JOURNAL OF CRITICAL REVIEWS

ISSN- 2394-5125 VOL 08, ISSUE 02, 2021

A MODEL FOR DARK MATTER AND NEUTRINO MASS

Mr. Narinder Kumar[1], Dr.Pawanjit Kaur[2]
[1,2]Guru Kashi University, Talwandi Sabo

Abstract

The growing evidence for non-baryonic dark matter, as well as the groundbreaking neutrino oscillations and their implications for neutrino characteristics both point to the need for new physics that doesn't fit into the Standard Model. They looked at various blends of Majorana singlet fermions and Majorana trio fermions in that paper to check whether the new U(1)X measure balance could be utilized to make new kinds of things they introduce is anomaly-free. The origin of neutrino mass in these scenarios varies depending on the combination of these additional fermions. Here, we'll look at one of these models that we think is most relevant to our needs. However, in order to attain the desired phenomenology, we change the scalar sector of that model. It is feasible to make sense of the 3.55 keV X-beam line and the additional gamma beams at the focal point of the system from a similar dim matter source on the off chance that you utilize this abelian check model. There are two sorts of dull matter up-and-comers in the model: scalar and fermionic dim matter. We decide to zero in on fermionic dull matter applicants because they are more likely to help us understand the universe better aim.

Keywords: model, dark, matter, neutrino, mass, etc

1. INTRODUCTION

The growing evidence for non-baryonic dark matter, as well as the groundbreaking neutrino oscillations and their implications for neutrino characteristics both point to the need for new physics that doesn't fit into the Standard Model. The simplest way to think about matter in the Standard Model is to think about how three generations of fermions interact with each other through the exchange of SU(3) SU(2) U(1) measure bosons. Two of the main things to be familiar with rudimentary molecule physical science and current cosmology are the way neutrino masses and blending come to fruition, and how dull matter is so strange. A famous dull matter competitor in the structure of super symmetry is the Minimal Super symmetric Standard Model (MSSM), which is the lightest super symmetric molecule, usually a neutral no. This is what we've talked about before. It is stable because of the ad hoc symmetry that goes with R-parity conservation.

- The current state of neutrino oscillation:

The lepton mixing matrix, which has been known for a long time, is the most important tool for describing oscillations. There are new phases in this matrix that aren't found in the quark sector at all. This is because neutrinos are Majorana, which means they don't have any effect on oscillations that are normal. They are, however, very important when we talk about leptonnumber-violating events like neutrinoless double beta decay.The latter also emphasises the original symmetric parametrization's conceptual advantage over its PDG version.

- **Origin of neutrino mass:**

The source of neutrino mass is still unknown. Weinberg's dimension-five operator is on the left side of the screen Fig. 1 is the simplest way to get it.

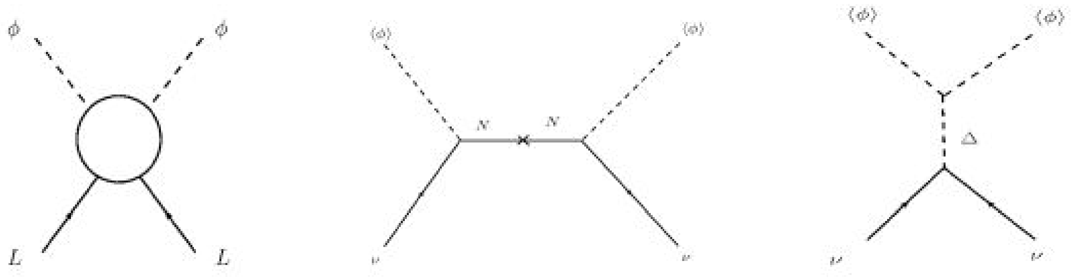

Figure 1: Weinberg operator and type-1/type-2 seesaw schemes

The seesaw is still a good way to explain why neutrinos have a small mass compared to other standard model fermions. This is because there is a large mass scale that is caused by lepton number violation. When two heavy neutrinos or heavy bosons are exchanged for each other or both, the effective neutrino masses get bigger. This is shown in the two middle panels of Fig. 1, where the effective neutrino masses are shown.

