Milky Way White Dwarfs as Sub-GeV to Multi-TeV Dark Matter Detectors

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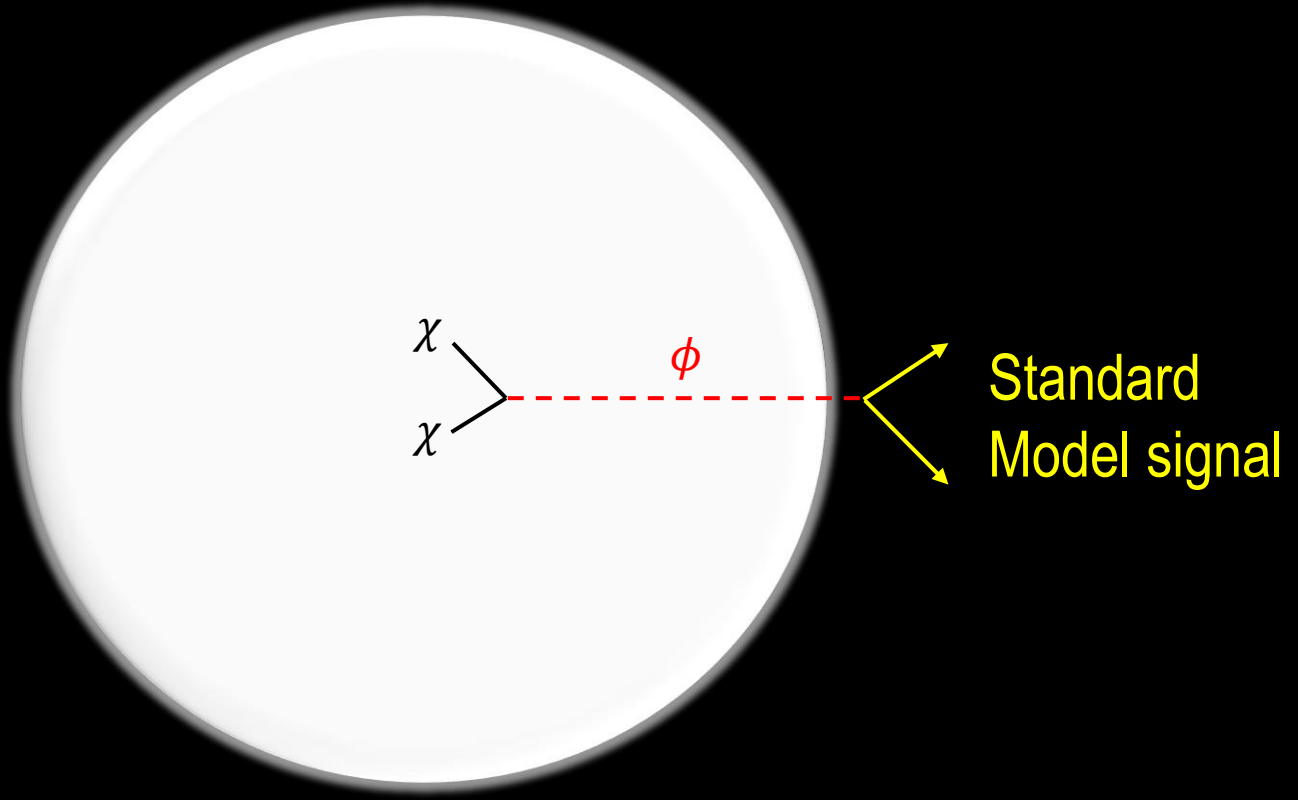
DM capture by celestial objects

- DM scatters off of particles inside the object and loses energy
- DM accumulates and annihilates into detectable signature



