Creating Matter-Antimatter Asymmetry from Dark Matter Annihilation in Scotogenic Scenarios

Based on arXiv:1806.04689 with
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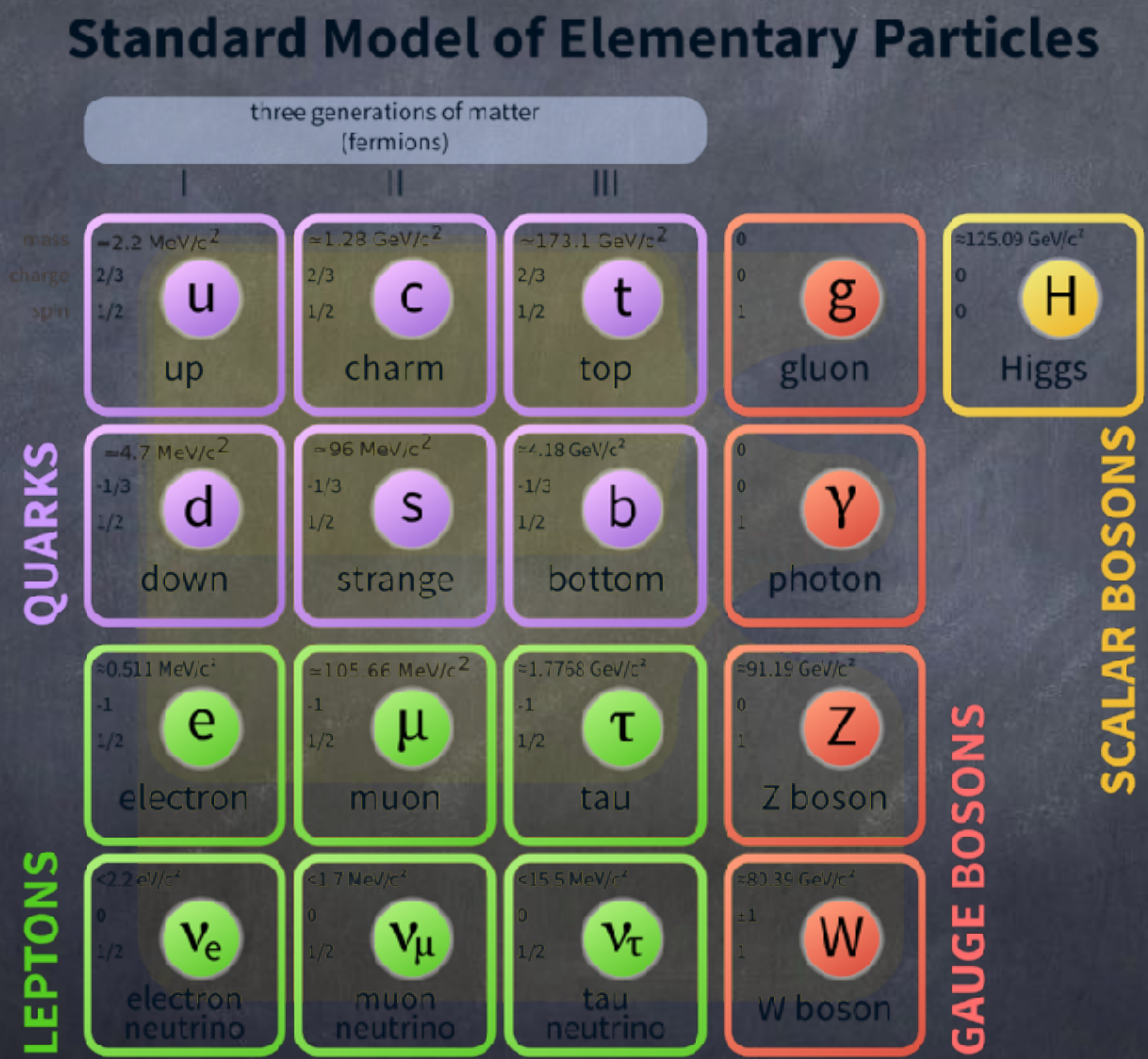
Outline

- Introduction
- Neutrino Mass and Mixing
- Dark Matter (DM)
- Baryon Asymmetry of Universe (BAU)
- Towards a Common Origin of DM and BAU
- Baryogenesis from DM annihilation in Scotogenic Model
- Conclusion

The Standard Model

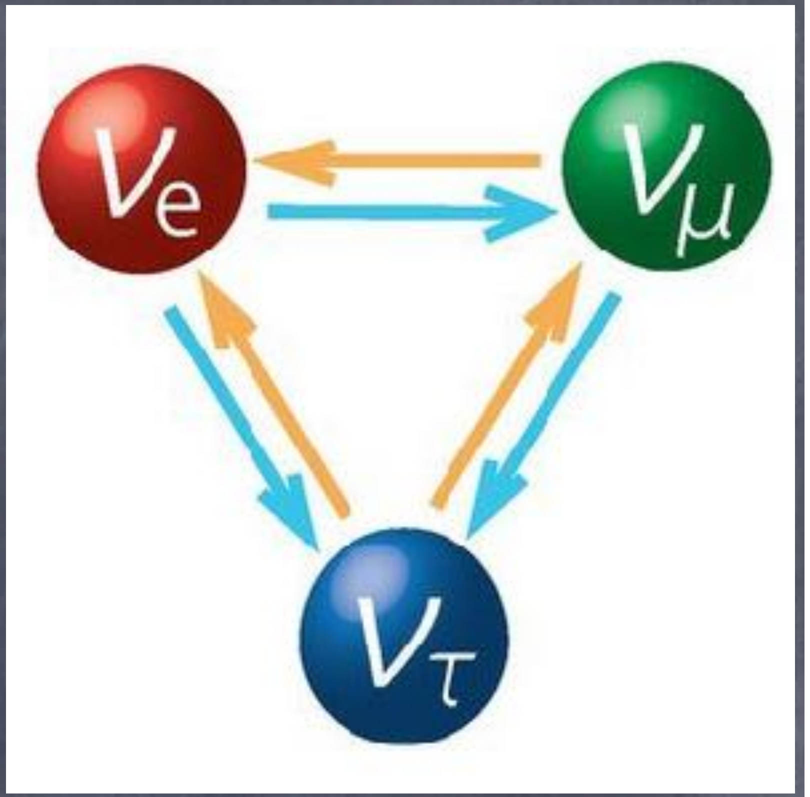


The Standard Model

- The SM has been very successful in describing the elementary particles and there interaction except gravity.
- The last missing piece of the SM, the Higgs boson was also discovered a few years back at the LHC (2012).
- Since then the LHC results have only been able to confirm the validity of the SM again and again, with no convincing signatures of new physics around the TeV scale.

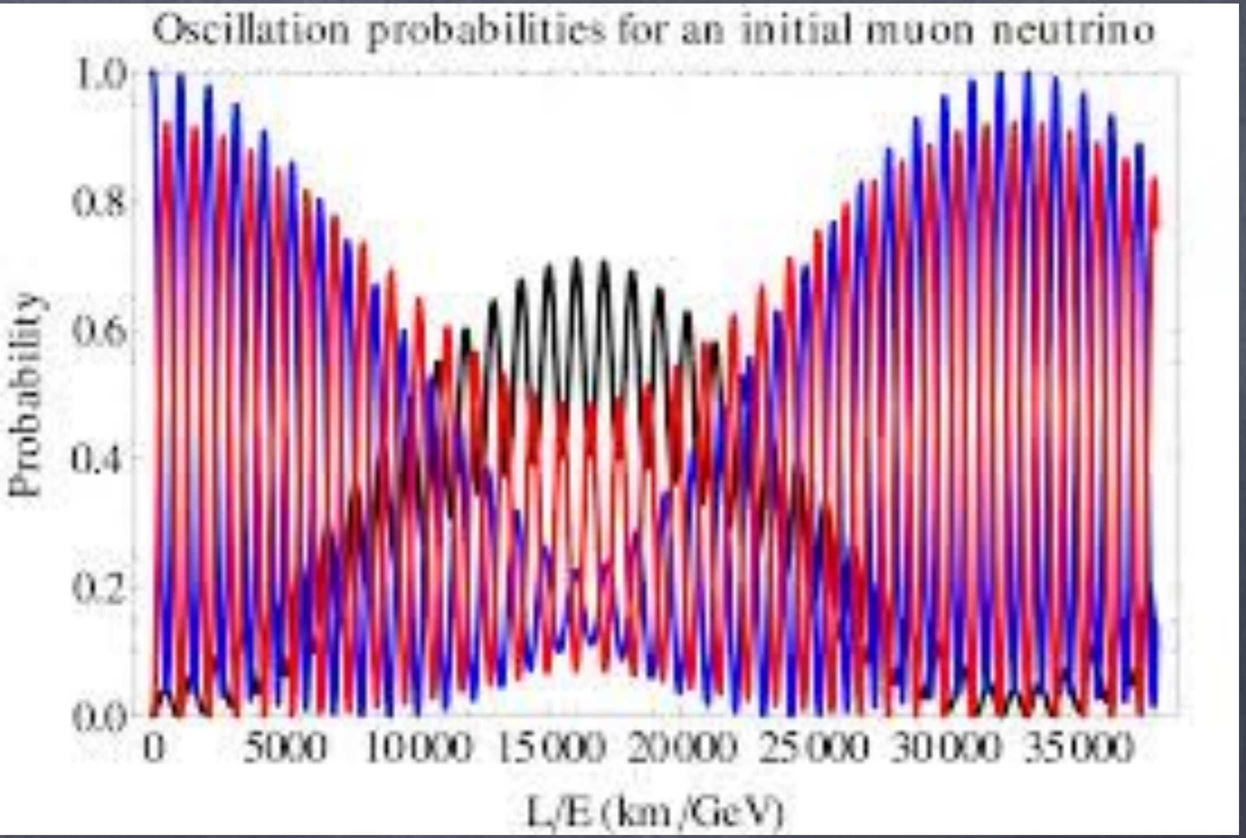
Problems in the SM

- SM cannot explain the observed neutrino mass and mixing
- SM does not have a dark matter candidate.
- SM cannot explain the observed baryon asymmetry



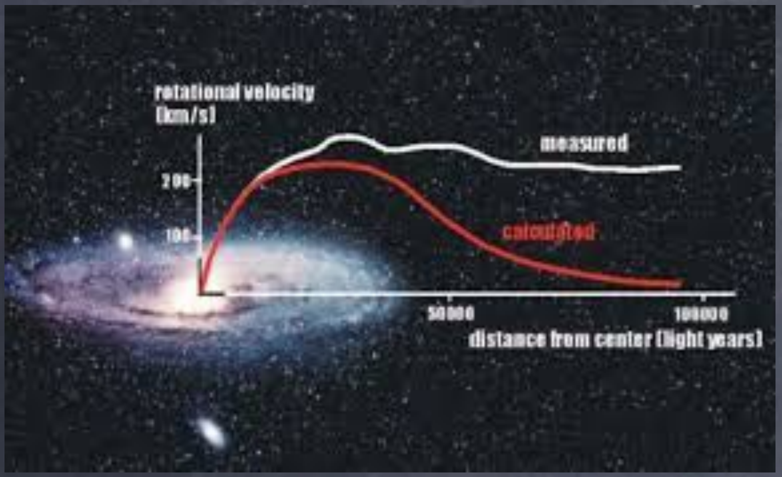
Neutrino Mass and Mixing

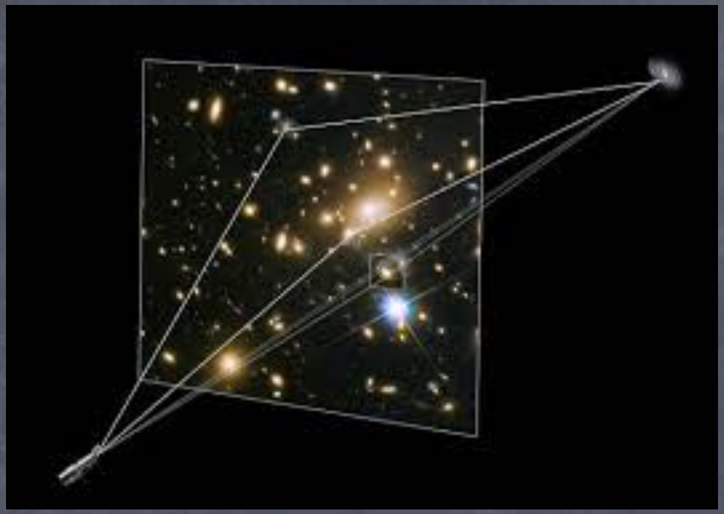
- Neutrinos can oscillate from one flavor to another, experimentally verified by the Super Kamiokande and Sabdury Neutrino Observatories. (Physics Nobel 2015)

