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Supernova Driven Accelerated Decay Confronts the Evidence

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Abstract

Supernova explosions emit debris including neutrinos and antineutrinos. In a previous paper these were linked to a hypothetical acceleron field and the variations in this acceleron field as the blast reached Earth were investigated as a cause for accelerated nuclear decays. In this paper some of the collateral reactions which would result are investigated to see if they are consistent with known things. This includes the known detections which are associated with Supernova 1987A and other supernovae. Also, the rate of supernova detections on Earth is considered. One cannot induce stars to explode, so we must be content with what has been observed. We find that there are no observations available at present which would rule out the existence of the acceleron field and the associated particle, as long as it has a mass within a specified range. Also, the recent discovery of uranium's presence in the spectra of some galactic halo stars is discussed in the context of the acceleron mechanism. A separate paper will discuss the dependence of supernova light curves on the nuclear decay of relevant nuclei.

Introduction

In order to match the evident amount of decay that has occurred in Earth rocks, and fit the Biblical timescale, the RATE project emphasized an accelerated decay episode, perhaps beginning early in the year of the Genesis Flood, and tapering off somewhere between a minimum of about ten years and a maximum somewhat less than a thousand years after the Flood (Vardiman, Snelling, and Chaffin, 2005). The exact mechanism of the accelerated decay was left an open question. It would be desirable to pinpoint more precisely the mechanism of accelerated decay. In Chaffin (2017), a possible origin of the accelerated decay was sought by considering the effects of a nearby supernova when fields and materials from the explosion arrived at Earth. This necessarily involved study of the *weak interaction*, since neutrinos escaping from a supernova remove prodigious amounts of energy and are considered the prime suspect in allowing the collapse and "bounce" of the interior of the star that "goes supernova" (Heger et al., 2001). As Heger et al. discussed, a number of different nuclei can undergo electron capture, a type of nuclear decay where a proton absorbs an electron, becoming a neutron and emitting a neutrino. The energy of the neutrino has a large probability of leaving the star, decreasing "pressure support and, all else being equal, decreases the effective Chandrasekhar mass that can be supported without collapsing" (Heger et al., 2001, p. 307).

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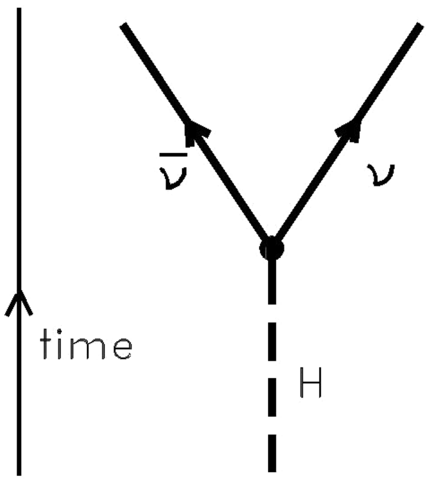

Figure 1. Feynman diagram of a Higgs particle decaying into a neutrino and an antineutrino. Here we replace the Higgs by an acceleron particle, which is much lighter.

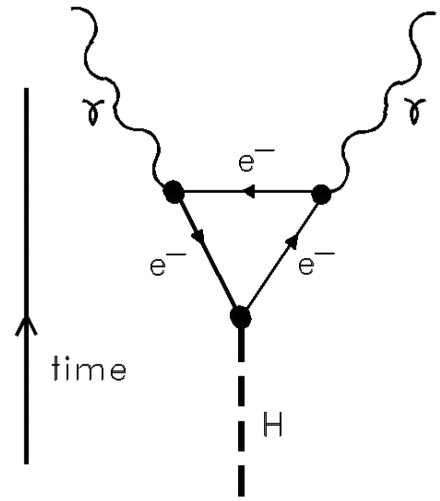

Figure 2. The Higgs-boson decay into two zero-mass photons must involve a loop of charged particles, here an electron and a positron. The backwards-in-time arrow on one of the electrons means that it represents a positron. Here we replace the Higgs by a much lighter acceleron particle.

Lepton	Lifetime (seconds)
Electron	stable
Muon	2.197x10^{-6}
Tau	3.3x10^{-13}
Electron neutrino	stable
Muon neutrino	stable
Tau neutrino	stable
Sterile neutrino	?

Figure 3. The known leptons plus the hypothetical *sterile* neutrino. Antiparticles of these leptons may also exist, but this is still an experimental question for the neutrinos.

It may be that a time dilation cosmology, a rapid expansion of space, or a larger speed of light prior to the Flood would be necessary to build a consistent history of the chronology of events in our galaxy. However, that is outside the scope of this paper.

The work discussed in this paper, a follow-up to the Chaffin (2017) paper, majors on showing that it is reasonable to postulate that the scalar field, the acceleron field introduced in that paper, decays over a time scale of ten to a thousand years. The relaxation time for the scalar field is related to how it couples to other fields. In modern physics, the established theory for this involves *Feynman diagrams*: drawings with lines, wavy lines, vertices, etc. representing, via the *Feynman rules*, calculational expressions for a physical process (Feynman, 1949a, 1949b; 1985). In this investigation it thus becomes necessary to consider some simple Feynman diagrams, see Figures 1 and 2. Our progress is aided by the small mass of our hypothetical acceleron particle. We shall see that the small value restricts the possible decays of the acceleron, and hence the possible diagrams.

