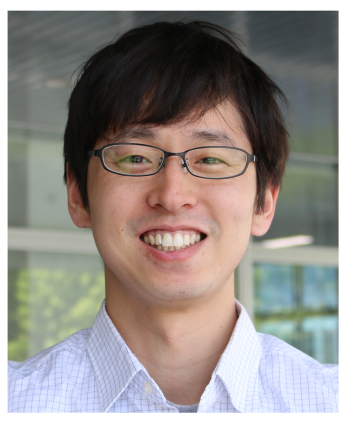
Current status and future prospects of the singlet-doublet dark matter model with CP violation



Tomohiro Abe (Nagoya University)

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in collaboration with **Ryosuke Sato** (DESY)

Abstract and Summary

Recent direct detection searches for dark matter give stringent bounds on the dark matter mass and couplings. One way to relax the constraint is to rely on pseudoscalar interactions with fermionic dark matter.

We focus on the singlet-doublet dark matter model, which predicts the pseudoscalar interactions by CP violation in the dark sector. Due to the CP violation, electric dipole moments (EDMs) are predicted. We show that the model can be tested by the combination of the direct detection experiments and the measurement of the electron EDM.

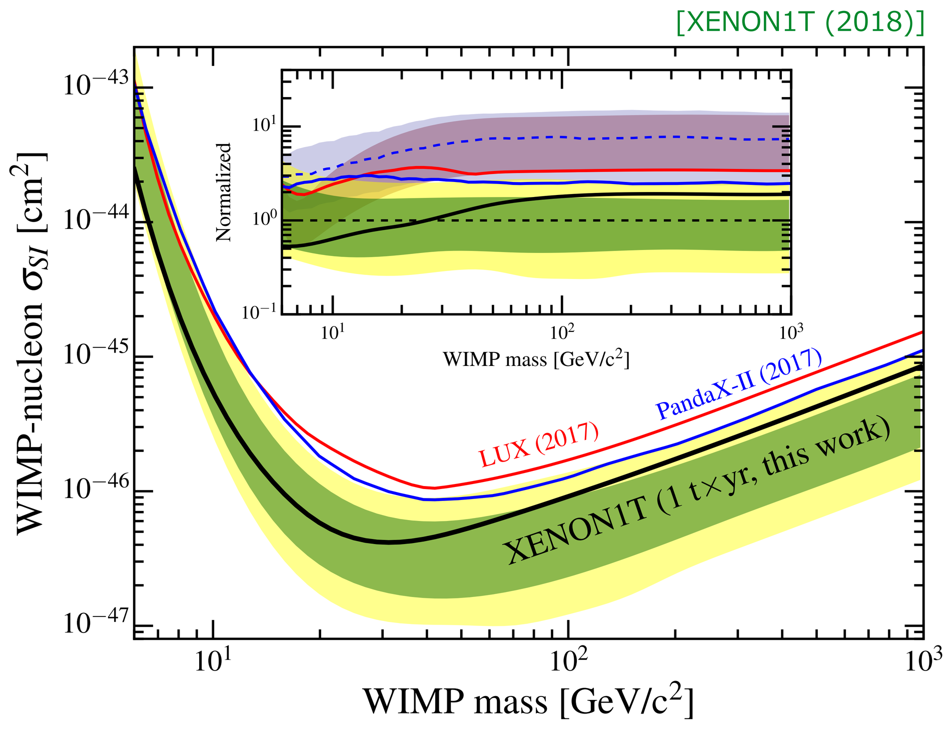
***Summary*:**

- ⋆ the singlet-doublet model can avoid the strong constraint from the Xenon1T experiment while keeping the right amount of DM energy density
- ⋆ the model is testable thanks to the correlation between ***"the direct detections"*** and ***"the electron EDM"***
- ⋆ the Higgs funnel region can be covered if eEDM reach to O(10^{-32})

