Novel Method for Detecting Ultralight Dark Matter

In preparation

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Introduction

- Dark matter is one of the most rigid new physics
- Which mass range?

Particle DM Mass Range

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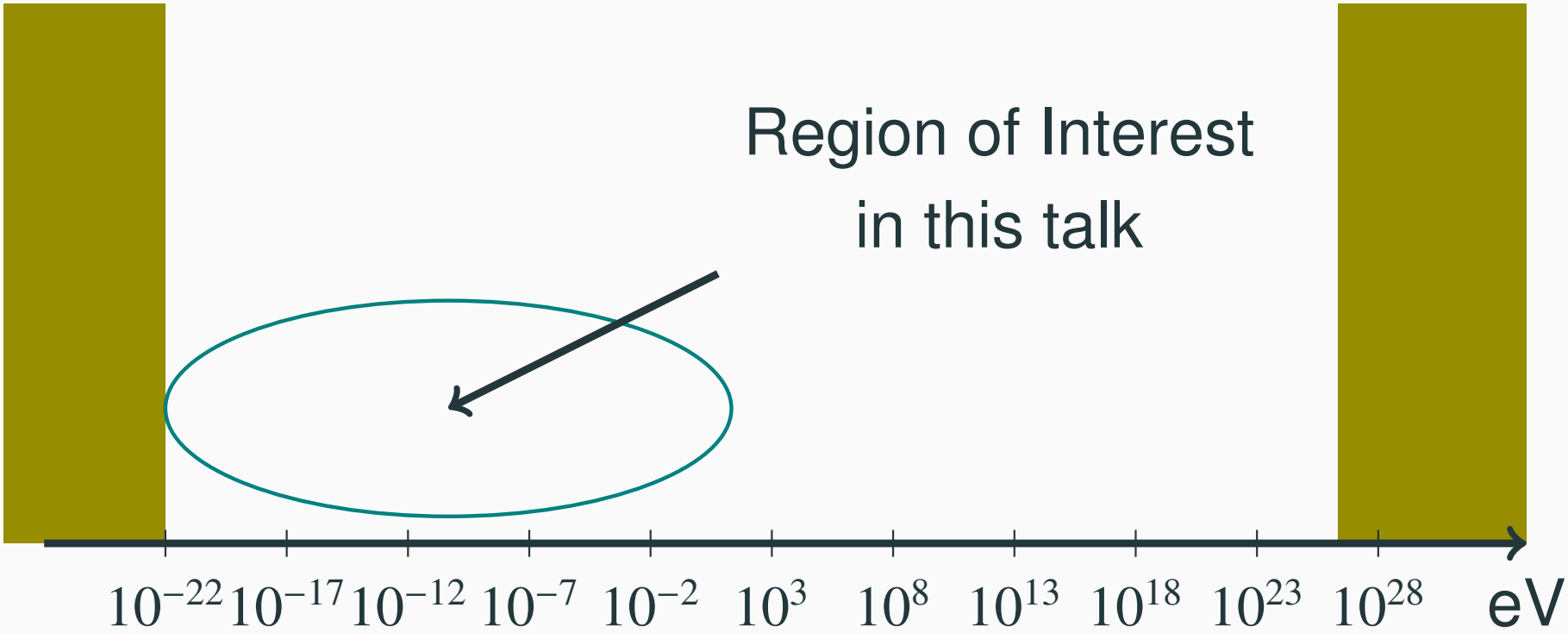


Ultralight DM (a.k.a. Fuzzy DM)

- DM for 10^{-22} eV $\lesssim m_{\rm DM} \lesssim$ eV
- Must be Bosonic
- Advantages in the small scale structure over WIMP Hu, *et al.*, 2000
- May be from moduli d.o.f.

