

Beyond standard WIMPs with direct detection experiments

CDM Annual Workshop 2022

Geelong, Nov. 2022



Jayden L. Newstead
The University of Melbourne

Two decades of dual-phase TPC progress



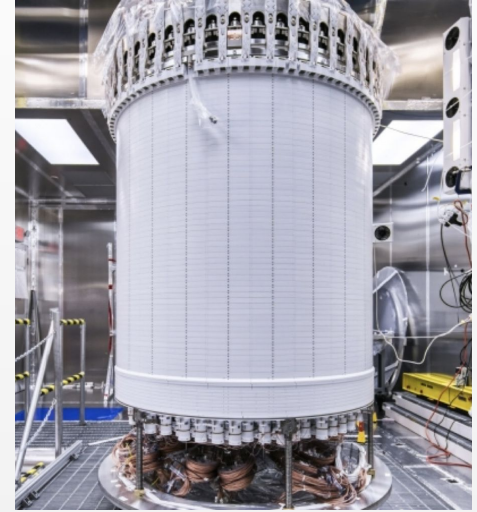
ZEPLINII & III
(photo ZIII Whitby
museum)



XENON100

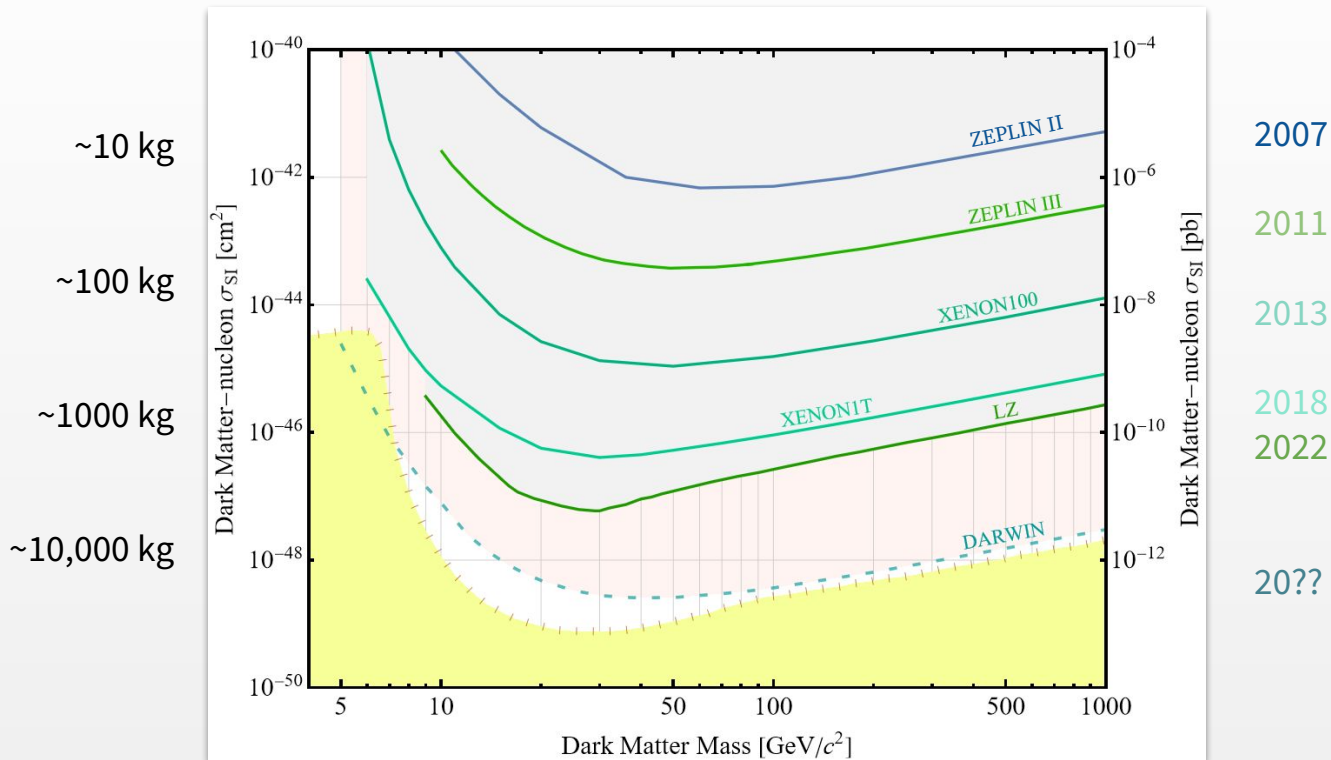


XENON1T



LZ

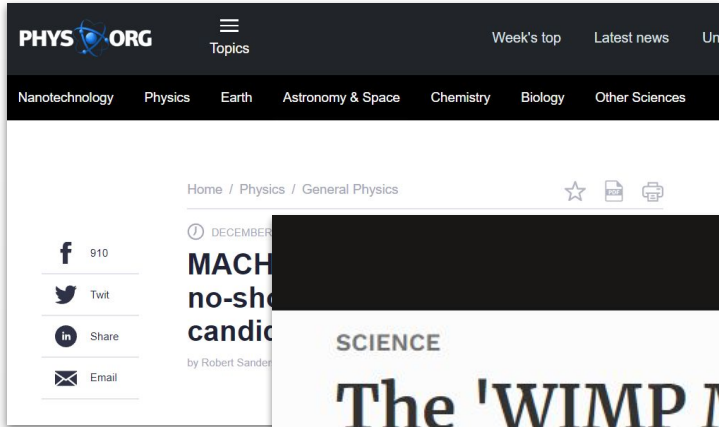
The WIMP parameter space



Where is the WIMP?

