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Edward A. Boudreaux  
*University of New Orleans*

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**PARTICLE INTERACTION ANALYSIS  
OF SOLAR FORMATION AND STABILIZATION**

**EDWARD A. BOUDREAU, PH.D.  
DEPARTMENT OF CHEMISTRY  
UNIVERSITY OF NEW ORLEANS  
NEW ORLEANS, LA 70148**

**ABSTRACT**

The evolution of the solar interior is analyzed from a classical, independent, particle interaction model. In this model, it is presumed that the plasma has attained an organized state of development, thus reaching a condition of static equilibrium. Henceforth, the ionized particles remain at essentially fixed distances of interaction.

Most current standard solar parameters, as well as standard data pertinent to the associated atomic particles, have been utilized. All associated energy quantities are computed within the frame-work of the model, employing conventional techniques. The possibility of "strong force" interactions between charged particles separated at nuclear distances, is also considered.

It is shown that the total repulsive energy exceeds all other stabilizing factors, including the gravitational potential energy. A proposal regarding the deficiency in detecting solar neutrinos is also presented.

**INTRODUCTION**

According to the Big Bang scenario, the sun (or any other star) is formed by the condensation of hydrogen into an ion-plasma. The pertinent process involved is the nuclear fusion reaction of

${}^1_1\text{H}^+$  (hereafter designated  $p^+$ ) producing  ${}^4_2\text{He}^{2+}$  (hereafter designated  $\alpha^{2+}$ ) in the presence of the ionized element ( $e^-$ ) to preserve electrical neutrality. The charges on the protons and alpha particles are explicitly specified as  $p^+$  and  $\alpha^{2+}$  respectively, so as to emphasize the nature of the charge interactions involved in the specific electrostatic computations. Although electrons are not explicitly involved in the nuclear reactions, they are, nonetheless, products of the initial processes and are thus regarded as non-negligible entities involved in the sum total of electrostatic interactions. Hence the reason for their explicit inclusion in equations (1a) through (1e).

$$2p^+ + 2e^- - 2n^0 - 1.56\text{MeV} \tag{1a}$$

$$2p^+ + 2n^0 + 2e^- - 2{}^1_1\text{H}^+ + 2e^- + 2v + 4.46\text{MeV} \tag{1b}$$

$$2{}^2_1\text{H}^+ + 2p^+ + 4e^- - 2{}^3_2\text{He}^{2+} + 4e^- + 10.98\text{MeV} \tag{1c}$$

$$2{}^3_2\text{He}^{2+} + 4e^- - \alpha^{2+} + 2p^+ + 4e^- + 12.85\text{MeV} \tag{1d}$$

these may be combined to yield the overall process

$$4p^+ + 4e^- - \alpha^{2+} + 2e^- + 2v + 26.73\text{MeV} \tag{1e}$$

The issue at hand is to examine the energetics of this process via an independent particle interaction model. The interactions of  $p^+$  and  $e^-$  will be considered first, followed by an analysis of the collective  $p^+$ ,  $e^-$  and  $\alpha^{2+}$  interactions. The question is whether or not either the  $p^+$ ,  $e^-$ , or the  $p^+e^-$  and  $\alpha^{2+}$  can be condensed into an ion plasma with particle interaction distances derived from known data, to produce the equilibrium conditions necessary for the stability of the sun or any other star.

## COMPUTATIONAL PROCEDURE AND RESULTS

In order to simplify the treatment of this problem into something that is manageable, we will employ a *frozen ion-plasma* model, in which it is presumed the plasma has attained an organized state of development, maintained in static equilibrium. Thus the interparticulate interactions take place at essentially fixed distances. This removes the complexities and associated uncertainties of a dynamical model and should be an adequate approximation for providing at least the relative magnitudes of the pertinent interactions. The required information regarding chemical composition and physical parameters of the sun are presented in Table 1, as obtained from various sources [9,10,4,13,8,7]. These data are given primarily for the interior region of the sun, which is least subject to any significant fluctuations. Also based on the Cosmion model, the solar interior contains (on the average) 79.1 per cent of the total mass [8]. Cox, Guzik and Raby (1990) developed a solar model in which weakly interacting, massive particles, called "cosmions", reduce the opacity by about  $10^{-3}$  within a central region one tenth of the solar radius, which also results in a reduced temperature of the isothermal core [7]. This model specifies a metallicity of 0.02, an initial He mass fraction of 0.277 and a mixing-length/pressure-scale-height ratio of 2.015, achieving an evolutionary stage of development to attain  $1L_{\odot}$  and  $1R_{\odot}$  in a time period of 4.6 Gyr (billion years) [7].

It is usual to express the total energy,  $E_T$ , in term of the total potential energy,  $E_p$ , by making use of the virial theorem, upon assuming that the ion-plasma has attained equilibrium.

