Dark matter direct detection with pseudoscalar mediators

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based on
JCAP 1803 (2018) no.03, 042 [arxiv:1711.02110]

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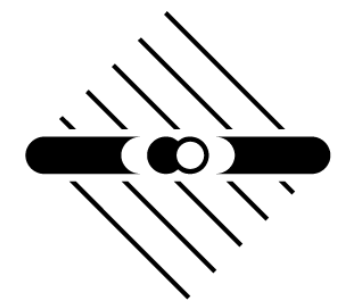
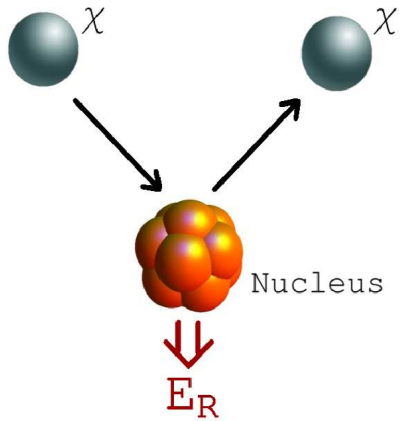


Introduction



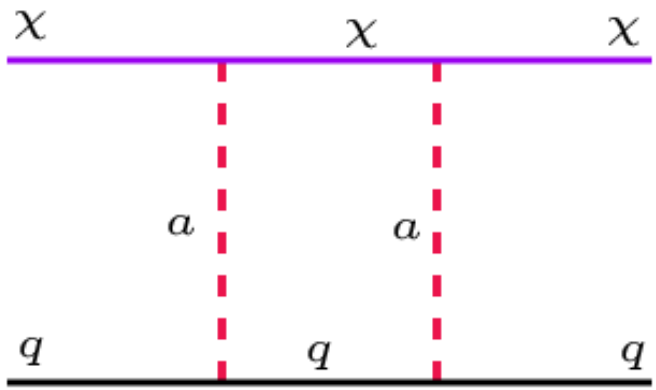
- direct detection imposes stringent limits on dark matter
- future sensitivity increases strongly
- Are there models with a naturally suppressed direct detection cross section?
- Are we going to probe these anyways?

Pseudoscalar portal

$$\mathcal{L} = ia\left(g_\chi \bar{\chi}\gamma_5\chi + c_a \sum_f \frac{m_f}{v_h}\bar{f}\gamma_5 f\right)$$

- direct detection cross section momentum suppressed and spin-dependent
- possible explanation of the galactic center excess (coy dark matter) Boehm+ 14
- considerable interest in LHC community, benchmark model for ATLAS/CMS dark matter searches