Previous work

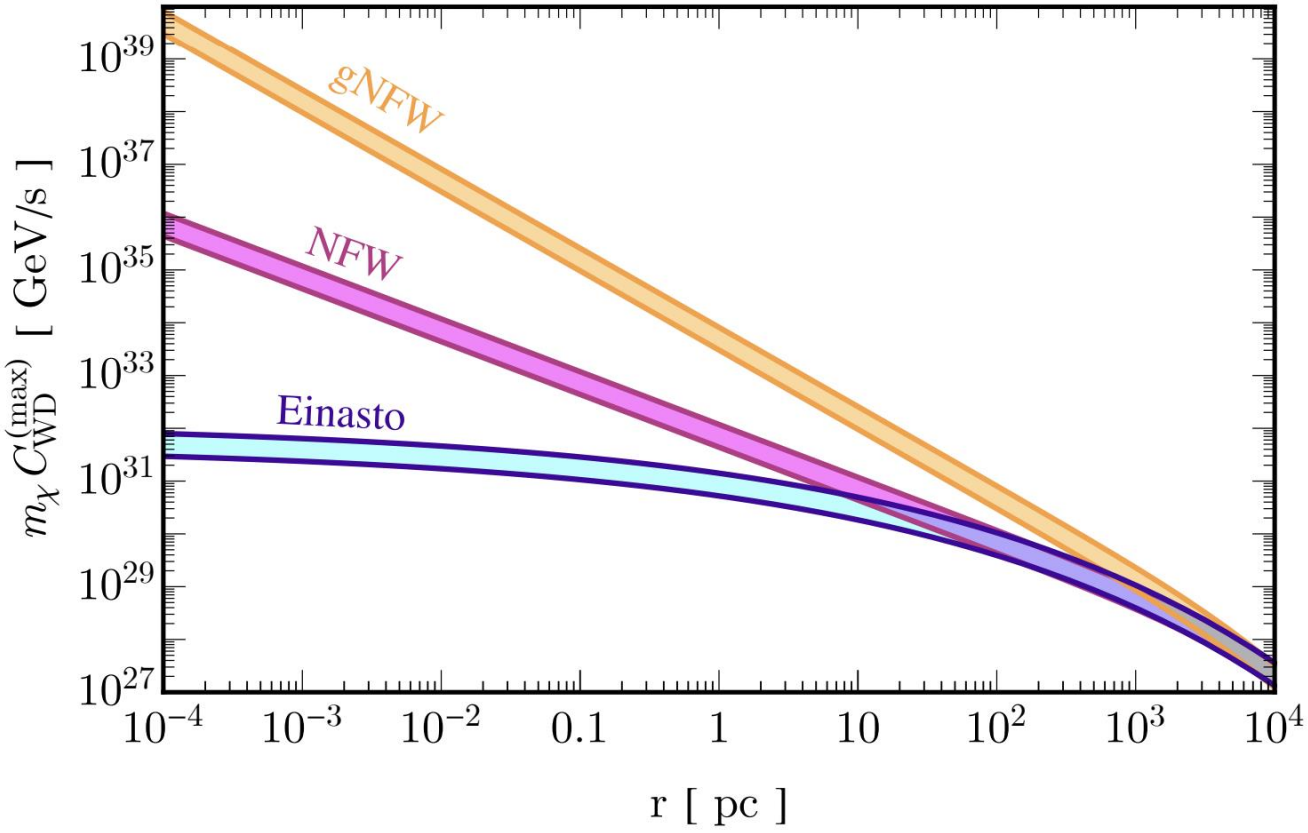
- Neutron stars and white dwarfs (WDs) are good celestial objects for DM searches
  - Both have high density -> more DM captured -> greater flux
- WDs are larger and more numerous than neutron stars
- WD heating in globular clusters studied in the past
  - Suspected high DM density, but with large uncertainty

This work

- Use WDs in Galactic center because DM density is high and better understood there
- Set limits on dark matter-nucleon cross section using Galactic center gamma-ray data
- Improve capture rate calculation in WDs

