

Neutron Repulsion

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(Received)

Neutron repulsion was discovered in nuclear rest mass data in 2000 as the overlooked source of nuclear energy that tied together many puzzling space-age observations of the previous four decades, like the keystone crown on an arch that locks the other pieces of the puzzle together. Members of the space, climate, and nuclear science communities neglected neutron repulsion, as they did three earlier, crucial discoveries about Earth's heat source that might have avoided the recent scandal over supposedly scientific predictions about Earth's climate: a.) The Sun gave birth to the solar system in a supernova explosion and then reformed on the collapsed supernova core (Fig. 1); b.) Excess ^{136}Xe from the r-process was a tracer isotope of primordial helium in meteorites and planets at the birth of the solar system (Fig. 2); and c.) Mass fractionation in the Sun (Fig. 3) enriches lightweight elements and lightweight isotopes of each element at the solar surface. Together these four findings are the framework that may explain why: 1.) Energy and neutrinos continuously pour from the iron-rich Sun and similar stars; 2.) An ordinary-looking star like the Sun formed on the neutron-rich core of a precursor star; 3.) Solar hydrogen from neutron-decay in the Sun induces mass fractionation and generates solar neutrinos by fusion on its journey to the H-rich surface before departing to interstellar space; and 4.) The cosmos fragments and expands as neutron repulsion overcomes gravitational attraction to produce violent stellar explosions or steady neutron-emission and neutron-decay into the hydrogen that departs stars as a waste product.

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Introduction

This review of events that led to the discovery of neutron repulsion and the implications of neutron repulsion for space and solar sciences was prepared for publication at this time as an expression of gratitude for a half century of discoveries and as an invitation to other scientists, world leaders and administrators of public research organizations—like the UN's Intergovernmental Panel on Climate Change (IPCC), the US National Academy of Sciences (NAS), the International Inter-Academy Panel on International Issues (IAP), the International Inter-Academy Council (IAC), the US Department of Energy (DOE), the US Environmental Protection Agency (EPA), etc.—to examine the empirical evidence of neutron repulsion for themselves and decide if this natural source of nuclear energy might advance understanding in their own disciplines.

As noted in the abstract, the discovery of neutron repulsion in 2000 was the triumphant arch through which many puzzling observations over the previous four decades could finally be viewed as pieces of a surprisingly simple mosaic of the origin, chemical composition and source of energy for the Sun and its planetary system.

The remarkably singular event that gave birth to the solar system and its elements is depicted in Fig. 1: Stellar debris¹⁻³ from the axial explosion of a star that had evolved along the path described in 1957 by B2FH⁴. This scenario was shown at 1976 AGU⁵ and ACS⁶ meetings, and the 1977 Welch Cosmochemistry Conference⁷, and discussed in these 1970's papers¹⁻³.

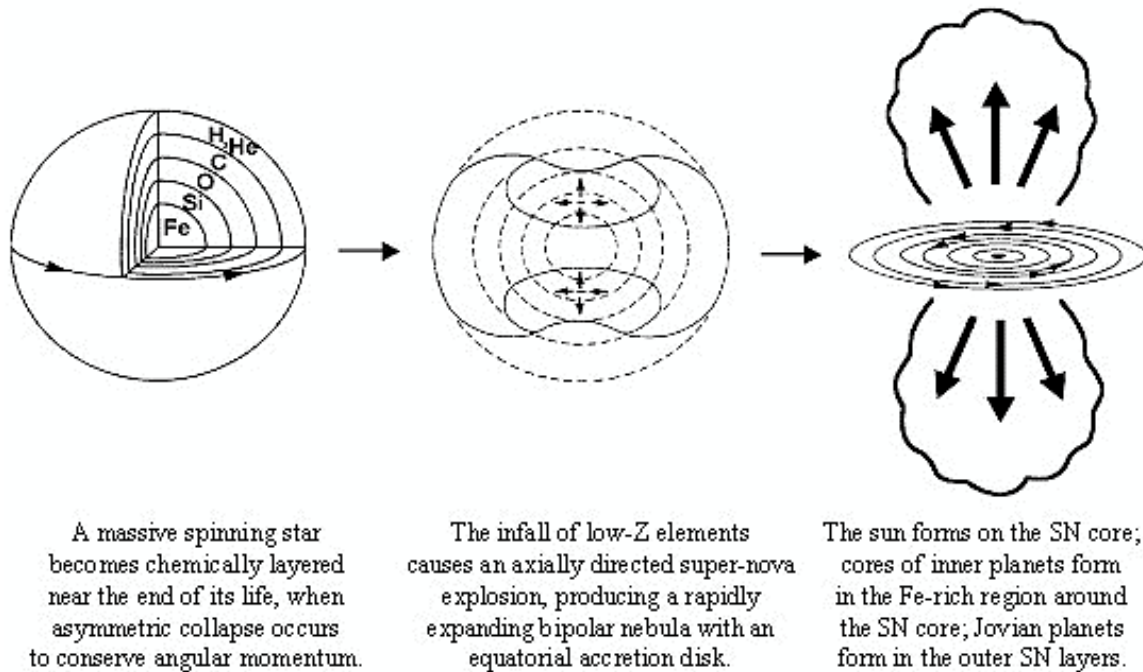


Fig. 1. The Sun and its planetary system formed directly from the debris of a precursor star that exploded axially and produced a planetary disk in the equatorial plane, orbiting the remnant neutron-rich core on which the Sun reformed.