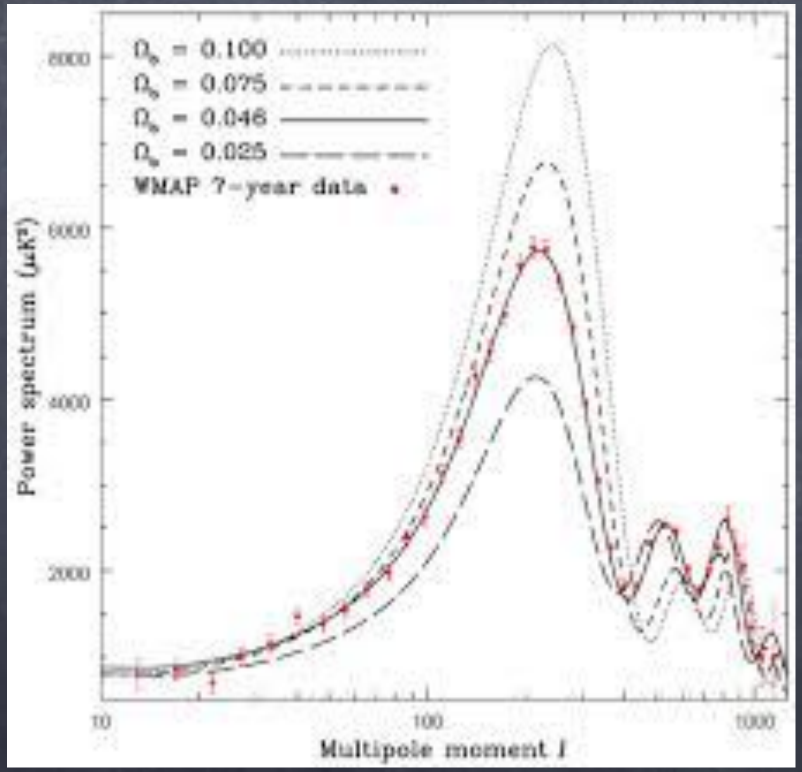


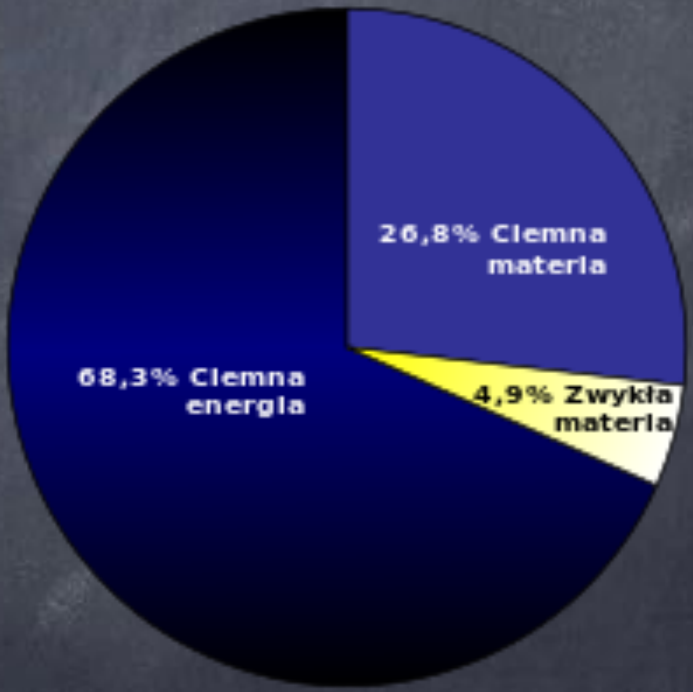
$$P_{\alpha\to\beta} = \delta_{\alpha\beta} - 4\sum_{i>j} Re(U^*_{\alpha i}U_{\beta i}U_{\alpha j}U^*_{\beta j})\sin^2\frac{\Delta m_{ij}}{4E} + 2\sum_{i>j} Im(U^*_{\alpha i}U_{\beta i}U_{\alpha j}U^*_{\beta j})\sin\frac{\Delta m_{ij}}{2E}$$

Dark Matter:Evidences









Credits:
HST, Chandra, DE Survey, WMAP

Dark Matter: 10 Points Test

- Does it match the appropriate relic abundance ?
- Is it cold ?
- Is it electromagnetic and color neutral ?
- Is it consistent with the Big Bang Nucleosynthesis ?
- Does it leave stellar evolution unchanged ?
- Is it compatible with constraints on self-interactions ?
- Is it consistent with the direct dark Matter searches ?
- Is it compatible with gamma-ray searches ?
- Is it compatible with other astrophysical bound ?
- Can it be probed experimentally ?

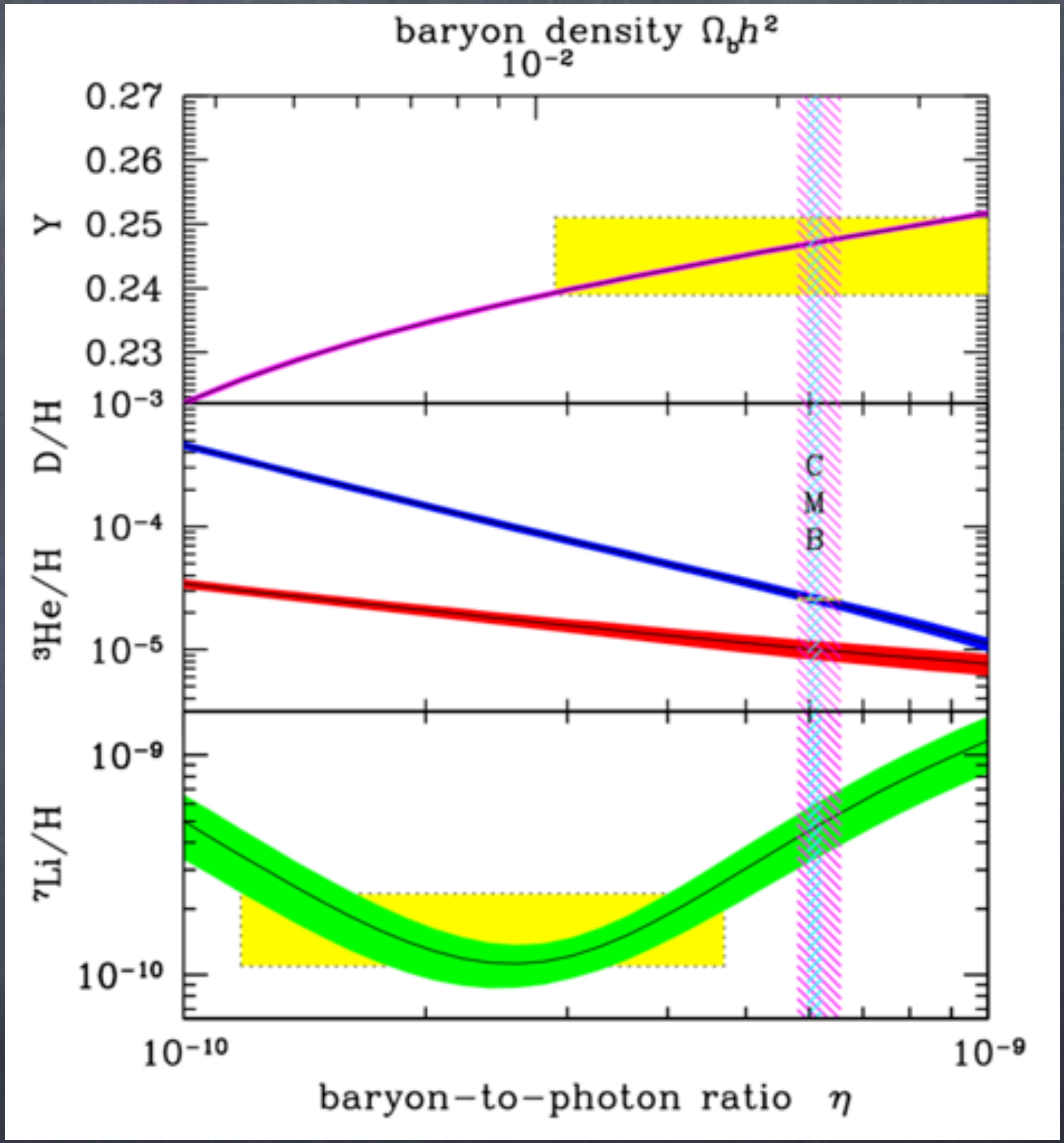
Taoso, Bertone and Masiero 2008

Baryon Asymmetry of the Universe

- The observed BAU is often quoted in terms of baryon to photon ratio

$$\eta_B = \frac{n_B - n_{\overline{B}}}{n_\gamma} = 6.04 \pm 0.08 \times 10^{-10}$$

- The prediction for this ratio from Big Bang Nucleosynthesis (BBN) agrees well with the observed value from Cosmic Microwave Background Radiation (CMBR) measurements (Planck, arXiv: 1502.01589).



Particle Data Group 2017

Sakharov's Conditions

Three basic ingredients necessary to generate a net baryon asymmetry from an initially baryons symmetric Universe (Sakharov 1967):

- Baryon Number (B) violation $X \to Y + B$
- C and CP violation.

$$\Gamma(X \to Y + B) \neq \Gamma(\overline{X} \to \overline{Y} + \overline{B})$$

$$\Gamma(X \to q_L + q_L) + \Gamma(X \to q_R + q_R) \neq \Gamma(\overline{q}_L + \overline{q}_L) + \Gamma(\overline{q}_R + \overline{q}_R)$$

- Departure from thermal equilibrium.

Baryogenesis

- The SM fails to satisfy Sakharov's conditions: insufficient CP violation in the quark sector and Higgs Mass is too large to support a strong first order electroweak phase transition (Electroweak Baryogenesis).

- Additional CP violation in lepton sector (not yet discovered) may play a role through the mechanism of Leptogenesis (Fukugida and Yanagida 1986)

- Typically, seesaw models explaining neutrino mass and mixing can also play role in creating a lepton asymmetry through out-of-equilibrium CP violating decay of heavy particles, which later gets converted into baryon asymmetry through electroweak sphalerons.

- Leptogenesis provide a common framework to explain neutrino mass, mixing and baryon asymmetry of the Universe.

