Dark Matter and the XENON1T electron recoil excess

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signal from elastic scattering

a simplified estimate: non-relativistic elastic DM-electron scattering $E_R \equiv E_{e'} - E_e = 2\mu v_{\rm rel} v_{\rm CM}$

the velocity saturates

for example:

$$E_R = 2.5\text{keV} \qquad v_e = 10\alpha$$

$$m_{\rm DM} \gg m_e : \quad v_{\rm DM} \approx 0.1$$

$$m_{\rm DM} \ll m_e : \quad v_{\rm DM} \propto m_e/m_{DM}$$

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differential scattering rate

DM-e cross section at fixed momentum transfer

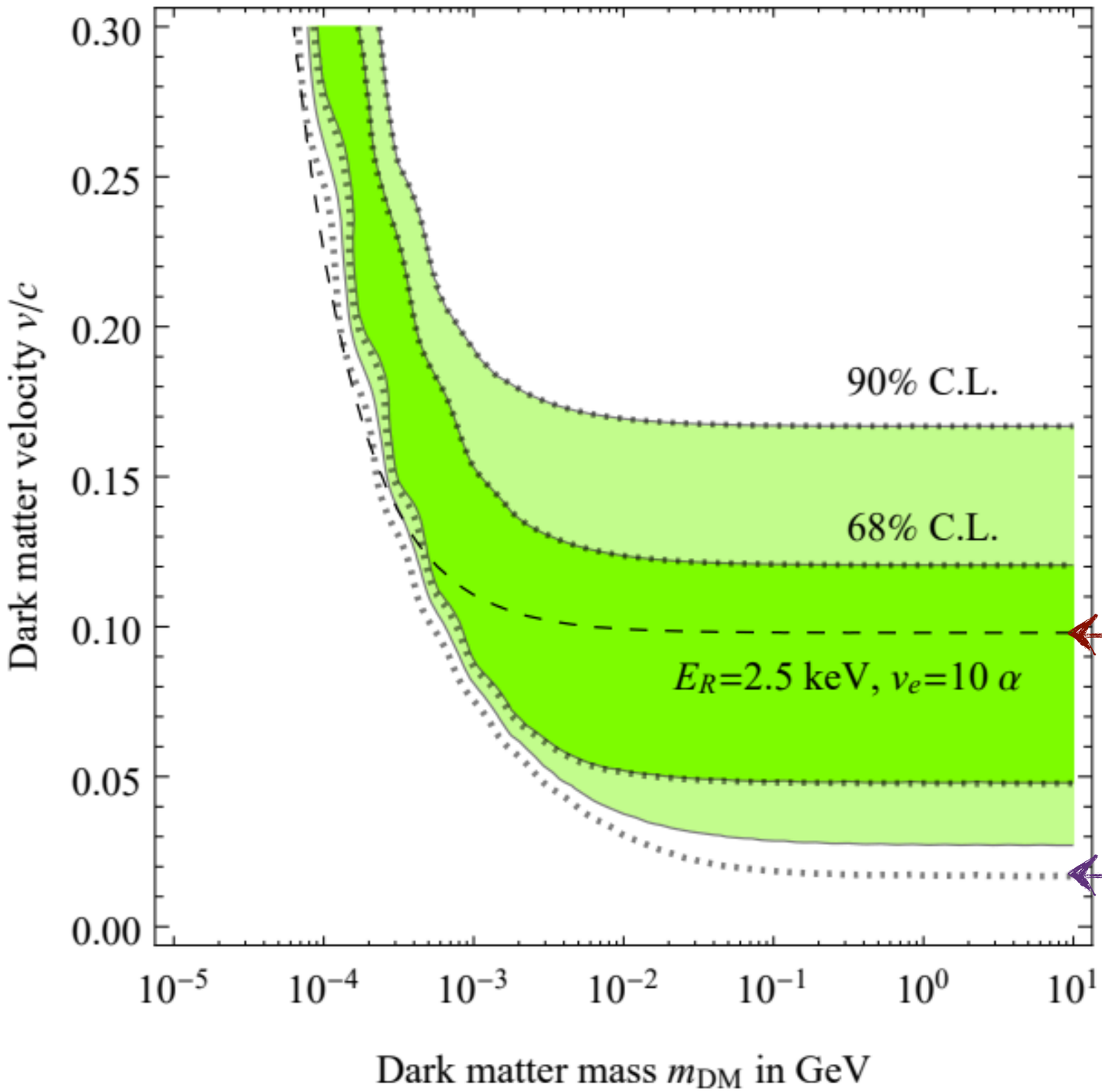
atomic exitation factor *[1604.04559]*

$$\frac{dR}{dE_R} = \frac{n_{\rm Xe}\, n_{\rm DM} \sigma_e}{2 m_e v} \int_{q_-}^{q_+} a_0^2\, q\, dq |F(q)|^2 K(E_R, q)$$