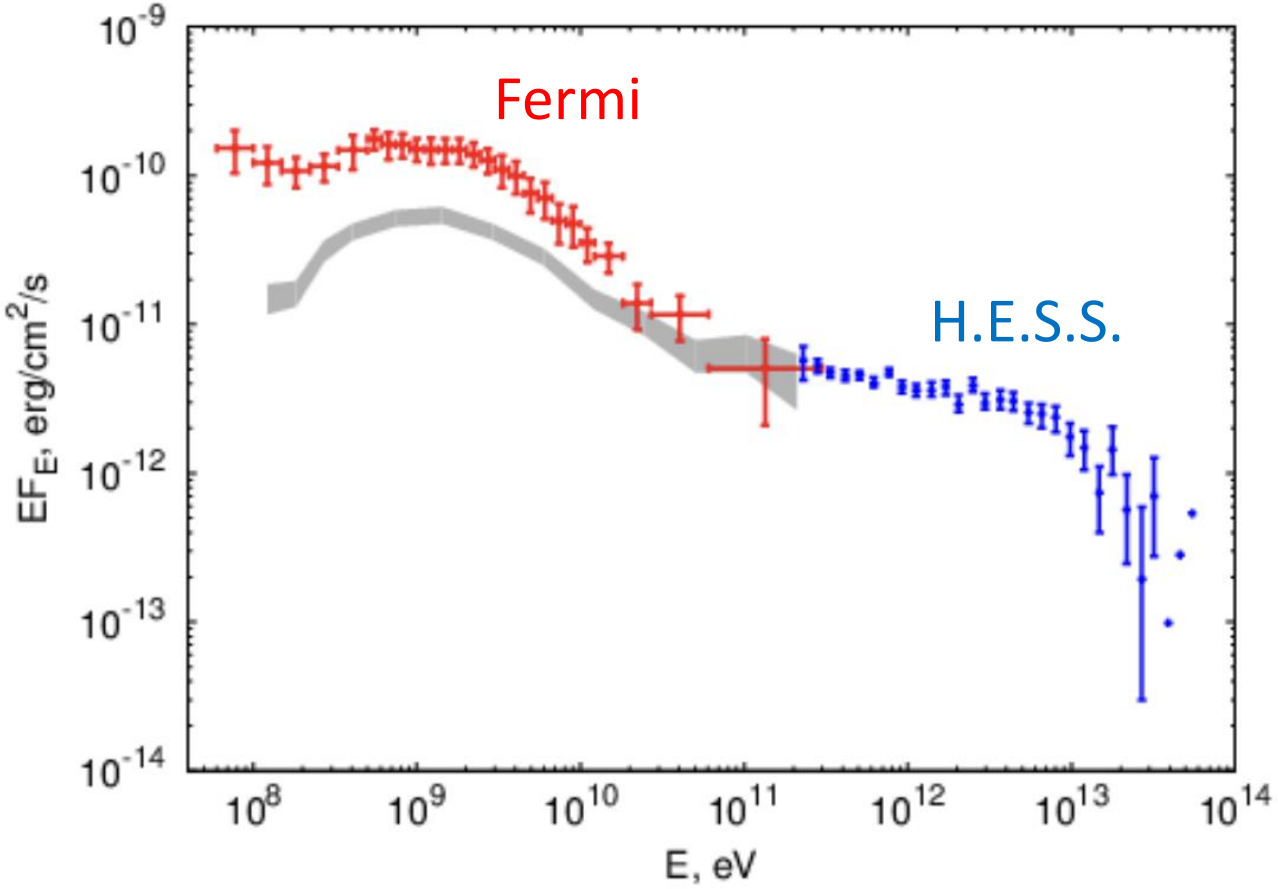
Dark matter density profiles

- Conservative (cored): Einasto
- Intermediate: Navarro-Frenk-White (NFW)
- Optimistic (cuspy): generalized NFW (gNFW)



