

Looking for ultraheavy dark matter in geological quartz

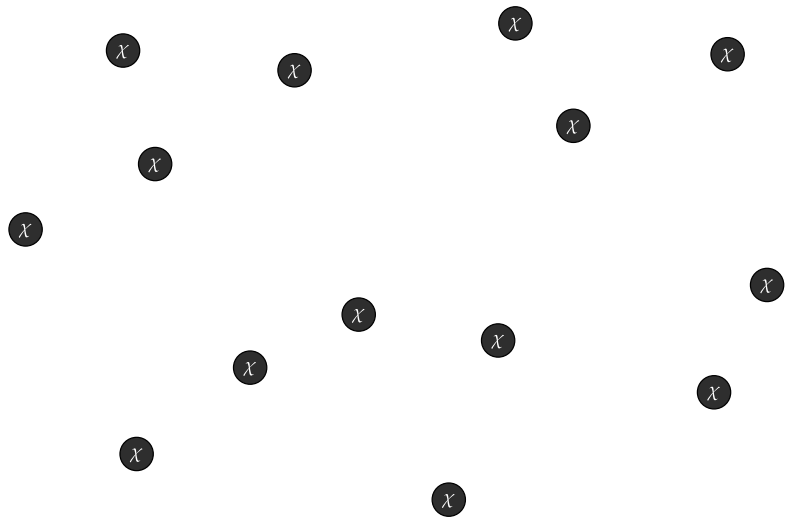
Based on Ebadi et al., Phys. Rev. D 104, 015041 (2021)
[arXiv/2105.03998]

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Johns Hopkins University

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University of Pittsburgh

9 May 2022

What does dark matter look like?



An alternative picture



(NASA, ESA, ESO,
University Arizona)

$$\Rightarrow \frac{\sigma_{\chi\chi}}{m_{\text{DM}}} \lesssim 1 \text{ cm}^2/\text{g}$$

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An alternative picture



Rare but potentially
dramatic signature!



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Geological Detectors

- ▶ $\sim 10^9$ years old: long exposure compensates for low flux
- ▶ Clear signature: long, straight damage tracks
- ▶ Well-studied backgrounds
- ▶ Abundant clean samples



Figure: Hydrothermal vein quartz in Arkansas (scorpiogirl2000, 2014)

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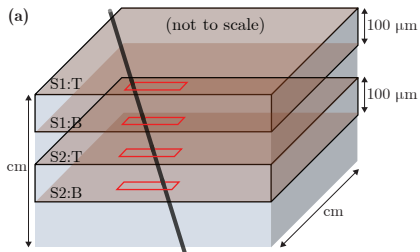
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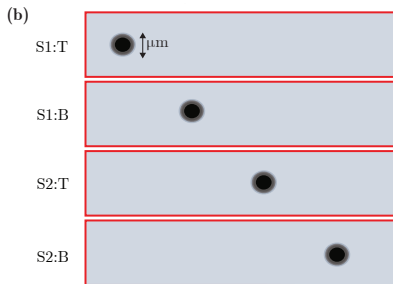


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The smoking gun



Energy deposited to SM nuclei
→ thermalize with e^- , loosen
molecular bonds → melting



Backgrounds (in order of importance)

- ▶ Noise
- ▶ Radioactive decays
- ▶ Geological stresses
- ▶ Cosmic rays
- ▶ Nothing produces long 1D damage track!

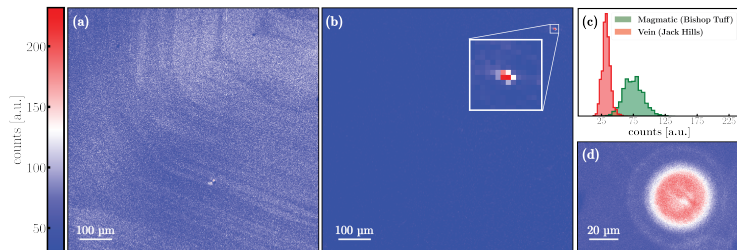


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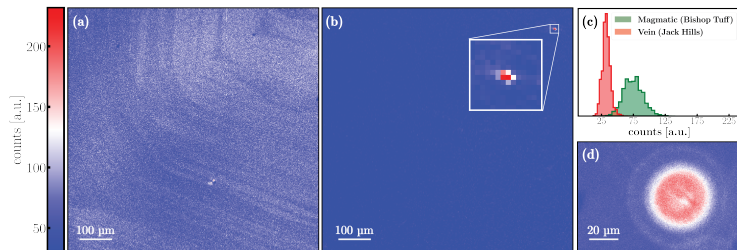