This theorem state that the total average kinetic energy,  $E_k$ , is expressible in terms of the displacement forces of all particles in the system, as follows:

$$2\bar{E}_k = -\sum_i \bar{s}_i \bar{F}_{si} \quad (2)$$

where  $s_i$  is the set of generalized coordinates (x,y,z) for all i particles, and  $F_{si}$  is the S component of force acting upon the  $i^{\text{th}}$  particles. The total potential energy,  $E_p$ , is given by:

$$\sum_i s_i \left( -\frac{\partial V_i}{\partial s_i} \right) = E_p \quad (3)$$

Since the total energy is  $E_T = E_k + E_p$  and Eq (2) is the negative of Eq (3), we have the result:

$$\begin{aligned} 2\bar{E}_k &= -\bar{E}_p \\ E_T &= -\bar{E}_k = \frac{1}{2} \bar{E}_p \end{aligned} \quad (4)$$

Thus, for all the initial particles to be stabilized in a unified ion-plasma, the total energy of the plasma must be equal to half the average potential energy of all particles in equilibrium.

For a primitive sun in its state of development at 4.6 Gyr of evolution, the appropriate data relating to its interior has been taken to be that reported by Cox and Coworkers [7]. The statistical mean values are presented in Table 1.

<b>TABLE 1</b> <b>Elemental Composition and physical Data for the Sun [9,10,4,13,8,7].</b>	
<b>ELEMENT</b>	<b>PERCENT</b>
H	78
He	20
O,C,Ne	1.7
All Others	0.3
<b>PHYSICAL DATA</b>	
$M_{\odot}$ (total mass) = $1.989 \times 10^{33}$ g $R_{\odot}$ (total radius) = $6.960 \times 10^{10}$ cm R (interior region): Intermediate Zone = 0.60 $R_{\odot}$ Core = 0.25 $R_{\odot}$	
$\bar{H}$ (interior magnetic field): $10^2 \leq \bar{H} \leq 10^4$ gauss (est.)	
<b>Current Mean Statistical Data for the Solar Interior [7,8]</b>	
<b>Current Sun</b>	<b>Primitive Sun</b>
Age = 4.6 Gyr <sup>a</sup> Cosmion Model: Cox, Guzik and Raby, 1990 [8]	Age = 0.0 Gyr <sup>a</sup> Standard Model: Cox, Guzik and Kidman, 1989 [7]
$\bar{M}(g) = 1.574 \times 10^{33}$	$7.718 \times 10^{34}$
$\bar{R}(cm) = 6.047 \times 10^{10}$	$6.093 \times 10^{10}$
$\bar{\rho}(g/cm^3) = 103.0$	81.44
$\bar{T}(K) = 1.00 \times 10^7$	$1.37 \times 10^7$
$\bar{V}(\bar{\rho})(cm^3)^b = 1.528 \times 10^{31}$	$9.477 \times 10^{32}$
$\bar{V}(\bar{R})(cm^3)^c = 9.262 \times 10^{32}$	$9.477 \times 10^{32}$
$\bar{P}(\text{dynes}/cm^2) = 1.463 \times 10^{17}$	$9.213 \times 10^{16}$

<sup>a</sup> Gyr =  $10^9$  yr.

<sup>b</sup> Derived from the mean density.

<sup>c</sup> Derived from the mean radius.

We will now proceed to the evaluation of various interactions involving the particles contained within the volume element of this system, i.e., electrostatic interactions (columbic and magnetic), gravitational, pressure-volume, effects, and the possibility of "strong force" interactions.

In treating the interionic coulombic interaction, the electrostatic energy of a fixed  $i^{\text{th}}$  in a "sea" of other mobile ions, is evaluated from statistical mechanics [11]. The pertinent expression is:

$$E(\text{el})_i = \frac{(Z_i e_j)^2}{2 \epsilon r_i} \left( 1 - \frac{\kappa r_i}{1 + \kappa a} \right) \quad (5)$$

$Z_i e_j$  = the electrostatic charge of the  $i^{\text{th}}$  ion,  $\epsilon$  = the dielectric constant,  $r_i$  = the radius of the  $i^{\text{th}}$  ion,  $a$  = distance of closest approach of mobile  $j$  ions to the  $i^{\text{th}}$  ion ( $a = r_i + r_j$ ), dependent only on the ion radii. For any ion,  $i$  or

j,  $\kappa_{ij}^2$ , the Boltzman distribution of the ionic strength of the medium, is most conveniently expressed in the form

$$\kappa_{ij} = 2 \left[ \left( \frac{\pi}{\epsilon kT} \right) \sum_{ij} (Z\theta)_{ij}^2 (N_{ij}/V) \right]^{1/2} \quad (6)$$

where  $k$  = Boltzman's constant.  $T$  = mean absolute temperature (see Table 1),  $(N_{ij}/V)$  the number density of ions pertinent to the appropriate volume element.