Most Important Point

- How could we detect them?
  - Production - $\times$
  - Indirect Detection - $\times$ (or $\triangle$)
  - **Direct Detection**

Direct Detection

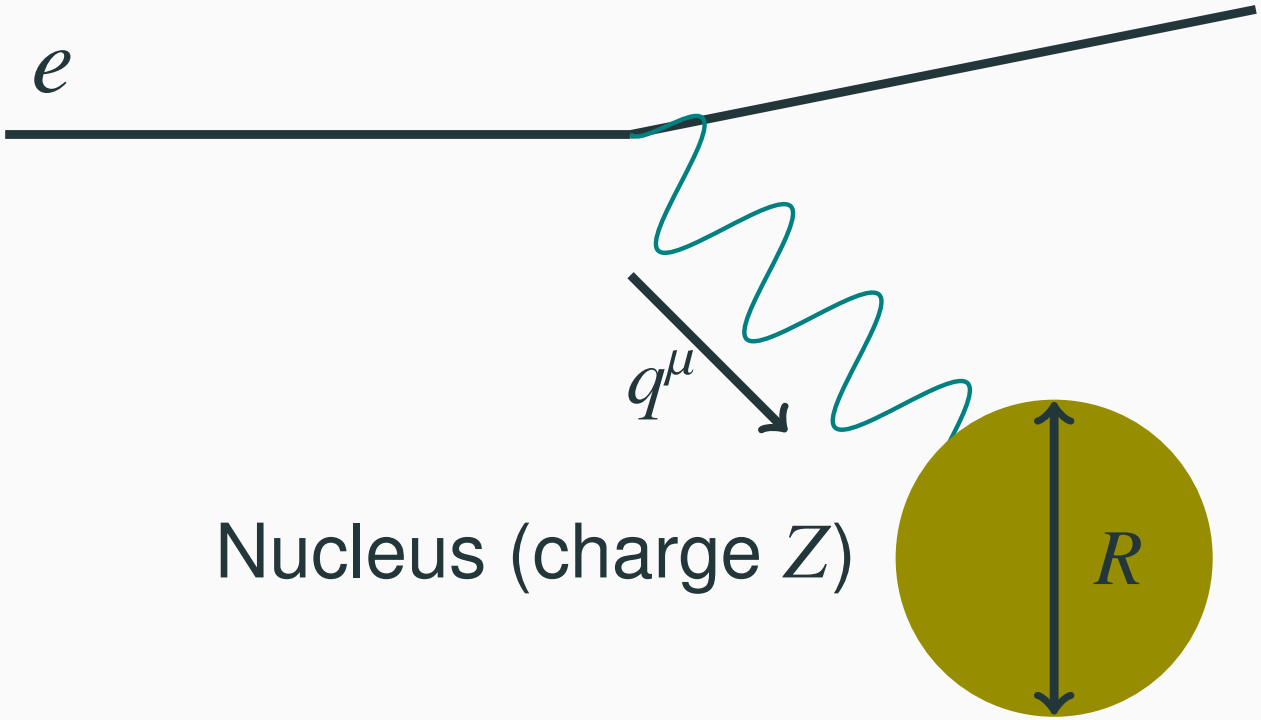
- One recoil may be small
  - Not enough to detect itself
- However, n_{DM} is quite large
- **What is an appropriate target?**
  - Measurement must be precise enough
  - Large enhancement

Enhancement Effect

- The cross section gets enhanced by
  - Stimulated emission
    - We don’t include since DM distribution is unknown
  - **Coherent effect on the target**

Coherent Effect

- e.g. Coulomb scattering



- For $qR < 1$, $\sigma \propto Z^2$!