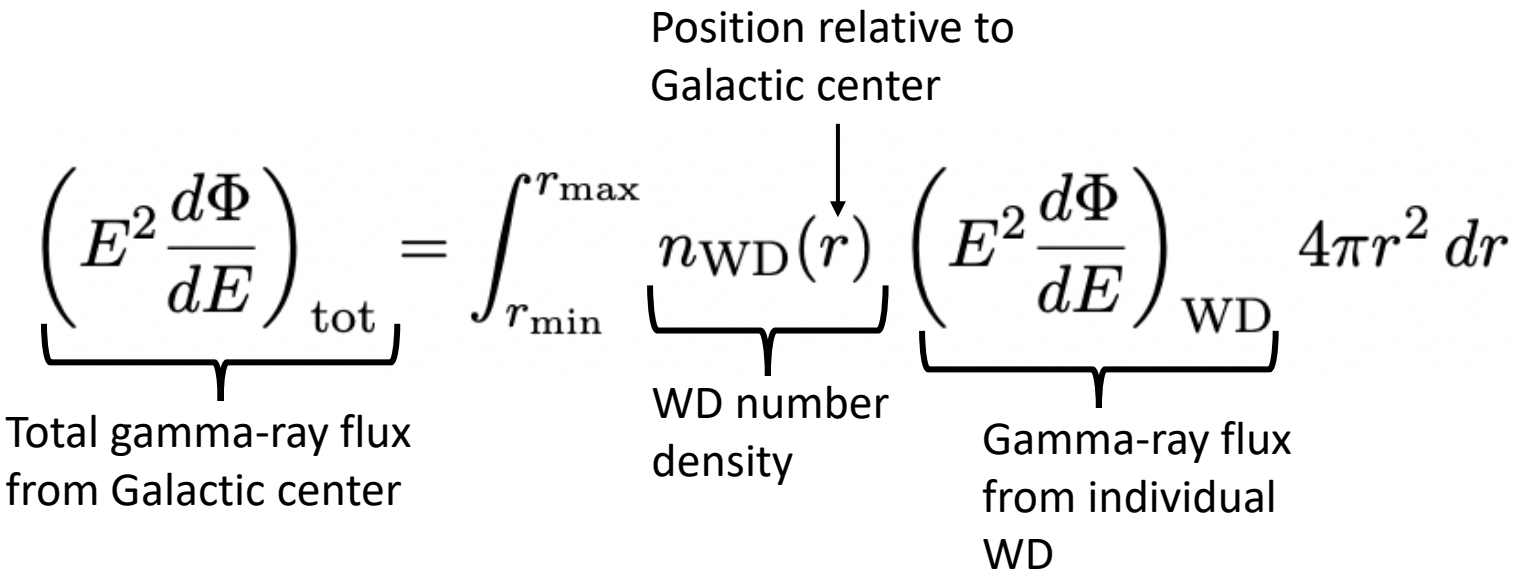
Galactic center gamma-ray data

- Telescopes:
  - Fermi Gamma-Ray Space Telescope (Fermi): sensitive to gamma rays up to order 100 GeV
  - High Energy Stereoscopic System (H.E.S.S): sensitive to gamma rays of order 10 GeV to 100 TeV
- Both telescopes have good exposure to the Galactic center

