Optimal Celestial Bodies for Dark Matter Detection

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Why use celestial bodies for dark matter detection?

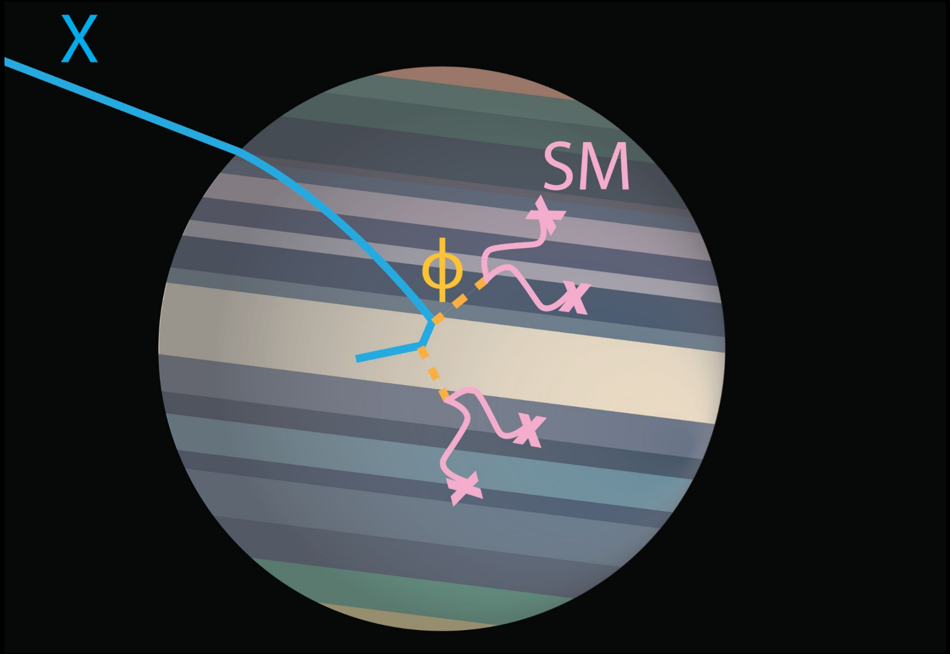
What celestial body is the best dark matter detector?

Dark matter energy injection (short decay length)

- Dark matter from Galactic halo may scatter and settle inside object

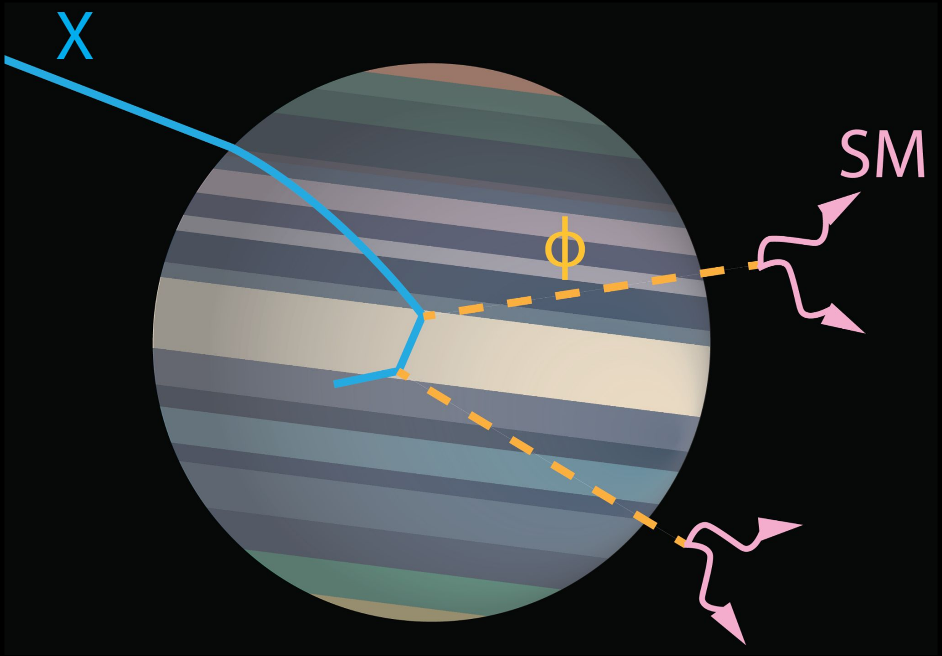
- Dark matter annihilates to SM and the energy is **injected** into body.