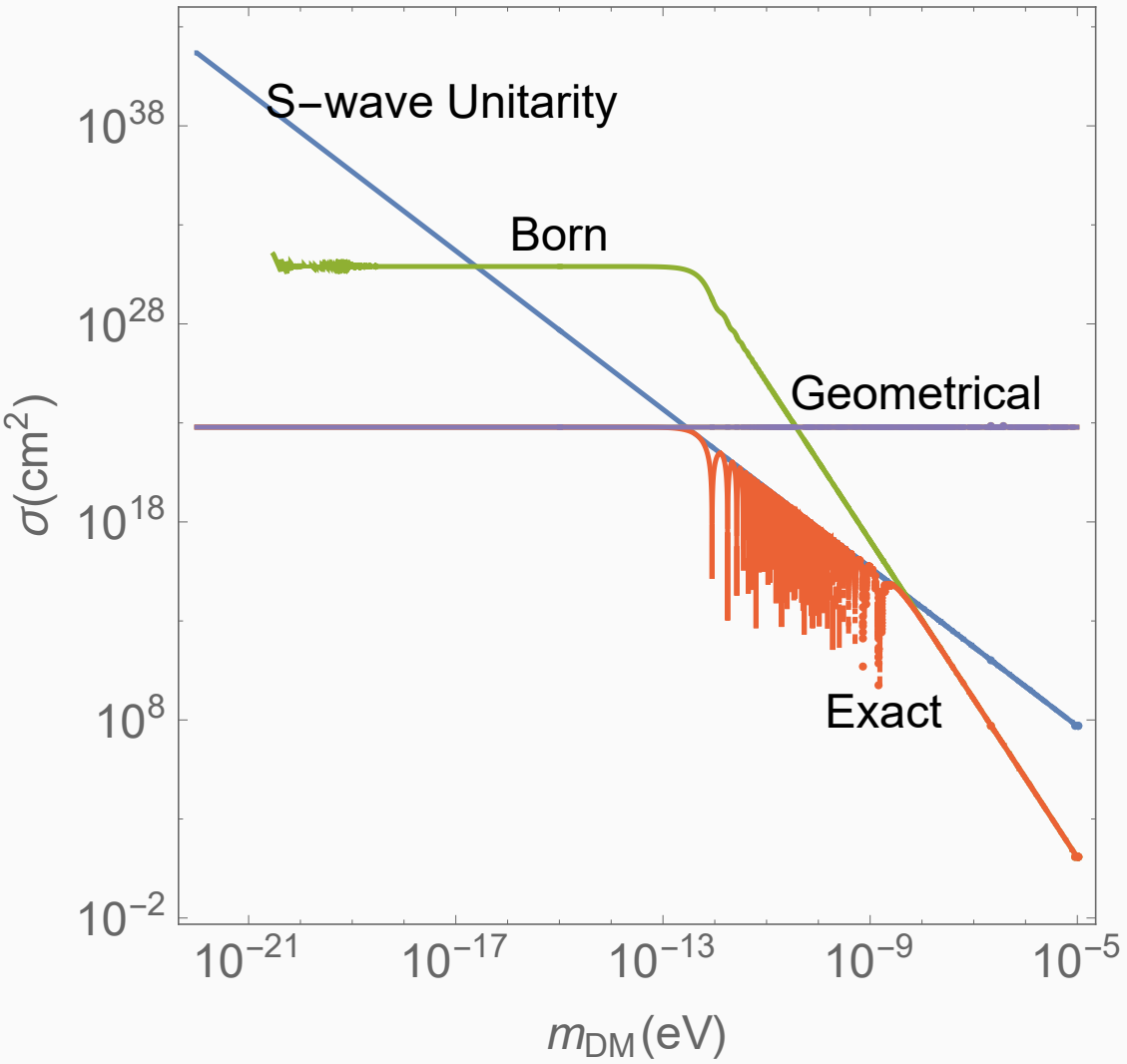
Coherent Effect

- Naively, $\sigma \propto N_{\text{targ}}^2$
- The larger, the better
- **Use planets as the target!**, $N \sim 10^{50\text{-}58}$
    - Measurement is very accurate, $\Delta v / v \Delta t \lesssim 10^{-(17\text{-}19)}\ \text{s}^{-1}$

Real Cross Section

- Unfortunately, simple N_{targ}^2 scaling is wrong
  - Incident wave is too disturbed
- Planets looks as uniform sphere to DM
- **Schrödinger eq. with** $V(r) = V_0\Theta(R - r)$
  - Coherent effect is now properly included

Real Cross Section



Final Result

- For the best target, we need one order more
  - $\sigma \sim {m_{\mathrm{DM}}}^2/\Lambda^4, \Lambda \sim 10^{13}$ GeV ($m \lesssim 10^{-14}$ eV)