

Some comments on an MeV cold dark matter scenario

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ABSTRACT: We discuss several aspects of astroparticle physics pertaining to a new model with MeV cold dark matter particles, which annihilate to electron-positron pairs in a manner yielding the correct CDM density required today, and explaining the enhanced electron-positron annihilation line from the center of the Galaxy. We note that the mass of the vector meson mediating the annihilations, should exceed the mass of CDM particle, and comment on possible enhancement due to CDM clustering, on the detectability of the new CDM, and on particle physics models incorporating this scenario.

KEYWORDS: Cosmology of Theories beyond the SM, Beyond Standard Model.

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1. Introduction

The possibility that cold dark matter (CDM) consists of \sim MeV scalar particles χ 's with cross-sections of $\sim 8 - 10$ pb at the freeze-out epoch for annihilating into electron positron pairs has attracted much attention lately (see, e.g., [1–14] and references therein). If the annihilation proceeds via an intermediate vector state, then its rate is proportional to the velocity squared. The reduced rate today can then reconcile the correct freeze-out density and the excess of the 511 keV annihilation line from the galactic center [15, 16].

The new $U(1)'$ abelian gauge interaction whose vector boson U is responsible for the annihilation in the above scenario ties in with earlier considerations of a light, weakly interacting new vectors [17–20]. While there have been extensive studies of the prospects and limitation of the new scenario from both astrophysics and particle physics points of view, we found a few points that to our knowledge have not been discussed before, and which we present in the following.

2. Lower bound on the U mass

The lower limit on the prospective CDM particle mass:

$$m_\chi > m_e \tag{2.1}$$

is required to kinematically allow the annihilation $\chi\chi \rightarrow e^+e^-$. This process, however, is accompanied by the process $\chi\chi \rightarrow e^+e^-\gamma$, which is due to electromagnetic radiative corrections. Thus, a more subtle upper bound [8]:

$$m_\chi < 20 \text{ MeV} \tag{2.2}$$

ensues by requiring that the radiative emission of an extra photon from the final electron in CDM annihilation will not yield too many energetic photons violating bounds from EGRET and COMPTEL.

An even more stringent upper bound [21]

$$m_\chi < 3 \text{ MeV} \tag{2.3}$$

results from the fact that a small fraction of the energetic positrons will annihilate to produce energetic gamma rays. Similar considerations with different assumptions about the ionization state of the interstellar medium in [22] lead to a more relaxed bound of $m_\chi < 7.5 \text{ MeV}$.¹

For the rest of this paper, unless stated otherwise, we will use the more relaxed upper bound from eq. (2.2) and set $m_\chi = 10 \text{ MeV}$.

The required $\chi\chi \rightarrow e^+e^-$ annihilation cross section at freeze-out is given by:

$$v_\chi \sigma_{\text{ann}} \simeq \frac{2}{3\pi} v_\chi^2 G'^2 m_\chi^2 \sim 10 \text{ pb}, \tag{2.4}$$

with $v_\chi^2 \sim 0.05$ at freeze-out (see eq. (2.12)), and fixes

$$\frac{g'_e g'_\chi}{(m_U^2)} = G' > 10^3 G_F \sim 10^{-2} \text{ GeV}^{-2}, \tag{2.5}$$

where g'_e and g'_χ are the coupling constants of the new U boson to the electron and the CDM particle. The definition of G' holds for situations when the total center of mass energy squared, s , is lower than m_U^2 which is exactly what our new inequality eq. (2.8) implies in the case of the $\chi\chi$ annihilations.

To minimize the effects of U exchange in the well-studied electron sector one assumes that:

$$g'_\chi \gg g'_e \tag{2.6}$$

and also that the new χ particle has no coupling to the Z boson to agree with the Z decay data from LEP. To maintain a small g'_e and a perturbative picture with $g'_\chi < 1$ one usually further limits:

$$m_U < \mathcal{O}(1 \text{ GeV}). \tag{2.7}$$

¹We would like to thank John Beacom for bringing this to our attention.