1.1 Dark matter in a three-loop radiative neutrino mass model

The finding existence of neutrino masses that are very small but not zero, as well as the presence of dim matter (DM) in the Universe, could assist us with observing new material science that doesn't fit the standard model (SM). Consolidating both things into a single framework has been getting a lot of attention recently. There are many different ways to think about the inert doublet model, but this is one of them. It makes one-circle neutrino masses by making the DM either an additional a scalar-doublet or a Majorana fermion that is stable because it has an accurate Z2. There are a lot of ways to make neutrino masses, but the neutrino mass scale is very small, so a lot of models have been proposed to make neutrino masses utilizing higher circle processes, similar to 3-circle processes with circle concealment (g2/162)3 1013, which is an electroweak-sized coupling) (v being electroweak scale). Krauss, Nasri, and Trodden (KNT) came up with an old model that had two charged scalar singlets and a right-given neutrino. In the interim, the model has a discrete balance that makes it difficult to sort out neutrino masses at the 3-circle level until new particles with masses on the request for TeV are utilized. Thusly, this model is intriguing on the grounds that it sees individuals' thought process. It's been discussed a great deal in the writing. Two singlets (one charged only once and the other twice) and a doublet (one charged only once, the other twice) make up the cocktail model to the SM, also shows the creation of 3-loop neutrino masses.

2. REVIEW OF THE LITERATURE

Amine Ahriche, Adil Jueid, and Salah Nasri (2021) We suggest extended version: A singlet Majorana particle can be used as dark matter (DM) in this letter, but it doesn't need to be very weakly coupled to another particle. For example, three singlet Majorana fermions are added to the Standard

Model, as well as one complex and real singlet scalar. The Z4 symmetry is broken into Z2 when the complex singlet scalar has a vev larger than the electroweak scale, which breaks the Z4 at that scale into Z2 at a scale greater than that of the electroweak scale. The cancellation of three diagrams a la scotogenic, which is a DM possibility that could be true for a wide range of mass, is used to get the small neutrino mass in this setting. The phenomenology is more detailed than the minimal scotogenic model.

Amine Ahriche, Adil Jueid, and Salah Nasri (2020) It's called the "scotogenic" modification, and it's a way to make the neutrino mass smaller. In this letter, we propose that the SM be extended by three single-particle Majorano fermions, an inert scalar doublet, and a real singlet calar. The neutrino mass is made smaller by cancelling three diagrams, like in the scotogenic model, and dark matter could be either the lightest Majorano fermion or a combination of both. This arrangement has a more complicated way of working than the simple scotogenic model.

Rukmani Mohanta, Shivaramakrishna Singirala, and Suchismita Sahoo (2019) A new way to look at dark matter is to look at it in a new version of a measure expansion of the Standard Model called the $U(1) L mu-L tau$ check augmentation. This new form adds three new unbiased fermions called "N e, N mu and N tau," as well as a $(bar3,1,1/3)$ scalar Leptoquark (SLQ) Lightest mass eigenstate of the $N mu, N tau$ nonpartisan fermions is called dim matter since it has very little mass. We sort out the WIMP-nucleon get segment and the artifact thickness through the idle doublet parts, the leptoquark, and the new $Zprime$ boson in the leptoquark entryway, as well as the artifact thickness. Limits on the Planck and PICO-60 cutoff points on turn subordinate direct location cross sections help us to limit the number of parameters that we can look at in this study. At the one-loop level, we also talk about how neutrino mass is created. We also talk about how to explain the current evidence for neutrino oscillations. In order to figure out what is going on, we need to look at the SLQ and the $Zprime$ gauge boson of extended $U(1)$ symmetry recognized difficulties in the flavor sector.

