New Perspectives On Indirect Detection: Dark Matter Very Low-Mass Stars

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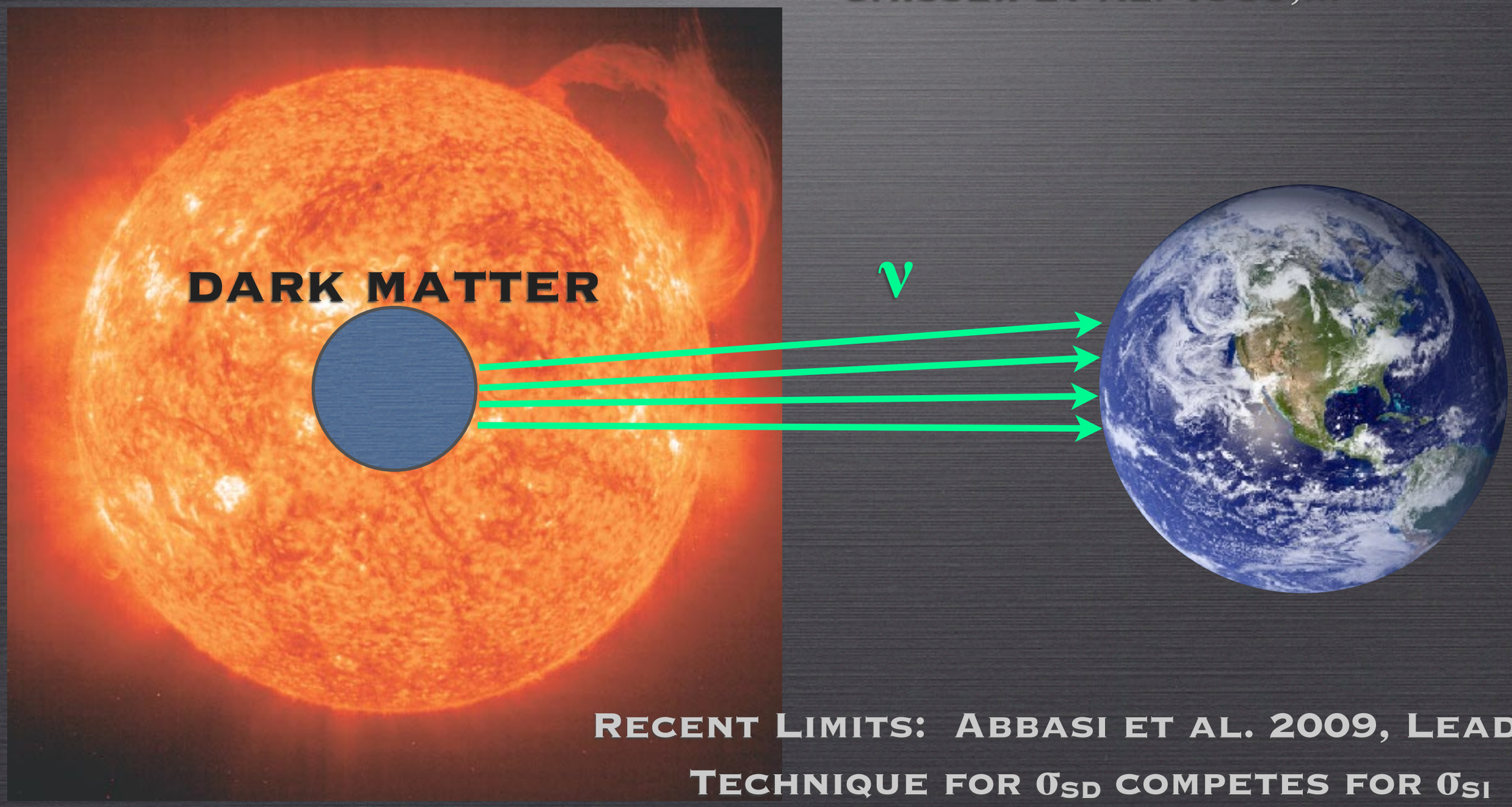
Outline

1. Dark Matter Particle Capture in the Sun and Stars
2. **Effects of Dark Matter Self-Interactions on Indirect Signals from the Sun**
3. Effects of Dark Matter on Stellar Structure
4. **How Asymmetric Dark Matter (ADM) May Alter the Conditions for Stardom**

High-Energy Neutrinos From The DM In The Sun

Silk et al. 1985, Krauss et al. 1986,
Gaisser et al. 1986,...



