河南省科学院 HENAN ACADEMY OF SCIENCES

遼寧師範大學 Liaoning Normal University

# The status of WIMP Dark Matter in the Supersymmetric Georgi-Machacek Model


## Xiaokang Du(都小康) 9/20/2025


Based on LLShang, YP Wang, **XK Du***, BF Yang, S Moretti, 2503.02653;
**Xk Du,** Z Li, LL Shang, S Moretti, 2510.****

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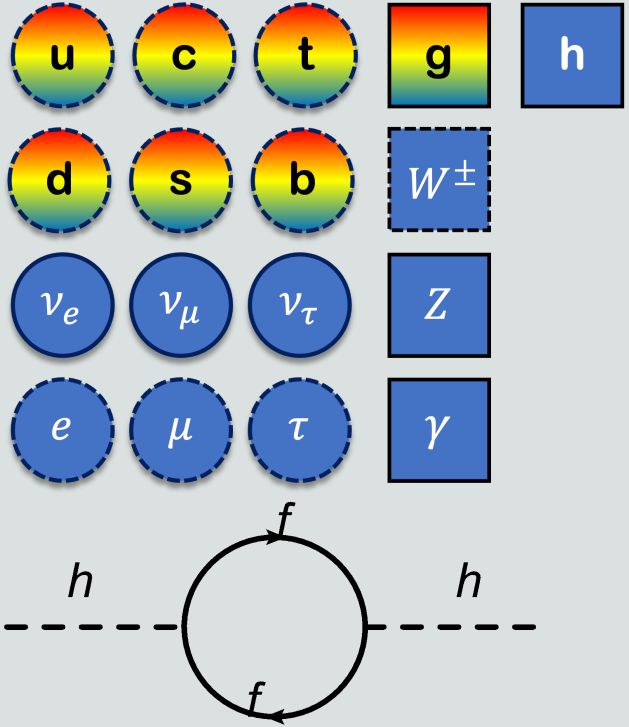
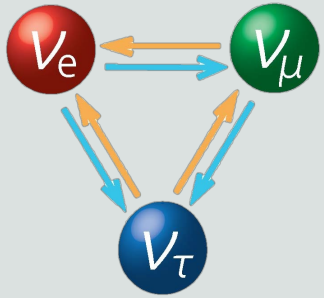
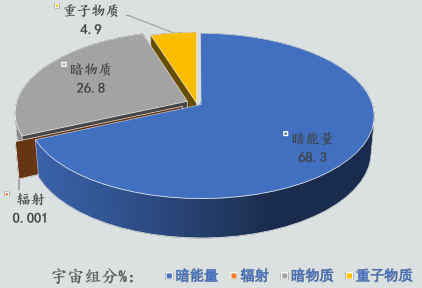
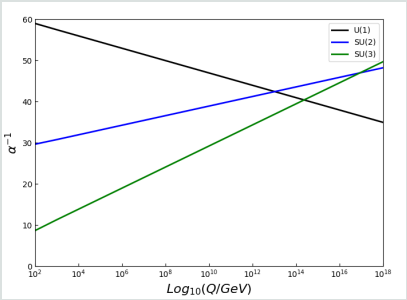
# CONTENTS

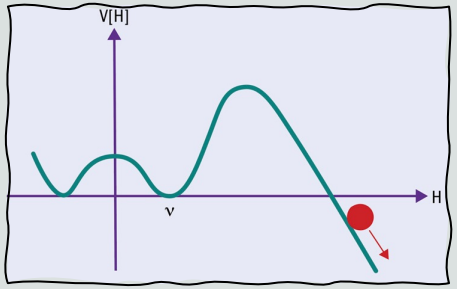
## the Standard Model



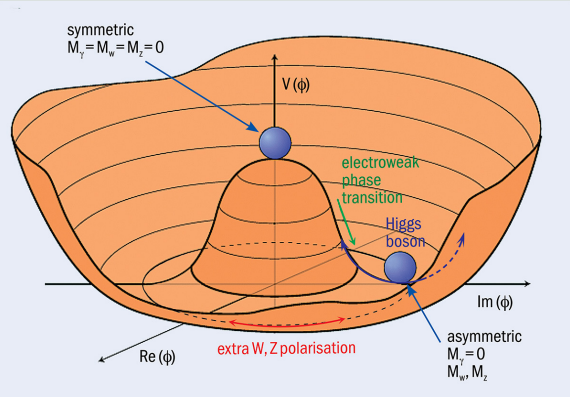




*Nucl.Phys. 22 (1961) 579-588, Phys.Lett. 13 (1964) 168-171, Phys. Rev. Lett.19 (1967) 1264–1266*

## Custodial symmetry

$$V(\Phi) = -\frac{\mu^2}{2}\mathrm{Tr}\left(\Phi^\dagger\Phi\right) + \frac{\lambda}{2}\mathrm{Tr}\left(\Phi^\dagger\Phi\right)^2$$

$$\Phi = \begin{pmatrix}\phi^+ \\ \phi^0\end{pmatrix} \qquad \Phi \xrightarrow{SU(2)_L\times SU(2)_R} L\Phi R^\dagger \qquad \Phi = \begin{pmatrix}\phi^{0*} & \phi^+ \\ -\phi^{+*} & \phi^0\end{pmatrix}$$




Credit: J Ellis/M Neubauer

EWSB

$v_{EW}$

$$SU(2)_L\times SU(2)_R \longrightarrow SU(2)_V$$

$$\rho_{\mathrm{SM}} = \frac{M_W^2}{M_Z^2\cos\theta_W} = \frac{g_2^2 v^2}{(g_2^2+g_1^2)v^2}$$

$$\Delta\rho = \rho - 1 = (3.1 \pm 1.9)\times 10^{-4}$$

(PDG2024)

**For new model extended with Higgs sector**

$$\Delta\rho_{NP} = \frac{\sum_i \left[I_i(I_i+1) - \left(I_i^3\right)^2\right] v_i^2 c_i}{2\sum_i \left(I_i^3\right)^2 v_i^2}$$

$I_i$: $SU(2)_L$ *isospin*, $I_i^3$: the third component,

$v_i$: vev of scalar field, $c_i$: $\begin{cases} 1 \text{ for complex scalar} \\ 1/2 \text{ for real scalar} \end{cases}$.

$$\begin{cases} v_i \approx 0 \quad (i \neq H) \\ \dfrac{\sum_i \left[I_i(I_i+1) - \left(I_i^3\right)^2\right] v_i^2 c_i}{2\sum_i \left(I_i^3\right)^2 v_i^2} = 0 \end{cases}$$

The Georgi-Machacek Model

$$\phi = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix}, \qquad \chi = \begin{pmatrix} \chi^{++} \\ \chi^+ \\ \chi^0 \end{pmatrix}, \qquad \xi = \begin{pmatrix} \xi^+ \\ \xi^0 \\ \xi^- \end{pmatrix}$$

| Fields | $U(1)_Y$ | $SU(2)_L$ | $SU(3)_C$ |
|---|---|---|---|
| $\phi$ | 1/2 | 2 | 1 |
| $\chi$ | 1 | 3 | 1 |
| $\xi$ | 0 | 3 | 1 |

$$\mathcal{L}_{GM} = \mathcal{L}_{kin} + \mathcal{L}_Y + \mathcal{L}_\nu - V_H$$

$$\begin{aligned} V(\Phi,\Delta) = {} & \frac{1}{2}\mathrm{m}_\Phi^2 \mathrm{Tr}\left[\Phi^\dagger\Phi\right] + \frac{1}{2}\mathrm{m}_\Delta^2 \mathrm{Tr}\left[\Delta^\dagger\Delta\right] \\ & + \lambda_1\left(\mathrm{Tr}\left[\Phi^\dagger\Phi\right]\right)^2 + \lambda_2\left(\mathrm{Tr}\left[\Delta^\dagger\Delta\right]\right)^2 \\ & + \lambda_3 \mathrm{Tr}\left[\left(\Delta^\dagger\Delta\right)^2\right] + \lambda_4 \mathrm{Tr}\left[\Phi^\dagger\Phi\right]\mathrm{Tr}\left[\Delta^\dagger\Delta\right] \\ & + \lambda_5 \mathrm{Tr}\left[\Phi^\dagger \frac{\sigma^a}{2} \Phi \frac{\sigma^b}{2}\right] \mathrm{Tr}\left[\Delta^\dagger T^a \Delta T^b\right] \\ & + \mu_1 \mathrm{Tr}\left[\Phi^\dagger \frac{\sigma^a}{2} \Phi \frac{\sigma^b}{2}\right] \left(P^\dagger \Delta P\right)_{ab} \\ & + \mu_2 \mathrm{Tr}\left[\Delta^\dagger T^a \Delta T^b\right] \left(P^\dagger \Delta P\right)_{ab} \end{aligned}$$

$SU(2)_L \times SU(2)_R$

$$\Phi = \begin{pmatrix} \phi^{0*} & \phi^+ \\ \phi^- & \phi^0 \end{pmatrix}, \Delta = \begin{pmatrix} \chi^{0*} & \xi^+ & \chi^{++} \\ \chi^- & \xi^0 & \chi^+ \\ \chi^{--} & \xi^- & \chi^0 \end{pmatrix}$$

$$\mathcal{L}_\nu \supset h_{ij} \overline{L_L^{ic}} i\tau_2 \chi L_L^j + h.c.$$

*Nucl.Phys.B 262 (1985) 463-477, JHEP 01 (2013) 026, JHEP 01 (2016) 120*

$$SU(2)_L \times SU(2)_R \xrightarrow[\langle \chi^0 \rangle = \langle \xi^0 \rangle = v_\Delta]{\langle \phi^0 \rangle = v_\phi} SU(2)_V$$

