



Journal Homepage: - www.journalijar.com
**INTERNATIONAL JOURNAL OF
 ADVANCED RESEARCH (IJAR)**

Article DOI: 10.21474/IJAR01/xxx
 DOI URL: <http://dx.doi.org/10.21474/IJAR01/xxx>



RESEARCH ARTICLE

NEUTRON REPULSION - SOCIAL COSTS FROM OVERLOOKING THIS POWER

***Oliver K. Manuel**

CSSI Associate & Emeritus Professor, University of Missouri, Cape Girardeau, MO 63701 USA

Manuscript Info

Manuscript History

Received: xxxxxxxxxxxxxxxx
 Final Accepted: xxxxxxxxxxxx
 Published: xxxxxxxxxxxxxxxx

Key words:-

Energy, Physics, Power, Sun, God,
 Einstein

Abstract

The purpose of this paper is to allow the public to understand better, and reap benefits from, Einstein's 1905 discovery that rest mass (m) is energy (E) and to explain the chain of events in 1905-1945 that obscured knowledge of a power offering these benefits to all humanity:

1. Abundant energy to sustain human life and to advance human civilization;
2. A better understanding of the origin and evolution of the universe, the chemical elements, the solar system, and life on Earth; and
3. Empirical confirmation - in rest masses of ordinary atoms - of many earlier spiritual and scientific insights, including Aston's 1922 promise of "powers beyond the dreams of scientific fiction," Max Planck's 1944 assertion that the force creating atomic matter was guided by "a conscious and intelligent Mind" (commonly attributed to God), and Kuroda's 1945 insight into the "beginning of the world" from Hiroshima's destruction.

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Introduction:-

Einstein (1905) reported mass (m) is stored energy (E), before it was known that atoms of the same element may have different atomic masses. Aston used the mass spectrograph to identify isotopes of several elements, measured and reported their masses as nuclear "packing fractions," and reported in the last paragraph of his Nobel Lecture (Aston, 1922) that these offer the human race command over "powers beyond the dreams of scientific fiction." Ten years later, Chadwick (1932) reported discovery of the neutron, "a proton and an electron in close combination." This explained Prout's 1815 hypothesis of hydrogen as a fundamental block, and Aston's confirmation of only whole integer values for all atomic mass numbers. Three years later, Weizsäcker (1935) developed the concept of nuclear "binding energy," based on the neutron-proton model of the nucleus. Bethe and Bacher (1936) used this neutron-proton model of the nucleus to explain stationary states of nuclei. When Aston repeated his 1922 Nobel Lecture at the Imperial University of Tokyo on **13 June 1936**, Kuroda (1992) noticed and commented on a misunderstanding of Aston's nuclear "packing fraction." This error will be illustrated below by comparing common disagreements between Aston's nuclear "packing fraction" and the Bethe-Weizsäcker concept of nuclear "binding energy." After Hahn and Strassman (1939) reported neutron-induced fission of uranium, scientists in other countries independently discovered and reported the number of secondary neutrons released and the possibility of inducing a self-sustaining chain of nuclear reactions in 1939 (Anderson *et al.*, 1939; Hagiwara, 1939; Halban *et al.*, 1939; Zinn and Szilard, 1939). Bohr and Wheeler (1939) used the Bethe-Weizsäcker model to propose the Coulomb repulsion model of nuclear fission.

Corresponding Author:- Oliver K. Manuel.

Address:- CSSI Associate & Emeritus Professor, University of Missouri, Cape Girardeau, MO 63701 USA.

As WWII ended, Max Planck (1944) spoke of “*a conscious and creative Mind*” guiding the force that makes and holds sub-atomic particles together. In ruins of Hiroshima in August 1945, Kuroda (1982) realized, “*The sight before my eyes was just like the end of the world, but I also felt that the beginning of the world may have been just like this.*”

Materials and Methods:-

Materials and methods are essentially those used in several other papers published over the last sixteen years (Manuel, *et al.*, 2000; Manuel, *et al.*, 2002; Manuel, 2016a,b): Precise atomic rest mass data from the National Nuclear Data Center, Brookhaven National Laboratory are used to identify the major sources of energy in rest masses of atoms and to explain why neutron repulsion was overlooked in the historical development of nuclear energy.