DM form factor = 1

$$q_\pm = m_{\rm DM} v \pm \sqrt{m_{\rm DM}^2 v^2 - 2 m_{\rm DM} E_R}.$$

fit in the m_{DM} - v_{DM} plane



- DM must be fast

  $v_{DM} > 0.05\ c$

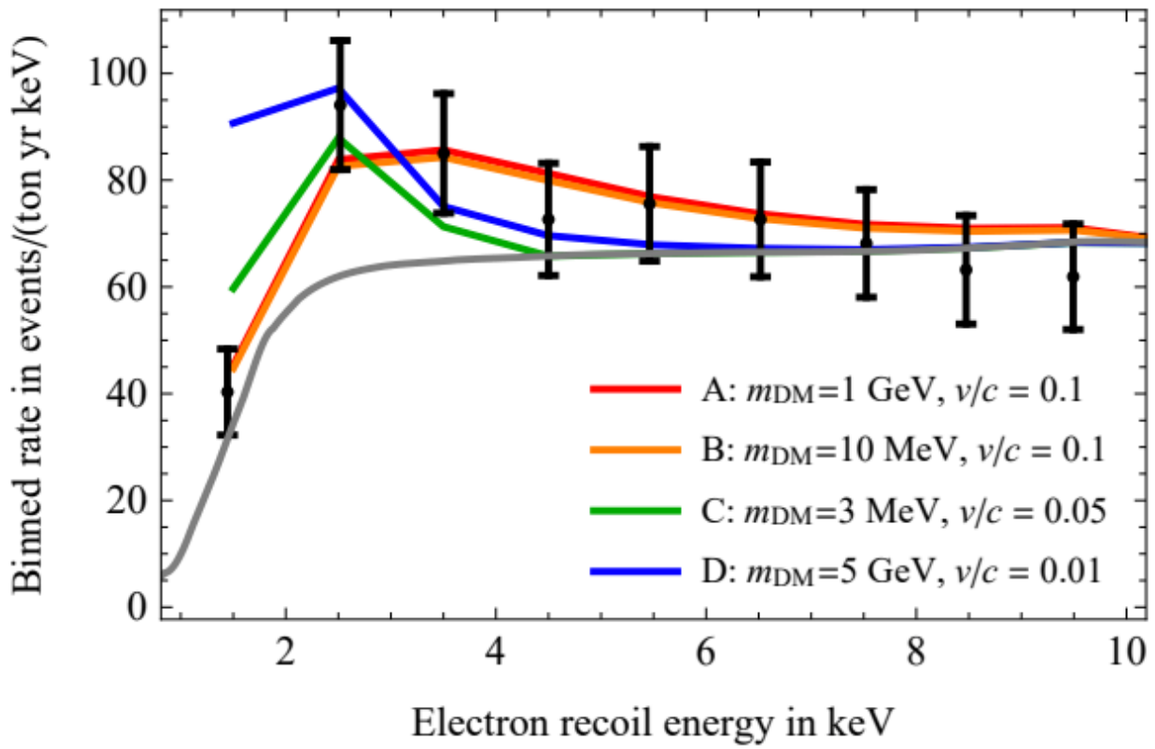
- including tritium does not affect the best fit region much

- the naive estimate captures the qualitiative features of the fit

naive estimate

including a free tritium abundance

examples of spectra:



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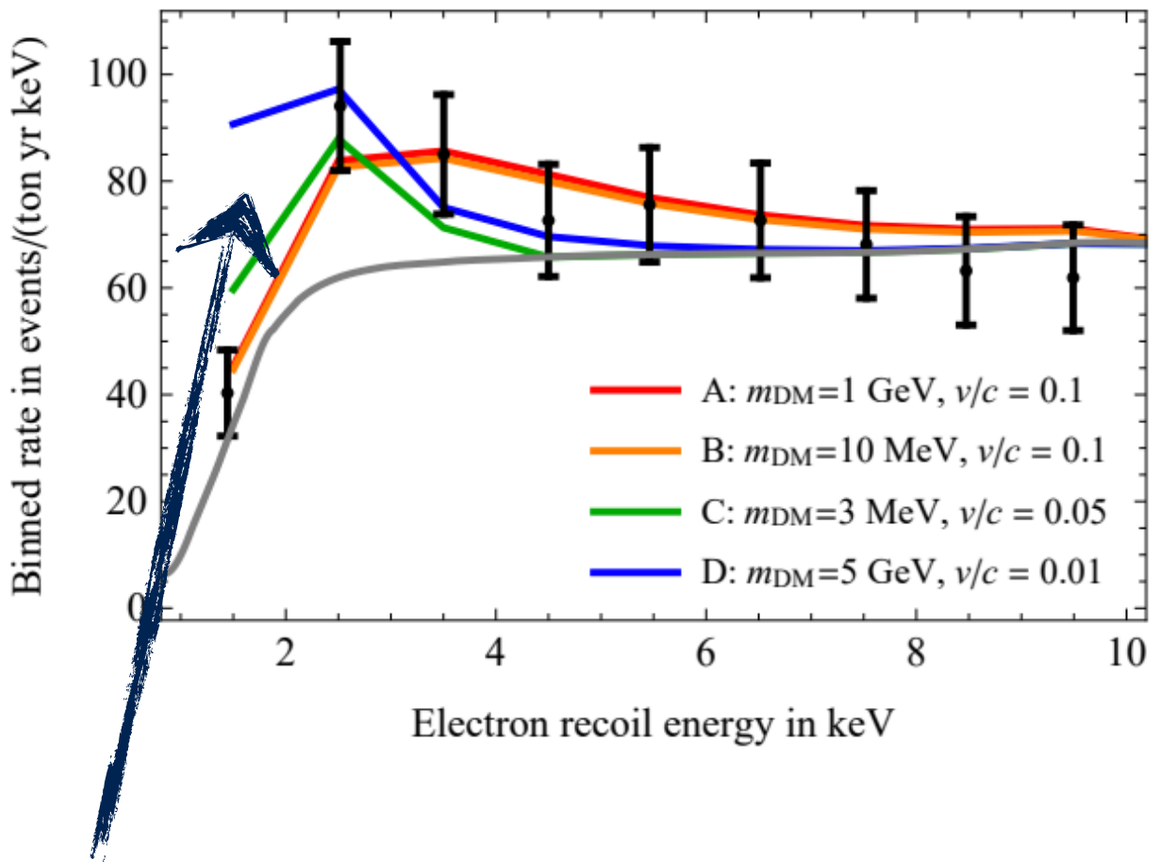

lower velocities or DM masses generate
a smaller electron recoil

too many events in the first bin

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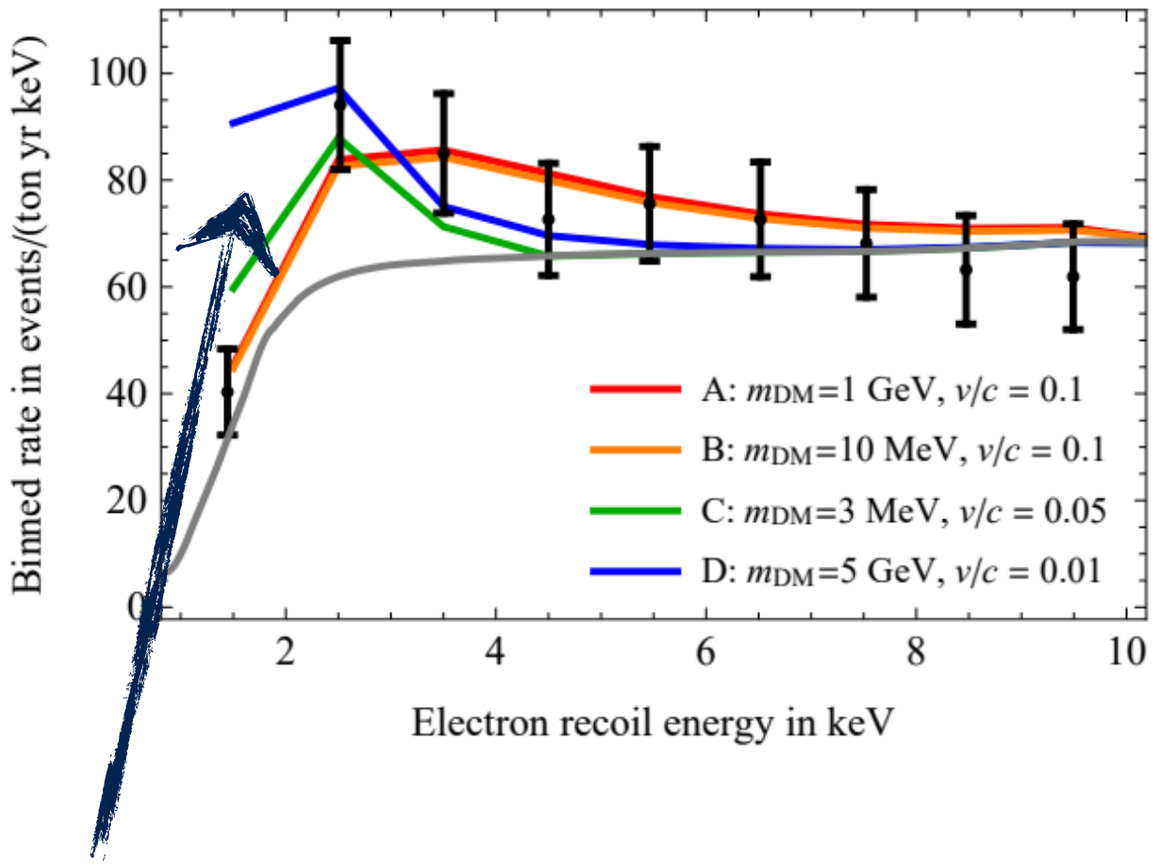

