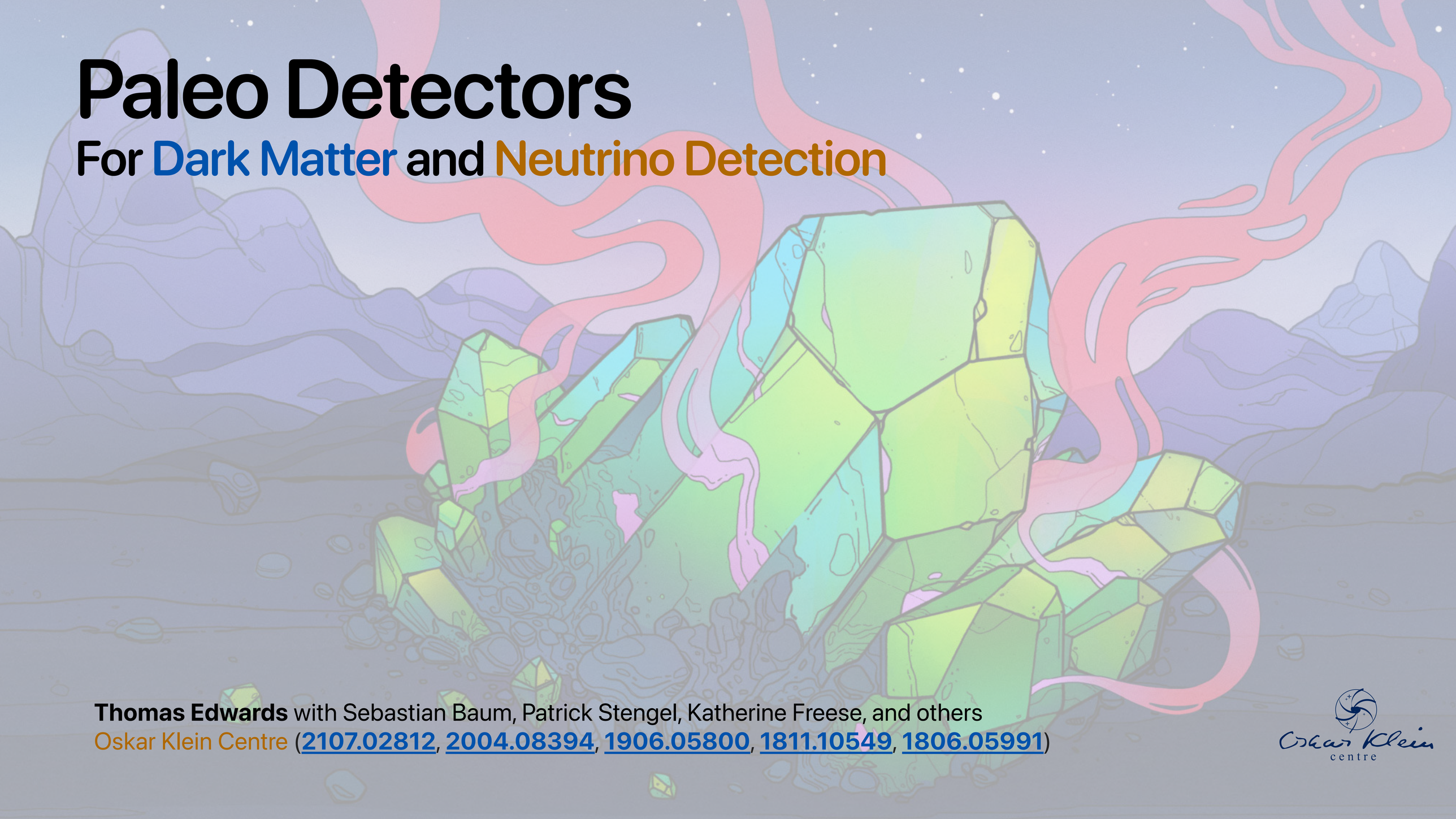
Paleo Detectors

For Dark Matter and Neutrino Detection



Thomas Edwards with Sebastian Baum, Patrick Stengel, Katherine Freese, and others
Oskar Klein Centre (2107.02812, 2004.08394, 1906.05800, 1811.10549, 1806.05991)

Oskar Klein centre

Overview:

1. Paleo-Detector Basics
2. Probing Dark Matter, Neutrinos, and Time-Varying Signals

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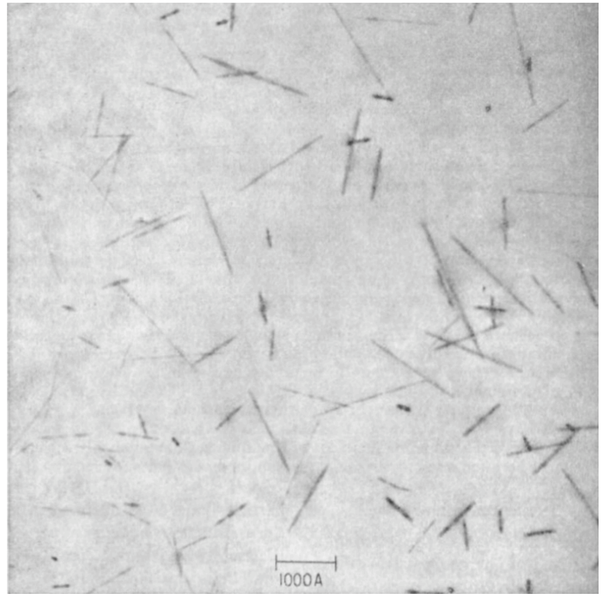
Paleo-Detector Basics

Paleo-detectors are minerals from **far below the Earths surface (5-10 km)**.

Instead of phonons, charge, and light, paleo-detectors look for **permanent damage track** features in the structure of the mineral.



$$\text{Recoil Rate} \propto \text{Target Mass} \times \text{Observation Time}$$

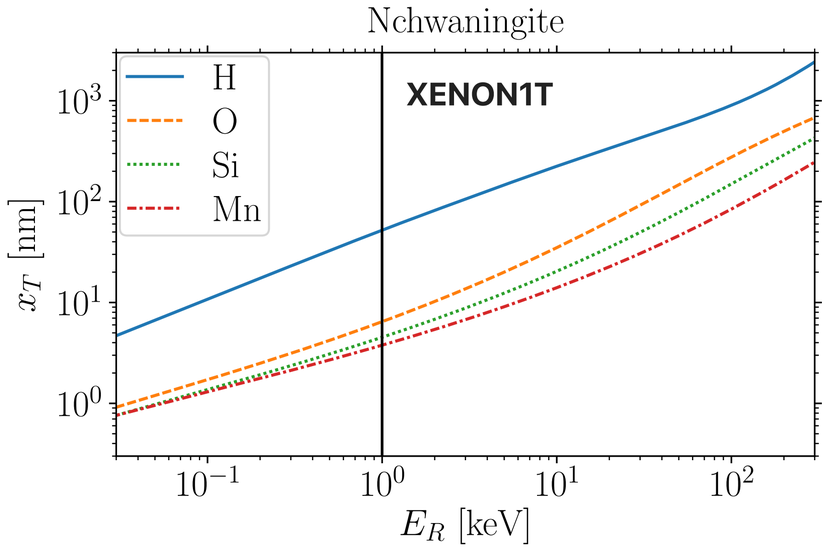
↓ **Smaller Targets**

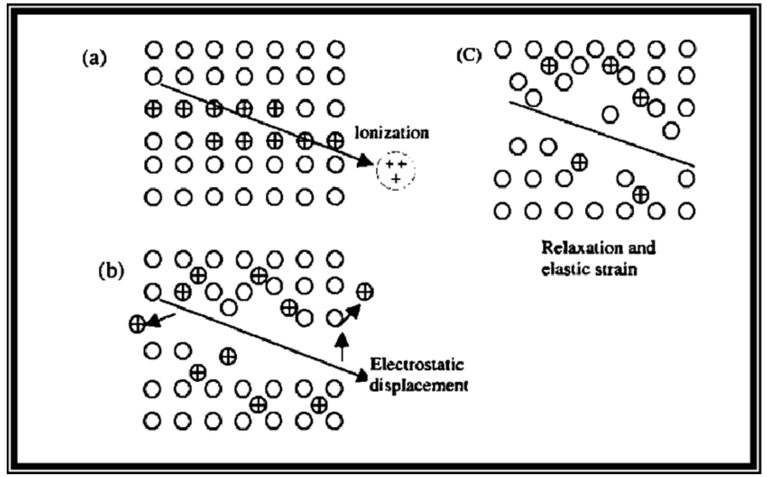
↑ **Huge Observation Time**

Paleo-Detector Basics: Tracks

Damage tracks are caused by **recoiling nuclei depositing energy** through multiple scatters. The detailed mechanism is unknown.

