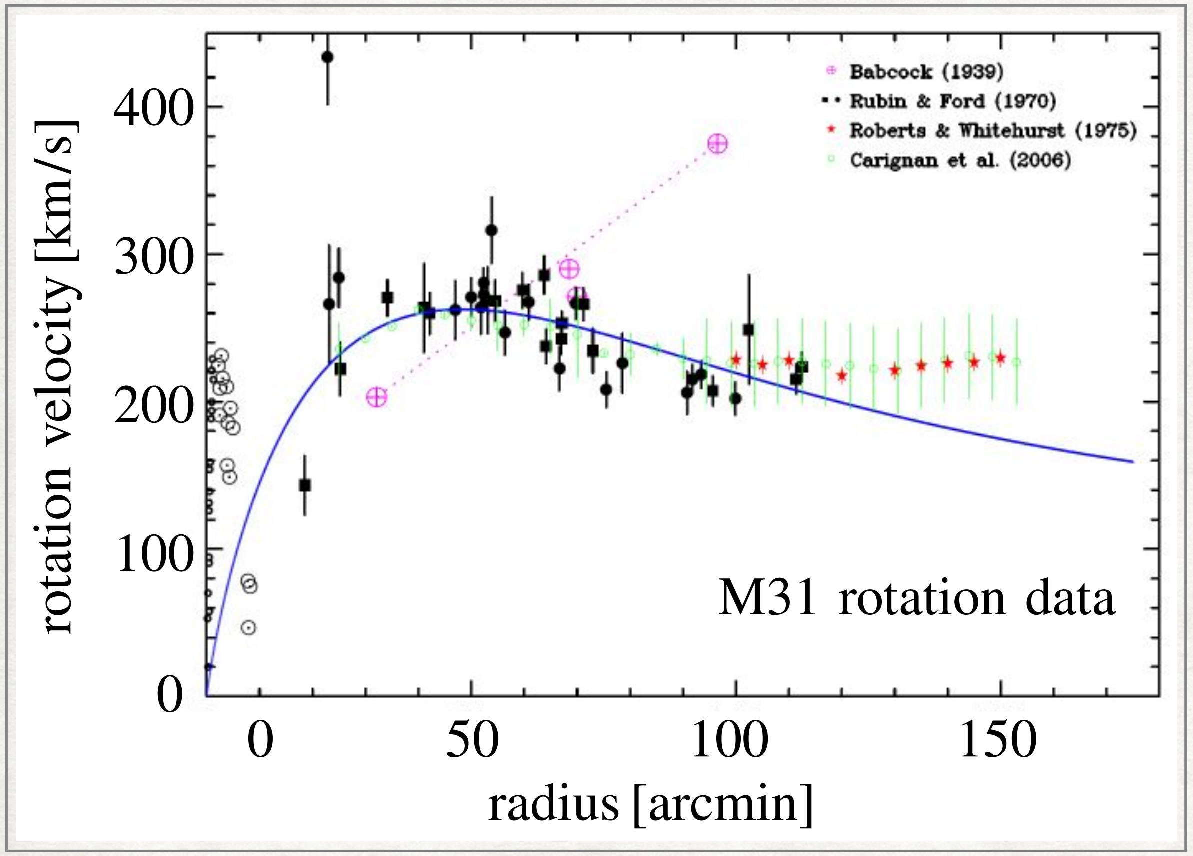
FIPs in the ALPs: Short Talk

Anupam Ray

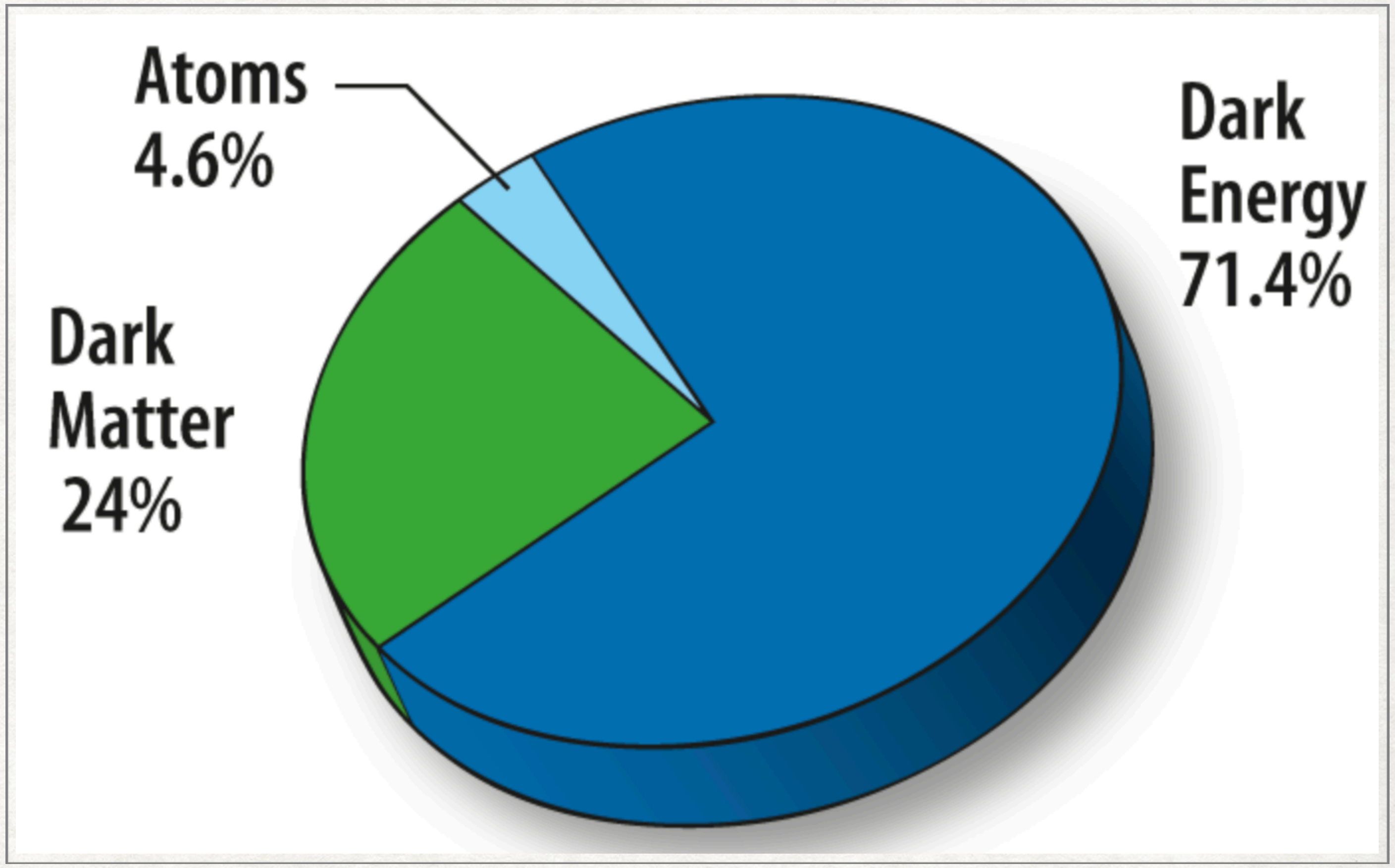
N3AS Fellow, UC Berkeley & University of Minnesota

