Neutrino Physics: Assignment 3

(Given 29/04/2009, To be submitted 13/05/2009)

1. Plot the survival probability of solar neutrinos as a function of energy (0.5 MeV $< E <$ 15 MeV) for the following scenarios:

   - VAC: $\Delta m^2 = 10^{-9}$ eV^2, $\theta = 45^\circ$
   - SMA: $\Delta m^2 = 5 \times 10^{-6}$ eV^2, $\theta = 2^\circ$
   - LMA: $\Delta m^2 = 8 \times 10^{-5}$ eV^2, $\theta = 32^\circ$

   Use $P_L = Exp(-\pi\gamma/2)$, with $\gamma \equiv \frac{\Delta m^2}{2E} \frac{sin^2 2\theta}{\cos 2\theta} \frac{1}{|A'/A|_{\rm resonance}}$. The density profile of the Sun is

   $$\rho(r) = 245 \times 10^{-10.54(r/r_\odot)} \ \ {\rm cm}^{-3}$$

   with $r_\odot = 700,000$ km.

2. (a) Calculate $P(\nu_e \to \nu_\mu)$ in vacuum in the three-flavour framework from first principles, expanding in the two small parameters θ_{13} and $\alpha \equiv \Delta m^2_{21}/\Delta m^2_{31}$. You may keep terms up to $\mathcal{O}(\theta^2_{13}, \alpha^2, \alpha\theta_{13})$, neglecting the higher order terms. (The answer should match the $\hat{A} = 0$ case of the expression shown in class and available on the course webpage.)

   (b) In the two-neutrino approximation ($\alpha \to 0$), plot the curve with $P(\nu_e \to \nu_\mu) = 0.1$ in the Δm^2–$\sin 2\theta_{13}$ plane.

3. Plot m_{ee}, the effective neutrino mass measured in the neutrinoless double beta decay, as a function of m_0, the lightest neutrino mass, for (a) Normal Hierarchy and (b) Inverted Hierarchy, in the same plot.

   Use any appropriate values for the neutrino mass squared differences, mixing angles, and phases, that are allowed by the current data. Specify which values you have used for all these parameters.