Neutron Repulsion

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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 EarthÕs 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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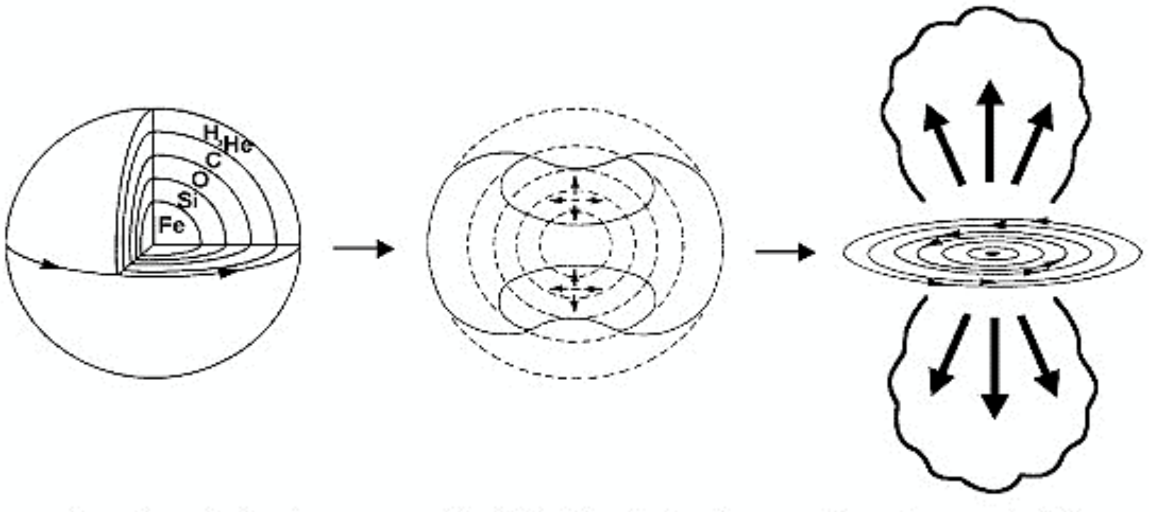
Introduction

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 organizationsÑ 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.Ñ 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 debris[1-3] from the axial explosion of a star that had evolved along the path described in 1957 by B2FH[4]. This scenario was shown at 1976 AGU[5] and ACS[6] meetings, and the 1977 Welch Cosmochemistry Conference[7], and discussed in these 1970's papers[1-3].



A massive spinning star becomes chemically layered near the end of its life, when asymmetric collapse occurs to conserve angular momentum.

The infall of low-Z elements causes an axially directed super-nova explosion, producing a rapidly expanding bipolar nebula with an equatorial accretion disk.

The sun forms on the SN core; cores of inner planets form in the Fe-rich region around the SN core; Jovian planets form in the outer SN layers.

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 findings[8-28] and led to recognition that mass solar fractionation[14-20] 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 (^{129}I, ^{244}Pu, ^{107}Pd and ^{26}Al) in meteorites[8-11], and the decay products of two of these short-lived radionuclides (^{129}I and ^{244}Pu) in the Earth[12-13] itself. [The first report of radiogenic ^{107}Ag from ^{107}Pd decay was wrong; radiogenic ^{107}Ag 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 fractionation[14-20] 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 B2FH[4];
    - a) Excess ^{124}Xe from the p-process[20],
    - b) Excess ^{136}Xe from the r-process[20], rather from than spontaneous fission of an extinct super-heavy element[21-25], and
    - c) Excess ^{16}O from helium burning or the ! -process[26],
- Inclusions in iron meteorite formed as early and trapped as much short-lived radioactivities as "primitive" meteorites[27]; and
- Excess ^{136}Xe from the r-process of nucleosynthesis[4] was a "marker isotope" for primordial helium that accompanied only "strange" xenon[20] (Xe-2) in meteorites[1-3].

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 <u>all</u> primordial helium was in the reservoir with "strange" Xe-2; none was with "normal" Xe-1.

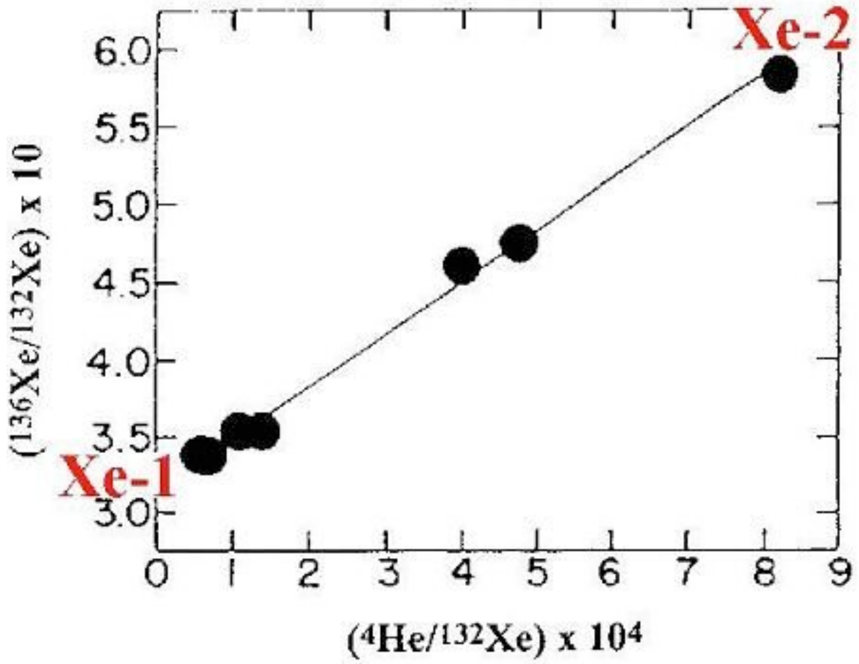


Fig. 2. The initial association of all primordial helium with excess ^{136}Xe in "strange" xenon[20] (Xe-2)" and its absence from "normal" xenon (Xe-1)" was the first indication that elements and isotopes never completely mixed in the supernova debris that formed the solar system[1-3].