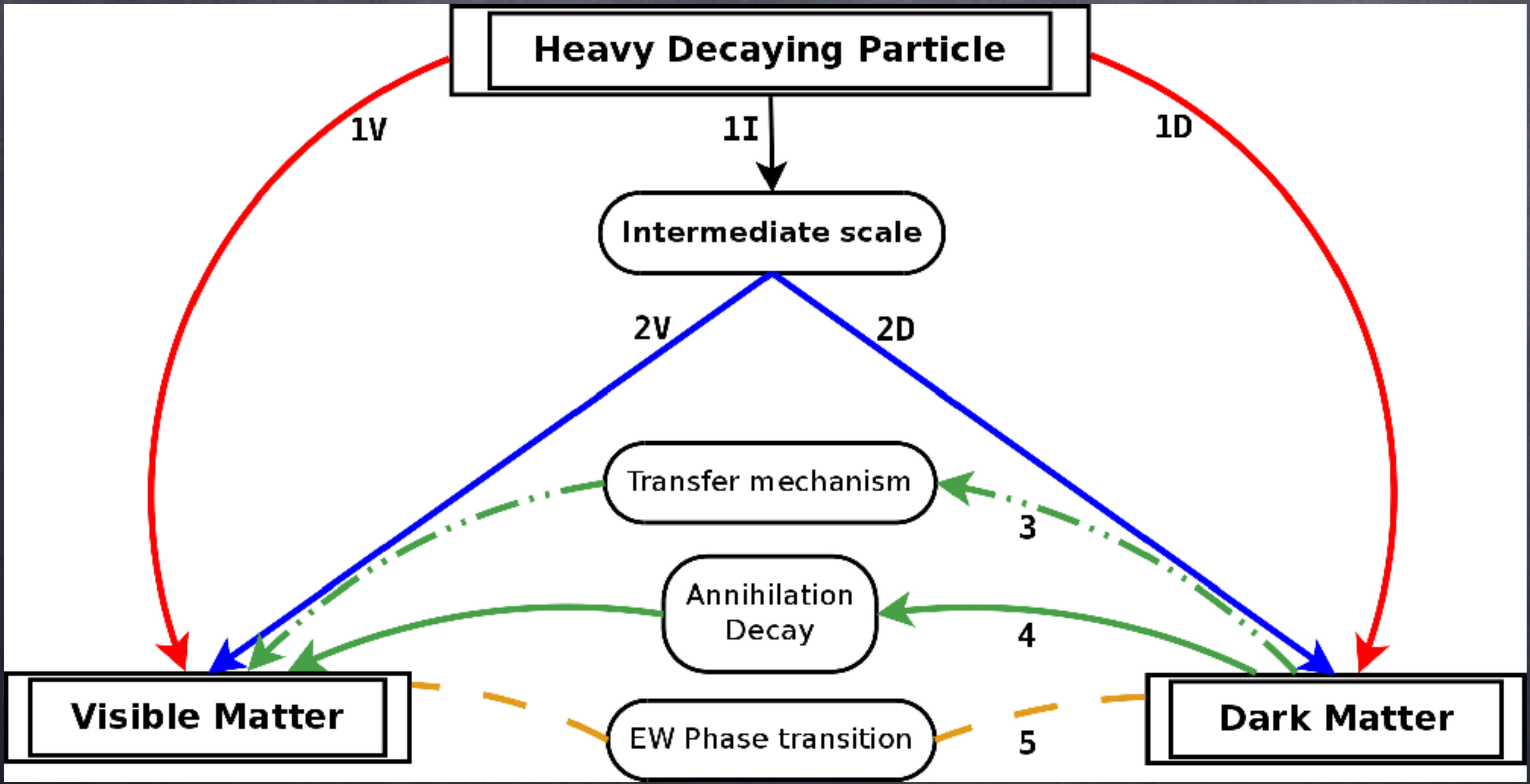
Baryogenesis & Dark Matter

- The observed BAU and DM abundance are of the same order

$$\Omega_{DM} \approx 5\Omega_B$$

- Although this could be just a coincidence, it has motivated several studies trying to relate their origins.
- Asymmetric DM, WIMPy Baryogenesis etc are some of the scenarios proposed so far.
- While generic implementations of these scenarios tightly relate BAU & DM abundances, there exists other implementations too where the connections may be loose.

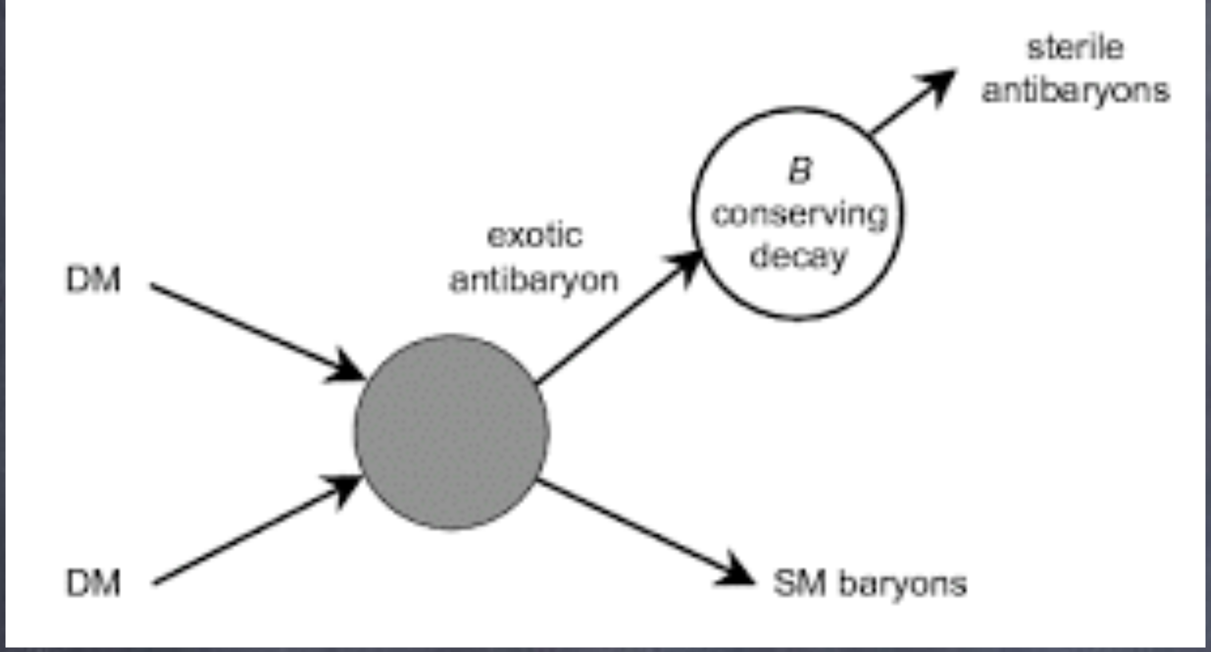
Baryogenesis & Dark Matter: Common Origin

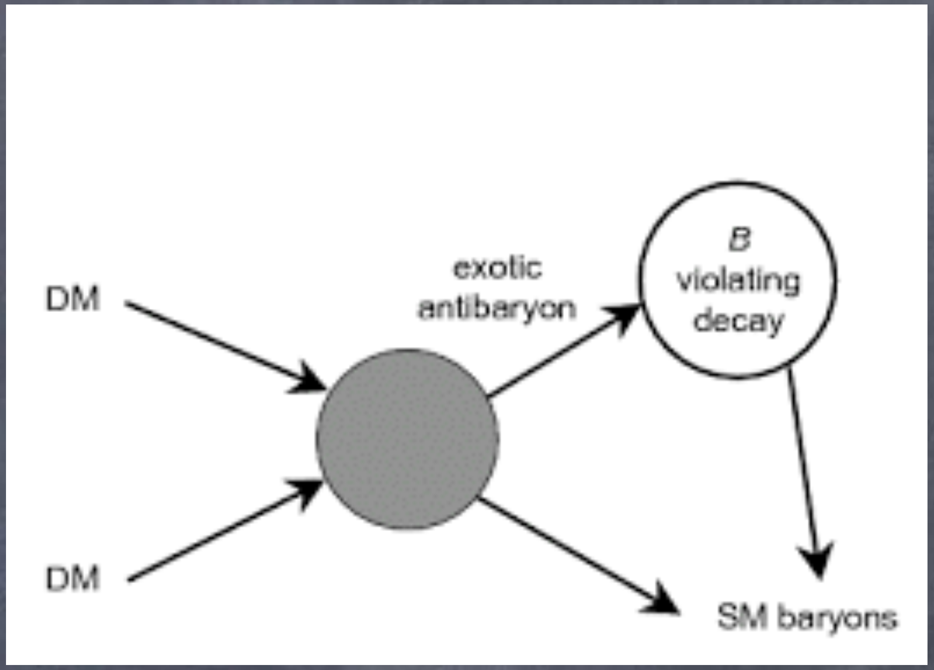


Boucenna & Morisi 2014

WIMPy Baryogenesis

Cui, Randall & Shuve 2011





1. WIMP annihilation violate B or L.

2. WIMP couplings to SM have CP violations.

3. Cooling of the Universe provides the departure from thermal equilibrium.

WIMPy Baryogenesis: General Framework

$$\frac{dY_X}{dx} = -\frac{2s(x)}{xH(x)}\langle\sigma_{ann}v\rangle\left[Y_X^2 - (Y_X^{eq})^2\right],$$

DM X annihilating into baryons

$$\frac{dY_{\Delta B}}{dx} = \frac{\epsilon s(x)}{xH(x)}\langle\sigma_{ann}v\rangle\left[Y_X^2 - (Y_X^{eq})^2\right] - \frac{s(x)}{xH(x)}\langle\sigma_{washout}v\rangle\frac{Y_{\Delta B}}{2Y_\gamma}\prod_i Y_i^{eq}$$

Integrating the 2nd equation gives

$$Y_{\Delta B}(x) = \int_0^x dx'\frac{\epsilon s(x')}{x'H(x')}\langle\sigma v\rangle\left[Y_X^2(x) - (Y_X^{eq})^2\right](x')exp\left[-\int_{x'}^x \frac{dx''}{x''}\frac{s(x'')}{2Y_\gamma H(x'')}\langle\sigma_{washout}v\rangle\prod_i Y_i^{eq}(x'')\right]$$

$$\approx -\frac{\epsilon}{2}\int_0^x dx'\frac{dY_X(x')}{dx'}exp\left[-\int_{x'}^x \frac{dx''}{x''}\frac{s(x'')}{2Y_\gamma H(x'')}\langle\sigma_{washout}v\rangle\prod_i Y_i^{eq}(x'')\right]$$

Assuming the wash-out process to freeze-out before WIMP freezes out, we can have the final asymmetry as

$$Y_{\Delta B}(\infty) \approx -\frac{\epsilon}{2}\int_{x_{washout}}^\infty dx'\frac{dY_X(x')}{dx'} = \frac{\epsilon}{2}\left[Y(x_{washout}) - Y_X(\infty)\right]$$

WIMPy Baryogenesis: General Framework

- For wash-out freeze-out to precede WIMP freeze-out, one must have the following quantity less than unity at the time wash-out freeze-out.

$$\frac{\Gamma_{washout}(x)}{\Gamma_{WIMP}(x)} \approx \frac{\langle \sigma_{washout} v \rangle \prod_i Y_i^{eq}(x)}{4\langle \sigma_{ann} v \rangle Y_X^{eq}(x) Y_\gamma}$$

  - This can be made sure for every process washing out the baryon asymmetry if

    1. One of the baryon states is heavier than dark matter so $\frac{\prod_i Y_i^{eq}(x)}{Y_X^{eq}(x) Y_\gamma} \ll 1$
    2. The baryon-number-violating coupling is small so $\langle \sigma_{washout} v \rangle \ll \langle \sigma_{ann} v \rangle$

  - The second scenario is difficult to realise because same couplings decide both the cross sections.

Scotogenic Model

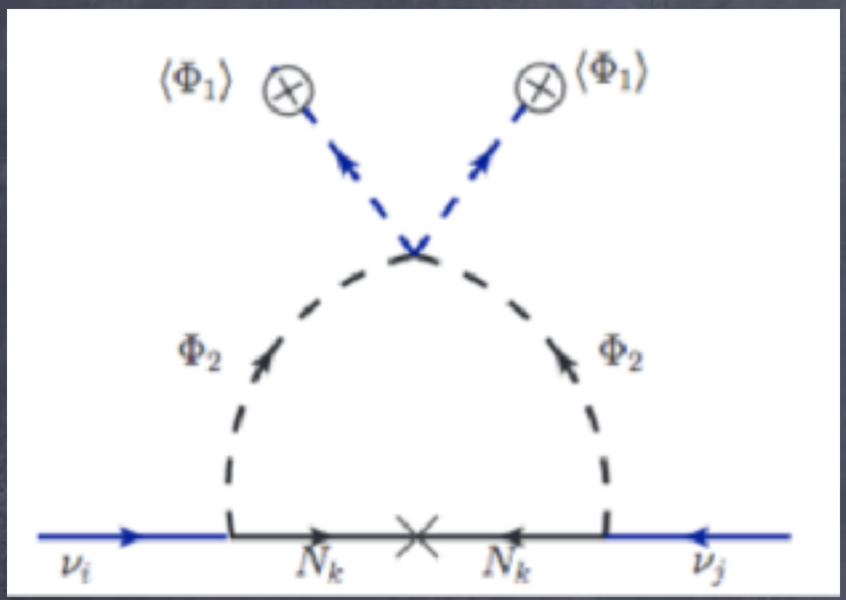
E. Ma 2006

- Extension of the SM by 3 RHN & 1 Scalar Doublet, odd under the a built-in Z_2 symmetry.
- The lightest of the Z_2 odd particles, if EM neutral is a DM candidate.
- Scalar DM resembles inert Doublet DM (hep-ph/0603188,0512090,0612275).
- Lightest RHN DM (1710.03824).
- Neutrino Mass arises at one-loop level.