Li-Gang Jin, Rui Tang, and Fei Zhang (2015) It's because of the existence of Majorana fermionic dark matter, which is kept in place by Z2. This makes it possible for us to come up with a model that gives neutrinos very small masses at the three-loop level. As far as the model goes, the lightest neutrino doesn't have any mass. Our example shows a typical parameter choice. This one is good for a normal neutrino mass spectrum and dark matter with m50-135 GeV and a large Yukawa coupling as allowed by relevant experimental data. It means that subsequent e+e- collisions can look for new particles.

Jose Valle (2012) Dark matter and neutrino mass may have a close relationship. We examine the current state of neutrino oscillations, as well as neutrino mass creation strategies that propose dark matter candidates, briefly reviewing their features and potential direct/indirect/collider detection possibilities.

3. OBJECTIVES

- To study Dark matter in a three-loop radiative neutrino mass model.
- To analyze Singlet Fermion Dark Matter and Light Neutrino Mass.

4. RESEARCH METHODOLOGY

4.1 The Model

In that paper, the authors looked at various combinations of Majorana singlet fermions and Majorana triplet fermions to see if the new U(1)X gauge symmetry they introduce is anomaly-free. The origin of neutrino mass in these scenarios varies depending on the combination of these additional fermions. Here, we'll look at one of these models that we think is most relevant to our needs. However, in order to attain the desired phenomenology, we change the scalar sector of that model. The authors refer to this as model C, and table 2 shows the fermion concentration. Table 2 displays the model's scalar content after modification, and the third column provides the quantum numbers of fields that meet the anomaly matching conditions are called U(1)X quantum numbers. Table 2 shows how the charges of the scalar fields are chosen based on what you want to happen. Higgs content isn't just any old thing. It has to be this way because it allows for radiative neutrino masses and a residual Z2 symmetry in the way that was proposed.To satisfy the anomalous matching conditions, two more singlets S1R, S2R must be present. Charged leptons (v, e)L are linked to 2 and quarks to 1 in this model. (v, e)L also connects to NR, S1R, and 3R through 1 and 3R through 2. In order to make sure that all of the model's particles have mass, the extra five singlet scalars must be added. There are a lot of different types of particles in this list, and the Lagrangian that can be formed from them all has an automatic Z2 symmetry, which makes it a good candidate for cold dark matter under this Z2 symmetry. The scalar Lagrangian that will be discussed in the future can be represented as

$$V_s \supset f_3\chi 1\chi^{\dagger}{}_3\Phi^{\dagger}{}_1\Phi_3 + f_5\chi^{\dagger}{}_3\chi_4\Phi^{\dagger}\ 3\Phi_2 + f_6(\Phi^{\dagger}{}_1\Phi^{\dagger}{}_3)\chi_3\chi_5 \quad (1)$$

Table 1: Fermion Content of the Model

Particle	SU(3) c ×SU(2) L ×U(1) Y	U(1) X	Z2
(u, d)L	(3,2,1/6)	n1	+
uR	(¯3, 1, 2/3)	1/4(7n1 −3n 4)	+
dR	(¯3, 1, −1/3)	1/4 (n1 + 3n4)	+
(ν, e)L	(1, 2, −1 2)	1 (n1 + 3n4)	+
(ν, e)L	(¯3,1,– 1/2)	n4	+
eR	(1, 1, −1)	1/4(−9n1 + 5n4)	+
NR	(1,1,0)	3/8 (3n1 +n 4)	-
Σ1R,2R	(1,3,0)	3/8 (3n1 + n4)	-
S1R	(1, 1, 0)	1/4 (3n1 + n4) 8	+
S2R	(1,1,0)	−5/ 8 (3n1 + n4)	-

Table 2: Scalar Content of the Model

Particle	**SU(3) c×SU(2) L ×U(1) Y**	**U(1) X**	**Z2**
$(\varphi^+,\varphi^0)_1$	(1,2, −1/2)	3/4(n1 −n 4)	+
$(\varphi^+,\varphi^0)_2$	(1,2, −1/2)	1/4 (9n1 − n4)	+
$(\varphi^+,\varphi^0)_3$	(1,2, −1/2)	1/8 (9n1 − 5n4)4	-
χ1	(1,1,0)	−1/2 (3n1 + n4)	+
χ2	(1,1,0)	−5/4 (3n1 + n4)	+
χ3	(1,1,0)	−3/8 (3n1 + n4)	-
χ4	(1,1,0)	−3/4 (3n1 + n4)	+
χ5	(1,1,0)	(3n1 − n4)	+