Science[2,28] published the debates between advocates of superheavy element fission[21-25] and nucleosynthesis[1-3,5-7,20] as the source of excess ^{136}Xe in meteorites. Evidence was soon reported of nucleogenetic isotopic anomalies in many other elements, but advancement was hindered by those who mistakenly[29] assigned mass fractionated forms of neon[30-33] 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 supernova[35] 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 ^{16}O in their oxygen isotopes[37].

¥ Researchers at the University of Chicago[38] and Caltech[39] 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 earlier[27] for inclusions in iron meteorites[40].

¥ The primordial link reported earlier[1-3]Ñ of anomalous xenon (Xe-2) with helium from the outer part of a supernovaÑ was confirmed in diverse types of meteorites[41].

¥ 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 reports[42-44]:
  - *a)* Professor Anders and another researcher at the University of Chicago joined researchers from the University of California-San Diego to publish evidence[42] in *Science* against the superheavy element fission hypothesis[21-25].
  - *b)* Under a banner news report, *"The demise of established dogmas on the formation of the Solar System"*, Nature reported[43] 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 shown[44] 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 birth[1-3] (Fig. 1), excess ^{136}Xe as a tracer isotope[1-3] for primordial helium (Fig. 2), solar mass fractionation[44] (Fig. 3), or the prediction[44] of excess ^{136}Xe 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 ^{136}Xe 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 report[45] from Harvard and the references cited there.

¥ Twelve years later xenon isotope data, collected as the Galileo probe entered Jupiter's He-rich atmosphere, confirmed[46-47] the link of excess ^{136}Xe with primordial helium (Fig. 2) and predictions of the iron-rich Sun and solar mass fractionation[44].

¥ A renowned geologist and space scientist at a first-class research university[48] challenged the dogma that iron meteorites formed by planetary differentiation.

¥ University of Tokyo studies[49-50] 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 elements[51] and heavy isotopes[52] in solar flares than in the solar wind: Flares by-pass ~3.4 stages of solar mass fractionation[52].

¥ 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., references [53-68].

¥ Excess lightweight s-products in the solar photosphere independently confirmed[69] solar mass fractionation[44] (Fig 3) and the dominant presence of Fe, O, Ni, Si, and S in the Sun from rapid nuclear reactions[4] near the core of a supernova (Fig. 1).

Fig. 3 compares the abundance pattern of elements in the solar photosphere[70] with the empirical patterns of mass fractionation measured across twenty-two (22) noble gas isotopes (A = 3-136 amu) in the solar wind[44] and across seventy-two (72) s-products[4] (A = 25-207 amu) in the solar photosphere[69].

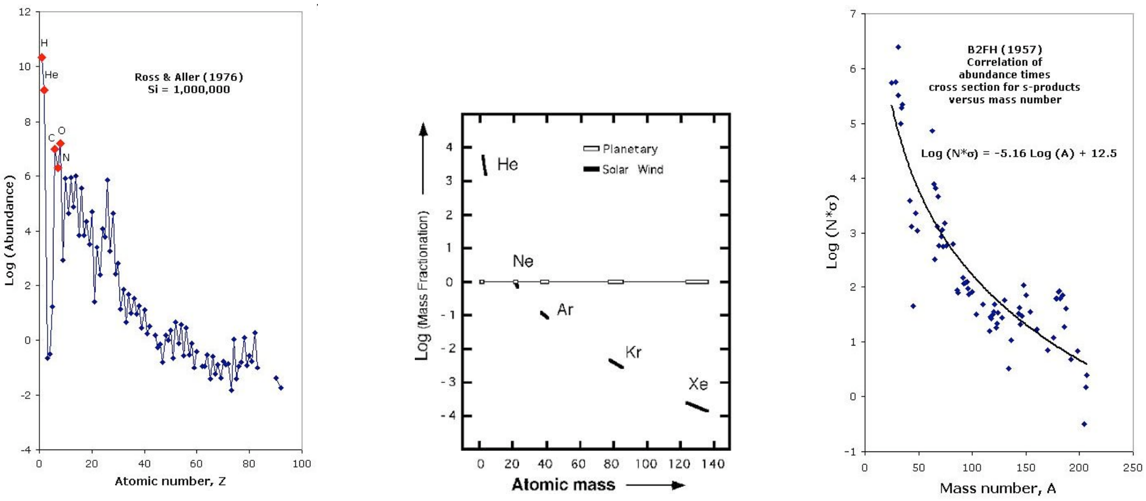


Fig 3. Lightweight elements[70] (left), lightweight isotopes[44] (center), and lightweight s-products[69] (right) from slow neutron capture[4] are enriched at the surface of the Sun by solar mass fractionation. The more abundant elements in the interior of the Sun are identified as Fe, O, Ni, Si and S when the abundance pattern of elements in the photosphere[70] (left) is corrected for the empirical mass fractionation observed across isotopes in the solar wind[44] (center) or across s-products in the photosphere[69] (right). Both show that the Sun consists mostly of the same elements found the Earth and in ordinary meteorites[71].