Recent Limits: Abbasi et al. 2009, Leading Technique for σ_{SD} competes for σ_{SI}

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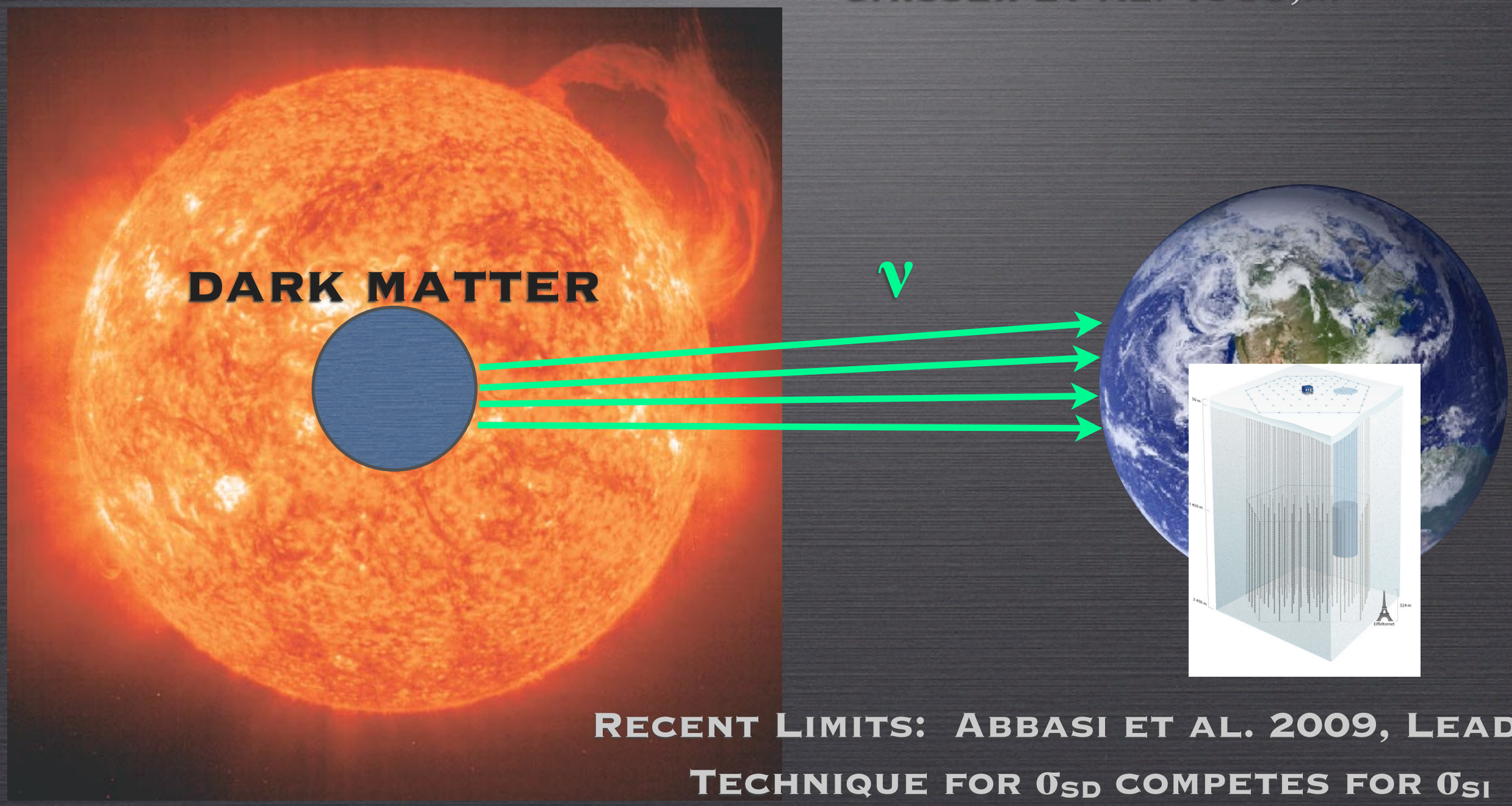

