WHAT DO SOLAR NEUTRINOS REVEAL ABOUT FUSION REACTIONS IN THE SUN?

Abstract

In the standard solar model (SSM), fusion reactions power the sun and some produce neutrinos. **Solar neutrino data imply that the entire SSM reaction suite may not occur and that the sun's central temperature is less than typically assumed.** The commonly hypothesized role of heavy element synthesis may be suppressed or absent, hydrogen fusion being the only significant solar nuclear reaction.

Reported confirmation of the SSM from Sudbury Neutrino Observatory data via neutrino oscillation theory overlooks the fact that **oscillation parameters are unknown and verifiable ultimately only with respect to the SSM itself.** Underlying assumptions in the SSM and difficulties unresolved by neutrino oscillation theory are discussed, including the function of CNO reactions in conventional nucleosynthesis.

Introduction

The standard solar model (SSM) postulates that the nuclear reactions in Table I power the sun (Bahcall, 1989, pp. 63-75; Cleveland et al., 1998, p. 506; Harwit, 1982, pp. 303-350). Several of these are believed to produce neutrinos (v_e), neutral, virtually massless particles much smaller than electrons. The fusion of H to produce deuterium (D), the *pp* reaction, produces many neutrinos, and is believed to be followed by *pep* and *hep* reactions to produce He and more v_e.

Table I lists v_e energies for neutrino-producing reactions, including: (1) the *pp* reaction; (2) fusion of two H atoms and an electron (e^-) to produce D (*pep* reaction); (3) fusion of ^{3}He and H to produce ^{4}He (*hep* reaction); (4) fusion of ^{7}Be with e^- yielding ^{7}Li (^{7}Be reaction); (5) decay of ^{8}B into ^{8}Be*, an excited beryllium state (^{8}B reaction); and (6) the CNO sequence, in the SSM a minor contributor to solar energy at ≈ 1.5 percent. The *hep* and ^{8}B neutrinos are "high energy"; other neutrinos are "low energy."

Solar v_e flux is measured by the solar neutrino unit (SNU), defined as a neutrino flux rate of 10^{-36} neutrino per target atom per second (Bahcall, 1989, p. 3; Davis et al., 1968, p. 1205). Detection of v_e from these reactions would confirm occurrence in the sun.

However, v_e pass through most matter undetected due to their tiny size, revealing their presence only in occasional collisions with atoms in a susceptible target substance, e.g., perchloroethylene (C_2Cl_4), gallium (Ga) metal, or heavy water (D_2O). Atoms are mostly empty space, so collisions are rare. Neutrino detectors thus use huge amounts of target material, and are underground to minimize target interaction with cosmic rays.

The search for solar v_e began in 1967 with the Homestake detector startup in the Homestake gold mine, South Dakota. Homestake used C_2Cl_4 as the target; v_e reacted with ^{17}Cl to yield ^{17}Ar which was collected to find the v_e detection rate. Other solar v_e detectors have included SAGE in Russia and GALLEX in Italy, both with targets of Ga metal convertible to germanium (Ge) by v_e bombardment, and Super-Kamiokande (Super-K) in Japan with a D_2O target. Homestake and Super-K detected mainly high-energy v_e; GALLEX and SAGE (the "Ga detectors") were sensitive mainly to low energy v_e. Until recently, these were the four operating solar v_e detectors (Fix, 1999, p. 391). However, neutrino studies are "a forefront research issue worldwide with many ongoing and planned activities" (Kolbe and Langanke, 2001, p. 1), a rapidly changing "industry" (Goodman, 2004, p. 1). *Table II lists six solar neutrino detectors which have operated as of mid-2004, as well as four planned for the future.*

Besides solar v_e, neutrinos come from cosmic processes, e.g., supernova explosions and atmospheric interaction with cosmic rays (cosmic neutrinos); and particle accelerators or nuclear reactors (terrestrial neutrinos). Table II lists detectors of cosmic and terrestrial neutrinos discussed in this paper. Some are sensitive to particles from more than one source; Table II lists only the source for each emphasized in this paper. Space is insufficient for further detector details; see Table II references.

Solar v_e detectors initially found less v_e than the SSM predicted. Homestake and Super-K detection ratios were ≈ _, 0.34 at Homestake (Aliani et al., 2003, p. 107) and 0.36 at Super-K (Super-K Collaboration, 1998b, p. 1158). SAGE and GALLEX detection ratios were slightly > ½, 0.60 at SAGE (SAGE Collaboration, 2002, p. 181) and 0.58 at GALLEX (Aliani et al., 2003, p. 107). **This implied the SSM did not fit solar processes and was the solar neutrino problem (SNP),** a serious dilemma. Fix (1999, p. 392) wrote,

> One suggestion [for the v_e deficit] is that the sun sometimes stops producing energy by fusion and contracts to produce energy instead. ... Apparently, something is wrong with our understanding of either the Sun or the properties of neutrinos.

In 2001 the Sudbury Neutrino Detector (SNO), a D_2O detector, reportedly detected v_e at a rate equal the SSM prediction, confirming the SSM reaction suite. Like Homestake and Super-K, SNO detected mainly ^{8}B v_e. Unlike earlier detectors, SNO detected not only electron neutrinos v_e but muon neutrinos (v_μ) and tau neutrinos (v_τ) which neutrino oscillation theory (NOT) says are transmutation products of v_e generated in the solar core.

However, **the claim that SNO has verified the SSM overlooks other facts:** (1) the SSM was believed for chronological reasons before reported confirmation by NOT; (2) the SSM is built around mostly unknown and unmeasurable solar properties which are adjustable parameters in SSM calculations; (3) the appearance of certainty in the SSM results from comparing models with other models; (4) the SNP was not the only pre-SNO contradiction of the SSM; the SNO claims ignore these other problems; (5) the NOT behind the SNO claims does not uniquely confirm the SSM, but can also disprove it and therefore confirms nothing; (6) NOT supports