Annealing timescales are **extremely long** compared to the age of the mineral.

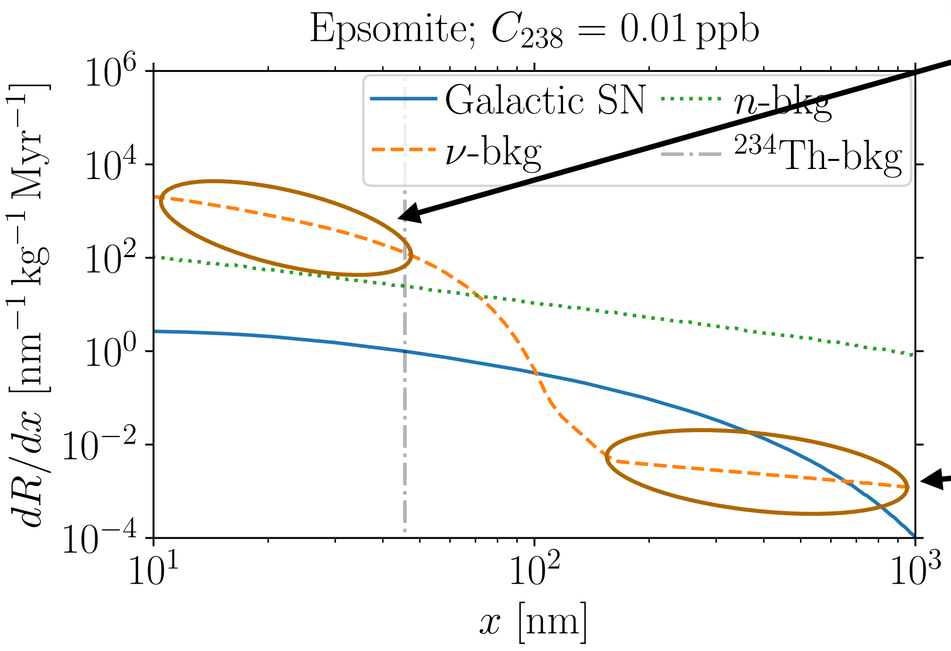




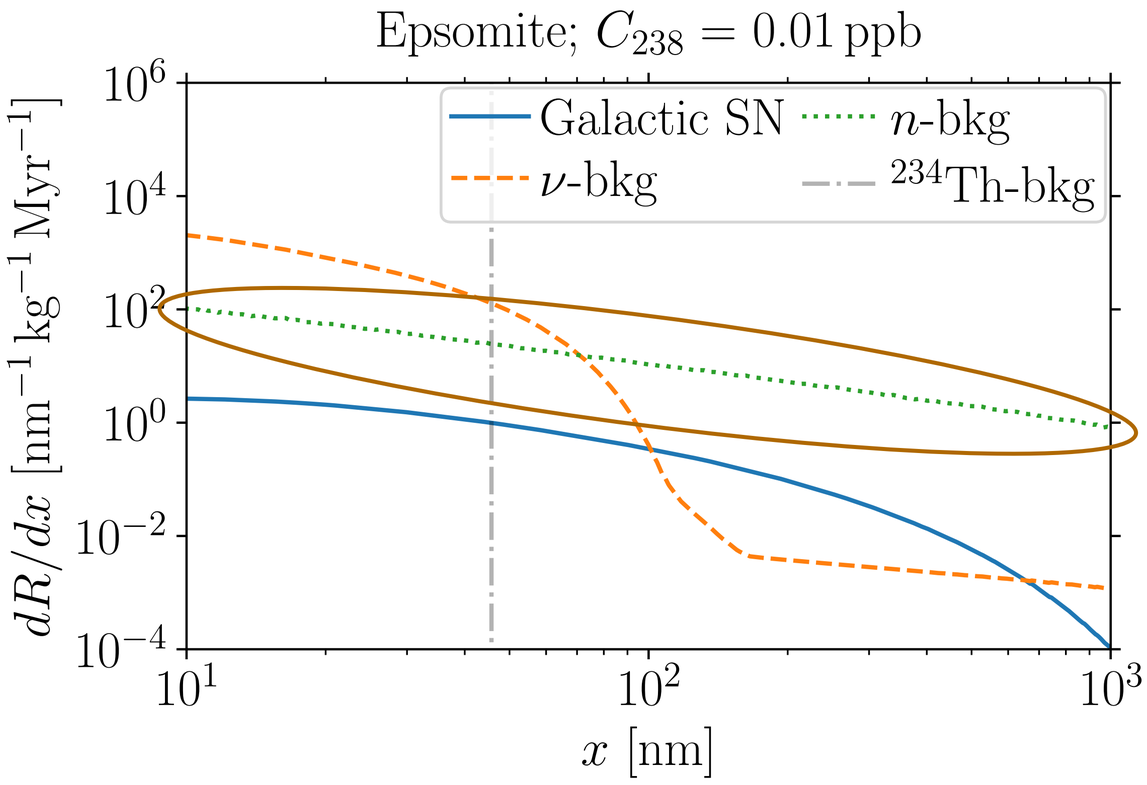
High track length resolution allows us to probe low energy recoils - We are therefore sensitive to lighter dark matter

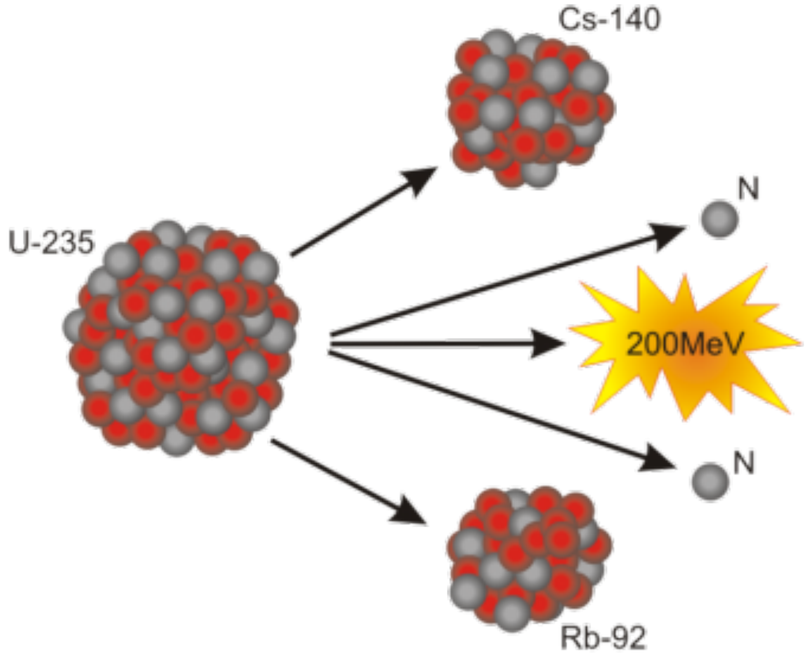
Paleo-Detector Basics: Background neutrinos

$$\mathrm{p} + \mathrm{p} \rightarrow \mathrm{d} + \mathrm{e}^{+} + \nu_{\mathrm{e}}$$