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Two Equations

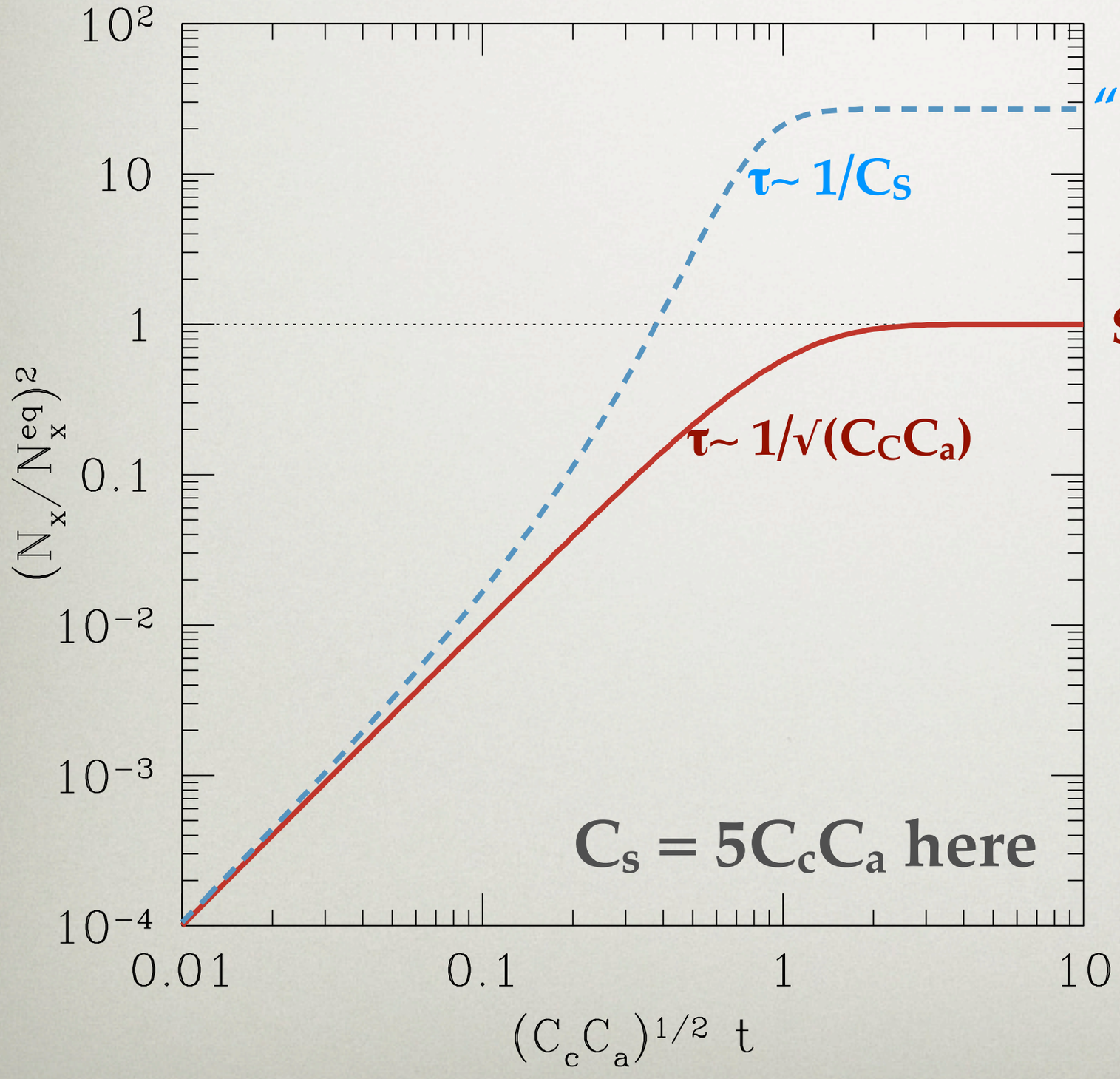
- **Standard wimp capture rates of dark matter in stars:**