The screenshot shows the top portion of a Physics.org article page. The header includes the Physics.org logo, a navigation menu with categories like Nanotechnology, Physics, Earth, Astronomy & Space, Chemistry, Biology, and Other Sciences, and links for 'Week's top', 'Latest news', and 'Un'. The article breadcrumb is 'Home / Physics / General Physics'. The main title is 'MACHOs are dead. WIMPs are a no-show. Say hello to SIMPs: New candidate for dark matter', dated 'DECEMBER 4, 2017', and attributed to 'Robert Sanders, University of California - Berkeley'. On the left, there are social sharing options for Facebook (910 shares), Twitter, LinkedIn, and Email. Utility icons for star, PDF, and print are also visible.

Where is the WIMP?



Where is the WIMP?

PHYS ORG

Topics

Week's top Latest news Un

Nanotechnology Physics Earth Astronomy & Space Chemistry Biology Other Sciences

Home / Physics / General Physics

DECEMBER

MACH

no-sh

candic

by Robert Sande

910

Twit

Share


Email

SCIENCE

The 'WIMP' For Dark M

Ethan Siegel Senior Contribut

Starts With A Bang Contributor Group ©



HACKADAY

HOME BLOG HACKADAY.IO TINDIE HACKADAY PRIZE SUBMIT ABOUT

THE WIMP IS DEAD, LONG LIVE THE SOLAR AXION!

by: [Moritz v. Sivvers](#)

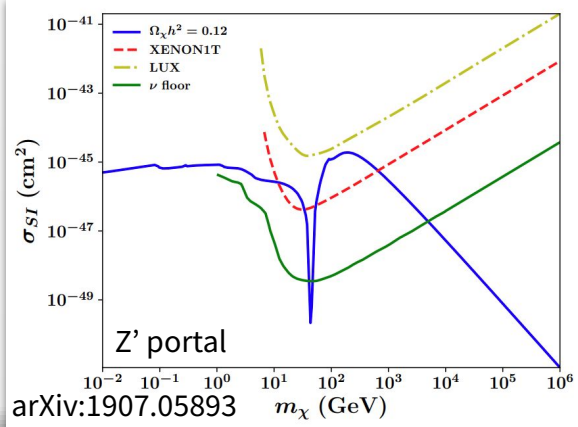
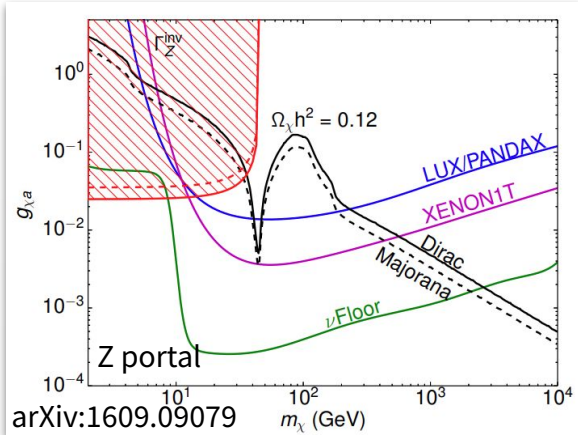
23 Comments

July 6, 2020

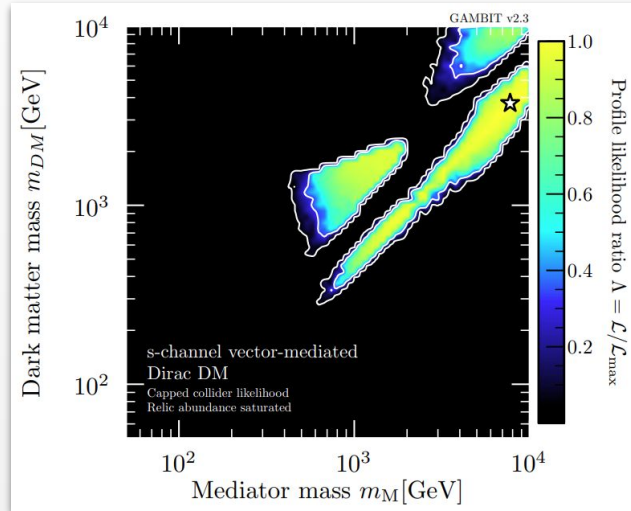
Feb 22, 2019, 02:00am EST

WIMPs are just fine..