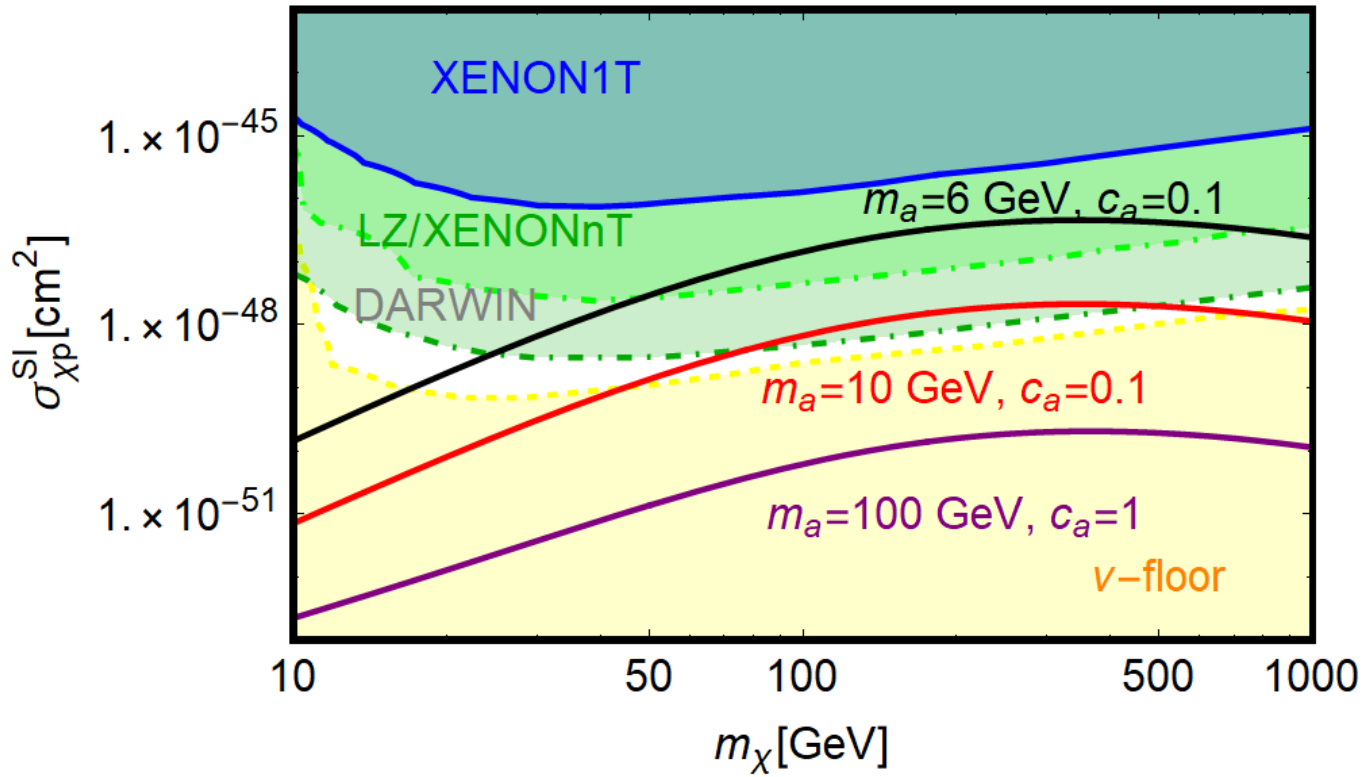
Loop induced direct detection



- effective interaction for SI direct detection generated at loop-level

$$\mathcal{L} = g_\chi^2 c_a^2 \sum_q \frac{m_q^2}{v_h^2} C_{S,q} \bar{\chi}\chi\bar{q}q$$

