

# Model for Dirac neutrino masses with two-component dark matter and extra gauge Abelian symmetry

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COMHEP 2022

November 30, 2022

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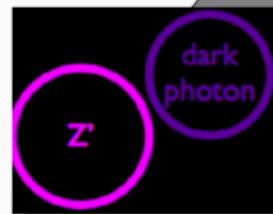
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# Motivation

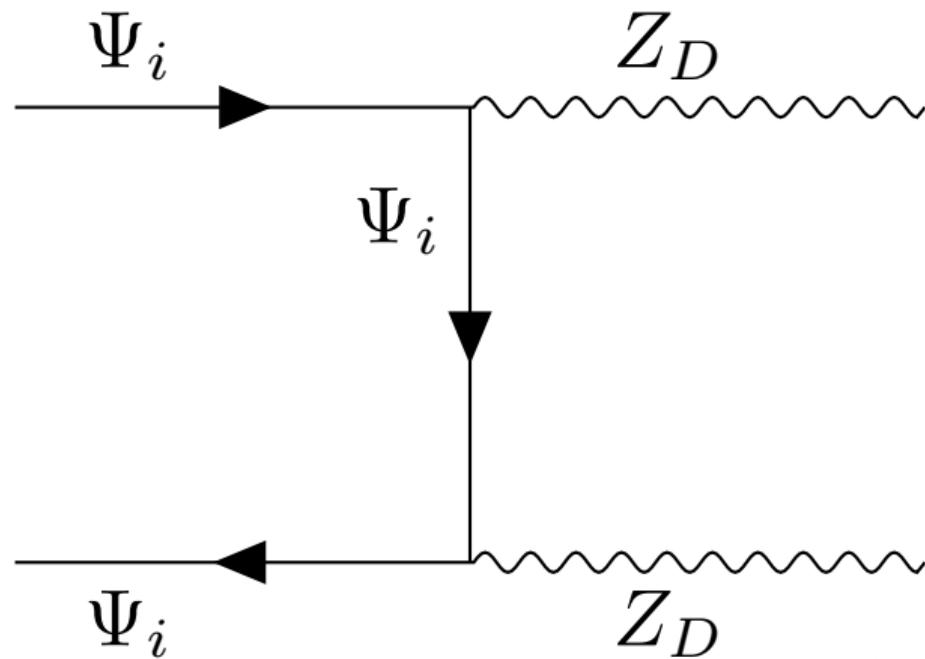


# Field Content

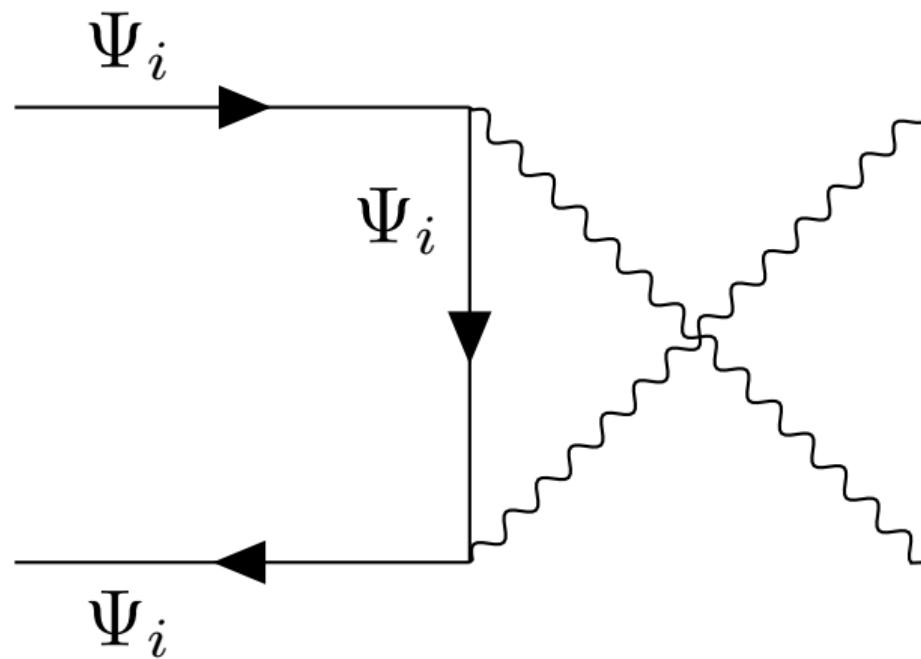
Field	Generations	$SU(2)_L$	$U(1)_Y$	$U(1)_D$
$\nu_{R\alpha}$	2	<b>1</b>	0	1
$\psi_{L1}$	1	<b>1</b>	0	-10
$\psi_{R1}$	1	<b>1</b>	0	-9
$\psi_{L2}$	3	<b>1</b>	0	6
$\psi_{R2}$	3	<b>1</b>	0	5
$H$	1	<b>2</b>	1/2	0
$S$	1	<b>1</b>	0	1
$\eta$	1	<b>2</b>	1/2	6
$\Phi$	1	<b>1</b>	0	6