It is prudent to point out that the acceleron field and its associated particle may not exist. That is a question for future experimental and observational work. However, as in any science we try to examine our hypothesis to see if it agrees with known things. It is no disgrace to discover disagreement of observation with a suggested model; the possibility of agreement and increasing our explanatory abilities makes the endeavor exciting.

There is a spectrum of three known neutrino masses, and there may also exist one or more sterile neutrinos. The sterile neutrinos, if they exist, do not couple to the $W^{\pm}$ or Z bosons and hence are referred to as "sterile." They might be compared to "ghosts" in that they interact only feebly (or weakly). Their importance may be that they would interact via gravity and they could carry off energy when emitted in decays.

The three known neutrino types, called "flavors," are the electron neutrino, muon neutrino, and tau neutrino, partnering with the electron (mass 0.510 electron volts (eV) in energy units), muon (105.66 eV), and tau (1777 eV). The muon and tau are not stable particles. The tau can decay into a muon with the emission of muon antineutrino and a tau neutrino, or follow other decay modes including decaying directly to an electron plus electron antineutrino and tau neutrino. The most probable decay mode for the muon is to an electron plus electron antineutrino and muon neutrino.

These neutrino types correspond to the three known "generations" of particles that make up the known roster of elementary particles. Everyday matter that we encounter on Earth is made from first generation particles: protons, neutrons and electrons. The higher generation particles can be created in particle accelerators (that is how they were discovered), but they rapidly decay back to the first generation due to their larger mass. However, neutrinos may have an "inverted hierarchy" where the tau neutrino is lighter than the muon neutrino which is lighter than the electron neutrino. This needs to be decided experimentally.

Neutrinos can also morph amongst, or oscillate between, the three (or more if sterile neutrinos exist) flavors. This is the accepted solution to the solar neutrino problem described by the late John Bahcall (1989). The Sun only produces electron neutrinos. However, the neutrinos undergo a "flavor" oscillation during their travel out of the Sun and through space to Earth. Experiments show that this reduces the probability of detection of electron neutrinos at Earth.

The neutrinos could possibly also oscillate to sterile neutrinos, and experiments have placed limits on this possibility but have not ruled it out (Chang, 2016; Carlson, 2020). Experiments such as Liquid Scintillator Neutrino Detector (LSND) at Los Alamos, New Mexico, and Mini Booster Neutrino Experiment (MiniBooNE) at the Fermi National Accelerator Laboratory in Batavia, Illinois, which had a relatively short beam length, have produced results favorable to the sterile neutrino hypothesis which other experiments cannot corroborate (Aguilar-Arevalo et al., 2018; Cho, 2018a). Originally (Schwarzschild, 1995) the Liquid Scintillator Neutrino Detector experimental collaboration reported evidence for antineutrino oscillation over a very short distance, which was not confirmed for a long time by any other group, including the MiniBoone collaboration. However, the MiniBoone group eventually switched from using a muon neutrino beam to a muon antineutrino beam in order to match more exactly what LSND had done (Schwarzschild, 2010), and then after several years of data collection was able to confirm the LSND results (but see Chang, 2016). Several years were required because of the low event rates. No one initially expected that the oscillations would give different results for antineutrinos than neutrinos, but that is what was found, experimentally.

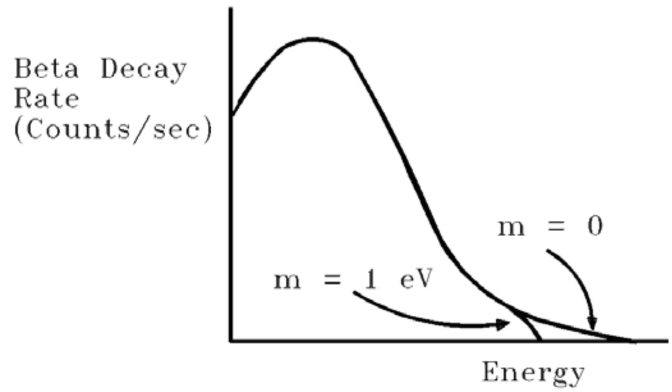

Figure 4. The projected electron energy spectrum of tritium decay, showing the count rate for beta decay versus the electron kinetic energy. Tritium has a comparatively low endpoint energy of 18.6 kiloelectron volts (keV) and a half life of 12.3 years. Near the endpoint, the form of the graph depends on the neutrino mass. The graph shows two curves for the cases of neutrino masses of 0 and 1 eV. When the neutrino mass is nonzero, the graph drops abruptly down at the endpoint, as shown for the 1 eV case, since a portion of the energy is tied up in the rest mass energy. This is what would enable the measurement of the rest mass. After Osipowicz et al. (2001).

The LSND and MiniBoone experiments find antineutrino oscillation over a distance of a hundred meters or so, while other experiments are concerned with distances much larger, including the distance to the Sun. The sterile neutrino, or neutrinos (if there is more than one), are a way to model these various results which mathematically cannot be done with just the three conventional types of neutrinos.

