Chapter 7
Light Sneutrino Dark Matter in the NMSSM

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Abstract Very light right-handed (RH) sneutrinos in the Next-to-Minimal Supersymmetric Standard Model can be viable candidates for cold dark matter. Very light RH sneutrinos can annihilate into either a fermion-antifermion pair, very light pseudo scalars or RH neutrinos. We investigate the prospects for their direct detection and the implications for Higgs phenomenology for each cases. We also calculate the gamma ray flux from RH sneutrino annihilation in the Galactic center.

7.1 Introduction

Very light weakly-interacting massive particles (WIMPs) are currently receiving much attention, since not only the DAMA/LIBRA [1, 2] but also the CoGeNT observed an annual modulation [3] in addition to an irreducible excess [4]. Those would correspond to a very light particle with a large elastic scattering cross section, these observations are challenged by the null results by other experimental collaborations e.g., CDMS [5, 6], SIMPLE [7] and XENON100 [8] though.

Various theoretical constructions with very light WIMP dark matter have been proposed. In the case of supersymmetric models, very light neutralino in the Minimal Supersymmetric Standard Model (MSSM) [9, 10] has been considered but nowadays suffers from constraints from low-energy observables [11] as well as Large Hadron Collider results. Another light WIMP is right-handed sneutrino in the Next-to-MSSM (NMSSM) [12, 13]. The NMSSM is an appealing model to solve

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the μ problem in the MSSM by the additional singlet Higgs superfield S. Since neutrino oscillation phenomena have been confirmed by various experiments, it might be important to add right-handed superfield N in the NMSSM. We here show the feature of very light RH sneutrinos [14].

7.2 Very Light RH Sneutrinos in the NMSSM

The superpotential of this construction is given by

$$W = W_{\mathrm{NMSSM}} + \lambda_N SNN + y_N L \cdot H_2 N. \tag{7.1}$$

It has been shown that sneutrinos with masses below 10 GeV could be in agreement with $\Omega h^2 \simeq 0.1$ [13]. There are three cases correspond to RH sneutrinos annihilating preferentially either in fermions ($\tilde{N}\tilde{N} \to f\bar{f}$, mainly into $b\bar{b}$), or in a pair of very light pseudo scalars ($\tilde{N}\tilde{N} \to A_1^0 A_1^0$), or in RH neutrinos ($\tilde{N}\tilde{N} \to NN$). Our computation has been made by modifying `NMHDECAY 2.3.7` code [15] to calculate the RH sneutrino observables and taking care of a new unrealistic vacuum recently pointed out [16].

7.3 Invisible Higgs Decay and Direct Detection

Let us now address the detectability of these particles in direct detection experiments and the appearance of a new invisible channel in the decay of the Higgs boson.

Let us address first the case in which sneutrino annihilation into a pair of fermions is dominant. The branching ratio of the SM-like Higgs boson decay and the scattering cross section with a proton σ_p are plotted in Fig. 7.1 for a typical example with this annihilation mode.

If the main annihilation mode is into a pseudo scalar pair, the predicted scattering cross section with a proton is smaller than that in the case of annihilation into $\bar{f}f$ because the couplings with quarks are weaker. Hence, this scenario is viable but does not reproduce the CoGeNT results.

Finally we address the scenario in which annihilation into a pair of RH neutrinos dominates. As in the case of annihilation into a pseudo scalar pair, the smallness of the λ_N parameter in the regions with the correct relic density implies that the resulting spin-independent RH sneutrino-proton cross section is significantly suppressed.

7.4 Indirect Detection

We show the possible signatures of our model in the gamma ray flux from the Galactic Center, a region which is currently being observed by the Large Area Telescope on the Fermi satellite (Fermi-LAT) [17]. In order to take into account the

