SOLAR NEUTRINOS AND A YOUNG SUN

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The failure to find solar neutrinos which should be a result of hydrogen fusion reactions in the sun indicates that the sun is young. Further, the solar global oscillations preclude the existence of fusion at all. The only viable alternative, gravitational contraction, which has a comparatively short time span, is indicated by actual observations of a decreasing solar diameter.

The well-known solar neutrino problem has been with us since 1968 and shows no signs of going away. Though many dozens of explanations have appeared, none has been satisfactory. The reason is that all scientists have approached the problem with uniformitarian presuppositions. When the problem is examined more objectively, it becomes obvious that the lack of solar neutrinos is almost irrefutable evidence for a recently created sun.

The single most important assumption in all of astrophysics is that the source of energy in stars is nuclear fusion, primarily the conversion of hydrogen into helium. All of stellar evolution theory depends entirely upon this assumption, and with it, most of the rest of astrophysics. Yet the actual occurrence of nuclear fusion in stars has never been verified. It has become accepted as dogma simply because it is the only conceivable process which could provide energy for the billions of years which stars are believed to have existed. Simple chemical burning would last for only about 5,000 years, and gravitational contraction can provide energy at the present solar luminosity for a mere 20,000,000 years. But nuclear fusion, because of the high mass defect of helium (about 0.7%) has the potential of providing immense amounts of energy, about 6.4×10^{18} erg/gram. This is adequate, if the entire mass of the sun were converted into helium, to keep it burning at the present luminosity for about 100 billion years. But because conditions for fusion are believed to exist only in the inner 10% of the mass of the sun, its main sequence lifetime would be limited to 10 billion years.

The basic reaction is believed to be

$$4\ \mathrm{H} \rightarrow \mathrm{He}$$

where only the nuclei are considered. Since the hydrogen nucleus is a single proton and the helium nucleus, or alpha particle, consists of two protons and two neutrons, it is necessary for two of the hydrogen nuclei to be converted, via beta decay, into neutrons. Charge conservation requires that a positron be produced to carry away the proton's positive charge, while lepton conservation requires the production of a neutrino.

$$p^+ \rightarrow n + e^+ + \nu$$

The sun is extremely opaque to all forms of electromagnetic radiation which might arise in the interior due to nuclear reactions. Harwit says, "The overall structure and appearance of the star can therefore give no clue about whether nuclear reactions indeed are responsible for stellar luminosities."[1] Neutrinos, on the other hand, being neutral and massless, have an extremely small cross section for interaction with matter, and should escape freely from even the center of the sun if they are being produced there. If such neutrinos could be detected on Earth, it would be a strong indication that nuclear fusion is indeed taking place in the sun.

The Search for Solar Neutrinos

In the 1960's Raymond Davis undertook an experiment to detect these solar neutrinos. Though the cross section for interaction with matter is small, the neutrinos ought to be produced in such copious numbers that a measurable fraction should be detectable. Years before Davis began his experiment, Cl^{37} was suggested as a target for detecting neutrinos. In the rare instance when a neutrino interacts with a Cl^{37} nucleus, it is transformed into an Ar^{37} nucleus. This isotope of argon is radioactive with a half-life of 35 days.[2] The neutrino energy threshhold to initiate the reaction is 0.814 MeV, so any solar neutrinos must have at least this energy to be detected.[3]

To learn what neutrino energies and fluxes are expected, we have to examine the proposed energy mechanisms in the sun as assumed in current solar models. The total number of neutrinos which the sun should be producing is easily calculated from the known solar luminosity, $L_\odot$, and the mass defect of the helium atom (equivalent to the total energy released for each helium atom, and thus for each two neutrinos, produced). So there should be $2L_\odot/26.2$ MeV $= 19.0 \times 10^{37}$ neutrinos/sec. Here $L_\odot$ is 4×10^{33} erg/sec and 26.2 MeV are released per helium atom.[4] At the Earth's distance from the sun, 1 AU, this is $19.0 \times 10^{37}\ \nu/\mathrm{sec}\ / (4\pi\,(1\ \mathrm{AU})^2) = 6.7 \times 10^{10} \nu/\mathrm{sec.} \cdot \mathrm{cm}^2$. A convenient unit has been established for expressing the neutrino capture rate. This is the Solar Neutrino Unit, or SNU, and is equal to 10^{-36} neutrino absorptions per target atom per second.