Direct detection limits

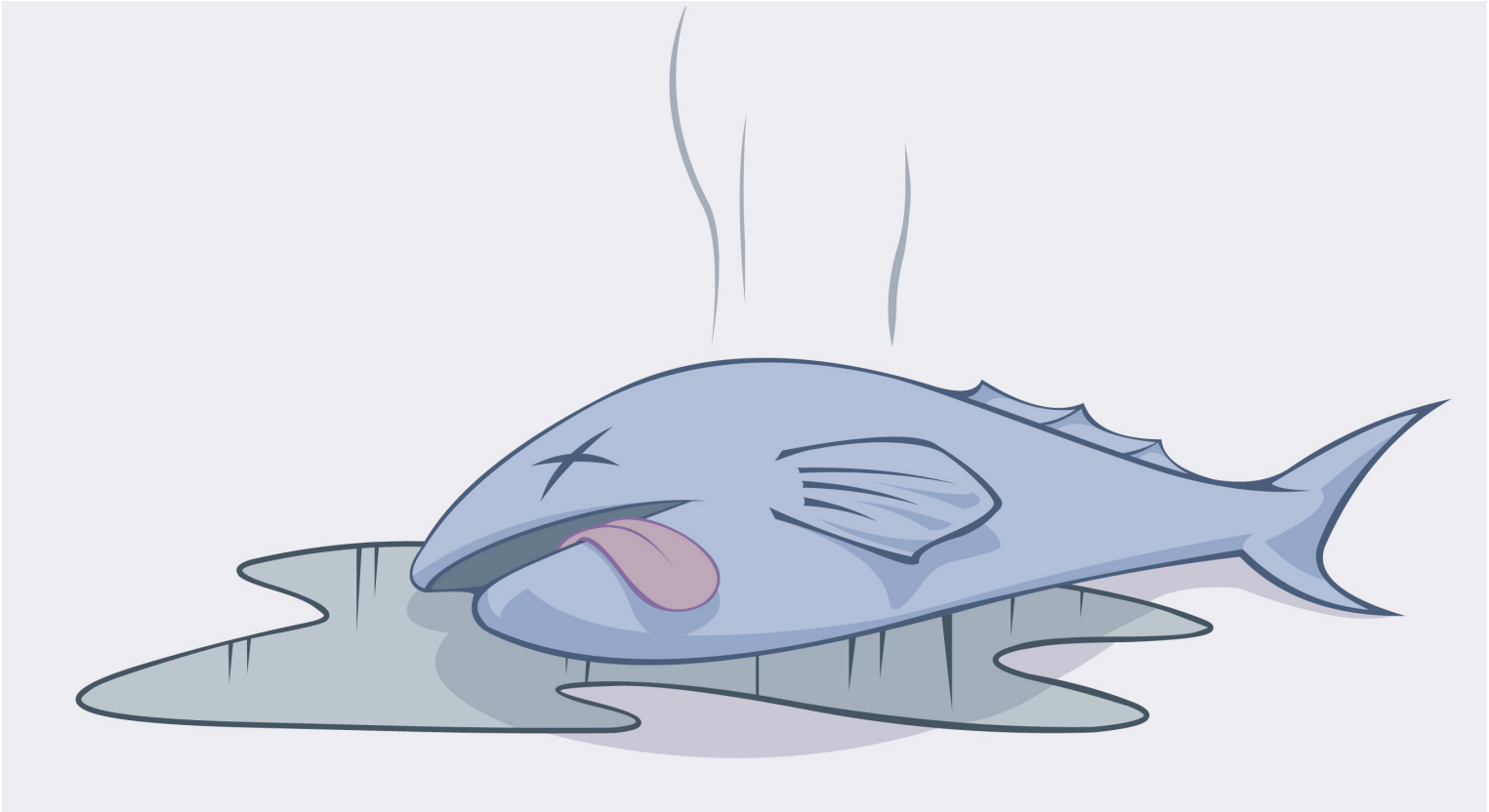


- strong dependence on m_a
- DD cross section in reach of upcoming experiments

Other constraints

- relic density
- indirect detection: Fermi-LAT limits on gamma-rays from dwarfs
- light pseudo scalar $\rightarrow$ constraints from low-energy observables
  - $\Upsilon \rightarrow a\gamma$ (tree-level)
  - $B_s \rightarrow \mu^+\mu^-$ (loop-induced FCNC)
  - $B \rightarrow K\mu^+\mu^-$ (loop-induced FCNC)

Is the fish rotten?



FCNC amplitudes are divergent

Issues of simplified model

$$\mathcal{L} = ia\left(g_\chi \bar{\chi}\gamma_5\chi + c_a \sum_f \frac{m_f}{v_h}\bar{f}\gamma_5 f\right)$$

- model incomplete
- either DM not a singlet or something fishy about interaction with SM
- issue stares you in the face in FCNC computation $\rightarrow$ result divergent
- new physics could also enter direct detection cross section

Let's start over

UV-completion

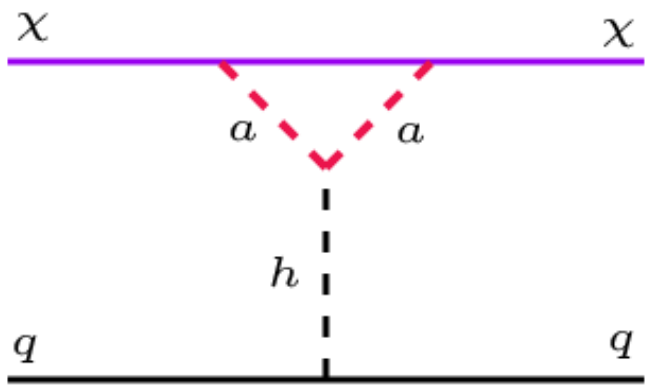
- various UV-completions possible
- 2HDM + singlet doublet DM see for example Berlin+ 15
- for singlet DM add new pseudoscalar (2HDM + a) see Ipek+ 14
- DM singlet +pseudoscalar