If the potential is repulsive, as in the case of  $p^+/p^+$ ,  $\alpha^{2+}/\alpha^{2+}$ , and  $e^-/e^-$  interactions, at  $a$  = short distances, equation (5) becomes:

$$E_R(l) = \frac{(Z\theta)^2}{2 \epsilon r_i} \left( 1 - \frac{\kappa r_i}{1 + \kappa a} \right) \exp(-2a) \quad (7)$$

It can be shown that  $E_R$  is independent of  $\epsilon$  [11].

The attractive coulombic interactions are evaluated from the following expression for a charged sphere-lattice model derived by Chiu [5,11], which is a close approximation to a Madelung lattice sum per electron

$$E_A(l) = - \frac{9}{10} \frac{Z_i^3 \theta^2}{r_e} \quad (8)$$

where  $Z$  is the absolute charge of the positively ionized particle and  $r_e$  is the effective radius of a sphere replacing the volume element per electron, given by  $\left( \frac{3}{4\pi N_e \theta/V} \right)^{1/3}$ . In this approximation, the closest distance of approach between oppositely charged particles has been assumed for all interactions.

Magnetic interactions are also possible since  $p^+$  and  $e^-$  have magnetic moments of  $8.806 \times 10^{-18}$  MeV/gauss and  $5.789 \times 10^{-18}$  MeV/gauss, respectively. The potential expression for the magnetic stabilization energy per particle is:

$$E_m(l) = -(\mu(l) \bar{H}) \quad (9)$$

where  $\mu$  is the particle magnetic moment and  $\bar{H}$  the effective magnetic field of the solar interior (see Table 1). The classic gravitational potential energy is provided by the standard expression:

$$E_G = - \frac{3}{5} \frac{G \bar{M}^2}{\bar{R}} \quad (10)$$

where the gravitational constant,  $G = 6.670 \times 10^{-8}$  dyn $cm^2/g^2$ ,  $\bar{M}$  and  $\bar{R}$  are respectively the mean mass and radius of the solar interior.

There is also another effect to consider due to comprehensive  $e^-$  pressure on the positively charged ion sphere. It is later shown that this effect is given by:

$$E_{pv} = \frac{F \bar{V}}{4\pi \bar{R}^2} \quad (11)$$

where  $F$  is the effective force applied to the ion-sphere surface,  $\bar{R}$  and  $\bar{V}$  are the mean radius and volume of the solar interior, respectively.

The final effect is that due possibly to Strong Force interaction, because of the close distance of separation between charged particles. This could be a very significant factor for  $p^+/p^+$  and possibly  $\alpha^{2+}/\alpha^{2+}$  interactions, which will be treated in detail at the appropriate place later in this paper.

## PRIMITIVE SUN

For a sun in its earliest stages of mature development, the pertinent physical data are those listed in Table 1. Assuming that the hydrogen would have condensed into a constant density sphere having the reported characteristic of the solar interior, the mean volume would have been  $\bar{V} = 9.477 \times 10^{32} \text{cm}^3$  (see table 1).

## Coulomb Interactions

The repulsive energies for  $p^+/p^+$  and  $e^-/e^-$  interactions are computed from equation (7) using data presented in Table 2.

**TABLE 2**  
Coulombic Interaction Data for Solar Ion-Plasma

Particle	$r_m = 10^{-13}$ (cm)	m ( $g \times 10^{-24}$ )	Primitive		Current		$\mu$ ( $\times 10^{-15}$ ) (MeV / Gauss)
			N ( $\times 10^{58}$ )	$N/\bar{V}$ (part/cm <sup>3</sup> $\times 10^{25}$ )	N ( $\times 10^{56}$ )	$N/\bar{V}$ (part/cm <sup>3</sup> $\times 10^{25}$ )	
$e^-$	2.818	0.0009	4.612	4.867	8.280	5.419	5.789
$p^+$	1.034	1.6725	4.612	4.867	7.338	4.802	0.008806
$\alpha^{2+}$	2.160	6.6883	-----	-----	0.471	0.308	-----

<sup>a</sup>N and  $\bar{V}$  are derived from Table 1.

The result for  $E_R(p^+/p^+) = 2.344 \times 10^{58}$  MeV and for  $E_R(e^-/e^-) = 6.665 \times 10^{57}$  MeV. Thus, the total  $E_r = 3.011 \times 10^{58}$  MeV.