An effort currently in progress is the Karlsruhe Tritium Neutrino (KATRIN) experiment (Arenz et al., 2018). Tritium is the isotope of hydrogen, ^3H, with two neutrons and one proton; it has a very low energy release of 18.6 kiloelectron volts (keV) and some other useful properties for the experimental objectives. The primary objective is to find the absolute neutrino mass scale, with a sensitivity of 0.2eV. Indications were that the neutrino masses should be, in energy units, between 10 milli-electron volts and 2 electron volts (eV). In late 2019, there was already enough data for the Karlsruhe Tritium Neutrino (KATRIN) collaboration to put an upper limit of 1.1 eV on the neutrino mass, improving by a factor of 2 the mass limits derived by previous measurements that directly characterized the particle mass (Aker et al., the KATRIN collaboration, 2019). This announcement was based on initial data, and in four or five years the collaboration should have enough data to reduce the sensitivity down to 0.2 eV, either finding the value for the mass or giving a new upper limit.

According to results from several experiments, at least two of the three neutrino masses are larger than about $8{\times}10^{-3}$ eV (Aker et al., the KATRIN collaboration, 2019; Brugnera, 2019). In interpreting experiments, sometimes an average or "effective" neutrino mass is referenced, since morphing between neutrino flavors may occur. If the effective mass is greater than 0.2 eV, KATRIN should eventually be able to measure it; otherwise, it will just establish a new upper limit. It depends on a precise measurement of the endpoint spectrum of tritium beta-decay (Figure 4).

In the following discussion we will use the word "neutrino" for both neutrinos and antineutrinos, unless otherwise specified.

The circumstance that neutrinos are now known to have nonzero rest masses changes our views about how they affect our universe. According to the Standard Model, the unification of weak and electromagnetic forces for which Weinberg, Salam, and Glashow received the 1979 Nobel Prize for physics, the neutrino mass should be exactly zero. The modern circumstances are thus pointing to a need to extend the Standard Model. More than that, neutrinos cannot be the "Dark Matter," as was thought in the 1990's (Roulet, 1993, p. 5247), because their rest mass is restricted to be less than 1.1 electron volts. Nevertheless, their non-zero rest mass means that they can slow down over time and clump together in clouds (Fardon et al., 2004). Quantum mechanically, neutrinos are a superposition of at least three mass eigenstates. The components of different mass move through space at slightly different speeds, which means that passing through high density regions can destroy neutrino oscillations (Beacom, 2010, p. 9), as can travel over large distances (Anada and Nishimura, 1989, pp. 60–61; 1990).

In the next section, we will discuss the decay modes available to the acceleron and the timescale involved. This controls the duration of the disturbance. Then we will consider the reported detections of uranium in galactic halo stars, and the implications regarding the acceleron. After that we will discuss some criticisms of various neutrino theories by Zhou (2011), which are relevant to our acceleron theory, and some relevant criticism of Firestone (2014) by Melott et al. (2015), as it relates to what was said in Chaffin (2017). We shall see that the acceleron-based model of an accelerated decay episode seems to survive these unanticipated criticisms. In a separate paper Chaffin (2020, submitted), we will relate the decline of supernova light curves to the radioactive decay of the important isotopes Ni-56 and Co-56.

The Duration of the Supernova Effect

In Chaffin (2017) a neutrino burst from a supernova was hypothesized to cause a change in the scalar acceleron field. Although the neutrino burst is quickly over, we shall see that the relaxation time for the associated acceleron field can be ten to a thousand years. This is negligible on an evolutionary timescale, but very significant on a recent creation timescale. The humans who lived through a supernova burst would not find an interval of ten to a thousand years negligible. We find that the accelerated decay may be initiated by the neutrino burst, but lasts long past the passing of the neutrino burst.

According to the Fardon et al. (2004) theory, discussed in Chaffin (2017), the neutrino mass is simply inversely proportional to the neutrino density. In their theory, there is background of neutrinos left over from the big bang. Since the density cannot be lower than that of the background, neutrinos in a region restricted only by this background have the heaviest mass possible.

The hypothetical acceleron field will have an increased value as a result of the supernova emission of neutrinos, and a pulse in the field will travel towards Earth along with the neutrino burst. As pointed out by Abbott, Farhi, and Wise (1982), such a pulse in the scalar field, the acceleron field in our case, may be thought of as a *coherent* state which decays by particle emissions. Dicke (1954) explained that in such a *coherent* state all the emitters are interacting with common fields and hence cannot be treated as independent. The decay rate of the acceleron field is the decay rate of an acceleron, considered as a particle. These rates may be found by evaluating the relevant Feynman diagrams. In quantum theory, each scalar particle has an associated wave packet. For the scalar acceleron field to be nonzero requires the wave packets of different acceleron particles to interfere constructively. If the wave packets were emitted chaotically rather than coherently, the waves would interfere destructively and an overall zero acceleron field would result (Figure 5). *Indistinguishability* of different sources is also involved.

When we are considering a field which is nonzero in empty space, a description in terms of only a few field quanta is inadequate. To approach such a problem, it is appropriate to consider the coherent states approach of Glauber (1963), suitably adapted to the type of field one is considering, the acceleron field in our case. As Glauber (1963, p. 2784) pointed out, electromagnetic radiation from a prescribed electric current distribution will lead invariably to a coherent state for that radiation. The same should apply to our acceleron field for a suitable source distribution or neutrino distribution.

As Fardon et al. (2004) discussed, a typical supernova produces a density of 10^{35} to 10^{37} neutrinos per cubic centimeter. Annihilation of neutrinos with antineutrinos producing pairs of accelerons, interaction of neutrinos with other neutrinos producing acceleron pairs, and inelastic scattering of neutrinos with nuclei producing accelerons are occurring during the supernova explosion. These processes rapidly increase the acceleron field in a burst traveling outward away from the explosion.