$$C_{\rm DM} \propto \rho_{\rm DM}\, \sigma_{\rm DM-N}\, \frac{v_{\rm esc}^2}{v_\infty}\, M_\star \sim 10^{22}\,{\rm s}^{-1}$$

- **Annihilation rate of dark matter in stars:**

$$C_{\rm ANN} = \frac{1}{2}\, C_{\rm DM} \quad \text{(Equilibrated)}$$

A Self-Interaction Changes The Picture

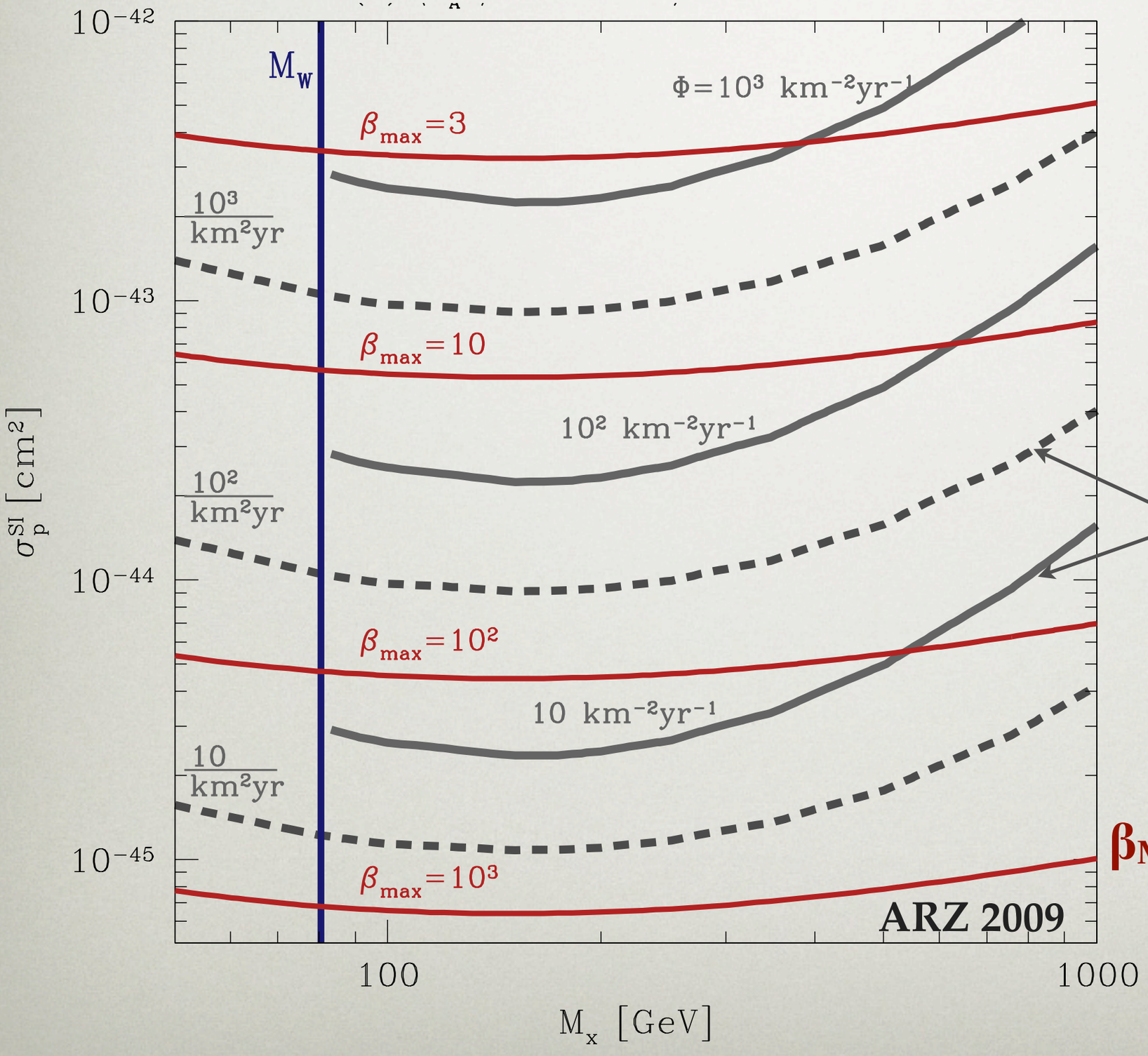


