Dirac sneutrino as a light dark matter

Osamu Seto

(Hokkai-Gakuen University)

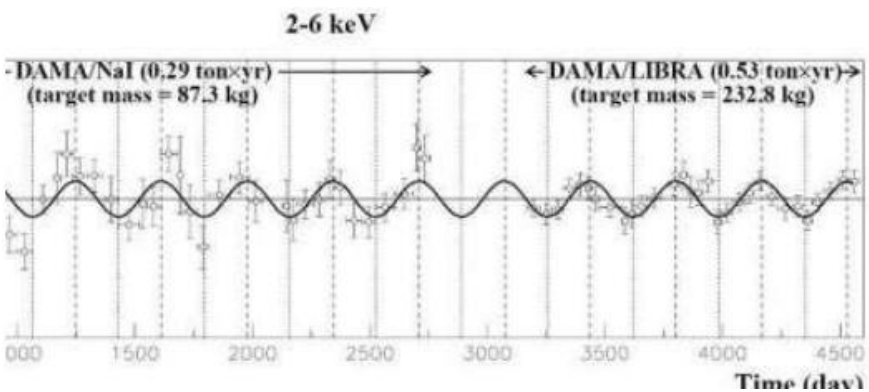
with Ki-Young Choi (APCTP and POSTECH)

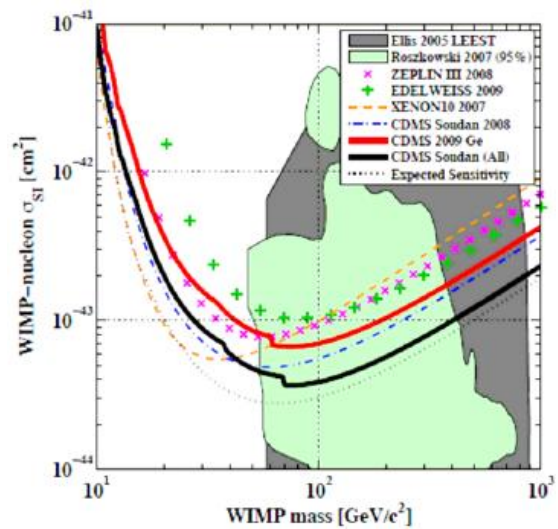
Based on **Phys. Rev. D 88, 035005 (2013)**

§ Motivation: direct detection

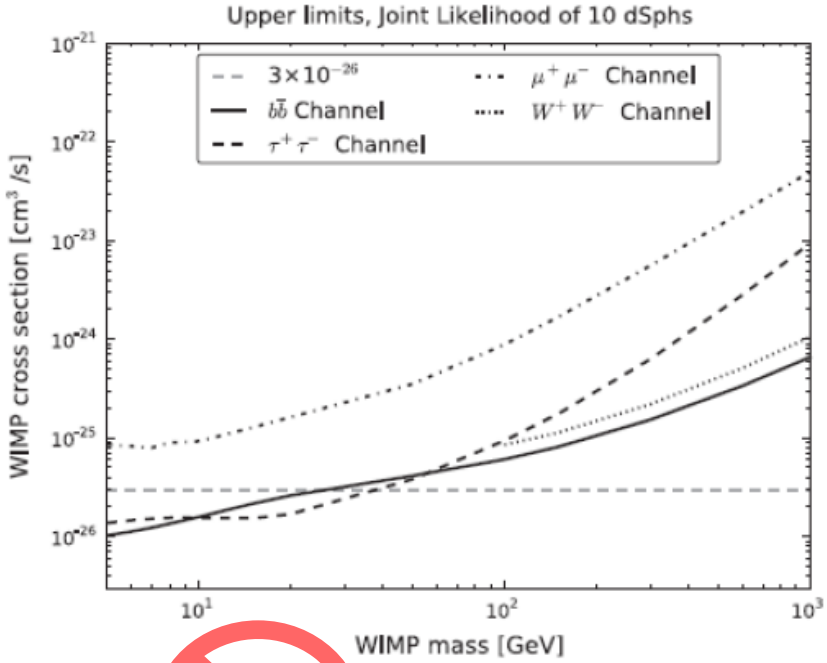
- DAMA/NaI [1999]
- DAMA/LIBRA [2008]
- CDMS-II [2010, 2011]
- CRESST-II [2011]

- All others [~2010]
- CoGeNT [2010,2011]
- XENON10/100 [2011]