As far as the  $p^+/e^-$  Coulombic attractive interactions are concerned, according to equation (8), the required value of  $r_e = 1.699 \times 10^{-9}$ cm. However, at a mean temperature of  $1.37 \times 10^7$ K, the energy available is 86.84 times that required to fully ionize the electron from the H atom, and 21.70 times the energy required to fully ionize the two electrons from He. At the energy of ionization for H (13.6 eV), the closest distance that the electron can be to the proton is given by  $n^2 a_{H1}$ , where n is the principal quantum number of the highest orbital from which the  $e^-$  is ionized and  $a_{H1} = 0.5295 \times 10^{-8}$ cm. From the electronic spectral tables of Moore [12], the highest quantum level to which the H electron is excited at the ionization limit, has  $n = 49$ . Hence the closest  $e^-p^+$  distance for which ionization is maintained, is  $(49)^2 (0.5295 \times 10^{-8}$ cm) =  $1.271 \times 10^{-5}$ cm. However, so as not to minimize the effects of coulombic attraction, the value of  $r_e = 1.699 \times 10^{-9}$ cm is adopted. Thus the computed upper limit is  $E_A(p^+/e^-) \leq -3.518 \times 10^{42}$ MeV.

It is important to realize that because of energy conditions, constraints are placed on the minimum  $p^+e^-$  distance of approach (ex.  $\sim 10^{-5}$ cm via H spectral data), which is  $10^8$  times greater than the closest  $p^+p^+$  and  $e^-e^-$  distances ( $\sim 10^{-13}$ cm). Thus it would appear that the solar interior structure may conform to a central  $p^+$  "sphere" cluster, with an outer spherical segment composed of clustered  $e^-$ , situated at a relatively large distance ( $\Delta r \approx 10^4$  or  $10^6$ cm) from the central  $p^+$  "sphere". This does not appear to be unreasonable, as the total volume occupied by the  $e^-$  and  $p^+$  in the solar interior is  $4.534 \times 10^{21}$ cm<sup>3</sup>. The volume of the primitive solar interior (from Table 1) is  $9.477 \times 10^{32}$ cm<sup>3</sup>, which is  $2.09 \times 10^{11}$  times greater than the total particle volume. The  $p^+$  "sphere" volume is  $2.135 \times 10^{20}$ cm<sup>3</sup>, with

a radius of  $3.708 \times 10^6$ cm, while the mean radius of the solar interior is  $\bar{R} = 6.093 \times 10^{10}$ cm (Table 1). Thus, the height of the spherical segment containing the  $e^-$  layer is  $\approx 10^7$ cm. The void between the  $p^+$  "sphere" and the  $e^-$  "spherical segment" would be  $6.091 \times 10^{10}$ cm high, very close to the mean radius of the solar interior itself. See Figure 1.

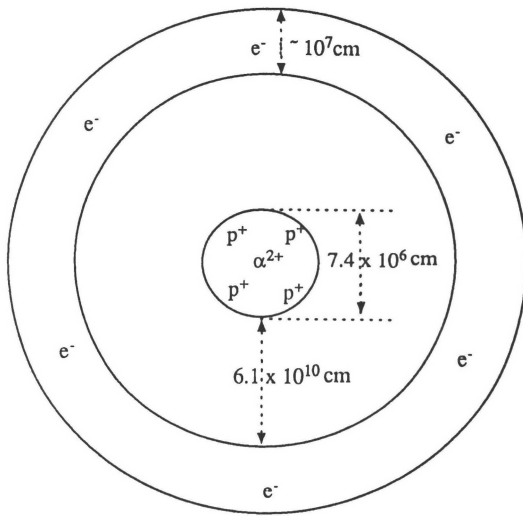


Figure 1. *Proposed Particle Structure of the Sun*

### PV Compression

Because of what has been proposed above regarding the structure of the solar interior, it is interesting to consider the magnitude of PV compression from the  $e^-$  layer directed against the  $p^+$  "sphere".

The total average kinetic energy,  $\overline{KE}$  of the solar interior is given in terms of the average

pressure  $\overline{P}$  and average volume  $\overline{V}$ , by  $\overline{KE} = \frac{3}{2} \overline{P} \overline{V} = 1.310 \times 10^{50}$  ergs for the primitive sun. Since the contribution for the electrons should be about 1800 times that of the protons, hence

$$\begin{aligned} \overline{KE}(e^-) + \overline{KE}(p^+) &= 1.310 \times 10^{50} \\ 1800\overline{KE}(p^+) + \overline{KE}(p^+) &= 1.31 \times 10^{50} \\ \overline{KE}(p^+) &= 7.274 \times 10^{46} \text{ ergs} \\ \overline{KE}(e^-) &= 1.309 \times 10^{50} \text{ ergs} \end{aligned}$$

The force that the  $e^-$  layer exerts on the  $p^+$  "sphere" is:

$$F(e^-) = 1.309 \times 10^{50} \text{ ergs} / 2\pi R(p^+),$$

where  $R(p^+)$  is the radius of the  $p^+$  "sphere" given above. Thus  $F(e^-) = 5.618 \times 10^{42}$  ergs/cm, and the pressure is

$$5.618 \times 10^{42} / 4\pi R(p^+)^2 = P(e^-) = 3.252 \times 10^{28} \text{ dynes/cm}^2$$

Hence, the work done on the  $p^+$  "sphere" is  $-P(e^-) \cdot V(p^+) = -6.942 \times 10^{48}$  ergs  $= -4.333 \times 10^{54}$  MeV. While this is substantially greater than the attractive coulombic energy, it is of significantly lower magnitude than the total repulsive energy.