Introduction

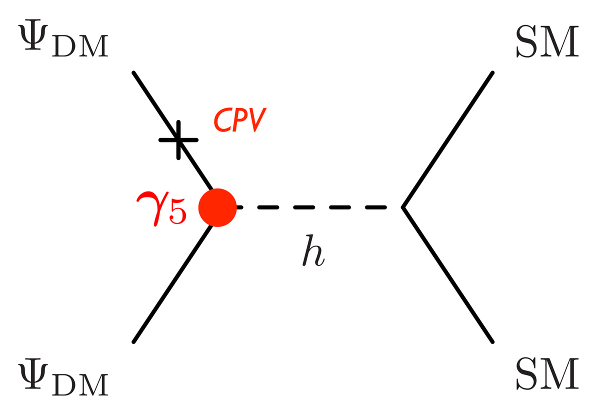
Motivation: to evade the strong constraints from DM direct detections while keeping the success of the freeze out mechanism

[XENON1T (2018)]



Simple solution = fermionic DM + pseudoscalar interaction

$$\overline{\Psi}_{\rm DM} i\gamma^5 \Psi_{\rm DM} S$$



s-wave for annihilation

- ⋆ good for keeping freeze out scenario

velocity suppression for scattering with nucleon

- ⋆ good for avoiding strong constrains on σ_{SI} and σ_{SD}

- CP violation in dark sector makes this interaction
- the SM Higgs is the mediator (no additional scalar fields)

Model

The singlet-doublet DM model

- new particles
  - ⋆ a Z_2-odd gauge singlet Weyl fermion ω
  - ⋆ a Z_2-odd $SU(2)_L$ doublet Dirac fermion (Y = 1/2)

  η : left handed
  $\xi^\dagger$: right handed
- mass and Yukawa interaction terms

$$\mathcal{L}_{int.} = -\frac{M_1}{2}\omega\omega - M_2 e^{-i\phi}\xi\eta - y\omega H^\dagger \eta - y'\xi H\omega + (h.c.).$$

- mass matrix for neutral Z_2-odd particles → three mass eigenstates

$$\mathcal{L}_{mass} = -\frac{1}{2}\begin{pmatrix}\omega & \eta^0 & \xi^0\end{pmatrix}\begin{pmatrix} M_1 & \frac{v}{\sqrt{2}}y & \frac{v}{\sqrt{2}}y' \\ \frac{v}{\sqrt{2}}y & 0 & M_2 e^{-i\phi} \\ \frac{v}{\sqrt{2}}y' & M_2 e^{-i\phi} & 0\end{pmatrix}\begin{pmatrix}\omega \\ \eta^0 \\ \xi^0\end{pmatrix} \qquad \begin{pmatrix}\omega \\ \eta^0 \\ \xi^0\end{pmatrix} \to \begin{pmatrix}\chi_1^0 \\ \chi_2^0 \\ \chi_3^0\end{pmatrix}$$

Features

Both scalar and pseudoscalar interactions exist

$$\frac{c_s}{2}\bar{\Psi}\Psi h + \frac{c_p}{2}\bar{\Psi} i\gamma_5 \Psi h$$

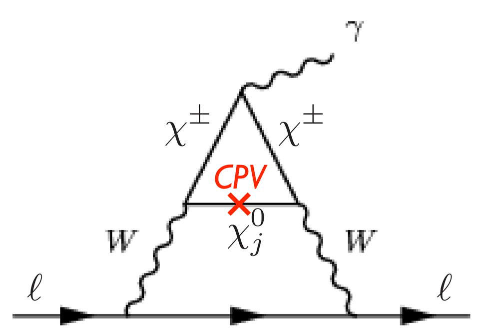
- ⋆ cannot forbid the scalar coupling
- ⋆ σ_{SI} can be small but we still have a chance for the direct detection

Indirect detection

- ⋆ s-wave annihilation of DM pairs into the SM particles produces γ-ray, e-, e+, …
- ⋆ Fermi-LAT measures γ-ray and gives a constraint for mDM < 100 GeV