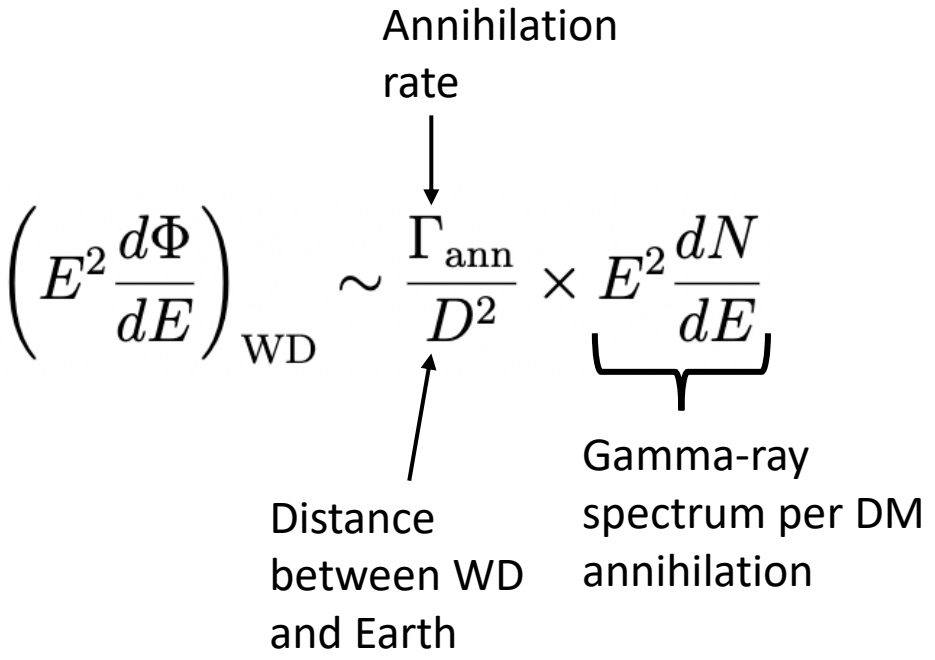


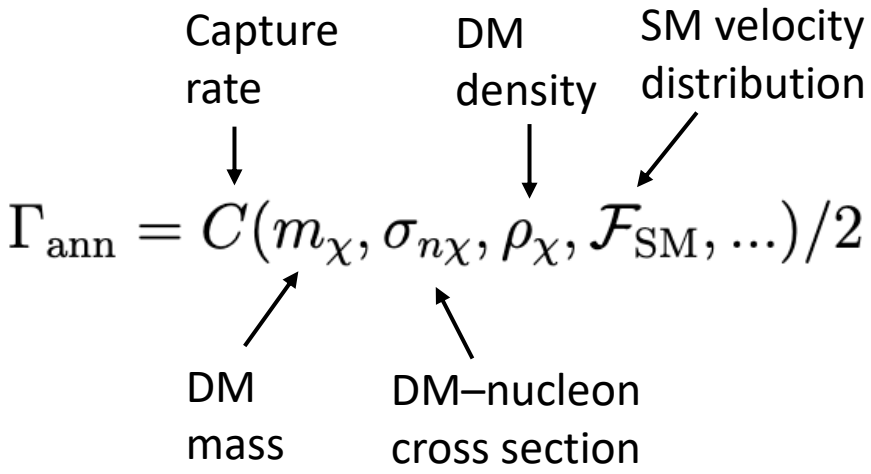
D. Malyshev, M. Chernyakova, A. Neronov, R. Walter (1503.05120)