Similarly, the model's relevant section of the Yukawa Lagrangian is expressed as

$$L_Y \supset y\bar{L}\Phi^{\dagger}{}_1 S_{1R} + hN\,\bar{L}\Phi^{\dagger}{}_3 N_R + h\Sigma\bar{L}\Phi^{\dagger}{}_3\Sigma_R + fN\,N_R N_R\chi_4 + f_S S_{1R}S_{1R}\chi_1 + f_\Sigma\Sigma_R\Sigma_R\chi_4 + f_{S2}S_{2R}S_{2R}\chi^{\dagger}{}_2 + f_{12}S_{1R}S_{2R}\chi^{\dagger}{}_3 \quad (2)$$

Let us write $<\emptyset^0{}_{1,2}>$ = v1,2 $<\chi^0{}_{1,2,4,5}>$ = u1,2,4,5 for the vacuum expectation values (vev) of various Higgs fields. The coupling constants of are also denoted $SU(2)_L$, $U(1)_Y$, $U(1)_X$ as g2, g1, gX respectively. The mass is acquired by the charged weak bosons.

$$M_W^2 = \frac{g_2^2}{2}(v_1^2 + v_2^2)$$

The masses of the neutral gauge bosons in the $(W^\mu{}_3, Y^\mu, X^\mu)$ basis is

$$M = \frac{1}{2}\begin{pmatrix} g_2^2(v_1^2+v_2^2) & g_1g_2(v_1^2+v_2^2) & M_{WX}^2 \\ g_1g_2(v_1^2+v_2^2) & g_1^2(v_1^2+v_2^2) & M_{YX}^2 \\ M_{WX}^2 & M_{YX}^2 & M_{XX}^2 \end{pmatrix} \quad (4)$$

Where

$$M_{WX}^2 = -g_2 g_X(\frac{3}{4}(n_1 - n_4)v_1^2 + \frac{1}{4}(9n_1 - n_4)v_2^2)$$

$$M_{YX}^2 = -g_1 g_X(\frac{3}{4}(n_1 - n_4)v_1^2 + \frac{1}{4}(9n_1 - n_4)v_2^2)$$

$$M_{XX}^2 = g_X^2(\frac{9}{4}(n_1-n_4)^2v_1^2+\frac{1}{4}(9n_1-n_4)^2v_2^2+\frac{1}{16}(3n_1+n_4)^2(4u_1^2+25u_2^2+9u_4^2)+(3n_1-n_4)^2u_5^2)$$

According to the above mass matrix, the If you want to make precise electroweak measurements, you need to keep the blending between the electroweak check bosons and the extra U(1)X boson very low. A very simple framework with no mixing between the electroweak gauge bosons and the extra U(1)X boson can avoid the tight mixing rule. Then, M2W X = M2Y X = 0, which means that the following is true restriction.

$$3(n4 - n1)v^2{}_1 = (9n1 - n4)v^2{}_2 \quad (5)$$

1 < n4/n1 < 9 If the U(1)X boson is discovered at the LHC, the n4/n1 ratio may be calculated empirically from its decay to $\overline{qq}$, $\overline{l}\,l$, and $\overline{vv}$. Quarks, charged leptons, and neutrinos are represented by the letters q, l, and n, respectively. In terms of the mass of the charged weak boson, we have

$$v_1^2 = \frac{M_W^2(9n_1 - n_4)}{g_2^2(3n_1 + n_4)}, \quad v_2^2 = \frac{M_W^2(-3n_1 + 3n_4)}{g_2^2(3n_1 + n_4)}$$

The neutral gauge bosons of the Standard Model have masses assuming zero mixing.

