Exploring Mixed Sterile Neutrino Dark Matter Models

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Abstract

Recent X-ray observations of galaxies and galaxy clusters suggest the existence of sterile neutrino dark matter with a mass of 7.1 keV. In this poster, we examine mixed dark matter models, comprised of both sterile neutrinos and cold dark matter, with sterile neutrino parameters consistent with the X-ray observations. We assess the compatibility of these models with observation by calculating cosmological observables resulting from sterile neutrino production mechanisms.

Introduction:

Fig. 1 shows the sterile neutrino properties consistent with the x-ray data assuming sterile neutrinos are 100% of the dark matter; however if sterile neutrinos are a fraction of the dark matter, fewer sterile neutrinos would need a larger mixing angle to create the same X-ray flux. As a result, fraction of dark matter that is sterile neutrinos (f) is inversely proportional to the mixing angle.

We calculated the sterile neutrino production with different mixing angles in both non-resonant (zero lepton number) and resonant (nonzero lepton number) scenarios using the sterile-nu code from Ref [2] to search for agreement between the production mechanism and the sterile neutrino mixing angle inferred from the X-ray data when sterile neutrinos are only a fraction of the total dark matter. We then used the CLASS code [3] to calculate the matter power spectrum created by these dark matter models that have a fraction of sterile neutrinos and the remainder cold dark matter.

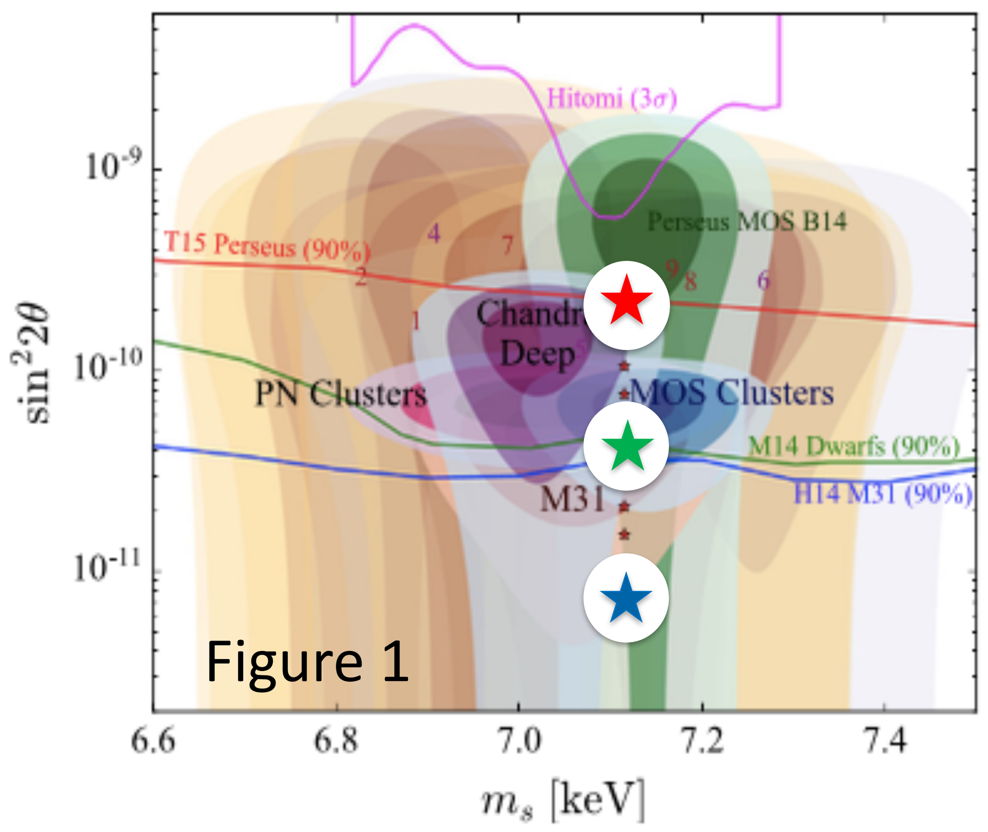

Figure 1 (modified from Ref [1]):
If the X-ray line is caused by sterile neutrino dark matter this figure shows the mass and mixing angle associated with sterile neutrinos being 100% of the dark matter, shaded regions are consistent with the X-ray data. We chose three models with a fixed mass (7.1 keV), and different mixing angles, as shown by the three large stars (red, green, blue) to create our models.