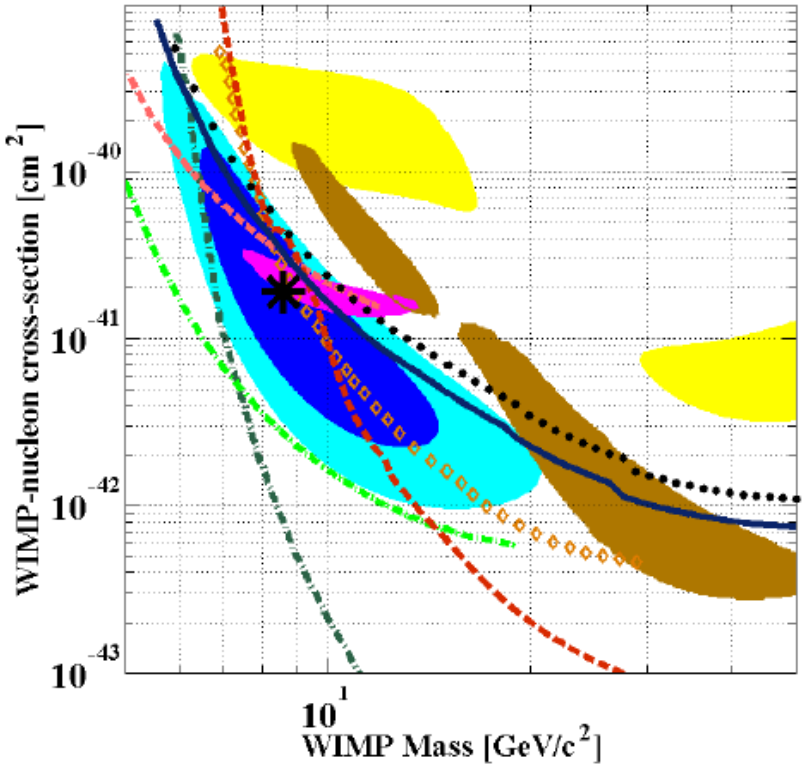


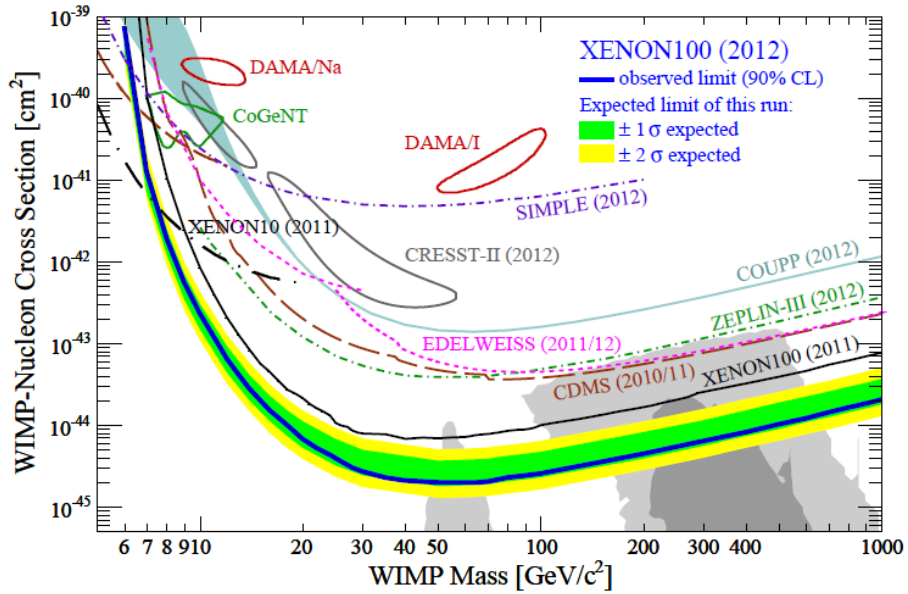
§ § + indirect searches and LHC



- Fermi-LAT dSph [2011]
- LHC (mh≃125 GeV, Γh(⟶inv)) [2012]

- Light neutralino [Bottino et al 2003]
- Light sneutrino [Cerdeño et al 2008]
- Higgs portal light scalar DM; SM+ϕ





- XENON10/100 [2011,2012]

- SIMPLE [2012]
- CDMS-II Si [2013]

§ Light Dirac RH sneutrino DM for recent CDMS II Si events

- SUSY DM candidate: Dirac RH sneutrino

- Q: "Why Dirac?"
- A: "scattering off via Z boson exchange"

