

Figure 1. The Solar System formed from debris of a spinning supernova

At last year's conference in Oulu, Finland [14] it was noted that neutron emission from the central neutron star at the core of the Sun likely triggers a series of reactions that generate solar luminosity (SL), neutrinos, and an upward flow of protons that maintains mass separation in the Sun and generates an outpouring of H^+ ions from the solar surface:

- Neutron emission from a central neutron star (>57% SL)
 - $\langle {}^1_0n \rangle \rightarrow {}^1_0n + \sim 10 - 22 MeV$
- Neutron decay (<5% SL)
 - ${}^1_0n \rightarrow {}^1_1H^+ + e^- + anti - \nu + 0.782 MeV$
- Fusion and upward migration of H^+ (<38% SL)
 - $4 {}^1_1H^+ + 2e^- \rightarrow {}^4_2He^{++} + 2\nu + 27 MeV$
- Escape of excess H^+ in the solar wind (100% SW)
 - Each year $3 \times 10^{43} H^+$ /year depart in the solar wind

Abrupt changes in climate and the heterogeneous, dynamic nature of the Sun have also been at odds with the assumption of a homogeneous Sun with a well-behaved H-fusion reactor at its core. Many of these violent events at the solar surface are driven by solar magnetic fields, deep-seated remnants of ancient origin [15] arising from a) the neutron star at the solar core, and/or b) the iron-rich, super-conducting [16] material that surrounds the central neutron star.

The present paper identifies the need for a better theoretical understanding of the processes that occur in an iron-rich Sun and suggests a few experimental measurements to test if these are part of the Sun's operation.

2. The source of luminosity in an iron-rich Sun

Over 20 years ago it became abundantly clear that the Sun must be iron-rich [2]. However the stable isotopes of iron contain tightly bound nucleons, so this could hardly be the source of solar luminosity. Finally on Christmas day of 2000, three students and I submitted a report to the Foundation for Chemical Research, Inc. [17] with a summary of information obtained when we abandoned the conventional approach and used something akin to the reduced variables in van der Waals' equation of corresponding states to study properties of the 2,850 nuclides tabulated in the latest report from the National Nuclear Data Center [18].

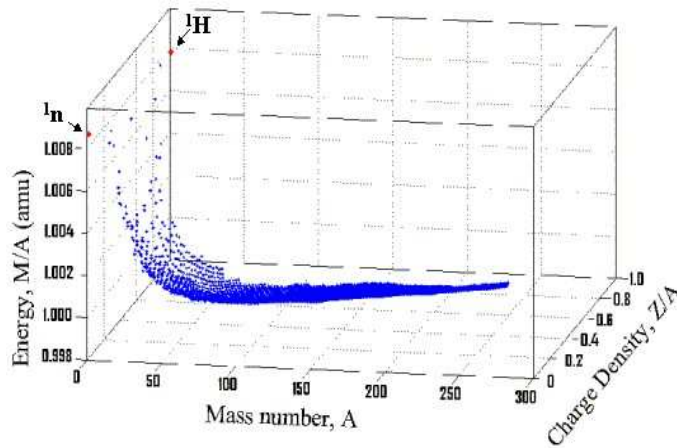


Figure 2. The ground states of the 2,850 nuclides define a “cradle”

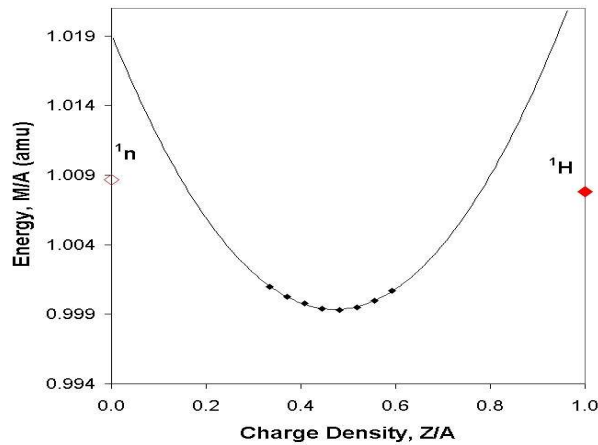


Figure 3. An illustrative cross section through Fig. 2 at $A = 27$

by ^{27}F , ^{27}Ne , ^{27}Na , ^{27}Mg , ^{27}Al , ^{27}Si , ^{27}P , and ^{27}S yields much higher values of M/A for an assemblage of 27 neutrons at $Z/A = 0$ or for an assemblage of 27 protons at $Z/A = 1.0$, respectively. Cross-sectional cuts through Fig. 2 at any other value of $A > 1$ reveal an empirical mass parabola with values of $M/A > M(^1\text{n})$ at $Z/A = 0$ and values of $M/A > M(^1\text{H})$ at $Z/A = 1.0$.