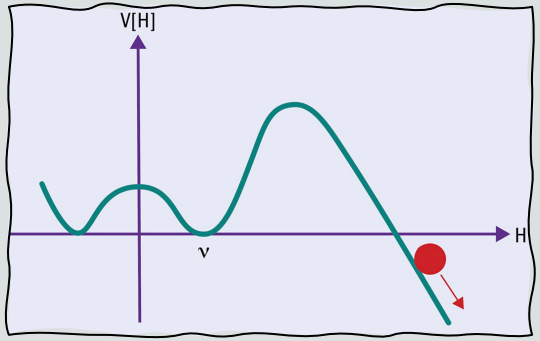
$$\begin{aligned} v_{EW}^2 &= \sum_i \left[4T_i(T_i+1) - Y_i^2\right] |v_i|^2 c_i \\ &= v_\phi^2 + 4v_\chi^2 + 4v_\xi^2 \\ &= v_\phi^2 + 8v_\Delta^2 = \frac{1}{\sqrt{2}G_F} \approx (246\text{GeV})^2 \end{aligned}$$

$$c_{T,Y} = \begin{cases} 1\,, (T,Y) \in complex\ representation \\ 1/2\,, (T, Y=0) \in real\ representation \end{cases}$$

$$\rho_{tree} \equiv \frac{m_W^2}{m_Z^2 \cos^2\theta_W} = \sum_i \left[4T_i(T_i+1) - Y_i^2\right] |v_i|^2 c_i \,/ \sum_i 2Y_i |v_i|^2$$

$$\Delta\rho_{tree} \equiv \rho - 1 = \frac{v_\phi^2 + 4v_\chi^2 + 4v_\xi^2}{v_\phi^2 + 8v_\Delta^2} - 1 \approx \frac{4v_\chi^2 - 4v_\xi^2}{v_{EW}^2}$$

## Vacuum stability




### Bounded-from-below

$$\lambda_1 > 0, \lambda_2 + \lambda_3 > 0, \lambda_2 + \frac{1}{2}\lambda_3 > 0,$$
$$-|\lambda_4| + 2\sqrt{\lambda_1(\lambda_2+\lambda_3)} > 0,$$
$$\lambda_4 - \frac{1}{4}|\lambda_5| + \sqrt{2\lambda_1(2\lambda_2+\lambda_3)} > 0.$$

*CW Chiang, K Yagyu, 1211.2658*
*K Hartling, K Kumar, H Logan, 1404.2640.*

Positive definiteness constraints

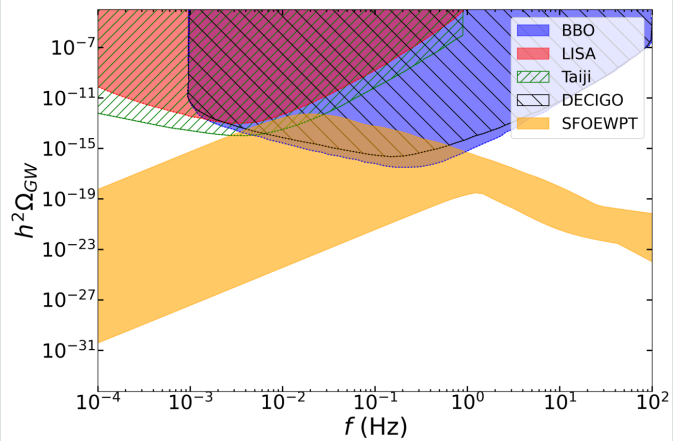
$$\lambda > 0\,, \quad \det\begin{pmatrix} \frac{\lambda}{4} & \frac{2\sigma_1+\sigma_2}{8} \\ \frac{2\sigma_1+\sigma_2}{8} & \frac{2\rho_1+\rho_2}{2} \end{pmatrix} > 0\,, \quad \det\begin{pmatrix} \frac{\lambda}{4} & \frac{2\sigma_1+\sigma_2}{8} & \frac{\sigma_1}{4} \\ \frac{2\sigma_1+\sigma_2}{8} & \frac{2\rho_1+\rho_2}{2} & \frac{3\rho_2}{2} \\ \frac{\sigma_1}{4} & \frac{3\rho_2}{2} & \rho_1+\rho_2 \end{pmatrix} > 0\,,$$
$$\det\begin{pmatrix} \frac{\lambda}{4} & \frac{2\sigma_1+\sigma_2}{8} & \frac{\sigma_1}{4} & \frac{\sigma_3}{2} \\ \frac{2\sigma_1+\sigma_2}{8} & \frac{2\rho_1+\rho_2}{2} & \frac{3\rho_2}{2} & \rho_4 \\ \frac{\sigma_1}{4} & \frac{3\rho_2}{2} & \rho_1+\rho_2 & \rho_4 \\ \frac{\sigma_3}{4} & \rho_4 & \rho_4 & 2\rho_3 \end{pmatrix} > 0\,, \quad \det\begin{pmatrix} \frac{\lambda}{4} & \frac{2\sigma_1+\sigma_2}{8} & \frac{\sigma_1}{4} & \frac{\sigma_3}{2} & \frac{\sigma_3}{4} \\ \frac{2\sigma_1+\sigma_2}{8} & \frac{2\rho_1+\rho_2}{2} & \frac{3\rho_2}{2} & \rho_4 & \frac{\rho_4}{2} \\ \frac{\sigma_1}{4} & \frac{3\rho_2}{2} & \rho_1+\rho_2 & \rho_4 & \frac{\rho_4}{2} \\ \frac{\sigma_3}{4} & \rho_4 & \rho_4 & 2\rho_3 & \rho_3 \\ \frac{\sigma_3}{2} & \frac{\rho_4}{2} & \frac{\rho_4}{2} & \rho_3 & \frac{\rho_3}{2} \end{pmatrix} > 0\,.$$

***Xk Du**, F Wang, 2409.20198,*
***Xk Du**, Hl Liu, Q Chang, 2502.06444*

# 1、The Georgi-Machacek Model

$$V(\Phi,\Delta)=\frac{1}{2}m_\Phi^2\mathrm{Tr}[\Phi^\dagger\Phi]+\frac{1}{2}m_\Delta^2\mathrm{Tr}[\Delta^\dagger\Delta]+\lambda_1(\mathrm{Tr}[\Phi^\dagger\Phi])^2+\lambda_2(\mathrm{Tr}[\Delta^\dagger\Delta])^2+\lambda_3\mathrm{Tr}[(\Delta^\dagger\Delta)^2]+\lambda_4\mathrm{Tr}[\Phi^\dagger\Phi]\mathrm{Tr}[\Delta^\dagger\Delta]$$
$$+\lambda_5\mathrm{Tr}\left[\Phi^\dagger\frac{\sigma^a}{2}\Phi\frac{\sigma^b}{2}\right]\mathrm{Tr}[\Delta^\dagger T^a\Delta T^b]+\mu_1\mathrm{Tr}\left[\Phi^\dagger\frac{\sigma^a}{2}\Phi\frac{\sigma^b}{2}\right](P^\dagger\Delta P)_{ab}+\mu_2\mathrm{Tr}[\Delta^\dagger T^a\Delta T^b](P^\dagger\Delta P)_{ab}$$

## Electroweak Phase Transition

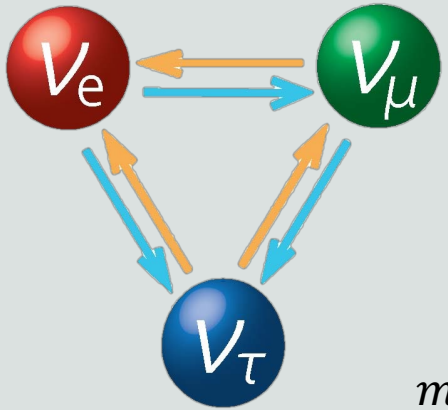


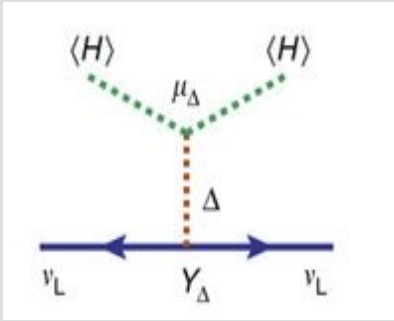

*1404.5182, 1812.06217,*

*1906.11664, 2205.02064, 2504.10930*

## Neutrino

$$\mathcal{L}_{type-II}\supset h_{ij}\overline{L_L^{ic}}i\tau_2\chi L_L^j+\mu_1\mathrm{tr}\left[\Phi^\dagger\frac{\sigma^a}{2}\Phi\frac{\sigma^b}{2}\right](P^\dagger\Delta P)_{ab}$$