Table I. Nuclear Reactions of the SSM

Name	Theoretical Fusion Reaction	Percent	Critical Temp., K	Expected Neutrino Energy, MeV	Expected Neutrino Flux, $10^{10}/cm^2 \cdot s$
Proton-Proton Chain					
pp	$H + H \rightarrow D + e^+ + \nu_e$	99.6	1×10^6	0.42/0.263	6.0
pep	$H + H + e^- \rightarrow D + \nu_e$	0.4		1.44	0.014
	$D + H \rightarrow {}^3He + \gamma$	100			
	${}^3He + {}^3He \rightarrow H + H + {}^4He$	86	1×10^7		
Hep	${}^3He + H + e^- \rightarrow {}^4He + \nu_e$	≈ 0		18.77/ ≈ 10	8×10^{-7}
	${}^3He + {}^4He \rightarrow {}^7Be + \gamma$	14			
^{7}Be	${}^7Be + e^- \rightarrow {}^7Li + \nu_e$			0.861 or 0.383	0.47
	${}^7Li + H \rightarrow {}^4He + {}^4He$				
	${}^7Be \rightarrow {}^8B + \gamma$	0.02			
^{8}B	${}^8B \rightarrow {}^8Be^* + e^+ + \nu_e$			15/ ≈ 7.2	0.00058
	${}^8Be^* \rightarrow {}^4He + {}^4He$				
CNO Bi-Cycle					
	$H + {}^{12}C \rightarrow {}^{13}N + \gamma$		17×10^6		
	${}^{13}N \rightarrow {}^{13}C + e^+ + \nu_e$			1.20/0.71	0.06
	$H + {}^{13}C \rightarrow {}^{14}N + \gamma$				
	$H + {}^{14}N \rightarrow {}^{15}O + \gamma$				
	${}^{15}O \rightarrow {}^{15}N + e^+ + \nu_e$			1.73/ ≈1.00	0.05
	$H + {}^{15}N \rightarrow {}^{12}C + {}^4He$				
	or				
	$H + {}^{15}N \rightarrow {}^{16}O + \gamma$				
	$H + {}^{16}O \rightarrow {}^{17}F + \gamma$				
	${}^{17}F \rightarrow {}^{17}O + e^+ + \nu_e$			1.74/ ≈ 94	0.00052
	$H + {}^{17}O \rightarrow {}^{14}N + {}^4He$				

Key to column headings, units of measurement, and symbols:

"Percent" column: the theoretical percentage occurrence of competing reactions.

"Critical Temperature" column: temperatures at which reactions of the SSM have rates compatible with a 5 billion year age for the sun.

"Expected Neutrino Energy" column: neutrino energies theoretically produced by reactions of the SSM, in units of millions of electron-volts (MeV). The first number in this column is the maximum neutrino energy, followed by the average energy. For the ^{7}Be neutrino-producing reaction, neutrinos have two possible maximum energies; 90% have a maximum energy of 0.861 MeV, and 10% a maximum energy of 0.383 MeV; the average energy = 0.80 MeV.

"Expected Neutrino Flux" column: flux in multiples of 10^{10} neutrinos passing through a 1 cm^2 cross section per second; 10^{10} neutrinos/$cm^2 \cdot s$ = 10^{-36} neutrinos/s, defined as 1 "solar neutrino unit" (SNU) if we use unit neutrino cross section of $10^{-46} cm^2$ (Bahcall, 1989, p. 209).

e^+ = positron, a particle with electron mass but positively charged

γ = gamma radiation; ν_e = electron neutrino

Table II. Neutrino Detectors Named in This Paper

	Detector	Particles Detected	Dates of Operation	Reference
1.	Homestake	Solar	1967-1994	Cleveland et al., 1998
2a.	Kamiokande	Solar	1983-1992	Hirata et al., 1988
2b.	Super-K	Solar	1996-	Super-K Collaboration, 1998b
3.	SAGE	Solar	1990-	SAGE Collaboration, 1999
4a.	GALLEX	Solar	1991-1997	Hampel, 1994
4b.	GNO	Solar	1998-	GNO Collaboration, 2000
5.	SNO	Solar	1999-	SNO Collaboration, 2000
6.	ICARUS	Solar	2003-	ICARUS Collaboration, 2003
7.	BOREXINO	Solar	Future	BOREXINO Collaboration, 2002
8.	HELLAZ	Solar	Future	Dolbeau, 1999
9.	HERON	Solar	Future	Adams et al., 2000
10.	Lithium	Solar	Future	Kopylov and Petukhov, 2003
11.	MACRO	Cosmic	1989-2000	Giacomelli, 2003
12.	LUNA	Terrestrial	1992-	LUNA Collaboration, 1998
13.	LSND	Terrestrial	1993-1998	LSND Collaboration, 1997
14.	CHOOZ	Terrestrial	1997-	CHOOZ Collaboration, 1998
15.	KamLAND	Terrestrial	2002-	KamLAND Collaboration, 2003
16.	MiniBooNE	Terrestrial	2003-	Mills, 2003

the SSM only if the SSM is accepted a priori; (7) solar phenomena challenge the significance of solar neutrino oscillations; (8) ^{7}Be v_e production is suppressed compared to SSM predictions, as are (9) *hep* v_e production and (10) *pp* v_e production; and (11) the CNO sequence, often taken to confirm the SSM, and a key process in nucleosynthesis theory (NST), has not been observed, thus rendering the entire scenario of conventional NST questionable.

Fusion Reactions in the SSM Are Tied to a Chronological Requirement

Solar fusion in the SSM is necessary to give the sun an age compatible with evolutionary chronology for the earth (Henry, 2003a, pp. 165-166; Henry, 2004, pp. 245-246), i.e., ≈ 4.5 billion yr. Also, solar interior reaction temperatures and reaction rates are unavailable by observation; Table I is a theoretical construct. This does not mean per se that these reactions do not power the sun, but no laboratory observations exist for reaction rates at presumed solar core conditions.

Neutrino researcher and Nobel laureate Raymond Davis (1994, p. 30) has asserted "there are many ad hoc elements in the standard model calculations." The numbers in Table I are "model calculations" (Wallerstein, et al. 1997, p. 1001). **At best, conditions for solar reactions are extrapolations from laboratory data** (Bahcall, 1989, p. 60).

For example, if it were desired to have the sun operate by fusion over a certain lifetime, one would not choose reaction temperatures so high as to cause excessive reaction rates, thus consuming the available nuclear fuel in too short a time. With nuclear reaction rate theory, one can compute the temperature below which a reaction rate is slow enough to allow the sun to live out its presumed lifetime (Harwit, 1982, p. 335):

> These reactions will not set in sharply as some given temperature ... is exceeded. The temperature is not a threshold ... [W]e can think of a critical temperature at which reactions will proceed at a certain rate. We will choose to define the critical temperature T_c as that ... at which the mean reaction time becomes as short as 5 billion years. Because of the rapid rise in reaction rates with temperature, the reactions will become completely exhausted in a very short time ... if T_c is exceeded.

Conventional solar "hydrogen burning" requires ≈ 10^{10} yr (Fix, 1999, p. 389). Some H would react as nuclear fusion commences (reaction time = 0); other H reserves must remain as the sun comes to the end of this putative interval. Thus mean reaction time ≈ 5 billion yr. **Even if the physics employed to estimate reaction rates were reliable at presumed solar core conditions, it is misapplied to satisfy a fallacious chronology.**

The SSM Is Built Around Unknown and Unmeasurable Solar Properties

Unconstrained by observed data, reaction rates and other properties are parametrically adjusted to give the sun a predetermined ~ 5 billion yr age while accounting for observed properties, e.g., luminosity, surface temperature, and radius. Table III lists some adjustable parameters in the SSM. Aside from these, the most basic parameter (other than observable properties) is the sun's presumed age (Liebacher, 1985, p. 48; Brun et al., 1998, p. 922; Bahcall et al., 2001, p. 991), currently set at 4.57 billion yr (Bahcall et al., 1995, p. 784).