- SM particles **heat** the object



Dark matter SM flux (long decay length)

- Dark matter annihilates to SM and the energy **escapes.**



Celestial body properties

Celestial bodies have relevant properties as dark matter detectors

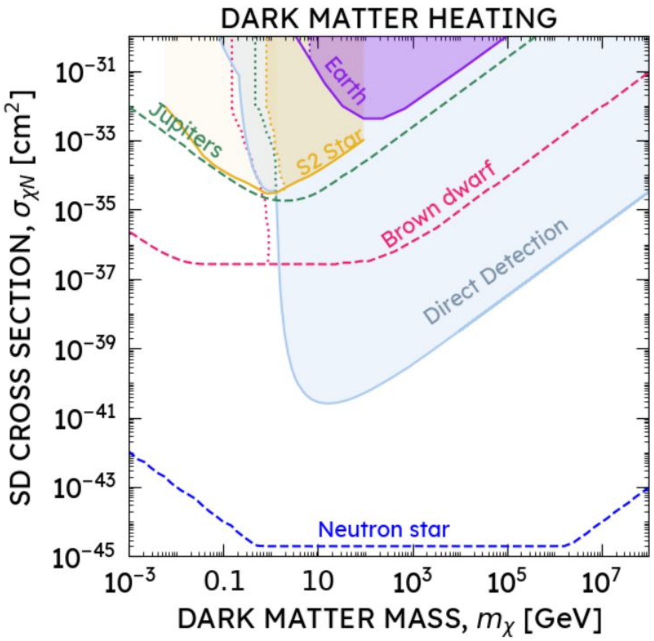
- Escape velocity (density)
  - Dense objects efficiently capture dark matter with low interaction cross sections
- Radius
  - Bigger object captures more dark matter. Large objects are more luminous and easier to detect.
- Core temperature
  - High temperature can give thermal kicks to dark matter to escape the gravitational potential (evaporate)

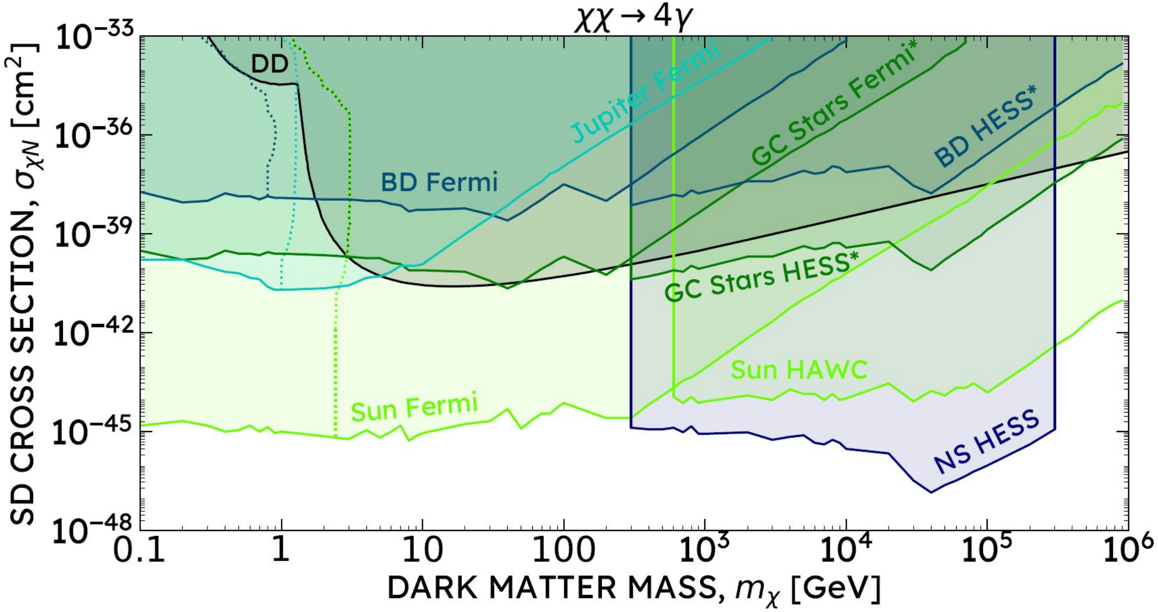
Location properties

The location and environment of a celestial body impacts the feasibility of a search

- Dark matter density
    - High dark matter mass density means more dark matter mass available to be captured
- Dark matter velocity
    - Slow moving dark matter is easier to capture. Therefore, low dark matter velocity environments are optimal
- Distance
    - The closer the object is to the telescope or detector, the larger the flux will be. Flux is inversely proportional to distance squared.