N3AS Network for Neutrinos, Nuclear Astrophysics, and Symmetries
PHYSICS FRONTIER CENTER

Dark Matter (DM)



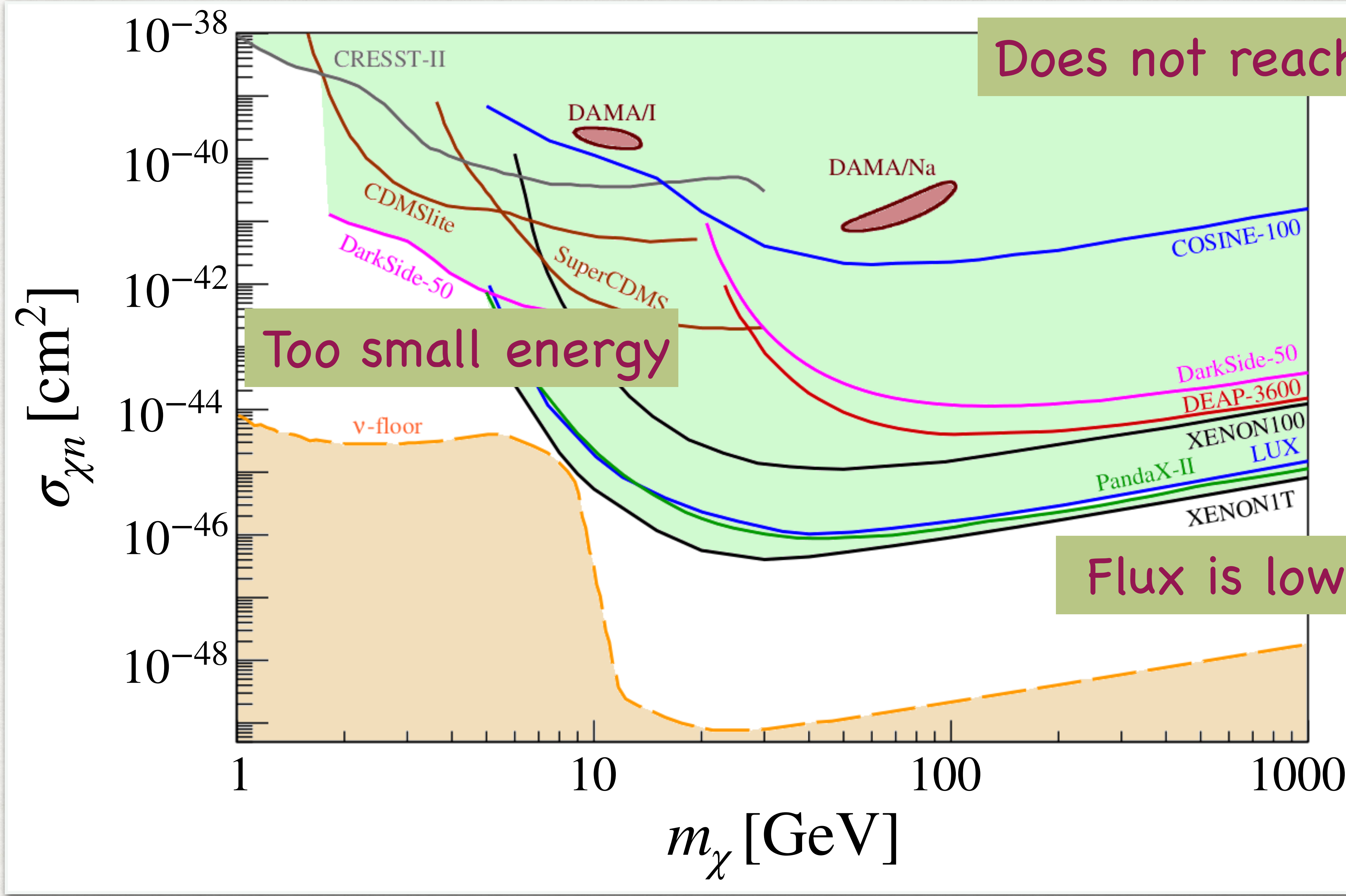
From: Bertone and Hooper, Rev. Mod. Physics (2016)



https://wmap.gsfc.nasa.gov/universe/uni_matter.html

- DM mass?
- DM interactions with baryons?

Results: Underground Detectors



- Light DM, Heavy DM and Strongly-interacting DM

— "3" Blind-spots to the underground detectors.

Take Away

- We show DM capture in celestial objects can provide unprecedented sensitivity to these blind-spots.