lower velocities or DM masses generate
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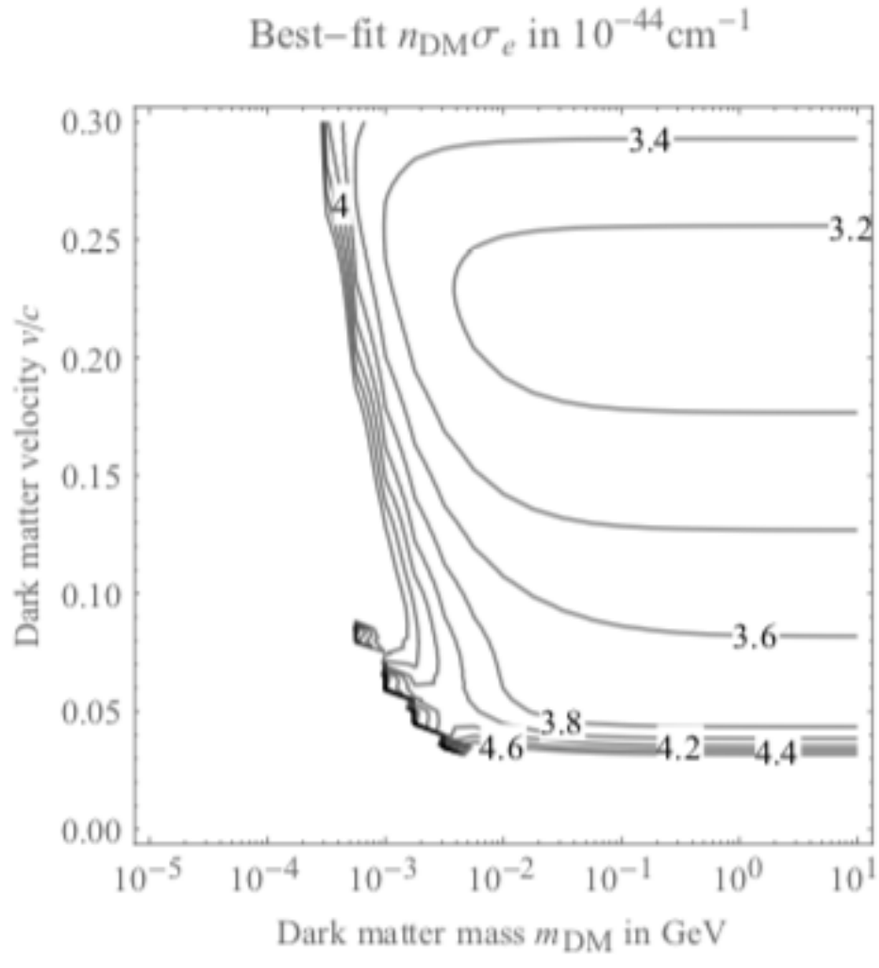
→ *too many events in the first bin*

best fit cross-section

$$n_{\rm DM}\sigma_e \approx 4 \times 10^{-44}{\rm cm}^{-1}$$



Conclusions and speculations

- an additional fast DM component required on top of CDM

- the source of fast DM?
  - *capture by Earth and semi-annihilation* $\phi\phi \to \phi X$

    * X denotes extra particles. A negligible m_X implies a mono-energetic flux with $v_{DM} = 0.6$.

    * efficient capture of CDM by earth producing an equilibrium flux of fast DM can be consistent with current direct detection bounds
  - *two component DM with a heavier and a lighter component (e.g. dark atoms)*
  - *dark stars (e.g. axion stars)*

    * production of photons must be suppressed