The landscape





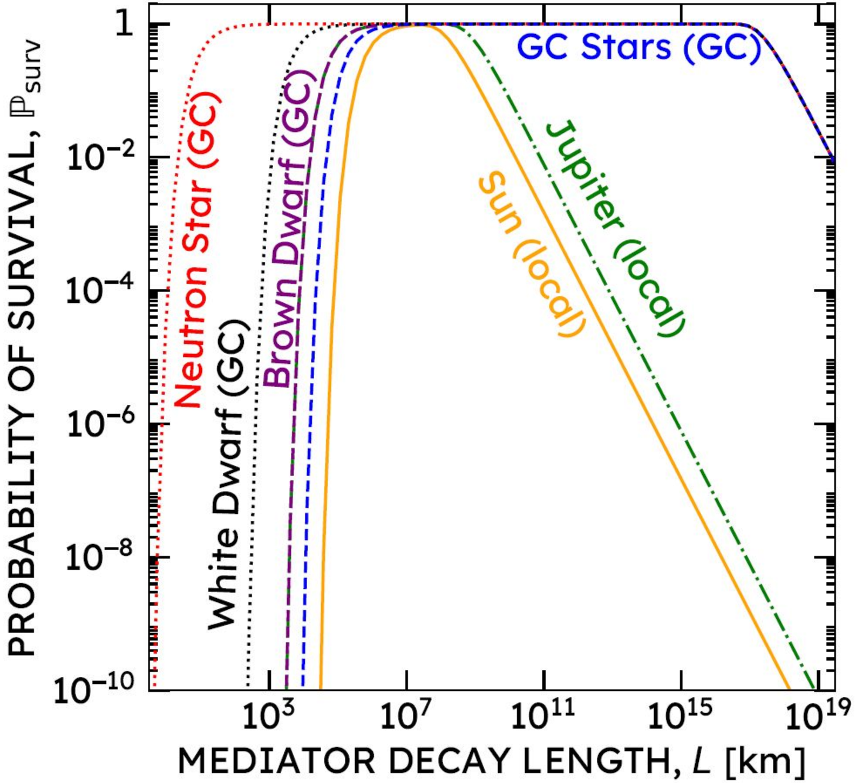
Assumptions go into this:

- Mediator
- Detectability
- Observing time

Signal dependence on the mediator

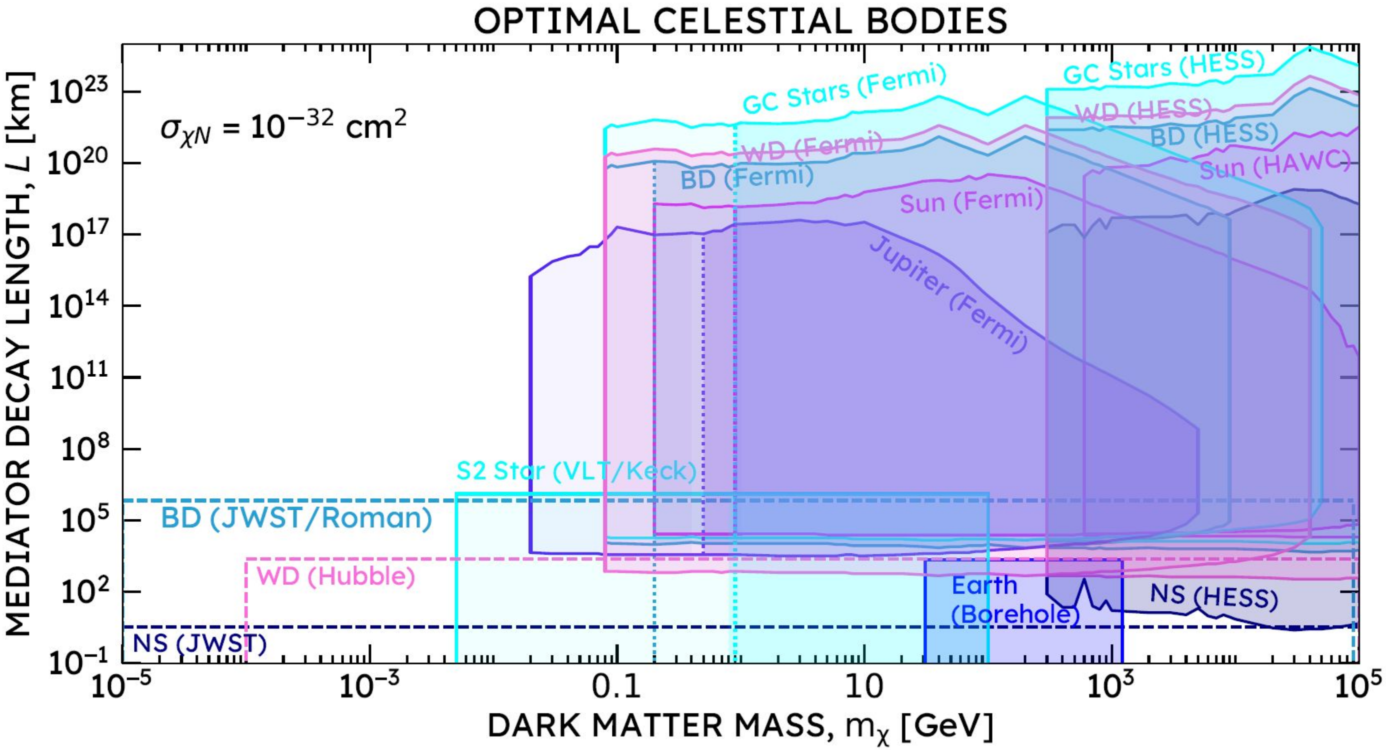
Signal dependence on object and mediator properties