### Magnetic Interactions

According to equation (9), the total magnetic coupling of  $p^+$  and  $e^-$  with the magnetic field of the solar interior is

$$E_m = -(\mu_p^+ N_p^+ + \mu_e^- N_e^-) \overline{H}. \text{ From the data in Table 2, } E_m \text{ is in the range } -2.674 \times 10^{46} - 2.674 \times 10^{48} \text{ MeV,}$$

depending on the value of  $\overline{H}$  (see Table 1).

### Gravitational Potential Energy

It is usually anticipated that the solar gravitational potential will swamp all other interactions. When the data for the

solar interior in Table 1 is substituted into equation (10),  $E_G = -2.442 \times 10^{57}$  MeV. This does not offset the maximum repulsive energy computed in Section 1 above, however.

A complete listing of all energy contributions for both the primitive and current sun will be provided in Table 3, after a comparable set of energy data are evaluated for the current sun. There is also the very important question as to what might be the possibility of strong force involvement at such close interparticle distances. This shall be treated subsequent to the evaluation of all classical interactions for the current sun.

**CURRENT SUN**

Using the data from Table 1, the current masses of H and He in the solar interior are  $1.207 \times 10^{33}$  and  $3.148 \times 10^{32}$ , respectively. This translates into  $7.3 \times 10^{56} p^+$ ,  $4.7 \times 10^{55} \alpha^{2+}$  and  $8.3 \times 10^{56} e^-$ .

**Coulomb Interaction**

Utilizing the data in Table 2 and equation (7), the repulsive energies are found to be  $E_R(p^+/p^+) = 2.645 \times 10^{56}$  MeV,  $E_R(\alpha^{2+}/\alpha^{2+} = 5.448 \times 10^{55}$  MeV and  $E_R(e^-/e^-) = 1.875 \times 10^{56}$  MeV.

The attractive interactions involve  $e^-/p^+$  and  $e^-/\alpha^{2+}$ . From equation (8),  $E_A(e^-/p^+) \leq -5.799 \times 10^{52}$  MeV,  $E_A(e^-/\alpha^{2+}) \leq -5.910 \times 10^{51}$  MeV. Here again, the appropriate value of  $r_e = 1.640 \times 10^{-9}$  cm, as determined from the data in Table 2.

**PV Compression**

From Table 1,  $\frac{3}{2} \bar{P}\bar{V} = 2.032 \times 10^{50}$  ergs, which yields  $\bar{K}E(e^-) = 2.032 \times 10^{60}$  ergs. The radius of the  $p^+ \alpha^{2+}$  "sphere" is  $1.087 \times 10^6$  cm. The force exerted upon the sphere by the outer band of  $e^-$  is  $F(e^-) = 2.974 \times 10^{43}$  ergs/cm, and the corresponding pressure is  $P(e^-) = 7.248 \times 10^{29}$  dynes/cm<sup>2</sup>.

Finally, the PV work done on the  $p^+ \alpha^{2+}$  "sphere" from equation (11), is  $-2.437 \times 10^{54}$  MeV.

**Magnetic Interactions**

From equation (9) and the appropriate data in Table 2,  $E_M(p^+ + e^-)$  is in the range  $-4.800 \times 10^{44}$  to  $-4.800 \times 10^{46}$  MeV, depending on the value of  $\bar{H}$  employed (see Table 1).

**Gravitational Potential Energy**

Upon substituting data from Table 1 into equation (10),  $E_G = -1.024 \times 10^{54}$  MeV. It is interesting to note that the total repulsive potential energy is 494.6 times greater than than the gravitational potential energy for the primitive solar interior. A listing of all energy contributions for both the primitive and current solar interiors is presented in Table 3.

TABLE 3 Solar Interior Energy Parameters		
Energy Term (1)	Solar Interior Model (2)	
	Primitive	Current
$E_R$	$3.011 \times 10^{58}$	$5.065 \times 10^{56}$
$E_A$	$\leq -3.518 \times 10^{42}$	$\leq -6.390 \times 10^{52}$
$E(PV)$	$-4.333 \times 10^{54}$	$-2.437 \times 10^{54}$
$E_M$	$-2.674 \times 10^{48}$ (max)	$-4.800 \times 10^{46}$ (max)
$E_G$	$-2.433 \times 10^{57}$	$-1.024 \times 10^{54}$
$\bar{K}E$	$8.179 \times 10^{55}$	$1.269 \times 10^{56}$

(1) All values in MeV.  
(2) See Table 1.