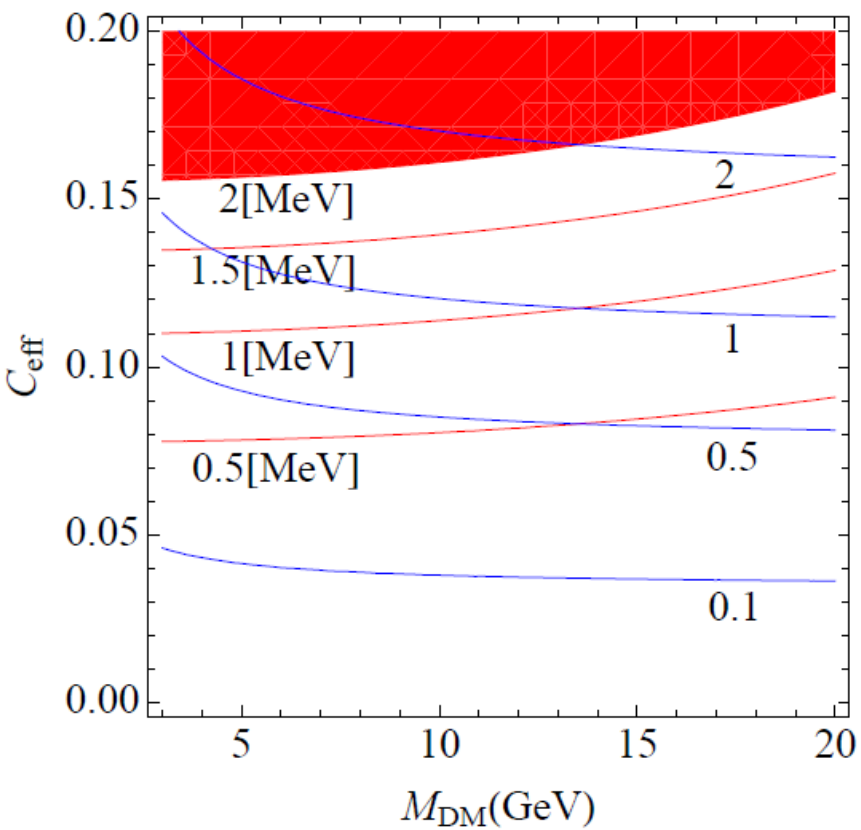
- Z boson invisible width is well measured!
- RH sneutrino has no coupling with Z!
- RH (s)neutrino has only Yukawa int.!

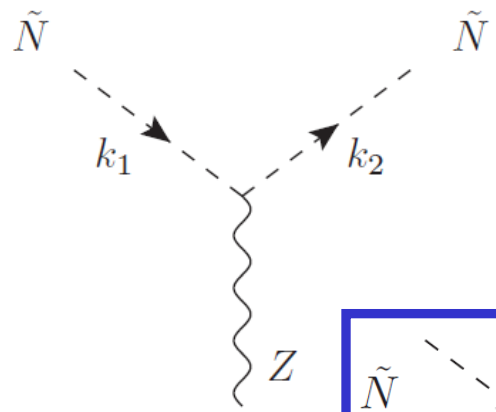
§ § Dirac RH sneutrino DM

- Z invisible width

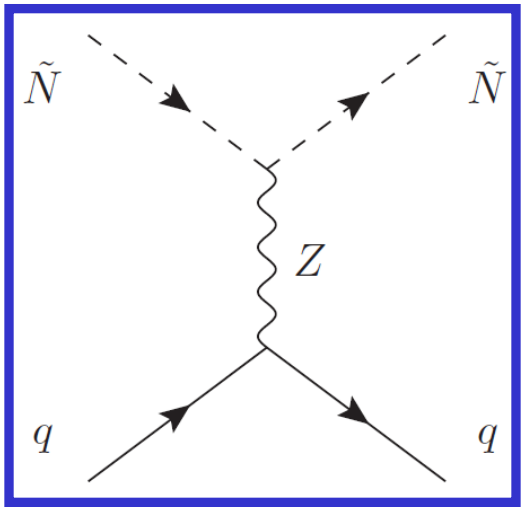
$$\Gamma_{Z\to\tilde{N}\tilde{N}^*} = \frac{|C_{\rm eff}|^2 g^2 M_Z}{192\pi\cos^2\theta_W}\left(1-4\frac{M_{\tilde{N}}^2}{M_Z^2}\right)^{3/2}$$

