Decaying Dark Matter (model independent analysis)

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In view of the astrophysical uncertainties, there is no pressing reason to explain the excess in the PAMELA positron fraction by means of DM. However, it is possible to interpret the anomalously high number of positrons in the energy range above $\sim 10\,GeV$ as product of DM decays or annihilation in the galactic halo. DM particles are assumed to undergo processes of this kind mainly in regions close to the galactic center, where the densities (motivated by measurements of the rotational velocities in galaxies) are large. The SM products of these inelastic processes are subject to interactions with the turbulent magnetic field, the interstellar medium and photons from starlight and the microwave background. The diffusive propagation of these particles is described by a diffusion-loss equation. Given the details of the injection spectrum, it yields predictions for the cosmic ray fluxes observed at earth.

In the past the possibility of DM annihilation received most attention. However, such scenarios are restricted by the non-observation of an excess in the γ-ray spectrum (measured by H.E.S.S in regions around the galactic center) and the $\bar{p}/p$ spectrum (measured by PAMELA and others). Some amount of model building and large 'boost factors' are required to bring annihilating DM into agreement with the experimental data (if DM annihilation are considered to be the only source for the observed anomaly).

The idea that DM decays could be responsible for the observations is less constrained. Classifying the DM in terms of its primary decay products the analysis can be performed in a model independent way. The proportionality of the fluxes to the number density of DM (instead of the number density squared as for annihilating DM) makes it easier to bring decaying DM into agreement with observations. It turns out that $GeV - TeV$ DM decaying mainly to leptons (to generate the hard spectrum of e^+) with lifetimes as large as $\sim 10^{26}\,s$ can fit the data. The long lifetimes guarantee that the decay has no impact on the cosmological expansion and that the DM is abundant today. Such decays can in a natural way be motivated by SUSY GUTs, since effective dim-6 operators yield lifetimes of the required order of magnitude.

Details can be found in the following references:

- TASI lectures, general DM introduction [1].
- Explanation of the PAMELA $e^+/(e^+ + e^-)$ excess by decaying dark matter [2] (includes many of the plots shown in the talk; includes bounds from H.E.S.S.), [3], [4].

- Analytical solution of the diffusion-loss equation for e^+ propagation [5].
- Constraints from gamma rays [6].
- Cosmological constraints for decaying DM [7].
- DM decays to leptons by dim-6 operators and some model independent discussion of derived bounds from original charged cosmic ray, γ-ray and neutrino data [8].
- New $e^+ + e^-$ measurements by Fermi/LAT [9] and H.E.S.S. [10], contradicting ATIC results.
- Analysis including the new FERMI data [11].

References

[1] Dan Hooper, *TASI 2008 Lectures on Dark Matter* (2009). 0901.4090

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[3] Peng fei Yin et al., *PAMELA data and leptonically decaying dark matter*, Phys. Rev. **D79** (2009) 023512. 0811.0176

[4] Alejandro Ibarra and David Tran, *Decaying Dark Matter and the PAMELA Anomaly*, JCAP **0902** (2009) 021. 0811.1555

[5] Junji Hisano, Shigeki Matsumoto, Osamu Saito, and Masato Senami, *Heavy wino-like neutralino dark matter annihilation into antiparticles*, Physical Review D (Particles and Fields) **73** (2006)(5) 055004 (pages 13). URL http://link.aps.org/abstract/PRD/v73/e055004

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[7] Santiago De Lope Amigo, William Man-Yin Cheung, Zhiqi Huang, and Siew-Phang Ng, *Cosmological Constraints on Decaying Dark Matter* (2009). Dark Matter seminar, 0812.4016

[8] Asimina Arvanitaki et al., *Astrophysical Probes of Unification* (2008). 0812.2075

[9] Fermi/LAT Collaboration, *Measurement of the Cosmic Ray e+ plus e- spectrum from 20 GeV to 1 TeV with the Fermi Large Area Telescope* (2009). 0905.0025

[10] H. E. S. S. Collaboration: F. Aharonian, *Probing the ATIC peak in the cosmic-ray electron spectrum with H.E.S.S* (2009). 0905.0105

[11] Patrick Meade, Michele Papucci, Alessandro Strumia, and Tomer Volansky, *Dark Matter Interpretations of the Electron/Positron Excesses after FERMI* (2009). 0905.0480