$$M_B = 0, \quad M_Z^2 = \frac{(g_1^2 + g_2^2)M_W^2}{g_2^2}$$

The photon and weak Z bosons are represented by these symbols. The mass of the U(1)X gauge boson is

$$M_X^2 = 2g_X^2(-\frac{3M_W^2}{8g_2^2}(9n_1-n_4)(n_1-n_4)+\frac{1}{16}(3n_1+n_4)^2(4u_1^2+25u_2^2+9u_4^2)+(3n_1-n_4)^2u_5^2) \quad (6)$$

5. RESULT AND DISCUSSION

5.1 Singlet Fermion Dark Matter

The Boltzmann equation determines a dark matter particle's relic abundance.

$$\frac{dn_\chi}{dt} + 3Hn_\chi = -\langle\sigma v\rangle(n_\chi^2 - (n_\chi^{eqb})^2) \quad (7)$$

Where nχ is the number thickness of the dim matter molecule, and neqb is the number thickness when the molecule was in balance. A dim matter molecule's destruction cross-segment is called v, and H is the rate at which the Universe is expanding. v> = a + bv2 when it comes to the expansion of partial waves The Boltzmann equation is numerically solved as follows:

$$\Omega_\chi h^2 \approx \frac{1.04 \times 10^9 x_F}{M_{Pl}\sqrt{g_*}(a + 3b/x_F)} \tag{8}$$

Where xF = mχ/TF, TF is g∗ is the quantity of relativistic levels of opportunity at the hour of freeze-out, and t is the freeze-out temperature. At temperatures in the reach xF ≈ 20 − 30, dull matter particles with electroweak scale mass and couplings freeze out. In general, the relation can be used to calculate x_F.

$$x_F = \ln \frac{0.038 g m_{PL} m_\chi < \sigma v >}{g_*^{1/2} x_f^{1/2}} \tag{9}$$