The simple scenario in Fig. 1 for the origin of the solar system addressed these puzzling space-age findings⁸⁻²⁸ and led to recognition that mass solar fractionation¹⁴⁻²⁰ is maintained by the upward flow of hydrogen as a by-product of neutron-emission from the solar core.

- ¥ Decay products of extinct, short-lived radioactivities (¹²⁹I, ²⁴⁴Pu, ¹⁰⁷Pd and ²⁶Al) in meteorites⁸⁻¹¹, and the decay products of two of these short-lived radionuclides (¹²⁹I and ²⁴⁴Pu) in the Earth¹²⁻¹³ itself. [The first report of radiogenic ¹⁰⁷Ag from ¹⁰⁷Pd decay was wrong; radiogenic ¹⁰⁷Ag was rediscovered in meteorites 18 years later.]
- ¥ The abundances of many isotopes of noble gases in meteorites, terrestrial and lunar samples had been severely altered by mass fractionation¹⁴⁻²⁰ in unknown site(s).
- ¥ Excesses of some isotopes were unexplained by mass fractionation but matched the products of specific stellar nucleosynthesis reactions described earlier by B2FH⁴;
 - a) Excess ¹²⁴Xe from the p-process²⁰,
 - b) Excess ¹³⁶Xe from the r-process²⁰, rather than spontaneous fission of an extinct super-heavy element²¹⁻²⁵, and
 - c) Excess ¹⁶O from helium burning or the s-process²⁶,
- ¥ Inclusions in iron meteorite formed as early and trapped as much short-lived radioactivities as "primitive" meteorites²⁷; and
- ¥ Excess ¹³⁶Xe from the r-process of nucleosynthesis⁴ was a "marker isotope" for primordial helium that accompanied only "strange" xenon²⁰ (Xe-2) in meteorites¹⁻³.

Fig. 2 shows the experimental observation that required radical change in the standard model for the formation of the solar system from an interstellar cloud of mostly hydrogen and helium: Meteorites sampled two primordial reservoirs of xenon (Xe-1 and Xe-2), but all primordial helium was in the reservoir with "strange" Xe-2; none was with "normal" Xe-1.

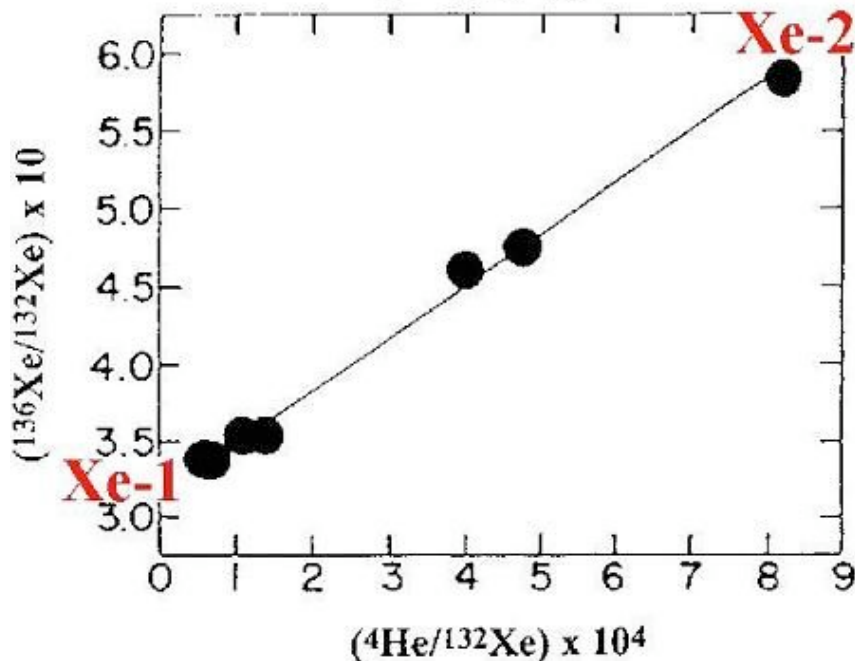


Fig. 2. The initial association of all primordial helium with excess ¹³⁶Xe in "strange" xenon²⁰ (Xe-2) and its absence from "normal" xenon (Xe-1) was the first indication that elements and isotopes never completely mixed in the supernova debris that formed the solar system¹⁻³.

Science^{2,28} published the debates between advocates of superheavy element fission²¹⁻²⁵ and nucleosynthesis^{1-3,5-7,20} as the source of excess ¹³⁶Xe in meteorites. Evidence was soon reported of nucleogenetic isotopic anomalies in many other elements, but advancement was hindered by those who mistakenly²⁹ assigned mass fractionated forms of neon³⁰⁻³³ to nucleosynthesis and by others who simply ignored the link^{1-3,34} between major elements and specific types of nucleogenetic isotopic anomalies" e.g., the close association of lightweight elements like primordial helium with r-products (Fig. 2)" and suggested that nucleogenetic isotopic anomalies could be explained by injecting a small amount of anomalous material from a nearby supernova³⁵ or by the presence of interstellar carrier grains in meteorites^{31,36}.