## STRONG FORCE INTERACTIONS

Since the inter-proton distance is of the dimensions associated with that in an atomic nucleus, it is important to attain an assessment of this effect for our  $p^+$  ion-plasma. The simplest model of a measured  $p+p^+$  interaction

is that present in the nucleus of a  ${}^3_2\text{He}$  atom. However, this also has a neutron ( $n^0$ ) in addition to the two  $p^+$ . Thus the total interactions are  $2(p^+n^0)$  plus  $p^+p^+$ . Hence, we must first obtain a value for the  $p^+n^0$  interaction. The

only measured case available is  ${}^2_1\text{H}$  atom. Using the following charge radii reported for the pertinent particles

[6]:  $R({}^2_1\text{H})=2.80\text{ fm}$ ,  $R_{(p^+)} = 1.034\text{ fm}$ ,  $R(n^0) = 0.45\text{ fm}$ . Summing the diameters,  $d_{(p^+)}$  of the  $p^+$  and  $d(n^0)$ , of the

$n^0$ , gives  $2.97\text{ fm}$ . The diameter of  ${}^2_1\text{H}$  =  $5.60\text{ fm}$ . Thus the  $p^+n^0$  separation =  $(5.60-2.97) = 2.63\text{ fm}$ . The

binding energy of  ${}^2_1\text{H}$  is  $2.22\text{ MeV}$  [14] and since only the strong-force  $p^+n^0$  interaction is involved, this is the magnitude of the strong-force pairing energy,  $E_{\text{SFP}}$ , between  $p^+$  and  $n^0$ . Of course, the magnitude of this will change with increasing numbers of nucleons in heavier nuclei, but except for even-odd relationships and nuclear surface effects, the strong-force interactions are essentially additive. We may express the binding energy

of  ${}^3_2\text{H}$  as:

$$E_B = 2E_B(p^+n^0) + E_B(p^+p^+) = 7.72\text{ MeV} \quad [11]. \quad (12)$$

hence  $E_B(p^+p^+) = (7.72-4.44) = 3.28\text{ MeV}$ , and  $R({}^3_2\text{He}) = 2,38\text{ fm}$  (ave.) [6]. For this case, the strong-force pairing energy is:

$$E_{\text{SFP}} = E_B(p^+p^+) + E_B(p^+n^0) \quad (13)$$

where  $E_c$  is the coulomb energy, which may be evaluated from the following expression [3]:

$$E_c = \frac{3}{5} \frac{Z^2 e^2}{R} \left[ 1 - 5 \left( \frac{3}{16\pi Z} \right)^{\frac{2}{3}} \right] - \frac{27}{16} \frac{Z^2 e^2}{k_F^2 R^3} \quad (14)$$

for which  $k_F = (\pi^2 Z \rho_{(q)})^{1/3}$  and  $\rho_{(q)} = 0.170\text{ Z/A}$ . Thus  $E_c = 4.32\text{ MeV}$  and  $E_{\text{SFP}} = 7.60\text{ MeV}$ . The determination of the interproton distance is complicated by the fact that the  $n^0$  binds the two  $p^+$  at a shorter distance than if it were

not involved. If we consider  $R({}^3_2\text{He})$ , the radius with the finite proton size,  $R_{(p^+)}$ , removed (see Ref. 10), the  $p^+p^+$

separation will be related to the following two factors 1)  $R({}^3_2\text{He}) - R_{(p^+)}$  and 2)  $R(n^0)$ . The latter factor is added to the first and the average of these two effects should yield a reasonable expression for the  $p^+p^+$  separation,  $r(p^+p^+)$

$$\begin{aligned} r(p^+p^+) &= \frac{1}{2} [R({}^3_2\text{He}) - R_{(p^+)} + R(n^0)] \\ &= \frac{1}{2} [1.34 - 1.034 + 0.45]\text{ fm} \\ &= 0.38\text{ fm}. \end{aligned} \quad (15)$$

The strong force pairing potential may be expressed as:

$$V_{\text{SFP}} = -\frac{Z^2 e^2}{R} e^{-bR} \quad (16)$$

where " $b$ " is an empirical parameter ranging from  $-27$  to  $45$  ( $\times 10^{13}$ ) depending on the value of  $R$ .  $V_{\text{SFP}}$  has its maximum value at  $R = 0.8\text{ fm}$ , " $b$ " =  $19.5 \times 10^{13}$ , and goes to zero for  $R \leq 0.35\text{ f}_m$ , " $b$ " <  $-27 \times 10^{13}$ , and for  $R \geq 4\text{ f}_m$ , " $b$ "  $\geq 45$ .

