

NON-DOMINATING HEAVY NEUTRINO DARK MATTER

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The evidences for the existence stable 4th neutrino with the mass about 50 GeV may shed light on the string phenomenology. Being subdominant form of the modern dark matter, 4th neutrino can still contribute significantly into direct and indirect effects of WIMPs in the Galaxy. The results of DAMA, EGRET and HEAT can find explanation in the framework of this hypothesis.

1 Evidences for 4th neutrino

By definition, primordial stable particles survive to the present time and should be present in the modern Universe. The net effect of their existence is given by their contribution into the total cosmological density. They can dominate in the total density being the dominant form of cosmological dark matter, or they can represent its subdominant fraction. In the latter case more detailed analysis of their distribution in space, of their condensation in galaxies, of their capture by stars, Sun and Earth, as well as of the effects of their interaction with matter and of their annihilation provides more sensitive probes for their existence. In particular, hypothetical stable neutrinos of the 4th generation with the mass about 50 GeV are predicted to form the subdominant form of the modern dark matter, contributing less than 0,1 % to the total density¹. However, direct experimental search for cosmic fluxes of weakly interacting massive particles (WIMPs) may be sensitive to the existence of such component, and may be even favors it². The dependence on 4th neutrino mass of the factor $\xi = \rho_{loc}/\rho_N$ (local density ρ_{loc} enhancement relative to the cosmological one ρ_N), at which the results² are reproduced, is given on Fig.1.

It was shown in ^{3, 4, 5} that annihilation of 4th neutrinos and their antineutrinos in the Galaxy can explain the galactic gamma-background, measured by EGRET in the range above 1 GeV. 4th neutrino annihilation inside the Earth ⁶ should lead to the flux of underground

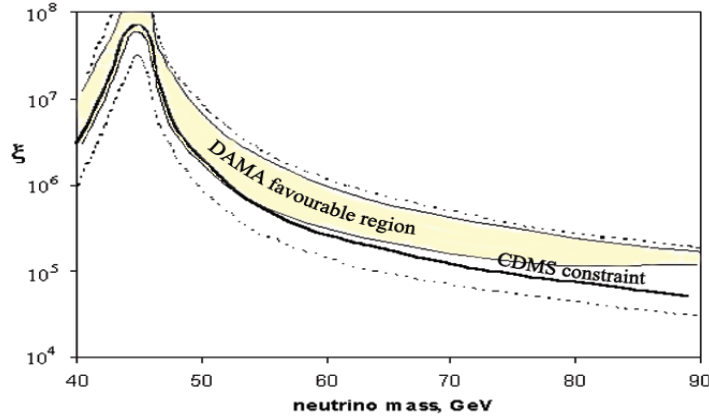


Figure 1: The dependence of ξ on the mass of 4th neutrino.

monochromatic neutrinos of known types, which can be traced in the analysis of the already existing and future data of underground neutrino detectors⁵. The enhancement of the predicted signal due to the existence of slow 4th neutrino component, captured by Solar system, and dominating in the 4th neutrinos capture by Earth, makes such analysis more sensitive to the existence of 4th neutrino⁷.

Dirac mass 50 GeV of 4th neutrino means that the masses of other 4th generation fermions are to be of the same order of magnitude, and they may be near the existing lower limits. If the lightest quark of 4th generation is stable, it can form stable charged hadrons, serving as nuclei of anomalous atoms of e.g. crazy helium⁸.

2 Test for heterotic string phenomenology

The theories of everything should provide the complete physical basis for cosmology. The problem is that the string theory⁹ needs special methods for its test¹.

One of them is related with the search for the experimentally accessible effects of heterotic string phenomenology. The mechanism of compactification and symmetry breaking leads to the prediction of fourth generation of quarks and leptons¹⁰. The comparison between the rank of the unifying group E_6 ($r = 6$) and the rank of the Standard model ($r = 4$) implies the existence of new conserved charges and new (possibly strict) gauge symmetries. New strict gauge U(1) symmetry (similar to U(1) symmetry of electrodynamics) is possible, if it is ascribed to the fermions of 4th generation. This hypothesis explains the difference between the three known types of neutrinos and neutrino of 4th generation. The latter possesses new gauge charge and, being Dirac particle, can not have small Majorana mass due to sea saw mechanism. If the 4th neutrino is the lightest particle of the 4th quark-lepton family, strict conservation of the new charge makes massive 4th neutrino to be absolutely stable. Following this hypothesis¹⁰ quarks and leptons of 4th generation are the source of new long range interaction (y -electromagnetism), similar to the electromagnetic interaction of ordinary charged particles. New strictly conserved local U(1) gauge symmetries can also arise in the development of D-brane phenomenology (see e.g. ^{11,12}).

y -electric charge of 4th neutrinos results in the appearance of yy channel of their annihilation and in the Sakharov enhancement¹³ of the annihilation of slow 4th neutrino-antineutrino pair. The latter is the effect of y -electromagnetism, similar to the Coulomb enhancement of annihilation and creation of pair of slow electric charged particle and antiparticle. In vicinity of Z-boson resonance yy channel is subdominant. Since the velocities of 4th neutrinos in the period of their freezing out are sufficiently large $v/c \sim 1/6$, Sakharov enhancement in this period is not