Table: .

# Relic Abundance I



# Relic Abundance II



# Dark Matter Conversion

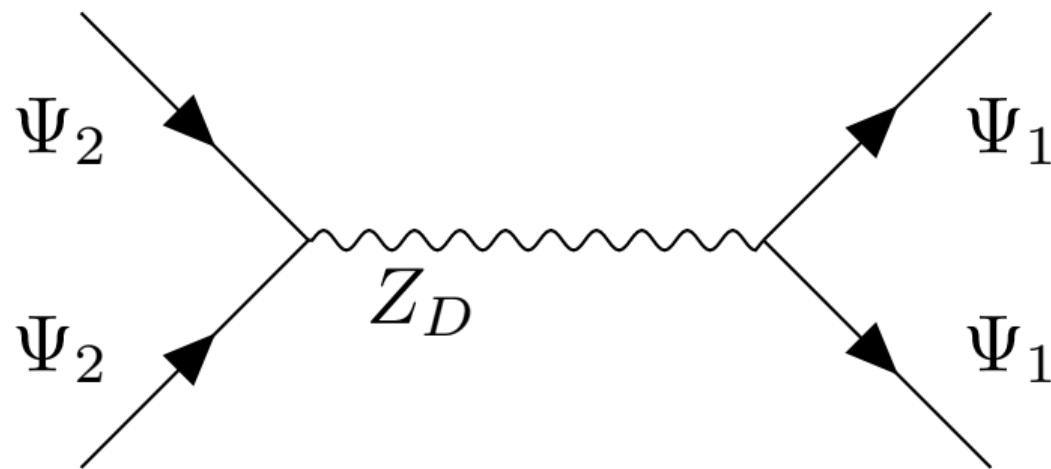


Figure:

## Boltzmann equations

For such scenario, the Boltzmann equations decouple each other, therefore:

$$\frac{d n_1}{d t} = - \sigma_{\nu}^{1100} (n_1^2 - \bar{n}_1^2) - \sigma_{\nu}^{2211} \left( n_1^2 - n_1^2 \frac{\bar{n}_1^2}{\bar{n}_2} \right) - 3Hn_1$$

$$\frac{d n_2}{d t} = - \sigma_{\nu}^{2200} (n_2^2 - \bar{n}_2^2) - \sigma_{\nu}^{1122} \left( n_2^2 - n_2^2 \frac{\bar{n}_2^2}{\bar{n}_1} \right) - 3Hn_2$$

However, we have the constraint:

$$\Omega_{\text{Total}} = \Omega_1 + \Omega_2$$

# Lagrangian for neutrino masses

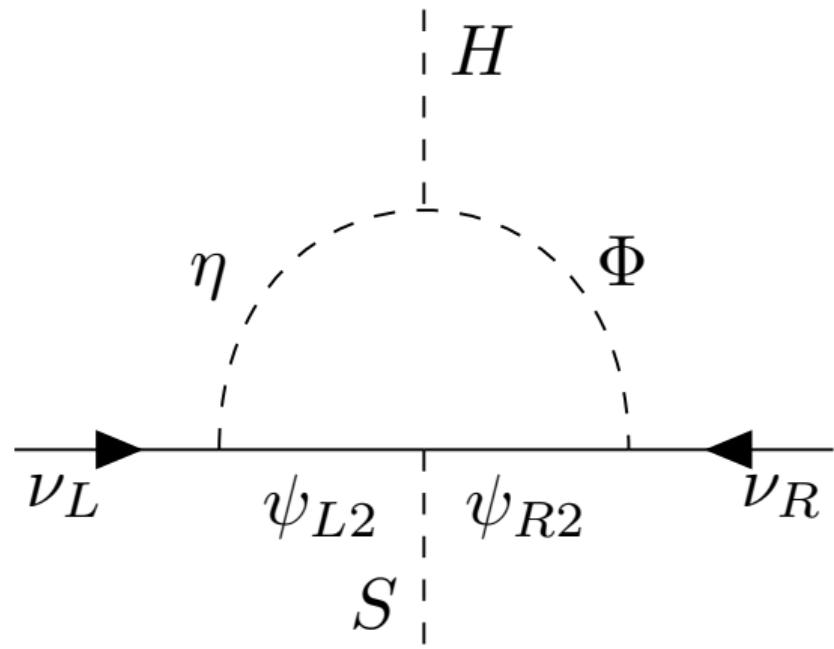
The relevant Yukawa terms for neutrino masses are:

$$-\mathcal{L} = y_S \psi_{L2} \psi_{R2} S + y_L \epsilon^{ab} \tilde{\eta}_a l_b \psi_{L2} + y_R S v \Phi$$

We consider the scalar potential on our model:

$$\begin{aligned} V = & \mu^2 \epsilon^{ab} \tilde{H}_a H_b - \frac{1}{2} \lambda_1 \epsilon^{ab} \epsilon^{cd} \tilde{H}_a H_b \tilde{H}_c H_d + \mu_p^2 |S|^2 - \frac{1}{2} \lambda_2 |S|^4 - \lambda_3 \epsilon^{ab} \tilde{H}_a H_b |S|^2 \\ & + m_\eta^2 \epsilon^{ab} \tilde{\eta}_a \eta_b - \frac{1}{2} \lambda_4 \epsilon^{ab} \epsilon^{cd} \tilde{\eta}_a \eta_b \tilde{\eta}_c \eta_d - \lambda_5 \epsilon^{ab} \epsilon^{cd} \tilde{\eta}_a \eta_b \tilde{H}_c H_d - \lambda_6 \epsilon^{ab} \epsilon^{cd} \tilde{\eta}_a H_b \tilde{H}_c \eta_d \\ & - \lambda_7 \epsilon^{ab} \tilde{\eta}_a \eta_b |S|^2 - m_\Phi^2 |\Phi|^2 - \frac{1}{2} \lambda_8 |\Phi|^4 - \lambda_9 \epsilon^{ab} \tilde{H}_a H_b |\Phi|^2 - \lambda_{10} |S|^2 |\Phi|^2 - \lambda_{11} \epsilon^{ab} \tilde{\eta}_a \eta_b |\Phi|^2 \\ & - \mu_S \epsilon^{ab} \tilde{\eta}_a H_b \Phi \end{aligned}$$

# Neutrino masses



# Neutrino mass matrix

The Neutrino mass matrix:

$$(\mathcal{M}_\nu)_{\alpha\beta} = \frac{\sin(\theta) \cos(\theta)}{16\pi^2 \sqrt{2}} \sum_k y_{L\alpha k} y_{R\beta k} M_k \left[ \frac{m_{s_1}^2}{m_{s_1}^2 - M_k^2} \ln \left( \frac{m_{s_1}^2}{M_k^2} \right) - \frac{m_{s_2}^2}{m_{s_2}^2 - M_k^2} \ln \left( \frac{m_{s_2}^2}{M_k^2} \right) \right]$$