$$\mathcal{L} = i g_\chi a_0 \bar{\chi} i\gamma^5 \chi$$

- couple to SM through scalar potential, i.e. mixing between a and A

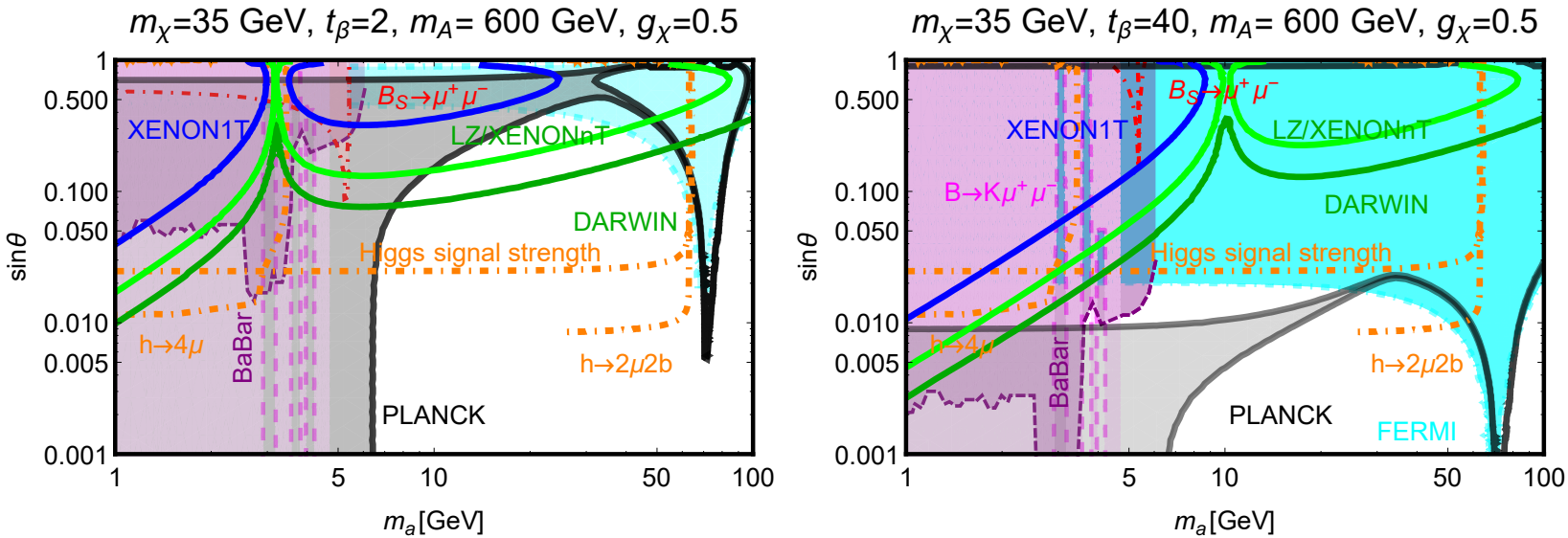
$$V = V_{\text{2HDM}} + \frac{1}{2} m_{a_0} a_0^2 + \frac{\lambda_a}{4} a_0^4 + \left(i\kappa a_0 H_1^\dagger H_2 + \text{h.c.} \right)$$

Direct detection



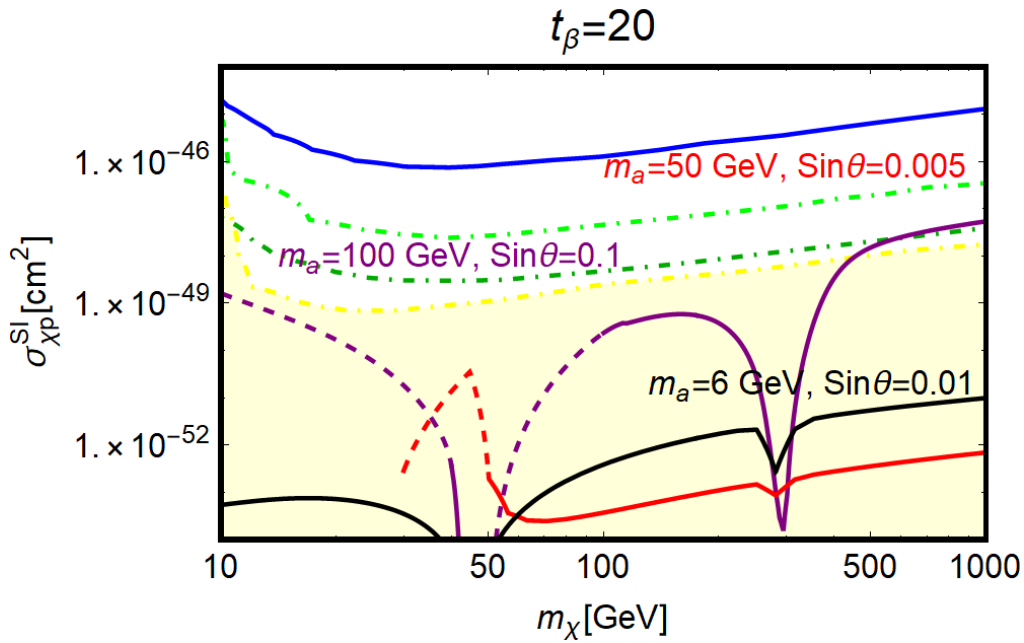
- loop induced interaction with SM Higgs leads to new contribution to direct detection
- triangle loop dominates for light m_a