Scotogenic Model

$$V(\Phi_1,\Phi_2) = \mu_1^2|\Phi_1|^2 + \mu_2^2|\Phi_2|^2 + \frac{\lambda_1}{2}|\Phi_1|^4 + \frac{\lambda_2}{2}|\Phi_2|^4 + \lambda_3|\Phi_1|^2|\Phi_2|^2 + \lambda_4|\Phi^\dagger\Phi|^2 + \left\{\frac{\lambda_5}{2}(\Phi_1^\dagger\Phi_2) + h.c\right\}$$

$$\mathscr{L} \supset \frac{1}{2}(M_N)_{ij}N_iN_j + (Y_{ij}\overline{L}\tilde{\Phi}_2N_j + h.c)$$



$$m_h^2 = \lambda_1 v^2$$

$$m_{H^\pm}^2 = \mu_2^2 + \frac{1}{2}\lambda_3 v^2,$$

$$m_H^2 = \mu_2^2 + \frac{1}{2}\left(\lambda_3+\lambda_4+\lambda_5\right)v^2$$

$$m_A^2 = \mu_2^2 + \frac{1}{2}\left(\lambda_3+\lambda_4-\lambda_5\right)v^2$$

One loop neutrino mass : $(m_\nu)_{ij} = \sum_k \frac{Y_{ik}Y_{jk}M_k}{16\pi^2}\left(\frac{m_R^2}{m_R^2-M_k^2}\ln\frac{m_R^2}{M_k^2} - \frac{m_I^2}{m_I^2-M_k^2}\ln\frac{m_I^2}{M_k^2}\right)$

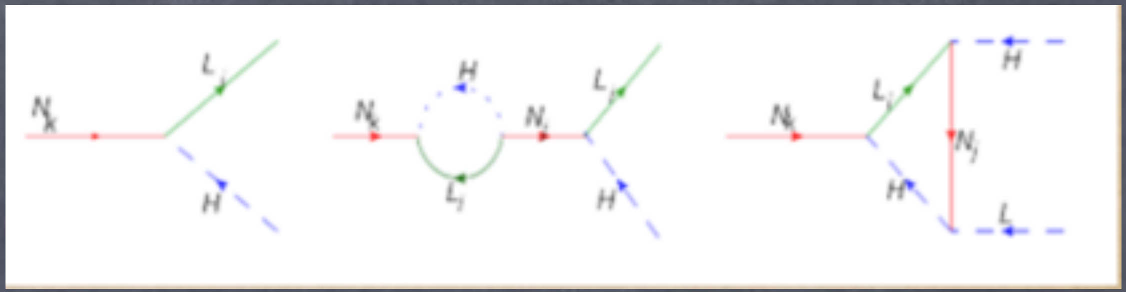
Which under the approximation $m_H^2 + m_A^2 \approx M_k^2$ boils down to

$$(m_\nu)_{ij} \approx \sum_k \frac{\lambda_5 v^2}{32\pi^2}\frac{Y_{ik}Y_{jk}}{M_k} = \sum_k \frac{m_A^2 - m_H^2}{32\pi^2}\frac{Y_{ik}Y_{jk}}{M_k}$$

Vanilla Leptogenesis in Scotogenic Model

- Right handed neutrino decays out of equilibrium (Fukugida & Yanagida 1986)

$$Y_{ij}\overline{L}_i\tilde{H}N_j + \frac{1}{2}M_{ij}N_iN_j$$



- CP violation due to phases in Yukawa couplings Y, leaves to a lepton asymmetry.

$$\epsilon_{N_k} = -\sum_i \frac{\Gamma(N_k \to L_i + H^*) - \Gamma(N_k \to L_i + H)}{\Gamma(N_k \to L_i + H^*) + \Gamma(N_k \to L_i + H)}$$

- At least two N's are required to generate an asymmetry due to the presence of interference between tree and one loop diagram namely, vertex diagram (Fukugida & Yanagida' 86) and self energy diagram namely, vertex diagram (Liu & Segre'93). For one N, the complex phase can be rotated away.

Vanilla Leptogenesis in Scotogenic Model

- The asymmetry freezes out at $T \ll M_i$
- The lepton asymmetry gets converted into baryons asymmetry through electroweak sphalerons (Khlebnikov & Shaposhnikov'88).

$$\frac{n_{\Delta B}}{s} = -\frac{28}{79}\frac{n_{\Delta L}}{s}$$

- The same right handed neutrinos also generate light neutrino masses at one-loop, along with scalar dark matter going inside the loop.

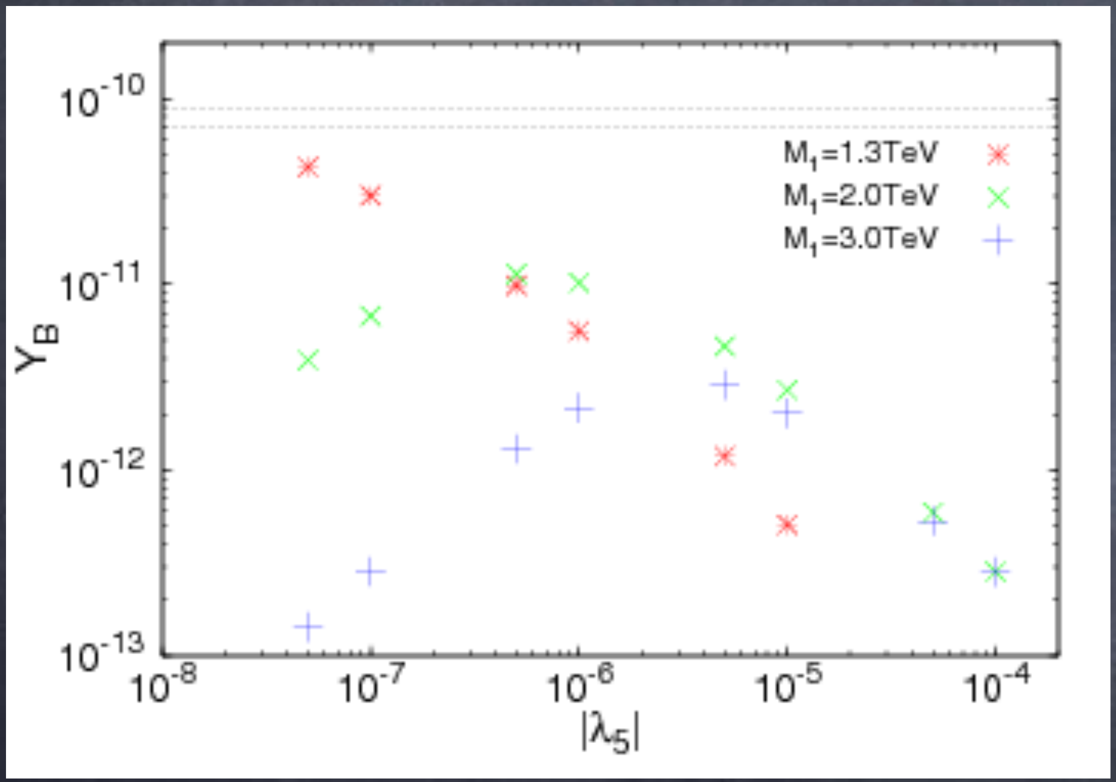
Leptogenesis in Scotogenic Model

1207.2594

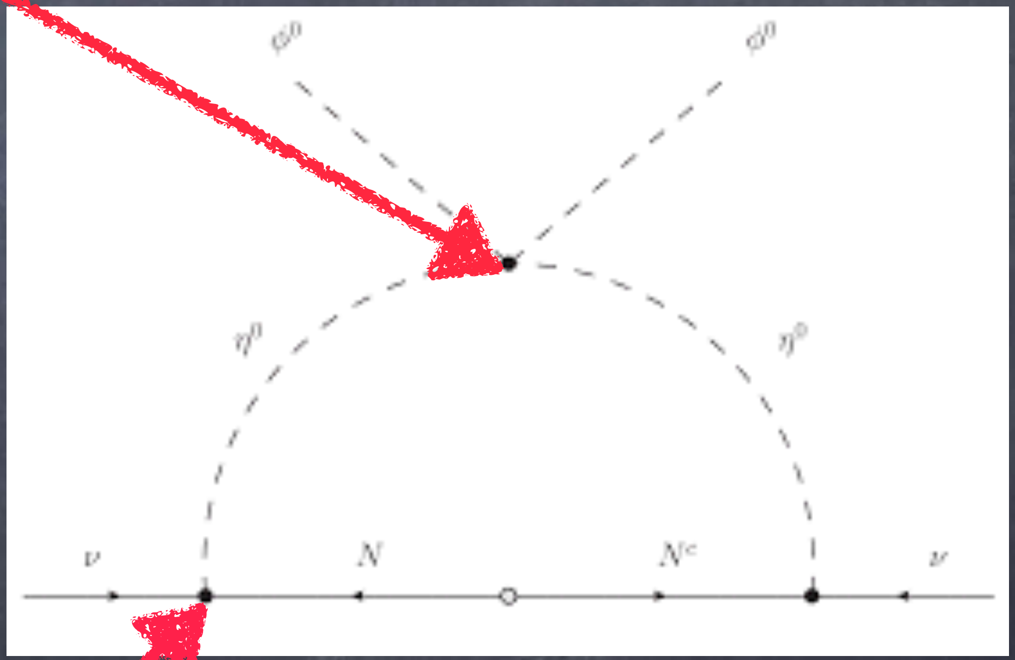
$$\varepsilon = \frac{1}{16\pi\left[\frac{3}{4}+\frac{1}{4}\left(1-\frac{M_\eta^2}{M_1^2}\right)^2\right]}\sum_{i=2,3}\frac{Im\left[\left(\sum_{k=e,\mu,\tau}h_{k1}h_{ki}^*\right)^2\right]}{\sum_{k=e,\mu,\tau}h_{k1}h_{k1}^*}\times G\left(\frac{M_i^2}{M_1^2},\frac{M_\eta^2}{M_1^2}\right)$$

$$\frac{dY_{N_1}}{dz} = -\frac{z}{sH(M_1)}\left(\frac{Y_{N_1}}{Y_{N_1}^{eq}}-1\right)\left\{\gamma_D^{N_1}+\sum_{i=2,3}\gamma_{N_1N_i}^{(2)}+\gamma_{N_1N_i}^{3}\right\},$$

$$\frac{dY_L}{dz} = \frac{z}{sH(M_1)}\left\{\varepsilon\left(\frac{Y_{N_1}}{Y_{N_1}^{eq}}-1\right)\gamma_D^{N_1}-\frac{2Y_L}{Y_l^{eq}}(\gamma_N^{(2)}+\gamma_N^{(13)})\right\},$$