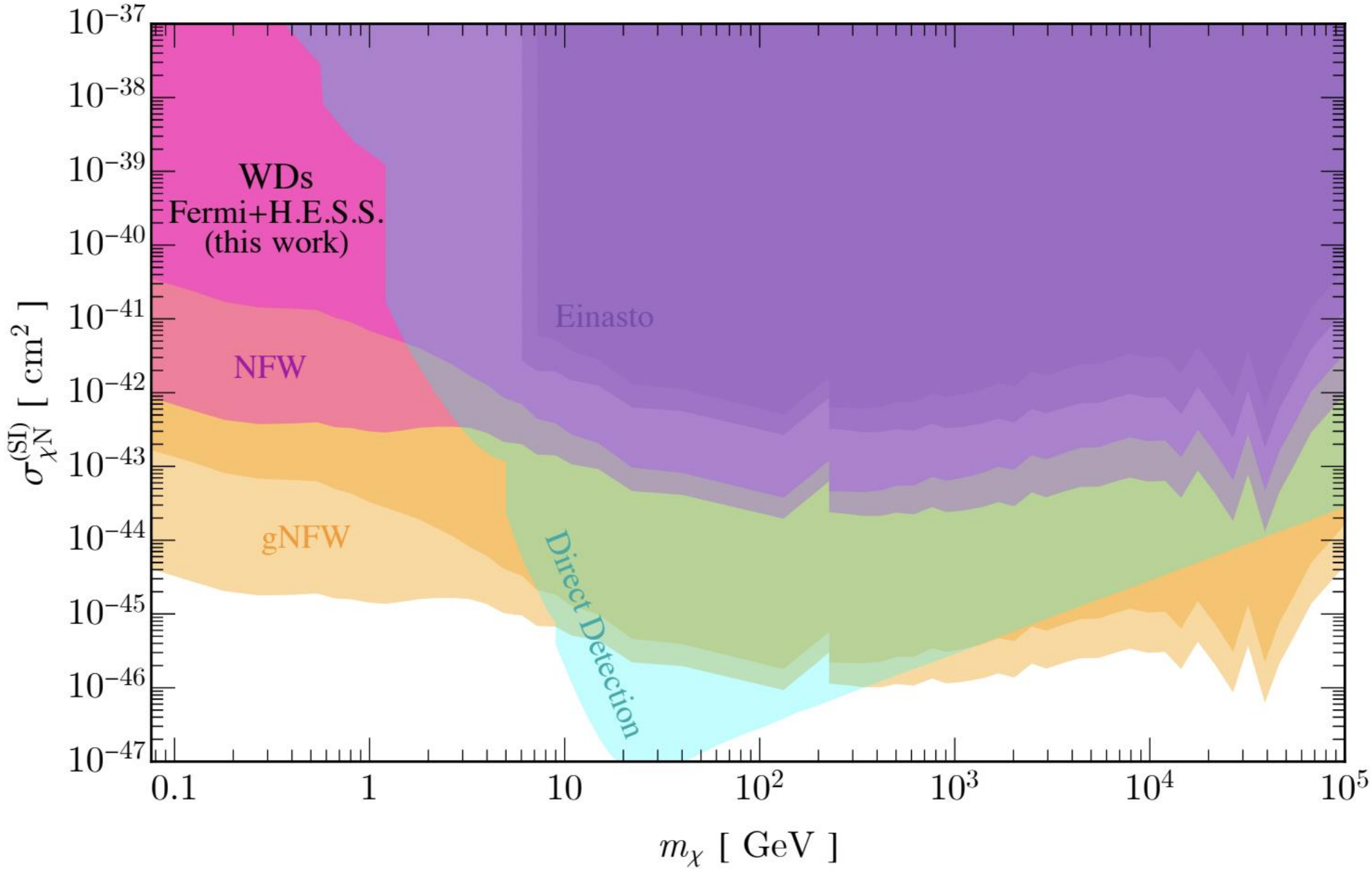
Total gamma-ray flux



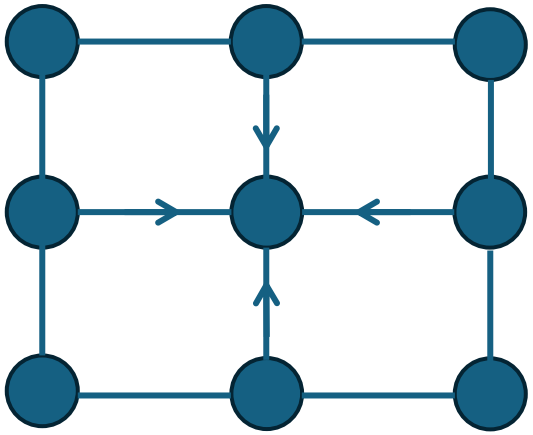
Individual gamma-ray flux






WDs
Fermi+H.E.S.S.
(this work)
NFW
gNFW
Einasto
Direct Detection
$\sigma_{\chi N}^{(\mathrm{SI})}$ [cm^2]
m_χ [GeV]
10^{-37}
10^{-38}
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
0.1
1
10
10^2
10^3
10^4
10^5

Improved capture framework for WDs



The WD ions feel an approximate harmonic oscillator potential with frequency ω_p

Ion mean squared velocity

WD temperature

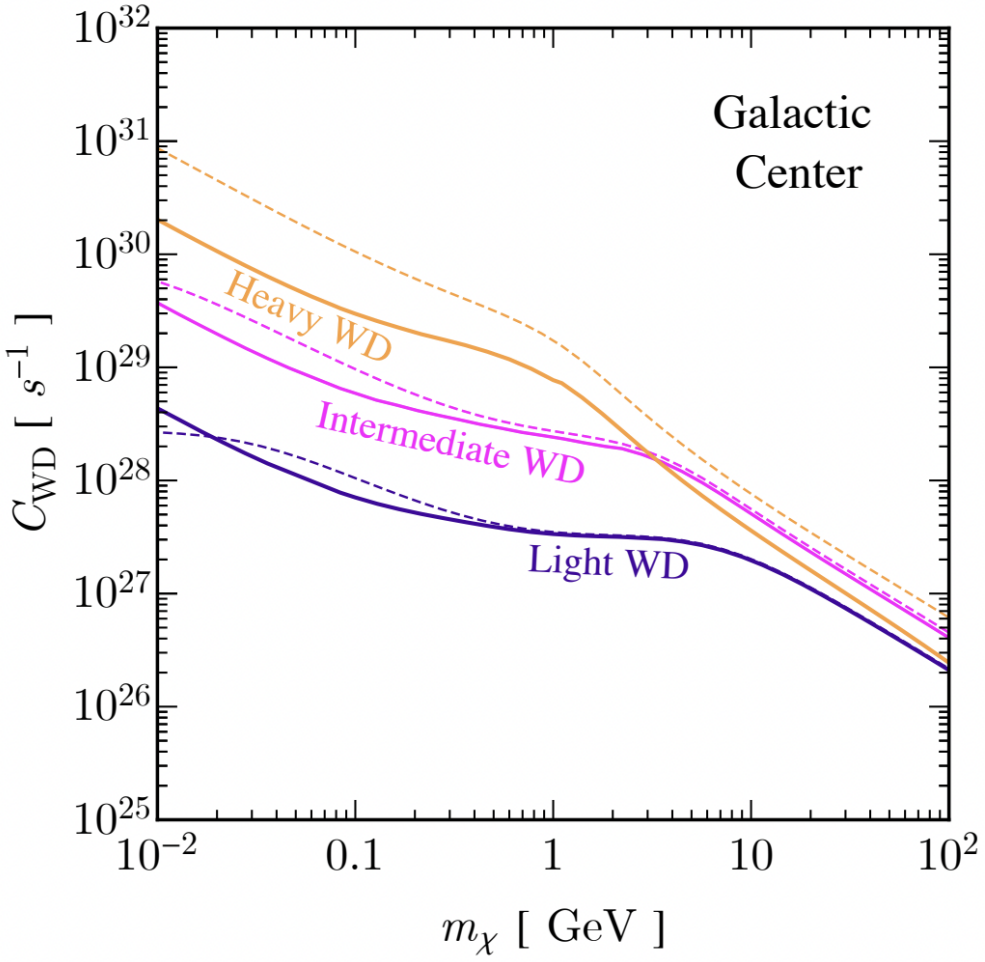
Previous treatment: $\langle v_N^2 \rangle \sim \frac{T_{WD}}{m_N}$

