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ORIGINAL ARTICLE

Electron-positron annihilation lines and decaying sterile neutrinos

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Abstract If massive sterile neutrinos exist, their decays into photons and/or electron-positron pairs may give rise to observable consequences. We consider the possibility that MeV sterile neutrino decays lead to the diffuse positron annihilation line in the Milky Way center, and we thus obtain bounds on the sterile neutrino decay rate $\Gamma_e \geq 10^{-28}$ s^{-1} from relevant astrophysical/cosmological data. Also, we expect a soft gamma flux of 1.2×10^{-4}–9.7×10^{-4} ph cm^{-2} s^{-1} from the Milky Way center which shows up as a small MeV bump in the background photon spectrum. Furthermore, we estimate the flux of active neutrinos produced by sterile neutrino decays to be 0.02–0.1 cm^{-2} s^{-1} passing through the earth.

Keywords Dark matter · Milky Way

1 Introduction

Understanding the nature of dark matter remains a fundamental problem in astrophysics and cosmology. Since the discovery of neutrinos' non-zero rest mass (Fukuda et al. 1998; Bilenky et al. 1998), the possibility that neutrinos contribute to cosmological dark matter has become a hot topic again. In particular, the sterile neutrinos belong to a class of candidate dark matter particles with no standard model interaction. Although the recent MiniBooNE data challenges the LSND result that suggests the existence of eV scale sterile neutrinos (Aguilar-Arevalo et al. 2007), more massive sterile neutrinos (e.g. keV, MeV) may still exist. The fact that active neutrinos have mass implies that right-handed neutrinos should exist which may indeed be massive sterile neutrinos. The existence of the sterile neutrinos has been invoked to explain many phenomena such as missing mass (Dodelson and Widrow 1994; Shi and Fuller 1999) and the high temperature of the hot gas in Milky Way and clusters (Chan and Chu 2007, 2008). Therefore, it is worthwhile to discuss observational consequences if massive sterile neutrinos exist, which may decay into light neutrinos, positron-electron pairs and photons. In this article, we consider the possibility that sterile neutrino decays give rise to the 511 keV lines in Milky Way and thus obtain bounds on the mass m_s and total decay rate Γ of the sterile neutrinos using relevant observational data.

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2 511 keV photon flux

The bright 511 keV annihilation line from Milky Way has been observed for a few decades (Leventhal et al. 1978; Knödelseder et al. 2005), and its origin has been much debated. Recent values of the 511 keV photon flux from the bulge and disk are $(1.05 \pm 0.06) \times 10^{-3}$ ph cm^{-2} s^{-1} and $(0.7 \pm 0.4) \times 10^{-3}$ ph cm^{-2} s^{-1} respectively (Knödelseder et al. 2005). Assuming a positronium fraction of $f_p = 0.93$, one can translate these intensities to annihilation rates of $(1.5 \pm 0.1) \times 10^{43}$ s^{-1} and $(0.3 \pm 0.2) \times 10^{43}$ s^{-1} respectively (Knödelseder et al. 2005). The annihilation rate in the bulge is several times larger than that in the disk. The source of positrons in the disk can be explained by the decay of ^{26}Al. Using a disk model, the photon flux is calculated to be 5×10^{-4} ph cm^{-2} s^{-1}, which can account for 60–100% of the disk emission (Knödelseder et al. 2005). However, the