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Astroparticle Physics (Physics 711)
Exercise 7

Universität Bonn, WS 2010/11,
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Problem 1: Indirect detection of dark matter (5P)

Indirect search for Dark Matter focuses on the detection of secondary particles, such as neutrinos, γ-radiation and anti-matter, produced in the annihilation of two WIMP particles. Supersymmetric WIMPs (i.e. Neutralinos) annihilate preferentially into heavy fermions or massive Gauge Bosons. Consider annihilation into $\tau + \bar{\tau}$ and an arbitrary WIMP mass $M_{\mathrm{WIMP}} > m_\tau$.

(a) Write down the four most inportant decay channels (in terms of branching ratio) of the τ. If necessary, you can consult the PDG particle listings.

(b) For the case of the decay into a single (charged) pion and tau neutrino, discuss the further decay of the pion: What are the branching ratios of $\pi^\pm \to \mu^\pm + \nu_\mu$ and $\pi^\pm \to e^\pm + \nu_e$ (again, if necessary consult the PDG) and explain why annihilation into the latter is so strongly suppressed (hint: helicity suppression). For a π at rest, how much of the energy is carried away by the muon neutrino? What is the energy spectrum in the laboratory frame, if one considers the fact that pions will be produced with a large Lorenz boost γ? Assume the pion is unpolarized.

(c) In the case of decay of an unpolarized τ into $\nu_\tau + \mu + \nu_\mu$, the energy spectrum of the muon neutrino in the laboratory frame can be expressed as:

$$\frac{dN_{\nu_\mu}(x)}{dx} = 2x^2(3 - 2x), \tag{1}$$

where x is the scaled energy $x = 2E_{\nu_\mu}/m_\tau$ with $0 \geq x \geq 1$. What is the average energy of the muon neutrino?

Problem 2: Computational data analysis (5P)

Write a program that does a least square fit for the SNe of the Union2 data set to the Hubble law (`http://www.supernova.lbl.gov/Union2/`). You can find the measured distance moduli (and errors) as a function of redshift at `http://www.supernova.lbl.gov/Union2/figures/SCPUnion2_mu_vs_z.txt`. Only use SNe with $z < 0.1$ to do your fit. In this redshift range, the distance luminosity is given by $d_{\mathrm{L}} \approx z/H_0$ What is the χ^2 of your fit? How many degrees of freedom are there?

Make a plot of the data as well as your best fit. Then, in a second plot, make a plot of the residuals, i.e. value of the data minus the value of the best fit (at the redshift of the data).

Write the results to an ASCII file.

Please send your program, the output file and the plot to `mkersch@physik.uni-bonn.de`, preferably with the subject "Astro Exercise 7".

Hint: A useful collection of fitting examples using the `SciPy` module in the programming language `python` can be found under `http://www.scipy.org/Cookbook/FittingData`