λ_5



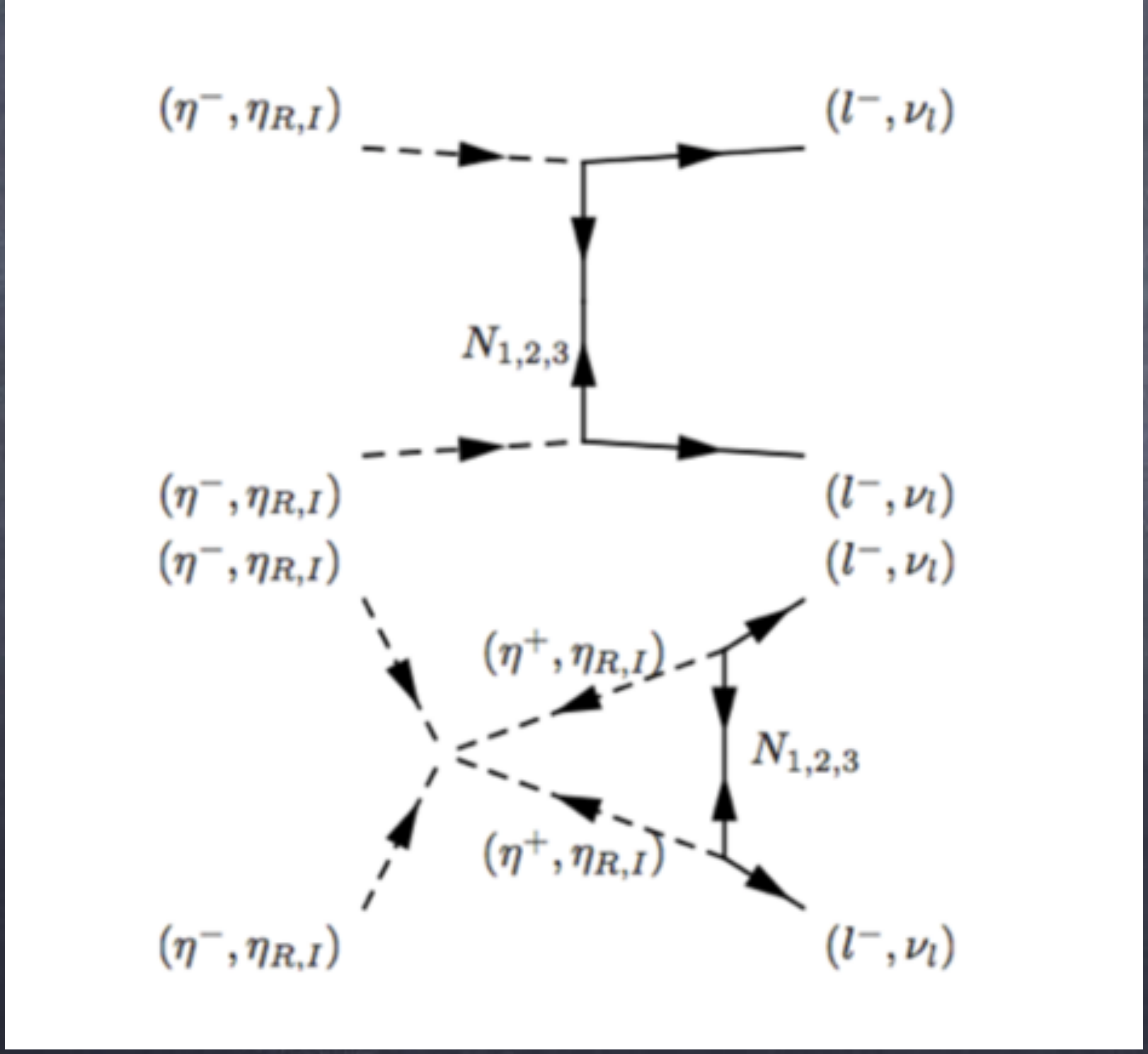
h_{ik}

Leptogenesis in Scotogenic Model

- Smaller values of λ_5 requires larger Yukawa h_{ij} for correct neutrino mass and vice versa.
- Large Yukawa results in more wash-outs. Small Yukawa will produce small asymmetry.
- For TeV scale RHN, one requires very small values of λ_5 to satisfy neutrino mass and baryon asymmetry requirements.
- Such small values of λ_5 leads to large inelastic scattering of DM, ruled out by data.
- TeV scale leptogenesis is not possible for hierarchal RHN, unless the lightest RHN is heavier than 10 TeV (1804.09660).
- Resonant leptogenesis can work (Pilaftsis 1997, B Dev et al 2013)

TeV Leptogenesis from DM annihilation

The annihilation of scalar DM can produce a leptonic asymmetry through the following processes



The Boltzmann Equations

$$\frac{dY_{DM}}{dz} = -\frac{2zs}{H(M_{DM})}\langle\sigma v\rangle_{DMDM\to SMSM}\left(Y_{DM}^2 - (Y^{eq})_{DM}^2\right)$$

$$\frac{dY_{\Delta L}}{dz} = \frac{2zs}{H(M_{DM})}\left[\epsilon\langle\sigma v\rangle_{DMDM\to LL}\left(Y_{DM}^2 - (Y_{DM}^{eq})^2\right)\right]$$

$$-Y_{\Delta L}Y_l^{eq}\left[\langle\sigma v\rangle_{DMDM->LL}^{wo} + \langle\sigma v\rangle_{DMDM\to LL}\right]$$

$$-Y_{\Delta L}Y_{DM}\left[\langle\sigma v\rangle_{DML\to DM\bar{L}}^{wo}\right] - \frac{1}{2}Y_{\Delta L}\left[\langle\sigma v\rangle_{DMDM\to SM\bar{L}}\right]$$

$$H = \sqrt{\frac{4\pi^3 g_*}{45}}\frac{M_{DM}^2}{M_{Pl}}, \quad s = g_*\frac{2\pi^2}{45}\left(\frac{M_{DM}}{z}\right)^3$$

Wash-out $\longrightarrow$

$$\Delta L = 1 \quad N\eta_{R,I}(\eta^\pm) \to LZ(W^\pm)$$

$$\Delta L = 1 \quad NN \to \eta\eta, L\eta L \to \overline{L}\eta$$

$$\epsilon = \frac{\langle \sigma v \rangle^1_{DMDM \to LL}}{\langle \sigma v \rangle^0_{DMDM \to LL}} \simeq \lambda \sin\phi \hat{\epsilon}$$

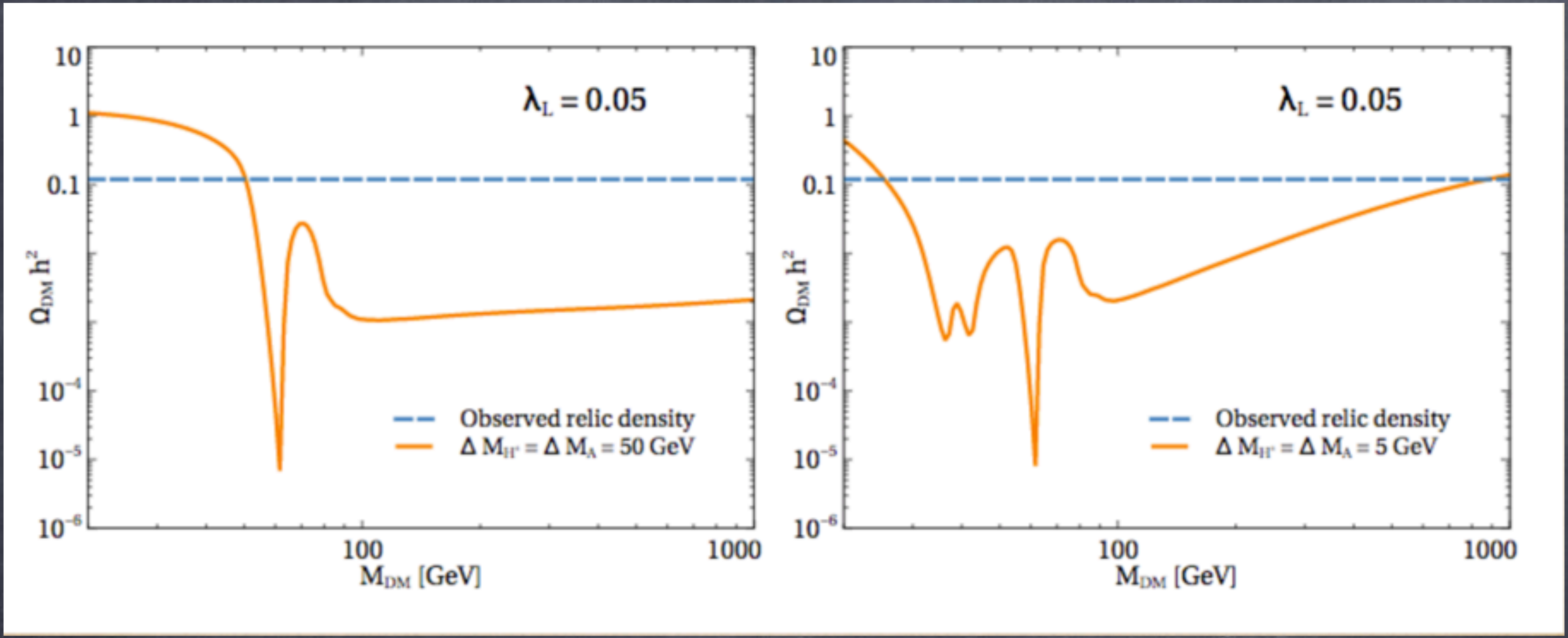
$$\hat{\epsilon} = \frac{1+x}{8\pi^2 x}\left[\ln\left(-\frac{(1+x)}{2x}\right)^2 + 2\mathrm{Li}_2\left(\frac{1}{2}\left(3+\frac{1}{x}\right)\right)\right.$$

$$-2\mathrm{Li}_2\left(\frac{(x-1)^2}{(1+x)^2}\right) + 2\mathrm{Li}_2\left(\frac{1+x(2-3x)}{(1+x)^2}\right)$$

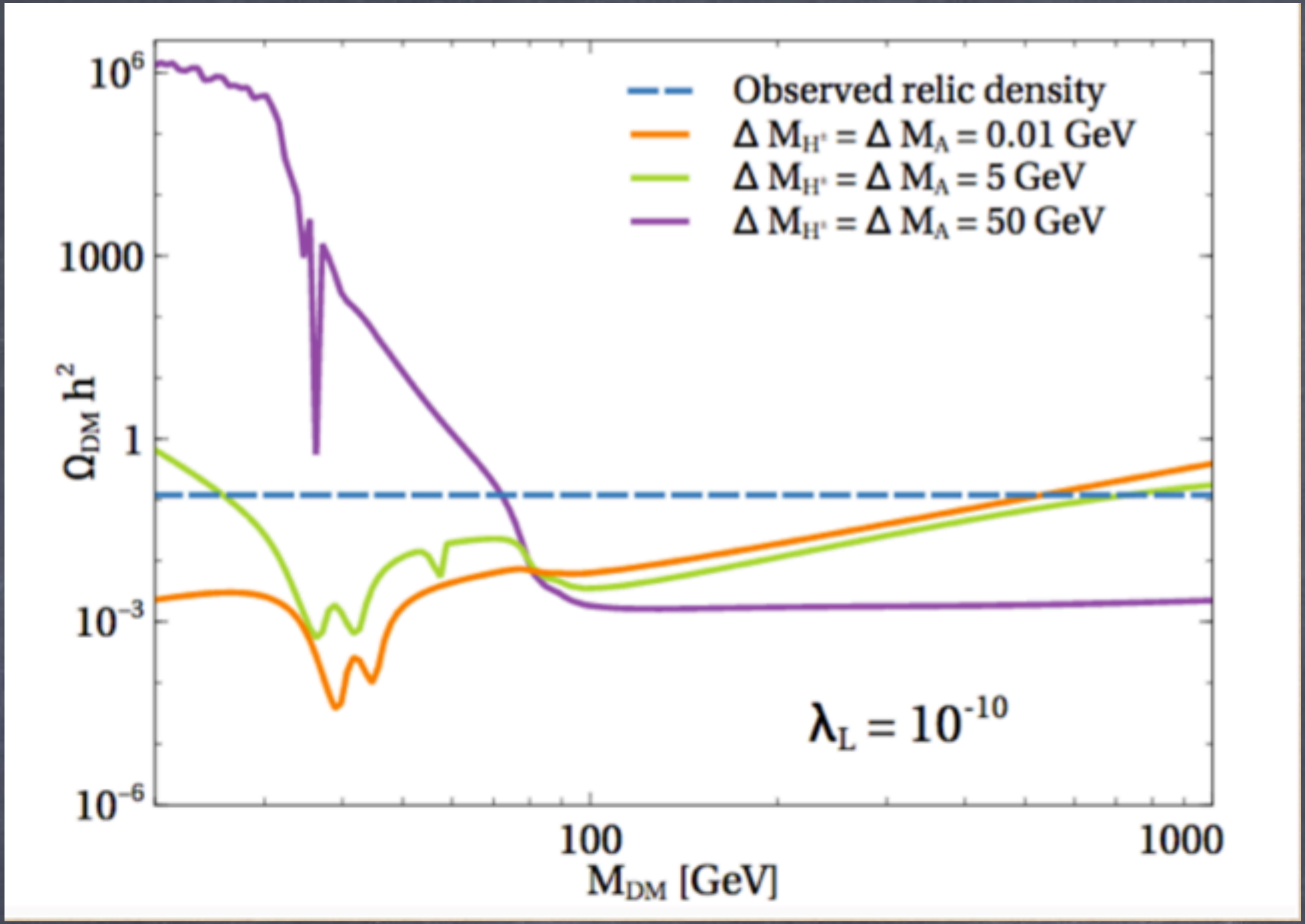
$$\left.-2\mathrm{Li}_2\left(3-\frac{2}{1+x}\right) + 4\mathrm{Li}_2\left(\frac{2-1-x}{1+x}\right)\right]$$

$$x = \frac{M^2_{\mathrm{DM}}}{M^2_N} \qquad \mathrm{Li}_2(y) = \sum_{k=1}^{\infty}\frac{y^k}{k^2}$$