- Celestial objects because of their large size and cosmologically long lifetime naturally act as gigantic DM detectors.

$$M_{\odot} - \text{Gyr} \gg \text{kT} - \text{year}$$

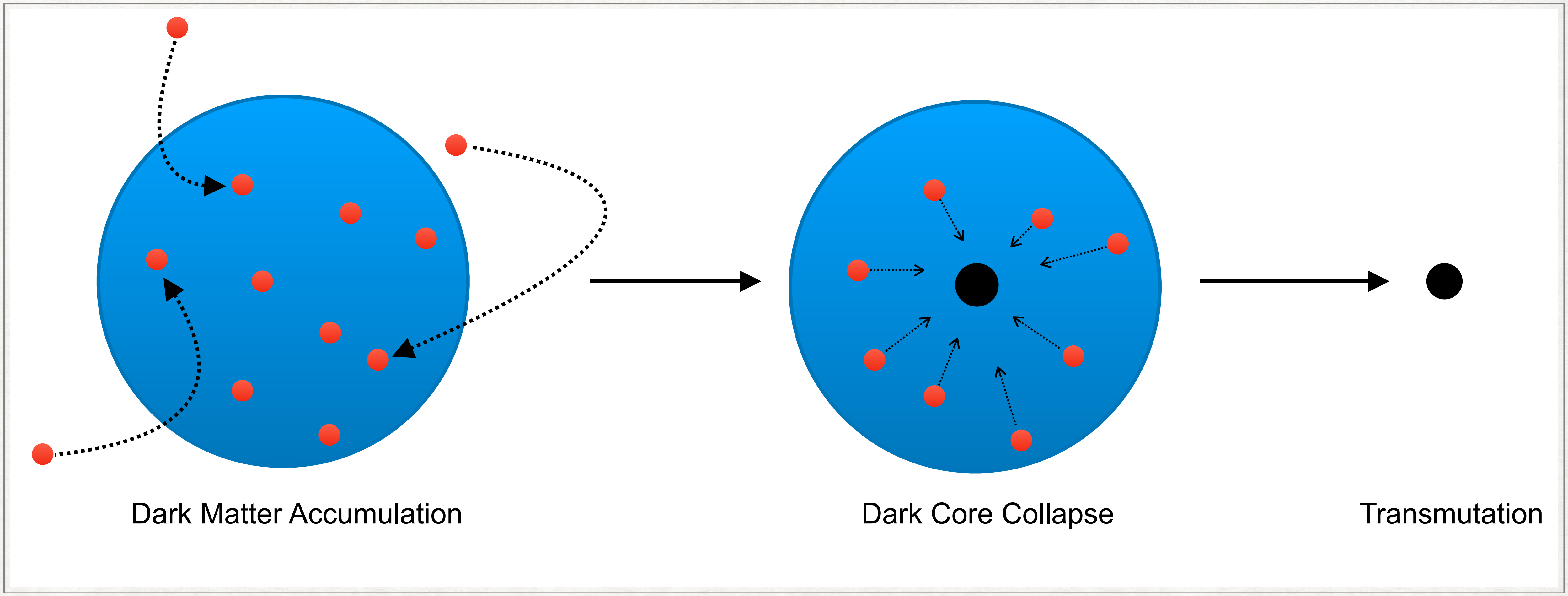
naturally providing sensitivity to the tiny flux of heavy DM

- In the weakly interacting regime, DM can be trapped in a significant number inside compact stars.

- In the strongly interacting regime, stellar objects with larger size are the most optimal for accumulation.

Non-compact objects are ideal

DM-induced Collapse

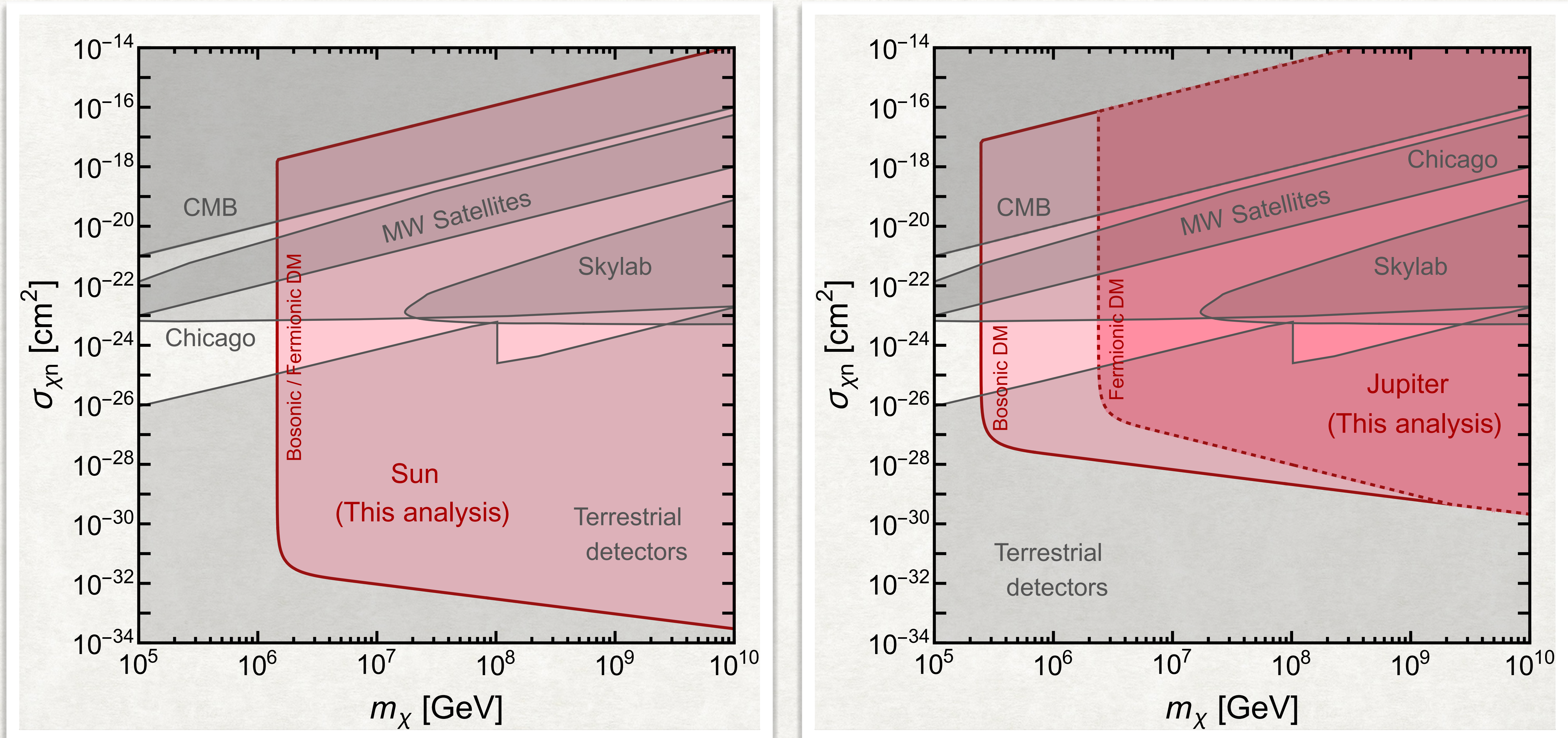


1. DM accumulation
2. DM thermalisation
3. DM distribution
4. Dark Core Collapse
5. Growth of micro-BH
6. Destruction of host