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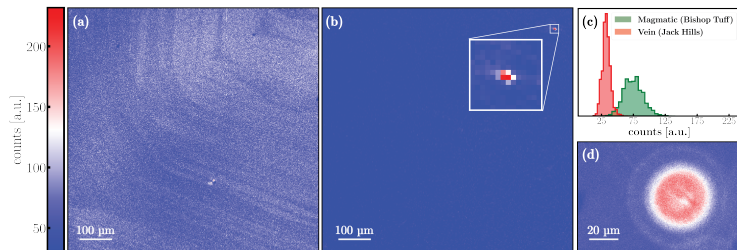


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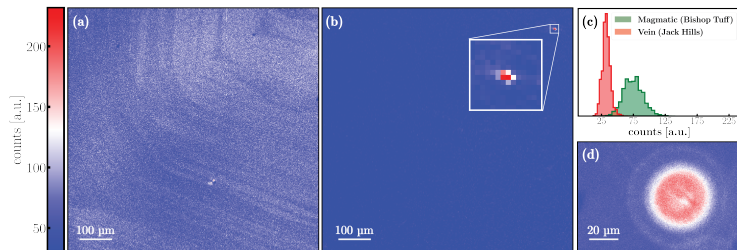


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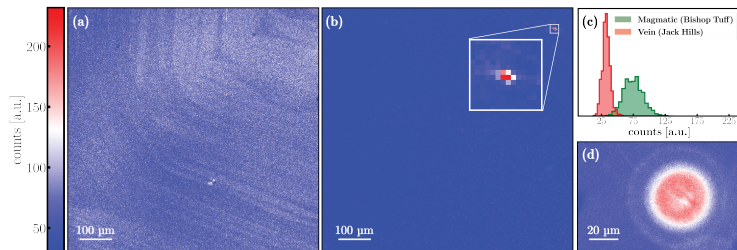
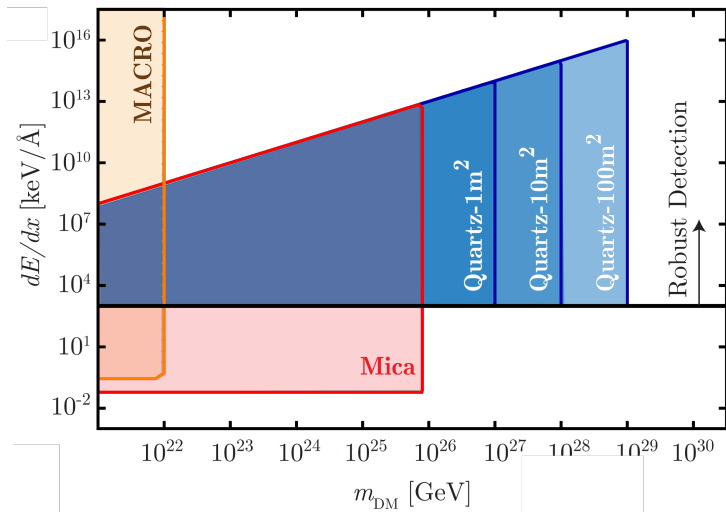
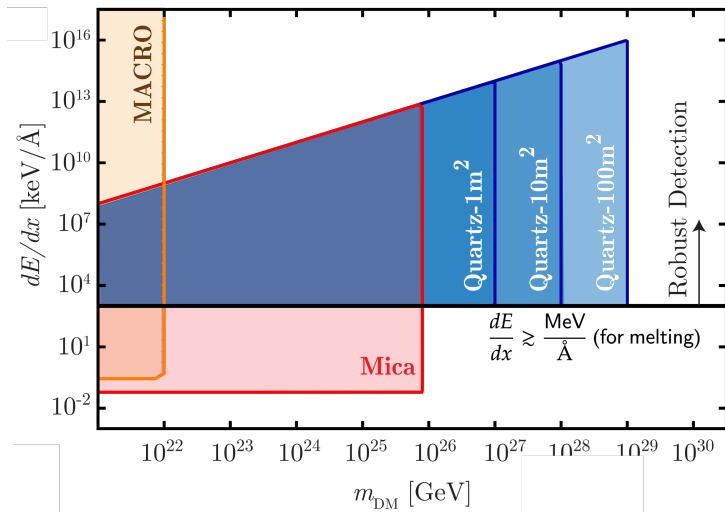


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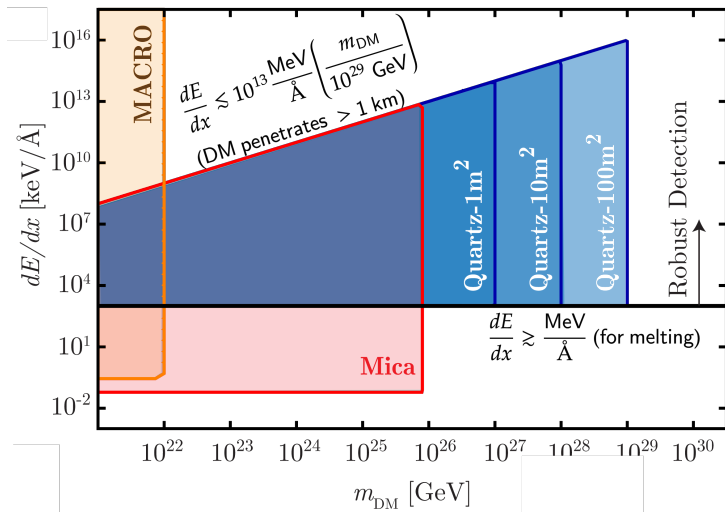
Sensitivity to Ultraheavy DM Energy Deposition