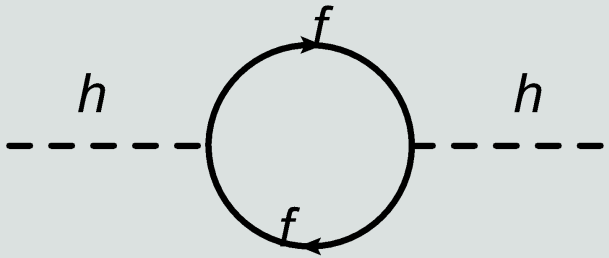



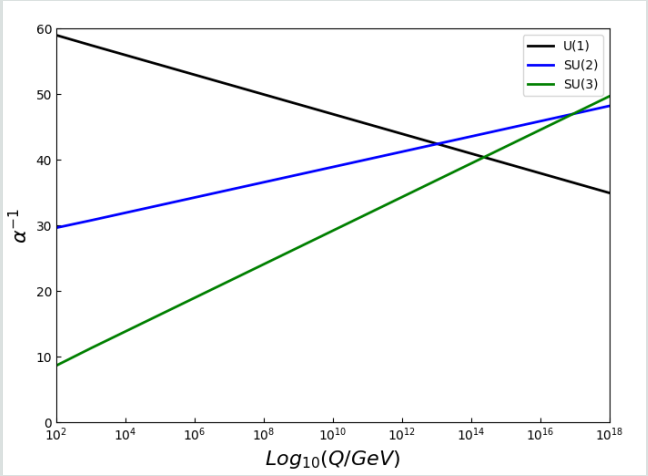

$$m_\nu\approx h_{ij}v_\Delta\sim h_{ij}v_\phi^2\mu_1/m_\Delta^2$$

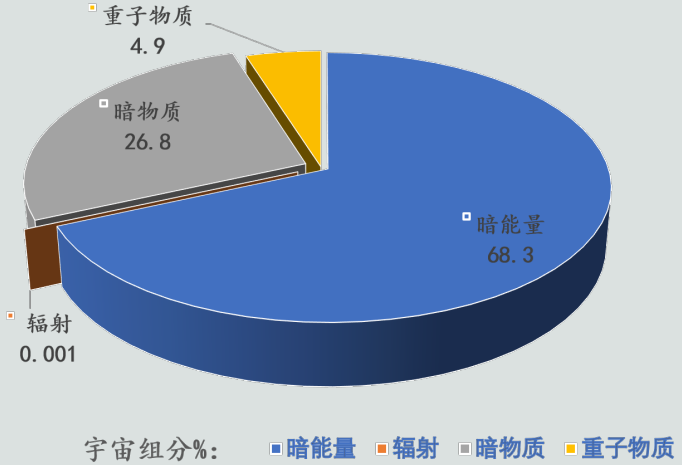
*S Godunov, M Vysotsky, E Zhemchugov, 1408.0184*

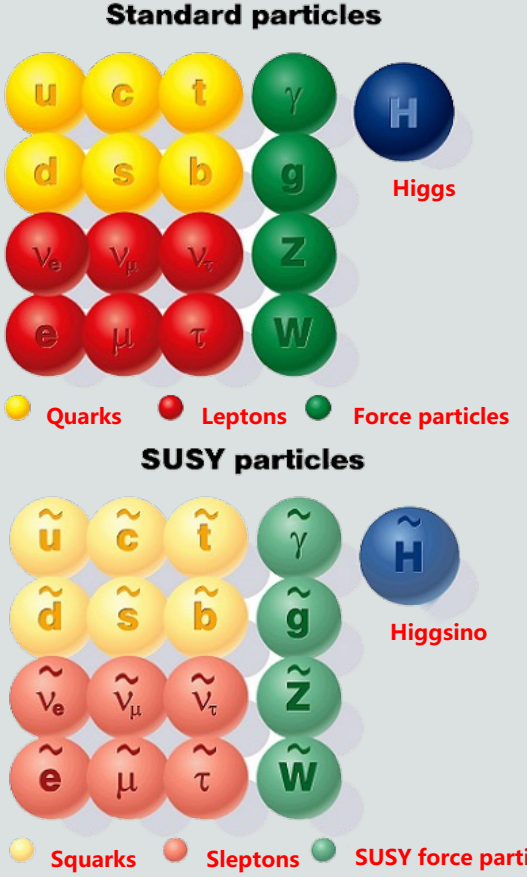
***Xk Du**, Z Li, F Wang, Yk Zhang, 2204.05760*

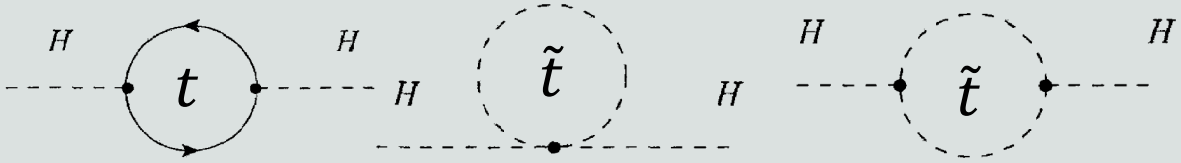
## Problems

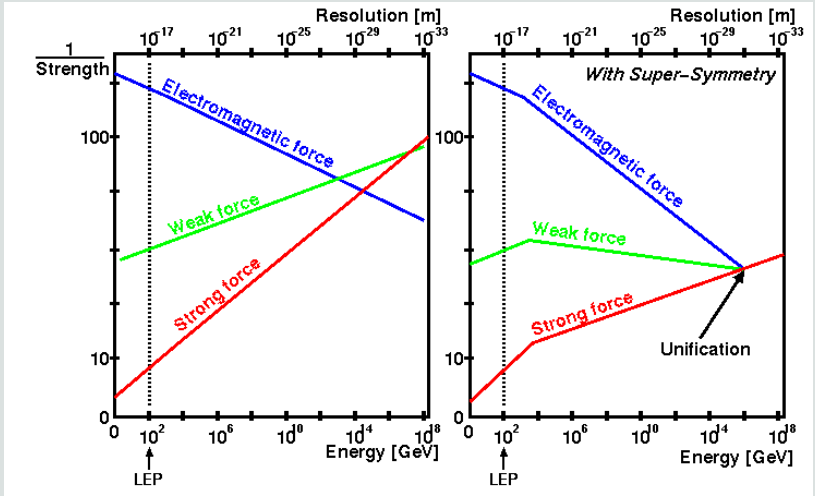

h
h
f
f


U(1)
SU(2)
SU(3)
$\alpha^{-1}$
$Log_{10}(Q/GeV)$


重子物质
4.9
暗物质
26.8
暗能量
68.3
辐射
0.001
宇宙组分%:
暗能量
辐射
暗物质
重子物质


Standard particles
u c t γ H
d s b g
νe νμ ντ Z
e μ τ W
Higgs
Quarks
Leptons
Force particles
SUSY particles
ũ c̃ t̃ γ̃ H̃
d̃ s̃ b̃ g̃
ν̃e ν̃μ ν̃τ Z̃
ẽ μ̃ τ̃ W̃
Higgsino
Squarks
Sleptons
SUSY force particles


H
t
H
H
t̃
H
H
t̃
H


Resolution [m]
1
Strength
Electromagnetic force
Weak force
Strong force
Energy [GeV]
LEP
With Super-Symmetry
Unification

$$R = (-1)^{2s+3B+L}$$

## supersymmetric GM Model

$$W_0 = W_{\rm MSSM} + \lambda \bar{H}\cdot\bar{\Delta}\bar{H} + \frac{\lambda_\Delta}{3}\mathbf{Tr}[\bar{\Delta}\bar{\Delta}\bar{\Delta}] + \frac{\mu_0}{2}\bar{H}\cdot\bar{H} + \frac{\mu_\Delta}{2}\mathbf{Tr}[\bar{\Delta}\bar{\Delta}]$$

$$W_{\rm MSSM} = \bar{u}y_u Q H_u - \bar{d}y_d Q H_d - \bar{e}y_e L H_d + \mu H_u H_d$$

$$H_d = \begin{pmatrix} H_d^0 \\ H_d^- \end{pmatrix}, H_{\rm u} = \begin{pmatrix} H_u^+ \\ H_u^0 \end{pmatrix}, \chi = \begin{pmatrix} \frac{\chi^-}{\sqrt{2}} & -\chi^0 \\ \chi^{--} & -\frac{\chi^-}{\sqrt{2}} \end{pmatrix}, \psi = \begin{pmatrix} \frac{\psi^+}{\sqrt{2}} & -\psi^{++} \\ \psi^0 & -\frac{\psi^+}{\sqrt{2}} \end{pmatrix}, \xi = \begin{pmatrix} \frac{\xi^0}{\sqrt{2}} & -\xi^+ \\ \xi^- & -\frac{\xi^0}{\sqrt{2}} \end{pmatrix}$$

$$\bar{H} = \begin{pmatrix} H_d \\ H_u \end{pmatrix}, \qquad \bar{\Delta} = \begin{pmatrix} -\frac{\xi}{\sqrt{2}} & \psi \\ -\chi & \frac{\xi}{\sqrt{2}} \end{pmatrix}$$

$Y = (-1, 1, 0)$ for the triplets

*Phys.Rev.D 88 (2013) 7, 075010 , Phys.Rev.D 91 (2015) 1, 015016 , JHEP 03 (2018) 168*

## supersymmetric GM Model

$$\langle H_u^0 \rangle = v_u, \langle H_d^0 \rangle = v_d, \langle \chi^0 \rangle = v_\chi, \langle \psi^0 \rangle = v_\psi, \langle \xi^0 \rangle = v_\xi$$

$$v_{EW}^2 \equiv v_u^2 + v_d^2 + v_\chi^2 + v_\psi^2 + v_\xi^2$$

$$\Delta\rho = \frac{2(2\,v_\phi^2 - v_\chi^2 - v_\psi^2)}{v_u^2 + v_d^2 + 2(2\,v_\phi^2 + v_\chi^2 + v_\psi^2)}$$

$v_\chi = v_\psi = v_\xi = v_\Delta$ ⇒ the supersymmetric custodial triplet model (SCTM)

$2\,v_\phi^2 = v_\chi^2 + v_\psi^2$ ⇒ the extra direction supersymmetric custodial triplet model (edSCTM)

