Set of problems

Astrophysical Neutrinos: JINR-ISU Baikal Summer School 2021

All problems are presented along the lectures, which set the required context, background and notation. Following them will allow for a better understanding of the problems and will make them easier to be solved. In some cases, required data are indicated in the slides of the lecture preceding the presentation of the problem.

1. What is the minimum energy for a particle not to experience (significantly) the East-West effect at the Equator?

   Use $B = 0.3$ G for the magnetic field.

2. Redo the Bethe and Peierls estimate for the neutrino mean free path in solid matter. What is the result in the interstellar medium?

   Use $\sigma_{\nu N} = 10^{-44}\ \mathrm{cm}^2$ and $n_{\mathrm{ISM}} = 1\ \mathrm{proton/cm}^3$.

3. What is the minimum neutrino energy from photohadronic (resonant) production off stellar light?

   Consider a background photon field with a wavelength of 200 nm.

4. To reach PeV neutrino energies, what is the minimum energy of the photon background needed in highly boosted sources ($\gamma \sim 300$)?

5. What does the fact that the transition from the Thomson to the Klein-Nishina regime in inverse Compton is at $E_e = m_e^2/\varepsilon_\gamma$ indicate?

6. Can we observe PeV electrons from the center of the Milky Way?

   Use energy losses via synchrotron radiation and consider the average galactic magnetic field.

7. What is (approximately) the current fraction of the volume of the disc of the Milky Way occupied by active SNRs?

   Assume there are 3 SNs per century, a Milky Way disc with a radius of 15 kpc and a thickness of 300 pc, $M_{\mathrm{SN}} = 10\ M_\odot$ and $n_{\mathrm{ISM}} = 1\ \mathrm{proton/cm}^3$.

   Recall that only 1% of the gravitational energy is converted into kinetic energy.

8. Show that for acceleration in magnetic gas clouds, the energy gain is second order in the relative speed, V_{cloud} (2nd order Fermi acceleration).

   Note that the probability of collision with the cloud, $P(\cos\theta_{ud})$, is proportional to the relative velocity between the cloud and the particle (which travels at a speed close to the speed of light) and the particle moves out of the cloud randomly, $P(\cos\theta_{du}) = \mathrm{constant}$.

   In this case, in the rest frame of the particles bath, and $v_d = V_{\mathrm{cloud}}$ and $v_u = 0$.

9. Compare the maximum energy obtained for Bohm diffusion with the case of Kolmogorov diffusion, $D_{\mathrm{Kolmogorov}} = D_{\mathrm{Bohm}} \left(\frac{1}{2\pi\, L\, E}\right)^{2/3}$.

   Take $L = 1$ pc for the injection length for turbulence and typical values for SNRs in our galaxy.