$$\mathbb{P}_{\rm surv} = e^{-R/L} - e^{-D/L}$$



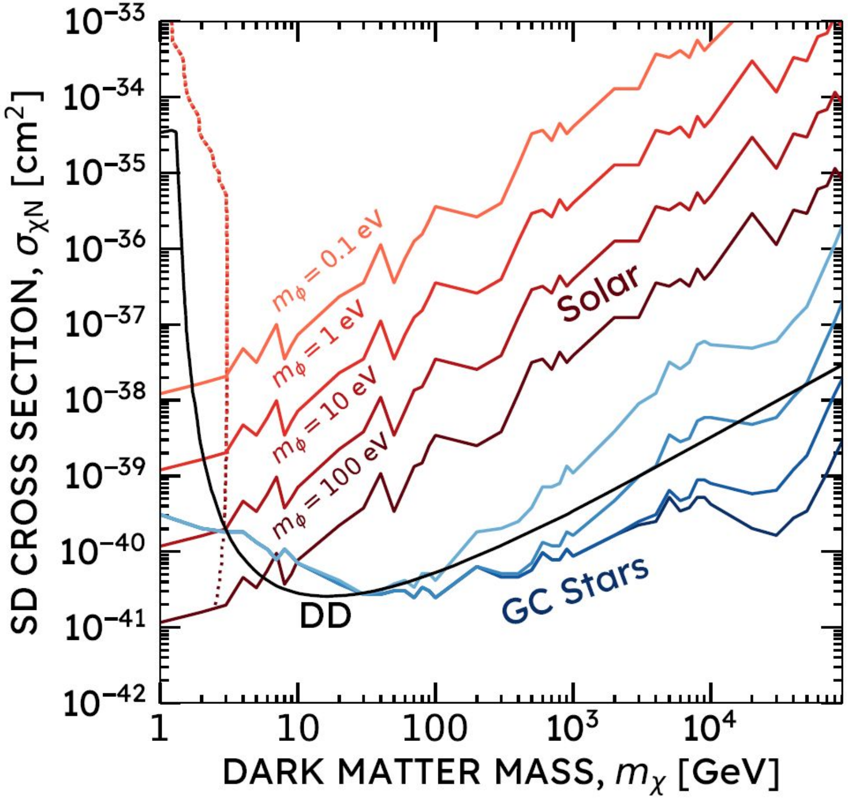
- DM signal proportional to survival probability
- SM flux searches typically assume survival probability ~ 1
- Survival depends on mediator properties
- Heat and survival interplay

Optimal celestial bodies



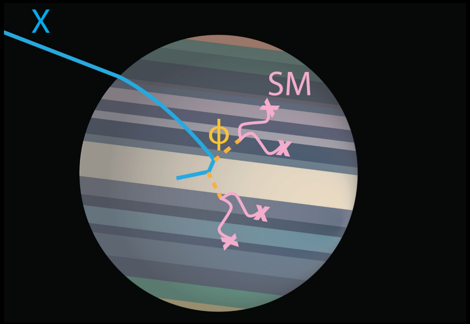
- Quantify dark sector parameters that lead to energy injection and gamma rays
- Intersecting space
- No single best object!
- Many assumptions in cross section sensitivities
- Mediator properties lead to different signals

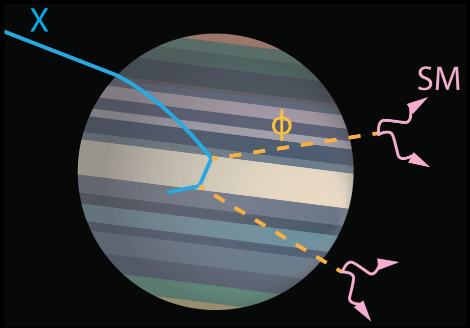
Stellar search



- We show a previously overlooked search
- GC Stars are more sensitive to light mediators because of their distance
- Mediator assumptions are important!

