Physics 661
Problem Set 1
Due: October 10, 2003

1. Consider charged particles reaching Earth from beyond the our galaxy.

   (a) The solar magnetic field will deflect particles as they approach the Earth. This field results in a low energy cut-off on particles which reach the Earth from beyond the Solar System. Estimate the energy of this cut-off.

   (b) The γp cross section is large above the pion production threshold (eg. γ p $\rightarrow \pi^0$ p). Due to this large cross section, the 2.7 K cosmic microwave background leads to a high energy cut-off. Calculate the high energy cut-off energy.

   (c) The flux of primary cosmic rays averaged over the Earth's surface is 1 $cm^{-2}s^{-1}$, and their average kinetic energy is 3 GeV. Calculate the cosmic ray energy density, and compare it to the energy density of the cosmic microwave background, and the critical density.

2. In a particular spiral galaxy whose disk is approximately normal to the line of sight from Earth, the observed light intensity in the disk (beyond the nuclear bulge) falls off exponentially with distance r from the galactic center. Assuming that the brightness in any region is proportional to the total material mass in that region, calculate the expected variation of the tangential velocity of the material, v_t, with r, and plot this on a graph. How does v_t vary with r for large values of r? How does this compare to the observations of v_t and what are the implications?

3. Show that if one chooses the Planck scale for the cut-off energy, the vacuum energy density can be estimated and is tens of orders of magnitude larger than the critical density. Estimate its size under this assumption and compare it to the critical density