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 measurements[21] that indicated excess ^{136}Xe from the r-process was a tracer isotope of primordial helium at the birth of the solar system. Primordial helium is conversely a tracer[41] for excess ^{136}Xe from the r-process. That fact made possible the 1983 prediction[44], and confirmation by Galileo probe measurements[46-47] in 1995, of excess ^{136}Xe 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 meteorites[71] 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 B2FH[4] 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 nucleus[72-74] with two or more neutrons. It was overlooked as a source of nuclear energy until 2000, when five students - Cynthia Bolon, Shelonda 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 nucleus[72] 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 paper[75].

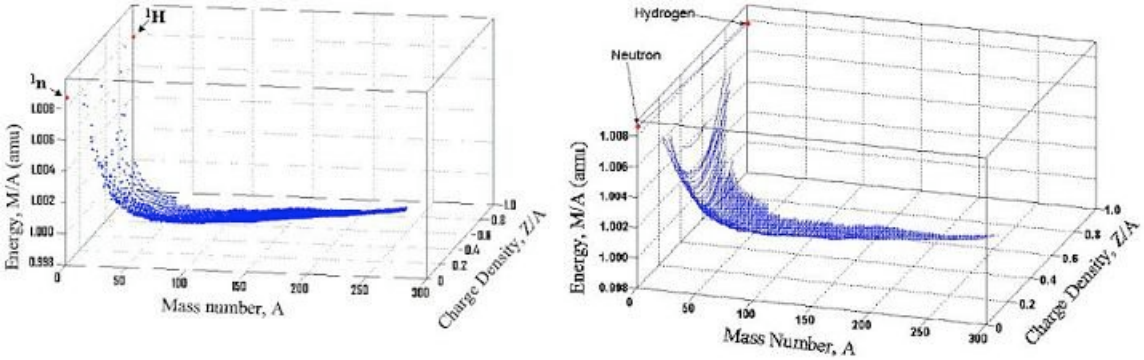


Fig 4. The author and five students in an advanced nuclear science class developed the "Cradle of the Nuclides" on the left in the Spring semester of 2000 [M = Mass in atomic mass units (amu); Z = Atomic number; A = Mass number]. The vertical axis is mass (potential energy) per nucleon (M/A), the horizontal 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 earlier[74].

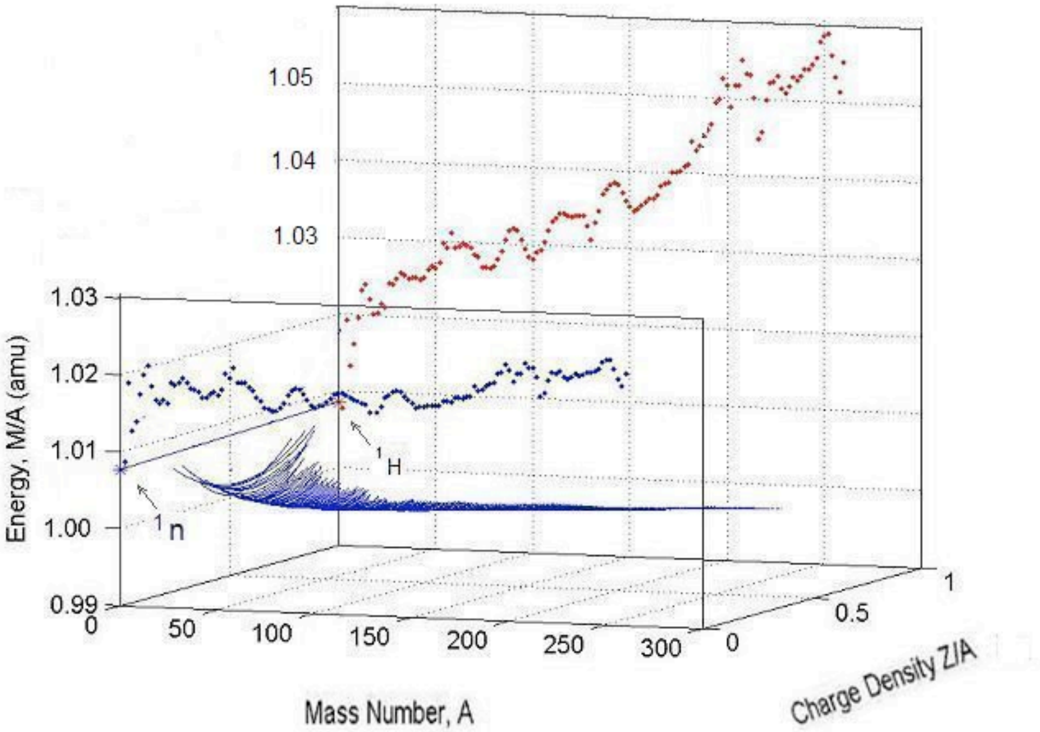


Fig 5. The potential energy per nucleon (M/A) from repulsive interactions between neutrons is shown as intercepts with the front panel at Z/A = 0 for mass parabolas fitted to nuclear rest mass data of ground state nuclides[72]. Coulomb repulsion between positive charges on protons explains[74] quantitatively 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 researchers[76] 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