References

[1] K. Abazajian, Physics Reports 711-712 (2017) 1-28
[2] T. Venumadhav, et al., Physical Review D 94, 043515 (2016)
[3] J. Lesgourgues, arXiv:1104.2392

Non-Resonant Production

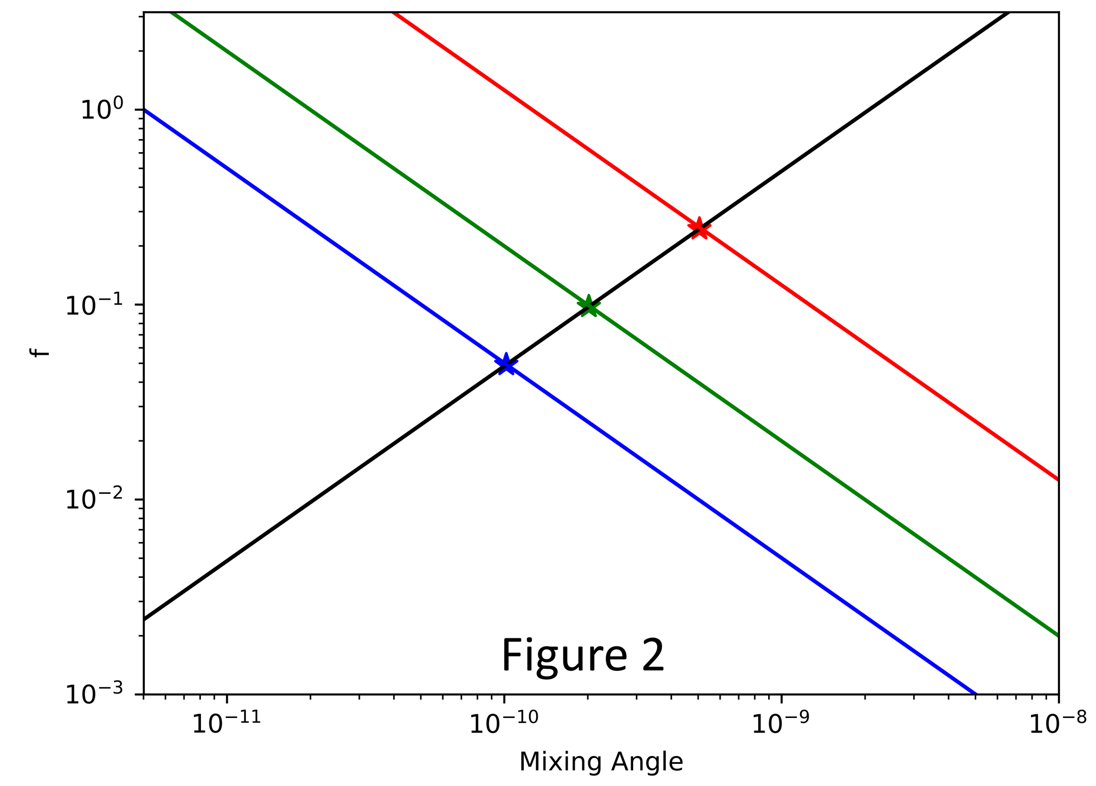

Figure 2: If sterile neutrino dark matter exists, then non-resonant production represents the minimum amount of sterile neutrino dark matter created in the early universe. The black line represents the non-resonantly produced fraction of the total dark matter that is sterile neutrinos as a function of mixing angle. The three colored lines are the models inferred from the data in figure 1. They show that if the fraction of sterile neutrinos is smaller, the mixing angle will be larger. The places where these lines intersect are models that fit the production and X-ray data.