Results

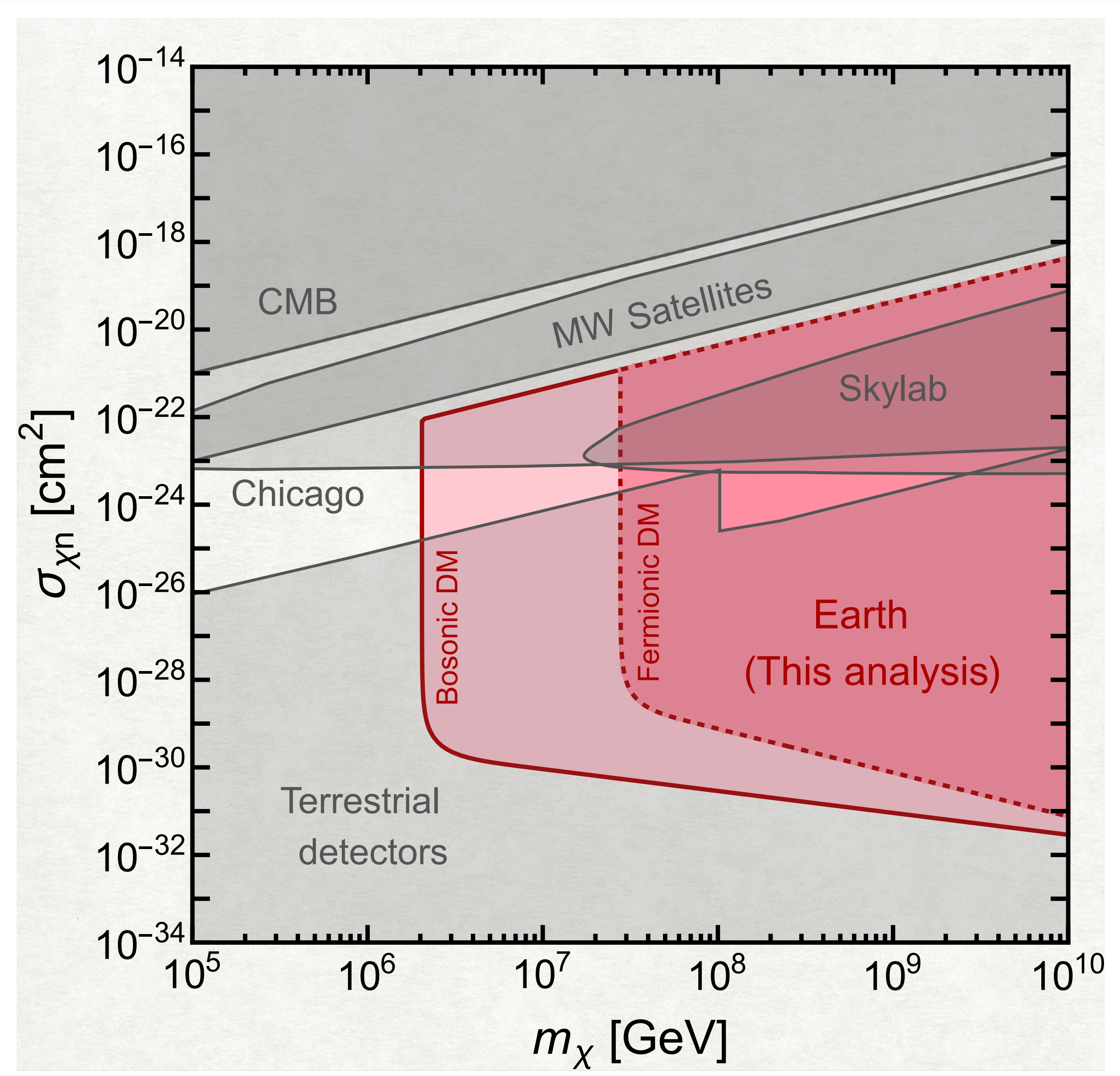
- DM parameters which predicts successful BH formation are excluded because we see Sun, Jupiter, Earth, Moon!