# CONTENTS

**SCTM** $v_\chi = v_\psi = v_\xi = v_\Delta \to \Delta\rho = 0$

$$W_0 = W_{\text{MSSM}} + \lambda \bar{H} \cdot \bar{\Delta} \bar{H} + \frac{\lambda_\Delta}{3} \mathbf{Tr}[\bar{\Delta}\bar{\Delta}\bar{\Delta}] + \frac{\mu_0}{2} \bar{H} \cdot \bar{H} + \frac{\mu_\Delta}{2} \mathbf{Tr}[\bar{\Delta}\bar{\Delta}]$$

$$\bar{H} = \begin{pmatrix} H_d \\ H_u \end{pmatrix}, \qquad \bar{\Delta} = \begin{pmatrix} -\frac{\xi}{\sqrt{2}} & \psi \\ -\chi & \frac{\xi}{\sqrt{2}} \end{pmatrix}$$

$$\begin{aligned} V_{\text{soft}} = {} & V_{\text{MSSM}} + m_H^2 \bar{H}^\dagger \bar{H} + m_\Delta^2 \mathbf{Tr}\left[\bar{\Delta}^\dagger \bar{\Delta}\right] \\ & + \frac{B_\mu}{2} \bar{H} \cdot \bar{H} + \frac{B_\Delta}{2} \mathbf{Tr}[\bar{\Delta}\bar{\Delta}] + A_\lambda \bar{H} \cdot \bar{\Delta} \bar{H} \\ & + \frac{A_\Delta}{3} \mathbf{Tr}[\bar{\Delta}\bar{\Delta}\bar{\Delta}] + h.c. \end{aligned}$$

| SF | Spin 0 | Spin $\frac{1}{2}$ | Generations | $(U(1) \otimes \mathrm{SU}(2) \otimes \mathrm{SU}(3))$ |
|---|---|---|---|---|
| $\hat{q}$ | $\tilde{q}$ | $q$ | 3 | $(\frac{1}{6}, \mathbf{2}, \mathbf{3})$ |
| $\hat{l}$ | $\tilde{l}$ | $l$ | 3 | $(-\frac{1}{2}, \mathbf{2}, \mathbf{1})$ |
| $\hat{H}_d$ | $H_d$ | $\tilde{H}_d$ | 1 | $(-\frac{1}{2}, \mathbf{2}, \mathbf{1})$ |
| $\hat{H}_u$ | $H_u$ | $\tilde{H}_u$ | 1 | $(\frac{1}{2}, \mathbf{2}, \mathbf{1})$ |
| $\hat{d}$ | $\tilde{d}_R^*$ | $d_R^*$ | 3 | $(\frac{1}{3}, \mathbf{1}, \bar{\mathbf{3}})$ |
| $\hat{u}$ | $\tilde{u}_R^*$ | $u_R^*$ | 3 | $(-\frac{2}{3}, \mathbf{1}, \bar{\mathbf{3}})$ |
| $\hat{e}$ | $\tilde{e}_R^*$ | $e_R^*$ | 3 | $(1, \mathbf{1}, \mathbf{1})$ |
| $\hat{X}$ | $X$ | $\tilde{X}$ | 1 | $(-1, \mathbf{3}, \mathbf{1})$ |
| $\hat{\Phi}$ | $\Phi$ | $\tilde{\Phi}$ | 1 | $(0, \mathbf{3}, \mathbf{1})$ |
| $\hat{\Psi}$ | $\Psi$ | $\tilde{\Psi}$ | 1 | $(1, \mathbf{3}, \mathbf{1})$ |

*Phys.Rev.D 88 (2013) 7, 075010 , Phys.Rev.D 91 (2015) 1, 015016 , JHEP 03 (2018) 168*

**Dark Matter:**

$$\psi_N = \left(\tilde{B}, \tilde{W}_3, \tilde{H}_d^0, \tilde{H}_u^0, \tilde{\phi}^0, \tilde{\chi}^0, \tilde{\psi}^0\right)$$

$$\mathcal{M}_N = \begin{pmatrix} M_1 & 0 & -\frac{1}{\sqrt{2}} g_1 \cos\beta\, v_H & \frac{1}{\sqrt{2}} g_1 \sin\beta\, v_H & 0 & -g_1 v_\Delta & g_1 v_\Delta \\ 0 & M_2 & \frac{1}{\sqrt{2}} g_2 \cos\beta\, v_H & -\frac{1}{\sqrt{2}} g_2 \sin\beta\, v_H & 0 & g_2 v_\Delta & -g_2 v_\Delta \\ -\frac{1}{\sqrt{2}} g_1 \cos\beta\, v_H & \frac{1}{\sqrt{2}} g_2 \cos\beta\, v_H & -\sqrt{2}\lambda v_\Delta & m_{\tilde{H}} & -\lambda \sin\beta\, v_H & 0 & -2\lambda \cos\beta\, v_H \\ \frac{1}{\sqrt{2}} g_1 \sin\beta\, v_H & -\frac{1}{\sqrt{2}} g_2 \sin\beta\, v_H & m_{\tilde{H}} & -\sqrt{2}\lambda v_\Delta & -\lambda \cos\beta\, v_H & -2\lambda \sin\beta\, v_H & 0 \\ 0 & 0 & -\lambda \sin\beta\, v_H & -\lambda \cos\beta\, v_H & \mu_\Delta & -\frac{1}{\sqrt{2}} \lambda_\Delta v_\Delta & -\frac{1}{\sqrt{2}} \lambda_\Delta v_\Delta \\ -g_1 v_\Delta & g_2 v_\Delta & 0 & -2\lambda \sin\beta\, v_H & -\frac{1}{\sqrt{2}} \lambda_\Delta v_\Delta & 0 & m_{\tilde{\Delta}} \\ g_1 v_\Delta & -g_2 v_\Delta & -2\lambda \cos\beta\, v_H & 0 & -\frac{1}{\sqrt{2}} \lambda_\Delta v_\Delta & m_{\tilde{\Delta}} & 0 \end{pmatrix}$$

$$\tan\beta = \frac{v_u}{v_d}, v_H = \sqrt{(v_u^2 + v_d^2)/2}, \qquad m_{\tilde{H}} = -\frac{1}{\sqrt{2}} v_\Delta \lambda + \mu, m_{\tilde{\Delta}} = -\frac{1}{\sqrt{2}} v_\Delta \lambda_\Delta + \mu_\Delta$$

*LLShang, YP Wang, **XK Du,** YF Yang, S Moretti, 2503.02653*

**Dark Matter:** $\psi_N = \left(\tilde{B}, \widetilde{W}_3, \tilde{H}_d^0, \tilde{H}_u^0, \tilde{\phi}^0, \tilde{\chi}^0, \tilde{\psi}^0\right)$

In the custodial basis

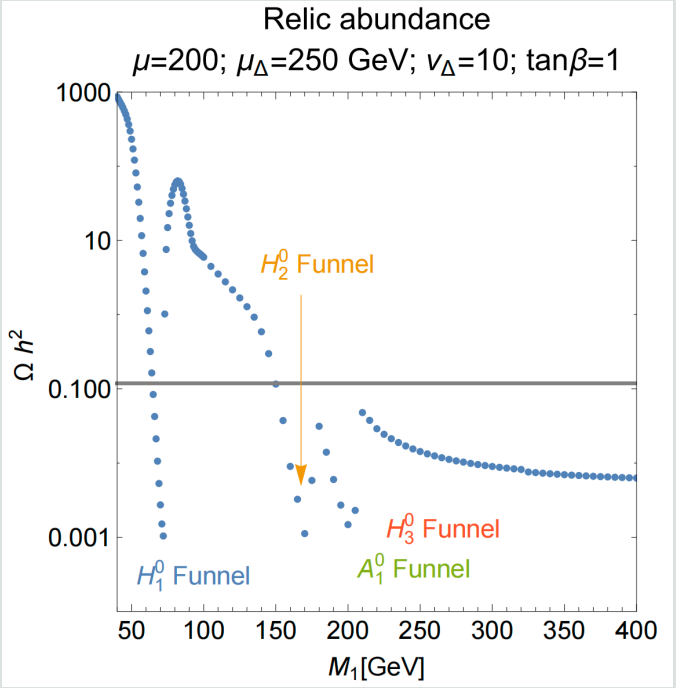
$$\psi_N = \left(\tilde{h}_1, \tilde{\delta}_1, \tilde{B}, \widetilde{W}_3, \tilde{h}_3^0, \tilde{\delta}_3^0, \tilde{\delta}_5^0\right)$$