Simple models:

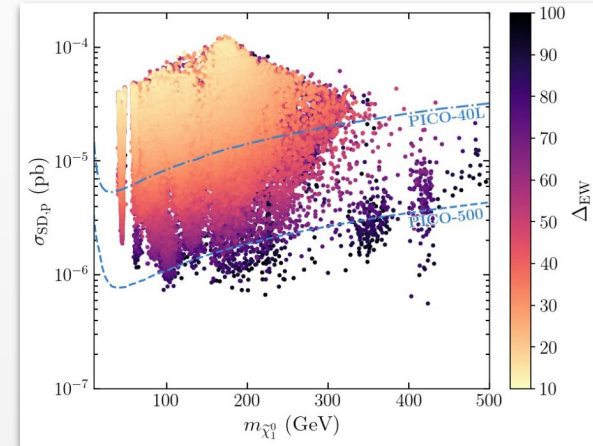


Simplified models:



arXiv:2209.13266

SUSY (pMSSM):

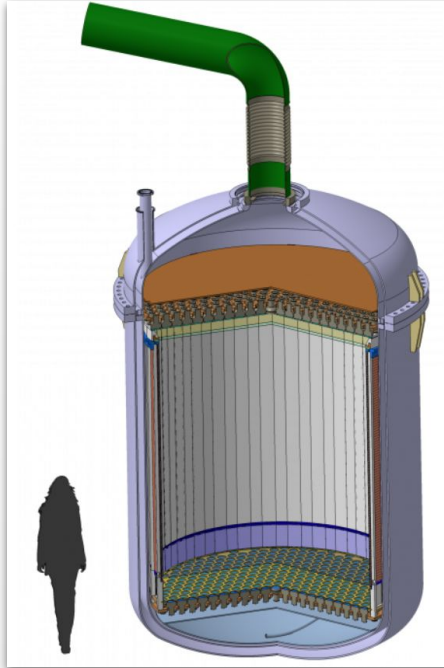


arXiv:2104.03245

What else can we do with >10t of xenon?

Dark matter physics

- Probe alternate production methods
- Bosonic dark matter absorption
- Luminous dark matter
- Planck scale dark matter



Other physics

- Neutrinos
 - Solar
 - Supernova
 - Geo
- Nuclear physics (rare decays)
- Solar axions
- Nucleon decay

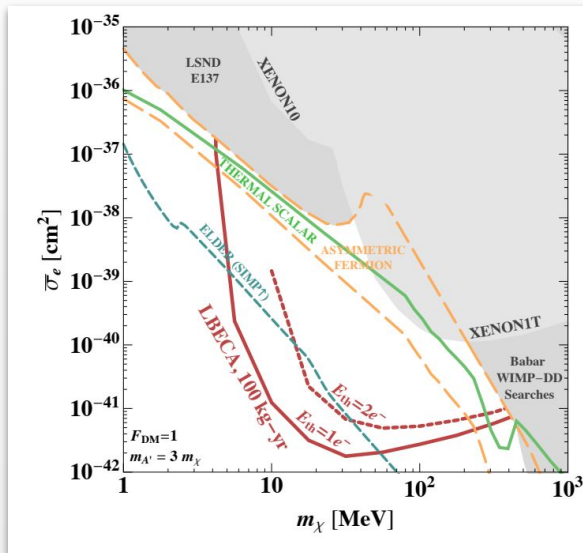
Dark matter-electron scattering

Some production mechanisms favour lighter DM e.g.:

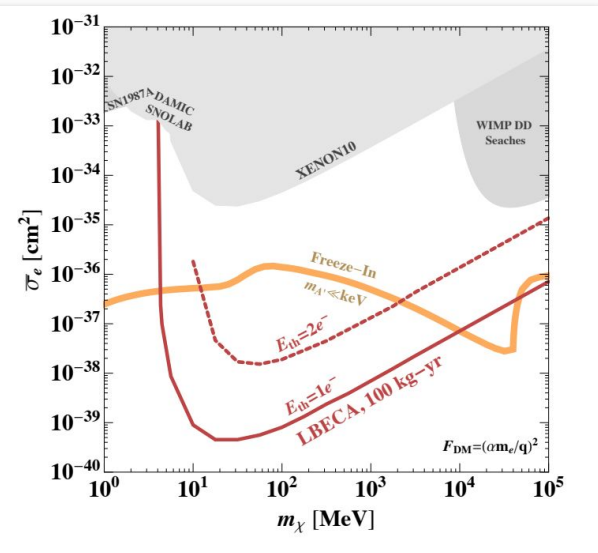
- Freeze-in
- Asymmetric DM
- Strongly self-interacting DM

Xenon can be low-threshold too
(at the cost of ER/NR discrimination)