Typically the excess energy associated with these assemblages of pure neutrons or protons is ~ 10 MeV per nucleon, plus the energy from Coulomb repulsion at $Z/A = 1$. Unlike the imagined dripping of neutrons near $Z/A \approx 0$ [ref. 19, page 381], it thus appears that neutron emission may release significant amounts of energy from a neutron star.

Coulomb repulsion contributes to the high value of M/A for the assemblage of 27 protons on the right side of Fig. 3, but not to a nucleus of 27 neutrons on the left. In fact, Coulomb repulsion accounts for the difference between values of M/A at the intercepts where $Z/A = 1.0$ and $Z/A = 0$, and this difference increases linearly with $A^{2/3}$ over the mass range, $A = 1 - 41$ [20]. The slope of this line is indistinguishable from that defined by the familiar β -decay of mirror nuclei close to the line of β -stability, e.g., $(^1\text{H}, ^1\text{n})$, $(^3\text{He}, ^3\text{H})$, $(^5\text{Li}, ^5\text{He})$, $(^7\text{Be}, ^7\text{Li})$, . . . , $(^{41}\text{Sc}, ^{41}\text{Ca})$ [20].

Thus, the values obtained for M/A from empirical mass parabolas at $Z/A = 1.0$ and Z/A

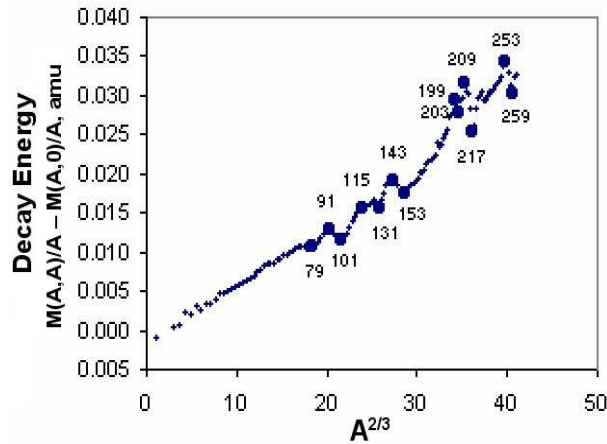


Figure 4. Decay energies of extreme nuclides, where the Coulomb energy drives ($Z/A = 1$) \rightarrow ($Z/A = 0$), for all odd values of A from $A = 1$ to 263

$= 0$ yield the same nuclear radius and the same coefficient for the Coulomb energy term as the mirror nuclei close to the line of β -stability for $A = 1 - 41$ [20].

The decay energy, and hence the Coulomb energy of heavier nuclides, $A > 41$, can also be obtained from differences indicated by mass parabolas for values of M/A at $Z/A = 1.0$ and $Z/A = 0$. Fig. 4 shows the results for all odd values of A , from $A = 1$ to $A = 263$.

The decay energies of light nuclides in Fig. 4 vary linearly with $A^{2/3}$, but fine structure starts to appear near $A \approx 80$. Peak energies, at $A = 91, 115, 143, 199, 209$ and 253 , likely arise from high Coulomb energy at $Z/A = 1$ because of clustering of nucleons into tightly packed structures. Likewise, valleys at $A = 79, 101, 131, 153, 203, 217$ and 259 likely mean low Coulomb energy at $Z/A = 1$ because of more loosely packed nucleons.

There is no Coulomb energy associated with the other extreme form of nuclides, at $Z/A = 0$. These are the intercepts of mass parabolas at each value of A with the front plane in Fig. 2. However, these neutron-rich nuclides at $Z/A = 0$ also reveal fine structure, as shown in Fig. 5 for all odd values of A from $A = 1$ to 263 .