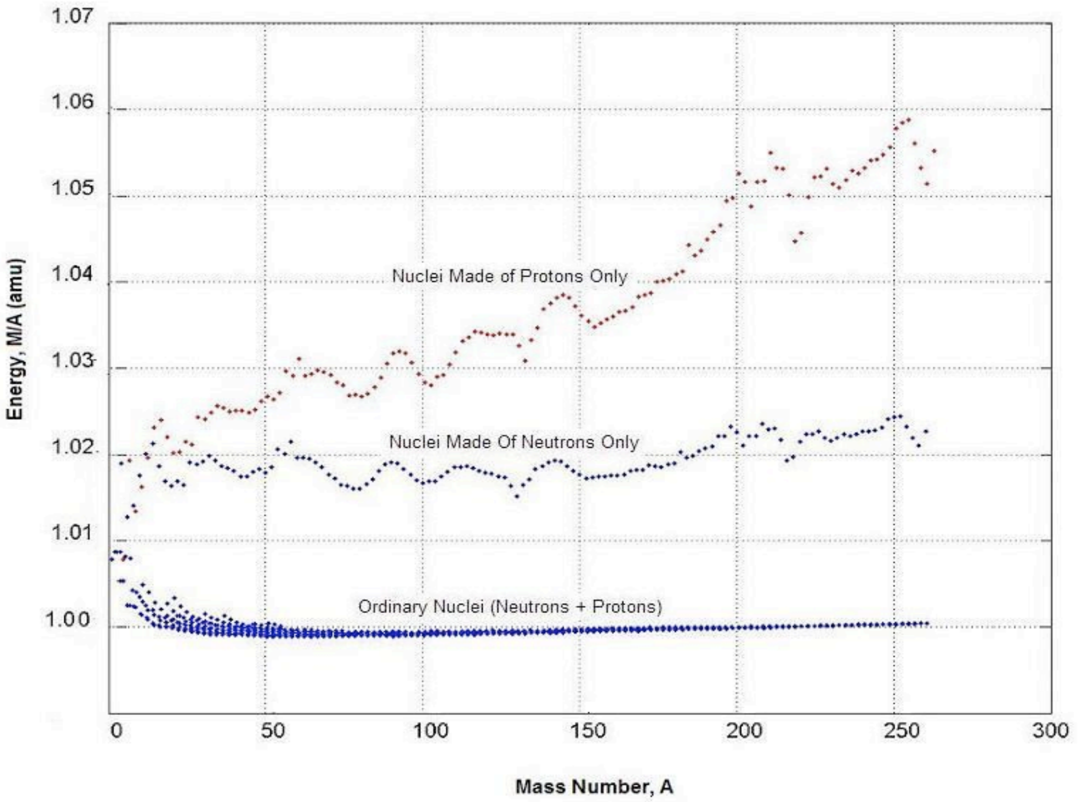


Fig 6. Most ordinary nuclei with Z/A ~ 0.5 lie along the lower part of this diagram and have values of M/A ~ 1.00 amu/nucleon. Light fusible nuclei have values of M/A ~ 1.00-1.01 amu per nucleon. Material in the massive neutron cores proposed[77-78] over seventy years ago for stars have Z/A ~ 0 and consist of neutrons with M/A ~ 1.02-1.03 amu/nucleon[74]. Neutron emission from such objects are expected to release ~10-22 MeV of energy[74]. Data calculated for nuclei made of protons only (Z/A ~ 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 ~ 0.1% of the rest mass as energy. Fusion of hydrogen into helium releases ~ 0.7% of the rest mass as energy. Complete fusion of hydrogen into iron releases ~ 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: $< {}_0^1n > \# \; {}_0^1n + \sim 10\text{-}22\ \text{MeV}$
2. Neutron decay: ${}_0^1n \# \; {}_1^1H^+ + e^- + \text{anti-}\$ + 0.782\ \text{MeV}$
3. Upward migration of H^+ & fusion: $4\ {}_1^1H^+ + 2\,e^- \# \; {}_2^4He^{++} + 2\,\$ + 27\ \text{MeV}$
4. Escape of excess H^+ in solar wind: $3 \times 10^{43}\ H^+/\text{yr}\ \#$ Depart in solar wind

The flux of solar neutrinos observed[89] 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 observed[89]. 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 diffuser[87] 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 neutrinos measurements have confirmed the standard solar model.
b) The mass of the Sun is less than the minimum mass of a neutron star.
c) Neutrons 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 continue[90] 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 fact[72-74] recorded in nuclear rest mass data. Neutron repulsion and proton repulsion are in addition to Coulomb repulsion[72-74] (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 measurement[84] 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 paper[88] noting that the Earth and the other planets orbit inside the SunÕs outer layerÑ the heliosphere. Cyclic and abrupt changes in EarthÕs 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 Rutherford[91] and Bohr[92] when their ! -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 ~0.07 g/cm^{-3}, and the density of the proton at its core is ~10^{15} 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 Carrina, 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.