The decay lifetime for the scalar field is what controls future decrease in the scalar field, hence the change in the neutrino mass. For the acceleron, we will find a mass, in energy units, of the

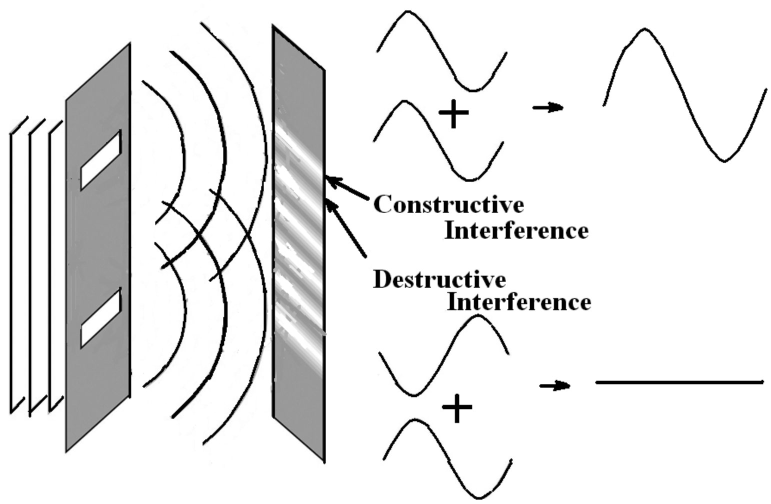

Figure 5. Addition of waves from different slits can involve constructive or destructive interference. This corresponds to coherent radiation versus chaotic addition of the source radiation.

order of tens to hundreds of eV, electron volts. For such a small mass, the only allowed decays of a scalar particle are decays into two photons (Resnick, Sundaresan, and Watson, 1973; Freund and Nandi, 1974; Sato and Sato, 1975; Ellis, Gaillard, and Nanopoulos, 1976; Gunion and Haber, 1993) or decays into a neutrino and antineutrino (Ellis, Gaillard, and Nanopoulos, 1976; Davidson and Logan, 2009; Ng and Beacom, 2014; Dawson, Englert, and Plehn, 2018). The Higgs boson, discovered experimentally in 2012, is also a scalar particle, similar to the acceleron but with a much larger mass, and hence totally different decay modes (Cho, 2018b). However, in the 1970's a Higgs particle mass of the order of 125 gigaelectron volts (125 GeV) had not yet been ruled out and was still thought possible, which makes study of these very old papers useful for application to our model.

The lifetime for decay to neutrino and antineutrino becomes infinite as the neutrino mass approaches zero, but it is known that the effective neutrino mass is not zero (Hecht, 2003). As Hecht explained, zero-mass particles would travel at the speed of light, and time stops for them. Hence, mixing between different neutrino types, electron, muon, and tau neutrinos, which has been experimentally observed, could not occur because the particles would travel without any passage of time. For this reason we know that the neutrino masses are not zero, even though the exact value remains to be determined. According to Osipowicz et al. (2001), the effective mass-energy of the three neutrino types must lie between 0.05 and 0.34 electron volts. For non-zero rest mass of the neutrino, the acceleron can decay into neutrino and antineutrino, as in the Feynman diagram shown in Figure 1.

A scalar particle cannot decay directly into two photons. However, Butterworth (2015, p. 186), while discussing the decay of the Higgs particle (a scalar particle), explained that this decay occurs nonetheless: "But since the photon's mass is zero, the Higgs really ought not to decay into photons at all. And it does not, directly. It has to go through a loop of some other particle,…" The intervening loop that Butterworth mentions must involve charged particles as shown in Figure 2. One of the arrows in Figure 2 is backwards, which Feynman interpreted as a positron, an electron moving backwards in time (Feynman, 1949a; 1985).

The lifetime for decay into two photons can be calculated by following the Feynman rules which go with the Feynman diagram (Figure 2). This was done, for example, by Resnick, Sundaresan, and Watson (1973), and the resulting lifetime is Planck's constant over 2π, called $\hbar$ [h-bar], divided by the decay width given in their paper. Sato and Sato (1975), in the case of a small scalar mass particle such as our acceleron, specified that according to the Resnick et al. equation the lifetime in seconds is inversely proportional to the cube of the mass m_f of the scalar, and is $6.6x10^{16}/m_\phi^3$. Here m_ϕ is in the energy units of electron volts in order to get the lifetime in seconds.

Appendix A contains some equations leading to a formula for the lifetime for decay into two photons.

If we change the Appendix A results to years, the lifetime formula is $1.06x10^8/m_\phi^3$. In order to fit the Biblical timescale, the RATE project would specify an accelerated decay episode, beginning early in the Flood year, and ending somewhere between ten and a thousand years after the Flood at the outset. However, let us expand this interval to from ten to ten thousand years for the decay to two photons, since we will see that the other decay mode is more restrictive. We can calculate straightforwardly that this requires our acceleron mass, in energy units, to be between 59 eV and 590 eV, where eV stands for electron volts, a unit of mass-energy. For unknown reasons, Sato and Sato (1975) reported values off by a factor of 19.7 from ours, and accepting their results alters these limits to 21.96 eV to 219.7 eV. The cube root of 19.7 is 2.7.