Comparison of constraints



- dependence on more model parameters, i.e. $\tan\beta$, m_A
- strong flavor bound for $m_a \lesssim 5$ GeV
- strong bounds from Higgs decays
- direct detection does not seem competitive for small m_a

Direct detection

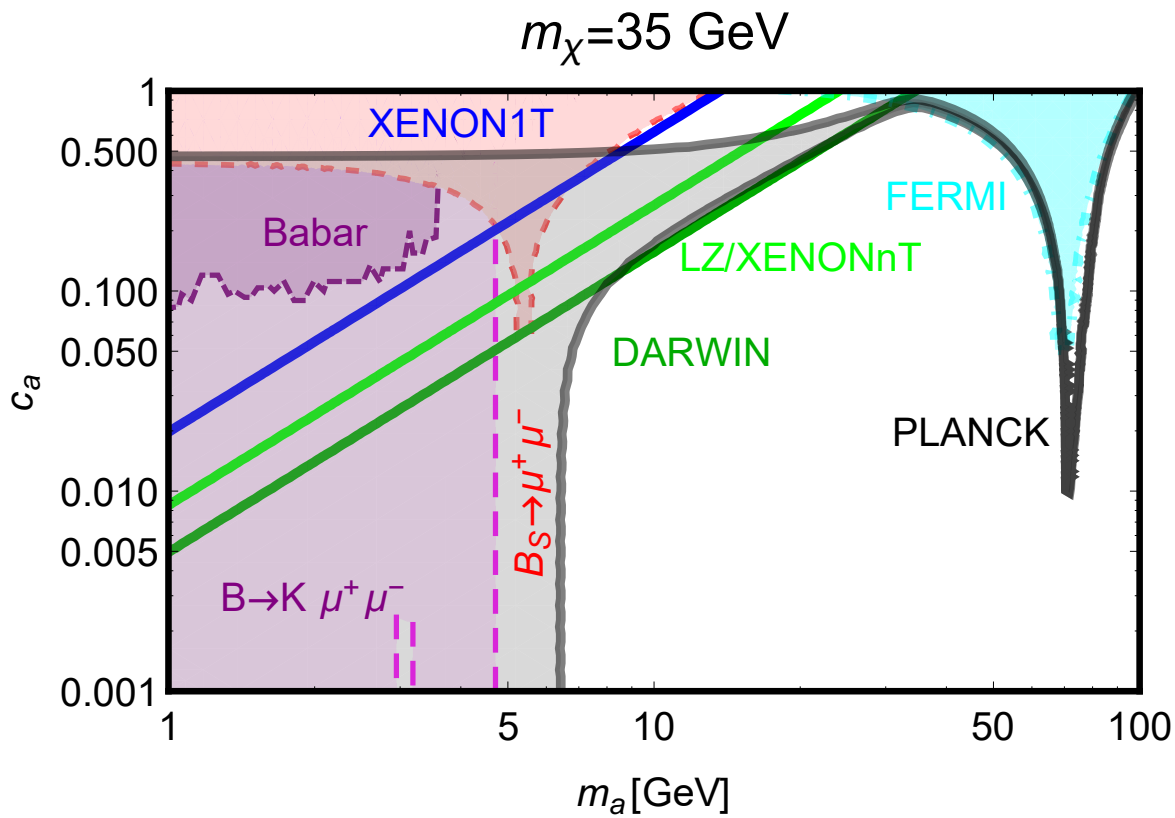


- DD cross section remains small overall
- scattering rates for heavy dark matter and heavier pseudoscalar above the neutrino floor

Conclusion

- direct detection cross section dominated by loops
- flavor constraints and Higgs more relevant for light m_a
- simplified models should be used with care

Comparison of simplified constraints



- currently low-energy observables dominate sensitivity
- future DD sensitivity best probe of thermal dark matter a intermediate values of m_a