Where g denotes the dark matter particle's intrinsic degrees of freedom χ

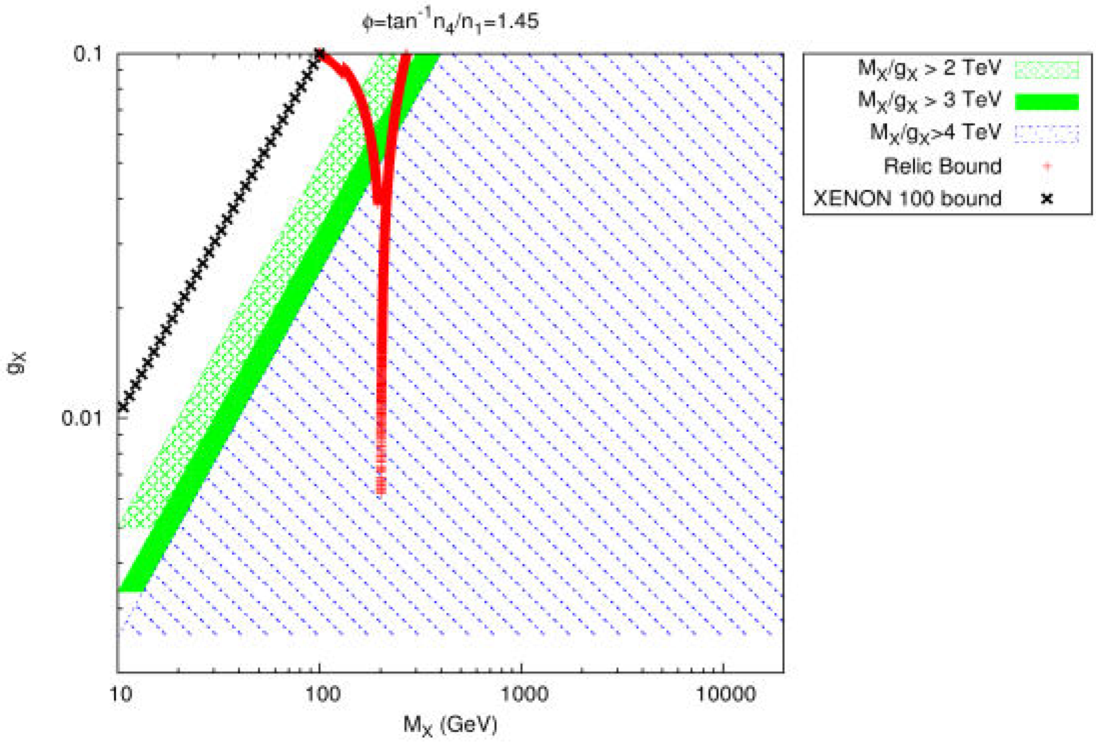

Figure 2: Parameter space in the gX − MX plane for mS$_{2R}$ = 100 GeV and mNR − mS$_{2R}$ = 3.55 keV. The green-hatched, green and blue dot-dashed regions correspond to the allowed region after the constraints on MX/gX are imposed. The area to the left of the black line is ruled out by XENON100 bounds on direct detection cross section. The solid red region corresponds to the parameter space favored by the relic density constraint

The 90% certainty level prohibition on MX/gX was determined utilizing standardization, and the least passable worth of MX/gX was viewed as approximately 2 TeV for φ = tan−1(n4/n1) = 1.5.We can determine both n1 and n4 using this and the normalisation relation involving n1 and n4. Because all U(1)X gauge charges are stated in terms of n1, n4, choosing Just these two numbers are enough to figure out all gauge charges. GX and u are changed and we change the dark matter density for each dark matter candidate individually after we have set the mass and number of relics. We then calculate the relic density of each candidate for dark matter individually.

5.2 Light Neutrino Mass

Through the Feynman diagram presented in figure 3, small a lot of things can happen on both the tree and loop level. To get a Dirac mass term for neutrinos, only S1R gives rise to this term. This means that only one of them gets a non-zero mass at a tree level through the type I seesaw process because v1 is the only thing that gives rise to this term. The Dirac mass term can be used to write the light neutrino's mass in terms of trees. and the mass of the heavy singlet neutrino S1R ($M_{S1R} = f_S u_1$) can be expressed as

$$m_\nu \approx \frac{2y^2 v_1^2}{f_S u_1} \quad (10)$$

Figure 3 shows that the allowable region from dark matter and collider limitations suggests u1 = u2 = u4 = u5 = u ≳ 2 TeV, so we have taken u1 ≈ 5 TeV and fsu1 ≈ 2 TeV. Since v1 ∼ 100 GeV, the Yukawa couplings y should associate with 3 × 10−6, which is generally equivalent to the electron Yukawa coupling in the SM, for light neutrino masses to be on the sub-eV scale, as indicated by condition (10) Only when the circle commitments in figure 3 are considered would the other two SM neutrinos be able to procure non-zero masses. As recently expressed, the one-circle commitment to neutrino mass (Mv)ij is given by

$$(M_\nu)_{ij} \approx \frac{f_3 f_5 v_1 v_2 u_1 u_4}{16\pi^2} \sum_k h_{N,\Sigma_{ik}} h_{N,\Sigma_{jk}} \left(A_k + (B_k)_{ij}\right) \quad (11)$$

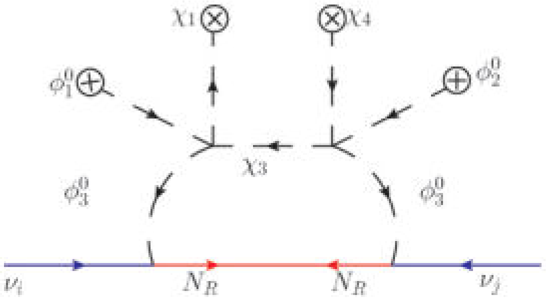

Figure 3: Neutrino mass at one loop level

Assuming that all of the scalar masses in the loop diagram are almost degenerate and are denoted as msc,

$$A_k + (B_k)_{ij} \approx m_{2k} \left[\frac{m_{sc}^2 + m_{2k}^2}{m_{sc}^2 \left(m_{sc}^2 - m_{2k}^2\right)^2} - \frac{(2-\delta_{ij})\, m_{2k}^2}{\left(m_{sc}^2 - m_{2k}^2\right)^3} \ln\left(m_{sc}^2/m_{2k}^2\right) \right] \quad (12)$$

