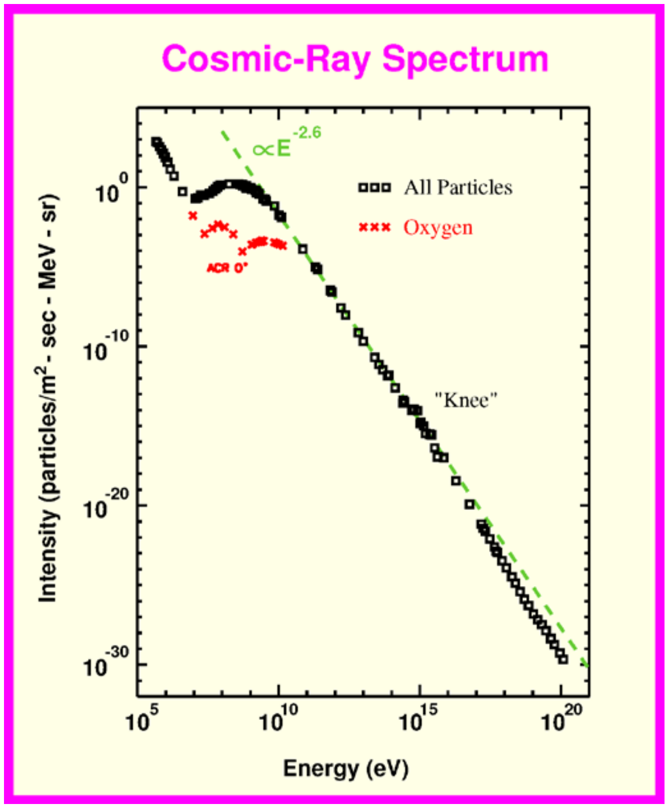
Heliophysics Summer School
Boulder, CO, July 16, 2013

Cosmic-Ray Transport Problem Set

1. The differential intensity spectrum of cosmic rays at Earth is shown at the right. Use this information to estimate:

   A. the number density of cosmic rays with energies above 1 GeV at 1AU. Compare to the typical solar wind density at 1 AU

   B. the energy density of cosmic rays with energies above 1 GeV at 1AU. How does this compare to the energy density in the interplanetary magnetic field at 1AU?



2. Suppose you are an astronaut on the moon far from your lander, or other shelter, when a mission controller informs you that a huge solar eruption has occurred. Comment on the possible options you may have to protect yourself from radiation in the form of high-energy charged particles from the Sun.

3. Consider the steady-state distribution of GCRs inside the heliosphere. Suppose the heliosphere can be approximated as a sphere with radius R and the solar wind emanates from the center of the sphere in the radial direction with a constant speed, V. Suppose the distribution function of GCRs outside the heliosphere is uniform and has a power law dependence on energy above 1 GeV. That is, $f(R,p)=f_0(p/p_0)^{-\gamma}$, where p_0 is the momentum of a 1GeV proton, and f_0 is a constant.

   A. Neglect energy change and assume the diffusion coefficient has the following form: $\kappa(r,p)=\kappa_0(r/R)g(p)$, where κ_0 is a constant. Determine the ratio of the distribution of GCRs at 1 GeV at Earth's orbit to that at the outer boundary (assume R=100AU).

   B. Now assume the diffusion coefficient is identically zero. Compute the same ratio discussed in A.

(there is one more problem on the next page)

4. In the “leaky box” model for GCRs in the Galaxy, cosmic rays are assumed to be produced at supernovae and undergo spatial diffusion in the turbulent Galactic magnetic field – which is assumed to have a mean that points in the plane of the disk – and “leak” out of the Galaxy with a characteristic loss time of 20 million years. Assume that they leak out primarily through the top and bottom of the Galactic disk, which has a thickness *h*, which is much smaller than the radius of the Galactic disk. Taking *h* to be 500 parsecs (1.5×10^{21}cm), estimate the diffusion coefficient of GCRs in the interstellar medium. Is this the parallel or perpendicular diffusion coefficient? From quasi-linear theory, it can be shown that the parallel scattering mean-free path of a TeV proton is about 1 parsec (3×10^{18}cm). Estimate the ratio of perpendicular to parallel diffusion coefficients at this energy.