Scalar Doublet Dark Matter

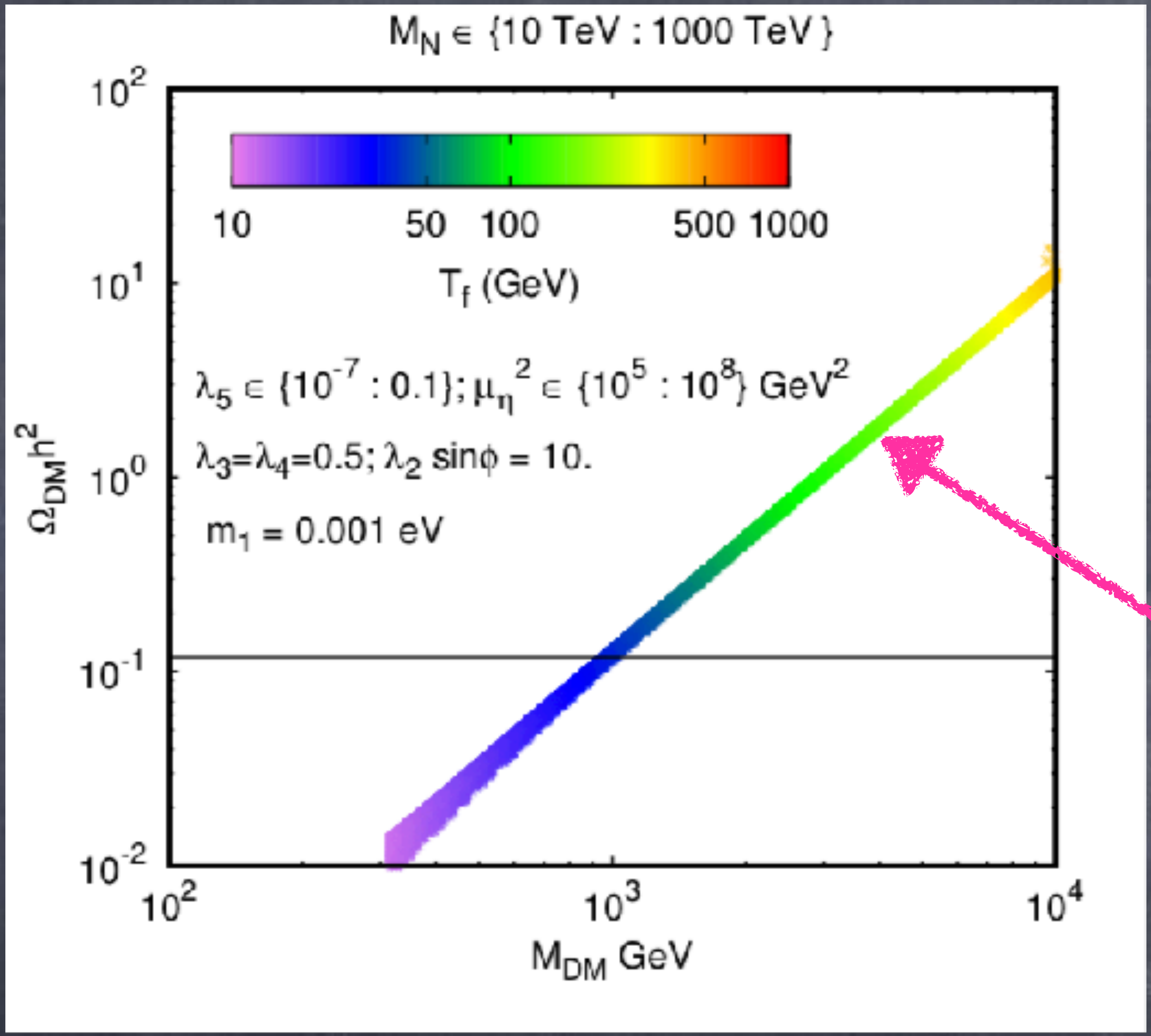


There exist two distinct mass regions satisfying the correct DM relic abundance



Clearly, DM is overproduced in the high mass regime, if the mass splitting is kept low!

Results: Minimal Scotogenic Model



DM Overproduced

Summary of Results: Minimal Scotogenic Model

- It is not possible to produce the correct lepton asymmetry above the electroweak phase transition from scalar DM annihilation while satisfying correct DM relic and neutrino mass constraints.

- While correct lepton asymmetry requires order one Yukawa which at the same time requires small λ_5 from neutrino mass point of view, DM direct detection gives an lower bound on

$$\lambda_5 \approx 1.65 \times 10^{-7} \left(\frac{\delta}{100 \text{ keV}} \right) \left(\frac{M_{\rm DM}}{100 \text{ GeV}} \right)$$

Minimal Extension

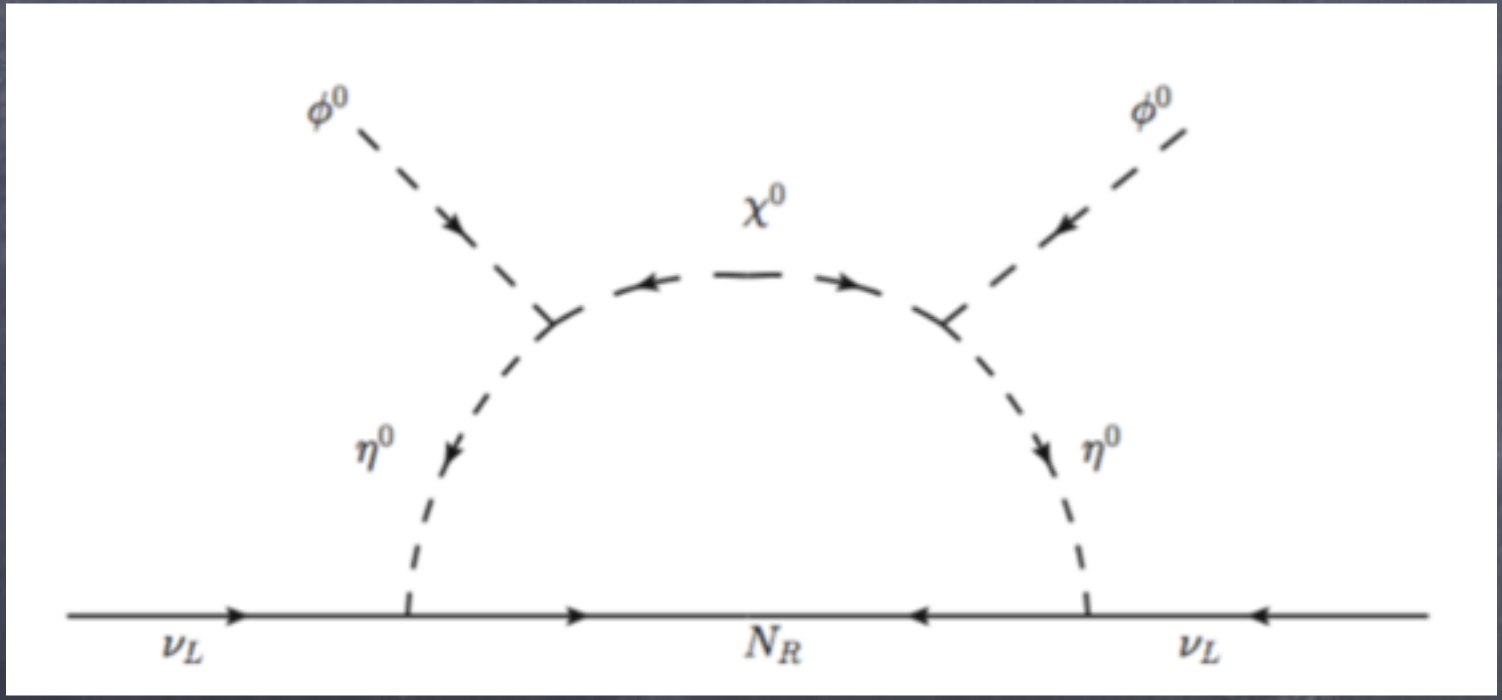
The scotogenic model can be extended by a complex singlet which results in the scalar potential

$$
\begin{aligned}
V = {} & \mu_H^2 H^\dagger H + \mu_\eta^2 \eta^\dagger \eta + \mu_\chi^2 \chi^* \chi + \frac{1}{4}\mu_4^2 \left[\chi^2 + (\chi^*)^2\right] \\
& + \mu(\eta^\dagger H \chi + H^\dagger \eta \chi^*) + \frac{1}{2}\lambda_H (H^\dagger H)^2 + \frac{1}{2}\lambda_\eta (\eta^\dagger \eta)^2 \\
& + \frac{1}{2}\lambda_\chi (\chi^* \chi)^2 + \lambda_4 (\eta^\dagger \eta)(H^\dagger H) + \lambda_5 (\eta^\dagger H)(H^\dagger \eta) \\
& + \lambda_6 (\chi^* \chi)(H^\dagger H) + \lambda (\chi^* \chi)(\eta^\dagger \eta)
\end{aligned}
$$

arXiv: 1512.08796

Physical Masses

$$m_H^2 = \lambda_H v^2, \quad m_{\eta^\pm}^2 = \mu_2^2 + \frac{1}{2}\lambda_4 v^2 \qquad M_{R,I}^2 = \begin{pmatrix} \mu_\eta^2 + (\lambda_4 + \lambda_5)v^2/2 & \mu v/\sqrt{2} \\ \mu v/\sqrt{2} & \mu_\chi^2 + \lambda_6 v^2/2 \pm \mu_4^2 \end{pmatrix}$$



$$(m_\nu)_{ij} = \sum_k \frac{Y_{ik}Y_{jk}M_k}{16\pi^2}\left(\frac{\cos^2\theta_R m_{\phi_1^R}^2}{m_{\phi_1^R}^2 - M_k^2}\ln\frac{m_{\phi_1^R}^2}{M_k^2} + \frac{\sin^2\theta_R m_{\phi_2^R}^2}{m_{\phi_2^R}^2 - M_k^2}\ln\frac{m_{\phi_\alpha^I}^2}{M_k^2} - \frac{\cos^2\theta_I m_{\phi_1^I}^2}{m_{\phi_\alpha^I}^2 - M_k^2}\ln\frac{m_{\phi_1^I}^2}{M_k^2} - \frac{\sin^2\theta_I m_{\phi_2^I}^2}{m_{\phi_2^I}^2 - M_k^2}\ln\frac{m_{\phi_2^I}^2}{M_k^2}\right)$$

Bechmark points

BP1

$m_{\phi_1^R} = 4.89$ TeV, $m_{\phi_2^R} = 4.90$ TeV, $m_{\phi_1^I} = 4.89$ TeV, $m_{\phi_2^I} = 4.90$ TeV, $m_{\phi^\pm} = 4.89$ TeV, $\mu_\eta = 4.89$ TeV,

$\mu_\chi = 4.89$ TeV, $\mu = 234.14$ GeV, $\mu_4 = 24.64$ GeV, $\lambda_4 = 2.24 \times 10^{-3}$, $\lambda_5 = 1.53 \times 10^{-4}$, $\lambda_6 = 5.95 \times 10^{-5}$,

$M_k = 15.02$ TeV $(k = 1,2,3)$

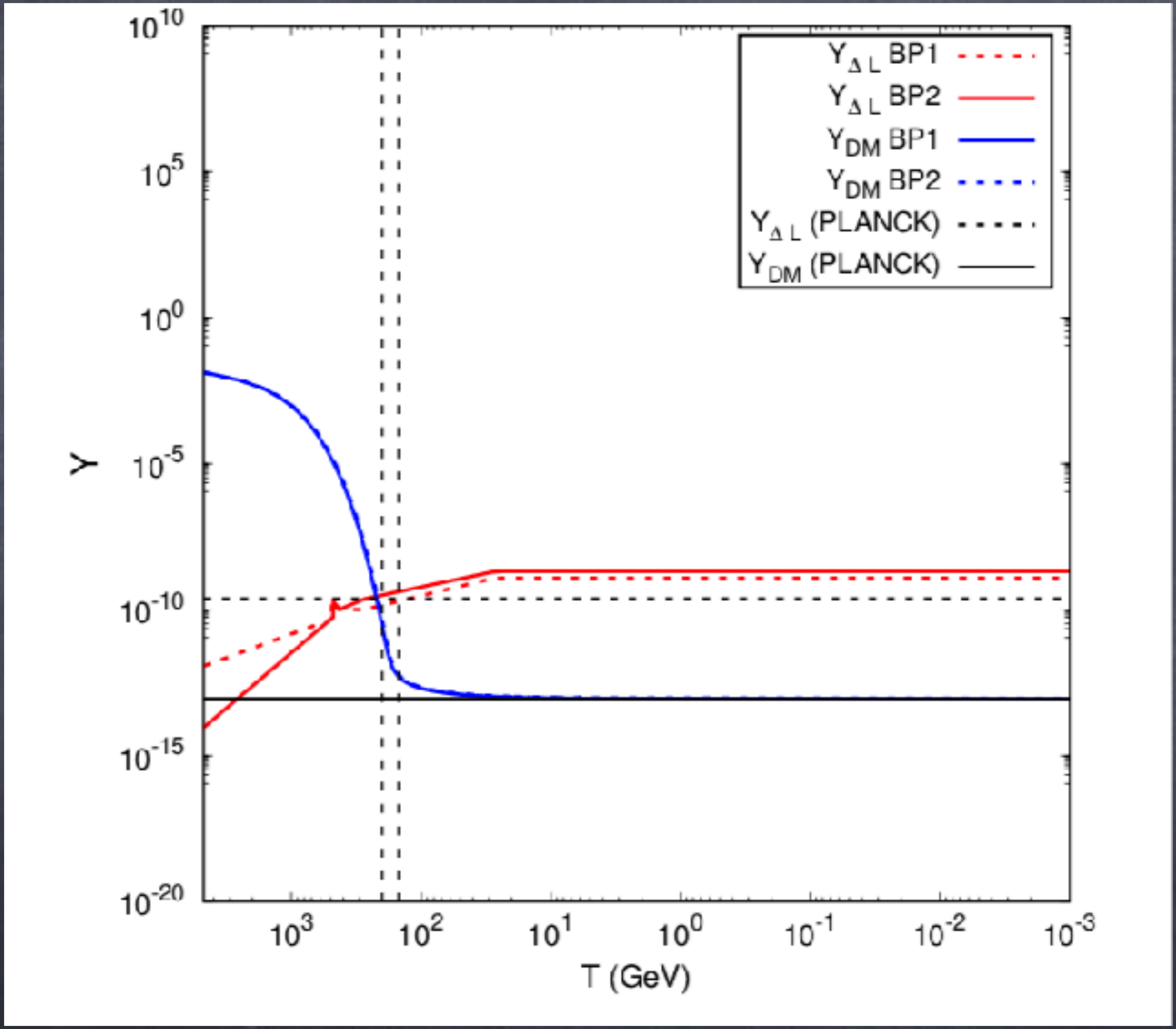
BP2

$m_{\phi_1^R} = 4.78$ TeV, $m_{\phi_2^R} = 4.79$ TeV, $m_{\phi_1^I} = 4.78$ TeV, $m_{\phi_2^I} = 4.79$ TeV, $m_{\phi^\pm} = 4.78$ TeV, $\mu_\eta = 4.78$ TeV,