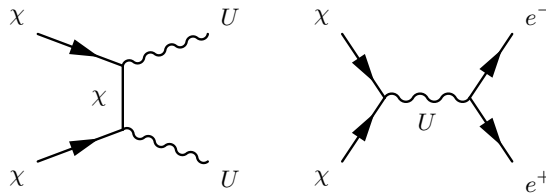


Figure 1: t -channel decay into U bosons and s -channel decay into electrons.

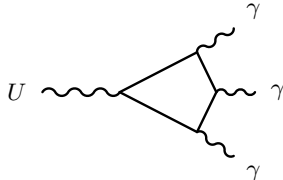


Figure 2: U decay into three photons

We would like to point out that the CDM scenario of the form discussed so far also requires an additional mass bound:

$$m_U > m_\chi \quad (2.8)$$

which becomes stronger when m_χ approaches the previous, upper bound on m_χ (eq. (2.2)). The argument for the new bound is straightforward: If $m_U < m_\chi$, the CDM annihilation into two U bosons via χ exchange in the t channel is much faster than annihilation into e^+e^- (figure 2). The first cross section is proportional to $g'_\chi{}^4$, and the second to the much smaller $g'_\chi{}^2 g_e'^2$. Also the two U 's annihilation is *not* suppressed by the p-wave v_χ^2 factor and completely dominates the annihilations in the halo at the present time.

Since the χ 's and the U 's stay in thermal equilibrium in the early universe until the freeze-out temperature

$$T_F = \frac{m_\chi}{x_F}, \quad (2.9)$$

where $x_F \sim 18$ for a 10 MeV particle [5], the χ abundance will be drastically suppressed relative to that of the U 's:

$$\frac{n_\chi}{n_U} \sim e^{-(m_\chi - m_U)/T_F} \ll 1. \quad (2.10)$$

The U particles in turn quickly decay and cannot serve as CDM. If $m_U > 2m_e$, then the decay $U \rightarrow e^+e^-$ occurs at times shorter than a millisecond (even for $g_e'^2 < 10^{-16}$). If $m_U < 2m_e$, U still decays into three photons via an electron box diagram (figure 2). Thus, if the new bound we suggest is violated we lose the CDM altogether.

Further difficulties arise from considering the present day 511 keV positron annihilation line. For $m_U > 2m_e$ with practically instantaneous $U \rightarrow e^+e^-$, the rate of positron production is controlled by $\chi\chi$ annihilation into UU . A substantial cross section for this annihilation is fixed by demanding a correct relic χ density.

Since this cross section is *not* suppressed by the v^2 p-wave factor, the resulting 511 keV line from the galactic center will be too strong.

For a p-wave annihilation at the freeze-out epoch

$$\sigma v = a + bv^2 = bv^2 \sim \mathcal{O}(10 pb), \quad (2.11)$$

which implies $b \sim 200 pb$ for

$$v^2 \sim \frac{T_F}{m_\chi} \sim \frac{1}{20}. \quad (2.12)$$

For velocities typical to the center of the galaxy ($v_\chi^2 \sim 10^{-6}$) the cross-section becomes

$$\sigma v \sim \mathcal{O}(10^{-4} pb). \quad (2.13)$$

When there is no p-wave suppression the cross-section is approximately velocity independent, thus dark matter particles annihilating to two U' bosons will yield a 511 keV flux which is $\sim 10^5$ larger than observed.

In the case of $m_U < 2m_e$ we have no 511 keV line but rather a continuum from the $U \rightarrow 3\gamma$ process.

We may have a consistent cosmology *and* present day annihilation line with

$$2m_e < m_U < m_\chi \quad (2.14)$$

if we finely tune g'_e to extremely tiny values (10^{-28}) thereby explaining the annihilation line excess via the ultra-slow decay of the U particles. This, however results in very large values of g'_χ (much larger than one), according to eq. (2.5), rendering perturbative calculations invalid.