Table III. Some Unknowns Treated as Adjustable Parameters in the SSM

Parameter	Reference(s)
1. Nuclear reaction rates	Bahcall et al., 1995, p. 783; Guenther and Demarque, 1996, p. 5; Hoffman et al., 2002, p. 1
1a. *p-p* cross section	Brun et al., 1998, p. 921
1b. *hep* cross section	Bahcall et al., 2001, p. 1002
1c. All cross sections	Bahcall et al., 1995, p. 783; Bahcall and Ulmer, 1996, p. 4203; Hoffman et al., 2002,p. 1; Fowler, 1984, p. 924
2. Primordial element abundances	Bahcall and Ulmer, 1996, p. 4203
2a. Primordial He abundance	Bahcall et al., 1995, p. 804
2b. Ne abundance	Bahcall et al., 1995, p. 785
3. Equations of state	Basu et al., 2000, p. 1092
4. Density profiles	Basu et al., 2000, p. 1089
5. Diffusion rates	Bahcall et al., 1995, p. 786
6. Core temperature	Bahcall and Bethe, 1993, p. 1298
7. Opacities	Guenther and Demarque, 1996, p. 6
8. Adiabatic indices	Basu et al., 2000, p. 1086

Though the sun's present operation says nothing about its age, SSM confirmation is perceived as validation of a long chronology. This is a circle of reasoning like the geological case in which "fossils date rocks and rocks date fossils." In conventional solar modeling, evolutionary chronology calls for certain parameter values; **the SSM with allowable parameter values confirms the chronology.**

There are really many SSMs, e.g., the 1995 Bahcall-Pinsonneault model, BP95 (de Gouvea et al., 1999, p. 3; Super-K Collaboration, 1998b, p. 1158); the BP98 model (Bahcall, 2002a, p. 10); the BP00 model (Bahcall et al., 2002, p. 15); the 2000 Bahcall-Basu-Pinsonneault model, BBP00 (Bandyopadhyay et al., 2001, p. 2); and the 2001 Bahcall-Pinsonneault-Basu model, BPB2001 (Aliani et al., 2004, p. 2; SNO Collaboration, 2004, p. 4). **These models differ in certain parameter values, but all SSMs share the same basic assumptions,** so are sufficiently similar that a specific SSM is often generically called "the SSM" (Aliani et al., 2003, p. 107; Bahcall, 2002a, p. 10; Bahcall et al., 2002b, p. 1; Kopylov and Petukhov, 2003, p. 2).

Shared assumptions are that (1) the sun is in hydrostatic and thermal equilibrium; (2) it derives energy from the fusion reactions in Table I; and (3) its material is described by an equation of state for gases (Bahcall, 1989, pp. 6-7; Davis, 1994, p. 24; Harwit, 1982, pp. 306-343).

Assumptions (1) and (2) follow from the assumption of great age (Henry, 2004, pp. 251-252). **With the parameters of Table III and others available for suitable adjustment, different SSMs can be forced to converge toward virtually any desired set of solar characteristics,** resulting in the claim that the SSM must be correct because various SSMs converge on a uniform set of solar predictions (Bahcall and Bethe, 1993, p. 1300; Bahcall and Pinsonneault, 1997, p. 4; Bahcall et al., 2001, p. 999). Indeed, apart from the chronological constraint, gravitational contraction could also model the sun's energy output (Fix, 1999, p. 387):

> The problem with explaining the Sun's energy output by gravitational contraction isn't that the Sun couldn't shrink fast enough, but that it couldn't have been doing so for long enough. ... The ... energy released would ... keep the Sun shining for about 20 million years.

In addition, solar scientist John Eddy has acknowledged that the sun could be modeled as young (Kazmann, 1978, p. 18):

> I suspect that the Sun is 4.5-billion years old. However ... I suspect that we could live with Bishop Ussher's value [4004 BC] for the age of the Earth and the Sun. I don't think we have much in the way of observational evidence in astronomy to contradict that.

In other words, the sun could be modeled over a wide range of parameters (e.g., all contraction or all fusion; young or old), but conventional modeling is restricted to a narrow parameter range (Bahcall et al., 1997, p. 173; Bahcall et al., 2001, p. 991) based on assumptions consistent with presumed long age (Bahcall et al., 1995, p. 786; Basu et al., 2000, pp. 1084, 1099; Bahcall et al., 2001, p. 998). Models with parameters in the acceptable range are "variant models"; models with parameters outside this range are said to be "deviant" (Bahcall et al., 2001, pp. 999-1000).

The SSM Appears Certain Because Models Are Compared with Each Other

Besides restricting the allowable parameter set due to chronometric concerns, the SSM avoids consulting helioseismic or angular momentum data. "No helioseismological constraints are used in defining the [SSM]" (Bahcall et al., 2001, p. 991), yet helioseismology reveals inconsistencies in the SSM (Henry, 2003b, p. 34).

The angular momentum problem is an old challenge to solar evolution, and even now "a proper understanding of the angular momentum evolution [of the sun] has not been reached"; despite this, the SSM is considered to be "robust" (Brun et al., 1998, p. 913).

One reason the SSM appears robust is that these potential challenges are ignored. Instead, the uncertainty of model predictions is often assessed by **comparing models with other models rather than models with data** (Bahcall and Bethe, 1993, p. 1299; Bahcall et al., 1995, pp. 782, 790; Bahcall et al., 2001, pp. 993-994). This has the effect of making model uncertainties appear quite small, since most researchers choose model parameters so as to show convergence with existing models rather than "deviance."

Modelers working outside the acceptable parameter range may find themselves the object of criticism (Bahcall and Pinsonneault, 1997, p. 10). **Model convergence is thus a result of (1) restricting parameter selection, and (2) restricting model uncertainty computations to inter-model comparisons.**

The SNO Results Do Not Resolve Other Pre-SNO Contradictions of the SSM

The Homestake v_e detection ratio ≈ _ was not the only pre-SNO difficulty for the SSM. From 1971-1983, v_e detection at Homestake was 2.1 SNUs (Kalbfleisch, 1995, p. 1) or 1/5 to ¼ expected flux, compared to 2.56 SNUs overall (Cleveland et al., 1998, p. 505). **The detection ratio depends on the SSM one uses to establish predicted flux,** and apparent improvements in v_e detection rates were partly due to model adjustments reflecting lowered expectations of the number of v_e to be found.