I can rewrite the neutrino mass matrix as:

$$(\mathcal{M}_\nu)_{\alpha\beta} = \sum_k y_{L\alpha k} y_{R\beta k} f_k ,$$

where:

$$f_k = \frac{\sin(\theta) \cos(\theta)}{16\pi^2 \sqrt{2}} M_k \left[ \frac{m_{s_1}^2}{m_{s_1}^2 - M_k^2} \ln \left( \frac{m_{s_1}^2}{M_k^2} \right) - \frac{m_{s_2}^2}{m_{s_2}^2 - M_k^2} \ln \left( \frac{m_{s_2}^2}{M_k^2} \right) \right] ,$$

# Parametrization

The parameters:

$$\begin{aligned} y_{R12} = & m_{\nu 2} (U_{32}y_{L13}y_{L22} - U_{32}y_{L12}y_{L32} - U_{22}y_{L13}y_{L32} + U_{12}y_{L32}^2 + U_{22}y_{L12}y_{L33} \\ & - U_{12}y_{L22}y_{L33}) [f_1(y_{L13}y_{L22}y_{L31} - y_{L13}y_{L21}y_{L32} - y_{L12}y_{L31}y_{L32} + y_{L11}y_{L32}^2 \\ & + y_{L12}y_{L21}y_{L33} - y_{L11}y_{L22}y_{L33})]^{-1}, \end{aligned}$$

$$\begin{aligned} y_{R13} = & m_{\nu 3} (U_{33}y_{L13}y_{L22} - U_{33}y_{L12}y_{L32} - U_{23}y_{L13}y_{L32} + U_{12}y_{L32}^2 + U_{23}y_{L12}y_{L33} \\ & - U_{12}y_{L22}y_{L33}) [f_1(y_{L13}y_{L22}y_{L31} - y_{L13}y_{L21}y_{L32} - y_{L12}y_{L31}y_{L32} + y_{L11}y_{L32}^2 \\ & + y_{L12}y_{L21}y_{L33} - y_{L11}y_{L22}y_{L33})]^{-1}, \end{aligned}$$

## Parametrization II

$$y_{R22} = m_{\nu 2} (U_{32} y_{L13} y_{L21} - U_{22} y_{L13} y_{L31} - U_{32} y_{L11} y_{L32} + U_{12} y_{L31} y_{L32} + U_{22} y_{L11} y_{L33} - U_{12} y_{L21} y_{L33}) [f_2(-y_{L13} y_{L21} y_{L32} + y_{L13} y_{L21} y_{L32} + y_{L12} y_{L31} y_{L32} - y_{L11} y_{L32}^2 - y_{L12} y_{L21} y_{L33} + y_{L11} y_{L22} y_{L33})]^{-1},$$

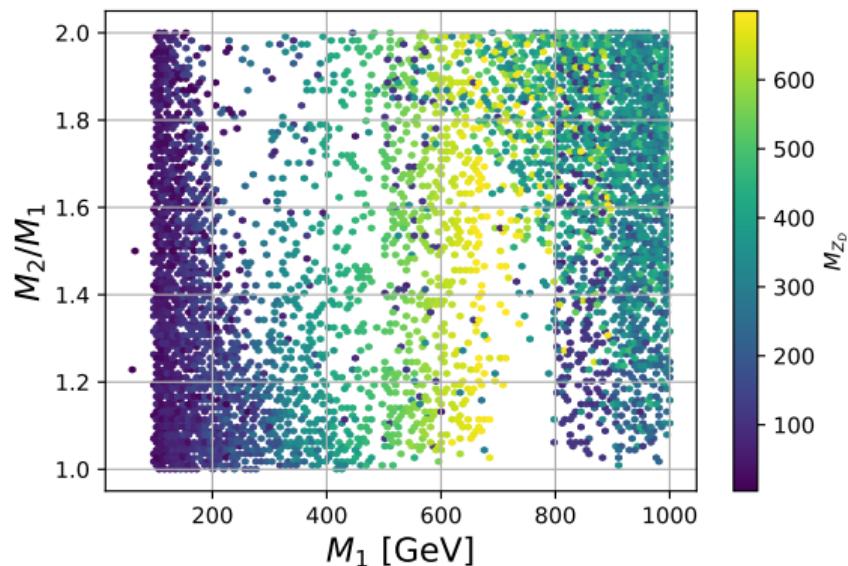
$$y_{R23} = m_{\nu 3} (U_{33} y_{L13} y_{L21} - U_{23} y_{L13} y_{L31} - U_{33} y_{L11} y_{L32} + U_{13} y_{L31} y_{L32} + U_{23} y_{L11} y_{L33} - U_{13} y_{L21} y_{L33}) [f_2(-y_{L13} y_{L22} y_{L31} + y_{L13} y_{L21} y_{L32} + y_{L12} y_{L31} y_{L32} - y_{L11} y_{L32}^2 - y_{L12} y_{L21} y_{L33} + y_{L11} y_{L22} y_{L33})]^{-1}$$