3. CDM clumping and enhanced annihilation rates

The rate of annihilation of dark matter is proportional to the square of its local number density. It scales as $n_\chi(r)^2$ and generally is enhanced by DM clustering. Indeed the enhancement of the 511 keV annihilation line from the galactic center is a basic feature of the present MeV CDM scenario. The DM density n_χ is maximal and the resulting positrons can be brought to rest there.

However, CDM is clumpy, forming structures on many smaller scales. Will the rate of mutual annihilation of CDM particles within any such smaller structure be enhanced as well?

We note here that when the annihilation rate is suppressed by the v_χ^2 , p-wave factor, this may *not* be the case. This is relevant for the MeV CDM scenario discussed here and even more so to certain variants of LSP (lightest SUSY partner) CDM. The smaller mass, yet denser, CDM “mini-haloes” form first and larger structures incorporating the previous clusters as well as some unclustered CDM particles form next. While the latter, bigger structures have lower densities, they have larger escape velocities, as required in order to “bind” unclustered particles which would escape from the smaller, earlier, structures.

The relative velocity of any pair of CDM particles within the *same* mini-halo is of the order of the (small) escape velocity from this mini-halo. The resulting $v_{rel}^2 \sim v_{escape}^2$

suppression factor tends to overcome the n_χ^2 enhancement of the annihilation rate of pairs of CDM particles from the same mini-halo.

An extreme example illustrating our point is provided by the 10^{-6} solar mass mini-haloes of size ~ 0.01 parsec numerically computed [23] and theoretically estimated for the case of heavy LSP CDM particles.

The average density in these mini-halos, $\sim 10 \text{ GeV}/(\text{cm})^3$, is ~ 100 times larger than the halo density near the center of the galaxy, so that in the absence of the p-wave suppression factor the annihilation rate there would be 10^4 times larger. However, the escape velocity from the mini-halo

$$v_{\text{M.H.}} = \sqrt{G_N \frac{M_{\text{M.H.}}}{R_{\text{M.H.}}}} \sim 10^2 \text{ cm/sec} \tag{3.1}$$

is 1/300,000 times smaller than the virial velocity in the galactic halo

$$v_{\text{G.H.}} \sim 3 \cdot 10^7 \text{ cm/sec.} \tag{3.2}$$

In the presence of a v^2 factor the rate of annihilation of CDM particles from the same mini-halo is smaller than the average annihilation rate in the galactic halo by a factor:

$$\left(\frac{v_{\text{M.H.}}}{v_{\text{G.H.}}}\right)^2 \left(\frac{\rho_{\chi(\text{M.H.})}}{\rho_{\chi(\text{G.H.})}}\right)^2 = 10^{-7} \tag{3.3}$$

where we used the fact that the CDM mass fixes the ratio particle number and mass densities. This feature persists in higher structures though to lesser and lesser degree.

Thus, envision a fractal geometric pattern for successively larger structures. The second generation objects just next to smallest mini-haloes, have masses: $M_2 = a \cdot M_1 = a \cdot 10^{-6} M_\odot$ and radii $R_2 = b \cdot R_1 = b \cdot 10^{-2}$ pc; likewise, $M_3 = a \cdot M_2$; $R_3 = b \cdot R_2$, etc., all the way to $M_N = M_{\text{G.H.}} \sim 10^{12} M_\odot$ and $R_N = R_{\text{G.H.}} \sim 50$ kpc. The rates of annihilations in successive structures also form then a geometric progression with the ratio a^3/b^7 which should be larger than unity, leading to a gradual increase of same cluster annihilation rate all the way from the smallest mini-haloes to the galactic halo. (To account for the fact that the density of the clusters decreases in each generation, $a/b^3 < 1$, we need the relation $b^2 < a < b^3$, which should hold for each generation separately).