Results and Discussion:-

The first figure shows rest masses of atoms, expressed as $1 + f$ (Aston’s packing fraction), as they appeared to Aston in 1922, before the neutron was known and the now popular semi-empirical formula for atomic masses was developed in 1935-36 (https://en.wikipedia.org/wiki/Semi-empirical_mass_formula).

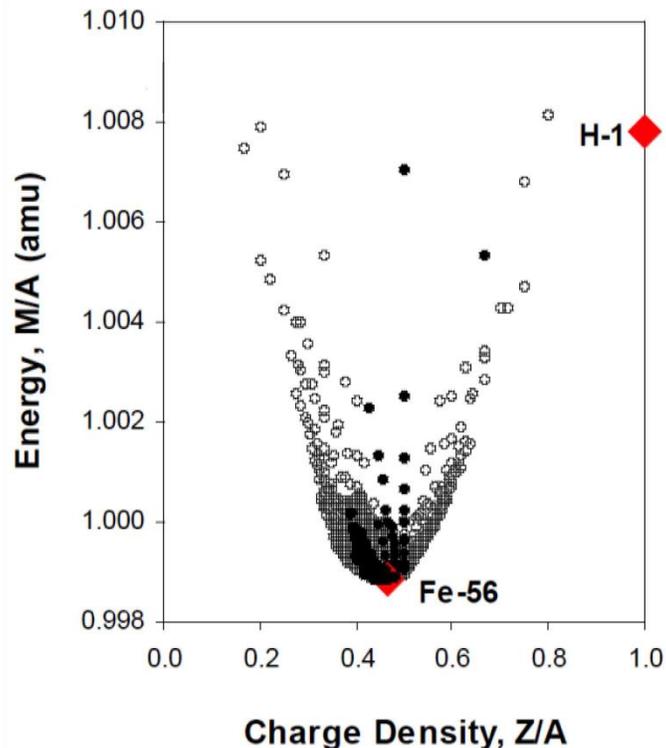


Figure 1:- The horizontal scale is charge density. The vertical scale is mass (energy) per nucleon, or $1 + f$, where f = Aston’s nuclear “*packing fraction.*” Atomic mass data points are filled for stable atoms; their range is shown by filled red symbols at Fe-56 and H-1. Open symbols identify unstable atoms.

Aston might have recognized evidence for neutron-, as well as, proton-repulsion in the symmetry of atomic rest mass data about values of $Z/A \sim 0.5$, but the neutron was not discovered until a decade later, in 1932.

To understand why neutron repulsion was overlooked as the knowledge of nuclear energy advanced, Figure 1 illustrates Aston’s view of rest mass data (Aston, 1922) before Chadwick (1932) discovered the neutron. The decrease in values of M/A as the charge density (Z/A) decreased from 1 to 0.5 might be explained by a decrease in Coulomb repulsion between positive charges. But Coulomb repulsion could not explain the mysterious, but unknown force that caused values of M/A to increase as the charge density (Z/A) decreased further, from 0.5 toward 0. The neutron was unknown, so Aston could not have possibly identified that force as “neutron repulsion” in 1922.

That is probably why Aston (1922) instead spoke of this as a mysterious force that offered the human race command over “*powers beyond the dreams of scientific fiction.*”

After Chadwick (1932) discovered the neutron, the next figure shows how rest masses of atoms might have appeared to Weizsäcker (1935), Bethe and Bacher (1936) and Bohr and Wheeler (1939) as they attempted to explain variations in masses of atoms and the fission of uranium atoms when irradiated with neutrons, before the force of neutron-repulsion was recognized in the atomic rest mass data.