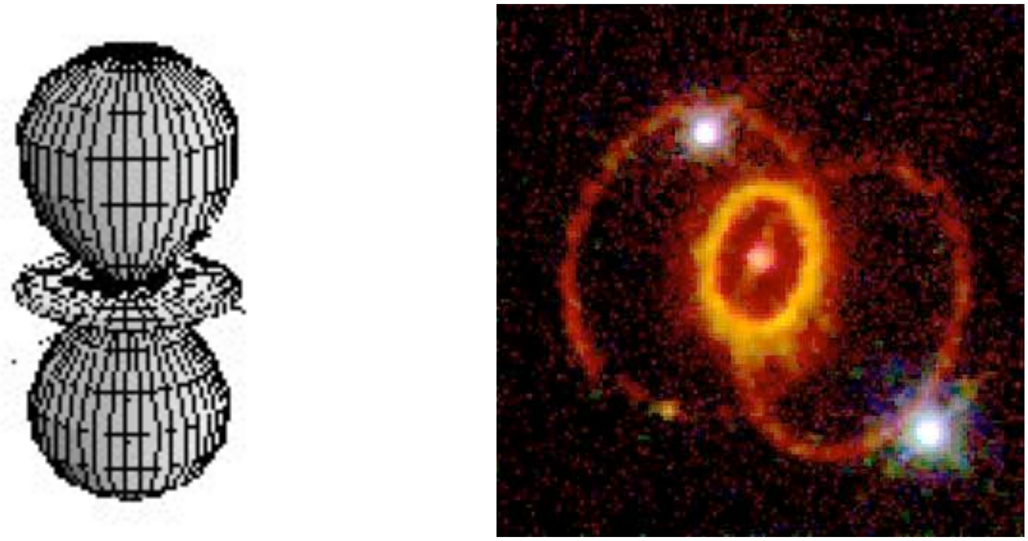


Fig 7. The image of Supernova 1987A (right) is from NASA. The drawing of the shape of the $d_{z}2$ orbital (left) is from the web page of Iori Fujita[93], who noted the remarkable similarities in the shapes of exploding and stable stars to wave functions for the electron in the excited (3d_{z2}) and ground (1s) states of hydrogen atom in a recent news story[94] 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 system[1-3].

Several others have noted similarities between stars and nuclei. Brown[95-97] and Brown and Gritzo[98] discuss evidence of repeated fragmentation in the cosmos to produce galaxies and stars. Harutyunian[99] 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 here[100]. Neutron repulsion is an obvious candidate for the energy source that drives cosmic fragmentation.

Conclusions

Neutron repulsionÑ an enormous source of nuclear energy that probably powers the Sun and the cosmosÑ is an empirical fact[72-74] 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 ^{238}U, ^{252}Cf, 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 mass[87]. Nucleogenetic 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 anomalies[37-38].

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 $\sim 10^{15}$. Dynamic competition between gravitational attraction and neutron repulsion appears to maintain the Sun, sustain life on Earth, and likely also powers the cosmos.

Acknowledgements

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References

1. Manuel O.K. and Sabu D.D. (1975) ÒElemental and isotopic inhomogeneities in noble gases: The case for local synthesis of the chemical elementsÓ, *Trans. Missouri Acad. Sci*. 9, 104-122.
2. Manuel O.K. and Sabu D.D. (1977) ÒStrange xenon, extinct superheavy elements and the solar neutrino puzzleÓ, *Science* 195, 208-209.
3. Ballad R.V. Oliver L.L. Downing R.G. and Manuel O.K. (1979) ÒIsotopes of tellurium, xenon, and krypton in Allende meteorite retain record of nucleosynthesisÓ, *Nature* 277, 615-620.
4. B2FH: Burbidge E.M. Burbidge G.R. Fowler W.A. and Hoyle F. (1957) ÒSynthesis of the elements in starsÓ, *Rev. Mod. Phys.* 29, 547-650.
5. Sabu D.D. and Manuel O.K. (1976) “The xenon record of element synthesis”, Eos **57**, 278.

6. Manuel O.K. and Sabu D.D. (1976) ÒThe noble gas record of nucleosynthesisÓ, paper presented at the *ACS Symposium on the Origin of the Elements,* abstract 52, September 2, 1976, San Francisco, CA, USA.
7. Manuel O.K. (1977) "Reply to: 'A super-heavy element in meteorites?' by Dr. Edward Anders" in Proceedings of the Robert A. Welch Foundation Conferences on Chemical Research XXI. COSMOCHEMISTRY, ed. W. O. Milligan, The Robert A. Welch Foundation, Houston, TX 77002 USA, pp. 263-272.
8. Reynolds J.H. (1960) ÒDetermination of the age of the elementsÓ, *Phys. Rev. Lett.* 4, 8-10.
9. Rowe M.W. and Kuroda P.K. (1965) "Fissiogenic xenon from the Pasamonte meteorite", J. Geophys. Res. **70**, 709-714.
10. Murphy, V. R. (1960) "Isotopic composition of silver in an iron meteorite", Phys. Rev. Lett. **5**, 539-541.
11. Gray C.M. and Compston W. (1974) "Excess ^{26}Mg in the Allende meteorite", *Nature* 251, 495-497.
12. Kuroda P.K. (1960) ÒNuclear fission in the early history of the EarthÓ, *Nature* 187, 36-38.
13. Boulos M.S. and Manuel O.K. (1971) ÒThe xenon record of extinct radioactivities in the earthÓ, *Science* 174, 1334-1336.
14. Reynolds J.H. (1960) ÒIsotopic composition of primordial xenonÓ, *Phys. Rev. Lett.* 4, 351-354.
15. Manuel O.K. (1967) "Noble gases in the Fayetteville meteorite," *Geochim. Cosmochim. Acta* 31, 2413-2431.
16. Kuroda P.K. and Manuel O.K. (1970) "Mass fractionation and isotope anomalies in neon and xenon," *Nature* 227, 1113-1116.
17. Manuel O.K. Wright R.J. Miller D.K. and Kuroda P.K. (1970) "Heavy noble gases in Leoville: The case for mass fractionated xenon in carbonaceous chondrites," *J. Geophys. Res.* 75, 5693-5701.
18. Hennecke E.W. and Manuel O.K. (1971) "Mass fractionation and the isotopic anomalies of xenon and krypton in ordinary chondrites," *Z. Naturforsch.* 20a, 1980-1986.
19. Srinivasan B. and Manuel O.K. (1971) "On the isotopic composition of trapped helium and neon in carbonaceous chondrites," *Earth Planet. Sci. Lett.* 12, 282-286.
20. Manuel O.K. Hennecke E.W. and Sabu D.D. (1972) ÒXenon in carbonaceous chondritesÓ, *Nature* 240, 99-101.
21. Lewis R.S. Srinivasan B. and Anders, E. (1975) ÒHost phase of a strange xenon component in AllendeÓ, *Science* 190, 1251-1262.
22. Anders E. Higuchi H. Gros J. Takahashi H. and Morgan J.W. (1975) "Extinct super-heavy element in the Allende meteorite", *Science* 190, 1262-1271.
23. Takahashi H Higuchi H Gros J. Morgan J.W and Anders E. (1976) "Allende meteorite: Isotopically anomalous xenon is accompanied by normal osmium", *Proc. Natl. Acad. Sci. USA* 73, 4253-4256.
24. Anders E. (1976) "Evidence for an extinct super-heavy element in meteorites", paper presented at the *ACS Symposium on the Origin of the Elements,* abstract 51, September 2, 1976, San Francisco, CA, USA.
25. Anders E. (1977) "A superheavy element in meteorites?", in Proceedings of the Robert A. Welch Foundation Conferences on Chemical Research XXI. COSMOCHEMISTRY,

