The Reason Gallium Detectors Measure Low Solar Neutrino Flux

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The neutral current and charged current electron neutrino interactions with deuterons are used to show that the predicted electron neutrino flux not measured by the gallium detectors does exist. It is not detected because, unlike in the deuteron reactions that always free a nucleon from the nucleus that can be detected and indicates that an interaction has occurred, a neutrino interaction with ^{71}Ga cannot separate a nucleon from the ^{71}Ga nucleus to be detected. Consequently, neutrinos interacting with ^{71}Ga nuclei that do not create ^{71}Ge nuclei go unrecorded by the detectors.

1. Introduction

When measuring the neutrino flux from the Sun, the gallium detectors, GALLEX/GNO [1] and SAGE [2] only registered about 55% of the flux the Standard Solar Model (SSM) predicted. [3] The chlorine detector only saw about one-third of what the SSM predicted [4] and the water detectors about 46% of the SSM prediction. [5] Consequently, it was speculated that the electron neutrinos leaving the Sun oscillate into muon and tau neutrinos on their way to Earth. [6] This caused only a fraction of them to arrive at Earth as electron neutrinos. The deuterium detector at Sudbury allegedly confirmed that some of the neutrinos that leave the Sun as electron neutrinos, apparently arrive at Earth as muon and tau neutrinos, causing the detectors to see only a fraction (~ ⅓) of the original solar neutrino flux. [7] This resolved what was known as the solar neutrino problem.

The following will show that the deuterium experiments provide a mechanism for explaining why the gallium experiments are seeing the full SSM prediction of electron neutrinos, but only showing just over half of them. Consequently, the gallium detectors do not support the claim that neutrinos oscillate on their trip from the Sun to Earth.

2. The Deuterium Reactions

When electron neutrinos interact with deuterium, two reactions can occur. [7] As shown in Figure 1, the neutrino scatters off the deuteron, breaking the bond holding the two nucleons together, resulting in a free proton and free neutron, the neutral current reaction.

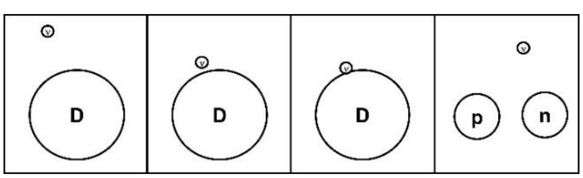

Figure 1. Deuteron neutral current reaction. A neutrino scatters off the deuteron, splitting it into a proton and a neutron.

However, sometimes instead of scattering off the deuteron, the electron neutrino is absorbed by it. The interaction still breaks the bond holding the two nucleons together, but once freed, the neutron emits an electron to become a proton. Figure 2 shows this neutrino interaction with the deuteron results in two protons and an electron. This is the charged current reaction. In both interactions, the bond holding the two nucleons together is broken, breaking up the deuteron, and signaling that a neutrino interaction with the deuteron has occurred.

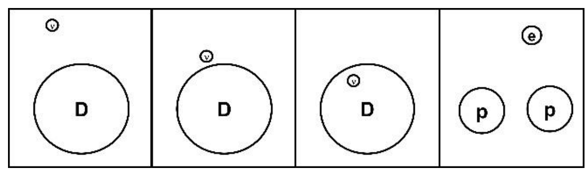

Figure 2. Deuteron charged current reaction. A neutrino is absorbed by the deuteron, separates the two nucleons, converts the neutron into a proton and becomes an electron.

3. The Gallium Reactions

When measuring the solar neutrino flux with ^{71}Ga, a neutrino interacts with a gallium nucleus, causing it to emit an electron and become ^{71}Ge, which is radioactive. [1] Because it is radioactive, it can be collected and counted to determine how much ^{71}Ge was made, and consequently, what the neutrino flux was that created the ^{71}Ge. [1,2] With the neutrino-infiltrated ^{71}Ga nucleus emitting an electron to become a ^{71}Ge nucleus, this interaction is similar to the charged current reaction for the deuteron. So, if neutrinos can interact with ^{71}Ga nuclei to produce charged current reactions, why can't they also scatter off ^{71}Ga nuclei similar to the neutral current reaction in deuterium? The answer to this question is they can, and they likely do, the reactions are just not detectable.

When a neutrino produces a neutral current reaction with a deuteron, it breaks the only bond holding the two nucleons that make up the deuteron together, causing the deuteron to break up into two individual particles. This is how the neutral current reaction is detected. A deuteron becomes a proton and a neutron. When a neutrino interacts with a ^{71}Ga nucleus, if it creates an electron as shown in Figure 3, it makes a ^{71}Ge nucleus that can be detected.

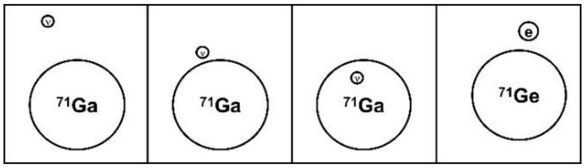

Figure 3. ^{71}Ga nucleus charged current reaction. The neutrino is absorbed by the ^{71}Ga nucleus, changes a neutron into a proton and becomes an electron

However, if the neutrino just scatters off the ^{71}Ga nucleus like in Figure 4, the reaction cannot be detected because the neutrino cannot separate a nucleon from the ^{71}Ga nucleus. Unlike the deuteron, where only one 2.23 MeV bond holds a nucleon to the nucleus, each nucleon in a ^{71}Ga nucleus is held to the nucleus by an average of four 2.23 MeV bonds (8.71 MeV/nucleon ÷ 2.23 MeV). Even if the scattering neutrino breaks one of the bonds holding a nucleon to the ^{71}Ga nucleus, that nucleon is secured by at least one other bond, so that it does not separate from the nucleus. If no nucleon separates from a ^{71}Ga nucleus as a result of a neutrino scattering off it, there is no indication that the interaction occurred.