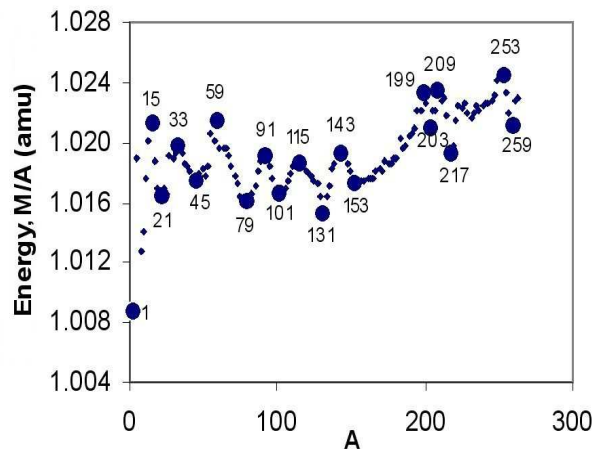


Figure 5. Values of M/A at $Z/A = 0$ for all odd- A parabolas, $A = 1-263$

The data in Fig. 5 includes, for example, $M/A = 1.019$ at $A = 27$, as shown earlier in Fig.

3. Note that all values of M/A for $A > 1$ are higher than that of the free neutron at $A = 1$. This was first recognized as an indication of repulsive interactions between neutrons [17]. Neutron emission from these nuclides would typically generate about 10 MeV per nucleon, as shown by the example in Fig. 3 at $A = 27$.

The rhythmic distribution with A in values of M/A at $Z/A = 0$ was not understood in 2000. However, the peaks and valleys in Fig. 5 occur at the same mass numbers as those in Fig. 4 for $A \geq 79$. Nuclear clustering into tightly packed structures produces peaks at $A = 91, 115, 143, 199, 209$ and 253 in Fig. 4 from enhanced Coulomb repulsion. Nuclear clustering into tightly packed structures produce peaks at these same mass numbers in Fig. 5 from enhanced repulsion between neutrons. Loosely packed nucleons produce valleys at $A = 79, 101, 131, 153, 203, 217$ and 259 in Fig. 4 from reduced Coulomb repulsion between loosely packed protons and in Fig. 5 from reduced repulsion between loosely packed neutrons.

The rhythmic scatter of data in Fig. 5 suggests that nuclear clustering also occurs below $A = 79$. However, the positive charge on light nuclei apparently maintains a spherical shape. Thus, the Coulomb energy is proportional to $A^{2/3}$ at $A < 79$ in Fig. 4, as well as in ordinary mirror nuclides [20].

4. Theoretical and experimental studies needed

The structure of the solar core likely involves a central neutron star surrounded by iron-rich material. In order to see if neutron emission from the central neutron star might trigger a series of reactions that generate solar luminosity, neutrinos, and an outpouring of H^+ ions from the solar surface [14], a better theoretical understanding is needed of:

- (a) repulsive interactions between neutrons
- (b) clustering of nucleons, and
- (c) neutron emission by penetration of a gravitational barrier.

Likewise, the proposed structure of the solar core can be tested by experimental measurements to look for evidence of:

- (d) low energy ($E < 0.782$ MeV), anti-neutrinos coming from neutron decay near the solar core
- (e) another source for the neutral neutrino current detected by SNO experiment [21], and
- (f) a dense object (about 10 km) at the solar core.

The empirical basis for concluding the likely involvement of processes (a) – (c) in the operation of the Sun was presented above. However, a better theoretical basis for these processes is needed.

The presence of process (d) could be detected by measuring inverse β -decay induced by low energy anti-neutrinos coming from the Sun. For example, the $^{35}\text{Cl} \rightarrow ^{35}\text{S}$ reaction might produce measurable levels of 87-day ^{35}S in the Homestake Mine or in underground deposits of salt (NaCl).

Regarding item (e), the SNO experiment [21] on solar neutrinos shows that the charge current comes from the direction of the Sun, but new measurements are needed to determine the source of the much larger neutral current.

A recent paper [15] suggests that the 22-year cycle of solar magnetic storms may arise from the neutron star at the solar core and/or from the iron-rich super-conducting material that surrounds it. Measurements of gravity anomalies and of the Sun's quadrupole moment might also provide information on (f), a dense object at the solar core.

5. Acknowledgements

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