$\mu_\chi = 4.79$ TeV, $\mu = 212.43$ GeV, $\mu_4 = 27.74$ GeV, $\lambda_4 = 1.37 \times 10^{-4}$, $\lambda_5 = 3.48 \times 10^{-5}$, $\lambda_6 = 3.55 \times 10^{-4}$,

$M_k = 17.79$ TeV $(k = 1,2,3)$.

Results

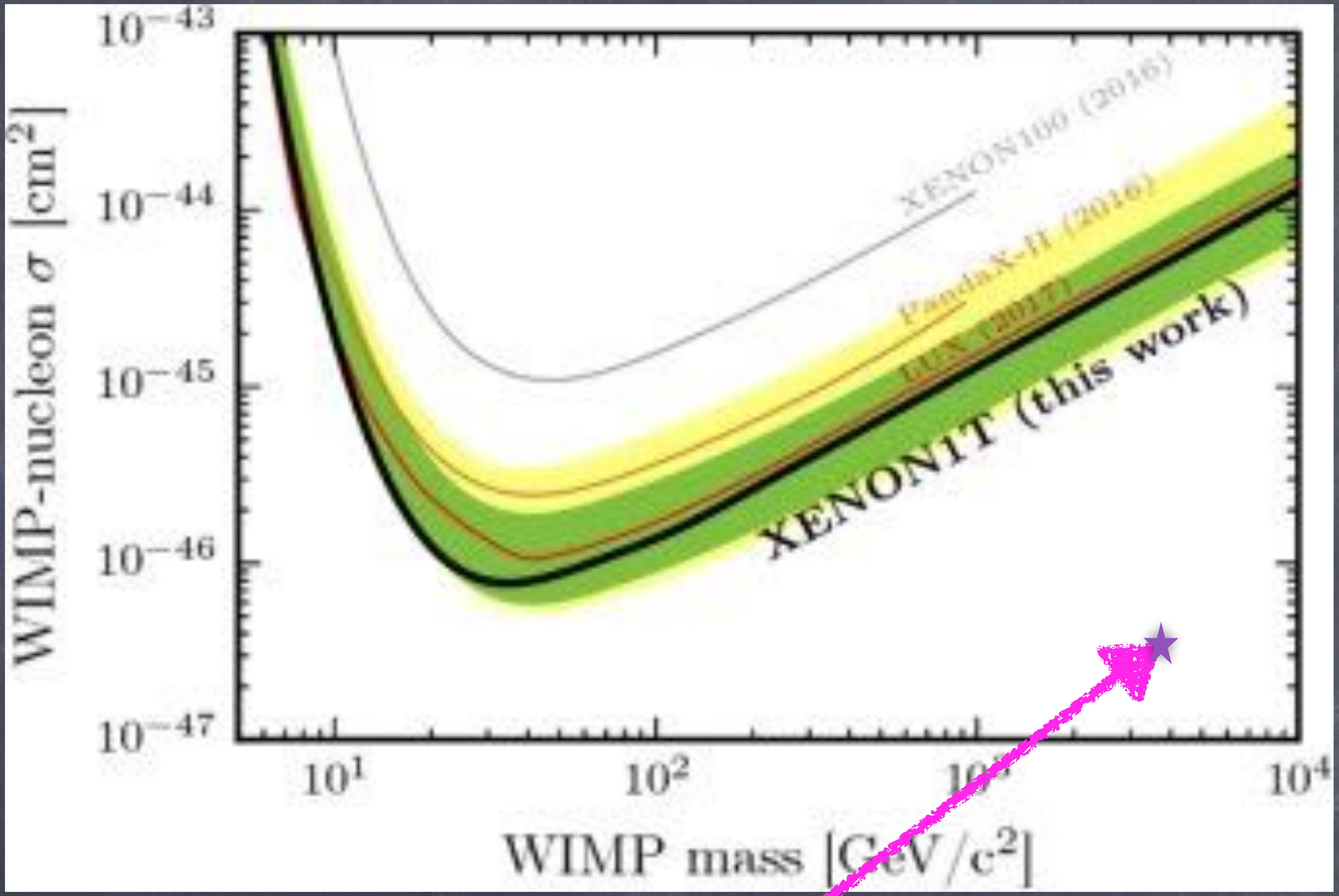


$Y_{\Delta L}$ BP1
$Y_{\Delta L}$ BP2
Y_{DM} BP1
Y_{DM} BP2
$Y_{\Delta L}$ (PLANCK)
Y_{DM} (PLANCK)
Y
10^{10}
10^{5}
10^{0}
10^{-5}
10^{-10}
10^{-15}
10^{-20}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
T (GeV)

Testability

- Since the particle spectrum of the model remains heavy, around 5 TeV or more, their direct production at the 14 TeV LHC remains suppressed.
- The model can however be tested at rare decay experiments looking for the lepton flavour violation.
- The prospects at the direct/indirect dark matter detection experiments remain weak.

Direct Detection

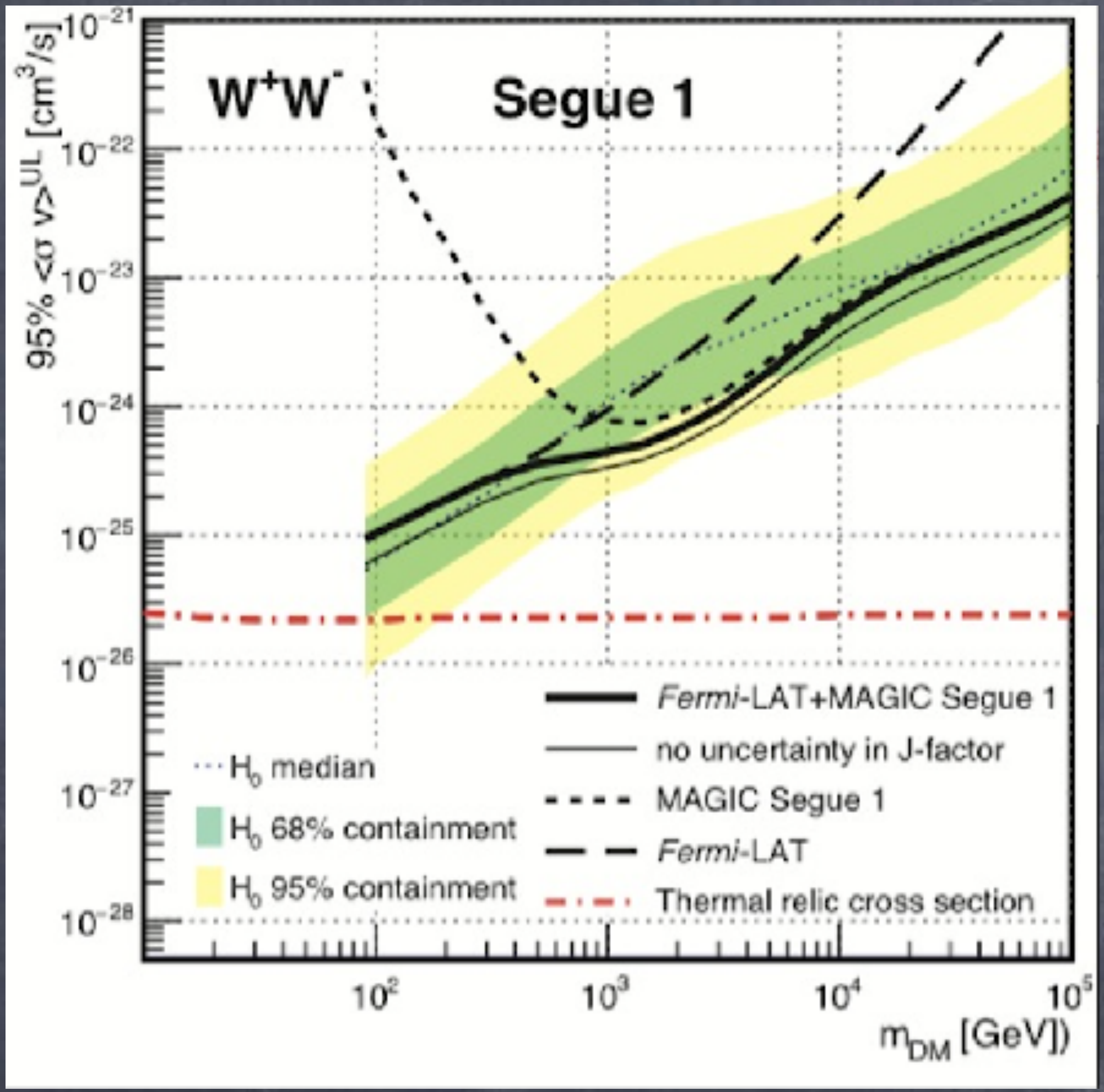


$$\sigma^{SI}_{DM\,n} = 3.527 \times 10^{-47}\mathrm{cm}^2 \quad \text{BP1}$$

$$\sigma^{SI}_{DM\,n} = 2.508 \times 10^{-47}\mathrm{cm}^2 \quad \text{BP2}$$

arXiv:1705.06655

Indirect Detection

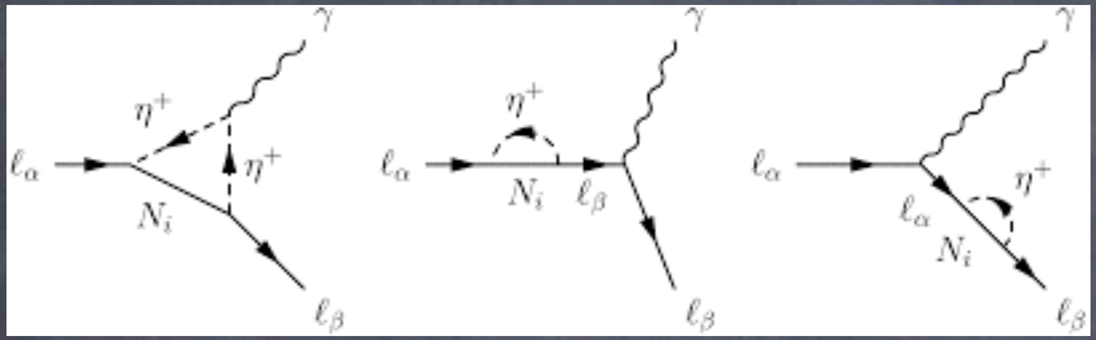


$$\langle \sigma v \rangle_{DMDM \to W^+W^-} = 2.83 \times 10^{-28}\ \mathrm{cm^3 s^{-1}} \quad \text{(BP1)}$$