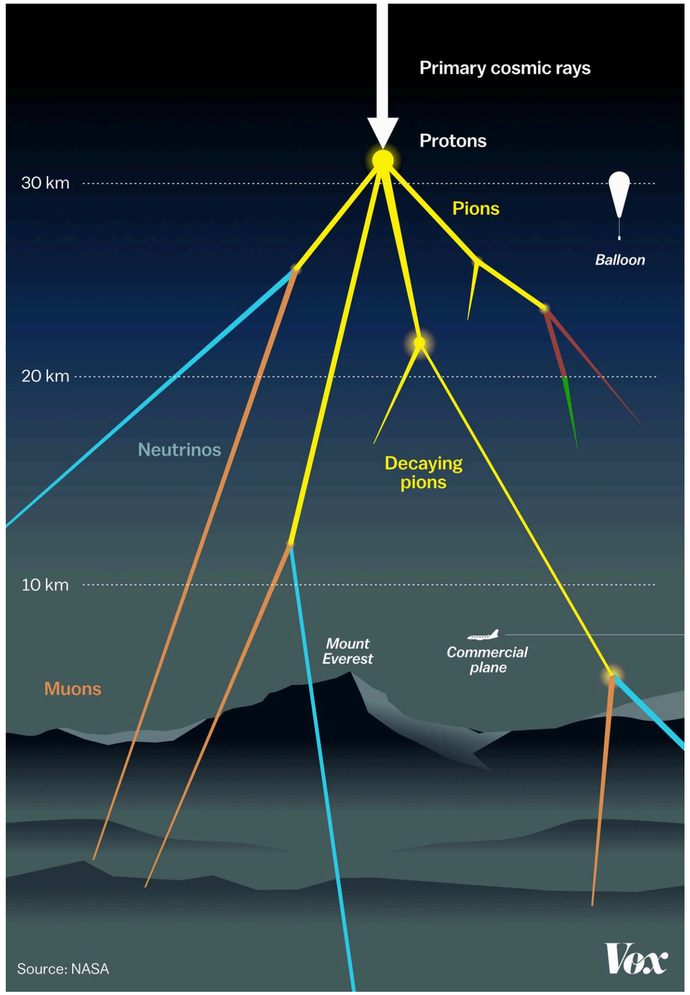
Paleo-Detector Basics: Radioactivity





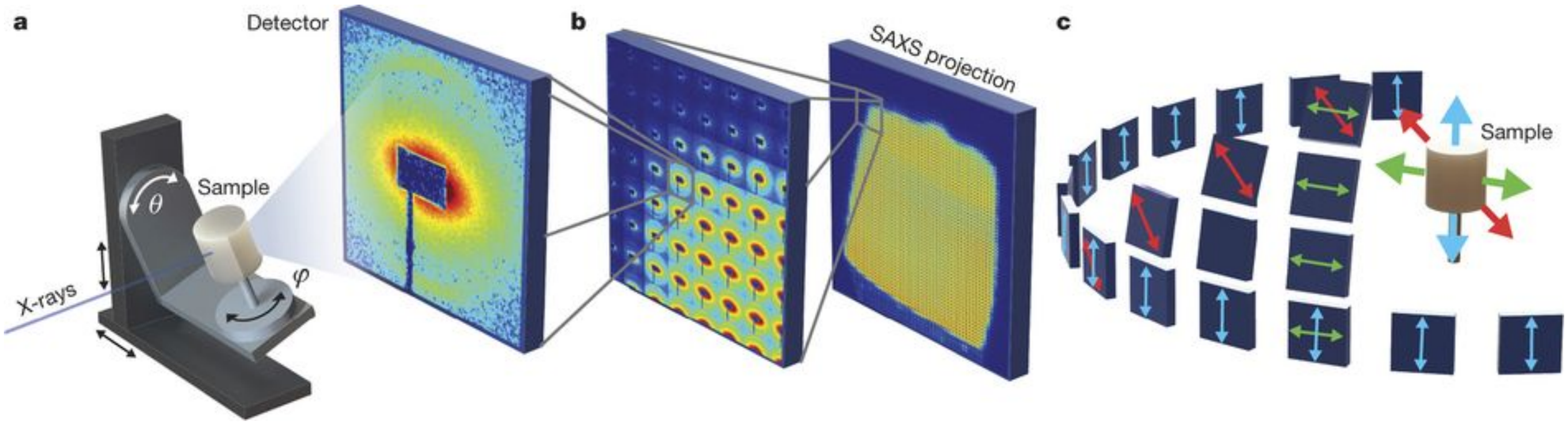
Uranium-238 Concentration ~ 0.01 ppb

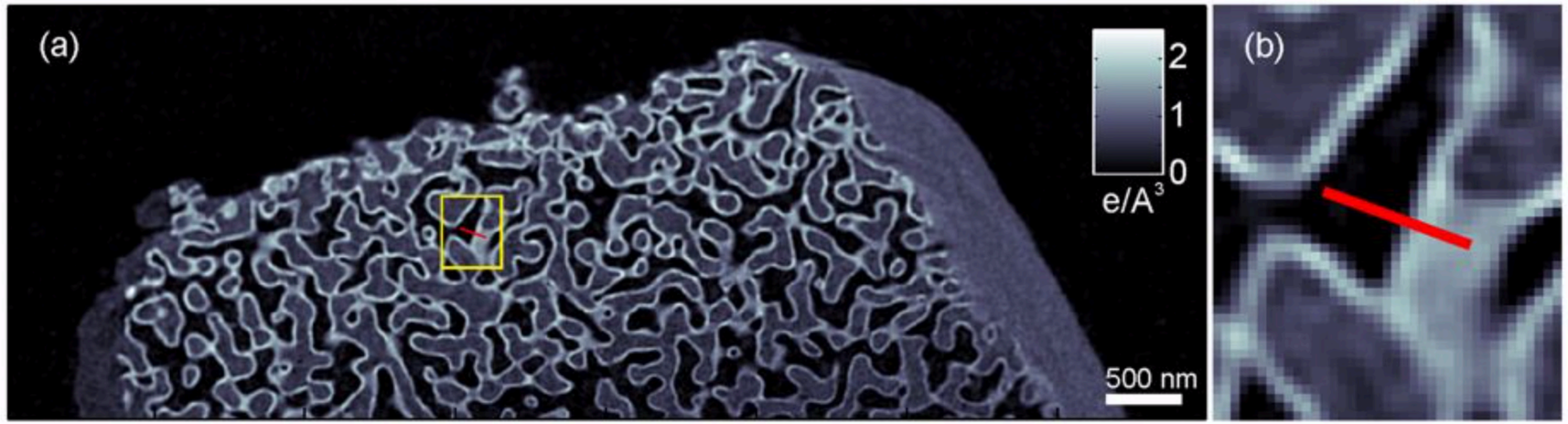
Paleo-Detector Basics: Cosmic Rays



Depth [km]	2	5	7.5	10
Neutron Flux [1/cm²/Gpc]	10^3	10^1	10^{-4}	10^{-8}

Paleo-Detector Basics: Readout



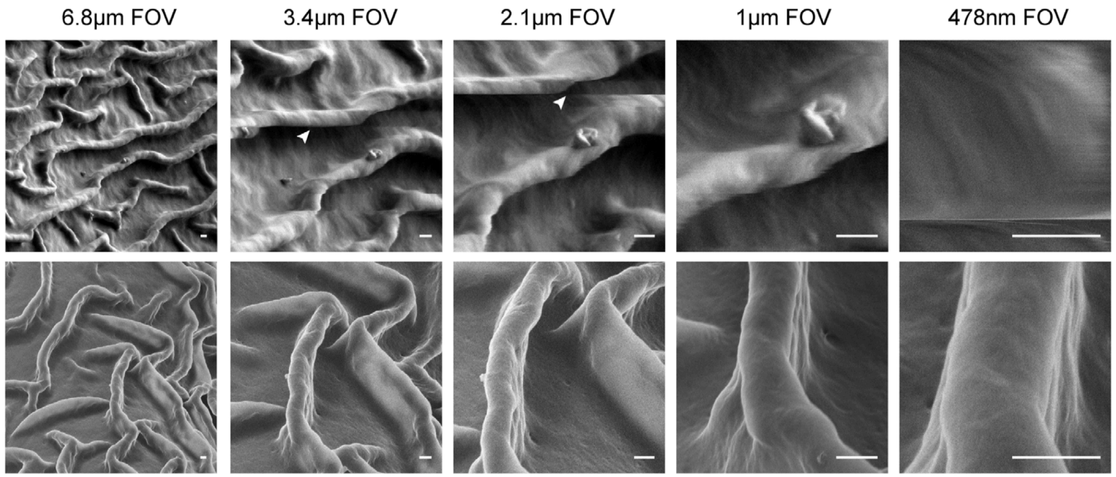


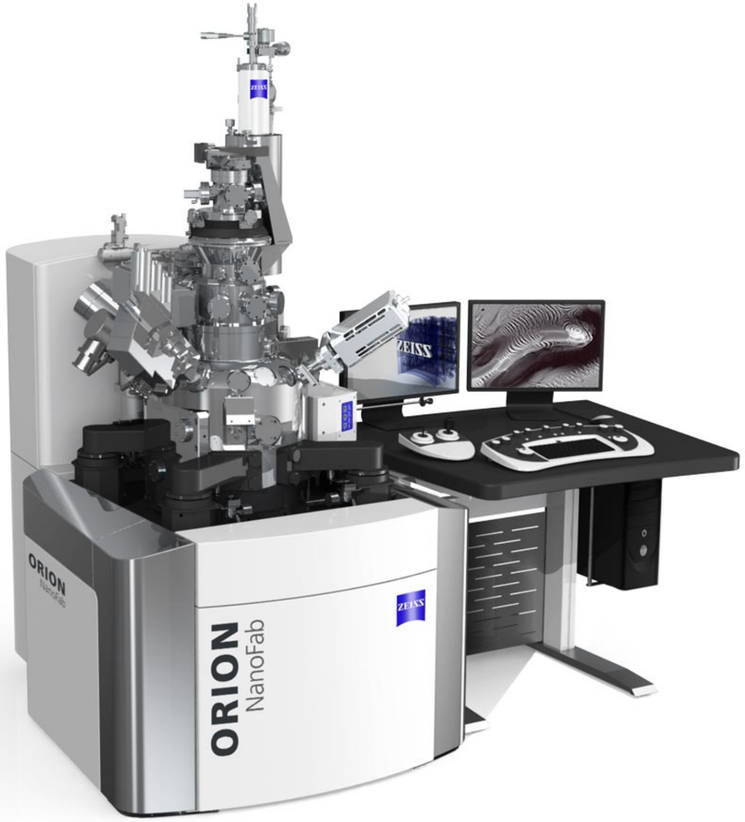
[Holler et. al. 14]