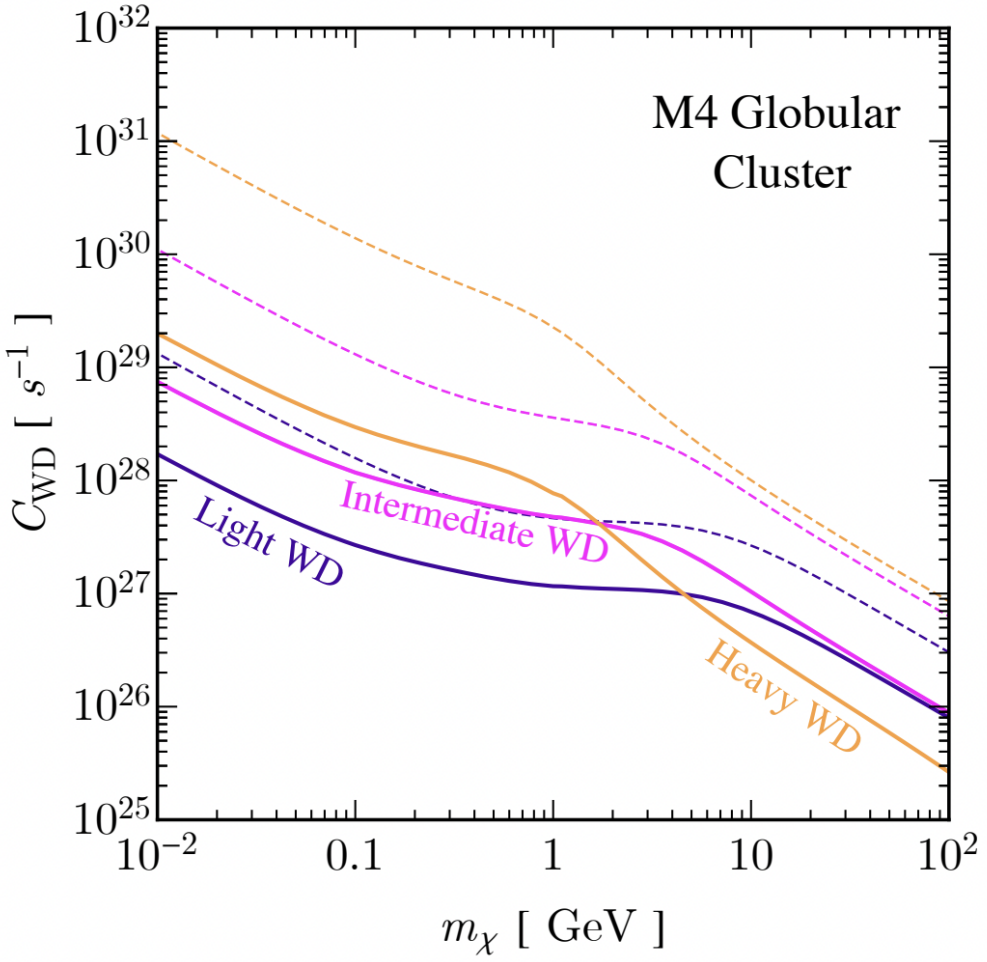
Ion mass

Our treatment: $\langle v_N^2 \rangle \sim \frac{\omega_p}{m_N}$

In volume relevant for capture,
$\omega_p \gg T_{WD}$

Improved capture framework for WDs





Summary

- White dwarfs are good celestial objects for DM searches because of their density and size, so they can capture a lot of DM
- We constrain the DM-nucleon cross section using gamma-ray data from the Galactic center
- Constraints from Galactic center WDs are stronger than existing limits by several orders of magnitude in the sub-GeV mass range
- We develop a new WD capture framework with an improved calculation of the ion velocity distribution