"Self-Interacting" Dark Matter,
flux ≈ $C_S^2/2C_a$

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

ARZ , Phys. Rev. D, 2009

Relative Flux From Self-Captured DM



Muon fluxes in "standard" scenario (Blennow et al. 2008), ~10^2 /km^2/yr "detectable"

$$\beta_{MAX} = \frac{\text{("interacting" model)}}{\text{(standard flux)}}$$

Self-Interactions

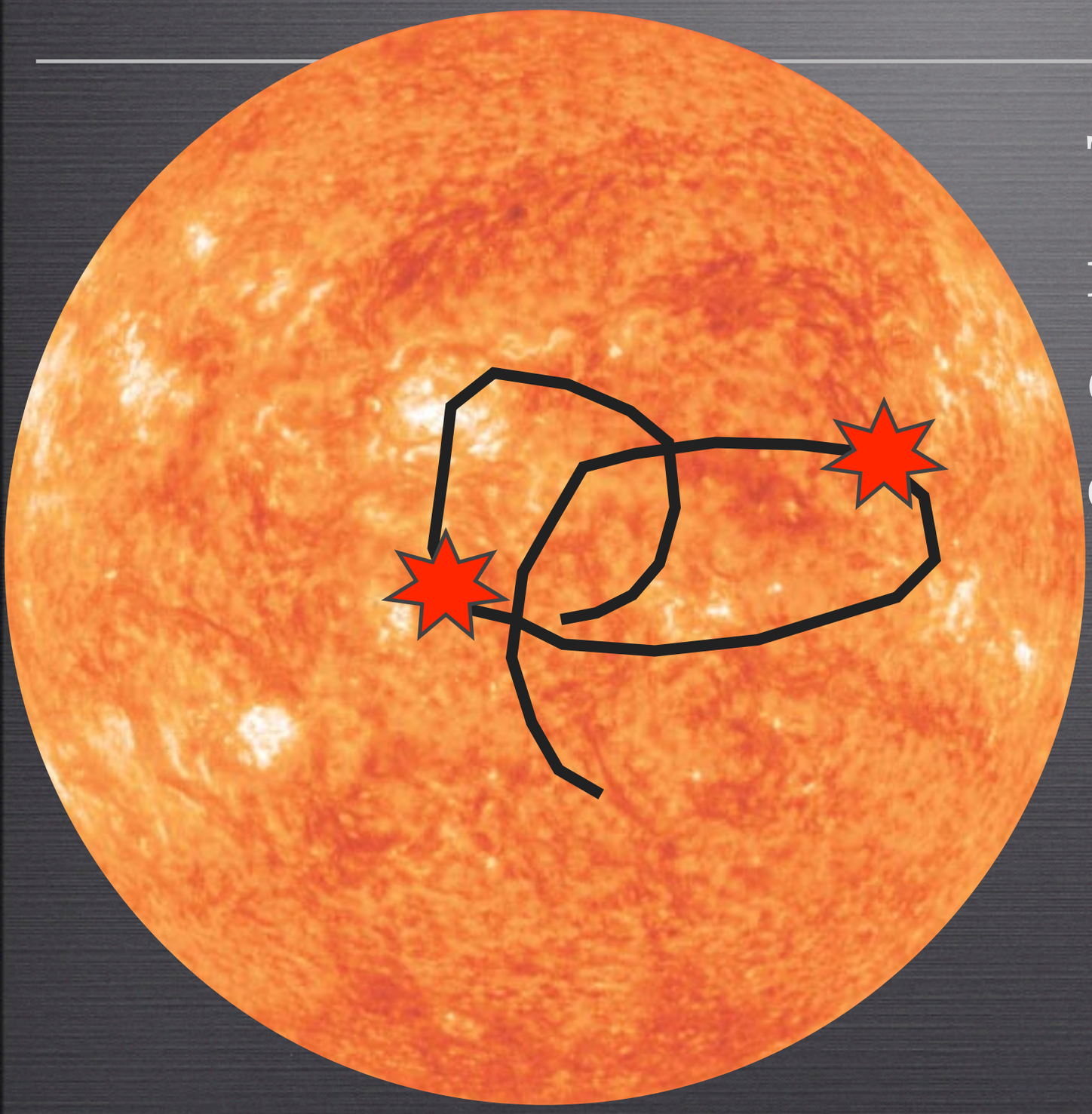
- **Consequence: A self-interaction can lead to an observable neutrino flux in Ice Cube, even when Direct Detection experiments place bounds on the DM-Nucleon cross section that would rule this out for a standard WIMP.**