However besides the flux of neutrinos, we need to know their energy distribution, because not all neutrinos will be able to initiate the detection reaction. The energy distribution of neutrinos depends upon the process which produces them. A number of variations of the simple hydrogen to helium fusion reaction are known and it is believed that all play a role in solar energy generation to a greater or lesser extent. The amount of participation of each branch, or variation, depends sensitively upon temperature and chemical composition. The reactions are summarized in Table 1. The two major classes of fusion reaction are the CNO bi-cycle and the proton-proton chain. The CNO bi-cycle is thought to require higher temperatures than exist in

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the solar core; and therefore it proceeds only slowly. Each variation, however, produces neutrinos of sufficient energy to be detected, more so, in fact, than the proton-proton chain which is expected to predominate in the sun. Therefore a high neutrino capture rate would be expected if the CNO cycle were at all important in the solar energy scheme. The low detection limits, which we shall examine presently, definitely eliminate this cycle from being an important energy source in the sun.

The proton-proton chain, because it may occur at lower temperatures, is thought to be the dominant fusion reaction in the sun, where the central temperature is thought to be 15 million degrees Kelvin.[5] Table 1 shows all three branches of the proton-proton chain. All have the first stages in common-fusion of two hydrogen nuclei into a deuterium (heavy hydrogen) nucleus via beta decay; and further fusion with a third hydrogen nucleus to produce He^3. Here they diverge, and the divergence is extremely important. Either two light helium nuclei will fuse into an alpha particle (normal helium nucleus) or a He^3 nucleus will fuse with an He^4 nucleus. In the former case, the reaction is over, since a new He^4 has been produced with the accompanying release of two of the original hydrogen nuclei. In the latter case the two helium nuclei fuse into beryllium which proceeds to take one of the other two possible branches.

Table 1. This shows the various reactions by which the fusion of hydrogen is believed to take place in the Sun

Process *Pro ton-pro ton Chain*	% *taking this branch*	*Neutrino Energy (MeV)*
$H^1 + H^1 \rightarrow H^2 + e^+ + \nu$	99.75	**0.42**
OR		
$H^1 + H^1 + e^- \rightarrow H^2 + \nu$	**0.25**	1.44
$H^2 + H^1 \rightarrow He^3 + \gamma$		
I. $He^3 + He^3 \rightarrow He^4 + 2H^1$	86	
II. $He^3 + He^4 \rightarrow Be^7 + \gamma$	14	
$Be^7 + e^- \rightarrow Li^7 + \nu$		**0.861** (90%) **0.383** (10%)
$Li^7 + H^1 \rightarrow 2He^4$		
III. $He^3 + He^4 \rightarrow Be^7 + \gamma$	**0.02**	
$Be^7 + H^1 \rightarrow B^8 + \gamma$		
$B^8 \rightarrow Be^{8*} + e^+ + \nu$		14.06
$Be^{8*} \rightarrow 2He^4$		
CNO bi-cycle		
$H^1 + C^{12} \rightarrow N^{13} + \gamma$		
$N^{13} \rightarrow C^{13} + e^+ + \nu$		0.71
$H^1 + C^{13} \rightarrow N^{14} + \gamma$		
$H^1 + N^{14} \rightarrow O^{15} + \gamma$		
$O^{15} \rightarrow N^{15} + e^+ + \nu$		1.00
$H^1 + N^{15} \rightarrow C^{12} + He^4$		
OR		
$H^1 + N^{15} \rightarrow O^{16} + \gamma$		
$H^1 + O^{16} \rightarrow F^{17} + \gamma$		
$F^{17} \rightarrow O^{17} + e^+ + \nu$		0.94
$H^1 + O^{17} \rightarrow N^{14} + He^4$		

Table 2. This shows the fluxes, and rates of capture, of solar neutrinos due to the various processes. These data are as in Reference 2. D. 40.