Resnick et al. stated that if the mass of the scalar meson m_ϕ is less than $2m_e$, then it cannot decay into an e^+e^- pair, and the only decay mode available is into two photons. In 1973, the date for the Resnick et al. work, the Weinberg model, today called the Standard Model, prevailed in which the neutrino mass is exactly zero, and consequently the lifetime for decay into neutrino plus antineutrino was infinite or that decay mode could not occur. This is now known to be false. The neutrino mass is between 0.01 eV and 1.1 eV, and the scalar meson has a lifetime for decay into neutrino plus antineutrino comparable to the lifetime for decay into two photons.

We therefore see that a second decay mode, the decay of the acceleron into neutrino and antineutrino (Figure 1), is possible. It turns out that this mode is even more restrictive. Butterworth (2015, p. 240) cited Ellis, Gaillard, and Nanopoulos (1976) for the calculation of the Feynman diagram (Figure 1) for the decay of the Higgs boson by this mode. Since the acceleron is a scalar, it follows the same Feynman diagram as the Higgs. Of course, the Higgs discovered at the Large Hadron Collider (LHC), is much more massive than our hypothetical acceleron, which opens up more possible decay modes for the Higgs particle which are not available to the acceleron. Using Ellis et al.'s equations, the decay width that they gave is the Fermi constant G_F times the fermion (the neutrino in our case) mass squared, times the acceleron mass, all divided by four π times the square root of two. The lifetime is then Planck's $\hbar$ [h-bar $=h/2\pi$] divided by this decay width. For simplicity, assume that the Fermi constant was the same as the modern value. This may not be the case (Chaffin, 2001). Then we find that an acceleron mass between 59 and 590 electron volts yields an acceleron lifetime between 217 and 21.7 years. There is a discrepancy between this result and that of Sato and Sato (1975), and the reason is obscure. If my calculations were off by a factor of 19.7, then 59 and 590 become 21.96 and 219.7 eV. The cube root keeps this from being a huge change. The acceleron lifetimes become 80.3 years and 8.03 years. The acceleron lifetime for this decay mode is comparable to, but slightly less than the two photon decay mode, where these lifetimes corresponded to ten thousand years and ten years, respectively.

Γ [GAMMA] is the rate for the coherent state ϕ to transfer energy into radiation. Abbott, Farhi, and Wise (1982) considered that an extended scalar field could be thought of as a "coherent" combination of scalar particles. As we already said, "coherent" means in this case that the particles have associated wavefunctions which oscillate in synchrony with each other. As discussed by Abbott, Farhi, and Wise, the Γ [GAMMA] is then simply the decay rate for the scalar particle ϕ, with mass $m_\phi \sim \mu^2/m_p$, to decay into radiation. In other words, Γ gives the number of particles decaying per unit time.

A decrease in energy of the scalar field could occur through the expansion of the universe or through decay radiation. The universe expansion will be a very slow process compared to the time development of a supernova explosion and dispersal of the debris from the star. Hence, we are mainly concerned with the decay modes of the scalar particles for our model of an accelerated decay episode.

A region of high neutrino density, means a region of large acceleron field. A large ϕ value [corresponding to a large neutrino density] makes G_F smaller, in the Fardon et al. (2004) model. The decay constant is proportional to G_F^2, where G_F is a constant of proportionality which we use for beta decay probability. The decay constant is ln 2/(half-life). The half-life is thus smaller for larger G_F or larger for smaller G_F. However, the half-life depends on other considerations besides G_F, and these other considerations can mean a much more drastic change in half-life. For example, a change in decay mode may occur, as for U-238 in the scenario discussed in Chaffin (2017, 2019). In that scenario, a change in the neutrino mass, and the associated change in the weak force, might alter the masses of neutrons and protons, and thus of U-238, and thus make beta-minus decay of U-238 energetically possible. One might point out that the alteration in mass could also occur if the change were a change in the strong force rather than the weak force. For other possibilities see Chaffin (2005a, 2005b; 2008; Oliver and Chaffin, 2012).

We should notice that a recent experimental analysis (Aprile et al., 2019), the XENON1T experiment, put an upper limit of 186 electron volts on scalar particles similar to the acceleron. The experiment searched for flashes of light emitted when dark matter particles interact with the two tons of liquid xenon in the detector. No dark matter particles were detected. In the process, the analysis performed ruled out a range of unknown particle candidates of specific masses. Future upgrades of the detector are planned which would increase the sensitivity, possibly either detecting or ruling out acceleron particles in the mass range considered here.

Uranium Detection in Stars

Miller (2007) pointed out that the only elements that "the Big Bang could have produced are hydrogen, helium, and possibly a trace of lithium, but no other metals." Nevertheless, heavy elements, including uranium, have been detected in some stars, which the standard paradigm explains as due to nucleosynthesis in stars. It has been thought that perhaps Uranium-238 could switch from predominately alpha decay to predominately beta-minus decay (Chaffin, 2017, p. 182) as the result of the change in the acceleron field as it reached our location from a supernova. If this could occur at Earth, other supernovae occurring elsewhere should affect the uranium in the surrounding stars. The Milky Way Galaxy has been described as having a spherical halo centered on the same central bulge as the disk in which the Sun is found. The stars in the halo are on average farther apart than those in the disk. We may not be able to pinpoint every supernova in the history of our galaxy, but one would expect on average less accelerated decay of the uranium in halo stars than on Earth, due to their probable location farther from historic supernovae. Halo stars are spread over a huge volume. Uranium has not been directly detected in solar spectra, but its presence in small concentrations in the Sun has been inferred from its concentration in meteorites (Asplund, 2009, Table 1).