‘Heavy’ mediator



‘Light’ mediator

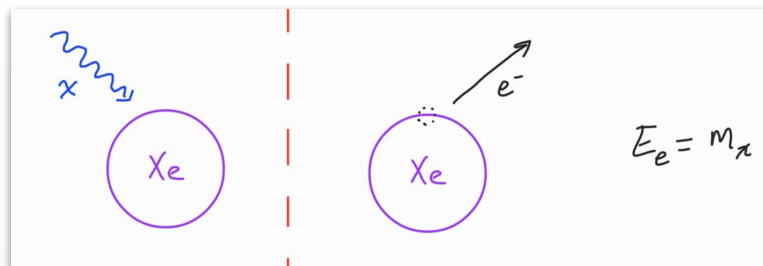


arXiv:2001.09311

Bosonic dark matter absorption

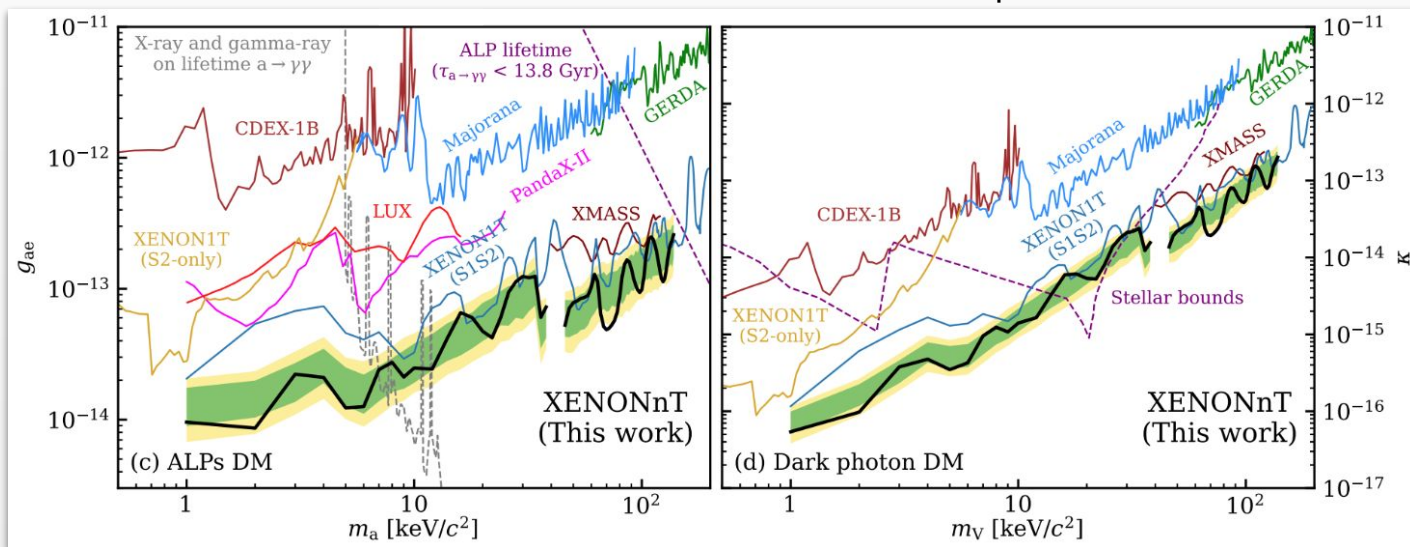
- Some models of bosonic DM don't have the usual elastic NR signatures
- WISPs are typically sub-eV, here we are looking at ~keV
- Typically these particles mix with the SM photon
- For example:
 - Axion-like particles (ALPs): generalised axions that *don't* solve the strong CP problem and don't tie f_a to m_a
 - Dark photons e.g. secluded U(1)'