Although the  $E_{\text{SFP}}$  varies substantially over a relatively small difference in  $r(p^+p^+)$ , the total binding energy increases regularly with the number of nucleons [14]. However, we have no way of knowing how this might behave outside the domains of atomic nuclei, A typical binding energy curve is presented in Figure 2, which shows that the binding

energy per nucleon,  $E_{B/A}$ , increases abruptly up to about  $20 p^+ + 20 n^0 = A = 40$ . It then reaches a maximum saturation limit in the range of  $(26-28) p^+ + 20 n^0 = A$ , but decreases smoothly out to  $A = 240$ . All elements having higher mass numbers are highly unstable, and are non-existent if  $E_{B/A} \leq 7$  MeV, for  $A > 240$ . Hence, it is highly questionable as to whether or not the typical nuclear strong-force factors even apply to a body as massive as the sun. However, if they do, then we can expect a direct proportion of  $E_{SFP}$  to its volume element of distribution. Thus

for the single  $p^+p^+$  pair in  ${}^3_2\text{He}$ , the  $7.6 \text{ MeV} = E_{SFP}$  is over a volume element of  $56.47 \times 10^{-39} \text{ cm}^3$ , but for the  $4.61 \times 10^{58} p^+p^+$  pairs in the solar interior, the distribution of  $E_{SFP}$  is over a volume of  $9.48 \times 10^{32} \text{ cm}^3$ . Now when the proportionalities between  $E_B$  and  $A$  in Figure 2 are applied linearly to the relative increases in nuclear volumes for nuclides,  $50 \leq A \leq 240$ , then  $E_{SFP} = -4.76 \times 10^{12} \text{ MeV}$  relative to the primitive solar interior.

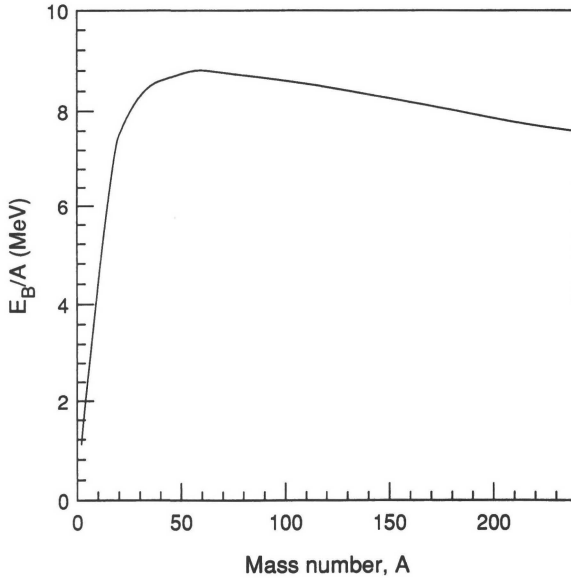
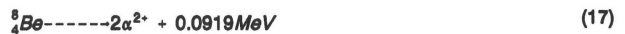


Figure 2. Variation of binding energy per nucleon,  $E_B/A$ , with atomic mass number,  $A$ .

In the case of the current solar interior,  $E_{SFP}$  may arise from  $p^+p^+$ ,  $p^+\alpha^{2+}$  and  $\alpha^{2+}\alpha^{2+}$  strong force pairing. A rational value for  $E_{SFP}(p^+p^+)$  has already been derived above. We now proceed to a derivation of  $E_{SFP}(\alpha^{2+}\alpha^{2+})$  and  $E_{SFP}(\alpha^+p^+)$ . The following nuclear process is will documented [15].



which provides the energy for decoupling two  $\alpha^{2+}$ . This represents the difference between  $E_{SFP}$  and  $E_c$  for the two entities, at the separation distance in the  ${}^8_4\text{Be}$  nucleus, as given by:

$$r(\alpha^{2+}\alpha^{2+}) - 2 [R({}^8_4\text{Be}) - 2R(\alpha^{2+})] \quad (18)$$

where  $R({}^8_4\text{Be})$  and  $R(\alpha^{2+})$  are effective nuclear radii determined from one  ${}^8_4\text{Be}$  nuclear volume and two  $\alpha^{2+}$  nuclear volumes, respectively. However, the  ${}^8_4\text{Be}$  nuclear charge radius is not listed in ref. [6], but may be interpolated from the comparisons of charge radii for  ${}^6_3\text{Li}$ ,  ${}^7_3\text{Li}$  and  ${}^{10}_5\text{B}$ ,  ${}^{11}_5\text{B}$ , relative to  ${}^9_4\text{Be}$ ,  ${}^8_4\text{Be}$ . The difference between the radii of the higher and lower mass numbered isotopes of Li and B, is an average value of 0.07 for [6].

Thus we may estimate the effective nuclear radius of  ${}^8_4\text{Be}$ , ie.  $R({}^8_4\text{Be})$  as follows

$$R({}^8_4\text{Be}) - R({}^9_4\text{Be}) + 0.07 \text{ fm} = 3.12 \text{ fm} + 0.07 \text{ fm} = 3.19 \text{ fm} \quad (19)$$

Since  $R(\alpha^{2+}) = 2.72 \text{ fm}$ , substitution into equation (18) gives  $r(\alpha^{2+}) = 0.94 \text{ fm}$ .