It should be emphasized that the annihilation of CDM particles within a particular cluster with CDM particles coming from the galactic halo at large are not affected by the clustering. The relative velocities are then typical galactic halo velocities and the long time average density seen by the external particle is that of the galactic halo as a whole as well.

Thus, in the presence of the p-wave suppression v_χ^2 factor the only effect of clustering is heterogeneous annihilations occurring more frequently in the denser regions. If the products are directly observable energetic gamma rays this can still help in identifying the CDM.

4. Can MeV CDM particles manifest in underground detectors?

The underground cryogenic detectors, optimized for detection of WIMPS of masses larger than $\sim 100 \text{ GeV}$ do not constrain the proposed MeV CDM scenario: The χ particle can

only deposit energies which are much below the $\mathcal{O}(\text{keV})$ detection threshold of the large bolometric devices.

Thus, in a collision with an electron the recoil energy (integrating over all possible incident angles) is

$$E_{\text{recoil}} \sim 2 \cdot \frac{1}{2} m_e \cdot v_\chi^2 \sim \frac{1}{2} eV \quad (4.1)$$

for the standard $3 \cdot 10^7$ cm/(sec) galactic halo virial velocity. (If the electron is bound by more than 1/2 eV then the whole atom recoils with much smaller energies). The rate of $\chi - e$ collisions is far larger than that of the usual $M_\chi \sim 100$ GeV WIMPs. This stems in part from the $M_\chi/(m_\chi) \sim 10^4$ larger number density and flux of the MeV CDM. Also the $\chi - e$ collisions generated by the “crossed” Feynman diagram with the U exchanged in the t channel have larger cross sections. Thus using eq. (2.4), removing the $(v_\chi)^2 \sim 1/20$, p-wave suppression factor and introducing the kinematical factor $[m_e/m_\chi]^2 \sim 2.5 \cdot 10^{-3}$ yields:

$$\sigma_{\chi e \rightarrow \chi e} v_\chi \sim \mathcal{O}(0.5 \text{ pb}). \quad (4.2)$$

The resulting elastic collision rate is then:

$$n_\chi v_\chi \sigma_{\chi e \rightarrow \chi e} \cdot n_{\text{free electrons}} \sim 100 \frac{\text{events}}{\text{gr} \cdot \text{day}} \quad (4.3)$$

where $m_\chi = 10$ MeV leads to a local CDM density n_χ of 10 particles/(cm)³ and we estimated $10^{22} \sim 10^{-2} N_{\text{Avogadro}}$ “free” electrons per gram since only valence electrons within 1/2 eV from the Fermi energy surface can scatter. The relatively large number of expected collisions suggests using much smaller bolometric devices with correspondingly lower thresholds. The detection in this case is not based on nucleon recoil as in the case of heavy WIMPs, but rather on ionization, which is easier to detect.

Using the more stringent upper bound for m_χ from eq. (2.3) and setting $m_\chi = 3$ MeV leads to ~ 4000 event per gram per day.

Since we rely directly on $\chi\chi \rightarrow e^+e^-$ annihilation rate which is fixed by the present CDM scenario and the only further theoretical input is crossing, the estimates of the number of χ electron collisions are robust, making efforts to look directly for such CDM most worthwhile.

5. $U'(1)$ charge conservation, the stability of χ and $U - Z$ mixing

The most important requirement of any DM candidate is that it will be stable, or at least have a lifetime exceeding $t_{\text{Hubble}} \sim 5 \cdot 10^{17}$ sec. In the present case we have even a stronger bound on the partial width of the putative $\chi \rightarrow e^+e^-$ decay. Unless

$$\Gamma(\chi \rightarrow e^+e^-) < 10^{-28} \text{ sec}^{-1} \quad (5.1)$$

the presently decaying χ 's would generate a 511 keV annihilation line which exceeds the one observed.

The dimensionless effective $\chi e_L \bar{e}_R$ coupling f needs then to be smaller than $\sim 10^{-24}$ to ensure this bound. A nice feature of the present CDM model is that the conservation of the new $U'(1)$ charge could ensure the stability of χ if χ is the lightest particle carrying the specific $U'(1)$ charge g'_χ .