Bosonic dark matter absorption



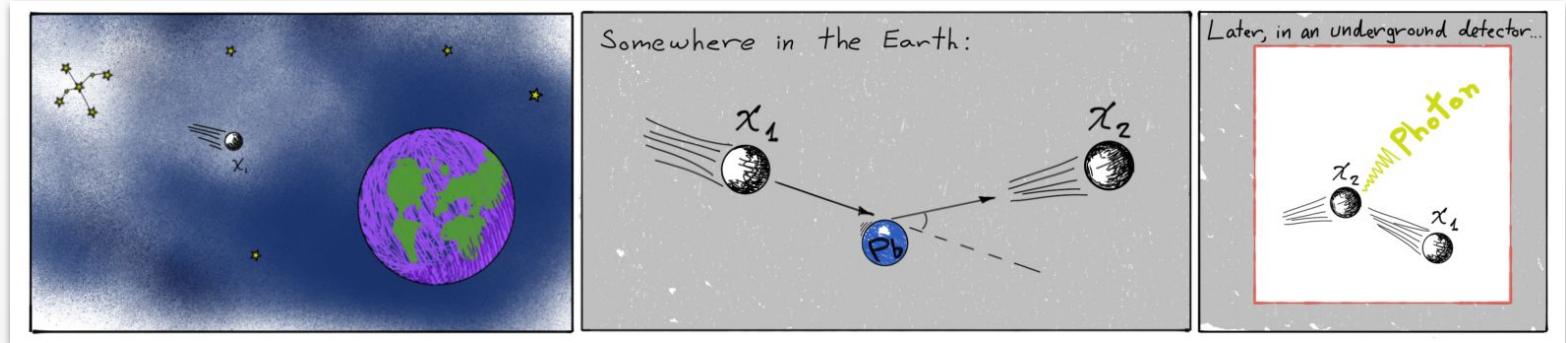
Axion-like particle DM

Dark photon DM



arXiv:2207.11330

Luminous dark matter

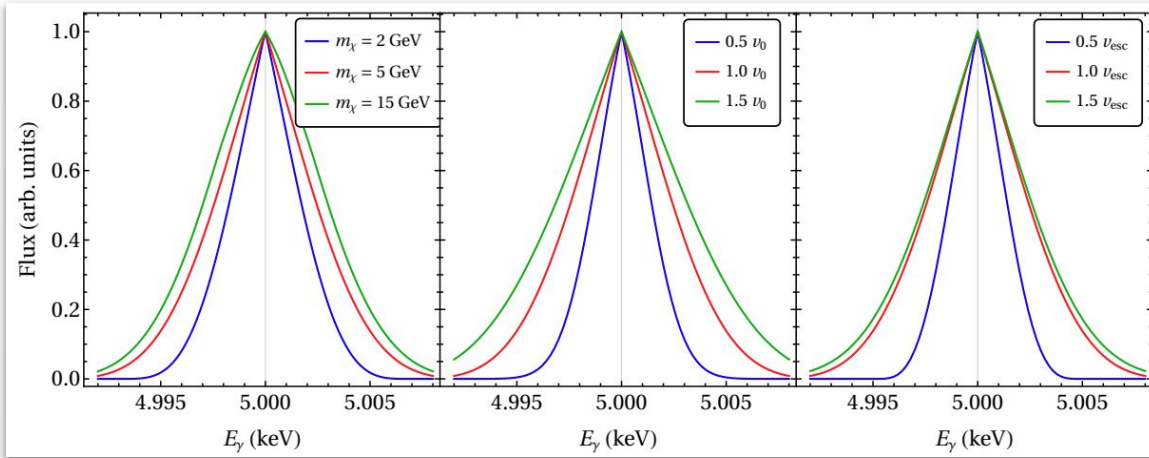


arXiv:1904.09994

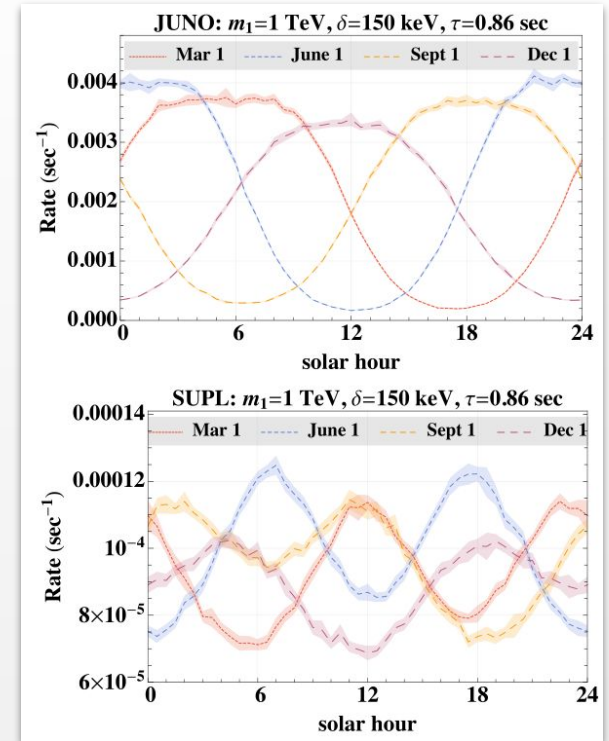
- Inelastic DM upscatters and then decays via photon emission
- Originally used to explain DAMA (arXiv:1008.1988)
- Rate scales with detector volume
- If the lifetime is short enough the upscatter and decay can occur in the detector
→ giving rise to a 'double bang' event

Luminous dark matter

- This type of model has unique signatures and opportunities:



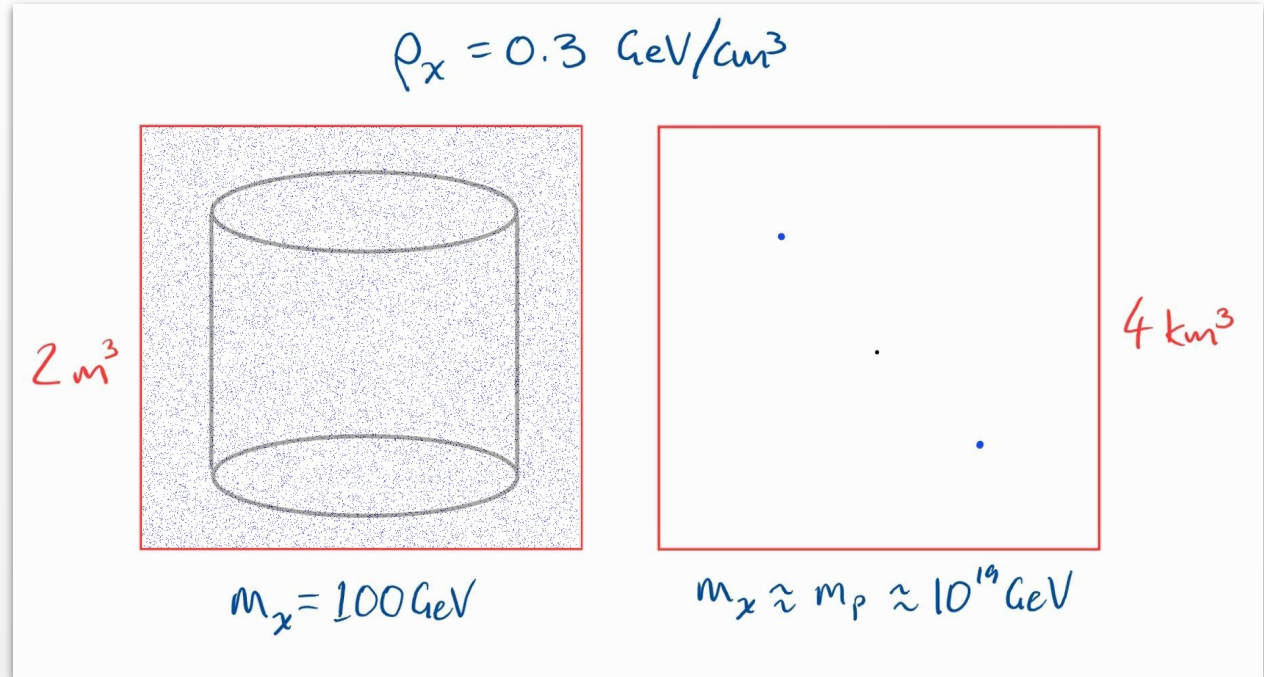
arXiv:2208.08020



arXiv:1904.09994

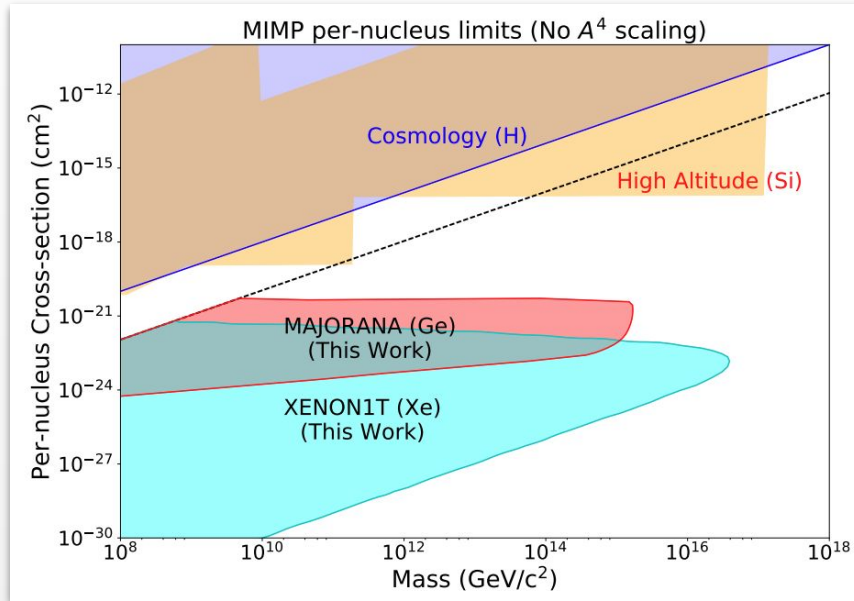
Ultra-heavy dark matter

- High scale physics (e.g. GUTs) could produce planck scale relics e.g. WIMPzillas, Q-balls, quark nuggets
- Much lower density puts us in a regime where a different analysis is required



Ultra-heavy dark matter

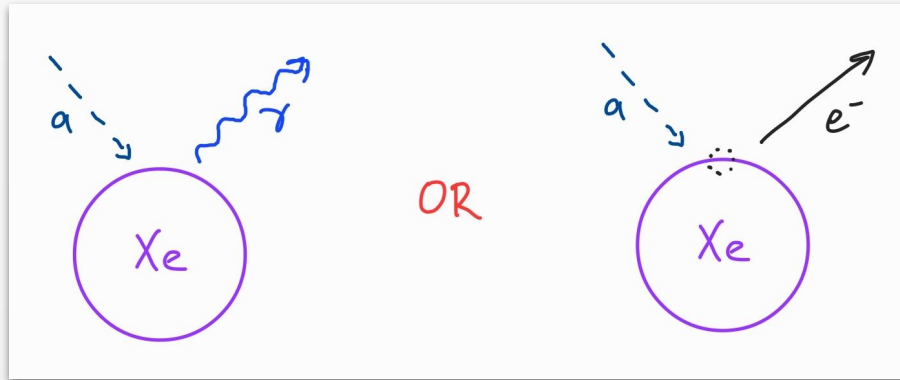
- The low flux means limits can only be set on large cross sections
- In this regime scattering is guaranteed and leaves tracks, but therefore can be attenuated in the overburden