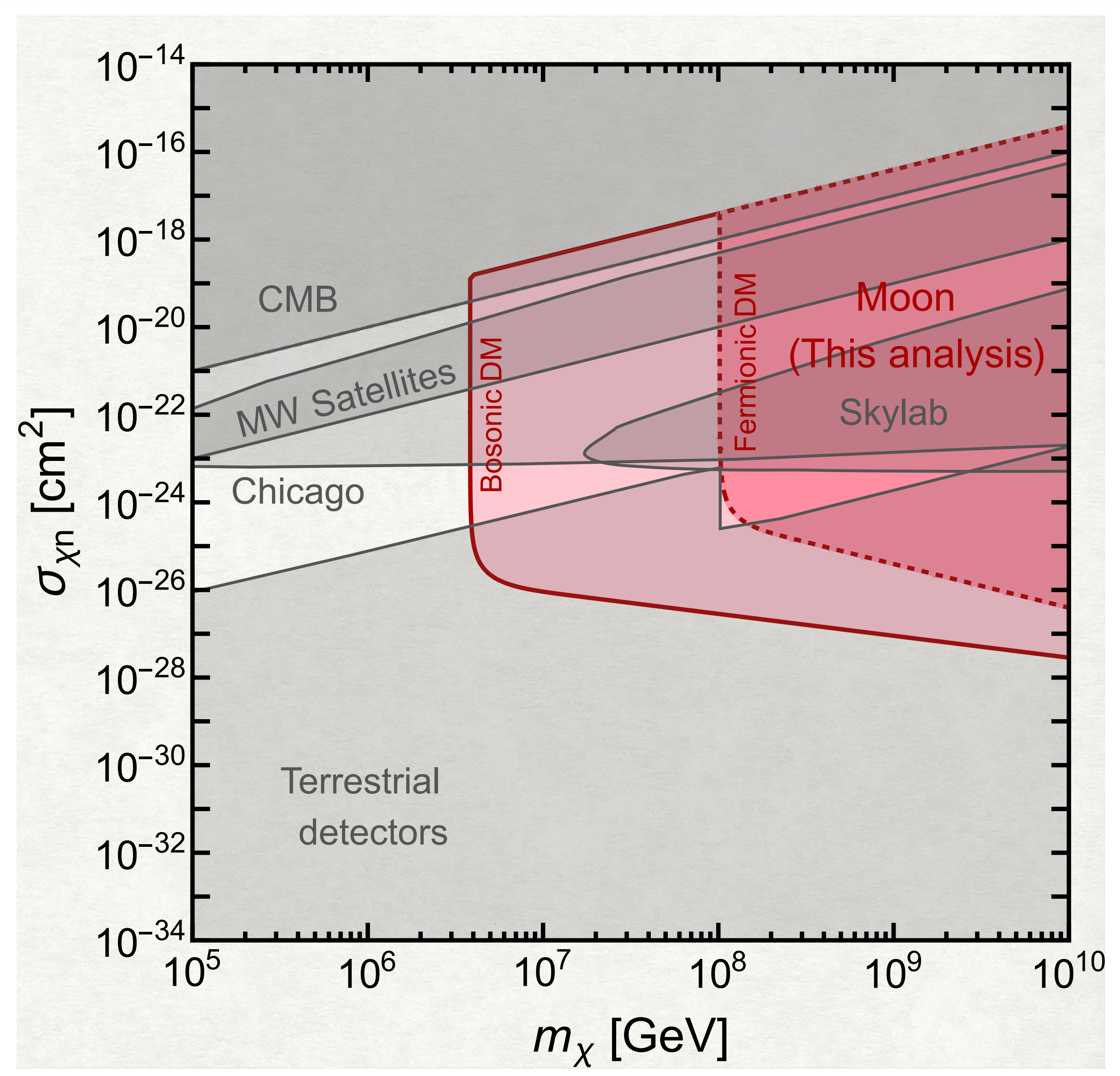
Ray (2023), 2301.03625 (PRD)



Results

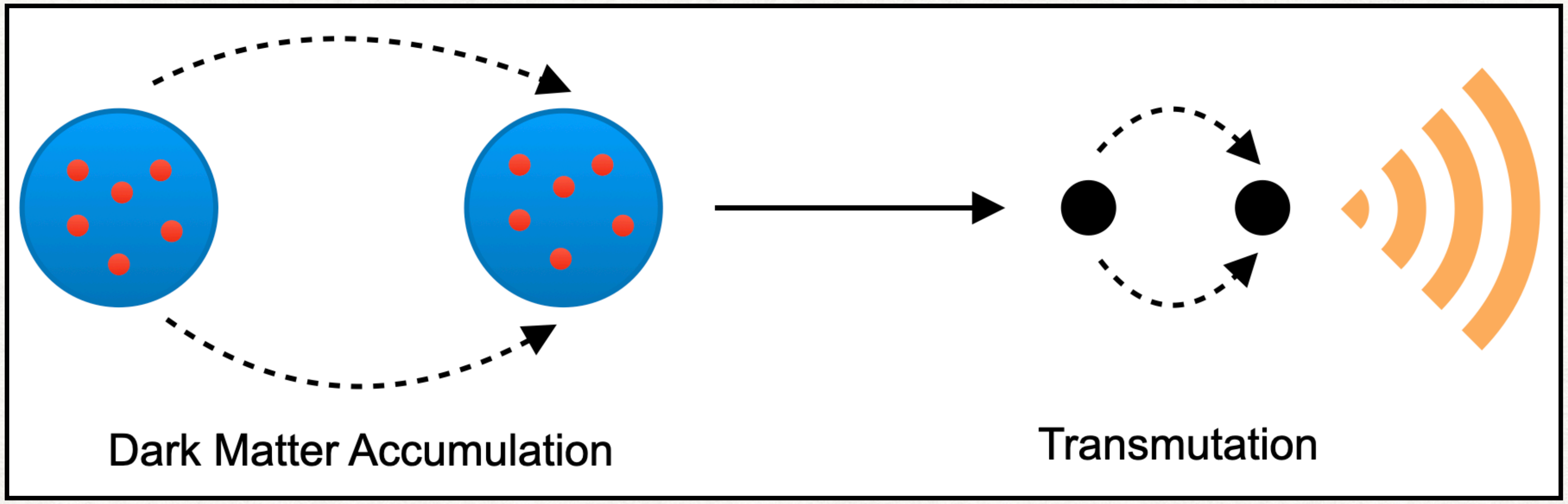
Ray (2023), 2301.03625 (PRD)





*** Stellar objects with larger size and the low core-temperature (Jupiter) are the ideal targets. Larger size implies more DM capture, and lower temperature implies easier BH formation.

Summary



- Binary neutron stars can be transmuted to anomalously low mass binary BHs via gradual accumulation of non-annihilating DM.