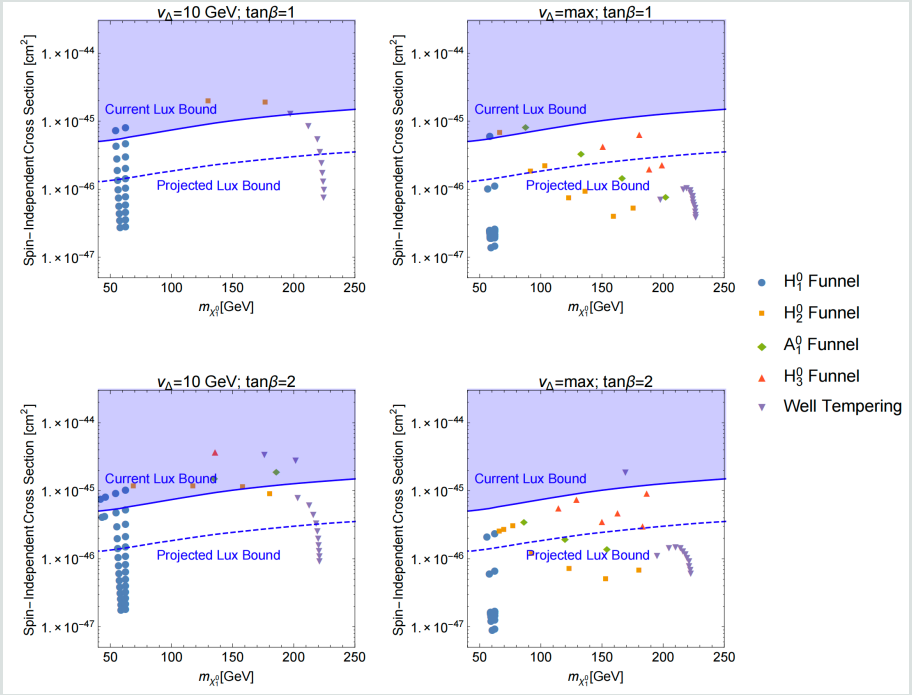
$$\mathcal{M}_N = \begin{pmatrix} \frac{3}{\sqrt{2}}\lambda v_\Delta - \mu & \sqrt{3}\lambda v_H & 0 & 0 & 0 & 0 & 0 \\ \sqrt{3}\lambda v_H & -\sqrt{2}\lambda_\Delta v_\Delta + \mu_\Delta & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{M_V^g}{g^2} & \frac{g_1 g_2 M_V}{g^2} & 0 & 0 & 0 \\ 0 & 0 & \frac{g_1 g_2 M_V}{g^2} & \frac{M_V^g}{g^2} & \sqrt{2}g v_H & \sqrt{2}g v_\Delta & 0 \\ 0 & 0 & 0 & \sqrt{2}g v_H & \frac{1}{\sqrt{2}}\lambda v_\Delta + \mu & -\sqrt{2}\lambda v_H & 0 \\ 0 & 0 & 0 & \sqrt{2}g v_\Delta & -\sqrt{2}\lambda v_H & \frac{1}{\sqrt{2}}\lambda_\Delta v_\Delta - \mu_\Delta & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{\sqrt{2}}\lambda_\Delta v_\Delta + \mu_\Delta \end{pmatrix}$$

$$M_V = M_2 - M_1, \qquad M_V^g = g_1^2 M_1 + g_2^2 M_2, \qquad g = \sqrt{g_1^2 + g_2^2}$$

*LLShang, YP Wang, **XK Du,** YF Yang, S Moretti, 2503.02653*

**Bino-like** $\psi_N = \left(\tilde{h}_1, \tilde{\delta}_1, \tilde{B}, \tilde{W}_3, \tilde{h}_3^0, \tilde{\delta}_3^0, \tilde{\delta}_5^0\right)$




*A Delgado, M Pepin, B Ostdiek, M Quiros, 1504.02486*

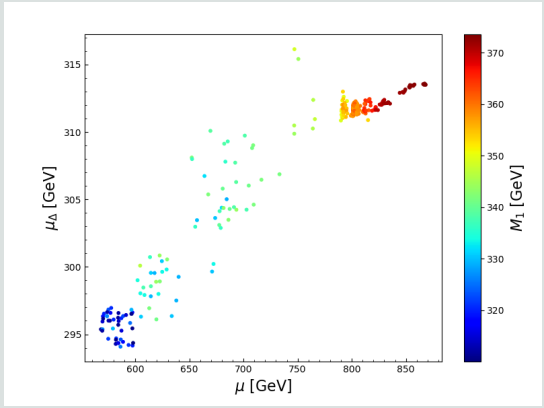
**Tripletino-like** $\psi_N = (\tilde{h}_1, \tilde{\delta}_1, \tilde{B}, \tilde{W}_3, \tilde{h}_3^0, \tilde{\delta}_3^0, \tilde{\delta}_5^0)$

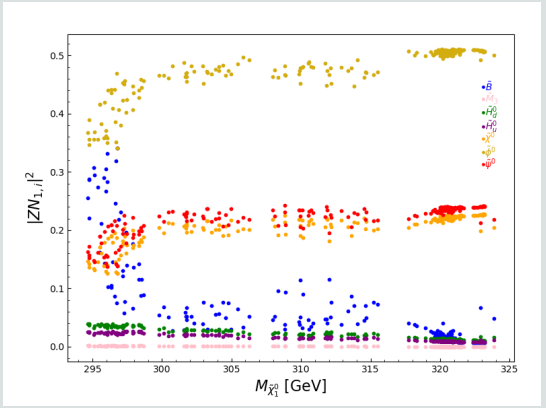
$v_\Delta < 40$ GeV

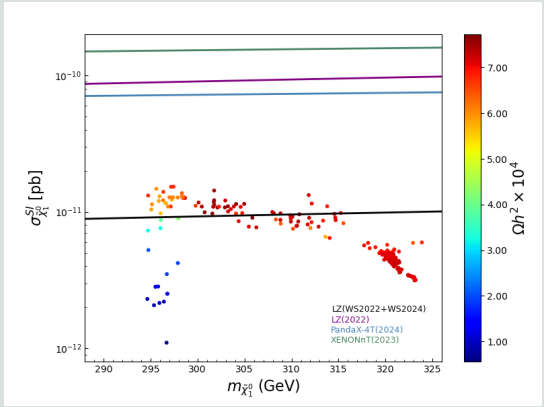
$M_2 > M_1, \mu > \mu_\Delta > 100$ GeV

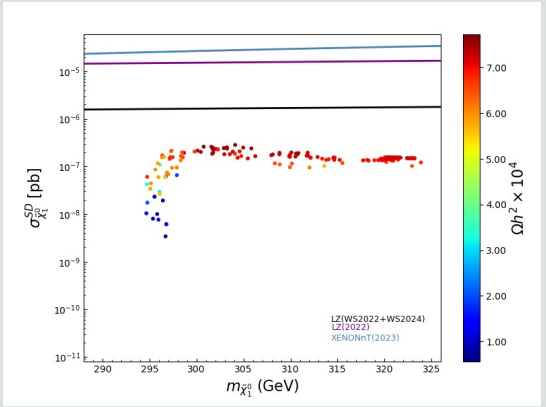
$|\lambda|, |\lambda_\Delta| < \sqrt{4\pi}$,
$1 < \tan\beta < 60$

$5000\ \text{GeV} > M_{\tilde{Q}_3, \tilde{U}_3} > 1500\ \text{GeV}$
$5000\ \text{GeV} > |A_t|$



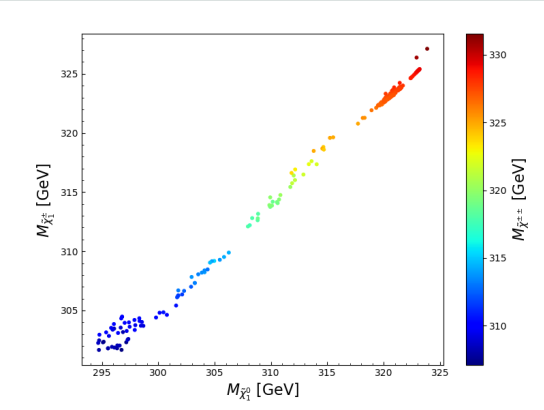



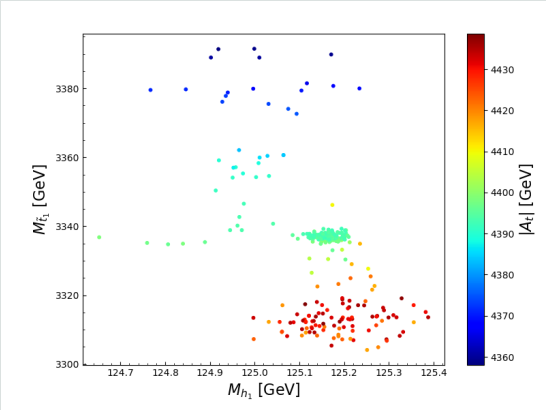



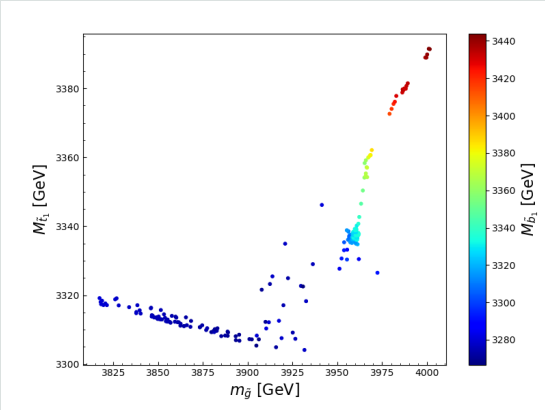



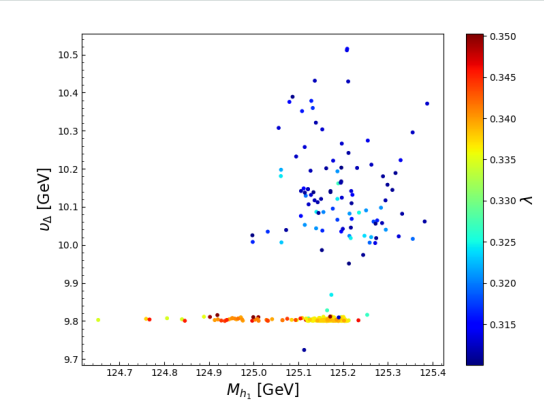
# 3、Tripletino-like dark matter in the general supersymmetric Georgi-Machacek model