For instance, the BP95 predicted flux was 9.5 SNUs for a detection ratio of 2.1/9.5 = 0.22 ≈ 1/5. The SSM revision, BP98, predicted a smaller flux of 7.7 SNUs for a detection ratio of 2.1/7.7 = 0.27 ≈ ¼ (Goldsmith, 1985, p. 277). However, model revisions did not account for all detection rate variability.

Homestake's low detection rate suggested that the v_e might not be ^{8}B v_e, but high energy particles from solar flares and other surface phenomena (Davis, 1994, p. 25). Solar flares were eliminated as a v_e source (Kamiokande Collaboration, 1990, p. 574; Hirata et al., 1988, p. 2653). Nevertheless, v_e flux variability and the solar cycle are related (Laclare, 1987, p. 451).

Even analyses of v_e flux showing no correlation with solar cycle have confirmed flux periodicities (Haubold, 1998, p. 201; Grandpierre, 1999, p. 993), and together with the periodic Homestake flux continue to imply that v_e may not emerge from the core unchanged. They may be converted to anti-neutrinos by solar internal magnetism believed to exist in the convective and radiative zones (Sturrock, 2003b, p. 1).

Homestake data over 20 yr had a periodicity of 21.3 days; at GALLEX and Kamiokande, "the flux of neutrinos [varied] by as much as 30 percent to 100 percent" (Holden, 1996, p. 1663). Flux at GALLEX and Super-K continues to show periodicity (Sturrock and Scargle, 2001, p. L101; Sturrock, 2004, p. 568). The possibility of core fluctuations causing such periodicities is typically ruled out. Over time apparent flux variabilities are supposed to level out to a constant value (Bahcall et al., 1998b, p. 5), for as Jeffrey Scargle stated, fluctuating core output "flies in the face of the standard picture of what goes on in the solar core" (Holden, 1996, p. 1663).

The ^{8}B v_e deficit was thus not the only challenge to the SSM in early detectors. Other challenges were (1) variable v_e flux, violating the constant flux the SSM expects; (2) the resulting possibilities that either (a) v_e arise in solar surface phenomena or interact with solar magnetism, again violating the SSM, or (b) core properties fluctuate periodically, also contradicting the SSM.

Further, SNO detects mainly ^{8}B neutrinos (Seife, 2001, p. 2227; SNO Collaboration, 2001, p. 2), but Schewe et al. (2003, p. 2) emphasize that:

> [T]he flux from ^{8}B decays represents a mere 0.02% of the predicted flux of solar neutrinos, and one wants to study other types of [neutrino] production to get a better grip on nuclear physics in the sun's core.

Thus SNO does not resolve neutrino shortfalls in other reactions, though the typical assumption is that the theory behind the SNO results can be applied to them. This assumption is unwarranted, as we will now see.

The Theory Behind the SNO Claims Does Not Uniquely Confirm the SSM

NOT was used to determine the SNO neutrino detection rate. If neutrino mass were non-zero, v_e from the solar core would theoretically undergo a transition or "oscillation" into forms unnoticed by older detectors, explaining the SNP (Bahcall, 1989, pp. 28-32, 258-284). Electron neutrinos (v_e) leaving the sun would become mu neutrinos (v_μ) or tau neutrinos (v_τ). According to NOT, earlier detectors missed these neutrinos because they changed "flavor"; SNO detected sufficient v_μ and v_τ to explain the SNP.

Rather than straightforwardly resolving the SNP, however, the **reported detection of neutrino oscillations** (Seife, 2001, pp. 2227-2228) **has increased the difficulty of interpreting neutrino data** (Bahcall, 1997, p. 367).

For example, based on expectations from particle physics, the "mixing angle" involved in solar neutrino detection was once predicted to be small. The value of the mixing angle is unknown a priori and therefore is an adjustable parameter. Large mixing angles must be chosen to generate agreement "between observed and predicted neutrino event rates" (Bahcall, 2002b, p. 9; SNO Collaboration, 2002, p. 4; Rosen, 1997, p. 58), i.e., neutrino observations were brought into line with SSM predictions by a suitable parameter adjustment (Bahcall, 2002b, p. 10; Rosen, 1997, p. 58).

In solar applications, NOT parameters are constrained generally by assuming the SSM is true, as will be further shown below. Yet ironically, "It was the discrepancy between the observed neutrino flux from the Sun and the expected value that led physicists to propose the neutrino transmutation model in the first place" (Gonzalez and Richards, 2004, p. 381). This proposal was not value-free, for as Guenther and Demarque (1996, p. 2) note, **neutrino fluxes were not consulted in framing the SSM, signifying that rather than allowing the SSM to be falsified, a way would be found to preserve it.**

The SNP challenged the SSM; the study of oscillations was prompted by desire to confirm it: "We must first understand neutrino oscillation phenomena ... to test precisely the theory of stellar evolution..." Further, confirming stellar evolution by detecting solar neutrinos was "our original goal" (Bahcall, 2002a, p. 20) and remains the goal of modern neutrino searches: "[A] precise determination of the *pp* solar flux will be of great interest as a crucial test of the theory of stellar evolution" (Bahcall et al., 2002a, p. 17). This motivation must be considered in claims that neutrino detection rates confirm the SSM.

Moreover, NOT has been used to disprove the SSM. Bahcall et al. (2003, p. 1) showed that with appropriate parameter selection, the CNO bi-cycle explains 99.95 percent of solar luminosity. This result was generated to illustrate the difficulty of parameter selection in NOT (Bahcall, 1997, p. 367).

Bahcall et al. did not believe that CNO reactions power the sun, but the reason for rejecting this possibility is chronological. CNO reactions are thought to have significant rates only at temperatures hotter than those of the SSM for the sun's core (Groombridge et al., 2002, p. 1). With higher temperature, solar lifetime would be less than that required by conventional chronology, i.e., the conventional age of the earth. **Chronology constrains the SSM, not the other way round.**

Oscillation Theory Supports the SSM Only If the SSM Is Accepted First

NOT views neutrinos as transmutating among different states in matter or in the vacuum of space. Transformation in matter of variable density such as the sun or earth is due to the Mikheyev-Smirnov-Wolfenstein (MSW) effect enhancing "matter oscillations," and is said to occur due to "resonance" as neutrinos interact with matter (BOREXINO Collaboration, 2002, p. 209); transmutations in space are vacuum oscillations.

