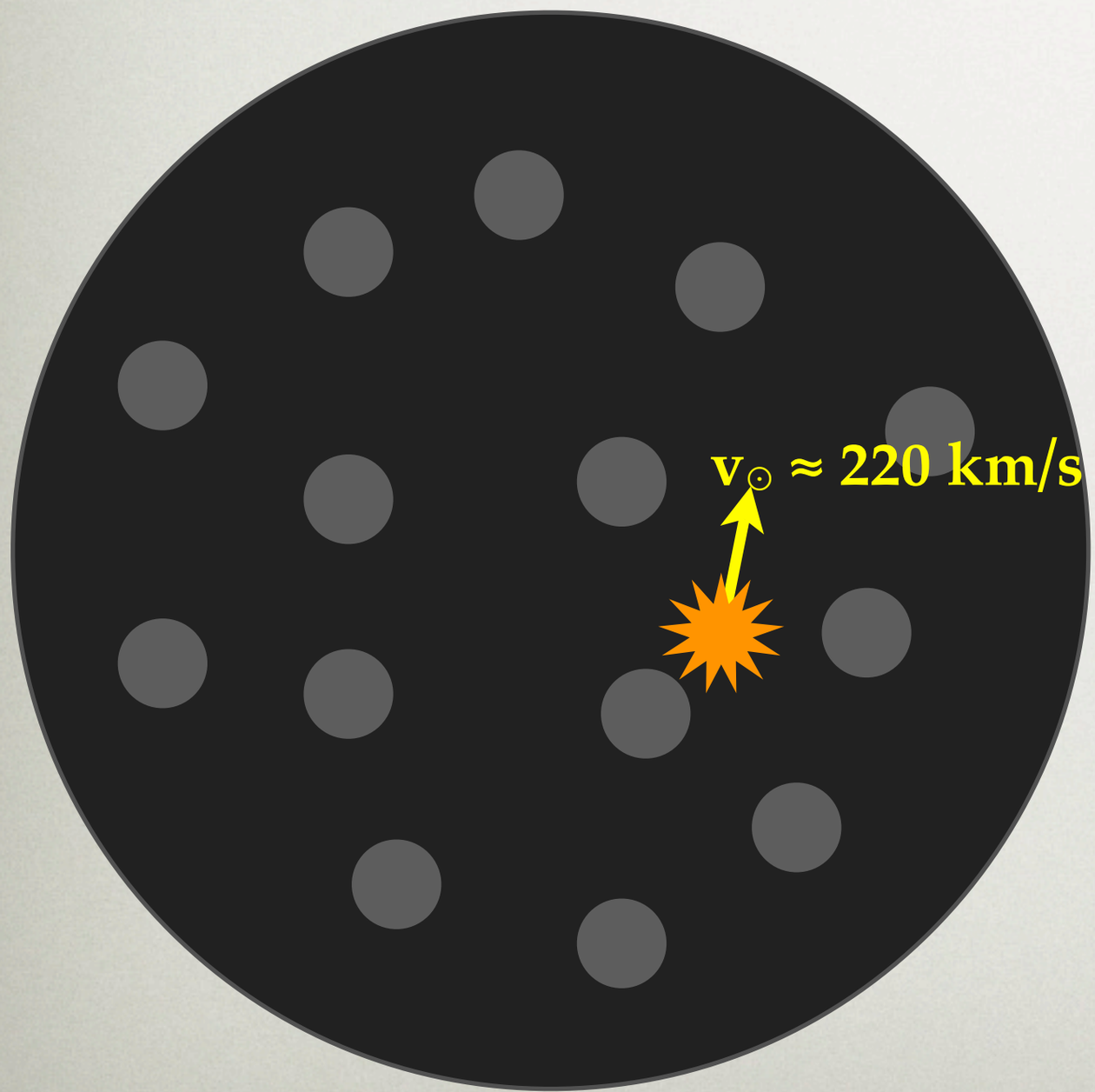
Relative Flux From Self-Captured DM



Can Halo Substructure Be Important?