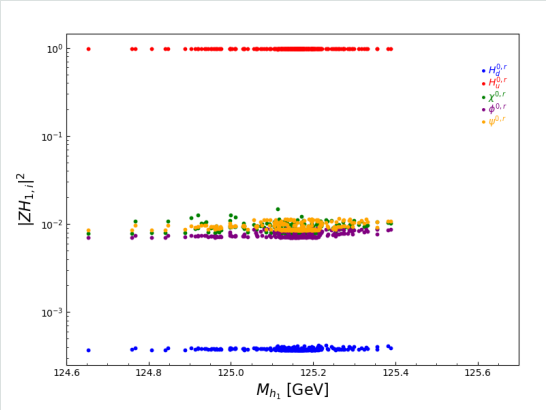
**Tripletino-like** $\psi_N = \left(\tilde{h}_1, \tilde{\delta}_1, \tilde{B}, \widetilde{W}_3, \tilde{h}_3^0, \tilde{\delta}_3^0, \tilde{\delta}_5^0\right)$

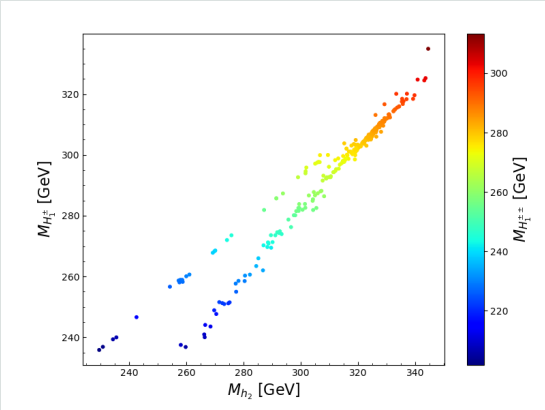


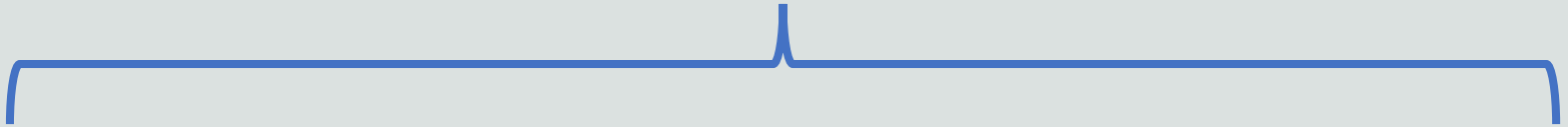



# CONTENTS

**edSCTM** $2\,v_\phi^2 = v_\chi^2 + v_\psi^2 \rightarrow \Delta\rho = 0$

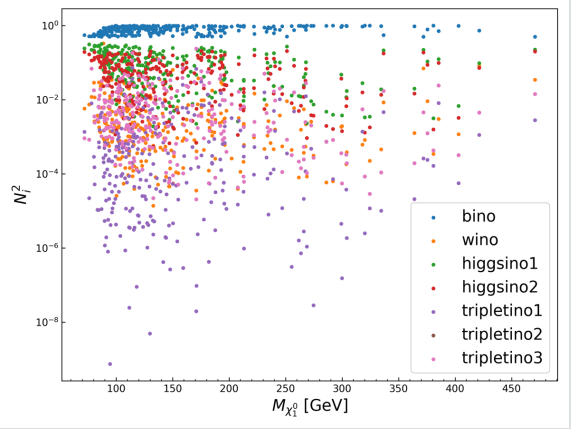
$$\psi_N = (\tilde{h}_1, \tilde{\delta}_1, \tilde{B}, \widetilde{W}_3, \tilde{h}_3^0, \tilde{\delta}_3^0, \tilde{\delta}_5^0)$$

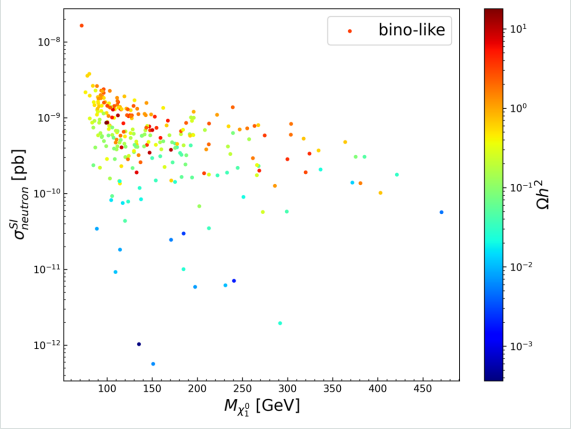


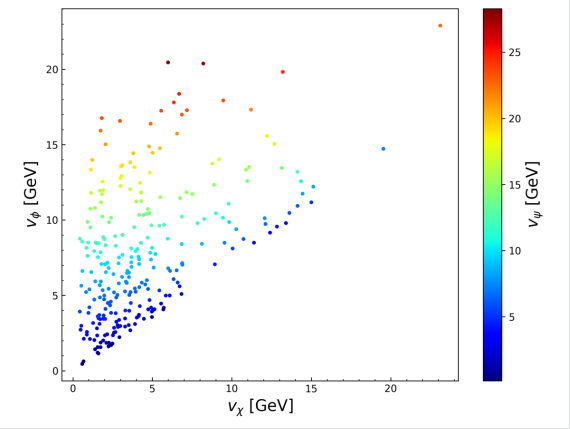
**Bino-like DM** | **Wino-like DM** | **Higgsino-like DM** | **Tripletino-like DM** | **Mixed DM**

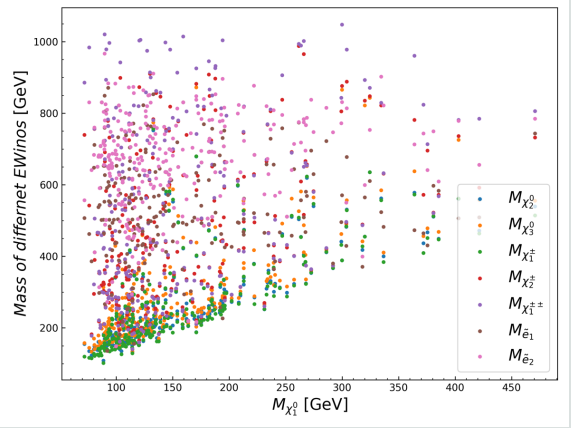
# 4、The status of WIMP Dark Matter in the extra direction supersymmetric Georgi-Machacek Model

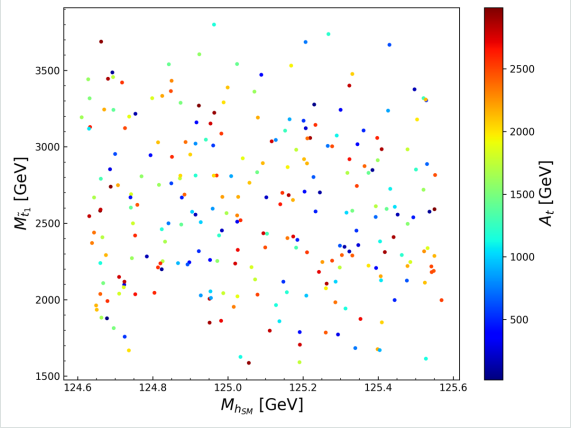
$$\psi_N = \begin{pmatrix} \tilde{h}_1 \\ \tilde{\delta}_1 \\ \tilde{B} \\ \tilde{W}_3 \\ \tilde{h}_3^0 \\ \tilde{\delta}_3^0 \\ \tilde{\delta}_5^0 \end{pmatrix}$$