Neutrino Sources and Energies (MeV)	*Flux on Earth* $(cm^{-2}\ sec^{-1})$	*Capture Rates in* Cl^{37} *in SNU's*
$H + H \rightarrow D + e^+ + \nu$ (0 - **0.42** MeV)	6.1 x 10^{10}	0
$H + H + e^- \rightarrow D + \nu$ (1.44 MeV)	1.8×10^8	**0.26**
Be^7 decay (**0.86** MeV)	3.4×10^9	0.99
Be^8 decay (0- **14** MeV)	3.2×10^6	**4.32**
O^{15} decay (0- 1.74 MeV)	1.8x 10^8	0.14
N^{13} decay (0- 1.19 MeV)	2.6×10^8	0.05
	Total	5.8 SNU's

This is dependent upon the existence of helium-4 already in the solar core. The first branch, the fusion of two He^3 nuclei, does not produce any neutrinos and is taken by 86% of all fusion reactions. The second branch, taken by almost all the remaining reactions, produces neutrinos with marginally detectable energies. The third branch, though taken by only 0.02 of the fusion reactions, produces highly energetic neutrinos and makes the largest contribution to the neutrino flux which should be detectable with chlorine atom detectors[6] The contributions of the various branches to the total flux at the Earth as well as the actual expected capture rate are shown in Table 2.

As a detector Davis chose the common cleaning fluid perchloroethylene, C_2Cl_4. This has the advantages that it is cheap, available, and contains a high proportion of chlorine atoms. To get enough of this in one place and then to isolate it from background radiation whose effects could swamp the minute effect of the solar neutrinos is a formidable problem. Davis filled a tank with 100,000 gallons of this fluid and put it at the bottom of the Homestake gold mine in Lead, South Dakota, 4850 feet underground. The great depth isolates his target from most of the secondary cosmic rays which could also cause the chlorine to argon reaction and confuse the results. Even at this great depth, however, the lower limit of Davis' detector is 0.4 SNU's because of the cosmic rays which penetrate nearly a mile of rock.[7] Natural radiation from the rock walls of the cavity where the tank is placed can also initiate the reaction. This can be nearly eliminated, however, by flooding the chamber with water.

The chlorine atoms, when converted to argon, are released into the liquid as a dissolved gas. They are recovered by bubbling helium gas through the tank. The helium picks up the argon atoms. They are later separated by cooling the gas in charcoal cooled to liquid nitrogen temperatures. The argon atoms are absorbed onto the charcoal and the helium is returned to the tank. After the argon is removed from the tank, the argon atom decays are counted for at least 150 days. The counts are quite low, typically 5 to 10 counts above background during a 70 day period.[8]

The first solar model formulated with the intent to predict the expected number of solar neutrinos was that of Sears in 1964. His parameters included an assumed age of 4.5×10^9 years and predicted a neutrino flux of 36 SNU's.[9] Further improvements in solar models continually lowered the expected flux to 22 SNU's in 1968. In the same year Davis' experiment set an upper limit to the solar neutrino flux of 3 SNU's.[10] The discrepancy is large, and despite constant revisions to solar models, persists to this day. Davis presents an expected flux of 5.8 SNU's,[11] while Bahcall has a model with 4.7 SNU's.[12] Meanwhile, Davis has improved his upper limit. His signal amounts to 0.24 ± 0.09 Ar^{37} atoms per day which amounts to 1.3 ± 0.4 SNU's. However he states, "We do not regard this result as a measurement of the solar neutrino flux because of uncertainties in various background effects."[13] Thus we can conclude that no signal at all has been conclusively detected from fusion processes occurring in the sun.