arXiv:2009.07909

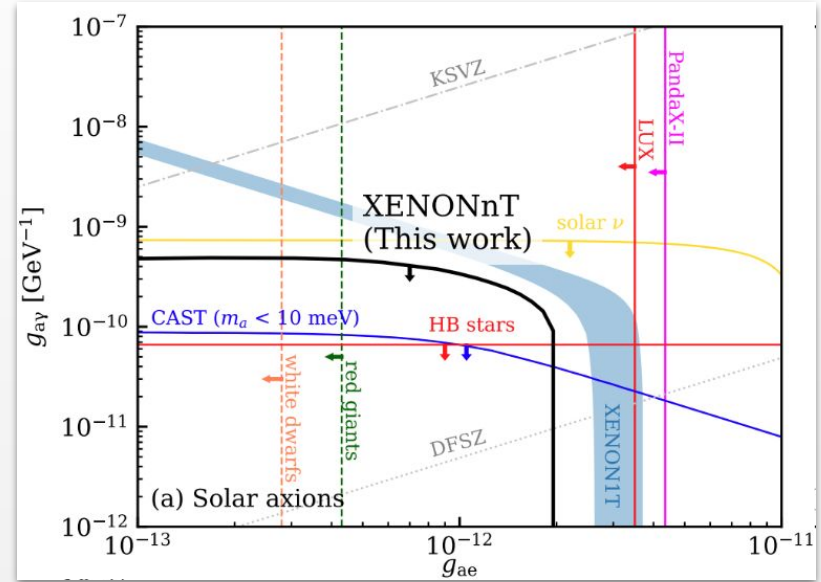
Solar axion detection

- Axions produced in the Sun will produce ER signals in xenon, both via the axioelectric effect and via inverse-Primakoff scattering



Inverse Primakoff

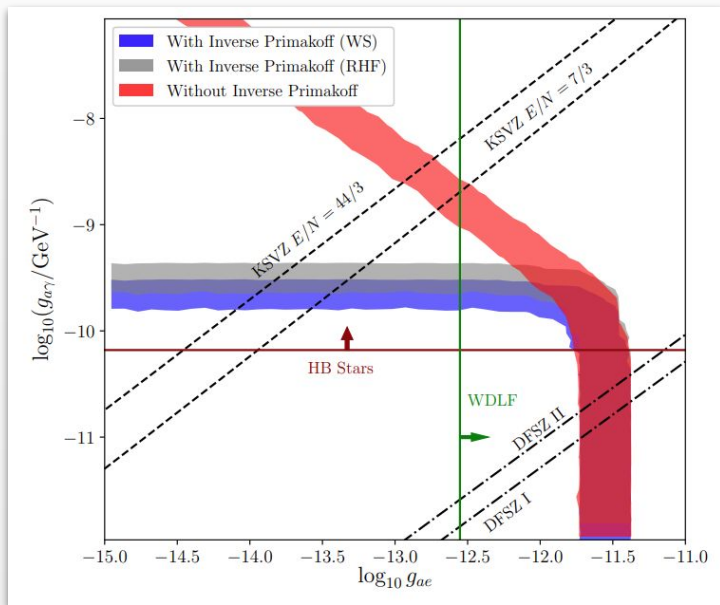
Axioelectric effect



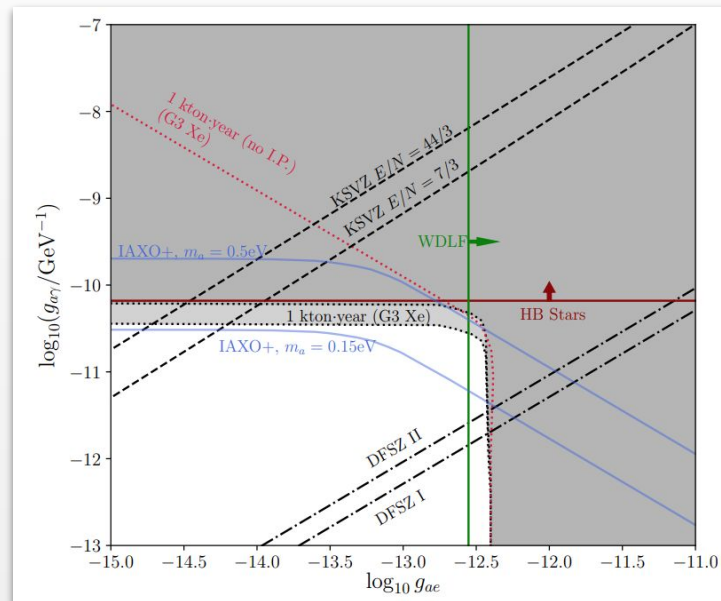
arXiv:2207.11330

Solar axion detection

- Side note: we pointed out the inverse-Primakoff channel in 2020 (along with 2006.14598)



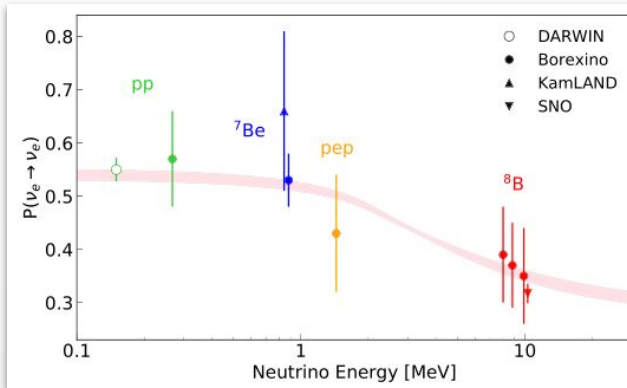
- Greatly improves sensitivity making xenon competitive with haloscopes



arXiv:2006.15118

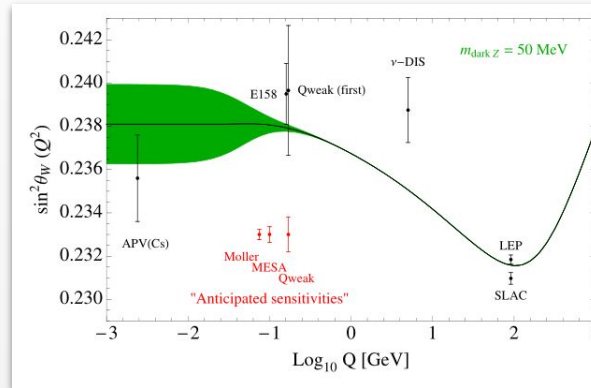
Neutrino physics

Measure survival probability:



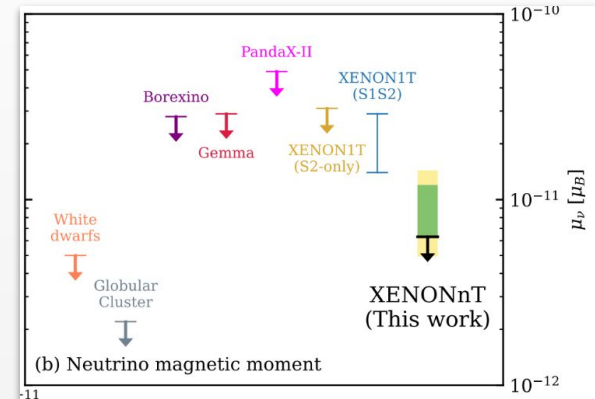
arXiv:2006.03114

Weinberg angle at low Q:



arXiv:1402.3620

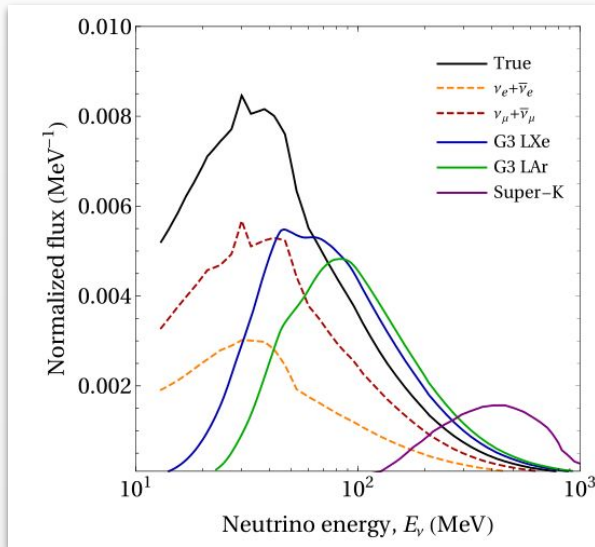
Constrain magnetic moment:



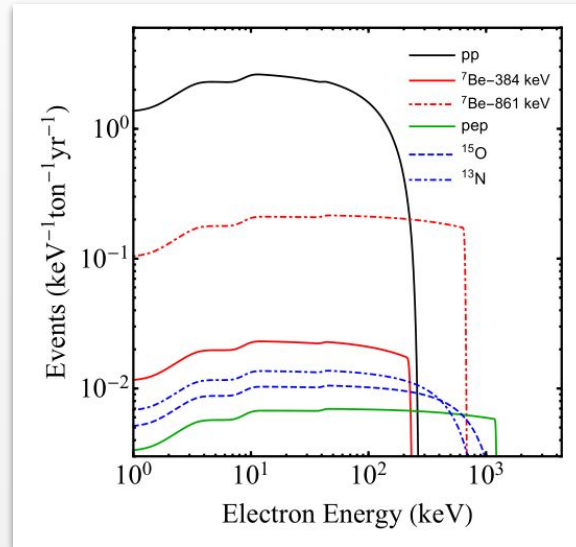
arXiv:2207.11330

Neutrino astrophysics

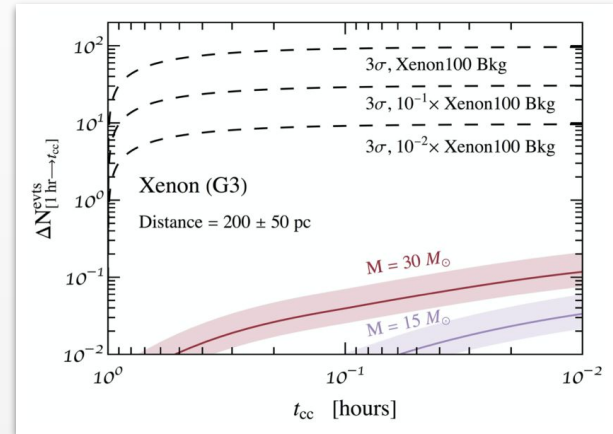
Atmospheric neutrinos:



Solar CNO neutrinos:



Supernova neutrinos:



From Xe G3 whitepaper

Conclusions

- There are many opportunities to explore with direct detection beyond the standard WIMP paradigm
- Xenon detectors are still leading the sensitive race to non-standard DM candidates
- Now that Australia (CDM) has officially joined XLZD we should look for ways to continue to contribute on the experimental-theoretical boundary