Institute for Research in Fundamental Sciences

School of Physics

Ph.D Defense Session

Title:

Dark Matter Model Building and Indirect Detection

Candidate:

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Abstract:

Our best understanding of fundamental forces is encapsulated in the standard model of particle physics and general relativity. Although various experiments have tested successfully the predictions of the standard model and general relativity, there are new phenomena that we cannot be described within the framework of these two theories. Among proposed possible explanations, dark matter seems to be the best possibility. Nature of dark matter is still unidentified and under investigation by indirect and direct searches. Various alleged indirect dark matter search signals have been reported and some of them disappeared by collecting more data. However, some of them, such as the 511 keV line from galaxy center or the PAMELA/AMS02 positron ecxess signal persist. In this thesis, we focus on model building for indirect dark matter signals. In particular, we consider 511 keV signal observed by INTEGRAL, as well as positron excess signal observed by PAMELA and AMS-02 that have been claimed to be due to the annihilation or decay of dark matter. Dark matter scenarios accounting for these observed signal, face challenges because they predict other accompanying signals that have not been observed and therefore, are ruled out. One such accompanying signal is delayed recombination and consequently impact on CMB. In this thesis, we propose a dark matter scenario to explain 511 keV signal and positron excess signal which can avoid these bounds. Our scenario is based on the decay of dark matter particles into intermediate millicharged particles which can be trapped by the galactic magnetic field. We consider the possibility that the 511 keV line from galaxy center is due to dark matter decay and propose a novel scenario which avoids the previuos accompanying signals: Absence of corresponding signal from dwarf galaxies and the absence of an impact on CMB through delayed recombination. In our scenario dark matter decays into a pair of intermediate millicharged particles with a lifetime much greater than the age of universe. The magnetic field in our galaxy is sufficient to keep the millicharged particles at a distance from galaxy center close to that at their production point. We will show that the annihilation of these intermediate particles leads to 511 keV signal and the morphology of the 511 keV line can be explained. In addition, various bounds on the parameters of our model is discussed and the prospect of testing the scenario by direct dark matter search experiments is explained. Furthermore, we consider the possibility that the rise in the positron fraction observed by the PAMELA satellite and AMS-02 experiment is due to the decay of dark matter particles into intermediate millicharged particles which can be trapped by the galactic magnetic field. Similar to the scenario proposed for explaining 511 keV signal, the subsequent de cay of the millicharged particles to electron positron in our vicinity can explain this excess. We show that our scenario avoids the bounds from isotropic gamma ray that had disfavored the previously proposed dark matter decay scenarios. Moreover, we discuss various bounds on the parameters of our scenario and the prospect of testing it by future experiments. The main message of this thesis is that for both 511 keV and positron excess signals, we revive the dark matter decay explanation by introducing a scenario in which dark matter particles decay to a pair of millicharged particles and can be trapped by magnetic field in galaxy. At the recombination, the millicharged particle density will be too small to lead to any significant reionization so the bound from CMB is circumvented. In the case of 511 keV signal, because of the smallness of the magnetic field, the dwarf galaxies are not expected to accumulate the millicharged particles and in consequence, no significant 511 keV signal is expected from them. In the case of positron excess signal, since millicharged particles diffuse out of the halo before decay, their contribution to the isotropic gamma ray background is expected to be much smaller than that in the canonic dark matter decay scenarios.

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