Despite these distractions, measurements continued to reveal new nucleogenetic isotopic anomalies linked to the chemical composition of the carrier grain, as expected from the scenario shown in Fig. 1 for the birth of the solar system from poorly mixed stellar debris:

- ¥ Researchers at the University of Chicago identified six different classes of meteorites and planets by the amounts of excess ¹⁶O in their oxygen isotopes³⁷.
- ¥ Researchers at the University of Chicago³⁸ and Caltech³⁹ collaborated on studies to show correlated nucleogenetic isotopic anomalies in dissimilar elements, O and Mg.
- ¥ Research at the University of California-Berkeley confirmed the ancient age reported earlier²⁷ for inclusions in iron meteorites⁴⁰.
- ¥ The primordial link reported earlier¹⁻³ of anomalous xenon (Xe-2) with helium from the outer part of a supernova⁴¹ was confirmed in diverse types of meteorites⁴¹.
- ¥ As measurement after measurement continued to accumulate on one side of the debate over the formation of the solar system (Fig. 1), it seemed that the debate might be finally settled in 1983 with the publication of three reports⁴²⁻⁴⁴:
 - a) Professor Anders and another researcher at the University of Chicago joined researchers from the University of California-San Diego to publish evidence⁴² in *Science* against the superheavy element fission hypothesis²¹⁻²⁵.
 - b) Under a banner news report, "The demise of established dogmas on the formation of the Solar System", *Nature* reported⁴³ that new findings ". . . led the principal defendants in the argument . . . to concur in favor of the supernova hypothesis."
 - c) By correcting element abundances in the photosphere for the mass fractionation observed across isotopes of elements in the solar wind, the interior of the Sun was shown⁴⁴ to consist mostly of elements "Fe, O, Ni, Si, S, Mg and Ca" elements produced near the core of the supernova shown in Fig. 1.
- ¥ But these 1983 reports did not convince administrators of federal research agencies and mainstream scientists to consider seriously the solar system's supernova birth¹⁻³ (Fig. 1), excess ¹³⁶Xe as a tracer isotope¹⁻³ for primordial helium (Fig. 2), solar mass fractionation⁴⁴ (Fig. 3), or the prediction⁴⁴ of excess ¹³⁶Xe in Jupiter. They construed ". . . independent evidence that so-called CCF-Xe is derived from a supernova involving both p- and r-processes, as first suggested by Manuel et al. (*Nature* 240: 99; 1972)", and concurrence ". . . in favor of the supernova hypothesis" to mean that the excess ¹³⁶Xe in meteorites came from any number of distant supernovae! This post-1983 consensus view on diverse supernova sources for isotopic anomalies is well illustrated by this 2002 report⁴⁵ from Harvard and the references cited there.

- ✘ Twelve years later xenon isotope data, collected as the Galileo probe entered Jupiter's He-rich atmosphere, confirmed⁴⁶⁻⁴⁷ the link of excess ¹³⁶Xe with primordial helium (Fig. 2) and predictions of the iron-rich Sun and solar mass fractionation⁴⁴.
- ✘ A renowned geologist and space scientist at a first-class research university⁴⁸ challenged the dogma that iron meteorites formed by planetary differentiation.
- ✘ University of Tokyo studies⁴⁹⁻⁵⁰ showed that massive iron meteorites solidified before isotopes of molybdenum from the r-, p- and s-processes of nucleosynthesis mixed.
- ✘ Measurements showed more abundant heavy elements⁵¹ and heavy isotopes⁵² in solar flares than in the solar wind: Flares by-pass ~3.4 stages of solar mass fractionation⁵².
- ✘ Many reports from other prestigious research universities and institutions worldwide, too numerous to list and discuss separately, confirmed that isotopic and elemental anomalies from nucleosynthesis are commonplace in material that solidified to form meteorites almost immediately after a supernova explosion, e.g., references⁵³⁻⁶⁸.
- ✘ Excess lightweight s-products in the solar photosphere independently confirmed⁶⁹ solar mass fractionation⁴⁴ (Fig 3) and the dominant presence of Fe, O, Ni, Si, and S in the Sun from rapid nuclear reactions⁴ near the core of a supernova (Fig. 1).

Fig. 3 compares the abundance pattern of elements in the solar photosphere⁷⁰ with the empirical patterns of mass fractionation measured across twenty-two (22) noble gas isotopes (A = 3-136 amu) in the solar wind⁴⁴ and across seventy-two (72) s-products⁴ (A = 25-207 amu) in the solar photosphere⁶⁹.