The MSW effect is a subset of NOT. Neutrino oscillations involve coherent forward scattering; "forward scattering" refers to propagation outward from a source; "coherent" signifies existence in linearly superimposable states; e.g., ordinary light is a mixture of "states" of polarized light in two planes. These states are coherent because they combine linearly into ordinary light (Rosen, 1997, p. 56). In NOT, neutrinos propagating from the solar core exist as linearly superimposable states (Smirnov, 2003, p. 1), e.g.,

$$v_e = \alpha_1 v_1 + \alpha_2 v_2 + \alpha_3 v_3;$$

$$v_\mu = \beta_1 v_1 + \beta_2 v_2 + \beta_3 v_3;$$

and

$$v_\tau = \gamma_1 v_1 + \gamma_2 v_2 + \gamma_3 v_3$$

The α_i, β_i, and γ_i are unknown parameters and differ for matter oscillations vs. vacuum oscillations; v_1, v_2, and v_3 are unobservable mass "eigenstates" manifesting themselves by "mixing" as v_e, v_μ, and v_τ. Other parameters such as θ, the mixing angle, and a single Δm^2, the square of the neutrino mass difference, can be mathematically derived from these, **but are also unknown and constrainable only with reference to external conditions taken to be those of the SSM** (Glashow et al., 1999, pp. 414-415; de Gouvea, 1999, p. 5).

There is no agreement whether solar neutrino oscillations are due to vacuum oscillations (Glashow et al., 1999, p. 412), matter oscillations (Maltoni et al., 2003a, p. 1), or a combination (Aliani et al., 2004, p. 2; Bandyopadhyay et al., 2001, p. 1; BOREXINO Collaboration, 2002, p. 210).

In an early paper proposing neutrino oscillations, Wolfenstein (1978, p. 2374) wrote: "[T]he effective distance over which neutrino oscillations take place is from the solar surface to the earth's surface; there are no significant oscillations inside the sun or in traversal through the earth," i.e., no MSW effect. In contrast, Chiang and Wolfenstein (2000, p. 1) state: "There are no [vacuum] oscillations between the sun and the earth."

Further, some oscillation models assume a fourth "sterile neutrino" which may exist (Smirnov, 2003, p. 3), or may not (Maltoni et al., 2003a, p. 1; BOREXINO Collaboration, 2002, p. 211). If they exist, the significance of the MSW effect in solar neutrino detection analysis depends on the "a priori unknown" occurrence of sterile neutrinos relative to others (Bahcall et al., 2002, p. 3). Sterile neutrinos, it is proposed, can answer an unsatisfied MSW prediction. Normally a reaction produces neutrinos spanning a range of energies called the energy spectrum.

MSW theory predicts that neutrino spectra should be distorted over against spectra with no MSW effect. **The expected spectral distortion has not been found** (BOREXINO Collaboration, 2002, p. 229); it is hoped sterile neutrinos can explain this null result (Smirnov, 2003, p. 20; de Holanda and Smirnov, 2004, p. 1). *ICARUS (Table II) will search for spectrum distortion in ^{8}B neutrino data (ICARUS Collaboration, 2003, p. 1).*

The very existence of the MSW effect depends on the choice of mixing angle which is set by reference to the SSM (Rosen, 1997, p. 58). **Apart from reference to the SSM, oscillation models suffer from a plethora of unconstrainable parameters, so it cannot be said that neutrino oscillation confirms the SSM.**

Therefore with neutrino oscillations, neutrino detection rates cannot be truly measured but must be interpreted from other data. Claims of "measuring" neutrino flux via NOT (e.g., Super-K Collaboration, 2004, p. 5) are inaccurate, and the following assessment about future ^{7}Be neutrino flux measurement applies generally (de Gouvea et al., 1999, p. 2):

> It is important to define what is meant by `measuring' the ^{7}Be neutrino flux. In reality, what the experiments are capable of measuring is the number of recoil electrons induced by solar neutrino interactions. ...This information can only be converted into a solar neutrino flux measurement if one knows the flavor composition of the solar neutrinos.

But the flavor composition is not known; the only way to constrain it is to consult the SSM (Super-K Collaboration, 2004, p. 2; Kopylov and Petukhov, 2003, p. 4). In other words, the SSM is used as input, but the goal was to confirm it. The claim that SNO measurement of neutrino flux is "in agreement with ... standard solar models" (SNO Collaboration, 2004, p. 1) should be seen in the light of the facts that (1) "measurement" really means interpretation of data to fit the SSM; and (2) various SSMs are compared among themselves to establish model convergence, as discussed above.

Granting that NOT is real, it remains impossible to say, apart from assuming the SSM is true, how much the actual SNO neutrino flux differs from the no-oscillation detection rate of 0.35 (Aliani et al., 2003, p. 108).

A number of non-solar neutrino detection studies are claimed as additional evidence that neutrino oscillations occur so as to confirm the SSM. Super-K and MACRO (Table II) found evidence of oscillations in non-solar neutrinos produced in the atmosphere by cosmic rays. Because the neutrino transformation did not involve v_e, the type generated in the sun (Super-K Collaboration, 1998a, p. 1562; Giacomelli, 2003, p. 211), these were seen at best as indirect confirmation of matter oscillations in v_e (Kolbe and Langanke, 2001, p. 1).

The LSND experiment claimed to see evidence for oscillations of particles from terrestrial reactors traveling through earth (Cardall and Fuller, 1996, p. 4421; Maltoni et al., 2003a, p. 1); other detectors of terrestrial neutrinos including CHOOZ (Table II) did not (Aliani et al., 2003, p. 105; CHOOZ Collaboration, 1999, p. 415; Kolbe and Langanke, 2001, p. 1).

Since LSND detected oscillations via disappearance of electron anti-neutrinos rather than v_e, the LSND evidence for matter oscillations is also perceived as provisional and subject to confirmation by MiniBooNE (Mills, 2003, p. 32; Sorel and Conrad, 2002, p. 1). There was an even more basic problem with the LSND oscillation claim. The LSND data could be interpreted as evidence for oscillations only by using a large mixing angle as required by the SSM (Super-K Collaboration, 1998a, p. 1566). **The LSND claim is not support for matter oscillations buttressing the SSM, because the SSM was consulted to generate this conclusion.**

The same statement applies to the subsequent KamLAND claim of matter oscillations in particles from nuclear reactors (KamLAND Collaboration, 2004, p. 1; Aliani et al., 2004, p. 1). Like LSND, KamLAND monitored the disappearance of anti-neutrinos (Bahcall et al., 2002, p. 3), and as with LSND, the mixing angle was unknown when interpreting the KamLAND data; it was sized using ^{8}B neutrino flux inferred from SNO results via consultation of the SSM (Bahcall et al., 2002, p. 6; KamLAND Collaboration, 2004, p. 4). In other words, to confirm the possibility of matter oscillations in the SSM, KamLAND data were interpreted as evidence of oscillations by assuming the SSM. These results do not independently verify the SSM.