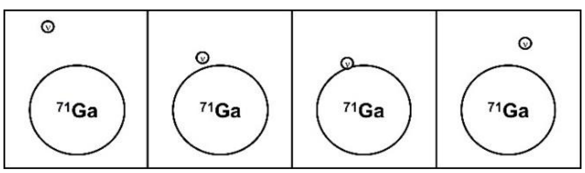

Figure 4. ^{71}Ga nucleus neutral current reaction. The neutrino scatters off the ^{71}Ga nucleus but produces no measurable indication that the interaction occurred.

4. Inside the Deuterium Reactions

When a neutrino interacts with a deuteron, one of two things happens inside the deuteron in addition to its bond being broken. The neutrino interacts with either the proton or the neutron. In the charged current reaction shown in Figure 5, the freed neutron is transformed into a proton and the neutrino, seemingly, into an electron. This implies that when the charged current reaction occurs, a neutrino has interacted with the neutron in the deuteron.

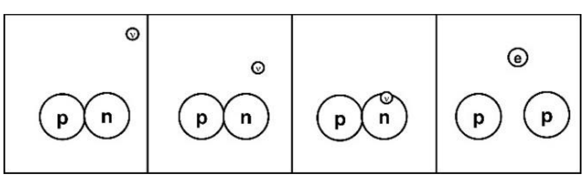

Figure 5. Charged current reaction inside the deuteron. A neutrino is absorbed by the neutron, separating the two nucleons. Then the neutron is converted into a proton and the neutrino into an electron.

However, during the neutral current reaction (Figure 6), the deuteron is broken up into its component particles, but the two freed nucleons retain their identities. Therefore, if a neutrino interaction with a deuteron occurs but no new proton or electron appears, that indicates the neutrino interacted with the proton inside the deuteron. The neutrino just scatters off the proton after breaking up the deuteron.

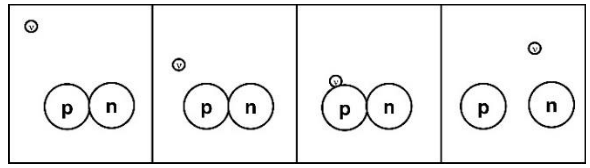

Figure 6. Neutral current reaction inside the deuteron. A neutrino scatters off the proton in the deuteron, breaking the bond holding the two nucleons together.

When a deuteron transforms a ^{71}Ga nucleus into a ^{71}Ge nucleus, the neutrino has transformed one of the 40 neutrons in the ^{71}Ga nucleus into a proton, increasing its proton count from 31 to 32, changing the gallium into germanium. As with a deuteron, a neutrino interaction with a neutron in the ^{71}Ga nucleus causes particles to change. But, if a neutrino interacts with a proton in the ^{71}Ga nucleus, like with the deuteron, it just scatters off the proton. However, unlike a deuteron, if the scattered neutrino breaks a bond holding the proton to the ^{71}Ga nucleus, it does not separate the proton from the nucleus because the proton is attached to the nucleus by more than one bond. Consequently, there is no way to directly see a neutrino interaction with one of the protons in a ^{71}Ga nucleus. There is, however, an indirect way to know that these reactions occur.

Using the ^{71}Ge produced by the neutrinos as a measure of the neutrino flux the ^{71}Ga saw, only the neutrino interactions with the neutrons in ^{71}Ga are recorded. It seems that the SSM cross section used to predict the solar neutrino flux considers the ^{71}Ga nucleus as a whole and does not calculate the proton and the neutron contributions to its prediction. In a uniform neutrino flux, each nucleon in a ^{71}Ga nucleus should have the same probability of having an encounter with a neutrino. Therefore, since there are 71 nucleons in the ^{71}Ga nucleus but only 40 of them are neutrons, only 40 out of the 71 or about 56% of the neutrino interactions with ^{71}Ga would show up as ^{71}Ge. That is why the gallium detectors only see about 55% of the SSM prediction. They could only see the charged current reactions occurring. The other 44% of the predicted flux is neutrinos scattering off the 31 out of 71 protons in ^{71}Ga, the neutral current reactions, that produce no detectable indication of their occurrence.

5. Conclusions

It appears the gallium detectors see all of the electron neutrinos the SSM predicts arrive at Earth from the Sun. The electron neutrino neutral current reactions with the 31 protons in the ^{71}Ga nuclei leave no measurable indication of their occurrence. Only interactions with the 40 neutrons that produce charged current reactions can be detected. Consequently, only the 40 out 71 electron neutrino interactions with ^{71}Ga, about 56% of the total interactions, get recorded. The SSM ^{71}Ga neutrino cross section accounts for neutron and proton interactions.

6. Implications

If this explanation of what is occurring in the gallium detectors is valid, it carries some interesting implications about the solar neutrino flux. First, and foremost, it shows that the gallium detectors are seeing all of the electron neutrinos believed to be leaving the Sun. This means these detectors see no measurable indication that the solar neutrinos oscillate during their trip to Earth from the Sun. Second, the interpretations of the measurements from the other types of detectors, thought to support the solar neutrino oscillation premise, are apparently incorrect. If all the neutrinos from the Sun are making it to the gallium detectors as electron neutrinos, they must also be arriving at the other detectors as electron neutrinos. Clearly, the shortfalls observed in the other detectors indicate they are not completely understood. Finally, perhaps it calls into question whether the neutrinos oscillate at all. Once solar neutrinos were thought to oscillate, it was easy to see oscillations everywhere. It may be useful to reexamine situations where neutrino oscillations were used to explain puzzling phenomena.

References

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