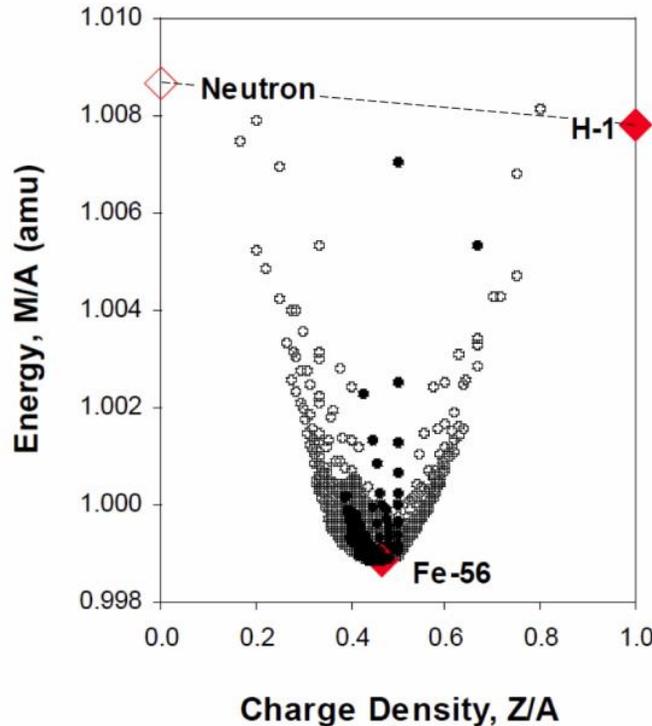


Figure 2:- The horizontal scale is charge density. Vertical distance of masses from the dashed line is Bethe-Weizsäcker’s “*binding energy*” per nucleon.

Bethe-Weizsäcker’s “*binding energy*” is illustrated in Figure 2 by the vertical distance down from the dashed line to any mass data point. Because the neutron has greater mass than the hydrogen atom, this distance is deceptively high for neutron-rich atoms, and deceptively low for proton-rich atoms. That is why neutron-rich radioactive atoms, like ^3H and ^{14}C , have higher calculated values of nuclear “*binding energy*” than their more stable decay products, ^3He and ^{14}N .

To explain further why neutron repulsion was over-looked as knowledge of nuclear energy advanced, the dashed line in Figure 2 shows subtle differences between Aston’s definition of nuclear “*packing fraction*” (Aston, 1922) – a thermodynamic state that is experimentally measured – and Bethe-Weizsäcker’s definition of nuclear “*binding energy*” – a thermodynamic path function that is calculated.

The third figure shows least-squares fitted mass parabolas to rest mass data at each mass number, A , with intercepts at $Z/A = 0$ (**blue**) and $Z/A = 1$ (**red**).

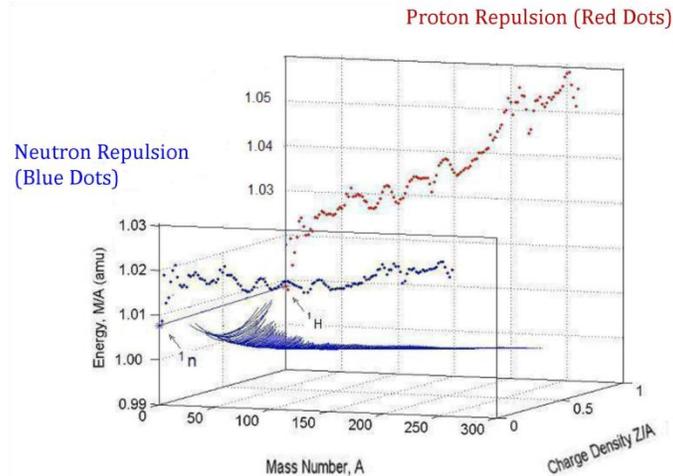


Figure 3:- The red dots, at $Z/A = 1$, show energy (mass) from proton repulsion and blue dots, at $Z/A = 0$, show energy (mass) from neutron repulsion.

Strong attractive forces between neutrons and protons produce low values of M/A in mass data points near $Z/A \sim 0.5$ in Figure 1 and in Figure 2, and in the mass parabolas in Figure 3 (Manuel, 2016a)

Blue dots in Figure 3 are values of M/A calculated from mass parabolas for hypothetical atoms composed of neutrons only at $Z/A = 0$. Neutron repulsion causes all values of M/A (blue dots) to be higher than that of the free neutron at $A = 1$. Neutron repulsion is a strong, but short-range nuclear force (Manuel, 2016a).

Red dots in Figure 3 are values of M/A calculated from mass parabolas for hypothetical atoms composed of hydrogen only at $Z/A = 1$. Proton repulsion causes values of M/A (red dots) to be consistently higher than that of hydrogen atoms at $A = 1$. Proton repulsion is long-range. Thus, the values of M/A at $Z/A = 1$ increase with mass number, A (Manuel, 2016a).