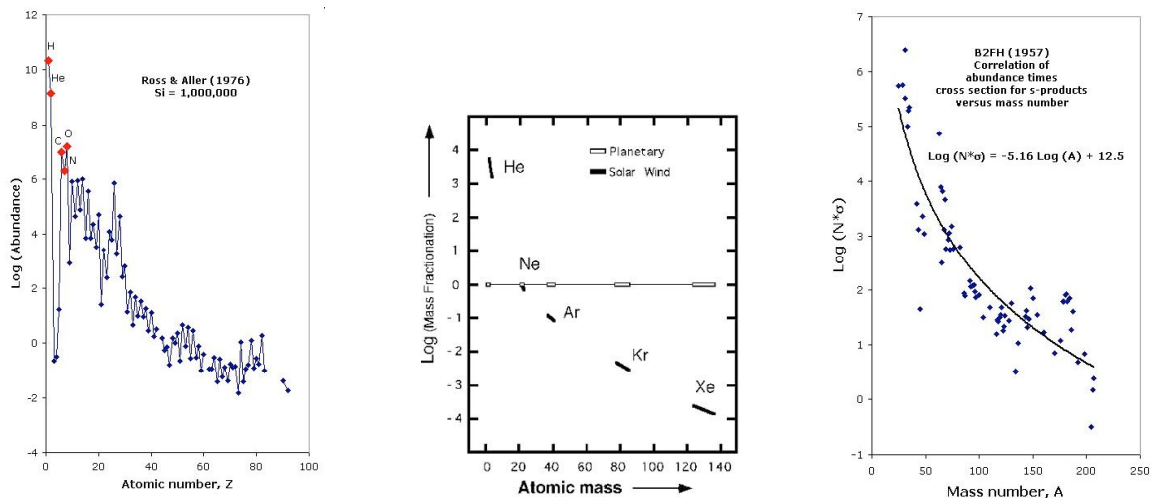


Fig 3. Lightweight elements⁷⁰ (left), lightweight isotopes⁴⁴ (center), and lightweight s-products⁶⁹ (right) from slow neutron capture⁴ are enriched at the surface of the Sun by solar mass fractionation. The more abundant elements in the interior of the Sun are identified as Fe, O, Ni, Si and S when the abundance pattern of elements in the photosphere⁷⁰ (left) is corrected for the empirical mass fractionation observed across isotopes in the solar wind⁴⁴ (center) or across s-products in the photosphere⁶⁹ (right). Both show that the Sun consists mostly of the same elements found on Earth and in ordinary meteorites⁷¹.

In summary, Fig. 1 shows the scenario for the birth of the solar system that fit experimental observations up to 1976 and has continued to fit new experimental observations since then.

Fig. 2 shows evidence from 1975 measurements²¹ that indicated excess ¹³⁶Xe from the r-process was a tracer isotope of primordial helium at the birth of the solar system. Primordial helium is conversely a tracer⁴¹ for excess ¹³⁶Xe from the r-process. That fact made possible the 1983 prediction⁴⁴, and confirmation by Galileo probe measurements⁴⁶⁻⁴⁷ in 1995 of excess ¹³⁶Xe from the r-process in the helium-rich atmosphere of Jupiter. Fig. 3 shows experimental evidence that mass fractionation enriches light elements and the lightweight isotopes of each element at the surface of the Sun, but the interior of the Sun consists mostly of the elements found in ordinary meteorites⁷¹ and rocky planets" Fe, O, Ni, Si and S.

Nuclei of Fe, O, Ni, Si and S all have high nuclear stability and were according to B2FH⁴ synthesized near the core of a supernova. Neutron repulsion in the remnant supernova core is the source of solar energy that ties together the above experimental findings and explains solar luminosity, solar neutrinos and solar hydrogen that pour from the Sun today.

Neutron Repulsion

Neutron repulsion is an empirical fact and a powerful source of nuclear energy. Neutron repulsion is recorded in the nuclear rest mass data of every nucleus⁷²⁻⁷⁴ with two or more neutrons. It was overlooked as a source of nuclear energy until 2000, when five students - Cynthia Bolon, Shlonda Finch, Daniel Ragland, Matthew Seelke and Bing Zhang - enrolled in Advanced Nuclear Chemistry (Chem 471) helped the author develop three-dimensional (3-D) plots and extrapolate trends in values of M/A, mass or potential energy per nucleon, versus Z/A, charge per nucleon for the rest masses of every nucleus⁷² known at the time. The graphs shown in Fig. 4 represent ~2,850 nuclei. These graphs offered a rational explanation for the current operation of the Sun that is consistent with information shown above for its origin and composition (Figs 1-3). Many of the experimental observations prior to the discovery of neutron repulsion were summarized here in a 1998 review paper⁷⁵.

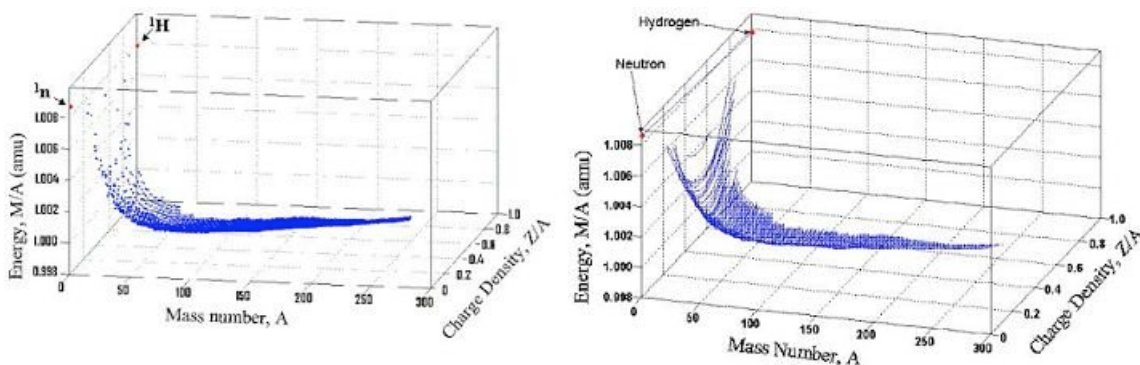


Fig 4. The author and five students in an advanced nuclear science class developed the "Cradle of the Nudies" on the left in the Spring semester of 2000 [M = Mass in atomic mass units (amu); Z = Atomic number; A = Mass number]. The vertical axis is mass (potential energy) per nucleon (M/A), the horizontal axis is mass number (A), and the depth axis is charge density (Z/A) or charge per nucleon. Mass parabolas were fitted to the data points at each mass number (A) in the graph on the left to produce the graph on the right. When these parabolas were extrapolated to the front panel, neutron repulsion was revealed as excess mass equal to ~10 MeV/nucleon.