Solar Neutrino Oscillations May Not Be a Significant Phenomenon

Variability in solar neutrino flux is evidence against a significant MSW effect (Sturrock et al., 2002, p. 791) which assumes constant flux; such variability exists as discussed earlier (Sturrock, 2003a, p. 1102) with periods of days or weeks. Sturrock and Scargle (2001, p. L101) conclude:

> [T]here is independent evidence [from Ga detectors] for variability on shorter time-scales [of days or weeks]... [T]ime variability has crucial significance for the resolution of the neutrino problem. If the flux is ... constant, then the most likely interpretation of the deficit is the MSW effect. ...[I]f the solar flux varies on a time scale of days or weeks, we must go back to square one [and] consider the possibility that nuclear burning is variable...

The MSW effect also predicts a difference in neutrino transformation between day and night (Rosen, 1997, p. 60). At night solar neutrinos travel through most of the earth to reach a detector on the other side; in daylight they must traverse less earth matter.

Observation of the expected "day/night asymmetry" would confirm the MSW effect (BOREXINO Collaboration, 2002, p. 210). Day/night asymmetry has been claimed at SNO and Super-K (de Holanda and Smirnov, 2002, p. 1; Maltoni et al., 2003b, p. 3). **However, the apparent day/night asymmetry was not an observation but resulted from evaluation of the mixing angle consistent with the SSM** (de Holanda and Smirnov, 2002, p. 5; Chiang and Wolfenstein, 2000, p. 1). Thus day/night asymmetry cannot be said to have confirmed the SSM (e.g., Chiang and Wolfenstein, 2000, p. 3) since the SSM was consulted to obtain this result.

Vacuum oscillation models predict a seasonal neutrino flux variation beyond that caused by yearly earth-sun distance changes, absence of which would be contrary evidence (Glashow et al., 1999, p. 413; BOREXINO Collaboration, 2002, p. 232). **However, evidence of seasonal variations would not uniquely confirm vacuum oscillations, because of non-NOT neutrino flux variabilities discussed above.**

Super-K claimed NOT-related seasonal variations which await confirmation by BOREXINO (Glashow et al., 1999, p. 413; de Gouvea, 1999, p. 1). However, neutrino data must be interpreted to infer variability due to vacuum oscillations by setting the "oscillation length," the value of which is unknown, but is typically selected to be 1 AU (de Gouvea et al., 1999, p. 5; BOREXINO Collaboration, 2002, p. 209). The subjectivity of this choice is termed "just-so" (de Gouvea et al., 1999, pp. 1, 5). **Further, vacuum oscillations require low production of *pp* ν_e and high ^{7}Be ν_e production (Gelb and Rosen, 1999, p. 1), both outcomes violating the SSM.** Thus vacuum oscillations are disfavored.

In summary, (1) vacuum oscillation models contradict the SSM; (2) day/night asymmetry implying an earth-matter MSW effect is inferred by consulting the SSM; (3) non-NOT ν_e flux variabilities imply an insignificant solar MSW effect.

^{7}Be Neutrino Detection Rates Are Below the SSM Prediction

SAGE and GALLEX/GNO (Table II) cannot detect ^{7}Be neutrinos alone (Bahcall, 2002a, p. 15; Gelb and Rosen, 1999, p. 2); most neutrinos found by Ga detectors are taken to be from *pp* fusion. If this is so, "little or no signal is left to account for the other neutrino fluxes also expected from the [SSM], in particular the ^{7}Be neutrinos" (GNO Collaboration, 2000, p. 17).

The BOREXINO Collaboration (2002, p. 207) concludes: "On this basis, the Ga signals would imply a near absence of ^{7}Be in the Sun. The compelling consequence is a near absence of ^{8}B as well, since that can be generated only from [^{7}Be]." **Lowering the flux share attributed to *pp* ν_e makes the problem worse for the SSM,** for then the *pp* flux, already low (≈ ½) compared to SSM expectations, is even lower. **This dilemma is the "^{7}Be-^{8}B problem."**

Before use of NOT to interpret SNO data, Homestake and Super-K detected ≈ 1/3 the expected ^{8}B ν_e. With NOT, ^{8}B neutrino flux at SNO matches SSM predictions (SNO Collaboration, 2004, p. 1), thus increasing the discrepancy between claimed ^{8}B production and that implied by the ^{7}Be-^{8}B problem. From the SSM's view, the SNP "remains unsolved" (BOREXINO Collaboration, 2002, p. 232); *BOREXINO (Table II) plans to search for ^{7}Be neutrinos (BOREXINO Collaboration, 2002, p. 205); HELLAZ (Table II) plans to distinguish "the ^{7}Be line from the pp spectrum" (Dolbeau, 1999, p. 2).*

^{7}Be neutrinos seem to be truly lacking. In the SSM ^{7}Be neutrinos produce a "line spectrum" (one line at 861 keV, another at 383 keV) instead of the diffuse neutrino spectra from other solar neutrino-producing reactions. **Yet these spectra are weak or absent, though their average energy ≈ 800 keV, detectable by Ga detectors with threshold energies of 233 keV.** Lack of ^{7}Be/^{8}B neutrinos implies lower solar core temperature than in the SSM.

The *hep* Neutrino Production Rate Is Evidently Suppressed

Homestake, Super-K and SNO are sensitive to *hep* neutrinos. Flux in these detectors is assumed to arise only from the ^{8}B reaction (SNO Collaboration, 2001, p. 3), because it is impossible "to find a reliable way of estimating an uncertainty in [the *hep*] production cross section" (Bahcall, 2001, p. 3). **Thus actual *hep* neutrino flux is unknown, but other factors indicate it is less than the SSM prediction.**

The *hep* reaction (Table I) is thought to be temperature sensitive, occurring rapidly at sufficiently high temperature. This would lead to rapid ^{3}He core depletion; ^{4}He production via *hep* would stop. **In the SSM this is the "^{3}He problem,"** because the SSM requires continued synthesis of ^{4}He from an assumed primordial level, ≈ 0.270-0.278 in ^{4}He fraction (Bahcall et al., 1995, p. 804), over ~ 4.6 billion yr. In the SSM, to continue producing ^{4}He, ^{3}He must be brought into the core by mixing.

If mixing were occurring, this could lead to cyclic contraction and expansion of the solar radius (Stockman, 2000, p. 1). As noted above, neutrino flux variability is correlated with oscillatory changes in solar radius; thus variability in ^{7}Be v_e flux may be related to variable ^{3}He production, falsifying the SSM expectation of constant core reaction rates. **Diminished or prohibited ^{3}He production is also consistent with a core temperature ≤ 4 million K, ≈ ¼ the SSM core temperature.** Thus, viewing the ^{3}He problem as a mixing problem in the SSM leads to conclusions contradicting the SSM.

However, the biblical creationist can view the sun as created with nearly its present ^{4}He content, so getting ^{3}He into the core to account for present ^{4}He abundance is unnecessary. The ^{3}He problem is not a genuine problem, and we need to think outside the SSM "box."