The electron also carries a charge g'_e . However, $U'(1)$ charges need not be quantized and, indeed, phenomenology demands that $g'_\chi \gg g'_e$ which automatically guarantees the stability of CDM. While there must be a spontaneous breaking of the local $U'(1)$ to provide mass — via a Higgs mechanism — to the associated gauge boson U, no renormalizable trilinear vertex can violate $U'(1)$.

This last feature is a source of considerable difficulty with models in which the new $U'(1)$ is not vectorial. An example of the latter is purely $U'(1)_R$ “minimalistic” model [3] where the doublet (e_L, ν_L) and all quarks and leptons (other than e_R) are assumed to be $U'(1)$ neutral. We recall the following mixing argument [24–26, 14]:

Any Higgs couplings $g_e H e_L \bar{e}_R$ implies that the Higgs in question — the standard model Higgs or another Higgs doublet \tilde{H} must also carry a $U'(1)$ charge $g' = g'_{e_R}$ to match that of e_R . An additional Higgs is required in supersymmetric theories and could, in principle, also provide the U mass (the single Higgs H^0 of the standard model accounts for only one longitudinal degree of freedom and makes only one gauge boson, namely, the Z^0 , massive).

Since the weak doublet \tilde{H} couples to both Z and U bosons we find a 2×2 (Z,U) mass² matrix:

$$M^2 = \begin{pmatrix} g^2 v^2 + g'^2 \tilde{v}^2 & gg' v \tilde{v} \\ gg' v \tilde{v} & g'^2 \tilde{v}^2 \end{pmatrix} \quad (5.2)$$

where g and $v = 246$ GeV are the ordinary weak coupling and Higgs vacuum expectation value. Diagonalizing the mass matrix yields a physical Z with essentially the same mass of gv and a tiny irrelevant admixture of U.

The important point is that the physical U is now:

$$U_{\text{Phys}} = U + [\tilde{v}g'/vg] \cdot Z \equiv U + \epsilon Z. \quad (5.3)$$

and has a “see-saw” like mass:

$$m_{\text{Phys}}(U) = \frac{g'^2 \tilde{v}^2}{m_Z}. \quad (5.4)$$

The Z “masquerading” as the light U contributes too much to processes such as $\nu - e$ scattering unless:

$$\epsilon = \frac{\tilde{v}g'}{vg} < \frac{m_U^2}{m_Z^2} \cdot 10^{-2}, \quad (5.5)$$

where the last factor is roughly the precision to which the standard model Z exchange correctly describes low energy neutrino electron scattering.

If we have only one Higgs (in which case, all right-handed fermions have $U'(1)$ charges equal to g') the last upper bound (and others coming from considering atomic parity violating experiments [4]) would too strongly limit g' making the CDM model untenable. Thus we need to take $\tilde{H} \neq H$ and

$$\tilde{v} \sim GeV \ll \langle H \rangle = v = 246 GeV. \quad (5.6)$$

Also, since $g' < 10^{-2}$, the above U mass, is too small violating our bound of eq. (2.8).

To generate the required U mass we need then an additional new $U'(1)$ carrying boson taken for simplicity as an $SU(2)_L$ singlet, ϕ , with a vev $\langle\phi\rangle$ such that $m(U) = g'_\phi \langle\phi\rangle$. We cannot use the CDM particle χ itself for this purpose since the Higgs mechanism leaves us with just one real, self charge conjugate, scalar which will not couple to the vector U.

The need to have $U'(1)$ charged Higgs doublets and ensuing $Z - U$ mixing is avoided if $U'(1)$ is vectorial. The right- and left-handed fermions carry then the same $U'(1)$ charges and the Higgs stays $U'(1)$ neutral.