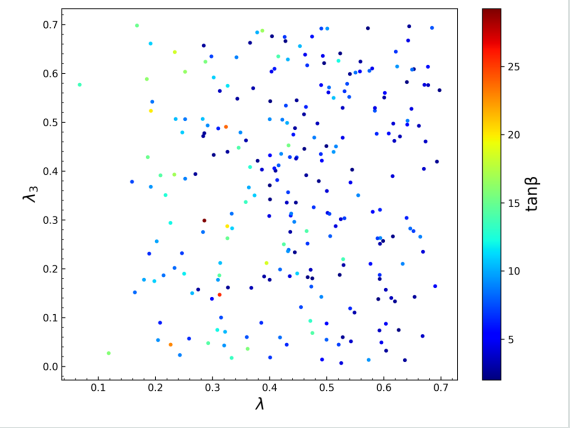


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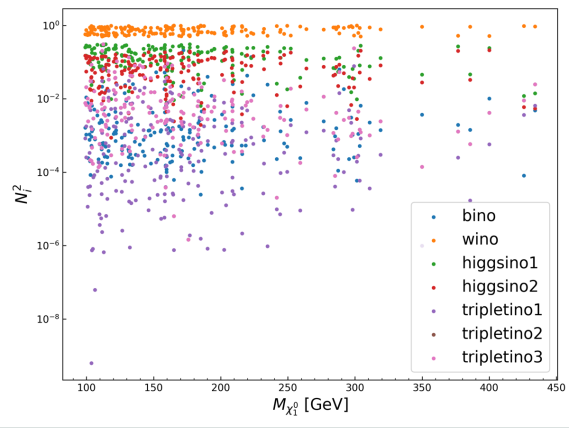
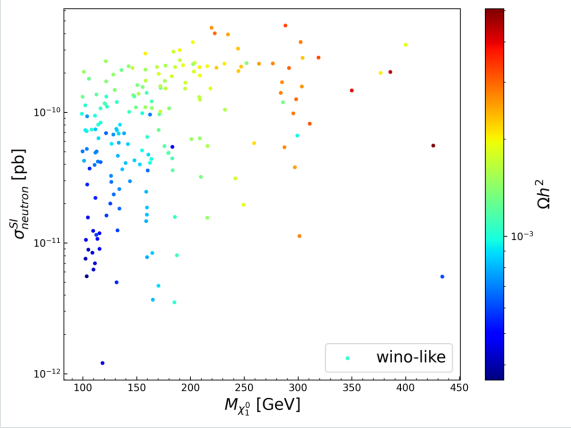
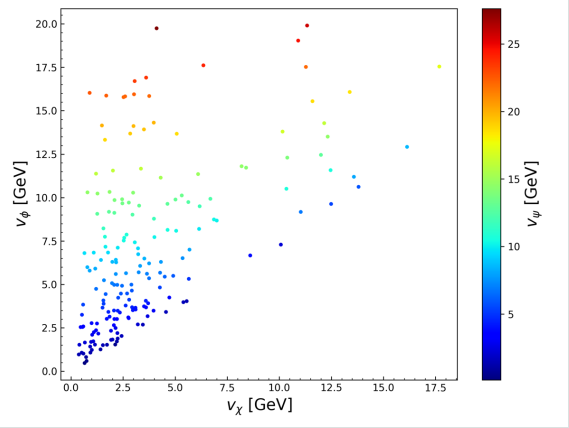
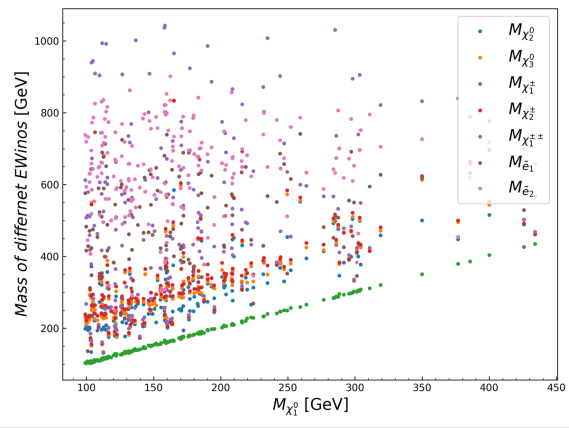
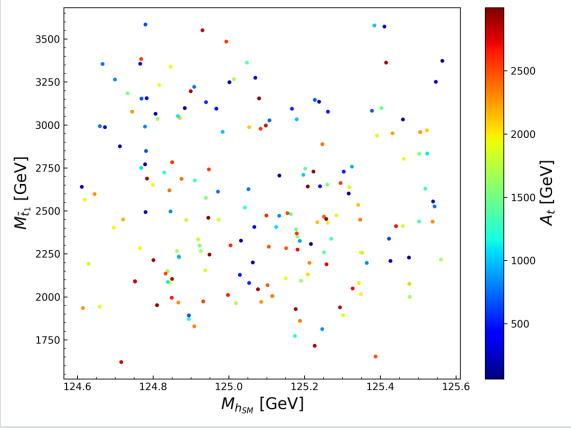
$$\psi_N = \begin{pmatrix} \tilde{h}_1 \\ \tilde{\delta}_1 \\ \tilde{B} \\ \tilde{W}_3 \\ \tilde{h}_3^0 \\ \tilde{\delta}_3^0 \\ \tilde{\delta}_5^0 \end{pmatrix}$$

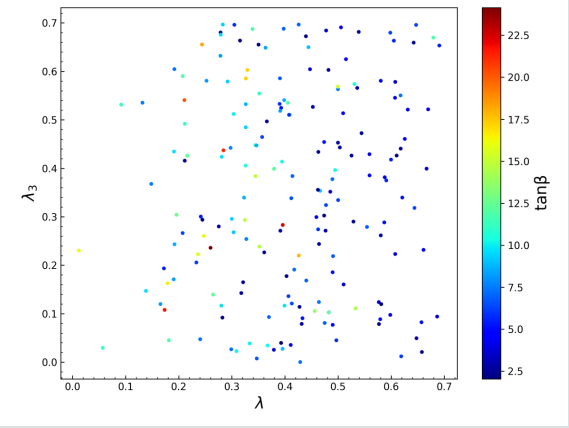


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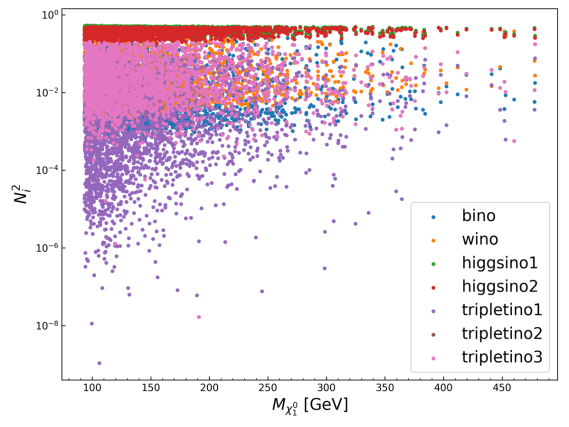


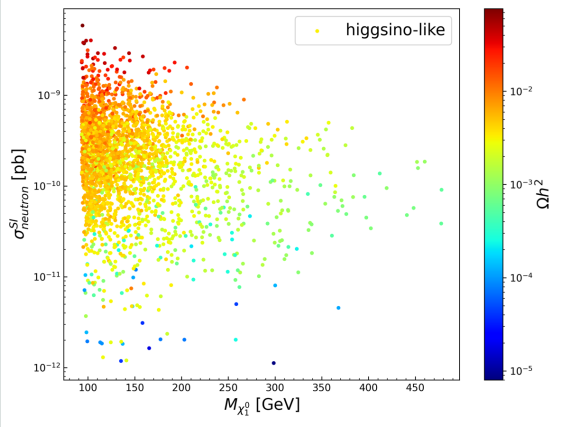


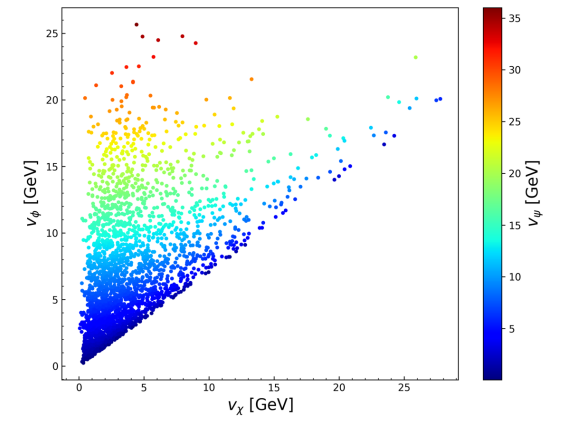


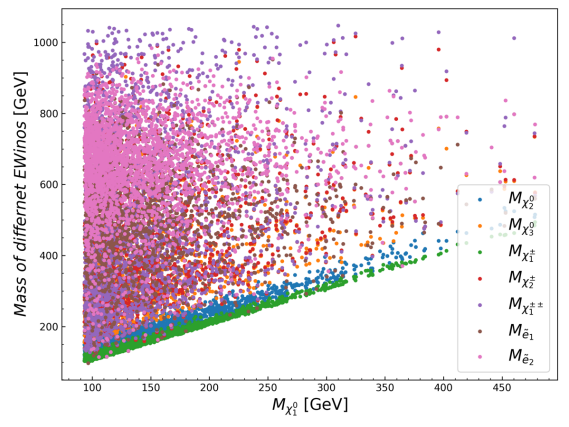


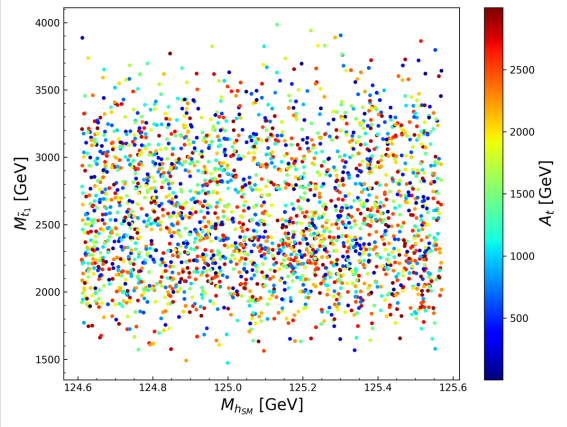


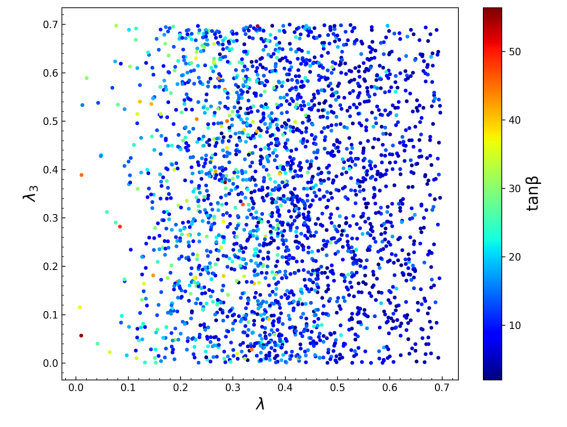

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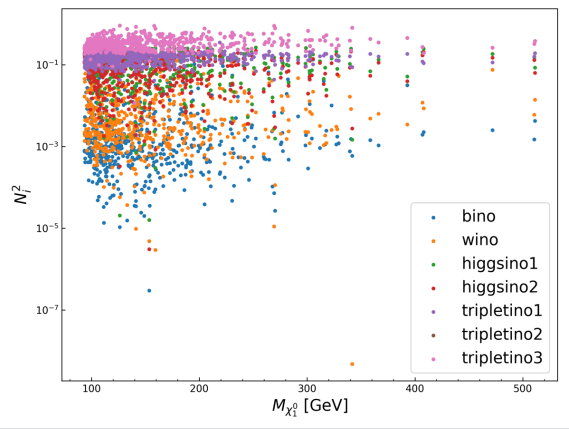