Proposed Explanations of the Lack of Solar Neutrinos

Besides possible experimental problems, which we shall discuss shortly, there are two possible explanations: 1) no nuclear reactions are taking place in the sun; or 2) the third branch only of the proton-proton reaction is not occurring as expected. Possibility number one, that no nuclear reactions at all are occurring in the sun, is the explanation which I shall present as the correct one later. However let us first examine the ramifications of the second possibility. From Table 1 it can be seen that the occurrence of the third branch of the proton-proton chain is dependent upon the presence of He^4 already in the solar core. If this amount is really different (i.e. lower) than anticipated, then the energetic neutrino flux should be lower. Thus the assumed amount of He^4 in the solar core is critical in determining the expected neutrino flux.

Scientists assume that the He^4 in the sun has come from two sources. The first is primordial helium, created, supposedly, in the big bang. This is mixed with hydrogen throughout the universe in the approximately constant proportion of about 30% by mass. Besides this is the end product of the nuclear fusion itself. If hydrogen has been burning into helium for 4.5 billion years, the helium should have been building up in the core for that length of time. If the sun is younger, there will be less helium than allowed in the current solar models, and consequently a lower neutrino flux.[14] Bahcall and Sears[15] present a formula illustrating the dependence of neutrino flux upon a variety of parameters. The age dependence is

$$\emptyset \text{ (flux)} \propto \left[\frac{\text{Age}}{4.7 \times 10^9 \text{ yr}} \right]^{+1.4}$$

Using Davis' measurement of 1.3 SNU's, this formula implies an upper limit for the age of the sun of 1.6×10^9 years.

Of course there are other factors in Bahcall and Sears' formula, including luminosity, metal abundances and various reaction cross sections. However most of these are constrained by direct measurements to values which cannot allow the neutrino flux to decrease adequately to explain the lack of neutrinos. Age is also considered well known and to be within a few percent of 4.5×10^9 years. This in turn is based upon a number of uniformitarian assumptions which have been dealt with in numerous other articles in this journal. The absence of solar neutrinos in the anticipated numbers is strong evidence for the youth of the sun.

Alternate explanations are not lacking, however. Since simply varying the relevant parameters cannot reduce the expected neutrino flux adequately, more exotic changes are often proposed. There are also those who maintain that the experiment is at fault. This seems unlikely, since the experimental apparatus is subject to direct testing. Argon recovery is not at fault since small amounts of argon were introduced into the tank and successfully recovered. Also, the conversion of chlorine to argon was induced by placing a neutron source inside the tank and all expected argon was efficiently recovered.[16] Cross sections for the neutrino interactions have been checked and rechecked, both experimentally and theoretically, and there is little likelihood that they are incorrect.[17]

Possible verification of the ability of the apparatus to detect neutrino-induced argon is found in one run, number 27, where an anomalously large (compared to other runs) number of argon atoms were produced. In fact this single run contributes significantly to the 1.3 SNU average presented earlier. Davis attributes this to statistical variations,[18] but John Bahcall presents an intriguing speculation. He suggests that this run may have actually detected neutrinos from the collapse of a star which was not detected optically. If true, this indicates both that the experiment functions correctly, and that neutrinos are stable over long time periods, eliminating the suggestion that Davis' negative results could be attributed to the decay of solar neutrinos en route to the Earth.[19] Of course this idea may be incorrect.

It is considered more likely that the problem lies within the sun. Some of the many suggestions are:

1. The initial helium abundance Y was less than 0.16-0.20[20]
2. Unexpected large errors exist in one or more of the relevant nuclear cross sections[21]
3. One or more of the neutrino absorption cross sections has been significantly overestimated[22]
4. The sun was initially inhomogeneous and remained so[23]
5. Significant mixing of the solar interior has occurred during the nuclear burning phase[24]
6. Strong, large-scale magnetic fields of up to 10^9 gauss exist in the solar interior[25]
7. The gravitational constant, G, increases with time[26]
8. The interior opacity may be lower than expected[27]
9. The core is in a transient state and is not currently producing neutrinos[28]