Paleo-Detector Basics: Readout

Able to reach **< 1nm resolution**

To take measurements efficiently, must remove layers and scan repeatedly

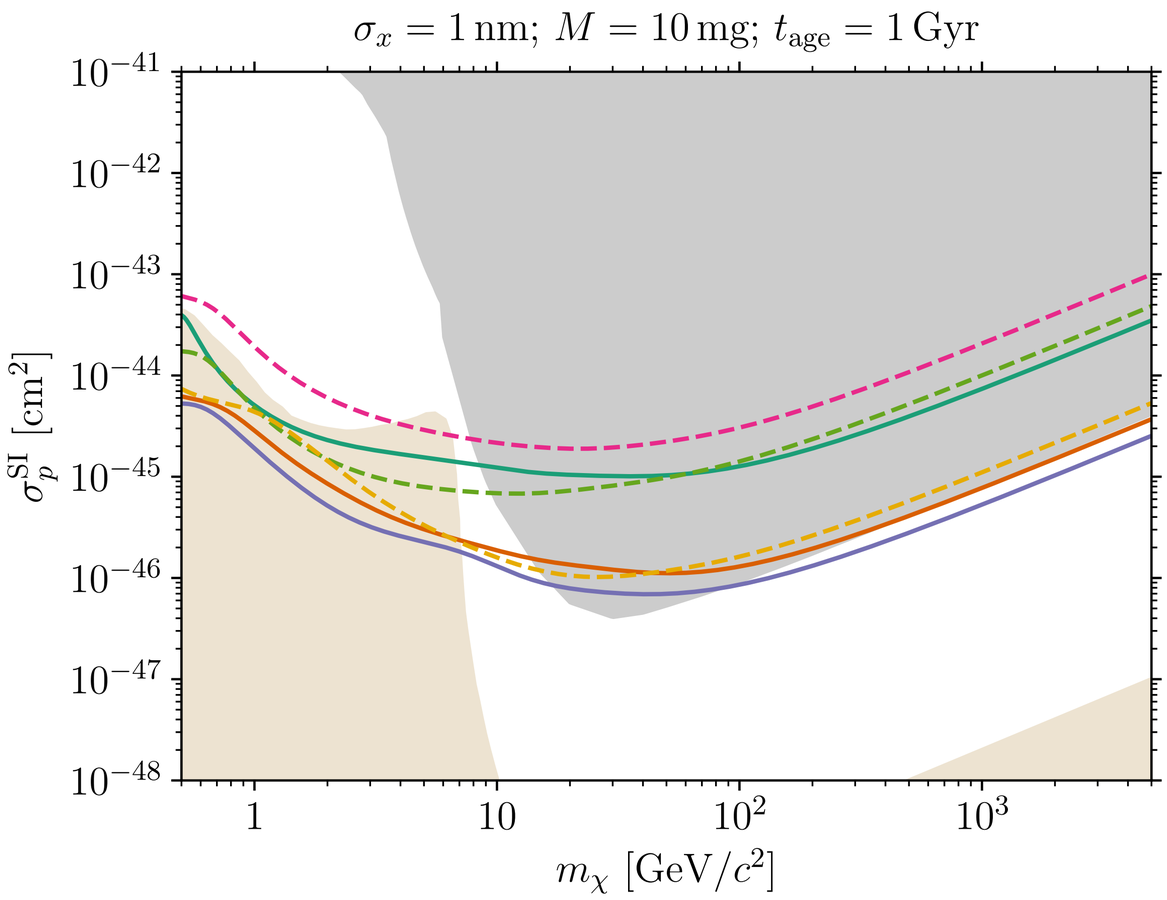




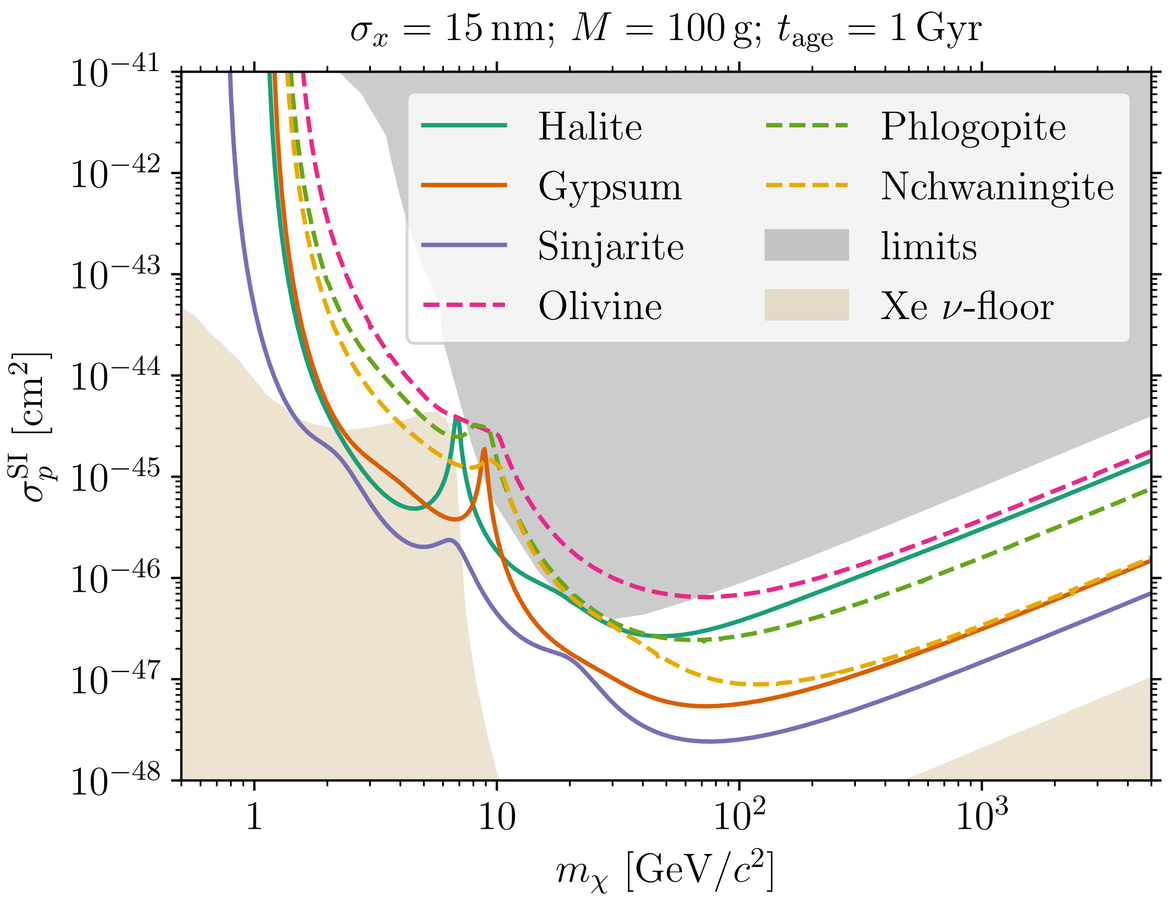
Overview:

1. Paleo-Detector Basics
2. Probing Dark Matter, Neutrinos, and Time-Varying Signals

Dark Matter Sensitivity



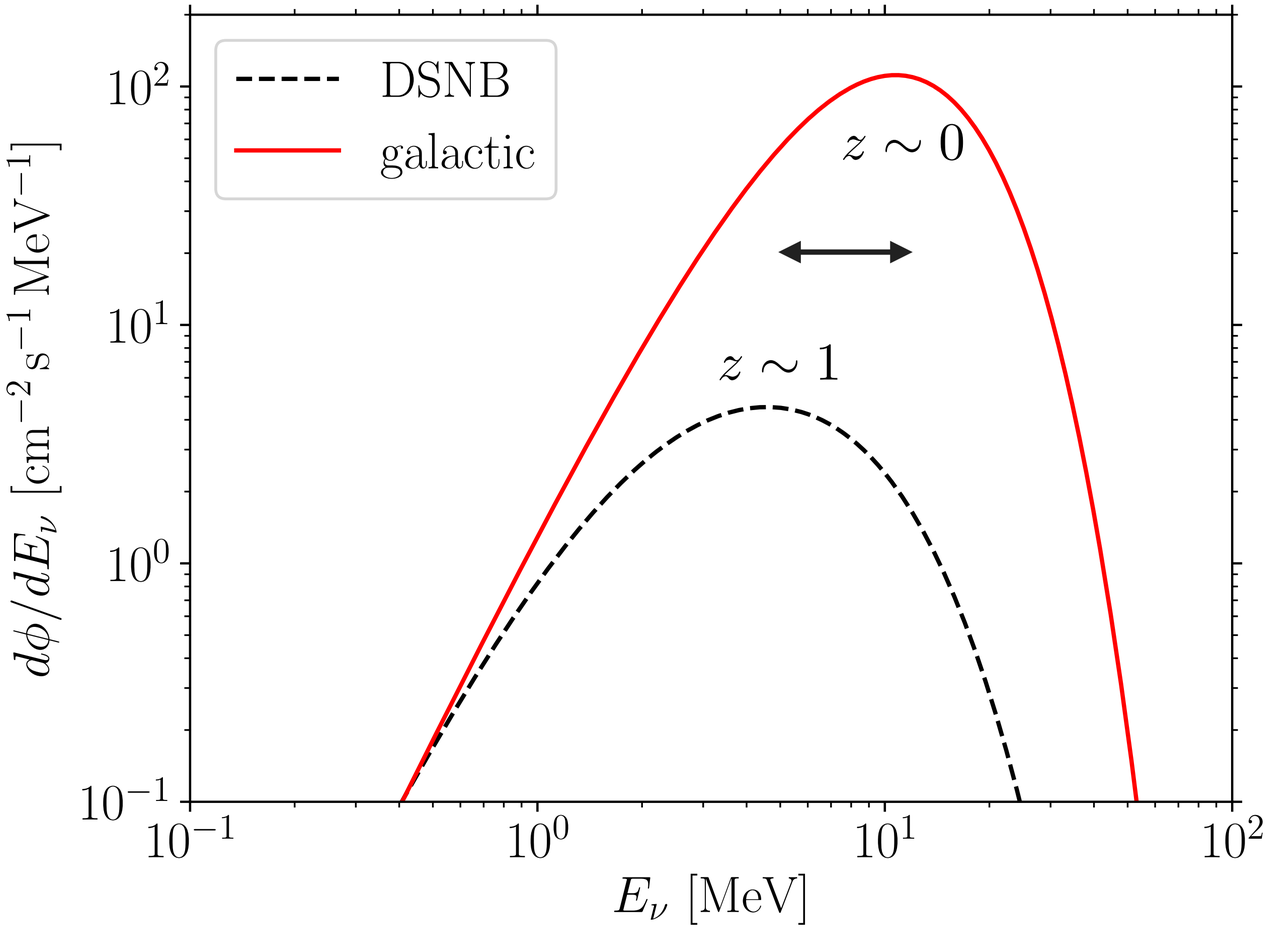
Using the faster scanning method we can can probe WIMP DM **well below** current experimental limits > 1 GeV



More precision allows us to probe **lighter** DM masses

[Baum, **TE** et. al: 2106.06559]