- Cross section with neutron in $10^{-40}\mathrm{cm}^2$ unit





$$\frac{g}{2\cos\theta_W}(k_1^\mu + k_2^\mu)C_{\rm eff}$$

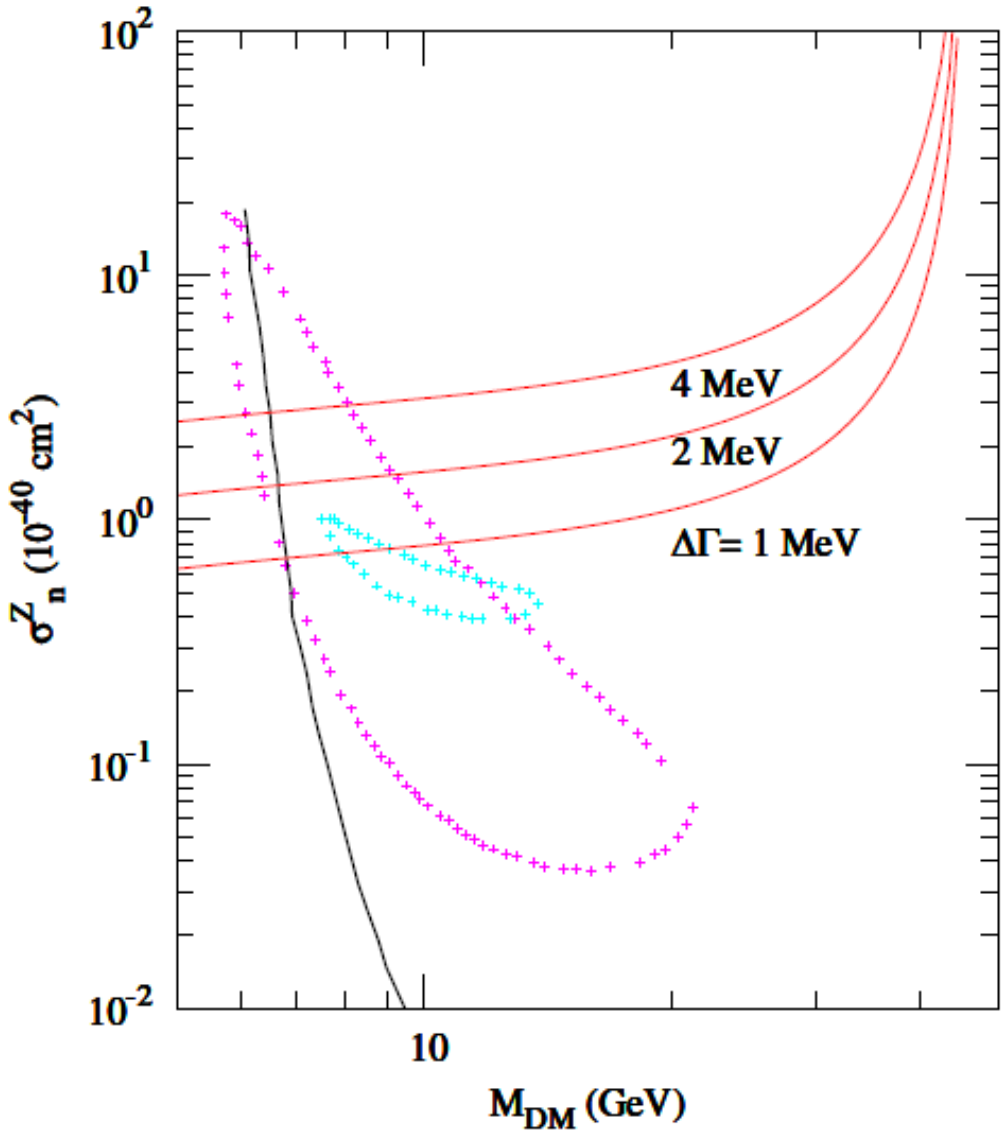


§ § Dirac RH sneutrino DM

- Comparison with "signal region"

- XENON 100
- CDMS II (Si)
- CoGeNT

- Z invisible



§ How to get a suitable C_{eff} ?

§ § Model

- Supersymmetric model with neutrinophilic Higgs doublet

§ § SUSY neutrinophilic model

- Superpotential

$$
\begin{aligned}
W \;=\; & y^u \bar{Q} H_u U_R + y^d \bar{Q} H_d D_R + y^l \bar{L} H_d E_R \\
& + y^\nu \bar{L} H_\nu N + \cancel{\frac{1}{2} M N^2} \\
& + \mu H_u H_d + \mu' H_\nu H'_\nu + \rho H_u H'_\nu + \rho' H_\nu H_d
\end{aligned}
$$