ed. W. O. Milligan, The Robert A. Welch Foundation, Houston, TX 77002 USA, pp. 245-263.

26. Clayton R.N. Grossman L. and Mayeda T.K. (1973) ÒA component of primitive nuclear composition in carbonaceous meteoritesÓ, *Science* 182, 485-488.
27. Alexander E.C. Jr. and Manuel O.K. (1967) "Isotopic anomalies of krypton and xenon in Canyon Diablo graphite," *Earth Planet. Sci. Lett.* 2, 220- 224.
28. Lewis R.S. Srinivasan B. and Anders E.A. (1977) "Reply Manuel O.K. and Sabu D.D.", *Science* 195, 209-210.
29. Sabu, D.D. and Manuel, O.K., ÒThe neon alphabet gameÓ, *Proc. 11th Lunar Planet Sci. Conf*. (1980) 879-899.
30. Niederer F. and Eberhardt P. (1977) "A neon-E rich phase in Dimmitt", *Meteoritics* 12, 327-331.
31. Srinivasan B. and Anders E. (1978) "Noble gases in the Murchison meteorite: Possible relics of s-process nucleosynthesis", *Science* 201, 51-56.
32. Eberhardt P. Jungck M.H.A. Meier F.O. and Niederer F. (1979) "Presolar grains in Orgueil: Evidence from Neon-E", *Astrophys*. *J*. 234, L169-L171.
33. Jungck M.H.A. and Eberhardt P. (1979) Ne-E in Orgueil density separates. *Meteoritics* 14, 439-441.
34. Manuel O.K. (1981) "Heterogeneity of isotopic and elemental compositions in meteorites: Evidence of local synthesis of the elements", *Geokhimiya* (12) 1776-1801.
35. Cameron A.G.W. and Truran, J.W. (1977) "The supernova trigger for formation of the solar system", Icarus **30**, 447-461.
36. Clayton D.D. (1975) "Extinct radioactivities: Trapped residuals of presolar grains", Astrophysics. J. **199**, 765-769.
37. Clayton R.N. Onuma N. and Mayeda T.K. (1976) "A classification of meteorites based on oxygen isotopes", Earth Planet Sci. Lett. **30**, 10-18.
38. Clayton R.N. and Mayeda T.K. (1977) ÒCorrelated oxygen and magnesium isotope anomalies in Allende inclusions, I: OxygenÓ, *Geophys. Res. Lett.* 4, 295-298.
39. Wasserburg G.J. Lee T. and Papanastassiou D.A. (1977) ÒCorrelated O and Mg isotope anomalies in Allende inclusions, II: MagnesiumÓ, *Geophys. Res. Lett.* 4, 299-302.
40. Niemeyer S. (1979) "I-Xe dating of silicate and troilite from IAB iron meteorites", Geochim. Cosmochim. Acta **43**, 843-860.
41. Manuel O.K. (1980) "The enigma of helium and anomalous xenon", *Icarus* 41, 312-315
42. Lewis R.S. Anders E Shimamura T and Lugmair G.W. (1983) "Barium isotopes in Allende meteorite: Evidence against an extinct superheavy element", Science **222**, 1013-1015.
43. Swart P.K. (1983) ÒThe demise of established dogmas on the formation of the Solar SystemÓ, *Nature* 303 286: http://tallbloke.files.wordpress.com/2010/01/swart-1983.pdf
44. Manuel O.K. and Hwaung G. (1983) "Solar abundances of the elements", Meteoritics **18**, 209-222.
45. Yin Q. Jacobsen S.B. and Yamashita K. (2002) "Diverse supernova sources of pre-solar material inferred from molybdenum isotopes in meteorites", *Nature* 415, 881-883.
46. Manuel O. (1998) "Isotope ratios in Jupiter confirm intra-solar diffusion", *Meteoritics and Planetary Science* 33, A97, abstract 5011.
47. Manuel O. Windler K. Nolte A. Johannes L. Zirbel J. and Ragland D. (1998) "Strange xenon in Jupiter", J. Radioanalytical and Nuclear Chemistry **238**, 119-121.