However, uranium has been detected in a handful of halo stars, including Cayrel's star CS31082–001 (Cayrel et al., 2001; Chaffin, 2001), J09544277+5246414 (Holmbeck et al., 2018), and CS29497–004 (Hill et al., 2016). The measured value of log(U/Th) in CS31082–001 is -0.74±0.15, and it is about 4 kiloparsecs away. CS29497–004 is located at about 26° below the celestial equator and Hill et al. (2016) reported log ε(U) = −2.20 ± 0.30. Uranium detection in J09544277+5246414 was reported as [U/Fe] = +1.40 (Holmbeck et al., 2018). Here Holmbeck et al. were using the usual spectroscopic notations that $[A/B] = \log_{10}(N_A/N_B)_* - \log_{10}(N_A/N_B)_{sun}$, and that $\log \varepsilon(A) = \log_{10}(N_A/N_H) + 12.0$, for elements A and B, where N represents abundance. In other words, the abundance of hydrogen is arbitrarily set to 12.0, or the logarithm to base 10 of the hydrogen abundance is made to be 12.0, and all other elements are given relative to this standard. Cowan et al. (2002) reported uranium in the star BD+17°324. The detection of such large amounts of uranium in these instances leads one to suspect that not as much accelerated decay occurred at those locations as on Earth, and perhaps is a step toward validation of our logic.

Overcoming Some Criticism Regarding Neutrinos and Their Interactions

In modern times, particle-physics models have been proposed in which there are more than one neutral scalar particle, with the Higgs boson being the one discovered in 2012 at the Large Hadron Collider (LHC). A hypothetical extra "light Higgs particle" has been proposed by Wang et al. (2006), Gabriel and Nandi (2007), Davidson and Logan (2009), and Sher and Triola (2011). This light scalar particle is very similar to our acceleron, while not necessarily having all of its characteristics. The motivation of these authors for introducing their extra scalar particle was to explain the small masses of the neutrinos, without the necessity of the usual very small *Yukawa coupling*. A Yukawa coupling is a constant occurring in the dynamical equations, named after the late Japanese physicist Hideki Yukawa, which also is a proportionality constant between the Higgs expectation value and the particle mass, the neutrino mass in this case, and the Yukawa coupling in the usual theory is about 10^{-12} to 10^{-13}, depending on what the exact neutrino mass is. The new theories said that the neutrinos coupled to the light Higgs rather than the usual one, with the result that the Yukawa coupling could be of order unity instead of 10^{-12} to 10^{-13}. Zhou (2011) submitted a formal comment or criticism of these papers on the basis of several arguments. While Zhou was not directly addressing our acceleron model, his criticisms still seem to need to be addressed. Nandi, in Maitra et al. (2014, p. 3), seemed to acquiesce in Zhou's conclusion, stating that astrophysical bounds on the neutrino Yukawa couplings in such extensions of the Standard Model were contradictory to motivations of the Gabriel and Nandi (2007) paper. The astrophysical bounds which Zhou (2011) mentioned included the fact that neutrinos from the supernova in the Large Magellanic Cloud, SN1987A, were observed by the Japanese Kamiokande detector as well as others (Woosley and Phillips, 1988; Woosley and Weaver, 1989). That being the case, restrictions are found on the reactions that the neutrinos might undergo in their 168 thousand light-year [51.4 kiloparsecs, where 1 parsec is 3.26 light years] journey to Earth. Sher, in Branco et al. (2012, p. 34) also seems to acquiesce, stating: "In particular, the neutrinos emitted by SN1987A would, if there is a light scalar, interact strongly with the relic neutrino background and would not reach Earth."

Zhou's paper mentioned, in particular, reactions of the neutrinos with relic neutrinos from the big bang, the so-called cosmic neutrino background. Zhou (2011, p. 1) stated:

> The observation of neutrinos from Supernova 1987A requires that the mean free path of electron antineutrinos in the presence of cosmic background particles should be larger than the supernova distance, i.e., $\lambda_{\nu e}^{-1}D < 1$ with D = 51.4 kpc, in order to avoid significant reduction of neutrino flux.

If this background of relic neutrinos exists, and if the hypothetical light scalar particles also exist, then certain reactions become possible. In particular, antineutrinos from the distant supernova could react with the relic neutrinos, producing pairs of the scalar particles. Zhou showed that the fact of the detection of the antineutrinos on Earth led to the restriction of the Yukawa couplings of the antineutrinos with the scalar particles. The Yukawa couplings had to be very small, contrary to the reasons given by Gabriel and Nandi (2007) for introducing these light scalar particles. The particles were introduced to explain why the Yukawa couplings might not be small. In essence, if the antineutrino and neutrino masses resulted from a different Higgs boson than that of other particles, a light Higgs particle rather than the one found in 2012, then that would allow the Yukawa coupling to be of the order of one [1] rather than very small. However, Zhou said that the SN1987A data contradicted this hypothesis. The reason is that, for neutrinos with the standard weak interaction, and for most neutrino energies, there is little hindrance to their propagation over cosmic distances. However, the light scalar particles that were considered should, according to Zhou, cause extra reactions with the cosmic neutrino background which could hinder the neutrinos, preventing their detection on Earth.