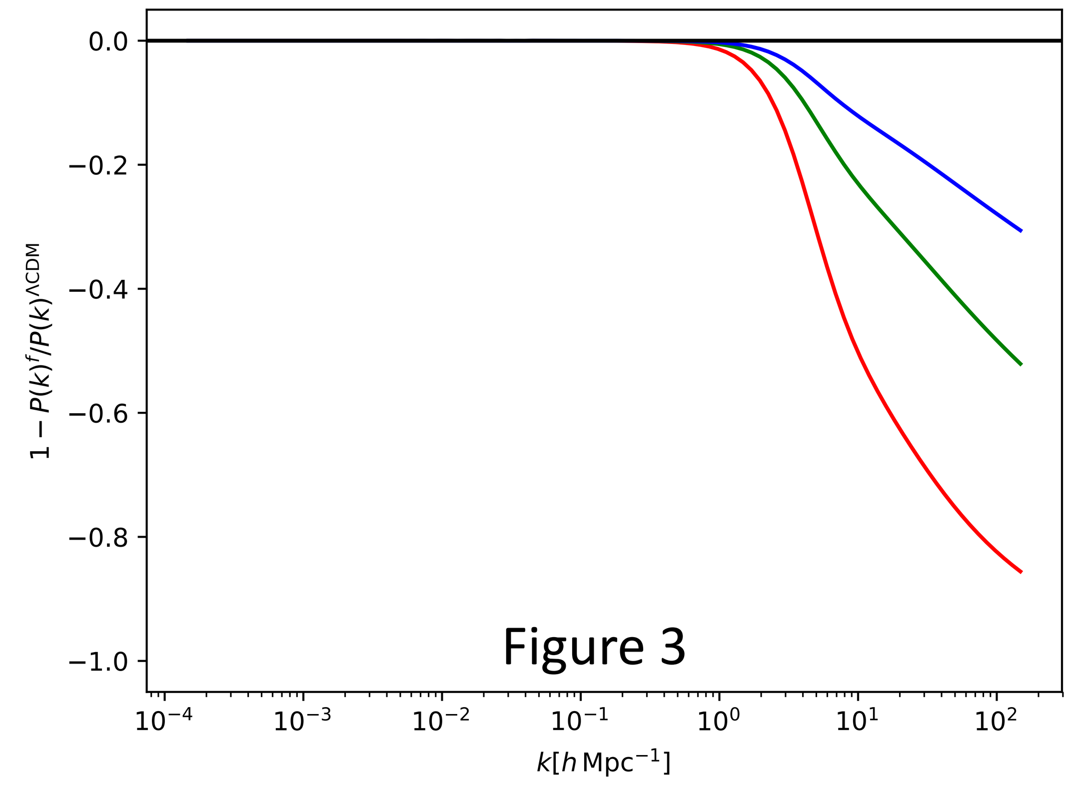

Figure 3: This is the matter power spectrum of the difference between the Lambda CDM model of the universe and our mixed dark matter models (indicated by the stars in figure 2). The green star in figure 2 corresponds to the green curve in figure 3 and likewise for the other two stars and curves. Non-resonantly produced sterile neutrino dark matter is a form of warm dark matter, which suppresses the formation of structure on small scales, as seen in the figure.

Resonant Production

Figure 4: Resonant production of sterile neutrino dark matter can create a larger fraction of the total dark matter. One method to resonantly produce sterile neutrino dark matter is by introducing a lepton number, a net overabundance of active neutrinos versus antineutrinos. The solid, dashed, and dotted lines on the figure represent the sterile neutrino dark matter yield produced with lepton numbers of 10^{-2}, 10^{-3}, and 10^{-4}, respectively. The colored lines in this figure represent the mixing angle inferred from the X-ray data when sterile neutrinos are a fraction of the dark matter, just as they are in figure 2. The stars in the figure represent the models that fit the various production models and the X-ray models.

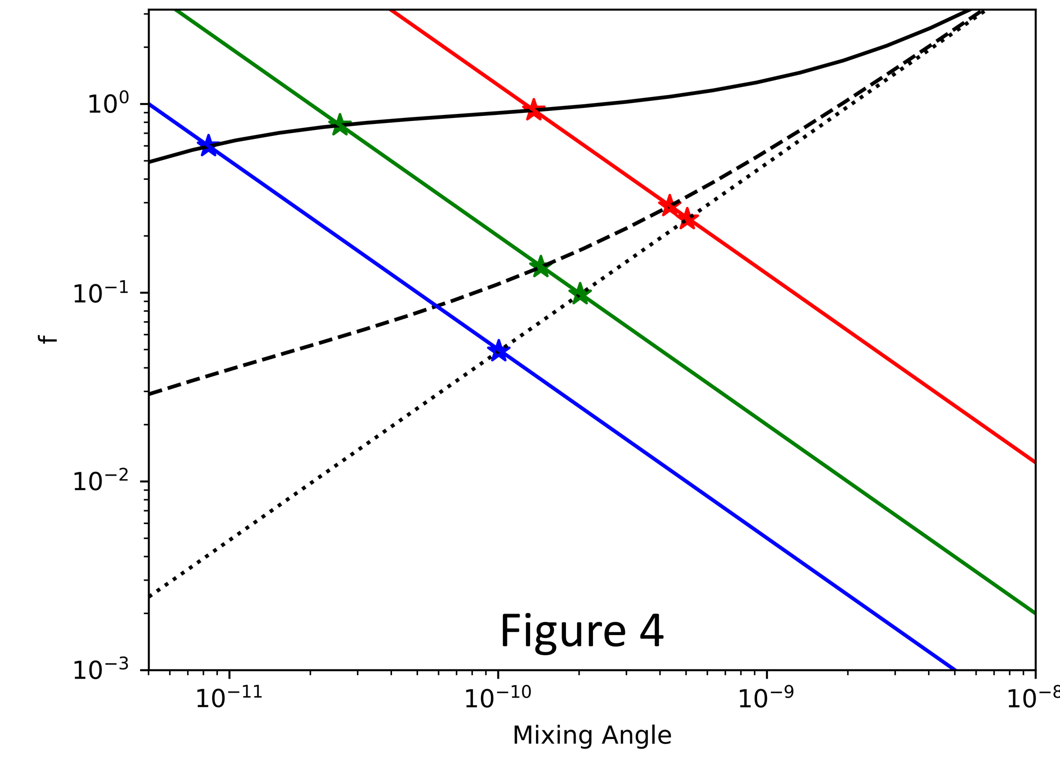

Figure 5: For each of the stars in figure 4, this graph shows the matter power spectrum of the difference between the Lambda CDM model of the universe and our mixed dark matter model. The stars and format of the line from figure 4 match up with the color and format of the line in this figure; for example, the red, solid curve in figure 5 corresponds to the red X-ray model in figure 4 and resonant sterile neutrino production with lepton number 10^{-2}, but the red, dashed line in figure 5 corresponds to the red X-ray model and resonant production with lepton number 10^{-3}. The 10^{-2} lepton number models all significantly suppress structure on ~100 kpc scales and are likely ruled out by observations of satellite galaxies, while the other models would require further consideration of their effects on the formation of small scale structure.