See Also: Koushiappas & Kamionkowski (2009) for similar conclusions due to non-trivial dark matter halo structure

Asymmetric Dark Matter

1. Not a thermal relic
2. Does not annihilate because of asymmetry between "particles" and "antiparticles": Accumulates in Stars
3. Relevant to low-mass dark matter ($M_x \lesssim$ 20 GeV)
4. Mass range relevant to DAMA/CoGeNT search "hints"

Stellar Structure



The occasional interactions of orbiting dark matter in stars, cools the stellar core.

Low-Mass Stars as DM Labs

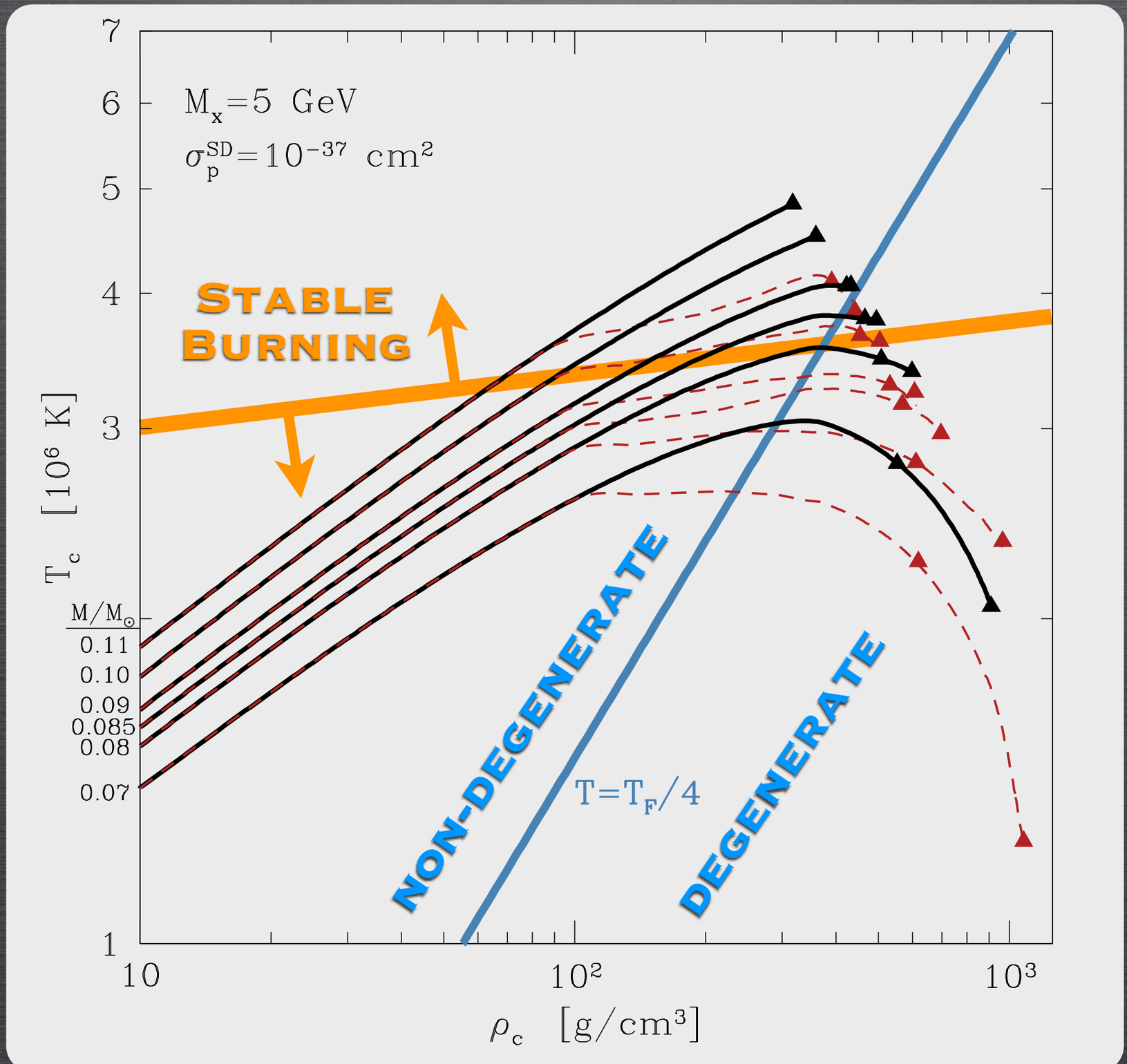
1. For stars, $M \propto R$: low-mass stars capture as much DM per unit mass as the Sun!
2. $L \propto M^{3.5}$: Less energy needs to be moved around to dramatically alter the stellar structure
3. Low-mass ($\lesssim 0.1\ M_\odot$) are just hot enough to fuse hydrogen and fusion rates are VERY sensitive to core temperature.
4. Astronomical observatories are just becoming capable of taking a census of low-mass stars!