One way to discern whether the cosmic neutrino background exists might be the Z-burst phenomenon. In this scenario, high-energy neutrinos or antineutrinos from deep space interact with the cosmic background, or relic neutrinos to produce a Z^0 boson. So far detectors of sufficient sensitivity to detect these cosmic Z^0 particles have not been constructed (Stal et al., 2007). Hence, observational data cannot yet tell us whether these "relic" neutrinos exist.

Recent creationists do not accept the big bang and the scenario that goes with it. Does this mean that we reject the existence of the cosmic neutrino background? Not necessarily. For instance Humphreys (1994, p. 133; 2014) proposed a creationist cosmology in which a cosmic microwave background exists. Also, the origin of the elements, starting from water, in Humphrey's cosmology involves beta decay, which introduces antineutrino and neutrino backgrounds (Humphreys, 1994, pp. 72–73; 2019, private communication).

Even in the secular literature not everyone agrees that the relic neutrino background exists. It is possible that the reasons given may also apply to creationist models. I will discuss two alternative scenarios, one due to Beacom et al. (2004) and the other due to Davoudiasl et al. (2018).

Basically, in the Beacom et al. scenario reactions between cosmic background or relic neutrinos result in their conversion into the scalar particles. However, some "secret interactions" have to be assumed. For example, one "secret" interaction is:

$$\bar{\nu}_e + \nu_e \rightarrow \phi + \phi$$

Here the reaction of an electron antineutrino with a relic neutrino destroys both, while producing two light scalar particles. These "secret interactions" either may not exist or may not have the strength that has to be assumed. The reactions will not exist if the light scalar particles ϕ do not exist, or the actual masses of the light scalars may make the above reaction improbable. Future experiments will decide. Beacom has already abandoned this idea (Hannestad, 2005, p. 1; Ng and Beacom, 2005, p. 2), but the reasons involve beliefs about cosmology which creationists may find doubtful.

Davoudiasl et al. (2018) proposed that the cosmic neutrino background left over from the big bang is mostly absent in our galactic neighborhood. Their hypothesis is that neutrino masses can be zero in vacuo and may be generated by the local distribution of dark matter through a feeble long range scalar force. This force is repulsive and expels low energy neutrinos from any region where dark matter has a significant presence, such as our neighborhood. They assume that the local dark matter population generates a neutrino mass of about 0.1 eV. The dark matter population acts like a repulsive potential barrier near the Solar System. The cosmic background neutrinos exist in other parts of the universe and are characterized today by kinetic energies of the order of 10^{-4} electron volts. Such low energy neutrinos and antineutrinos would not have enough energy to enter our region of space and would be repelled from it.

If the Beacom et al. (2004) or the Davoudiasl et al. (2018) scenarios or something like them should prove correct, then that would largely free us from the criticisms of the type that Zhou (2011) gave for the papers of Wang et al. (2006), Gabriel and Nandi (2007), and Sher and Triola (2011). These theories are vulnerable to falsification by future experimental or observational findings, as all significant theories should be. If they are correct in that there is no relic neutrino background in our neighborhood, or repulsive dark matter is prevalent out to the Large Magellanic Cloud, then the neutrinos from SN1987A should be able to reach us. This would save some basic ideas, including the one of Fardon et al. (2004) and ours from the Zhou (2011) type criticism. However, one notes that in the Fardon et al. model one expects overdensities of neutrinos inside galaxies rather than the Beacom or Davoudiasl et al. regions inside galactic halos where background neutrinos have been either expelled or destroyed in secret reactions. Clustering of neutrinos caused by gravity had been discussed by Wigmans (2002) or Adler (2008, 2009). Wigmans thought that dark matter clumps to form a halo around galaxies, including our own. Adler explored the possibility that it could also clump around the Sun or around planets. At one time, when neutrino masses in the range from 30 to 100 electron volts were thought possible, some considered the possibility that neutrinos were the dark matter (Roulet, 1993). Clumping of neutrinos was modeled, or distributions of neutrinos were found that would explain galaxy rotation curves. Experiments have since ruled out neutrino masses that large. However, clumping of non-zero mass neutrinos is still considered possible although neutrinos are too light to allow them to be dark matter. In the Fardon et al. model there is the circumstance that the neutrino mass is *inversely* proportional to the neutrino density. Fardon et al. expect a larger neutrino density, not a smaller one, contrary to Davoudiasl et al. (2018).

Hence, a good answer to the Zhou criticism is probably not to deny the existence of the cosmic relic neutrinos in the solar neighborhood, but rather to assume that the masses of the scalar particles, the acceleron particles, are different enough from the neutrino masses that Zhou's assumed reactions are very improbable. The neutrino masses are thought to be less than 1.1 electron volts, and we have seen that the acceleron mass favored by our scenario is considerably larger, at least 59 electron volts. Since the neutrinos from SN1987A have kinetic energies in the MeV range it is possible to convert, during collision with the lower energy background neutrinos, some of this kinetic energy into rest mass of the scalar particles, the ones produced in the reaction considered above [$\bar{\nu}_e + \nu_e \rightarrow \phi + \phi$], and still conserve momentum. However, the reaction becomes less probable when the rest masses of the neutrinos and the scalar particles are found to be more and more different (Weiler, 1982, p. 234; Kolb and Turner, 1987, p. 2895; Yoshida et al., 1997, p. 551).