Galactic Supernova Neutrinos



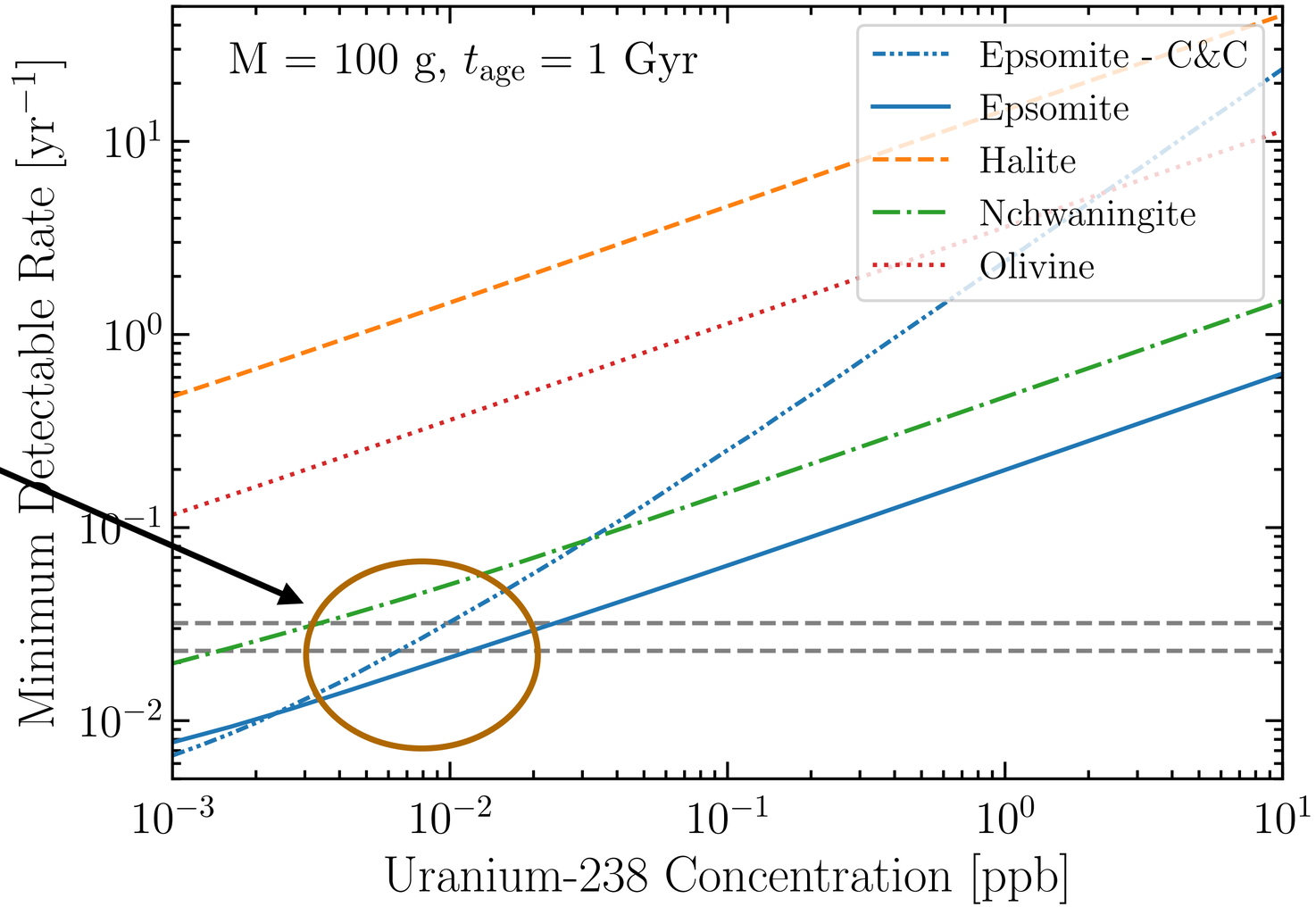
Signal from galactic supernova is **much larger than DSNB**