That is why neutron repulsion remains relatively unimportant in light atoms, when the nuclear core is neutron-proton pairs and the extra neutrons are at the nuclear surface, but neutron repulsion becomes increasingly important for heavier atoms, and at $A = 144$ amu, Coulomb repulsion is strong enough to completely invert the nuclear structure. For $A < 144$ amu, the nuclear core is neutron-proton pairs and extra neutrons are on the nuclear surface. For $A > 143$ amu, the nuclear core is neutrons and the nuclear surface is neutron-proton pairs (Manuel, 2016a).

Thus, the Bethe-Weizsäcker model of nuclear “binding energy” has obscured neutron repulsion, exaggerated proton repulsion and confirmed the validity of Kuroda’s concern when a physicist asked, “**What is meant by packing fraction?**” after Aston had lectured on nuclear “packing fractions” at the Imperial University of Tokyo on 13 June 1936 (Kuroda, 1992).

Finally, the fourth and final figure shows why neutron repulsion in the Sun’s core is of interest to all humanity, and of special interest to scientists.

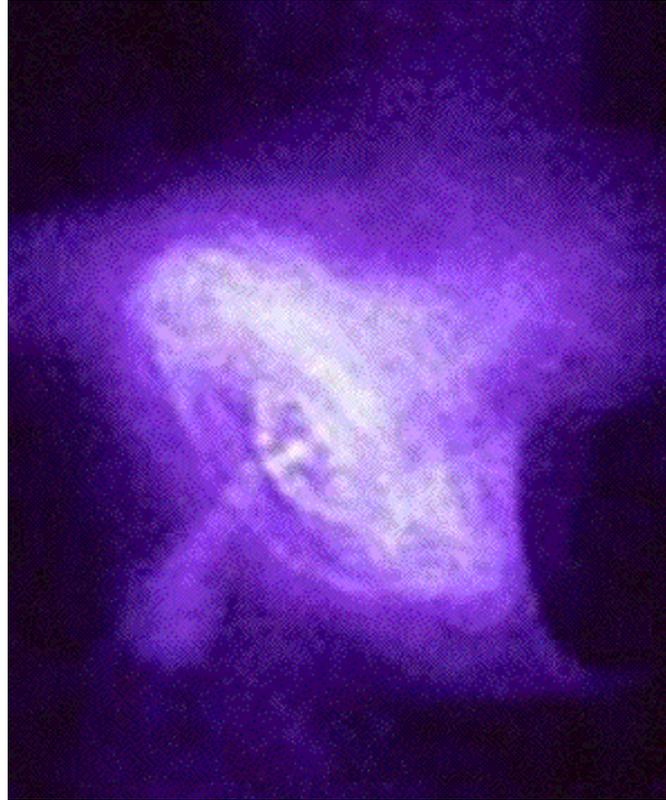


Figure 4:- Neutron repulsion in the Sun's core made our elements, birthed the solar system five billion years (5 Ga) ago, sustained the origin and evolution of life on Earth after ~3.8 Ga ago, causes solar eruptions and climate change (Carrington, 1859; Manuel *et al.*, 2002; Karoff *et al.*, 2016), and may even generate the force field that holds spinning sub-atomic particles together as atoms (Planck, 1944; Jenkins and Fischbach, 2009).

Conclusions:-

Neutron repulsion is the strong nuclear force that Aston (1922) probably envisioned offering the human race command over "*powers beyond the dreams of scientific fiction.*" The impact on the human psyche of knowing that we really live only 1 AU (astronomical unit) away from the powerful pulsar shown in Figure 4 is beyond the author's comprehension, but that knowledge has greatly improved the author's appreciation for earlier scientific and spiritual insights into mankind's place in the universe.

Acknowledgments:-

The author acknowledges with deep gratitude helpful hints in Kuroda's autobiography about possible errors in the developments of concepts in nuclear energy in 1936-1949 (Kuroda, 1992), and the encouragement from other scientists to explain to the public concisely why neutron repulsion was overlooked, especially to two leaders of the geo-ethics community - Professor Nils-Axel Mörner and Professor Václav Němec.

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