Summary

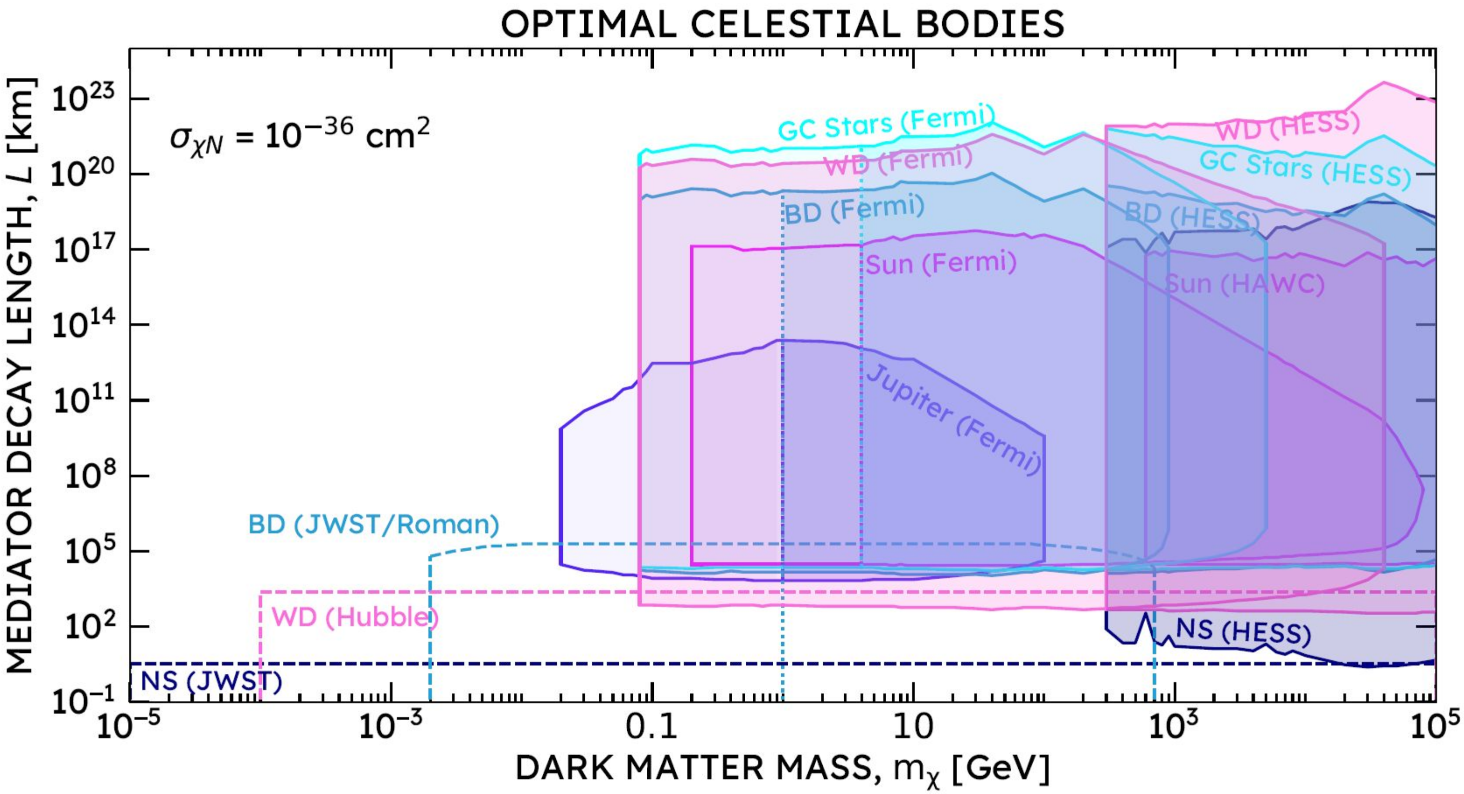




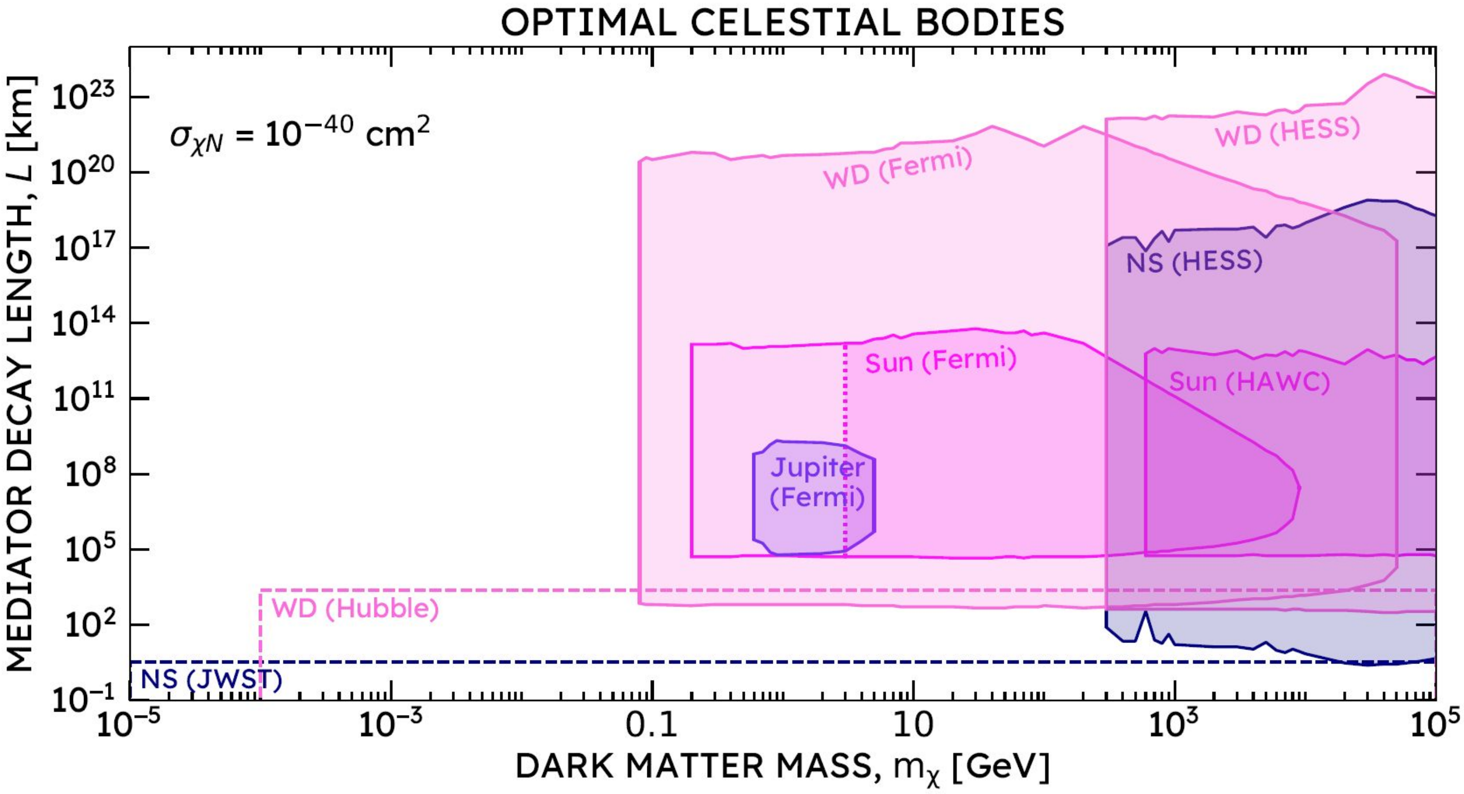
- Using celestial bodies provides complementary information about the dark sector
- Quantify the dependence on model class **assumptions** and **detectability**
- As an example, deconstructing these assumptions leads us to a new search using the stellar population at the galactic center

Thank you, questions?