6. Anomalies and “Hard” $F_{(\mu\nu)}^{em} F'_{(\mu\nu)}$ mixing

The cancelation of all triangular $V_\alpha V_\beta A_\gamma$ axial anomalies is required in any gauge theory. For $SU(3) \times SU(2) \times U(1)$ with the standard assignment of hypercharge and weak isospin, all anomalies cancel in each generation separately. (Indeed, with one extra right-handed neutrino the 16 fermions in each generation form a representation of the anomaly free $SO(10)$ group.)

If the new $U'(1)$ is not purely vectorial, many additional $U'(1)^3$, $U'(1)U_Y^2$, $U'(1)U_{em}^2$, etc., anomalies arise; the cancelation of which requiring extra, electrically charged fermions. For vectorial $U'(1)$ we have only $U'(1)^2 U_{SM}$ type anomalies which cancel if $U'(1)$ couples equally to all fermions or like $B - L$.

In principle we need also to worry about “hard” $U - \gamma$ mixing generated via the electron loop. Unless the logarithmically divergent part is canceled, an $F \cdot F'$ mixing would be generated. This $U - \gamma$ mixing makes mini-charged χ 's and CDM, with many additional problems. A mixing of two $U(1)$ gauge groups is avoided if the latter are embeddable in a large Lie group with the quarks and leptons forming an irreducible representation of the latter. The cancelation of the divergent parts of all mixings, namely, $Tr(Q_\alpha Q_\beta) = \delta_{\alpha\beta}$ is then automatic.

It will also happen here if, as suggested in [4], the $U'(1)$ couples universally to all fermions as then the cancelation conditions $Tr(Q_{em}) = 0$, etc., are all satisfied.

7. Can the new U mesons be searched for in hadronic machines?

If the new U vector meson couples equally to quarks and leptons (in a given generation) as the above arguments may suggest, then low energy high current proton beams on a fixed target set-up may provide ideal hunting grounds for the new U vector. If $m_U < m_\pi$ we can work below pion threshold and look for, say, $pp \rightarrow pp U$ with the U decaying into e^+e^- .

Further, if $m_U < 2m_\chi$, the invisible decay mode, $U \rightarrow \chi\chi$, which would otherwise dominate by $\sim 10^6$ factor or more is absent. Altogether this set-up would then have much higher statistics and far smaller radiative QED “trident” diagram contributions than in e^+e^- colliders or e^-p experiments.

8. Is there a consistent $SM \times U'(1)$ model for the MeV CDM scenario?

The absence of dangerous $U - Z$ mixing and anomalies strongly suggest $U'(1)_V$. However, in that case an $SU(3) \times SU(2)_L \times U(1) \times U'(1)_V$ implies that the $U'(1)$ vector boson couples to e_R, e_L and the other member of the $SU(2)_L$ doublet $\nu(e)_L$ with the same coupling

$$g'_e = g'_\nu \equiv g', \tag{8.1}$$

which, as pointed out by several authors, entails various difficulties.

At energies

$$s = 2m_e \cdot E_\nu \sim (10 \text{ MeV})^2 \tag{8.2}$$

neutrino-electron scattering has been studied with precision in accelerators. The U exchange amplitude $\sim g'^2/(m_U)^2$ (for an assumed $s < m_U^2$) should be smaller than $\sim 1\%$ of the weak amplitude G_F (the precision level). Comparing this with our required $g'_e g'_\chi / (m_U)^2 > 10^3 G_F$ (eq. (2.5) above), this implies that $g'_e/g'_\chi < 10^{-5}$.

The authors of ref. [9] pointed out also a qualitative astrophysical argument which tends to strongly exclude a vectorial $U'(1)_V$. The argument runs as follows: The bound

$$m_\chi < 20 \text{ MeV} \tag{8.3}$$

implies that these CDM particles will be abundantly produced in a supernova collapse. The scattering cross sections of χ off both electrons and neutrinos are (at least) $\sim 10^6$ times larger than the typical weak ($G_F^2 E^2$) cross sections at these energies. Hence, the χ 's will be trapped by the electrons and, in turn, trap the neutrinos. This yields longer cooling times and lower energies of the emitted neutrinos than what was observed for supernova SN 1987(a).

