MIXED SCALAR DARK MATTER AND DIRAC NEUTRINO MASSES IN AN EXTENDED B-L MODEL

Nimmala Narendra[1], *Subhasmita Mishra*[2], *Prafulla Kumar Panda*[3], *Nirakar Sahoo*[3]

[1] Physical Research Laboratory, Ahmedabad, India

[2] School of Applied Sciences, Centurion University of Technology, Odisha, India

[3] Department of Physics, Utkal University, Bhubaneswar, India

1.Introduction

- The standard model is augmented by an extra B-L gauge symmetry, B being the baryon number and L is the lepton number of the particle.
- The neutrinos get Dirac mass at one loop level.
- The dark matter emerges out as a mixed state of a singlet real scalar and the CP even component of a neutral doublet scalar, after the spontaneous break down of the symmetry of the model.

2.Model

- 3 right handed neutrinos ν_R having B-L charge -4,-4,5 are added as required for anomaly cancellation. Apart from these two vector like fermion doublets N_1, N_2 are also added in the fermion sector of the model.
- In the scalar sector a doublet scalar η, one complex scalar χ_2 and a real scalar χ_1 are added.
- The Yukawa Lagrangian including the new interaction is given as

$$L_{Yuk} = \sum_{\alpha,\beta=1,2} M_{N_{\alpha\beta}} \bar{N}_\alpha N_\beta + \sum_{\alpha=2,3}\sum_{\beta=1,2} y'_{\alpha\beta}\bar{N}_\beta \tilde{\eta}\nu_{R\alpha} + \sum_{\alpha=e,\mu,\tau}\sum_{\beta=1,2} y_\beta \bar{l}_\alpha \chi_1 N_\beta + h.c$$

- The χ_1 field and the neutral component of η mix with each other after the breaking of symmetry.

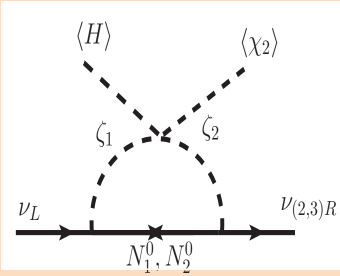
$$(\chi_1, \eta^0)\begin{pmatrix} M^2_{\chi_1} & \lambda_D v v_2 \\ \lambda_D v v_2 & M^2_{\eta^0} \end{pmatrix}\begin{pmatrix} \chi_1 \\ h^0 \end{pmatrix}$$

- In the mass basis
$$\zeta_1 = \cos\alpha\chi_1 + \sin\alpha\eta_0$$
$$\zeta_2 = -\sin\alpha\chi_1 + \cos\alpha\eta_0$$
- And the mixing angle
$$\tan 2\alpha = \frac{2\lambda_D v v_2}{M^2_{\eta^0} - M^2_{\chi_1}}$$
- An extra Z_2 symmetry is imposed to make the dark matter stable.

3.Neutrino Mass

- Two of the neutrinos get Dirac mass at one loop level as shown in the figure.
- The neutrino mass calculated as

$$(m_\nu)_{ij} = \frac{y_{ik} y'_{jk} M_N \sin\alpha\cos\alpha}{16\sqrt{2}\pi^2}\left(\frac{M^2_{\zeta 1}}{M^2_{\zeta 1} - M^2_N}\ln\frac{M^2_{\zeta 1}}{M^2_N} - \frac{M^2_{\zeta 2}}{M^2_{\zeta 2} - M^2_N}\ln\frac{M^2_{\zeta 2}}{M^2_N}\right)$$



- For a typical set of values

  y=y'=0.0005, M_N= 1000 GeV, sinα=0.01

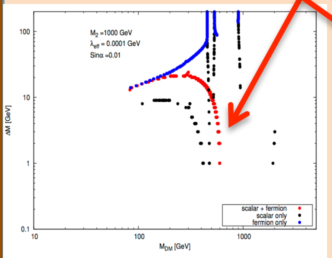
  $M_{\zeta 1}$ =800 GeV, $M_{\zeta 2}$ =810 GeV m_ν =0.1 eV

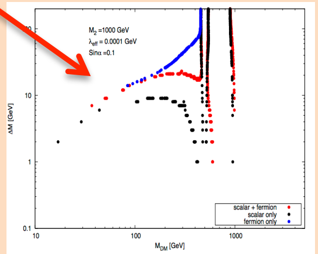
4.Dark Matter Phenomenology

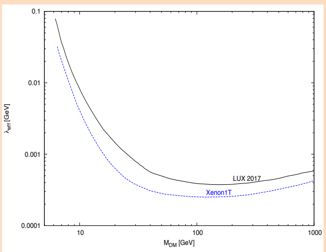
- ✓ The Z_2 stabilized lightest field ζ_1 which is a mixture of singlet and doublet scalars, serves as a viable dark matter candidate of the universe.
- ✓ The relic density is obtained including both the annihilation processes and the co-annihilation processes.
- ✓ The new odd sector particles η and N_1, N_2 plays an important role in relic density calculation but do not affect the direct detection cross-section.

Relic Density

Constraint from direct detection







5.Summary

- ❖ Neutrinos are massless at the tree level due to the non-trivial B-L charge of the right handed neutrinos. They get small Dirac Masses at one loop level.
- ❖ Dark matter relic density can be obtained in the small mixing angle limit.
- ❖ The coannihilation channels play an important role when the mass splitting is small between the dark matter and its coannihilating partner.
- ❖ The direct detection constraint is well satisfied by the model parameters.

6.References

1. E. Ma and O. Popov, Phys. Lett. B 764, 142 (2017), 1609.02538.
2. J. C. Montero and V. Pleitez, Phys. Lett. B675, 64 (2009), 0706.0473.
3. S. Kanemura, T. Nabeshima, and H. Sugiyama, Phys. Lett. B 703, 66 (2011), 1106.2480.

Acknowledgement

NS would like to thank RUSA 2.0, NHRD, India for financial support.