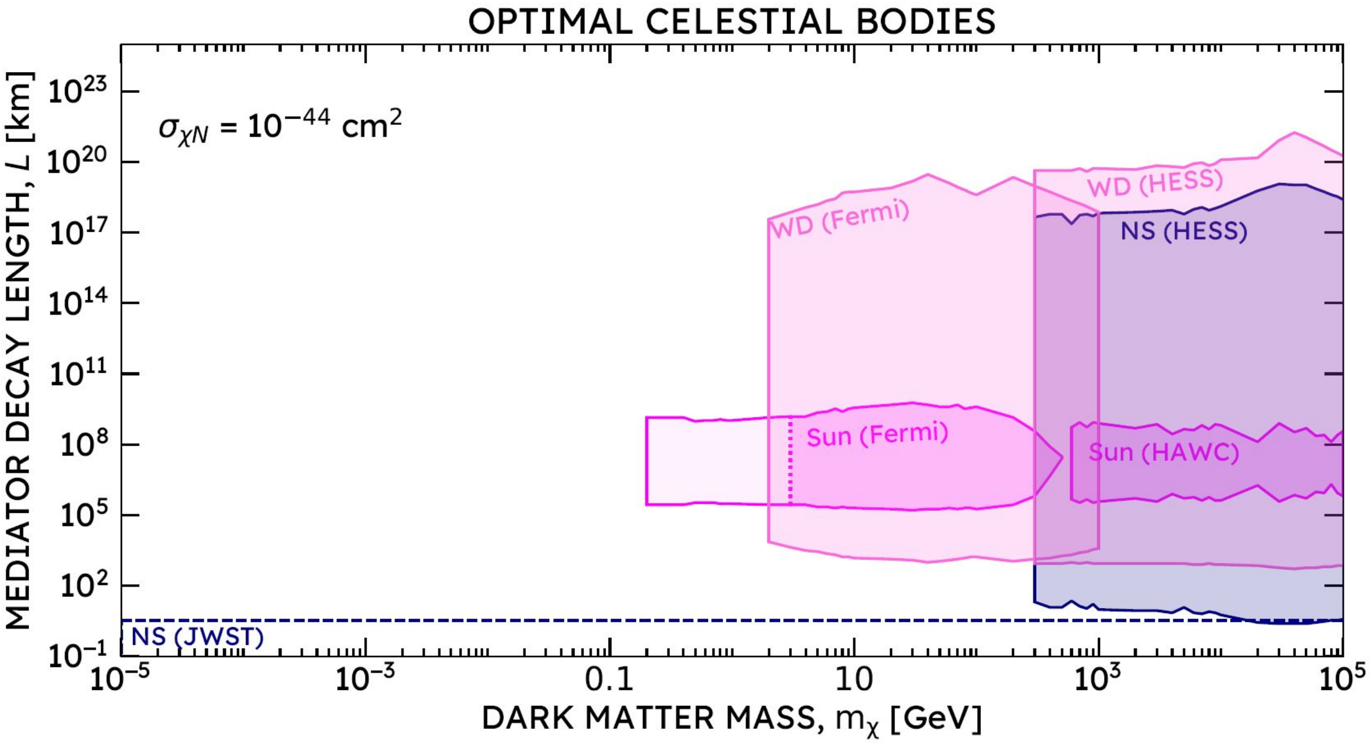
Optimal celestial bodies



Optimal celestial bodies

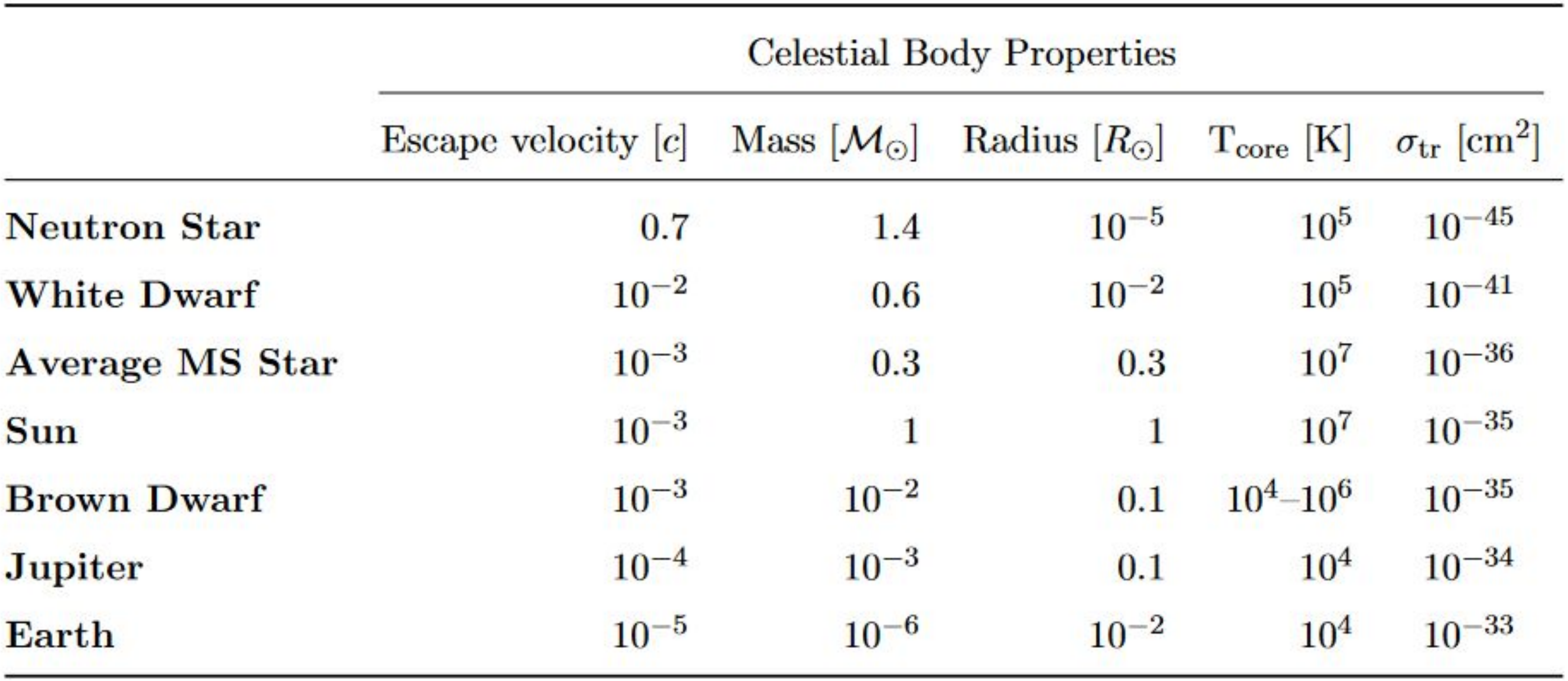


Optimal celestial bodies



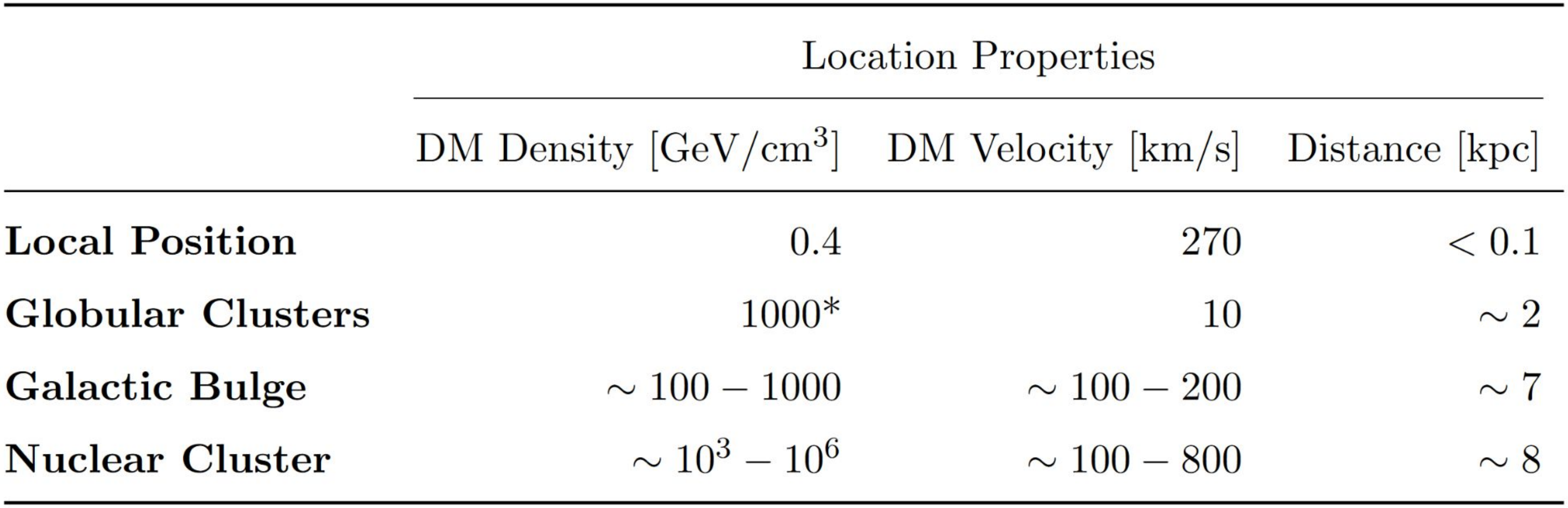
- Only dense objects at small cross sections

A wide variety of objects



	Celestial Body Properties				
	Escape velocity [c]	Mass [$\mathcal{M}_\odot$]	Radius [$R_\odot$]	T_{core} [K]	σ_{tr} [cm^2]
Neutron Star	0.7	1.4	10^{-5}	10^5	10^{-45}
White Dwarf	10^{-2}	0.6	10^{-2}	10^5	10^{-41}
Average MS Star	10^{-3}	0.3	0.3	10^7	10^{-36}
Sun	10^{-3}	1	1	10^7	10^{-35}
Brown Dwarf	10^{-3}	10^{-2}	0.1	10^4–10^6	10^{-35}
Jupiter	10^{-4}	10^{-3}	0.1	10^4	10^{-34}
Earth	10^{-5}	10^{-6}	10^{-2}	10^4	10^{-33}

Location properties



	Location Properties		
	DM Density [GeV/cm^3]	DM Velocity [km/s]	Distance [kpc]
Local Position	0.4	270	< 0.1
Globular Clusters	1000*	10	~ 2
Galactic Bulge	$\sim 100 - 1000$	$\sim 100 - 200$	~ 7
Nuclear Cluster	$\sim 10^3 - 10^6$	$\sim 100 - 800$	~ 8