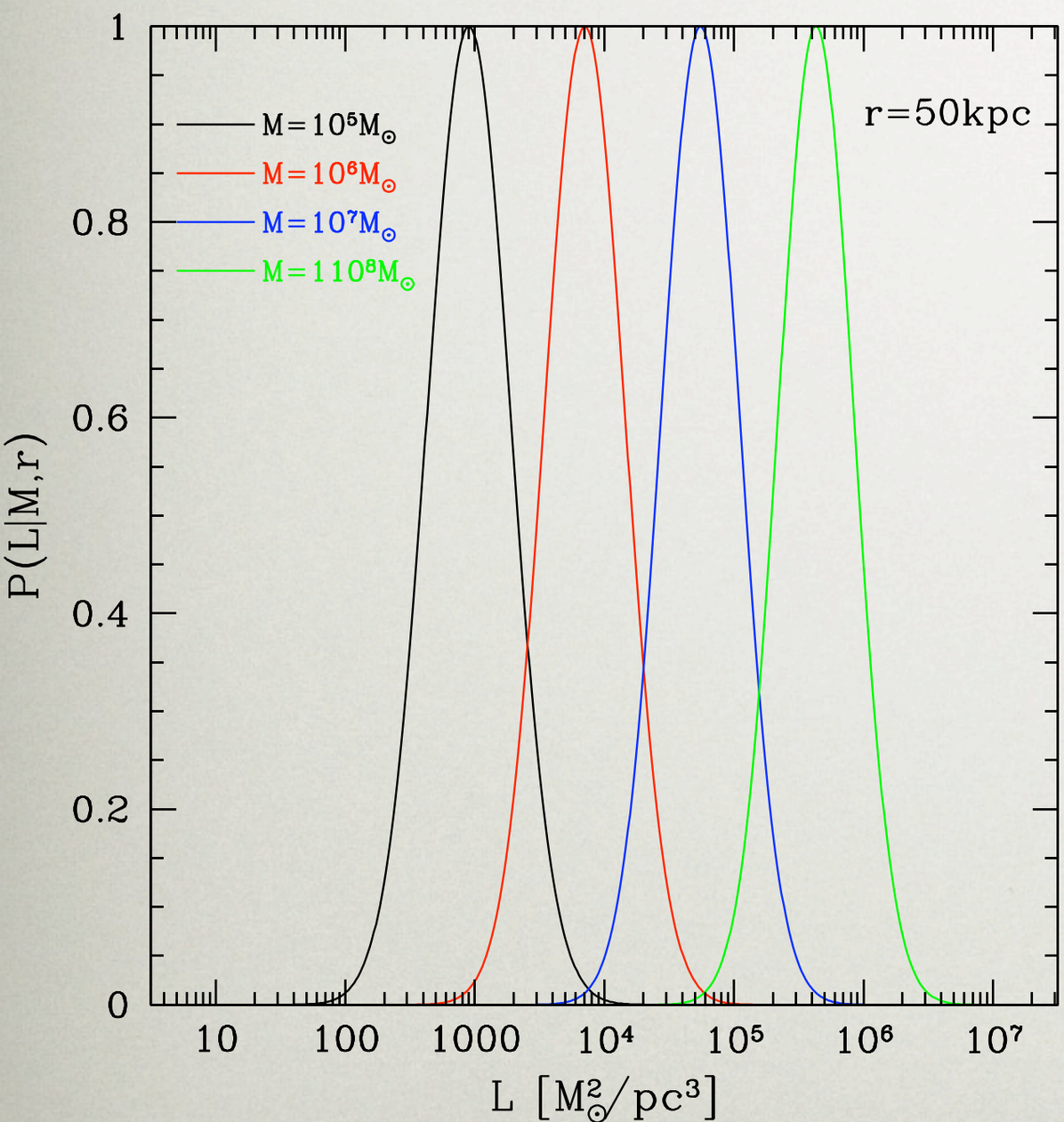


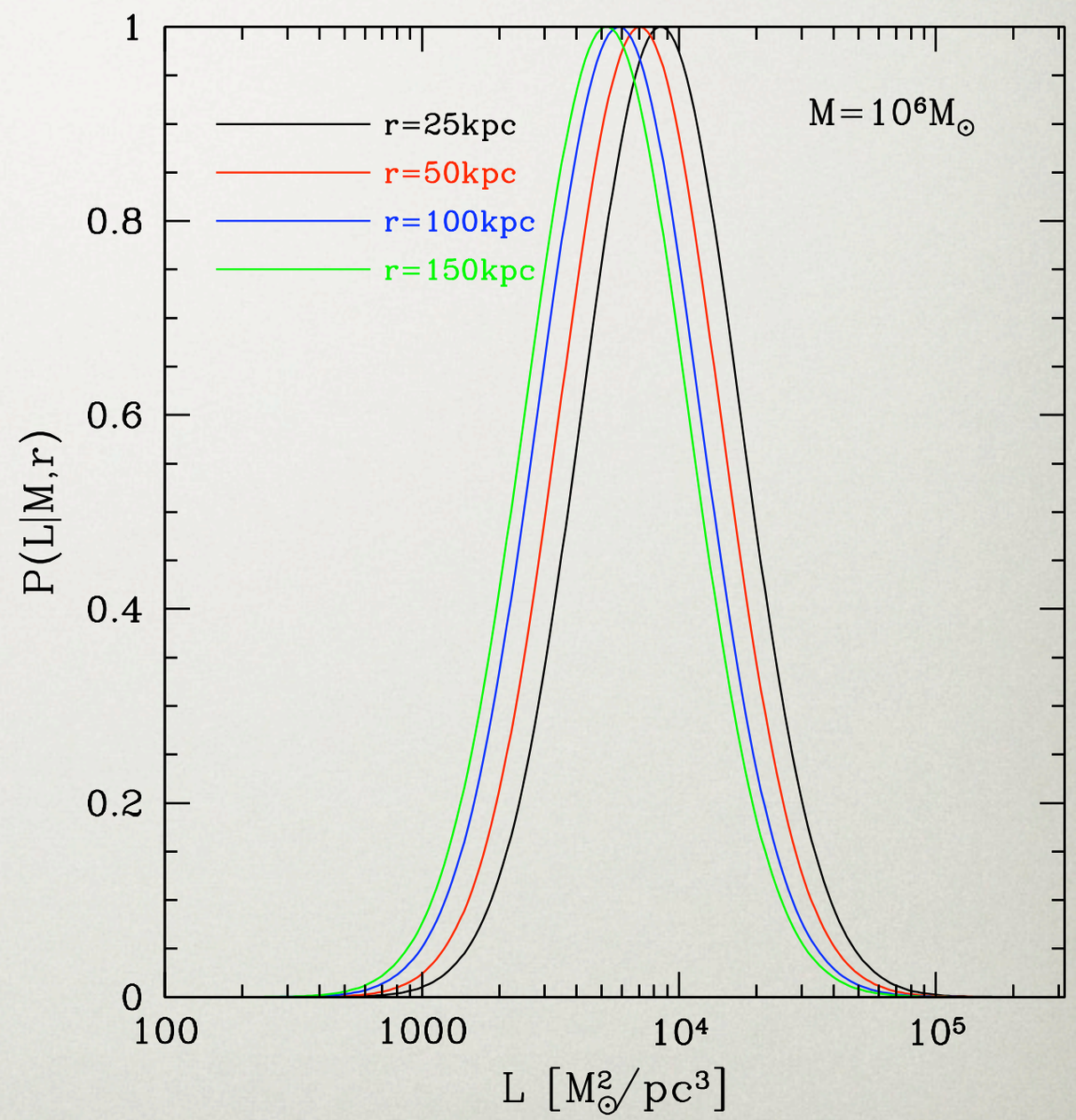
High-Energy Neutrinos And Substructure



- The Sun encounters a subhalo of mass **m** every $\mathbf{t_{enc} \sim 10^6\ (M_\odot/m)^{0.3}}$ **yr.**
- The Sun's orbital period is $\mathbf{t_{orb} \approx 2.3\times10^8}$ **yr**
- The Sun's age is $\mathbf{t_\odot \approx 5\times10^9}$ **yr**

Halo Sub-Structure





Koushiappas, ARZ, Kravtsov in prep, 2009(?)

To Summarize...

1. Dark Matter kinematics can be important in any model where $\langle \sigma_A v \rangle$ depends upon velocity
2. A "self-scattering" dark matter particle may have a signature in high-energy neutrinos from the Sun
3. Halo substructure is important for annihilation products in the halo & possibly from within the Sun!