## Parametrization III

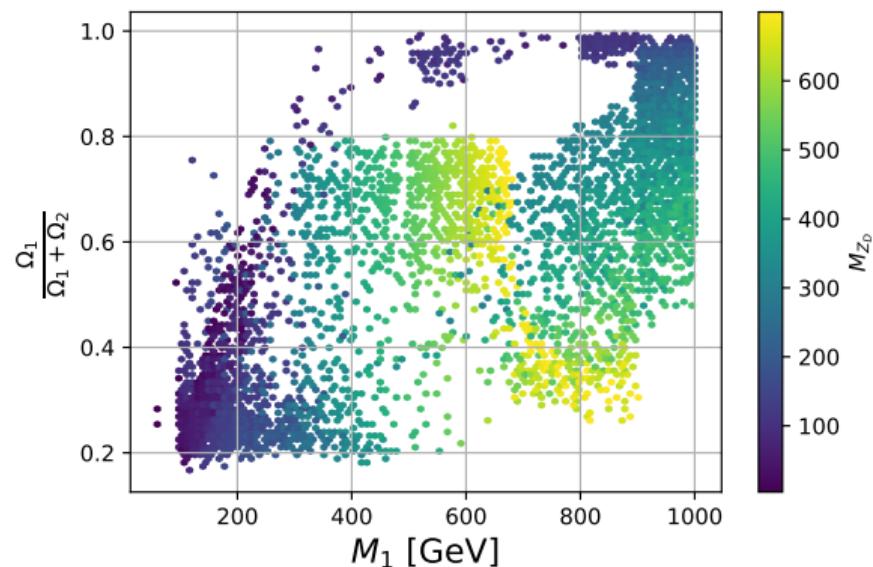
$$y_{R32} = m_{\nu 2} (U_{32} y_{L12} y_{L21} - U_{32} y_{L11} y_{L22} - U_{22} y_{L12} y_{L31} + U_{12} y_{L22} y_{L31} + U_{22} y_{L11} y_{L32} - U_{12} y_{L21} y_{L32})) [f_3(y_{L13} y_{L22} y_{L31} - y_{L13} y_{L21} y_{L32} - y_{L12} y_{L31} y_{L32} + y_{L11} y_{L32}^2 + y_{L12} y_{L21} y_{L33} - y_{L11} y_{L22} y_{L33})]^{-1},$$

$$y_{R33} = m_{\nu 3} (U_{33} y_{L12} y_{L21} - U_{33} y_{L11} y_{L22} - U_{23} y_{L12} y_{L31} + U_{12} y_{L22} y_{L31} + U_{23} y_{L11} y_{L32} - U_{13} y_{L21} y_{L32}) [f_3(y_{L13} y_{L22} y_{L31} - y_{L13} y_{L21} y_{L32} - y_{L12} y_{L31} y_{L32} + y_{L11} y_{L32}^2 + y_{L12} y_{L21} y_{L33} - y_{L11} y_{L22} y_{L33})]^{-1}.$$

# Parameter Space I



## Parameter Space II



# Conclusions

We propose a model with a multicomponent and multiflavor dark matter which allows the realization of an effective operator for Dirac neutrino masses. Furthermore, it has an extra Abelian gauge symmetry that is spontaneously broken and generates masses for particles in the dark sector and it is responsible for the stability of dark matter candidates. We explore the parameter space of the model and we analyze the impact of the constraint of the relic abundance of the candidates of dark matter.