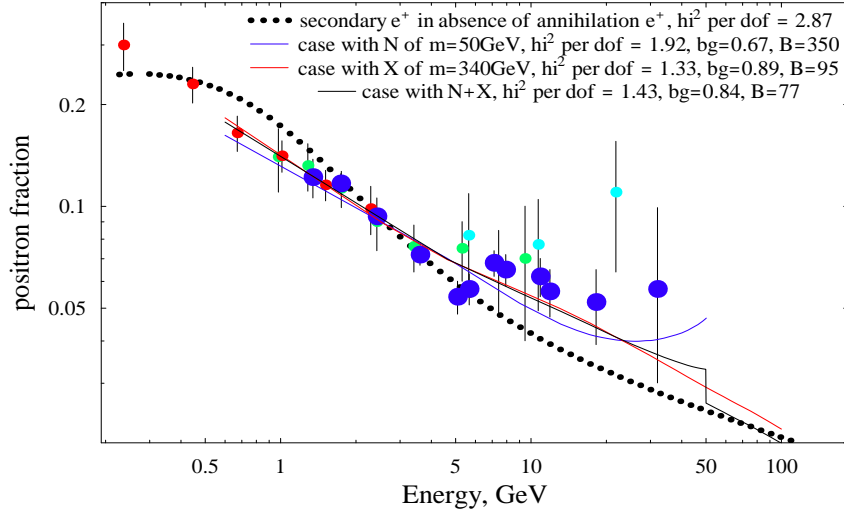


Figure 2: Cosmic positrons from annihilation of 4th neutrino (N) and neutralino (X) with mass $m = 340\text{GeV}$ together with secondary ones. Observational data are shown by the circles, where blue ones are the HEAT data. χ^2 values, secondary positron flux scaling (bg) and boost factors for annihilation positrons (B) are pointed out.

strong, and the effects of y -electromagnetism, increasing the annihilation rate, do not lead to substantial decrease of primordial 4th neutrino abundance. On the other hand, in the Galaxy 4th neutrinos are sufficiently slow (e.g. $v/c \leq 10^{-3}$ in the halo) to increase the effect of their annihilation significantly due to Sakharov enhancement¹³.

It is interesting, that heterotic string phenomenology embeds even in its simplest realisation both supersymmetric particles and the 4th family of quarks and leptons, in particular, the two types of WIMP candidates: neutralinos and massive stable 4th neutrinos. So in the framework of this phenomenology the multicomponent analysis of WIMP effects is favorable. It can give some clue to explanation of cosmic positron anomaly, claimed to be found by HEAT (see Fig.2). Assuming neutralino to be the dominant form of galactic dark matter and neutrino to account for DAMA data², the unique value for boost factor B, accounting for unknown details of N and X distribution, was found, reproducing the data on cosmic fluxes of antiprotons, positrons and gamma by combined hypothesis^{3, 4, 8} and¹⁴. It can point to their annihilation nature.

3 Higgs boson and 4th neutrino

For a wide range of Higgs boson masses, 4th neutrino channel dominates in the Higgs boson width, making Higgs boson dominantly invisible¹⁵, what should be taken into account in accelerator searches for Higgs boson. On the other hand the inverse effect of Higgs boson mediated annihilation is viable in for a rather narrow window of 4th neutrino and Higgs boson masses (see Fig.3). The thermal distribution of 4th neutrinos in the period of their freezing out in the early Universe was taken into account in the calculations of Fig.3.

4 Towards realistic WIMP scenarios

The qualitative correspondance of the predictions of 4th neutrino hypothesis to observations appeals to more detailed analysis of the predicted effects, in which the multicomponent WIMP content (say, neutralino + 4th neutrino), realistic WIMP distribution in space and its possible clumpiness are taken into account.

One should also take into account that different WIMP effects are sensitive to different features of this distribution, as well as that the test for indirect effects of WIMP annihilation

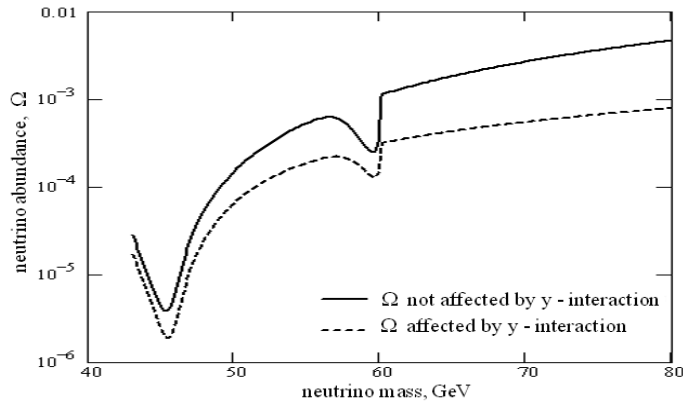


Figure 3: Higgs boson influence on 4th neutrino abundance.

implies additional hypotheses, for example, about the positron and antiproton diffusion in the Galaxy. It's important to have in mind that direct WIMP search is sensitive to the contemporary local flux of WIMPs, WIMP annihilation effects in galactic gamma background are sensitive to the WIMP distribution in the halo in the period of annihilation (moved to the past by the period of gamma ray propagation), effects of annihilation in the Sun are determined by the total amount of WIMPs captured by Sun during its lifetime, whereas these effects in the Earth are dominantly determined (as it is in the case of 4th neutrino) by the slow WIMP component, captured by the Solar system. In the indirect effects of WIMP annihilation on the fluxes of cosmic rays positron and antiproton diffusion is important, leading to the nontrivial dependence of the predicted spectra on the both source distribution in space and galactic magnetic fields. It makes the test of realistic multicomponent WIMP scenarios more complicated, but exciting.

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