Transmuted Black Holes (TBHs)

Dasgupta, Laha, Ray (PRL, 2021)

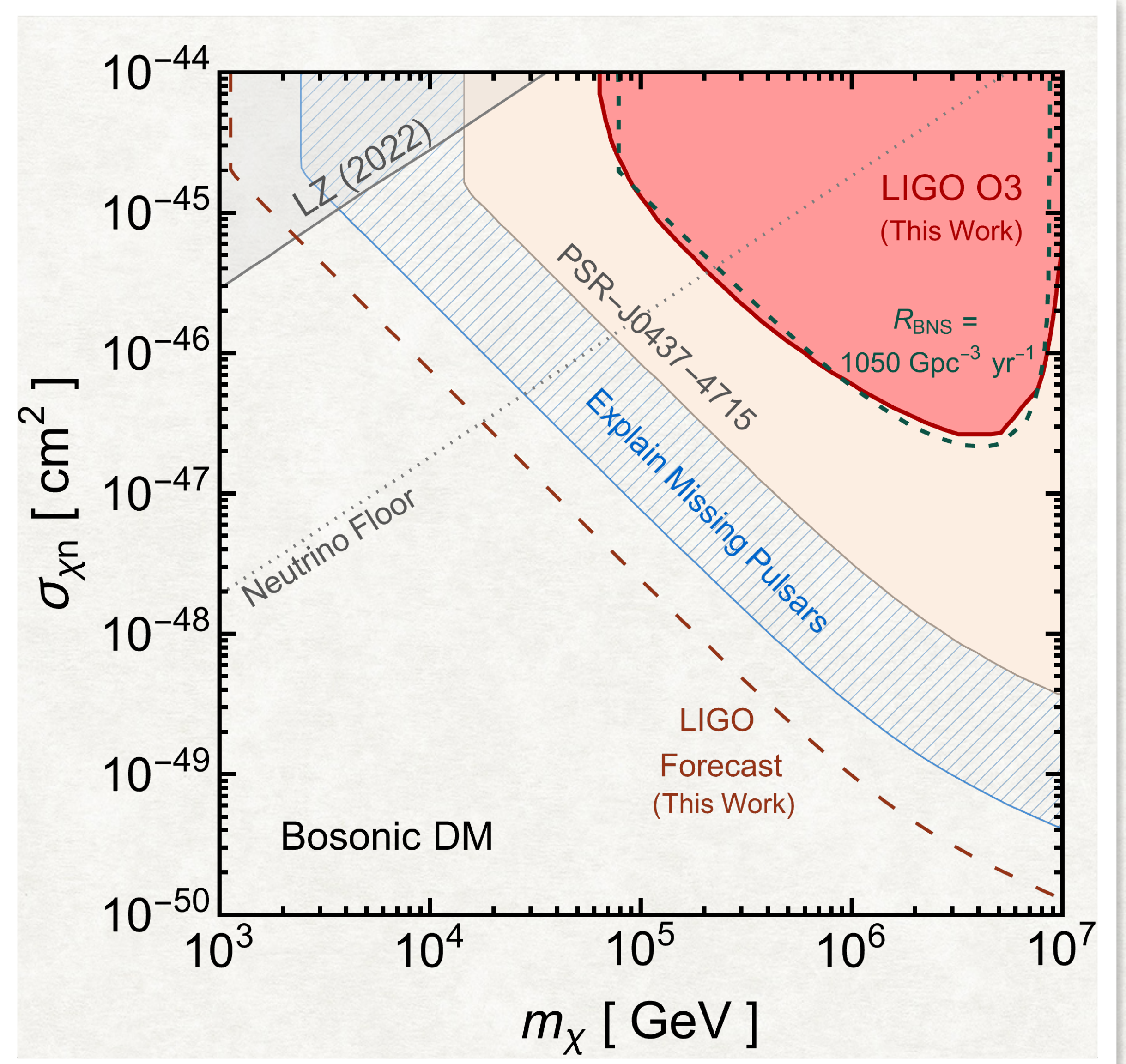
- Non detection of such binary BHs in the existing GW data provide novel constraints on weakly-interacting heavy DM interactions.

