The Sun, Fusion, and Science: Counting Neutrinos

Fusion reactions in the core of the sun produce helium, energy, and neutrinos. An outline of the process is on the screen in the front of this room.

Neutrinos are a special type of particle; they have no mass and can only interact with normal matter via the weak nuclear force. What does that mean? It means they can go right through many light years of solid matter without stopping. In the time it took you to read this sentence, several trillion passed through your body![1]

These neutrinos provide a window into the core of the Sun because any neutrinos produced there pass through the rest of the Sun and get to Earth in about 7 minutes. This activity takes you through an estimate of the number of neutrinos produced in the Sun due to nuclear reactions.

1. For each Helium nucleus produced, how many neutrinos are made? *Explain.*

The reaction that produces each helium nucleus releases a small amount of energy. Suppose that amount of energy produced when one helium nucleus is made is 0.1 energy units and the total energy output of the Sun in one second was 1,000 energy units, (**Note:** neither of the numbers given are actually the correct numbers for our Sun, they are just being used for illustration.)

2. How many reactions need to happen in one second to produce the energy output of the Sun? *Explain briefly how you got your answer.*

3. Use your answers to 1 and 2 to predict how many neutrinos should be made each second.

[1] The expected solar neutrino flux is $\sim 2 \times 10^{11}$ neutrinos per square centimeter of area facing the Sun per second (based on the Bahcall-Pinsonneault Standard Solar Model). That's a big number!

When neutrinos from the Sun were first observed there was a disagreement between the predicted number based on the standard model for nucleus fusion powering the Sun (a number like your answer to 3) and the number actually seen in neutrino "telescopes"; the number observed was roughly third the number expected.

4. What do you think should be concluded about fusion in the Sun? If you think fusion happens, how might you explain the difference between observation and prediction? If you think fusion doesn't happen how might you explain how the Sun gets its energy? **Note:** You are not expected to have the correct answer, but you are expected to try to think of things that might have been left out in our simple analysis.