Recalling that  $E_{\text{SFP}}(\alpha^{2+}\alpha^{2+}) = 0.0919 - E_c(\alpha^{2+}\alpha^{2+})$  (MeV), we now calculate  $E_c(\alpha^{2+}\alpha^{2+})$  from Eq (14), with  $\rho_{(0)} = 0.085$  and  $k_F = 1.832$ , which gives  $E_c(\alpha^{2+}\alpha^{2+}) = 14.74$  MeV. Thus  $E_{\text{SFP}}(\alpha^{2+}\alpha^{2+}) = 14.83$  MeV at  $r(\alpha^{2+}\alpha^{2+}) = 0.94$  fm, and using Eq (16), it is found that the  $E_{\text{SDP}}(\alpha^{2+}\alpha^{2+})$  is reduced from 42 MeV at 0.94 fm to 3.5 MeV at 2.24 fm, which is nearly a 92% decrease. On applying the energy density proportionality presented above, it is found that the effective  $E_{\text{SFP}} = -4.55 \times 10^{13}$  MeV over a volume of  $9.26 \times 10^{32}$  cm<sup>3</sup>.

We can reasonably estimate that the  $E_{\text{SFP}}(p^+\alpha^{2+})$  = the average of that for  $p^+p^+$  and  $\alpha^{2+}\alpha^{2+}$ , respectively, which gives the value  $-2.51 \times 10^{13}$ . Hence, if we add the  $E_{\text{SFP}}$  for all particles, the total  $E_{\text{SFP}} = -7.54 \times 10^{13}$  MeV. This again is not sufficient to overcome the repulsive energy.

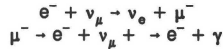
## CONCLUSION

The details of an independent particle interaction model have been presented for both the H<sup>+</sup> ion-plasma model of a primitive sun and H<sup>+</sup>/He<sup>2+</sup> ion-plasma model based on the currently reported composition of the sun. In both cases, it is found that the inter-ion repulsive energy exceeds all other stabilizing energy contributions of the system.

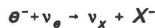
An expression of the total energy in terms of Eq (4) from the Virial Theorem yields the obvious conclusion that neither the primitive nor the current particle structure of the solar interior conforms to this theorem. Admittedly, this treatment is approximate, but should, nonetheless, not be in error by orders of magnitude. Thus, it would appear that the *a priori* assumption that the Virial Theorem is necessarily satisfied in solar energetics, is not justified on the basis of this analysis. However, since the solar structure is obviously stabilized, there must be some other explanation. Either unjustified constraints must be placed on the factors employed in this analysis, or the assumption that strong force stabilization decreases in proportion to the volume element over which it operates (as implied from the nuclear binding energy curve in Fig. 2, is erroneous.

Could it be that the twenty-odd years of attempts to detect solar neutrinos, having provided substantially fewer neutrinos than predicted by equation (1e), has something to do with the findings of this report? Of themselves, such results have called the solar H<sup>+</sup> fusion model into question: nonetheless, the proposal of Bahcall and Bethe [1] requiring a conversion of massless electron neutrinos,  $\nu_e$ , to neutrinos of "another flavor"  $\nu_x$ , having small mass, cannot be ignored and does indeed appear to be vindicated as more careful experimentation progresses.

It is tempting to speculate on this matter in terms of the solar, particle-structure proposed here. Well known electron-neutrino processes include:



Recall the proposed distribution of the outer band of  $e^-$  about the  $p^+, \alpha^{2+}$  core of the solar interior. A collision of a  $\nu_e$  emanating from this core with an  $e^-$  will occur with an availability of 0.380 MeV per  $e^-$  (see Section B.1 and B.2 above). It was reported that the upper limits to the kinetic energies of  $\nu_e$  and  $\nu_\mu$  were  $\leq 200$  eV and  $\leq 3 \times 10^6$  eV, respectively [16,2] but the currently accepted mass-energy equivalents are  $< 18$ eV and  $< 0.25$  MeV, respectively. Thus if the  $\nu_e$  acquired a substantial portion of instantaneous energy to mass transfer, then a neutrino of flavor  $\nu_x$  with mass  $\leq 0.380$  MeV/c<sup>2</sup>, will appear to be produced nonadibatically. The corresponding reaction scenario is:



where  $X^-$  is some unstable (admittedly hypothetical) X-type meson undergoing very rapid decay. The net result is that the majority of  $\nu_e$  produced initially are converted to  $\nu_x$ , which are annihilated back to the electrons.

This simplistic proposal is in accord with the predictions made from the eloquent quantitative treatments of Bahcall and others [17].

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