The potential energy (mass) per nucleon from repulsive interactions between neutrons can be seen more clearly in Fig. 5 as intercepts of empirically defined mass parabolas with the front panel at $Z/A = 0$. Intercepts with the front panel show what the values of M/A would be if each nucleus were composed entirely of neutrons. Likewise intercepts of the same mass parabolas with the back panel at $Z/A = 1$ show the higher potential energy (mass) per nucleon generated by all repulsive interactions between protons. Differences between the values of these intercepts at the front and back panels are caused by Coulomb repulsion between positive charges on assemblages of protons, as explained here earlier⁷⁴.

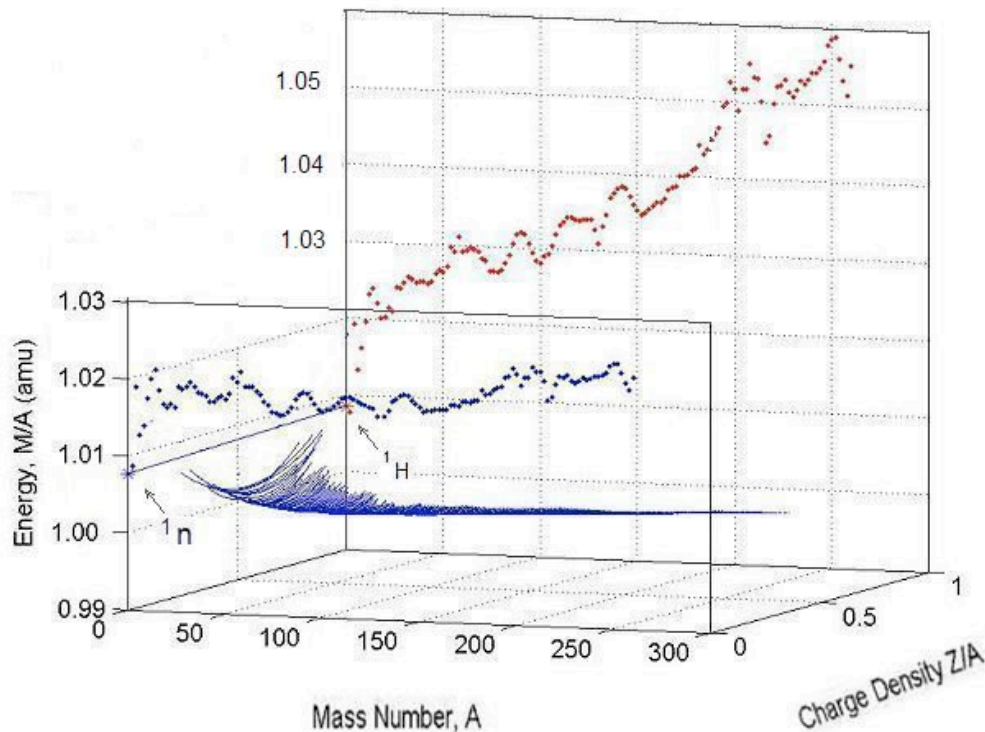


Fig 5. The potential energy per nucleon (M/A) from repulsive interactions between neutrons is shown as intercepts with the front panel at $Z/A = 0$ for mass parabolas fitted to nuclear rest mass data of ground state nudides⁷². Coulomb repulsion between positive charges on protons explains⁷⁴ quantitatively why values of intercepts with the back panel at $Z/A = 1$ become increasingly higher as the mass number, A , increases.

Before using information on neutron repulsion from Figs 4 and 5 to illustrate the energy source that powers the neutron star at the core of the Sun, it may be helpful to point out that other researchers⁷⁶ have independently concluded that useful information on neutron stars can be obtained by extrapolating atomic mass data out to "homogeneous or infinite nuclear matter (INM)" (ref. 76, page 1042). It may also be helpful to display the information shown in Figs 4 and 5 on a conventional, two-dimensional (2-D) graph that compares the values of potential energy per nucleon (M/A) for ordinary nuclei with those calculated for homogeneous infinite nuclear matter (INM) at the intercepts where $Z/A = 0$ and $Z/A = 1$. This is shown in Fig. 6