48. Alexander E.C. Jr. (2000) "Iron meteorites and paradigm shifts" in *Origin of Elements in the Solar System: Implications of Post-1957 Observations*, edited by O. Manuel, New York, Kluwer Academic/Plenum Publishers, pp. 401-406.
49. Qi-Lu (1991) "High accuracy measurement of isotopic abundance ratios of molybdenum in iron meteorites and molybdenites and the fundamental studies for chemical separation and mass spectrometryÓ, *Ph.D. Thesis*, The University of Tokyo.
50. Qi-Lu and Masuda A. (2000) ÒVariation of molybdenum isotopic composition in iron meteoritesÓ in *Origin of Elements in the Solar System: Implications of Post-1957 Observations*, edited by O. Manuel, New York, Kluwer Academic/Plenum Publishers, pp. 385-400.
51. Reames D.V. (2000) "Abundances of trans-iron elements in solar energetic particle events," Ap. J. **540**, L111 - L114.
52. Manuel O. (2000) "Isotopic ratios: The key to elemental abundance and nuclear reactions in the SunÓ in *Origin of Elements in the Solar System: Implications of Post-1957 Observations*, edited by O. Manuel, New York, Kluwer Academic/Plenum Publishers, pp. 279-287.
53. Frick U. and Chang S. (1978) "Elimination of chromite and novel sulfides as important carriers of noble gases in carbonaceous meteorites", *Meteoritics* 13, 465-469.
54. Lee T. Papanastassiou D.A. and Wasserburg G.J. (1978) "Calcium isotopic anomalies in the Allende meteorite", Astrophys. J. **220**, L21-L25.
55. Ligmair G.W. Marti K. and Scheinen N.B. (1978) "Incomplete mixing of products from r-, p-, and s-process nucleosynthesis: Sm-Nd systematics in Allende inclusions EK 1-04-1", Lunar and Planet. Sci. ***IX*** (Abstracts), 672-674.
56. Lewis R.S. Alaerts L. Matsuda J.-I. and Anders E. (1979) ÒStellar condensates in meteorites: Isotopic evidence from noble gasesÓ, *Astrophys*. J. 234, L165-L168.
57. Ott U. and Begemann F. (1990) "Discovery of s-process barium in the Murchison meteorite", Ap. J. **353**, L57-L60.
58. Begemann, F. (1993) "Isotopic abundance anomalies and the early solar system" in Origin and Evolution of the Elements, ed., Prantos, N., Vangioni-Flam, E. and Cassé, M., Cambridge University Press, Cambridge, UK, pp. 518-527.
59. Lee J.T. Li B. and Manuel O.K. (1996) "Terrestrial-type xenon in sulfides of the Allende meteorite", Geochem. J. **30**, 17-30.
60. Lee, J.T. Li B. and Manuel O.K. (1996) "Xenon isotope record of nucleosynthesis and the early solar system", Chinese Sci. Bull. **41**, 1778-1782.
61. Lee J.T. Li B. and Manuel O.K. (1997) "On the signature of local element synthesis", Comments Astrophys. **18**, 335-345.
62. Nicolussi G.K. Davis A.M. Pellin M.J. Lewis R.S. Clayton R.N. and Amari S. (1997) "s-Process zirconium in presolar silicon carbide grains", Science **277**, 1281-1283.
63. Nicolussi G.K. Pellin M.J. Lewis R.S. Davis A.M. Amari S. and Clayton R.N. (1998) "Molybdenum isotopic composition of individual presolar silicon carbide grains from the Murchison meteorite, Geochim. Cosmochim. Acta **62**, 1093-1104.
64. Nicolussi G.K. Davis A.M. Pellin M.J. Lewis R.S. Clayton R.N. and Amari S. (1998) "Strontium isotopic composition in individual circumstellar silicon carbide grains: a record of s-process nucleosynthesis, Phys. Rev. Lett. **81**, 3583-3586.
65. Richter S. Ott U. and Begemann F. (1998) "Tellurium in presolar diamonds as an indicator for rapid separation of supernova ejecta", Nature **391**, 261-263.
66. Maas R. Loss R.D. Rosman K.J.R. DeLaeter J.R. Ott U. Lewis R.S. Huss G.H. Anders E. and Lugmair G.W. (2000) "Isotope anomalies in tellurium in interstellar diamonds", in

Origin of Elements in the Solar System: Implications of Post 1957 Observations, ed. O. Manuel, Kluwer Academic/Plenum Publishers, New York, pp. 361-367.