10. A black hole at the center of the sun with a mass of 10^{-5} of the solar mass, $M_{\odot}$, could produce half the sun's luminosity[29]
11. The sun could have formed in two phases, the inner half having a high metal abundance and the outer layers having a low metal abundance[30]
12. There is a departure from the Maxwellian velocity distribution at high energies[31]
13. There is a critical temperature below which hydrogen and helium are immiscible[32]
14. The sun has substantial amounts of He^3 so that the principle energy source is He^3 (He^3, 2p) He^4 [33]
15. There are competing nuclear reactions which tend to reduce the amount of B^8 produced[34]
16. There is a variation in the strength of the weak interaction with increasing gravity[35]

Obviously, many of these suggestions are quite fanciful, and none is entirely satisfactory. Perhaps the most popular one, though one of the most general, is number 9, which simply says that for one reason or another, the sun is temporarily turned off. There is no need to discuss these suggestions one by one. It is sufficient to note that none is considered adequate, there is little independent evidence for any, and the problem persists.

Maybe there is no Fusion in the Sun

Thus the near absence of solar neutrinos alone is enough to indicate that the sun is considerably younger than usually assumed. But, as I mentioned earlier, I plan to take an even more radical position and will argue that there is no nuclear fusion occurring in the sun at all. If this is true, the age of the sun will be limited to the maximum time provided by an alternate energy source, necessarily very much less time than would be provided by nuclear fusion.

Davis' average solar neutrino flux is 1.3 ± 0.4, including run #27. If this is excluded, using Davis' data,[36] the value is 1.0 ± 0.4. From Table 2 the expected neutrino flux from fusion processes *other* than branch three of the proton-proton chain is 1.48 SNU's. Thus the observed flux is so low as to eliminate not only the Be^8 reactions, but others as well. When this is added to Davis' statement that he does not regard the 1.3 SNU's as measurement of the solar neutrino flux, there is little reason to believe that nuclear fusion of any kind is taking place in the sun. Certainly nuclear fusion would be as good a source of solar energy as any other; any source that could provide energy for more than about 10,000 years would be satisfactory within the creationist time frame. But the evidence is against fusion, and this is in our favor, for no other energy source could provide energy as long as 4.5 billion years. The sun is surely younger than its accepted (uniformitarian) age.

But there are other reasons as well for thinking that the sun's energy source is other than nuclear fusion. One is the relatively recently discovered global oscillations of the sun. Henry Hill and his associates were attempting to measure the oblateness of the sun in an attempt to distinguish between different versions of the general theory of relativity. They did not measure the oblateness, but they did detect that the sun is oscillating or ringing like a bell in several different modes.[37] The numerous periods range from 5 to 300 minutes. There are two reasons why this observation is relevant to the solar neutrino problem. The first has to do with energy transport. The temperature gradient in the sun is computed on the basis of energy transport by radiation. High energy photons produced by fusion reactions are absorbed and reemitted countless times as they diffuse towards the surface. It is said that energy transported in this way would take 30 million years to reach the surface, the sun is so opaque.[38] Because of this extremely high opacity, the temperature gradient in the sun is high, causing the sun's center to be at 15 million degrees, if the current models are correct. If, however, the acoustic waves are real, they also could transport energy and very rapidly. The effective opacity to energy transport is much reduced and therefore so is the temperature gradient. This allows a lower central temperature in the sun. Since the rate of nuclear reactions is so extremely temperature-sensitive, the decrease in temperature would be enough to reduce the third branch of the proton-proton chain enough to make its neutrinos below the threshhold of detection.

This may sound like a point in favor of the evolutionists, for is the neutrino problem not solved by this discovery? Hardly. While it is true that under the right conditions the lack of solar neutrinos could be solved by the acoustic waves, the waves bring up a problem which is just as bad, which brings me to the second reason for mentioning the solar oscillations. The 2 hour 40 minute oscillations are too long to be ascribed to the surface layers of the sun. The best explanation is that they are radial pulsations involving the entire sun, and the period is consistent with the sun's being a homogeneous sphere![39] This leads to a central temperature so low that nuclear fusion is almost nonexistent.[40] Thus solar oscillations solve the solar neutrino problem by not only reducing the temperature so that fewer neutrinos are produced, but to such an extent that nuclear fusion itself is effectively eliminated. Severny *et al.* estimate that the luminosity due to nuclear fusion would be about 2.5×10^{29} erg/second[41] or only 6.25×10^{-5} of the observed luminosity.