Galactic SN spectrum **peaks at different energy** due to redshift

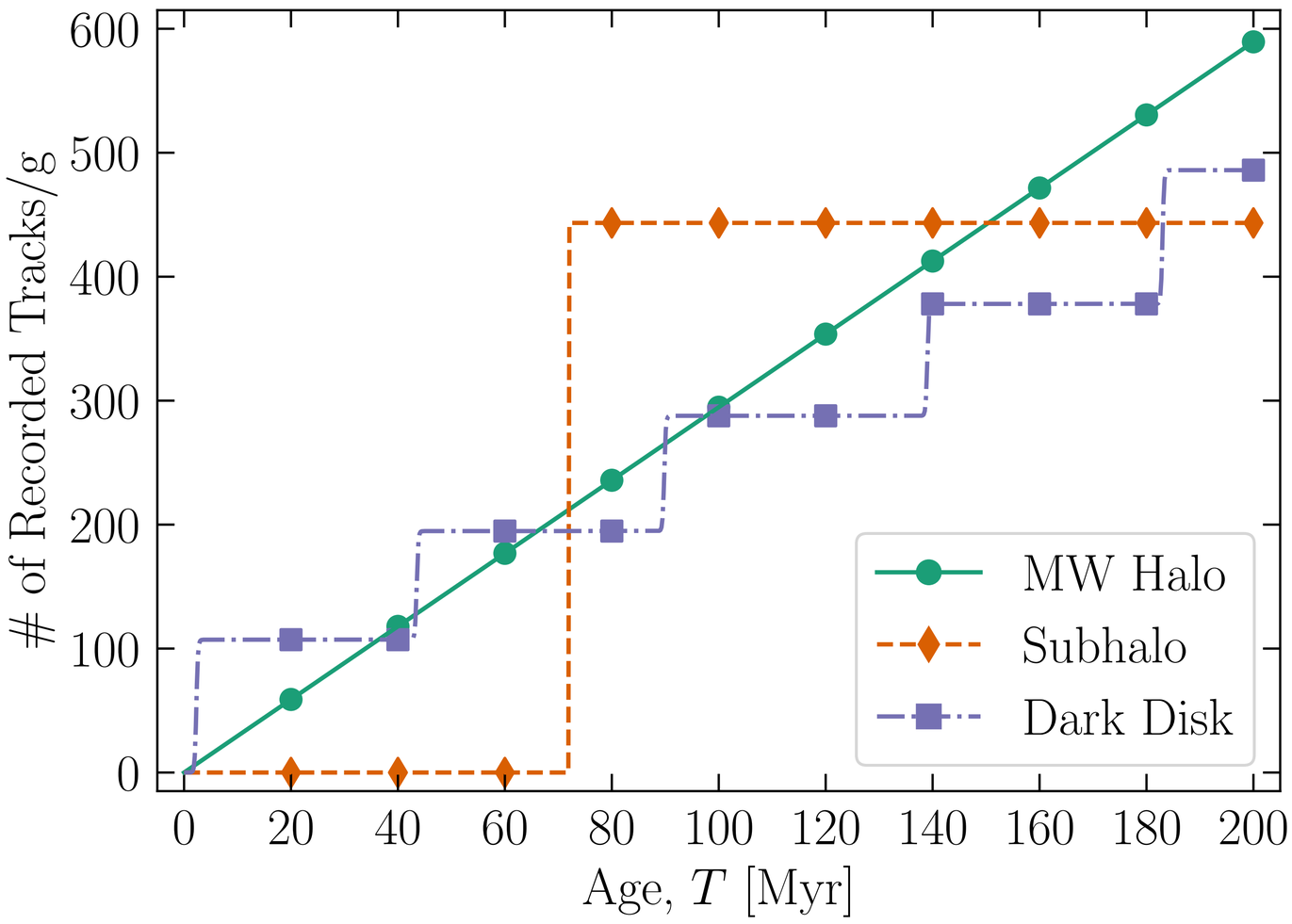
Galactic Supernova Neutrinos

3-sigma detection if we achieve low enough concentrations of Uranium-238