Where $(M_{N,\Sigma})_k = m_{2k}$. M2k≪msc and so the preceding expression can be approximated for fermion singlet light dark matter as

$$A_k + (B_k)_{ij} \approx \frac{m_{2k}}{m_{sc}^4}$$

The mass of a single-loop neutrino can be represented as

$$(M_\nu)_{ij} \approx \frac{f_3 f_5 v_1 v_2 u_1 u_4}{16\pi^2} \sum_k h_{N,\Sigma ik} h_{N,\Sigma jk} \left(\frac{m_{2k}}{m_{sc}^4}\right) \quad (13)$$

Taking u1, u4 to be at 5 TeV and msc ≈ 500 GeV, v1, v2 at At 100 GeV, the singlet mass m_{2k} is on the electroweak scale.

It's worth noting that the proper explanation for the Gamma ray excess from the galactic centre can be found if one examines the following factors mNR ≈ mS2R ≈ m_{2k} = 35 GeV.

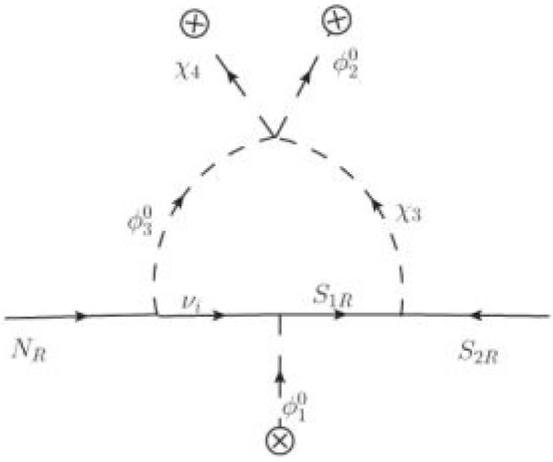

Figure 4: Mass splitting between NR and S2R at one loop level

If two dark matter competitors have keV mass parting, they could make the 3.55 keV X-beam line while meeting exploratory cutoff points on dim matter artifact thickness and direct identification cross area. For this situation, a dull matter molecule that is a fermion singlet will self-destruct into SM particles through an abelian vector boson. A portion of these things are additionally considered, similar to the collider limitations on an additional a vector boson and its check coupling. This is in spite of the way that the artifact thickness and direct location limitations take into account a great deal of boundary space. As far as possible put the boundary space in the s-wave reverberation region, where the check boson mass is almost double that of dull matter. It settles the score more tight by adding a X-beam line information bound on the rot width of the heavier dim matter molecule. Then, at that point, we check whether a similar model can make sense of the additional gamma beams seen by the Fermi Gamma Ray Space Telescope at the centre of the galaxy. This is similar to dark matter annihilation. When we are done, we check to see if the dark matter masses we chose are in line with neutrino masses that are less than a few electrons in length whether a keV scale mass splitting between two electroweak scale singlet fermion dark matter particles is possible.

6. CONCLUSION

It is feasible to make sense of the 3.55 keV X-beam line and the additional gamma beams at the focal point of the cosmic system from a similar dull matter source assuming you utilize this abelian check model. There are both scalar and fermionic dim matter applicants in the model; in any case, we may be taking a gander at the dim matter up-and-comers that have fermionic properties since they will better assist us with accomplishing our objective. After the abelian measure evenness is broken unintentionally, the dim matter competitor makes certain to remain stable due to a Z2 balance that was left finished. Lightest Z2 odd molecule (S2R) and lightest Z2 odd molecule NR, both singlet fermions, are remembered to make up the dull matter. This would make sense of the 3.55 keV line in X-beams. The two of them have a mass contrast of 3.55 keV, which lets one of them rot into the other and a photon at circle level.

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