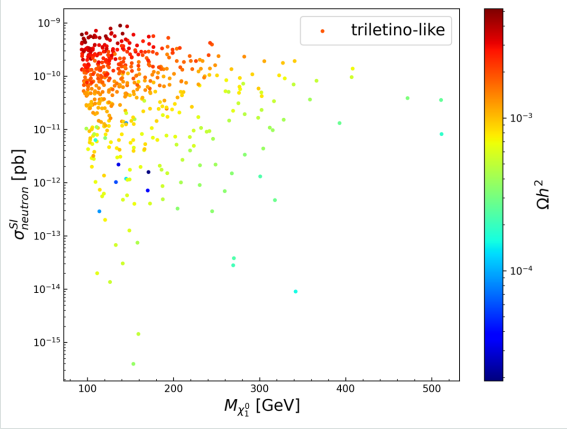


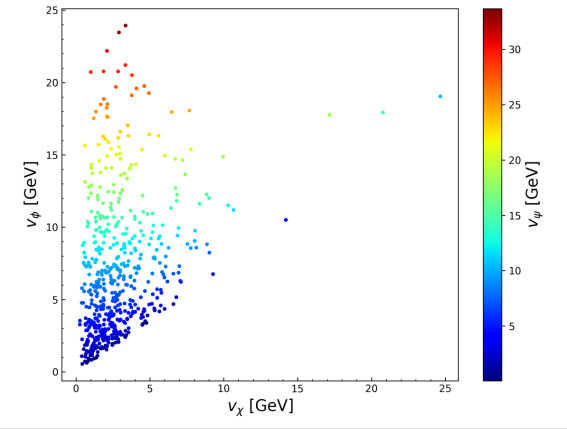


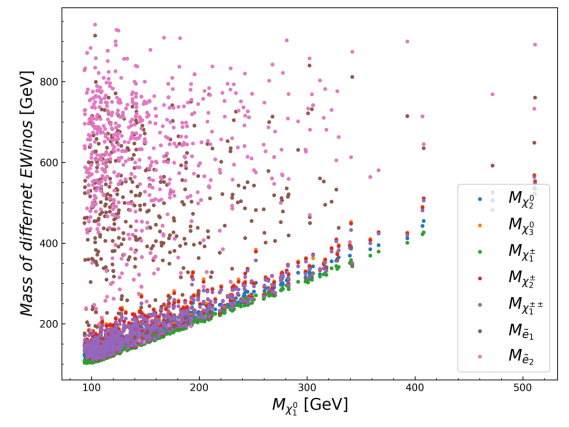


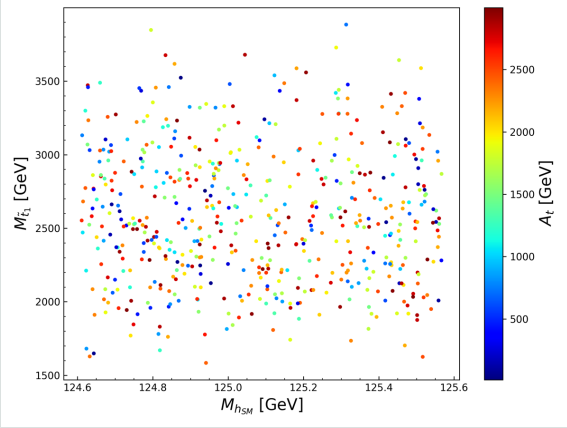


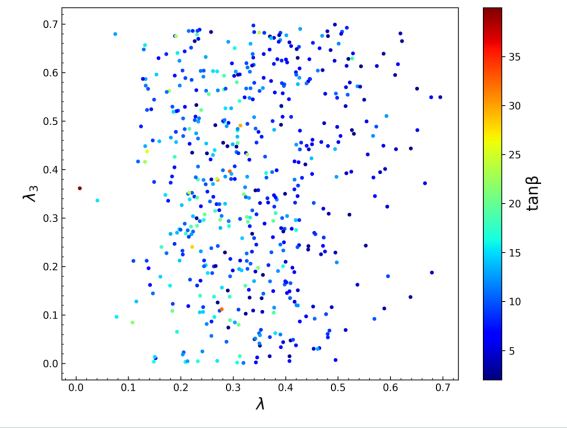

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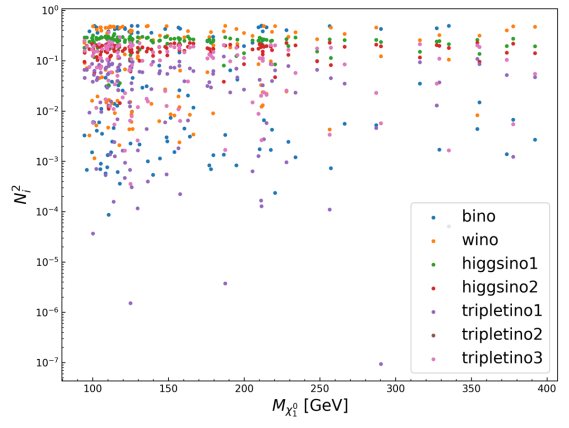


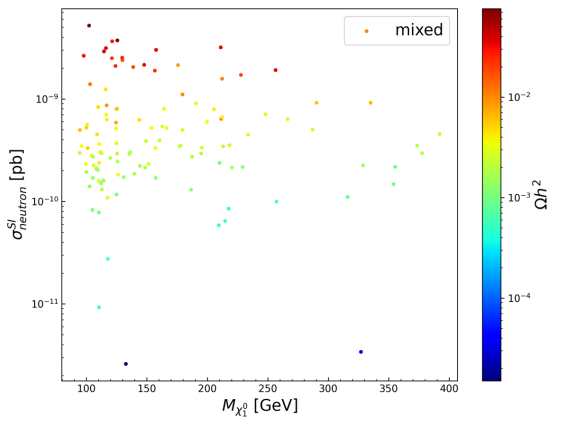


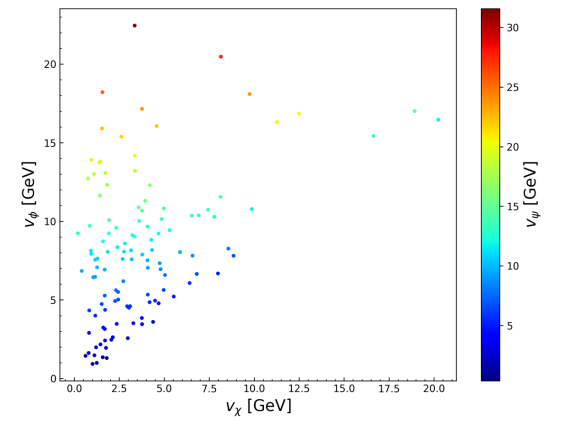


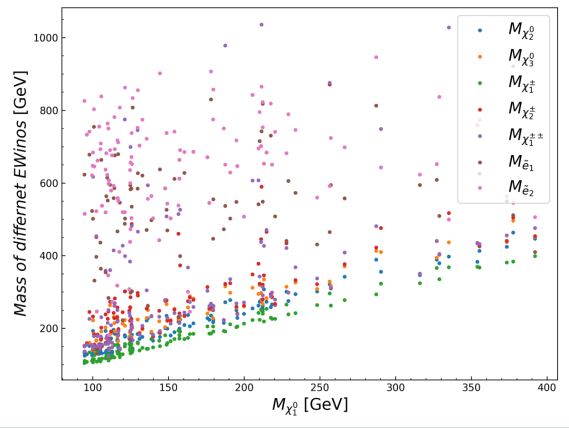


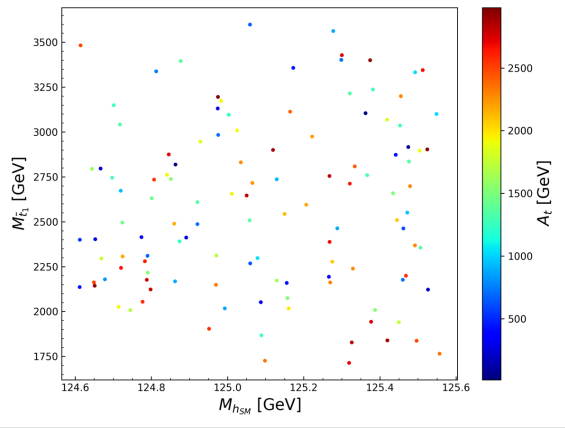


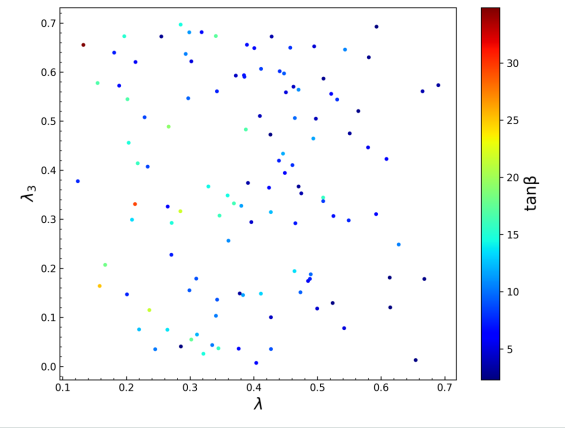

1. We identified viable parameter space regions for tripletinolike WIMP-type DM in the SCTM despite the increasingly stringent constraints coming from DM direct detection experiments.

2. We conducted a systematic study on the dark matter candidates in the dSCTM model. There is a much larger viable parameter space to explore compared to the SCTM.

# THANKS