Here we assume a constant rate of SNe throughout the history of the galaxy

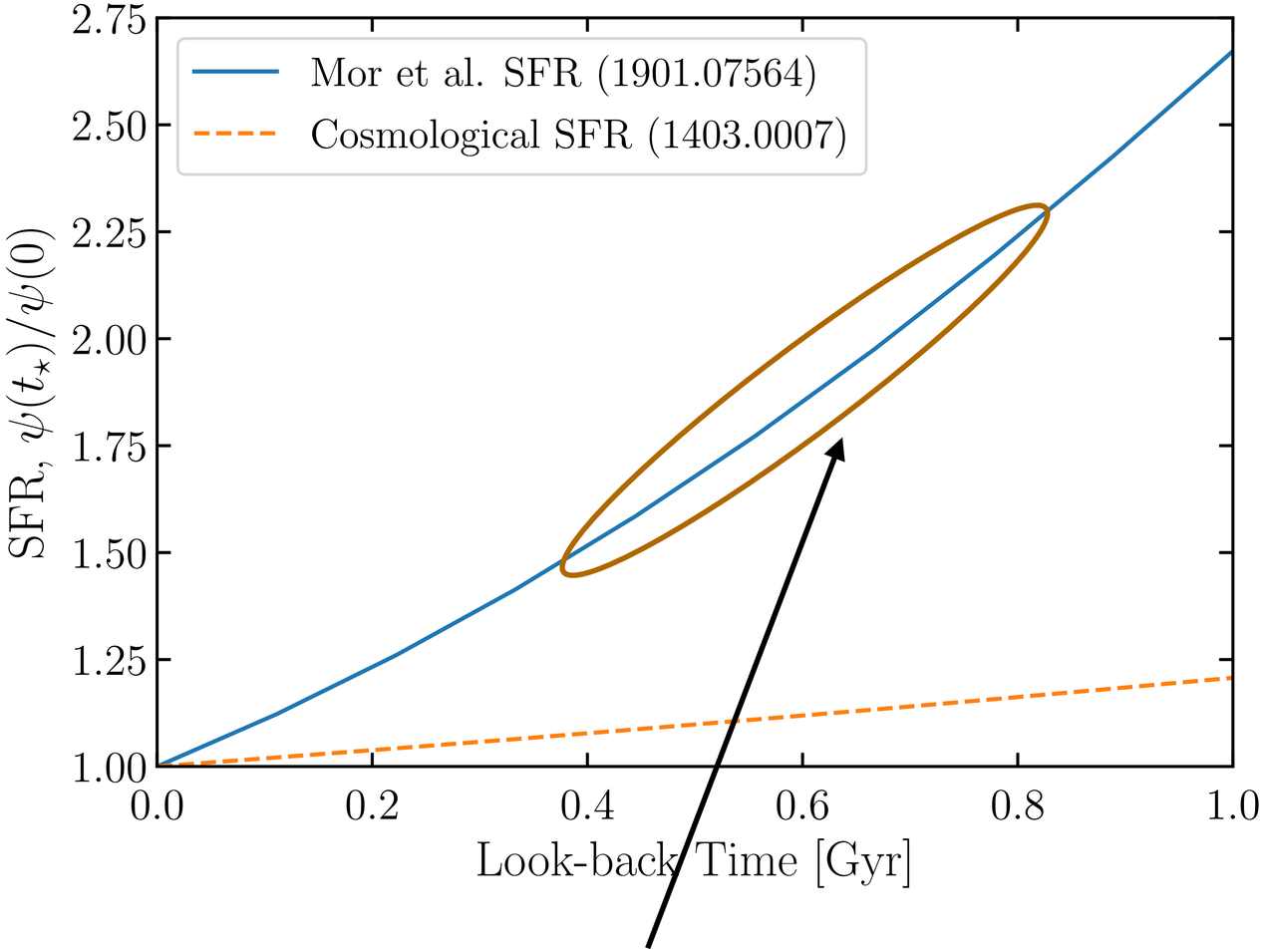


Time Varying Signals

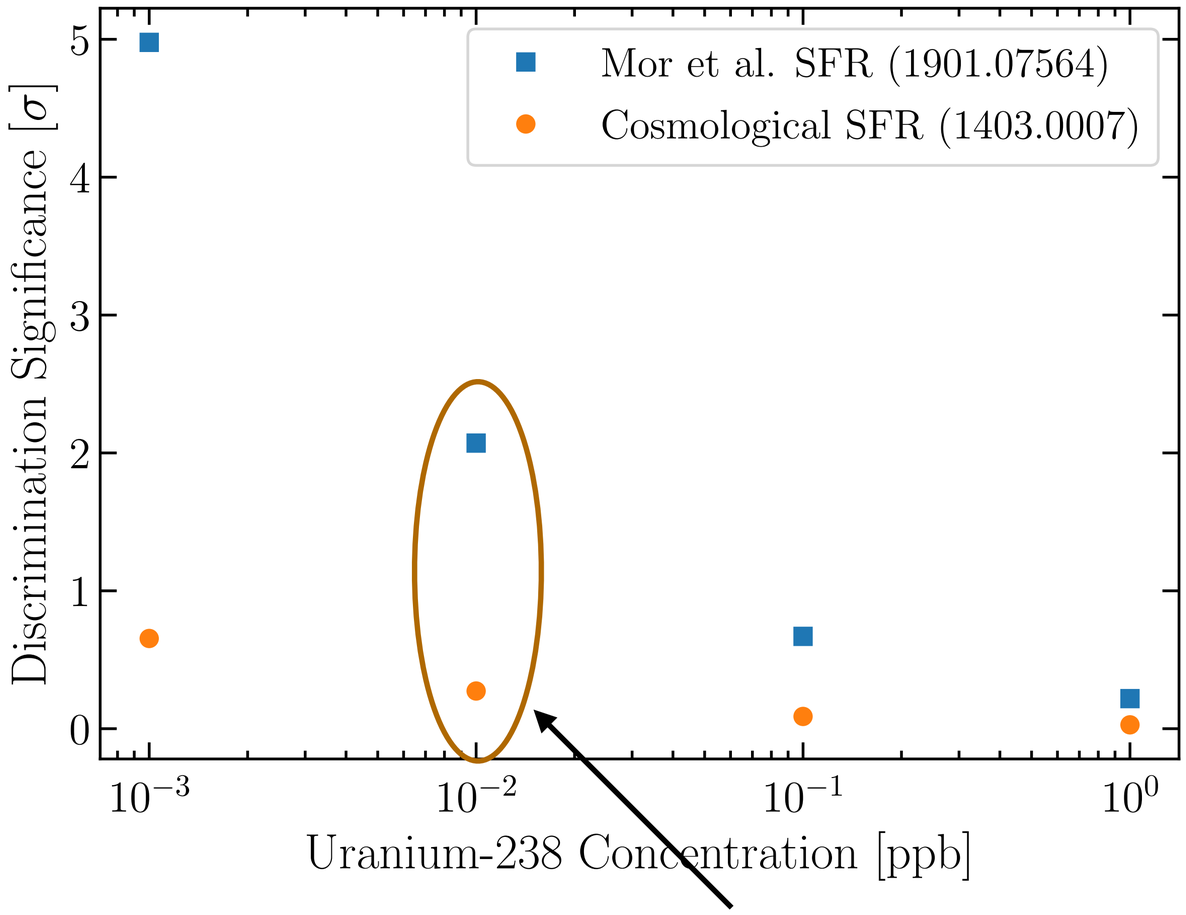


[**TE,** Baum, DeRocco, Kalia: 2107.02812]