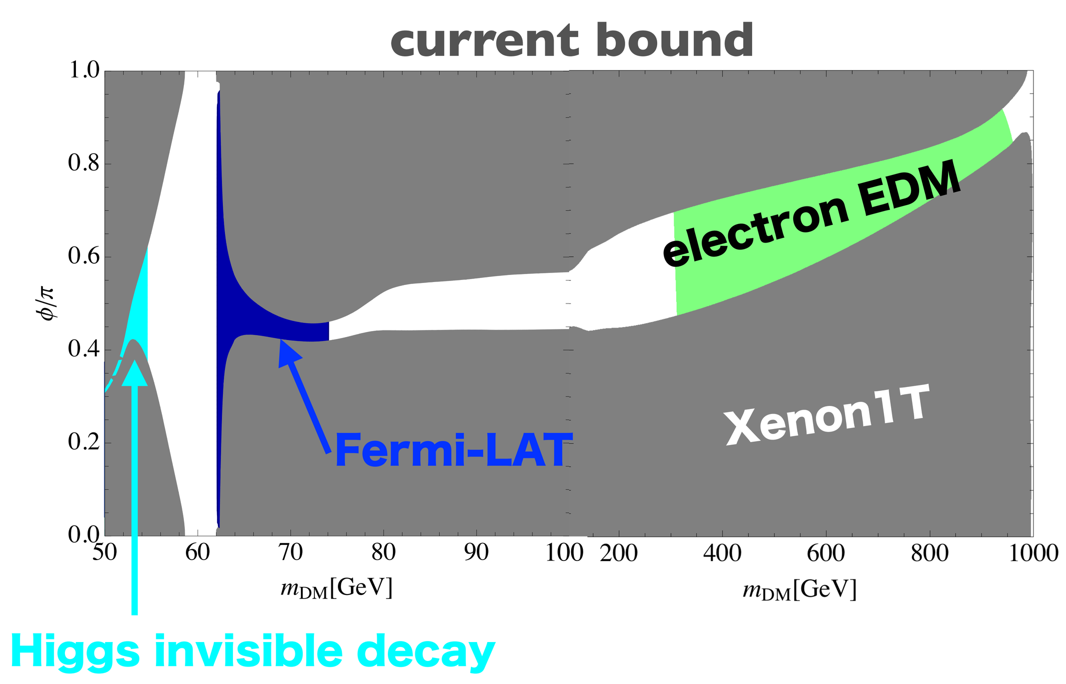
Electric Dipole Moment (EDM)

- ⋆ EDMs are induced by the CPV (see the diagram on the right)
- ⋆ large pseudo-scalar coupling is disfavored by EDM