If ^{3}He were absent in the solar interior, this would imply a central temperature $\leq 5 \times 10^5$ K, since ^{3}He synthesis is thought to progress rapidly above this point (Hubbard, 1984, p. 244). There is furthermore another reason for suspecting lower interior ^{3}He abundance than the SSM requires - the pre-SNO failure to detect the expected ^{8}B v_e flux (Steidl, 1979, pp. 93-94):

> Astronomers expect that, since the sun has been burning hydrogen into helium for billions of years, there would be sufficient helium present for [^{8}B decay] to occur. ... Astronomers ... cannot understand why the [expected number of] neutrinos have not been detected. The obvious answer is simply that there is not enough helium ... The reason that there is not enough helium ... is that the sun has [been] converting hydrogen into helium for [only] a few thousand years. The lack of [^{8}B neutrinos] is strong evidence that the sun is not ... old...

In other words, belief in an old sun led to the SSM predicting excessive ^{8}B v_e flux. Attempting to bring observed ^{8}B v_e flux into line with the SSM by NOT is ultimately tied to the belief that the sun is old. Considering that oscillation parameters are evaluated with reference to the SSM, the SNO pre-oscillation detection rate of 0.35 may have been near the actual flux.

pp Neutrino Detection Rates Are Below the SSM Prediction

The *pep* reaction is a three-body process and thus rare, believed to produce ~ 0.4 percent of solar D; *pp* fusion is the only significant route to D synthesis leading to ^{3}He, and theoretically requires a temperature ~ 10^6 K for a hydrogen burning lifetime of order 10^{10} yr. **A cooler solar interior $\leq 5 \times 10^5$ K as discussed above would support the *pp* reaction at a correspondingly low rate.** This would (1) explain the lack of low energy v_e detected, and (2) imply that solar luminosity is only partly due to H fusion. Lest it be objected that this conclusion is impossible, consider that (1) Ga detectors have found ≈ ½ the expected low-energy v_e flux, and (2) this flux is attributable to ^{7}Be v_e as well as to *pp* v_e; neither has been observed separately (Bahcall, 2002, p. 15).

Thus "there is no direct experimental evidence that *pp* neutrinos have been detected" (Bahcall et al., 1996, p. 1); "Unfortunately, we do not have a direct measurement of this flux. ...The most urgent need for solar neutrino research is to develop a practical experiment to measure directly the *pp* neutrino flux" (Bahcall, 2002a, p. 15). *HELLAZ and HERON (Table II) are planned for this purpose (Dolbeau, 1999, p. 2; Adams et al., 2000, p. 112).*

There is another reason for accepting this conclusion. The SSM requires *pp* neutrino detection at the predicted rate to account for ^{4}He synthesis over ≈ 4.6 billion yr of evolution from the putative solar nebula (Hubbard, 1984, pp. 8-9). The biblical creationist has no such requirement. **If the sun were young and somewhat homogeneous, then surface D abundance might be related to interior abundance** (Henry, 2003b, pp. 36-37).

Helioseismic data indicate that the boundary between the solar radiative and convective zones is not as sharp as the SSM expects (Bahcall et al., 1998a, pp. 5-6), implying a degree of homogeneity. Further, if only *pp* fusion occurred and the sun were homogeneous, the solar D/H ratio would be within an order of magnitude of the D/H ratio in the interstellar medium (ISM) and intergalactic medium (IGM). The ISM and IGM originate in stars, implying that *pp* fusion synthesizes D not converted to ^{3}He (Henry, 2003b, p. 36).

The CNO Sequence Has Been Inferred, Not Observed

If the CNO sequence (Table I) occurred, there would be significant CNO neutrino flux at Ga detectors: "^{71}Ge detected in the gallium experiments could, in principle [be produced] by somewhat higher energy CNO neutrinos" (Bahcall et al., 1996, p. 1).

Mentioned earlier was the fact that using NOT, CNO reactions can be modeled as powering the sun. Since *pp* neutrino flux has not been directly measured, "[E]xperiments that measure the flux of low energy [pp] neutrino events, such as BOREXINO or HELLAZ/HERON [Table II], are necessary to rule out this [CNO] model via neutrino observations" (Bahcall, 2001, p. 5; Bahcall et al., 1996, p. 1; Adams et al., 2000, p. 112).

Additional experiments "are required to establish empirically that the sun shines by the *pp*, not the CNO, reactions" (Bahcall et al., 1996, p. 4). *A lithium detector (Table II) is planned to* *search for CNO neutrinos explicitly (Kopylov and Petukhov, 2003, p. 1; Bahcall et al., 2001, p. 1000).* **Failure to find the expected CNO neutrinos would leave the possibility that the sun derives energy from a non-SSM "other source"** (Kopylov and Petukhov, 2003, p. 4), e.g., gravitational contraction.

However, detection of CNO neutrinos would raise another problem for the SSM. CNO neutrinos have energies of order ~ 0.1 that of ^{8}B neutrinos, i.e., ~ 1 MeV (Table I), but the SSM-expected CNO neutrino flux $\approx$ 200 times higher than for ^{8}B neutrinos, thus should be detected by Homestake and Super-K (Bahcall et al., 2001, p. 1000). Assuming the Homestake and Super-K flux is all ^{8}B neutrinos, neither detector has found CNO neutrinos. It is open to question whether the CNO sequence occurs, as we will now see.

In 1939 Hans Bethe made a proposal of nucleosynthesis by solar fusion. He believed the CNO reactions, sometimes called the CN cycle (Cleveland et al., 1998, p. 506), provided most solar energy (Bahcall et al., 2003, p. 1). However, stellar NST was encountering problems until 1953 when astrophysicist Fred Hoyle, working with William Fowler, successfully predicted a resonance for ^{12}C in the CNO sequence which would allow it to occur under solar conditions (Wallerstein et al., 1997, p. 999; Salpeter, 1999, p. S220).

Later, the CNO sequence was recognized as less and less likely to occur in the interior of the sun or any normal star (Hoyle, 1954, p. 146). Fowler et al. (1955, pp. 167, 180) then proposed that C, N, and O reactions happen on the surfaces of stars due to local heating by magnetic fields. After this, the CNO bi-cycle was ruled out as significant in solar-type stars (Caughlin and Fowler, 1962, p. 453).

C, N, and O reactions have been postulated for very hot, massive stars (Wagoner et al., 1967, p. 3; Hoffman et al., 2002, p. 1), or supernovae (Hoyle and Fowler, 1960, p. 565; Arendt, 1999, p. 234). **Evidence (as opposed to theory) fails to confirm that the CNO sequence occurs significantly anywhere.**

Further, reaction rates for C, N, and O reactions are some of the most uncertain quantities in stellar NST (Wallerstein et al., 1997, p. 999; Salpeter, 1999, p. S220). This has long been acknowledged (Salpeter and van Horn, 1969, p. 183; Austin et al., 1971, p. L79; Khairozzaman, 1983, p. 179). The LUNA Collaboration recently revised the rate for onset of CNO burning down by $\approx$ 50 percent, changing estimated ages of globular clusters by ~ 1 Gyr (LUNA Collaboration, 2004, pp. 625, 626), and decreasing more the potential significance of CNO reactions in the sun and other stars.

