Antineutrinos in the Sudbury Neutrino Observatory

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While the Sudbury Neutrino Observatory (SNO) has been designed to study the interactions of electron neutrinos (ν_e) produced by the fusion of light elements within the sun[1], it is also an excellent detector to look for the interaction of electron antineutrinos $(\bar{\nu}_e)$. The $\bar{\nu}$ interactions which are possible in SNO are:

$$\begin{array}{lll} \bar{\nu}_e + p & \longrightarrow & e^+ + n \\ \bar{\nu}_x + d & \longrightarrow & \bar{\nu}_x + p + n \\ \bar{\nu}_e + d & \longrightarrow & e^+ + n + n \end{array}$$

The first interaction has a large cross section, and, when coupled with the neutrino composition expected from supernovae, will provide the largest component of the neutrino signal observed from a supernova within our galaxy. The events will occur almost exclusively in the H_2O region of the detector, and will be detected by the Cherenkov light produced by the outward-going e^+. The n will capture on a proton in the H_2O and emit a 2.2 MeV gamma-ray, but this will be below the detection threshold.

The second reaction is the analog of the neutral current neutrino reaction which is being used in SNO to measure the total solar neutrino flux. This antineutrino process will be indistinguishable from the neutrino process.

The third reaction is the analog of the charged current neutrino reaction which is being used in SNO to measure the flux of ν_e from the sun[2]. The antineutrino process, however, is particularly interesting because all of the particles in the final state may be observed in SNO. The e^+ may be detected by the Cherenkov light, and the two neutrons will produce gamma-rays when they capture on nuclei in the D_2O. The capture time for neutrons is ~ 40 ms in pure D_2O and ~ 4 ms in D_2O with NaCl. Thus this third interaction may be detected by searching for a two or three-fold coincidence in the detector. By using a coincidence algorithm, the analysis can be made essentially background free.

Estimates of the expected event rates from various sources of antineutrinos have been performed.

Relic Supernovae: from all supernovae which have occurred over the lifetime of the universe, we expect 0.2 $\bar{\nu}_e$ interactions/year/kton.

Nuclear Reactors: from the fission processes occurring in the nuclear reactors within a 700 km radius of the detector, we expect 1.4 $\bar{\nu}_e$ interactions/year/kton.

Atmospheric: from the decays of pions and muons created by cosmic ray interactions in the atmosphere, we expect 8.4 $\bar{\nu}_e$ interactions/year/kton.

In addition to looking for the antineutrinos from these known sources, we can look for unexpected sources such as the sun. The nuclear fusion in the sun is not expected to produce any high energy antineutrinos, however extensions to the Standard Model can allow for $\nu_e \longleftrightarrow \bar{\nu}_e$. The current limits on the $\bar{\nu}_e$ flux from the sun are at the level $< 3.5\%$ of the standard solar model ν_e flux, and are derived indirectly from the observed ν_e flux[3]. A measurement in SNO should be able to easily improve on this limit, and do so by directly measuring the antineutrinos.

References

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