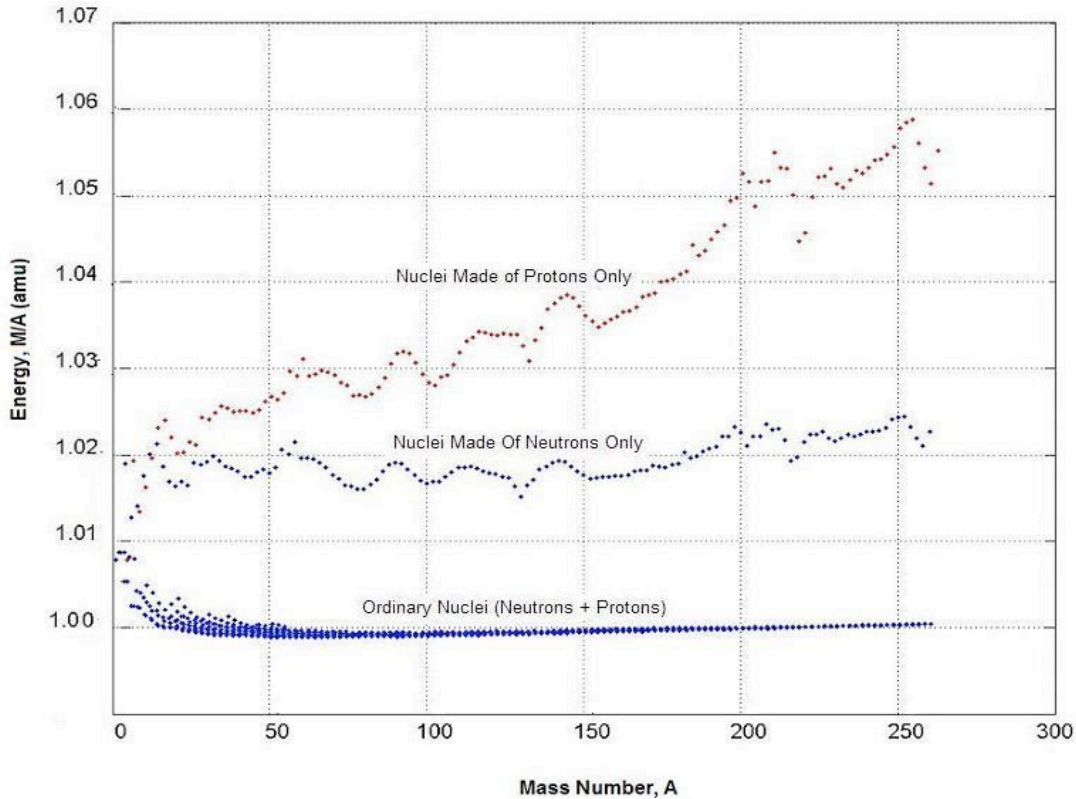


Fig 6. Most ordinary nuclei with $Z/A \sim 0.5$ lie along the lower part of this diagram and have values of $M/A \sim 1.00$ amu/nucleon. Light fusible nuclei have values of $M/A \sim 1.00-1.01$ amu per nucleon. Material in the massive neutron cores proposed⁷⁷⁻⁷⁸ over seventy years ago for stars have $Z/A \sim 0$ and consist of neutrons with $M/A \sim 1.02-1.03$ amu/nucleon⁷⁴. Neutron emission from such objects are expected to release $\sim 10-22$ MeV of energy⁷⁴. Data calculated for nuclei made of protons only ($Z/A \sim 1$) are of little practical interest. Coulomb repulsion prevents the formation of proton-only nuclei heavier than the hydrogen atom.

Nuclear fission involves small changes in nuclear stability in the lower part of Fig. 6 and typically release $\sim 0.1\%$ of the rest mass as energy. Fusion of hydrogen into helium releases $\sim 0.7\%$ of the rest mass as energy. Complete fusion of hydrogen into iron releases $\sim 0.8\%$ of the rest mass as energy. A far greater nuclear energy source powers the Sun: Neutron repulsion triggers neutron emission and a series of reactions that together produce solar luminosity, solar mass fractionation, solar neutrinos, and solar-wind hydrogen^{73-74,79-88}.

1. Neutron emission: $\langle {}^1_0n \rangle \# {}^1_0n + \sim 10-22 \text{ MeV}$
2. Neutron decay: ${}^1_0n \# {}^1_1\text{H}^+ + e^- + \text{anti-}\nu + 0.782 \text{ MeV}$
3. Upward migration of H^+ & fusion: $4 {}^1_1\text{H}^+ + 2 e^- \# {}^4_2\text{He}^{++} + 2 \nu + 27 \text{ MeV}$
4. Escape of excess H^+ in solar wind: $3 \times 10^{43} \text{ H}^+/\text{yr} \# \text{ Depart in solar wind}$

The flux of solar neutrinos observed⁸⁹ and total solar luminosity suggest that neutron emission (*Rx 1*) from the core of the Sun releases ~12 MeV of energy per nucleon and generates ~60% of solar luminosity. Neutron decay (*Rx 2*) releases ~1 MeV of energy per nucleon and generates ~5% of solar luminosity. Upward migration and fusion of hydrogen (*Rx 3*) releases ~7 MeV of energy per nucleon and generates ~35% of solar luminosity and 100% of the solar neutrinos observed⁸⁹. The solar wind (*Rx 4*) releases ~1% of the hydrogen produced by neutron decay and accounts for ~100% of the solar wind hydrogen.

Thus, the four processes listed above offer a reasonable explanation for solar luminosity, solar mass fractionation, solar neutrinos and solar wind hydrogen observed coming from the iron-rich Sun. They are also consistent with literally hundreds of space-age measurements since 1960 that suggest the Sun is a plasma diffuser⁸⁷ that separates atoms by mass, sending the most lightweight element, hydrogen, to the top of the Sun's atmosphere and giving the illusion that the Sun might be a giant ball of hydrogen described by the standard solar model.

Opposition to the concept of neutron repulsion as the primary source of solar energy source usually takes these forms:

- a) Solar neutrino measurements have confirmed the standard solar model.
- b) The mass of the Sun is less than the minimum mass of a neutron star.
- c) Neutron repulsion is impossible because neutrons do not have a charge.
- d) Anti-neutrinos have not been observed coming from the Sun.
- e) The density of the Sun precludes a neutron star at the solar core.