Yet occurrence of CNO reactions is believed to be essential for stellar nucleosynthesis of elements above B (Groombridge et al., 2002, p. 1; Fowler, 1984, p. 922). CNO burning "is central to the idea that the heavy elements are formed by nuclear processing in stars during their late stages of evolution" (Fushiki and Lamb, 1987, p. 368). It has been invoked theoretically to drive He synthesis (Salpeter, 1952, p. 326) in He stars (Oke, 1961, p. 166) or novae (Cameron, 1959, p. 916) as well as white dwarfs and neutron stars (Schramm et al., 1992, p. 579).

In the SSM most excited boron (^{8}B*) decays via ^{8}Be* into two α particles at SSM solar core conditions, though the overall reaction $^8\mathrm{B}^* + \alpha \rightarrow {}^{12}\mathrm{C}$ would hypothetically provide ^{12}C to feed into the CNO sequence (Salpeter, 1952, p. 327). According to NST, conditions in certain other stars allow the triple alpha (3α) process, "the collision of three α-particles" (Fushiki and Lamb, 1987, p. 368) to form ^{12}C via a ^{12}C resonance (Salpeter, 1953, p. 41; Pichler et al., 1997, p. 55); the ^{12}C thus synthesized feeds into CNO reactions.

Fowler (1956, p. 173), Cook et al. (1957, p. 508), and Salpeter (1957, p. 516) reported what has been characterized as "experimental discovery" of the ^{12}C resonance Hoyle predicted (Fushiki and Lamb, 1987, p. 368). This claim has led to the belief that the CNO sequence is based on observation, so by inference the SSM as a subset of NST has also been confirmed by observation. This belief needs correcting. Despite Hoyle's successful prediction, **solar/stellar NST has not answered basic questions about how the elements originated** (Fowler, 1984, p. 934):

> In spite of the past and current research in experimental and theoretical nuclear astrophysics ... Hoyle's grand concept of element synthesis in stars [is not] truly established. ...It is not just a matter of filling in the details. There are puzzles and problems in each part of the cycle which challenge the basic ideas underlying nucleosynthesis in stars.

Moreover, since the sun can be modeled with CNO reactions producing nearly all luminosity, Hoyle's prediction was not a confirmation of the SSM which is based on hydrogen burning instead of CNO burning. **Finally, ^{12}C synthesis with Hoyle's predicted resonance has not been observed; the actual "experimental discovery" was of ^{12}B decaying to an excited ^{12}C state (^{12}C*),** followed by decay to three α particles (Cook et al., 1957, p. 508).

Thus *decay* into 3 α was observed, not the inverse 3α process. "[B]y reciprocity [^{12}C] could be formed from 3α" (Fowler, 1984, p. 923), but the required three-body process is problematic (Fedorov and Jensen, 1996, p. 631); indeed, the inverses of three-body decays "cannot be observed, because three particles must be brought together" (McGervey, 1973, p. 517).

Thus formation of 3 α by decay is irrelevant to putative ^{12}C synthesis, and the process leading to ^{12}C remains unobserved. Confusing decay processes with putative synthesis is endemic in conventional astronomy (Henry, 2003c, p. 124). **It may be objected that reciprocity guarantees occurrence of the 3α process, but in fact the very mechanism of ^{12}C synthesis is disputed** (Hong and Lee, 1999, p. 46). There may not be a 3α interaction: "Despite the long history of investigations it is yet unclear to what extent the three-body picture accounts for the real [process]..." (Fedorov and Jensen, p. 631).

The SSM, conventional NST, and stellar evolution are co-dependent concepts (Fowler, 1984, p. 922). It may be objected that "evolution" in astronomy means mere change, but in fact stellar evolution in particular, and cosmic evolution in general, are seen ultimately as upward developmental processes like biological evolution (Henry, 2003b, p. 124) which biblical creationists rightly reject.

In biology, "If evolution meant only [mere change], it would be utterly uncontroversial" (Wells, 2000, p. 5); the same is true in astronomy. This comment applies particularly to NST which postulates progressive build-up of all elements ultimately from primordial H, a concept negating biblical teaching that God made a finished creation (Gen. 2:1).

The biblical creationist must avoid assuming that post-creation nucleosynthesis occurs in line with conventional theory, for as with the SSM, NST parameters are set by presuming an old universe. Absent commitment to a long chronology, neutrino data do not confirm the SSM and its presumed nucleosynthesis, but confirm biblical teaching that "[t]here was no gradual evolution of stars and galaxies ..." (Morris, 2004, p. a).

Conclusions

SSM parameter selection assumes an old sun so is chronologically dependent. Before neutrino oscillation theory (NOT), the SSM was considered reliable, despite the SNP, based on comparisons among models. **NOT was developed to explain the SNP; among solar detectors, NOT has been applied only to ^{8}B neutrinos in SNO.** Neutrino detection rates are evaluated with NOT parameters adjusted with reference to the SSM; an alternate NOT parameter set results in CNO reactions powering the sun, not H fusion as the SSM requires.

NOT predictions of earth-matter oscillations and day/night asymmetry verify the SSM only if the SSM is used to constrain oscillation parameters. Neutrino flux periodicities imply insignificance for a solar MSW effect; vacuum oscillation makes predictions contradicting the SSM.

Claims of SSM support from NOT ignore other issues, including (1) ^{8}B/^{7}Be v_e flux periodicities associated with solar cycles or other non-NOT solar processes, implying core fluctuations not allowable in the SSM; (2) virtual absence of the predicted ^{7}Be v_e line at 861 MeV in Ga detectors; and (3) the ^{7}Be-^{8}B problem, (2) and (3) implying a genuine lack of ^{7}Be and ^{8}B v_e.

Treatment of SNO ^{8}B neutrino results and the SSM generally is an elegant exercise in parameter selection, revealing commitment to the SSM with its utility in buttressing evolutionary chronology. NOT is a fruitful approach in appearing to verify SSM expectations for the ^{8}B reaction. It is to be expected that eventually other SSM reactions will be likewise "verified."

The ^{7}Be-^{8}B problem implies lack of ^{3}He production, which in turn implies a central temperature $\leq 5 \times 10^5$ K, consistent with (1) evident suppression of the *pp* reaction and (2) H fusion into which is not further processed. CNO reactions are key for element synthesis beyond B. Claimed observations of key ^{12}C synthesis are actually of 3 α formation by decay via a $^{12}C^*$ intermediate. **Though assumed, inverse 3α synthesis of ^{12}C is unobserved.**

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