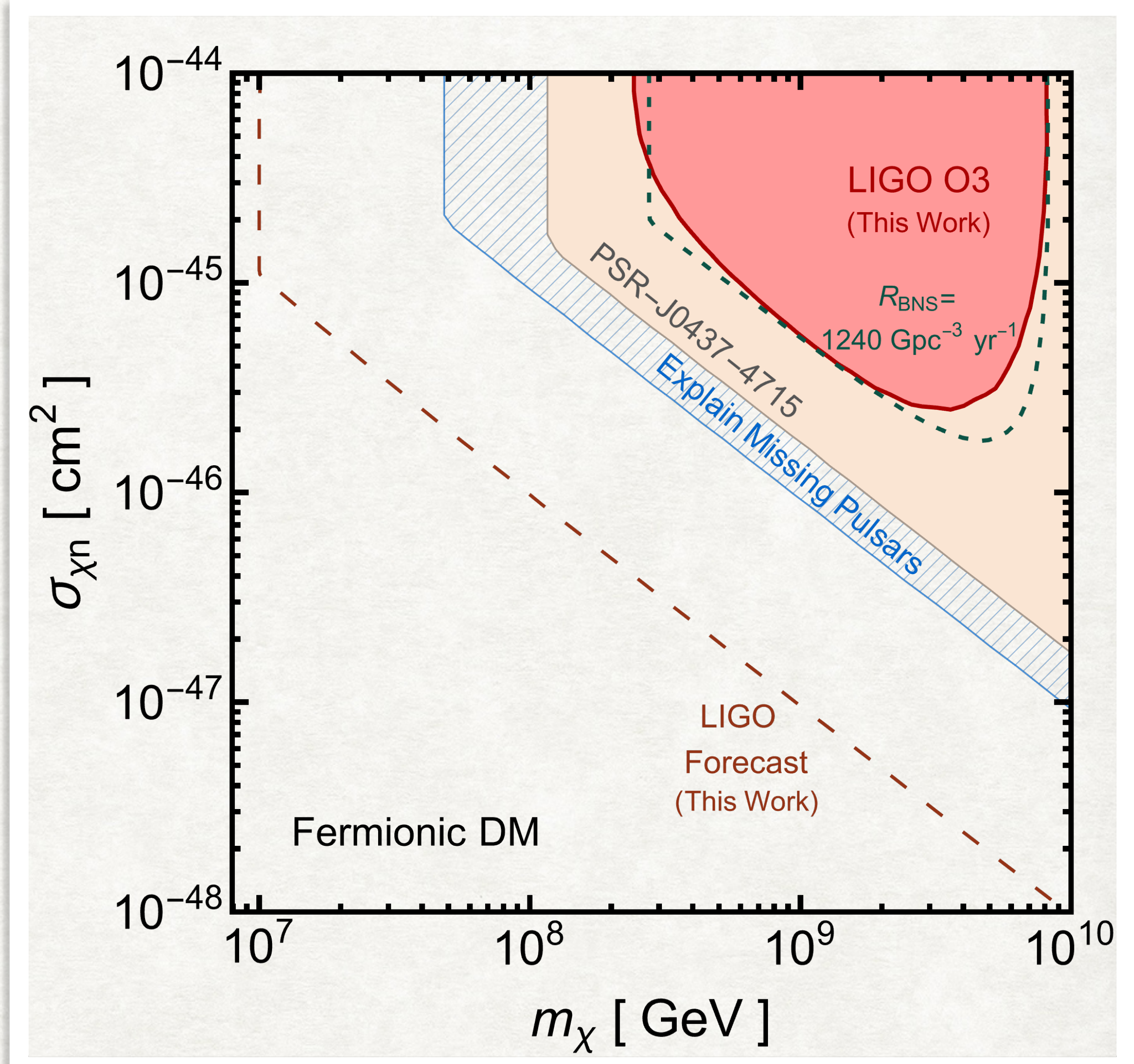
LIGO as a novel DM detector

Bhattacharya, Dasgupta, Laha, Ray (2023) arXiv: 2302.07898

Results

Bhattacharya, Dasgupta, Laha, **Ray** (2023) arXiv: 2302.07898





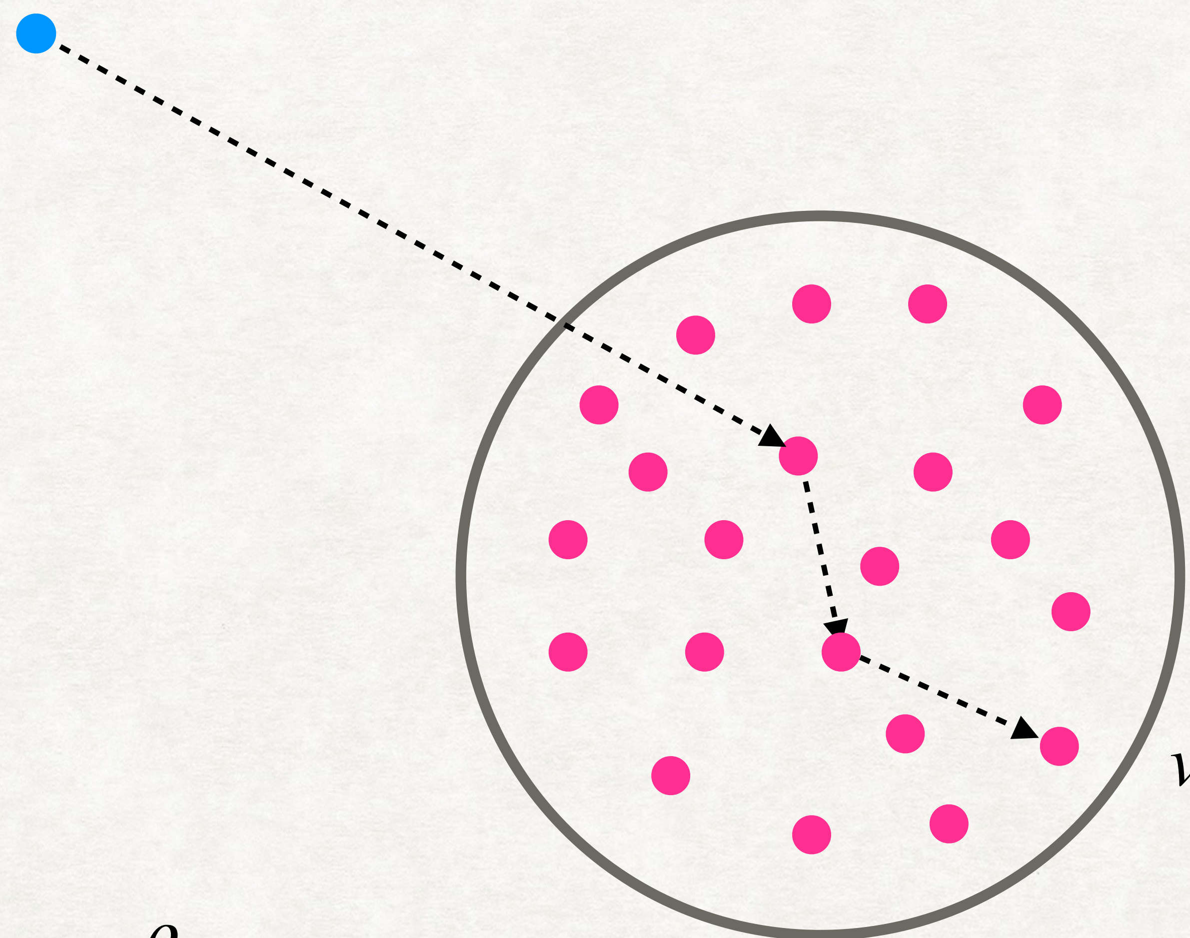
(Left) Bosonic DM (Right) Fermionic DM

See Sulagna's talk!

Earth-Bound DM

GeV mass DM almost uniformly distribute over the Earth volume.

Gould & Raffelt (1990, APJ), Leane & Smirnov (2022),...