67. Ott U. (2000) "Isotope abundance anomalies in meteorites: Clues to yields of individual nucleosynthesis processes", in Origin of Elements in the Solar System: Implications of Post 1957 Observations, ed. O. Manuel, Kluwer Academic/Plenum Publishers, New York, pp. 361-367.
68. Podosek F.A. Prombo C.A., Amari S. and Lewis R.S. (2004) "s-Process Sr isotopic compositions in presolar SiC from the Murchison meteorite", Ap. J. **605**, 960-965.
69. Manuel O. Pleess M. Singh Y. and Myers W.A. (2005) "Nuclear Systematics: Part IV. Neutron-capture cross sections and solar abundance", *Journal of Radioanalytical and Nuclear Chemistry* 266, 159Ð163.
70. Ross J.E. and Aller L.H. (1976) "The chemical composition of the Sun", *Science* 191, 1223-1229.
71. Harkins W.D. (1917) "The evolution of the elements and the stability of complex atoms", J. Am. Chem. Soc **39**, 856-879.
72. Tuli J.K. (2000) Nuclear Wallet Cards, Sixth Edition, Upton, NY: National Nuclear Data Center, Brookhaven National Laboratory, 74 pp.
73. Manuel O. Bolon C. Katragada A. and Insall M. (2001) "Attraction and repulsion of nucleons: Sources of stellar energy", J. Fusion Energy **19**, 93-98 .
74. Manuel O Bolon C. and Zhong M. (2002) "Nuclear systematics Part III: The source of solar luminosity", *Journal of Radioanalytical and Nuclear Chemistry,* 252, 3-7.
75. Manuel O.K. Lee J.T. Ragland D.E. MacElroy J.M.D. Li B. and Brown W. (1998) "Origin of the solar system and its elements", *Journal of Radioanalytical and Nuclear Chemistry* 238, 213-225.
76. Lunney D. Pearson J.M. and Thibault C. (2003) "Recent trends in the determination of nuclear masses," *Rev. Mod. Phys.* 75, 1021-1082
77. Baade W. and Zwicky F. (1934) "Cosmic rays from super-novae", *Proceedings Nat. Academy Sciences* 20, 259-263.
78. Oppenheimer J.R. and Volkoff G.M. (1939) "On massive neutron cores", *Phys. Rev.* 15, 374-381.
79. Manuel O. Bolon C. and Jangam P. (2001) "The sun's origin, composition and source of energy", in Lunar and Planetary Science **XXIX**, Abstract 1041, available as 1041-pdf from Lunar and Planetary Institute, Houston, TX (CD-ROM, 2001)
80. Manuel O. and Katragada A. (2003) "The Sun's origin and composition: Implications from meteorite studies", Proceedings of Asteroids, Comets, Meteors (ACM 2002), 29 July - 2 August 2002, Technical University Berlin, Berlin, Germany (ESA-SP- 500, editor: Barbara Warmbein), pp. 787-790.
81. Manuel O. (2003) "The standard solar model versus experimental observations", Proceedings of the Third International Conference on Beyond Standard Model Physics - BEYOND 2002 (IOP, Bristol, editor: H. V. Klapdor-Kleingrothaus) pp. 307-316.
82. Manuel O. and Friberg S. (2003) "Composition of the solar interior: Information from isotope ratios", Proceedings of the SOHO/GONG Conference on Helioseismology, 27 Oct-1 Nov 2002, Big Bear Lake, CA, U.S.A. (ESA SP-517, editor: Huguette Lacoste) pp. 345-348.
83. Manuel O.K. Ninham B.W. and Friberg S.E. (2003) "Superfluidity in the solar interior: Implications for solar eruptions and climate", Journal of Fusion Energy **21**, 193-198.
84. Manuel O. (2004) "The Need To Measure Low Energy, Anti-Neutrinos (E < 0.782 MeV)", Physics of Atomic Nuclei **67**, 1959-1962.

85. Manuel O. and Katragada A. (2004) "Is there a deficit of solar neutrinos?", Proceedings of the Second International Workshop on Neutrino Oscillations, Venice, Italy, 3-5 Dec 2003.
86. Manuel O. Kamat S.A. Mozina M. (2006) "Isotopes tell origin and operation of the Sun", AIP Conference Proceedings **822**, pp. 206-225.
87. Manuel O. Kamat S.A. Mozina M. (2006) "The Sun is a plasma diffuser that sorts atoms by mass", Physics of Atomic Nuclei **69**, 1874-1856.
88. Manuel O. (2009)"Earth's heat source - the Sun", Energy & Environment **20** 131-144.
89. Ahmad Q.R. et al. (2002) "Direct evidence for neutrino flavor transformation from neutral-current interactions in the Sudbury Neutrino Observatory", Phys. Rev. Lett. 89 011301 (~180 coauthors).
90. Pallavicini M. *et al.* (2010) "Solar neutrino results from Borexino and main future perspectives", *Nuclear Instruments and Methods* in *Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment,* in press doi:10.1016/j.nima.2010.06.067 (~80 co-authors on behalf of the Borexino Collaboration)
91. Rutherford E. (1911)"The scattering of α and β particles by matter and the structure of the atom", *Philosophical Magazine* 21, 669-688.
92. Bohr N. (1914)"On the constitution of atoms and molecules", *Philosophical Magazine* 26, 1-24.
93. Iori Onestone Fujita Grossfeld, "Fascinating objects in space" (2006) http://www.geocities.jp/imyfujita/galaxy/galaxy02.html
94. Guttridge N. (11 August 2010) "Supernova ejects material asymmetrically" in *Physicsworld.com* http://physicsworld.com/cws/article/news/43451
95. Brown W.K. (1980) "A model of the formation of spherical galaxies", *Astrophys. & Space Sci.,* 72, 15-31.
96. Brown W.K. (1986) "An indicator of galactic violence", *Astrophys. & Space Sci.,* 126, 255-267.
97. Brown W.K. (2000) "The birth of planetary systems directly from supernovae", in Origin of Elements in the Solar System: Implications of Post 1957 Observations, ed. O. Manuel, Kluwer Academic/Plenum Publishers, New York, pp. 225-240.
98. Brown W.K. and Gritzo L.A. (1986) "The supernova fragmentation model of solar system formation", *Astrophys. & Space Sci.,* 123, 161-181.
99. Harutyunian G.A. (2003) "Fragmentation of cosmic objects in the course of their evolution and possible role of Hubble expansion in this process", 46, 81-91; *Astrofizika,* 46, no. 1, 103-118.
100. Manuel O. Mozina M. and Ratcliffe H. (2003)"On the cosmic nuclear cycle and the similarity of nuclei and stars", Journal of Fusion Energy **25**, 107-114.