Low-Mass Stars

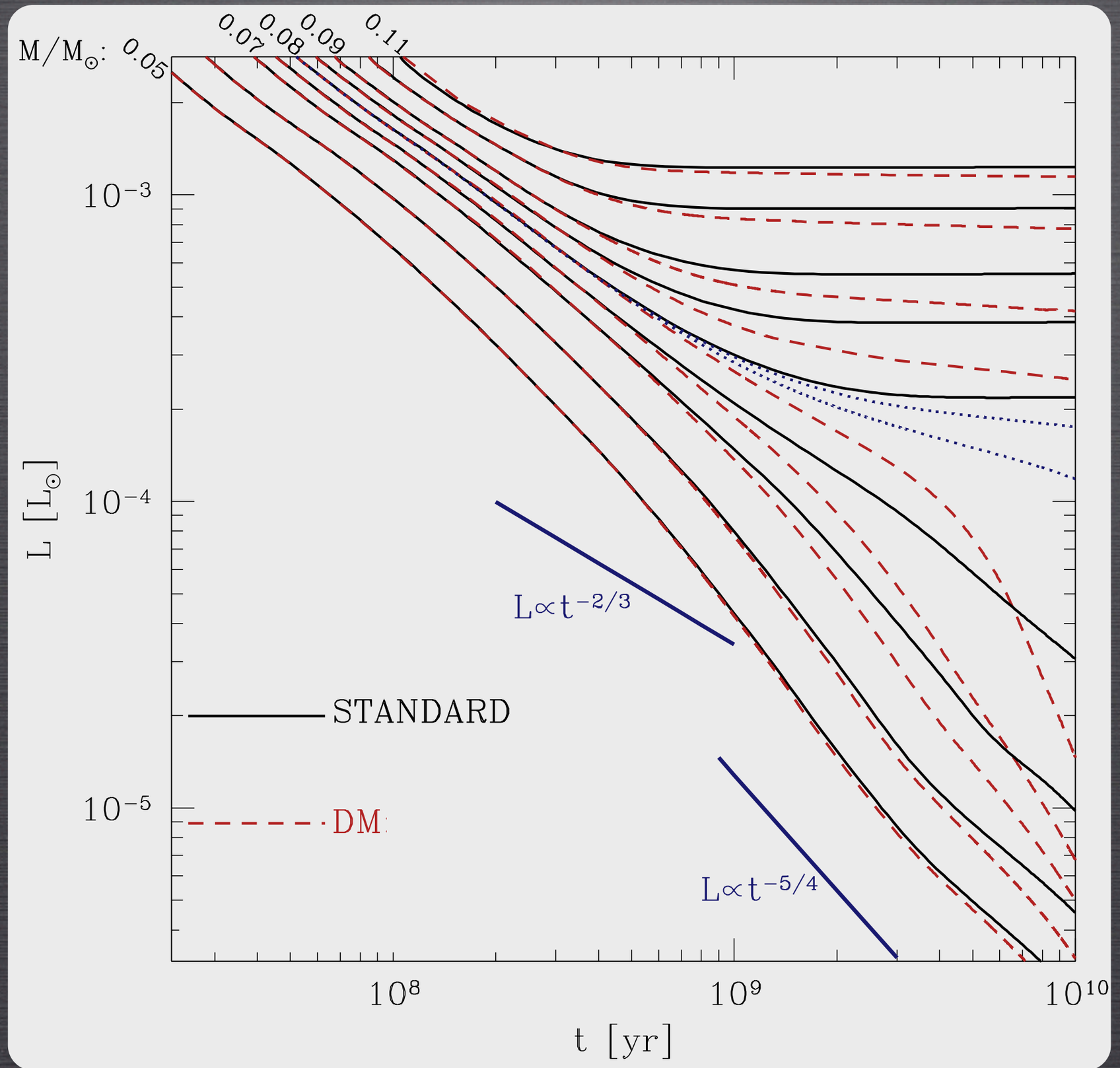
"Stars" are objects in hydrostatic equilibrium in which energy is provided by nuclear fusion.

"Brown Dwarfs" are objects insufficiently massive to ignite nuclear fusion in their cores - they are supported by electron degeneracy at temperatures too cool for fusion.

Core Temperature



Evolution



Luminosity [Solar Luminosities]

Time [Years]

ADM & Stars

- Viable models of Asymmetric Dark Matter may cool the cores of low-mass stars such that they **do not become stars at all**

- Brown dwarfs will cool significantly **more quickly** in such models

- Forthcoming astronomical censuses of very low-mass stars may aid **indirect DM identification** efforts, **stellar evolution may be altered by DM** (and perhaps other applications...)

See Also: Iocco et al. (private communication, to be submitted) for related results in solar mass stars

The Current Cosmic Energy Budget