If not Fusion, then What?

What, then, is the energy source of the sun? Before the arrival of the nuclear fusion theory, several mechanisms were advanced, most of which were incorrect for obvious reasons. The most successful was that of Hermann von Helmholtz. He postulated that the contraction of the sun was sufficient to supply its entire luminosity, the energy being derived from its gravitational field. This process would keep the sun shining for about 20 million years into the past if the sun were assumed to have started from a cloud with infinite radius.[42] Certainly this is more than enough for creationists. Ley objects to this mechanism, in addition to the limited time period, by pointing out that solar contraction should be measurable.[43] The approximate magnitude of this change is easily calculated. Using Novotny's formula for the energy release of the sun as it shrinks from R to $R_{\odot}$[44]

$$E = -GM^2 \left(\frac{1}{R_\odot} - \frac{1}{R}\right)$$

setting E equal to 4×10^{33} ergs (the energy released by the sun per second), and solving for R gives a shrinkage of 2.9×10^{-4} centimeters per second, or about 10,000 cm per year. At the sun's distance this amounts to 1.4×10^{-4} seconds of arc per year, or 0.014 seconds per century, definitely too small to be measurable.

But we have by no means reached the end of this possibility. In a paper presented to the American Astronomical Society in June, 1979, John A. Eddy and Aram A. Boornazian announced that the sun is shrinking at a rate of 2 seconds of arc per century.[45] This is considerably more than the amount required to produce all the sun's luminosity. Since this is so much larger than the requisite amount, it implies that the whole sun is not shrinking uniformly, but more likely, it is only the outer layers which are involved. This amounts to about 5 feet per hour in the horizontal direction and about half that vertically. The announcement was the result of solar diameter measurements recorded over the last 143 years, and they speculate that it may have been going on longer. Of course they do not allow the possibility that it has been going on for more than a few hundred years, since this would totally dethrone stellar evolution. Rather, they consider it a temporary phase.

However, they admit that the energy produced by this contraction is adequate to make up for the amount which apparently is not being produced by fusion; and, as we saw, this is nearly 100%. Thus it is not unreasonable to suppose that this contraction is responsible for the entire solar luminosity, and has been from the time of creation. In the last 10,000 years, the entire shrinkage of the sun would amount to 1.3×10^5 kilometers, or a little less than 10% of the sun's present diameter.

Another study shows a somewhat smaller rate of decrease. Sofia *et al* gives a shrinkage value of 0.2 arc seconds per century,[46] a factor of ten smaller than Eddy's measurements, but still a factor of 10 larger than the amount necessary to supply the sun's entire luminosity. The difference appears to be due to the way in which the data were selected. Nevertheless, both agree that the sun is shrinking, just as would be expected from the Helmholtz model.

There is one final consideration. What if Eddy is right in saying that the shrinkage is only temporary, and that in the long run nuclear fusion is the real solar energy source? Is there any way to tell? Yes. At the NATO Advanced Study Institute on The Origin of the Solar System, A. G. W. Cameron presented a paper in which he calculated that if the sun had contracted from a gas cloud, and material fell inward to form a core with the present density, the temperature would have only reached one million degrees Kelvin! This is far too low for any nuclear reactions to take place.[47] Thus if the sun had formed according to an evolutionary process, nuclear burning could never have been initiated.

Conclusion

The evidence is clear. If the sun had formed as is assumed by most scientists today, nuclear fusion could never have become its energy source. Evidence from the solar neutrino experiment, global solar oscillations, and measured solar shrinkage all are strong evidence against the existence of nuclear fusion in the sun. Any alternate energy source necessarily means a shorter maximum lifetime, 20 million years at most for contraction, and apparently less at the present high contraction rate. Therefore, as the Biblical creation account tells us, the sun is a young object.

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