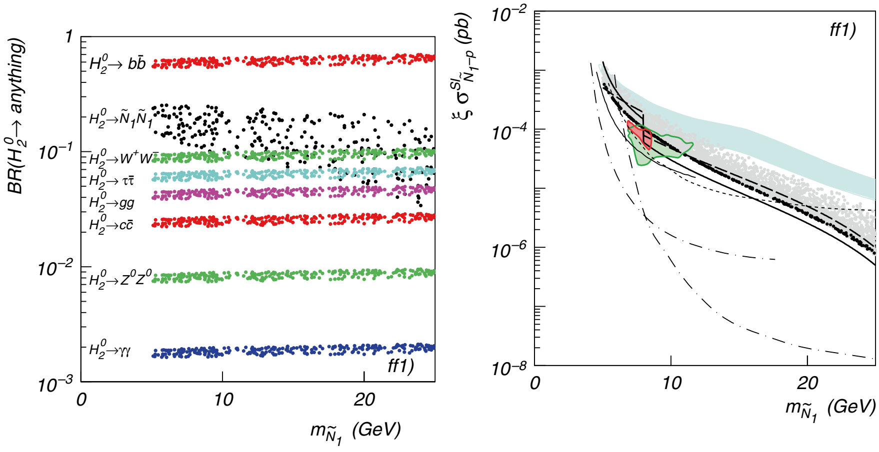

Fig. 7.1 Branching ratios of the decays of the SM-like Higgs (*left*) and the spin-independent cross section (*right*) with the results by various experiments; the CoGeNT (*green* and *red*), the DAMA/LIBRA without channeling (*light blue shaded*), the SIMPLE (*dashed*), CDMS (*solid*) and XENON (*dot-dashed*) (Color figure online)

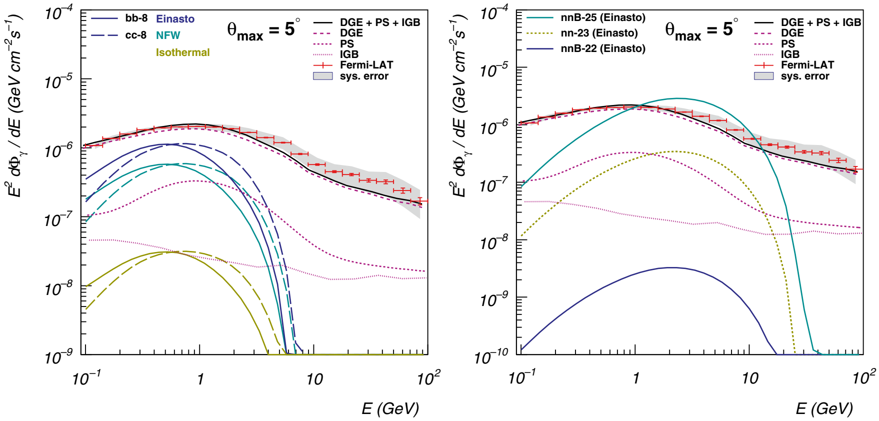

Fig. 7.2 Expected gamma ray flux for 5° region of interest from annihilation into $f\bar{f}$ (*right*) and NN with the Breit-Wigner enhancement (*left*)

possible astrophysical uncertainties, we use three halo models NFW [18], Einasto [19] and the isothermal halo model [20, 21].

Let us first consider the case in which RH sneutrinos annihilate into a pair of fermions. We have chosen the RH sneutrino mass $m_{\tilde{N}}=8$ GeV which is compatible with the CoGeNT result. The predicted gamma ray flux is represented in the left window of Fig. 7.2. However, here we note that after our this work [14] the Fermi collaboration has derived the constraints on dark matter annihilation cross section by analyzing gamma ray flux from dwarf spheroidal satellite galaxies, which now stringently constrains this class of annihilation mode [22].

Next we consider the case in which RH sneutrinos annihilate into a pair of RH neutrinos. These cases are potentially very interesting due to subsequent decay of RH neutrino into three fermions ($N \to ll\nu_L$ or $N \to lqq$) as well as possible the Breit-Wigner enhancement [23, 24] or suppression. The Breit-Wigner enhanced predicted gamma ray flux for the Einasto halo profile is shown in the right window of Fig. 7.2. The Breit-Wigner suppressed annihilation is also interesting since the constraints by dwarf spheroidal satellite galaxies mentioned above may be avoided.

7.5 Summary

We have shown the viability of very light RH sneutrinos in the NMSSM and analyzed the implications for direct dark matter detection, the potential effects on Higgs phenomenology and the prospects for indirect detection through gamma rays.

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