Brief replies to the first four concerns are these:

- a) Measurements continue⁹⁰ on possible solar neutrino oscillations
- b) There is no minimum mass on neutron stars that emit neutrons^{73-74,79-88}.
- c) Neutron repulsion is an empirical fact⁷²⁻⁷⁴ recorded in nuclear rest mass data. Neutron repulsion and proton repulsion are in addition to Coulomb repulsion⁷²⁻⁷⁴ (Figs 5 & 6). Interactions between nucleons are unlike Coulomb interactions (Figs 5 & 6).
- d) It is difficult to measure low-energy (<0.782 MeV) neutrinos coming from neutron-decay in the Sun. The author noted the need for this measurement⁸⁴ and encouraged use of the solar neutrino detector in the Homestake Mine to look for inverse % decay induced by low-energy anti-neutrinos from the Sun: Cl-35 # S-35. The facility was flooded before measurable levels of 87-day S-35 accumulated in the Homestake Mine,

The last and most widespread concern "that the density of the Sun precludes the existence of a small, dense neutron core" is difficult for the author to grasp because the internal structure and outer edge of the Sun are unknown. This was briefly addressed in a recent paper⁸⁸ noting that the Earth and the other planets orbit inside the Sun's outer layer, the heliosphere. Cyclic and abrupt changes in Earth's climate reflect changes that occur in the Sun^{83,88}.

Average density is the total mass divided by the total volume, but one could arbitrarily consider and calculate the average density of the Sun from the top of the photosphere inward, ~1.4 g/cm⁻³. Those who believe that this density value precludes a solar neutron core have

not explained why this puzzle is more difficult than that faced by Rutherford⁹¹ and Bohr⁹² when their α -scattering experiments suggested that almost all of the mass of an atom is contained in an incredibly tiny, incredibly dense core. For example, in the hydrogen atom the average density determined from measurements on liquid hydrogen is $\sim 0.07 \text{ g/cm}^3$, and the density of the proton at its core is $\sim 10^{15} \text{ g/cm}^3$. This analogy of the Sun with an atom is not meant to convey the impression that the fractions of the total masses in the cores of atoms and stars are necessarily the same.

There is another intriguing analogy between stars and atoms. Observations with the Hubble telescope of stellar explosions e.g., Supernova 1987A and the Planetary Nebula Eta Carina, show that fresh stellar debris is frequently shaped like two dumbbells on the opposite sides of a doughnut hole, as was shown earlier in the panel on the right side of Fig. 1 for the supernova debris that formed the solar system.

Fig. 7 (below) compares the shape of the $3d(z^2)$ orbital of the electron in the hydrogen atom (left) with a recent photograph of stellar debris from Supernova 1987A. Both show two dumbbells on opposite sides of the hole of a doughnut. From this point of view, the Sun and other quiescent stars are shaped like the $1s$ orbital of the electron in the ground state of the hydrogen atom, and exploding stars like SN 1987A are shaped like the $3d(z^2)$ orbital of the electron in the hydrogen atom: Two dumbbells, centered on opposite sides of a doughnut

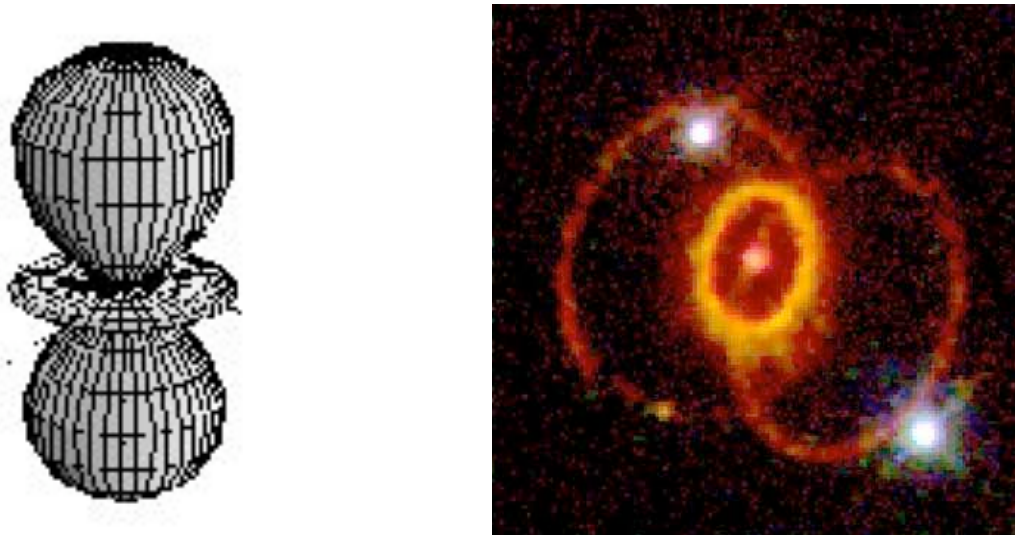


Fig 7. The image of Supernova 1987A (right) is from NASA. The drawing of the shape of the d_{z^2} orbital (left) is from the web page of Iori Fujita⁹³, who noted the remarkable similarities in the shapes of exploding and stable stars to wave functions for the electron in the excited ($3d_{z^2}$) and ground ($1s$) states of hydrogen atom in a recent news story⁹⁴ on the shape of SN1987A. The shape of the d_{z^2} orbital on the left of Fig. 7 is also like the drawing on right side of Fig. 1 for the stellar debris that formed the solar system¹⁻³.