soft breaking

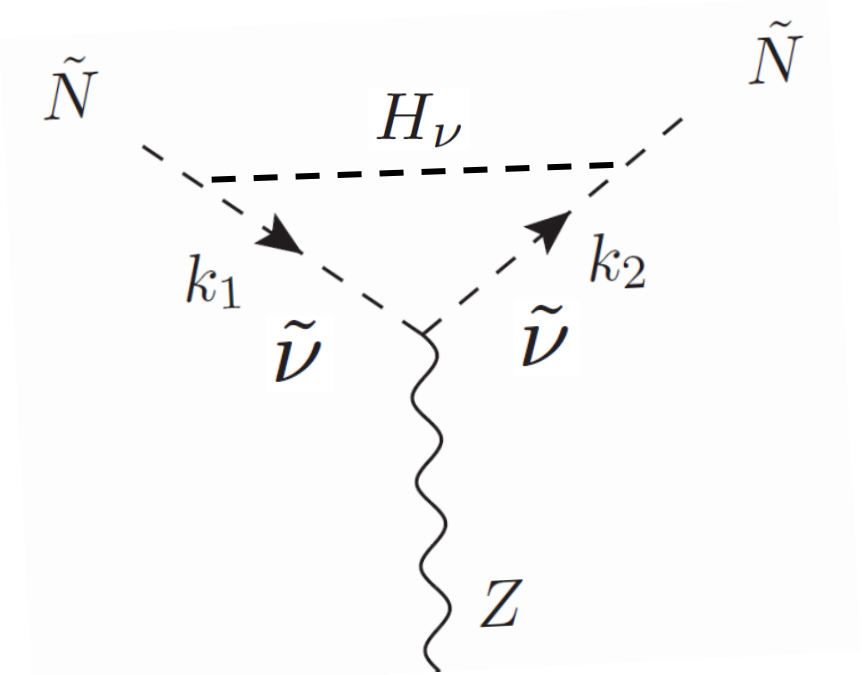
- Parity assignment

fields	Z_2-parity
MSSM Higgs doublets, H_u, H_d	$+$
new Higgs doublets, $H_\nu, H_{\nu'}$	$-$
right-handed neutrinos, N	$-$
others	$+$

§ § Sneutrino sector

- C_{eff}

$$C_{\text{eff}} = \frac{(-i)(y_\nu A_\nu)^2}{12(4\pi)^2 M^2}$$



masses of particles in the loop $M = M_{H_\nu} = M_{\tilde{\nu}_L}$

$$y_\nu A_\nu \simeq 14.4\, M$$

§ § Cosmic relic density

- Annihilation $\langle \sigma v \rangle = \langle \sigma v \rangle_{f\bar{f}} + \langle \sigma v \rangle_{2\gamma}$

$$\langle \sigma v \rangle_{2\gamma} \simeq \frac{\alpha_{\rm em}^2}{8\pi^3} \frac{y_\nu^4 (A_\nu^2 + \mu'^2)^2}{M_{\rm ch}^4} \frac{4}{M_{\tilde{N}}^2}$$

[Choi and Seto 2012]

$$= 2.8 \times 10^{-8}\ {\rm GeV}^{-2} \left(\frac{6\,{\rm GeV}}{M_{\tilde{N}}} \right)^2 \frac{y_\nu^4 (A_\nu^2 + \mu'^2)^2}{M_{\rm ch}^4}$$

$$\simeq 10^{-3}\ {\rm GeV}^{-2}$$

Oops, too large!!

§ § Cosmic relic density

- Annihilation $\langle \sigma v \rangle = \langle \sigma v \rangle_{f\bar{f}} + \langle \sigma v \rangle_{2\gamma}$

$$\langle \sigma v \rangle_{2\gamma} \simeq \frac{\alpha_{\rm em}^2}{8\pi^3} \frac{y_\nu^4 (A_\nu^2 + \mu'^2)^2}{M_{\rm ch}^4} \frac{4}{M_{\tilde{N}}^2}$$

$$= 2.8 \times 10^{-8}\ {\rm GeV}^{-2} \left(\frac{6\,{\rm GeV}}{M_{\tilde{N}}} \right)^2 \frac{y_\nu^4 (A_\nu^2 + \mu'^2)^2}{M_{\rm ch}^4}$$

$$\simeq 10^{-3}\ {\rm GeV}^{-2}$$

Sneutrino is lepton!! $Y_{\tilde{N}} \equiv \frac{n_{\tilde{N}} - n_{\tilde{N}*}}{s} = \mathcal{O}(10^{-10})$

→ **Asymmetric DM**

Indirect dark matter search free

§ Summary

- We have constructed a viable SUSY model for GeV mass dark matter.

- Dirac sneutrino with ν-philic Higgs is a candidate.
- DM asymmetry is useful to reproduce the desired relic density as well as escape indirect search consrtaints.