Tracking Star Formation



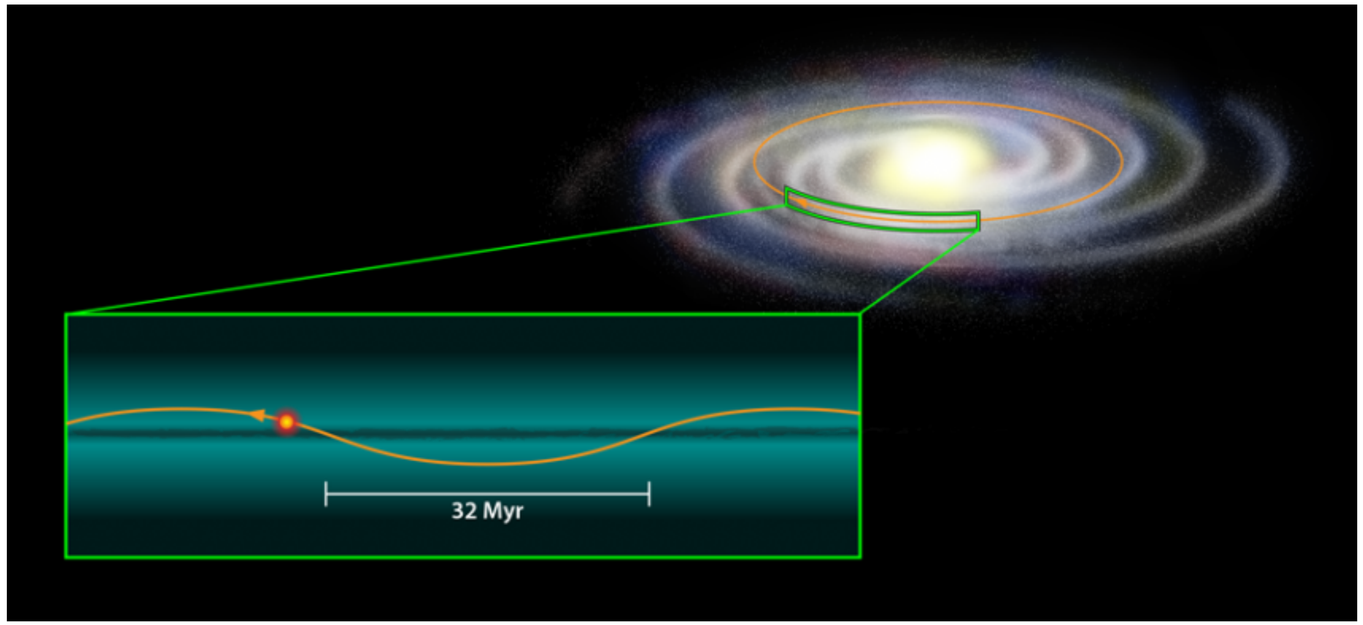
Estimate of the Milky Way SFR from Gaia



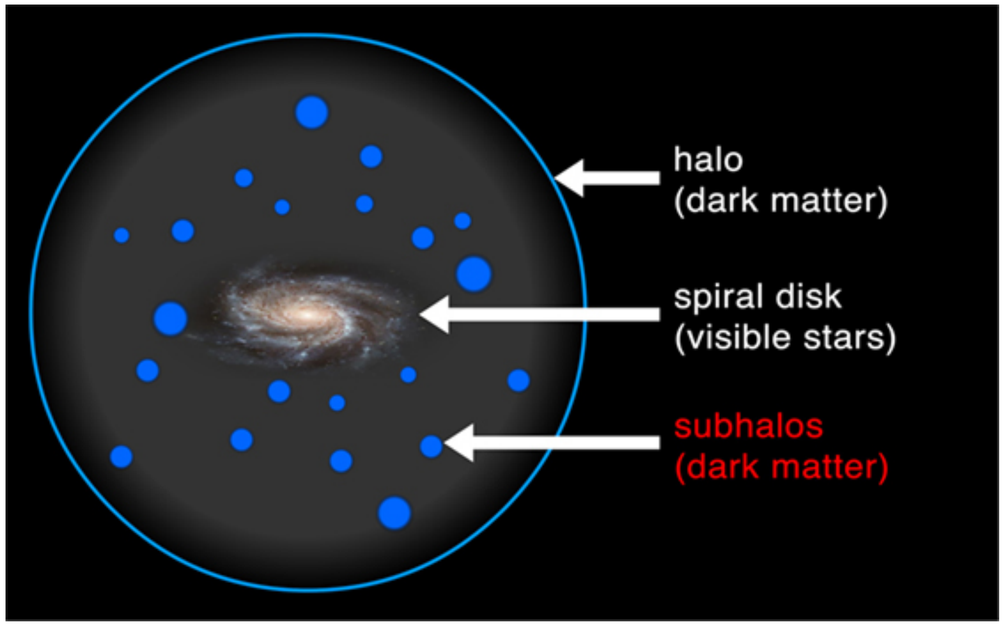
Baseline case can rule out constant rate at **2 sigma** depending on model

[Baum, **TE** et. al: 1906.05800]

Dark Matter Substructure



Dark Disks

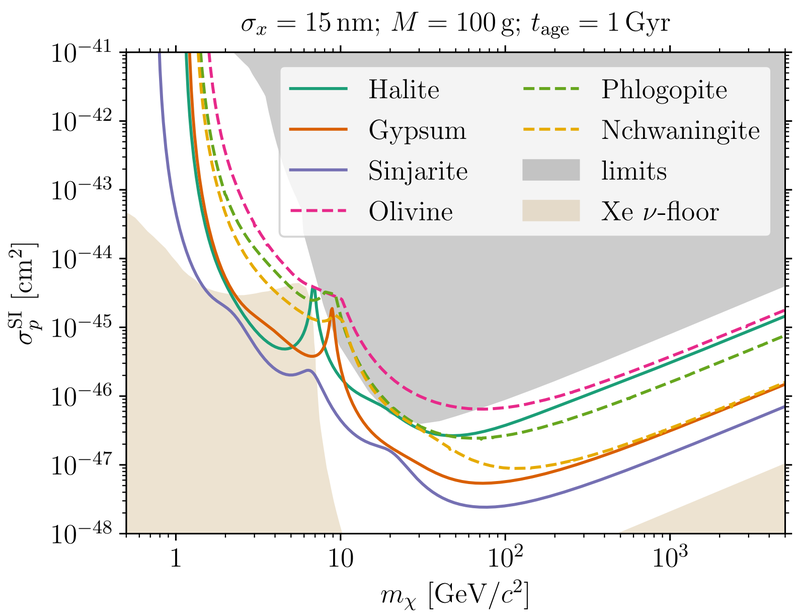
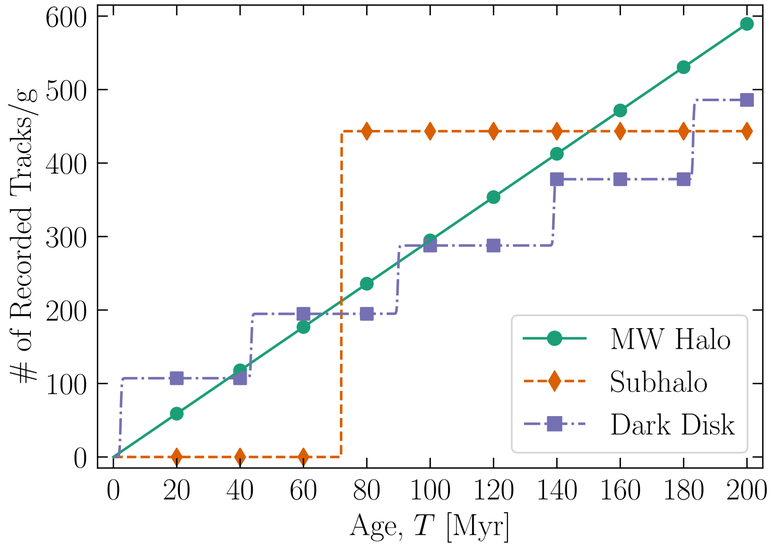


SubHalos

[**TE,** Baum, DeRocco, Kalia: 2107.02812]

Conclusions

1 Paleo-Detectors represent a novel detection strategy for rare event searches



2 Paleo-Detectors have the unique ability to see into the past, and probe time varying signals