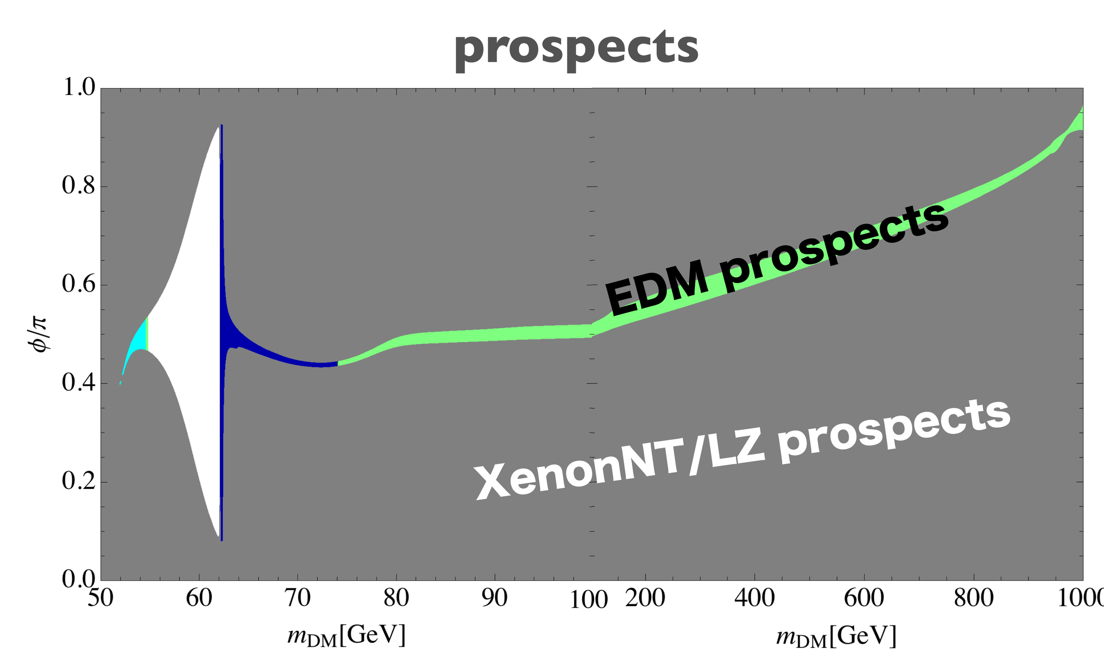


Results

current bound

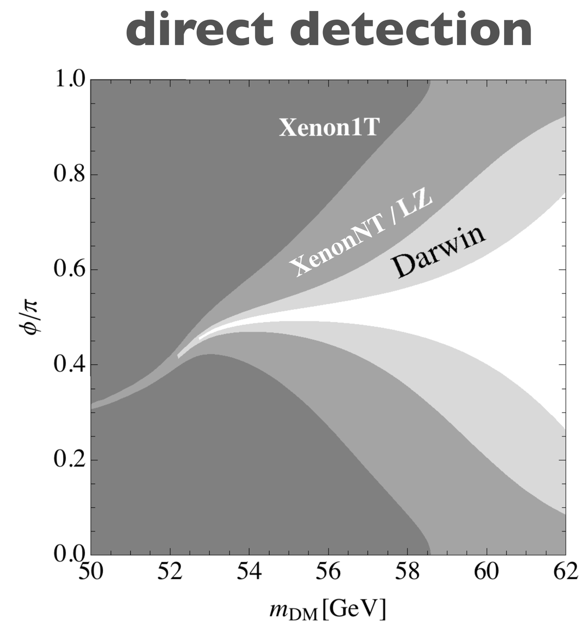


prospects

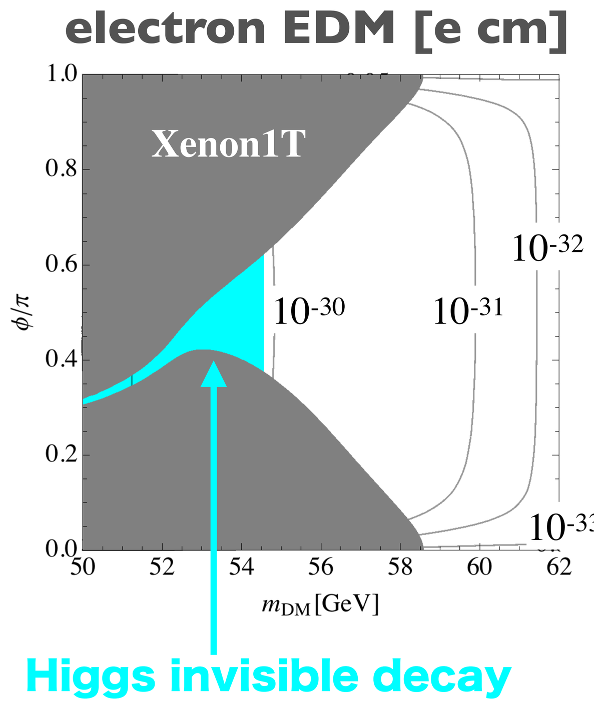


Higgs funnel region

direct detection



electron EDM [e cm]



electron EDM

- ⋆ ***current bound*** **:** $|d_e|$ < 1.1 x 10^{-29} e cm [ACME experiment (2018)]
- ⋆ ***prospect:*** $|d_e|$ < O(10^{-30}) e cm [1208.4507, 1502.04317, …]

- We take M_2 = 1000GeV, y/y' = 1 as an example
- We take y and y' to obtain the right amount of DM relic density Ωh^2 = 0.12

Result

- ⋆ direct detection + electron EDM cover most of the region
- ⋆ funnel region can be covered *if* electron EDM reach to O(10^{-32})