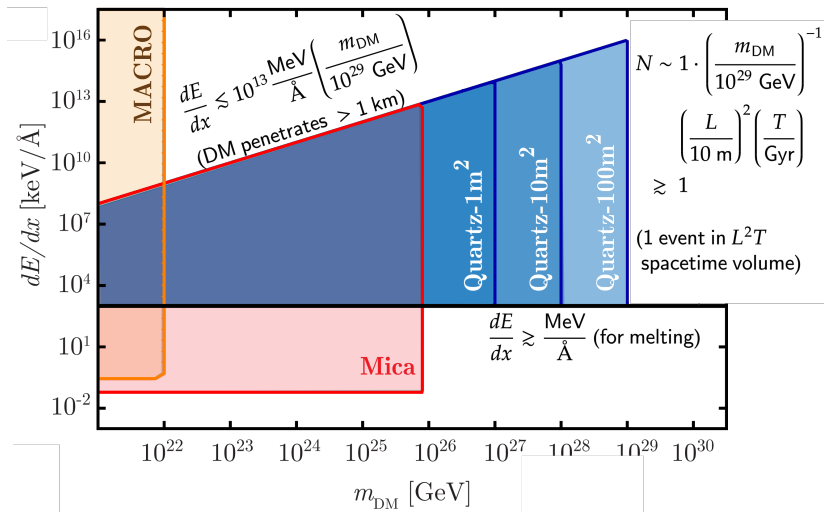
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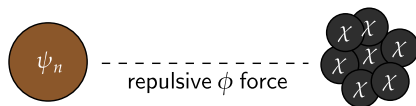


Concrete Model

- ▶ DM composed of N_χ individual fermions χ bound at scale Λ_D , interacting with SM nucleons ψ_n through light mediator ϕ :

$$\mathcal{L} \supset -\frac{1}{2}m_\phi^2\phi^2 - g_n\phi\bar{\psi}_n\psi_n + g_\chi\phi\bar{\chi}\chi$$

such that $m_\chi \sim N_\chi\Lambda_\chi$, $R \sim N_\chi^{1/3}\Lambda_\chi^{-1}$



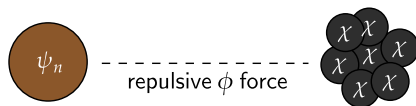
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- ▶ Constraints:
 - ▶ Direct detection: MACRO, fifth-force searches
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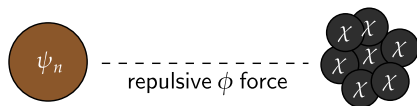
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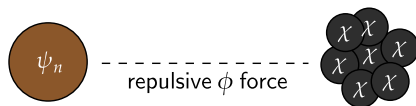
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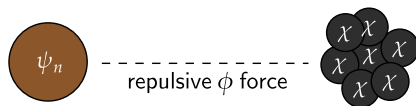
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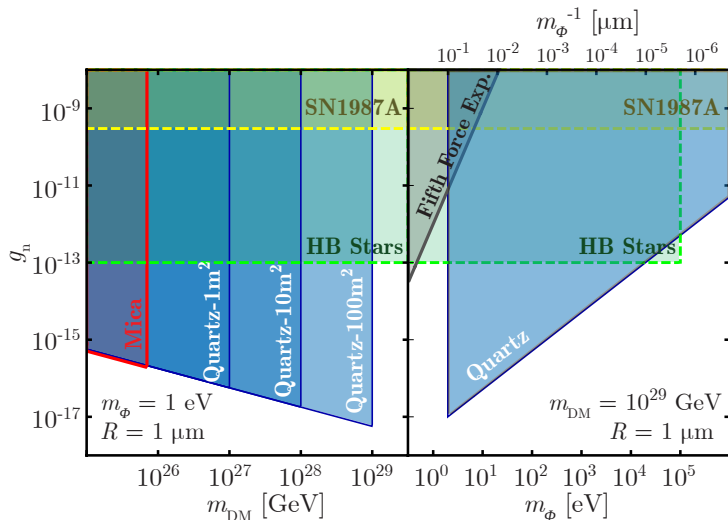
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Sensitivity to Model Parameters



- ▶ Phenomenology of ultraheavy DM underexplored
- ▶ Geological quartz a compelling detector
- ▶ Long, straight tracks beat all backgrounds
- ▶ Next steps: experimentalist colleagues working on signal + noise calibration

Thank you!