Our bound $m_U > m_\chi$ only strengthens this argument: as we push to higher m_χ to suppress the number of these problematic particles in the core of the supernova, m_U becomes larger and possible reductions of the $e - \chi$ and $\nu - \chi$ cross sections by the U propagator for energies $E > m_U$ do not occur in the supernova core.

9. Could the new U boson be associated with a “Horizontal” gauge group?

Optimally the new U boson and new $U'(1)$ would match some expectations of specific new physics beyond the standard model. The fact that Fayet has anticipated a new light U and associated $U'(1)_V$ some time ago in a particular SUSY setting is very intriguing.

Here we would like to comment on the possibility that the new U boson is associated with a gauged horizontal symmetry group. Indeed, the dynamics of the three families and their mass pattern is an outstanding puzzle which has prompted considering Horizontal groups (H.G.'s - see for instance [27]). These groups must be spontaneously broken. For global H.G. the resulting massless Goldston “Familons” could manifest in $K \rightarrow \pi +$ “missing zero mass particles” or similar muon to electron decays. This then implies very severe bounds ($F_H > 10^{10} \text{ GeV}$) on the symmetry breaking scale.

The situation is better when we have gauged H.G. with a Higgs mechanism providing masses to the horizontal gauge bosons. Horizontal gauge couplings similar to the above $g'_e \sim 10^{-4}$ and masses $\sim m_{Z_H} \sim 100$ GeV for the intergenerational horizontal vector bosons are consistent with the existing limits on $\mu \rightarrow 3e$ and $K \rightarrow \pi + 2\nu$. We assume that the light U in the present CDM scenario corresponds to a more weakly broken $U'(1)$ which couples only to the first generation quarks and leptons with MeV - 10 MeV masses of order of the U mass itself.

Note that all the anomaly and other cancelation discussed above occur for each generation separately and are consistent with U coupling to the first generation fermions only.

Amusingly also the difficulty with super-nova data is partially alleviated if only the electron and its neutrino couple to $U'(1)$. The μ and τ type neutrino would then normally escape had it not been for the, say, annihilation process $\nu_\mu + \bar{\nu}_\mu \rightarrow Z \rightarrow \nu_e + \bar{\nu}_e$. Since the μ, τ neutrinos keep escaping this reaction will proceed mainly in the reverse direction and the extended delay largely avoided. Also the relative precision of measurement of electron neutrino scattering is lower than that of the μ neutrino, and ensuing limits are less stringent.

10. Summary and conclusions

In the above we have made various comments pertaining to the new MeV CDM scenario and its possible embedding in a particle physics model.

Our first result, $m_U > m_\chi$ becomes particularly useful in conjunction with other restrictions on the model. We next pointed out the general amusing results that when the p-wave v^2 suppression factor is present, the overall rate of annihilations in small CDM mini-halos need not be enhanced.

We noted the likely direct detection of the MeV CDM by small bolometric underground devices, using CDM — electron scattering — the cross section of which follows in an almost model-independent way from the crossed annihilation process which is the basic ingredient of the MeV CDM scenario. Also the easier detection of light U boson in proton fixed target experiments was noted.

Finally we commented on some more theoretical aspects of particle physics models for the scenario, and, in particular, on possible connections with horizontal gauged symmetries.

The new MeV CDM model puts strong demands on any underlying particle physics model. We need a new light scalar χ when to date no elementary scalars have been observed at any mass. We also need a new $U'(1)$ with very large ratios of the $U'(1)$ charges of the χ and electron when all known electric charges are quantized to a 10^{-21} accuracy.

All that notwithstanding, we believe that one should try as hard as possible to experimentally refute this scenario, or verify it and the abundant new physics which necessarily attends it.

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