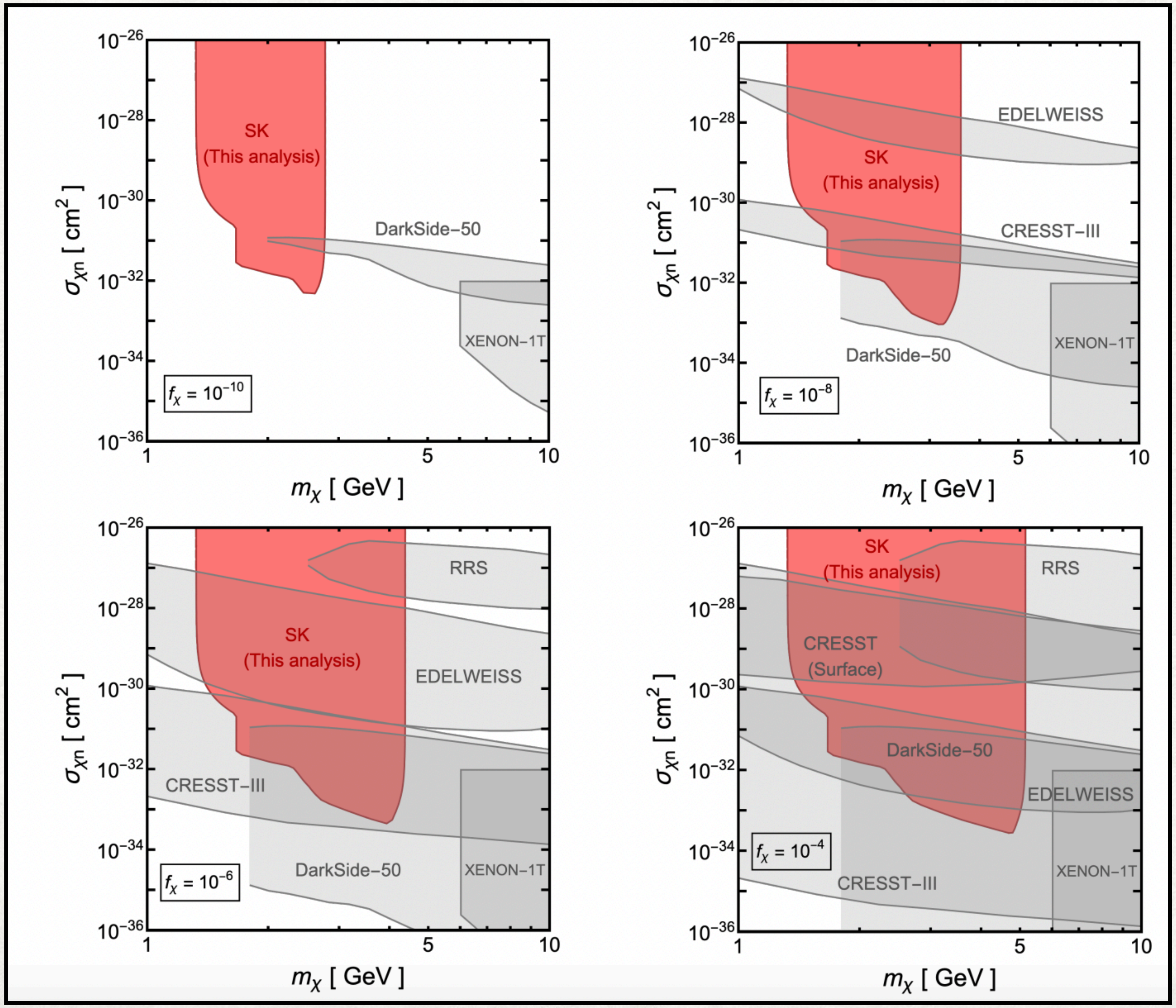
DM density $\sim m_\chi \dfrac{\pi R^2 \frac{\rho_\chi}{m_\chi} \bar{v} t_{\rm age}}{\frac{4}{3}\pi R^3} \sim 10^{15}\,\mathrm{GeV/cm^3}$

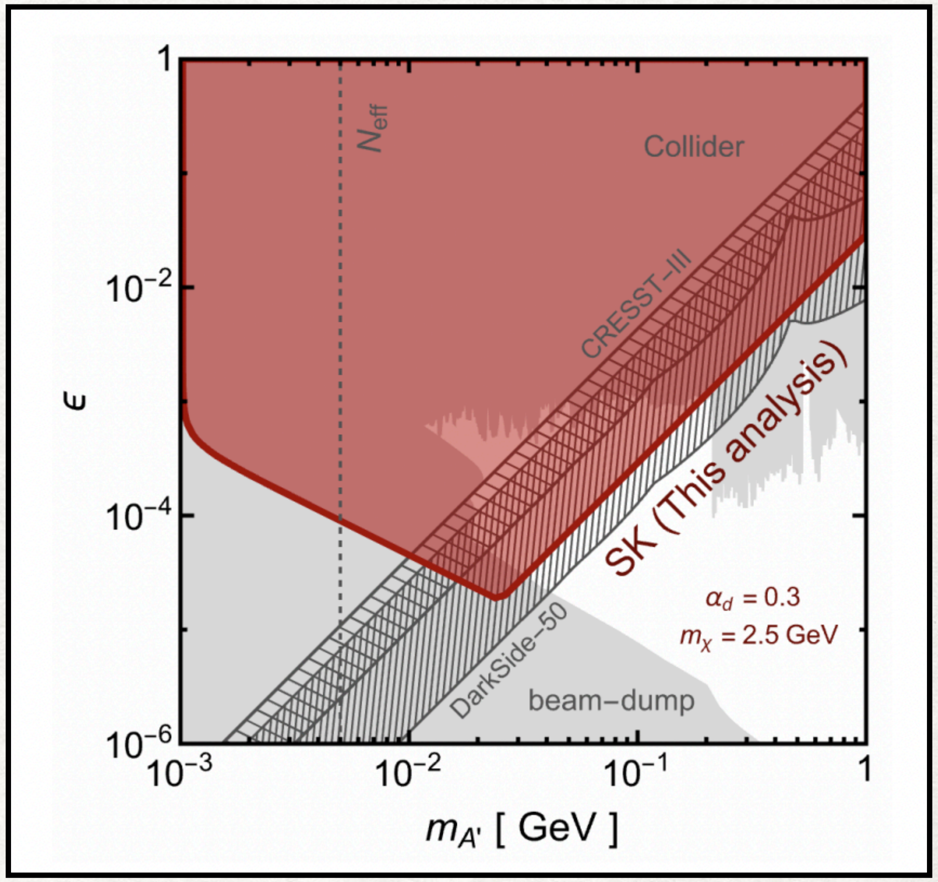
16 orders of magnitude larger than the Galactic DM density!

How to detect them?

McKeen, Morrissey, Pospelov, Ramani, **Ray** (2023), 2303.03416

- By looking at their annihilation signatures inside Large volume neutrino detectors such as Super-K.





Summary

- DM capture in celestial objects provides a prominent astrophysical probe of DM interactions.

- For non-annihilating DM: existence of celestial objects, GW observations of low mass compact objects provide novel constraints on heavy DM.

  much more stringent than the underground/surface detectors

- For annihilating DM: local annihilation inside Super-K volume provide unprecedented sensitivity to DM interactions (even in the limit of minuscule fraction of the DM density).