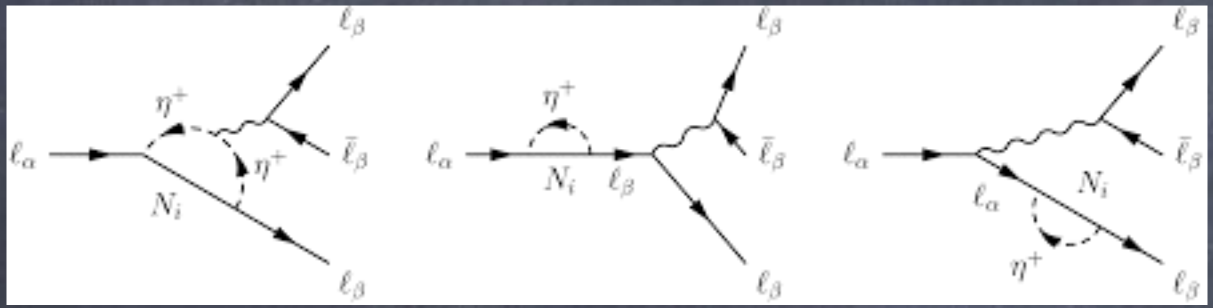
$$\langle \sigma v \rangle_{DMDM \to W^+W^-} = 3.24 \times 10^{-28}\ \mathrm{cm^3 s^{-1}} \quad \text{(BP2)}$$

arXiv:1601.06590

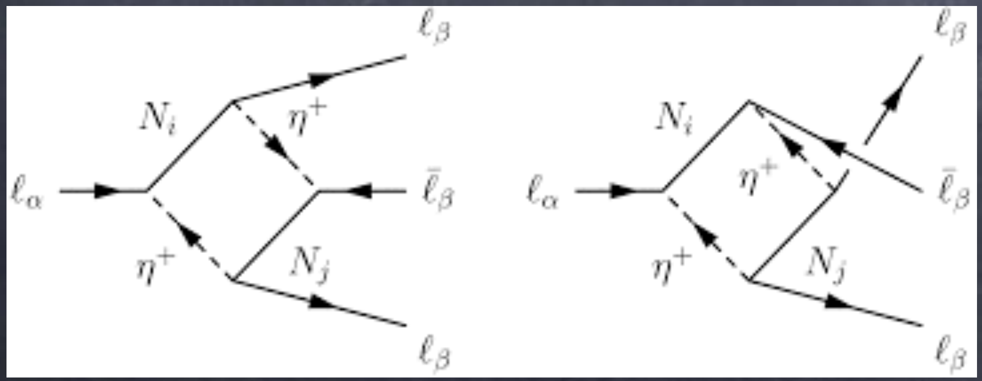
Lepton Flavor Violation



$l_\alpha \to l_\beta \gamma$



$l_\alpha \to 3 l_\beta$

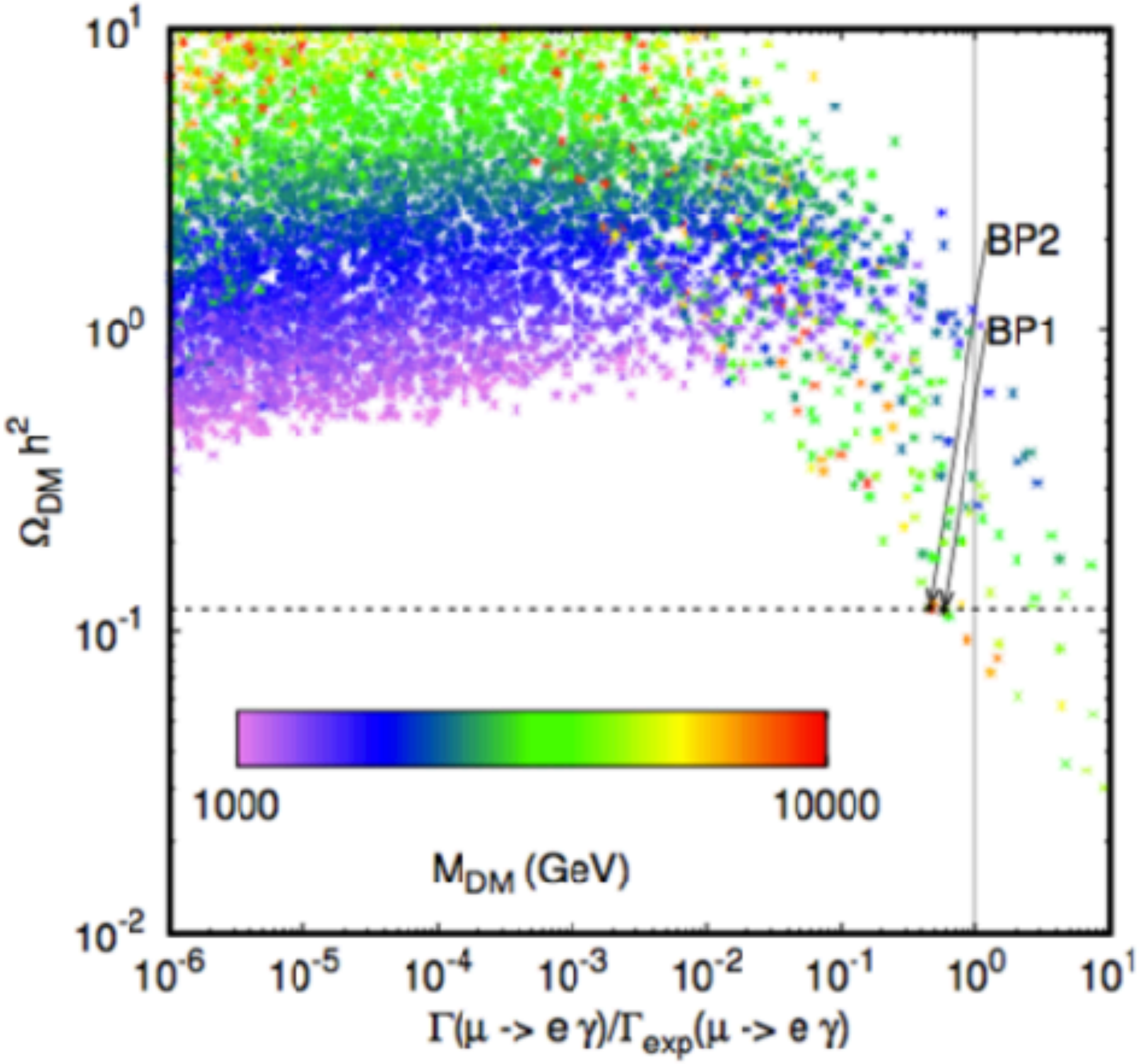


arXiv:1312.2840,1412.2545

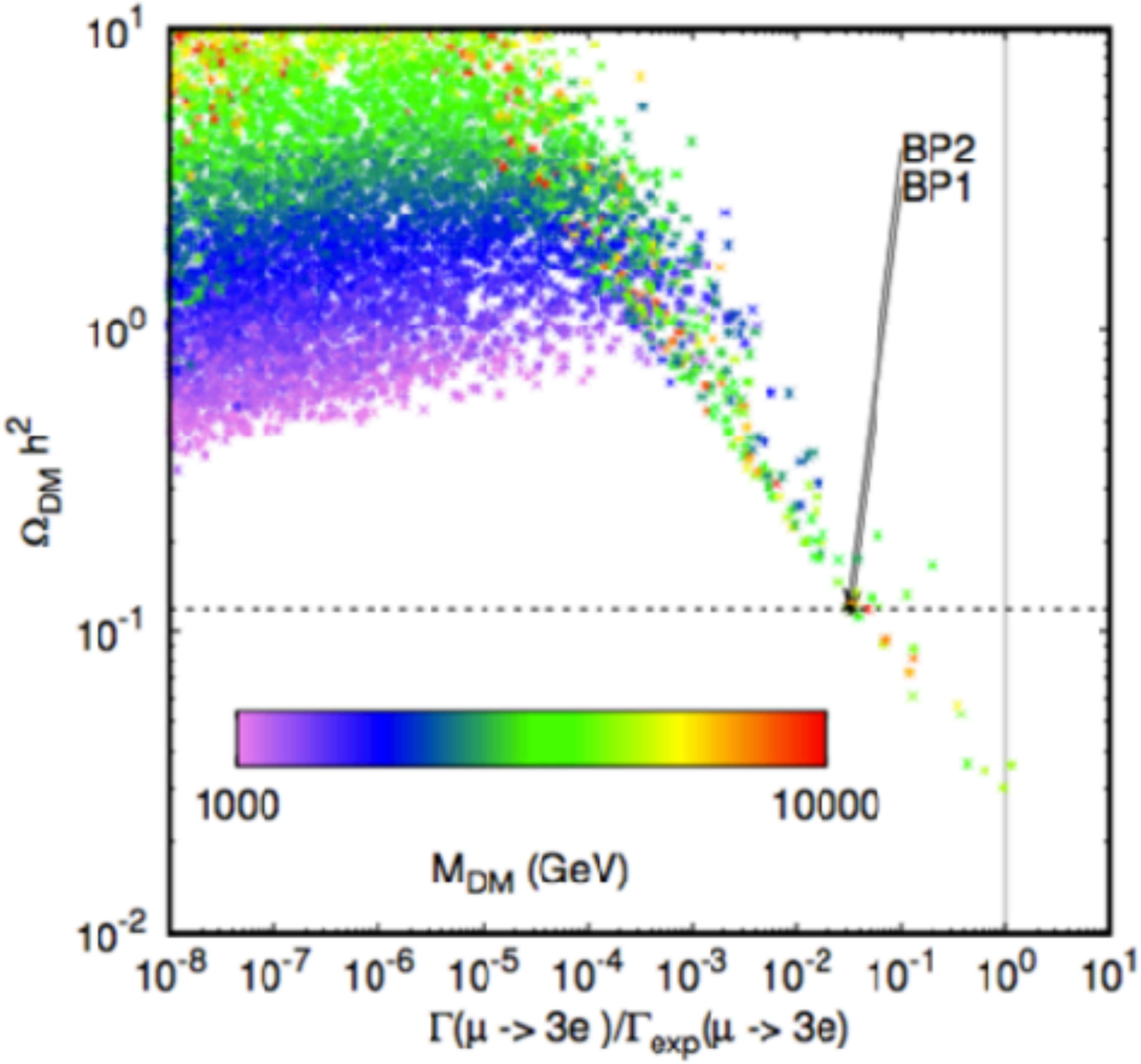
Lepton Flavor Violation

LFV Process	Present Bound	Future Sensitivity
$\mu \to e\gamma$	5.7×10^{-13} [25]	6×10^{-14} [26]
$\tau \to e\gamma$	3.3×10^{-8} [39]	$\sim 3 \times 10^{-9}$ [40]
$\tau \to \mu\gamma$	4.4×10^{-8} [39]	$\sim 3 \times 10^{-9}$ [40]
$\mu \to eee$	1.0×10^{-12} [28]	$\sim 10^{-16}$ [27]
$\tau \to \mu\mu\mu$	2.1×10^{-8} [41]	$\sim 10^{-9}$ [40]
$\tau^- \to e^-\mu^+\mu^-$	2.7×10^{-8} [41]	$\sim 10^{-9}$ [40]
$\tau^- \to \mu^-e^+e^-$	1.8×10^{-8} [41]	$\sim 10^{-9}$ [40]
$\tau \to eee$	2.7×10^{-8} [41]	$\sim 10^{-9}$ [40]
$\mu^-, \mathrm{Ti} \to e^-, \mathrm{Ti}$	4.3×10^{-12} [42]	$\sim 10^{-18}$ [35]
$\mu^-, \mathrm{Au} \to e^-, \mathrm{Au}$	7×10^{-13} [43]	
$\mu^-, \mathrm{Al} \to e^-, \mathrm{Al}$		$10^{-15} - 10^{-18}$
$\mu^-, \mathrm{SiC} \to e^-, \mathrm{SiC}$		10^{-14} [32]

arXiv:1312.2840,1412.2545



BP2
BP1
1000
10000
M_DM (GeV)
Ω_DM h^2
Γ(μ -> e γ)/Γ_exp(μ -> e γ)



BP2
BP1
1000
10000
M_DM (GeV)
Ω_DM h^2
Γ(μ -> 3e)/Γ_exp(μ -> 3e)

Conclusion

- Scenarios relating DM and baryon abundance are more constrained than individual DM or baryogenesis models and have implications in a wide range of experiments starting from particle physics, cosmology & astrophysics.
- We show here the WIMPy baryogenesis cannot be realised in minimal scotogenic model.
- With a minimal extension by a scalar singlet, scotogenic model can accommodate successful leptogenesis from DM annihilation while keeping the scale of leptogenesis as low as 5 TeV that can be probed at rare decay experiments

Thank You