Several others have noted similarities between stars and nuclei. Brown⁹⁵⁻⁹⁷ and Brown and Gritz⁹⁸ discuss evidence of repeated fragmentation in the cosmos to produce galaxies and stars. Harutyunian⁹⁹ notes that the steady decay and violent fragmentation of heavy nuclei, like the actinide elements, is similar to the steady production of stellar luminosity and the violent fragmentation of cosmic matter into clusters of stars and galaxies. These and a few other papers on similarities of nuclei and stars are given here¹⁰⁰. Neutron repulsion is an obvious candidate for the energy source that drives cosmic fragmentation.

Conclusions

Neutron repulsion is an enormous source of nuclear energy that probably powers the Sun and the cosmos. It is an empirical fact⁷²⁻⁷⁴ recorded in nuclear rest mass data. Neutron repulsion may prevent the collapse of neutron stars to black holes, cause violent fragmentation of massive ones, and steady emission of neutrons through the gravitational barrier of others. In this respect the gravitational barrier acts like the Coulomb barrier in ²³⁸U, ²⁵²Cf, etc. Details of the internal structure of the Sun are not well known, but it appears that neutron repulsion in the neutron star from the birth to the solar system (Fig. 1) triggers: (i) Neutron emission; followed by (ii) Neutron decay to hydrogen; (iii) Fusion of most hydrogen during its upward journey; and (iv) Release of excess hydrogen in the solar wind. These processes are consistent with information collected from space-age measurements on the early solar system (Fig. 1), and they offer viable explanations for the current discharge from the Sun of solar luminosity, solar neutrinos, solar mass fractionation, and solar wind hydrogen.

Thus observations suggest that nuclear matter is mostly dissociating and expanding locally, rather than fusing together and shrinking in volume, as material "evaporates" from the central neutron star by neutron emission, "expands" in volume by ~15 orders-of-magnitude during neutron decay, "shrinks" only slightly when hydrogen fuses to helium, and then the products (excess hydrogen and helium) depart the Sun carrying trace levels of heavier elements with them. Steady neutron emission and neutron decay may occur in other stars that discharge hydrogen and helium to interstellar space as voluminous products of this basic process:

Compact nuclear matter = (*dissociates*) => Dispersed atomic matter

The origin of the precursor star was not addressed here, but measurements suggest that the precursor star operated much like the current Sun, as a plasma diffuser that sorts atoms by mass⁸⁷. Nucleogenic and mass fractionation-produced isotopic anomalies were often found together in solids that formed early in the solar system. This puzzling discovery in 1977 resulted in the name "FUN" (Fractionation Unknown Nuclear) isotopic anomalies³⁷⁻³⁸.

From the above consideration we can see that nuclear matter here seems to be dissociating rather than coalescing (fusing together) in our small corner of the universe, and the volume is expanding on the particle scale by a factor of ~10¹⁵. Dynamic competition between gravitational attraction and neutron repulsion appears to maintain the Sun, sustain life on Earth, and likely also powers the cosmos.

Acknowledgements

The discovery of neutron repulsion would not have been possible without the loving support of my wife, Caroline Annette Howk Manud, other family members and literally hundreds of friends, colleagues and former students. I am especially grateful for the kindness of students near the end of my career that helped: a.) Demonstrate mass separation of s-products in the Sun⁶⁹; b.) Develop the "Cradle of the Nudides" (Figs 4-6)Ñ the key to solar luminosity; and c.) Decipher isotope data from the Galileo probe of Jupiter's atmosphere⁴⁶⁻⁴⁷ that confirmed ¹³⁶Xe as a tracer isotope for primordial helium (Fig. 2) across planetary distances and mass fractionation⁴⁴ in the Sun: Cynthia Bolon, Shdonda Finch, Lude Johannes, Cara Lietz, Adam Nolte, Marcel Pleess, Daniel Ragland, Matthew Seelke, Ken Windler, Bing Zhang and Joshua Zirbel. This paper is dedicated to my mentor in nuclear chemistry, the late Professor Paul Kazuo Kuroda (1917-2001), who reached out to the author when I was an angry graduate student in 1960, shared early reports that showed meteorites formed almost immediately after element synthesis, and convinced me to start research on the origin of the solar system and its elements. Another of Dr. Kuroda's former students, the late Dr. Dwarka Das Sabu, helped develop the ideas in early papers on the formation of the Sun from supernova debris^{1,2,5,6,20}. In view of the current climate of tyranny that pervades the scientific community, the rest of my acknowledgements will be limited to anonymous or deceased supporters who helped when further progress seemed impossible: The former editor of *Science*, the late Dr. Philip H. Abelson, for publishing our unpopular views²; my research advisor in geophysics, the late Professor John H. Reynolds; two Chancellors at the University of Missouri-Rolla, the late Drs. Raymond L. Bislinghoff and Gary Thomas; and the late Nobel Laureate Professor Glenn T. Seaborg, who became an active opponent of tyranny in space sciences near the end of his life and agreed to co-chair the 1999 ACS Symposium on the Origin of Elements in the Solar System^{48,50,52,66-67}. Support is gratefully acknowledged from the University of Missouri-Rolla (UMR) and the Foundation for Chemical Research, Inc. (FCR). FCR granted permission to reproduce figures from earlier grant reports.

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