An analogy of collisions with basketballs or bowling balls may help here. If a basketball collides with another basketball, then in a direct collision, one ball stops losing its kinetic energy and the other ball goes off with a gain in kinetic energy. Kinetic energy is a scalar quantity with no direction. Also, when a golf ball collides with a much heavier bowling ball it glances off with very little change in kinetic energy. When the colliding particles are considerably different in mass, neither particles change their kinetic energy very much.

Zhou also considered reactions where the electron antineutrino is scattered by an acceleron:

$$\nu_i + \phi \rightarrow \nu_i + \phi$$

For this reaction, if the acceleron is much heavier than the antineutrino, then basic physics shows that in most cases there will be very little kinetic energy lost by the antineutrinos as they move past. If there is a direct collision, a backward scattering can take place, but there will still be antineutrinos detected at Earth from the other cases.

Zhou himself concluded that some other possible reactions were of no consequence or not appropriate for our case. This included consideration of cooling of supernova cores by emission of the scalar particles, but Zhou made some assumptions which are not applicable to our case.

Hence, for the acceleron masses that support our scenario where the acceleron field remains abnormally large for ten to a thousand years, reaction of the SN1987A neutrinos with cosmic relic neutrinos is not very likely. Also we are not concerned with the size of the Yukawa coupling which Zhou tried to rule out. This nullifies any criticism of the type given by Zhou that would claim that the SN1987A data forbid the existence of light scalars such as our acceleron particle.

Criticism Regarding Supernova Rates in Our Galaxy

Wallner et al. (2016) estimated the rate of supernovae in our local galactic neighborhood within a distance of about 100 parsecs from Earth at 1 supernova every 2–4 million years (Myr), based on the total SN-rate in the Milky Way (2.0±0.7 per century).

Biblical creation constrains the timeframe of Earth history and standard theories of stellar evolution do not fit the timeframe. In the astronomy literature, these standard theories have been used to estimate the rate of nearby supernovae. Gehrels et al. (2003) gave a value of 1.5 per Gigayear for core-collapse supernovae occurring within 8 parsecs [26 light years] of Earth. Van den Bergh (1993) gave a value of $1.2_{(+1.7,-0.7)}$ supernovae per century in our galaxy based on theories of stellar evolution, but 2.6±1.2 per century based on historic supernova rates for supernovae that exploded within 4,000 parsecs [about 13,000 light years] of Earth. Several authors have noted that, if mass extinctions occur when supernovae are within a distance R, which is of the order of 3 to 10 parsecs, then the supernova rate is too small to explain mass extinctions observed in the conventional geologic column (van den Bergh, 1994; Gehrels et al., 2003). Melott (2016) seemed to question these conclusions, pointing to the detection of Fe-60 in ocean-floor crust.

In Chaffin (2017), a paper by Firestone (2014) was cited which gave radiocarbon evidence for numerous (23) nearby (d < 300 parsecs) supernovae. Subsequently, a criticism by Melott et al. (2015) appeared. Interestingly, although the Firestone paper appeared in *The Astrophysical Journal*, the subsequent Melott et al. criticism appeared in the *International Journal of Astrobiology*. Melott et al. point out that, if the rate of supernovae implied by the Firestone (2014) paper were true, this would have strong implications for the irradiation of the Earth. They wrote: "… at this rate, the mass extinction level events due to SNe [supernovae] would be more frequent than 100 Myr." Since this was an unacceptable rate, the data sets used by Firestone were questioned, and it was claimed that Firestone's results were not valid. They did not dispute indications of relatively nearby supernovae, pointing to Fe-60, a likely supernova byproduct, detections on Earth. They only disputed the large number of recent supernovae claimed by Firestone. In Chaffin (2017), only one nearby supernova was needed, hence the Melott et al. criticism of Firestone (2014) would not change the main conclusions, only possibly whether Firestone's results should be accepted.

On a related thread, a paper by Retejum (2019) recently analyzed bristlecone pine tree-ring data from the mountains of the western United States and analyzed growth rates near the known dates for historic supernova, AD 185, 393, 1004, 1054, 1181, 1572, and 1604. Significant but temporary decreases in tree-growth rates following these supernovae were reported.

The Local Bubble

Figure 6 shows the Sun in relation to a map of the Milky Way Galaxy. In trying to identify recent supernovae, astronomers recognize features of the Milky Way Galaxy known as the Local Bubble and the nearby Loop I Bubble (Figure 7). This should not be confused with the "heliosphere." The heliosphere is a bubble-like region of space which surrounds and is formed by the Sun. It is the cavity formed by the Sun in the surrounding interstellar medium. The Local Bubble is a larger region, of average radius 100 parsecs, of low density gas, about 0.005 atoms per cm^3, although the density is larger at about 0.1 to 0.3 atoms per cubic centimeter within a local cloud where the Sun resides (Sfeir et al., 1999). Astronomers have attempted to identify candidates for the supernovae which would have blasted out this region of low-density gas within the galactic disk.

We have seen that Firestone was criticized for the high rate of supernova explosions (SNe) that his findings implied. However, to blast out the Local Bubble seems also to be incongruous with expectations for the supernova rate near the Sun. Benítez et al. (2002, p. 1) wrote: "The paucity of SNe in the Galaxy makes it very unlikely that several isolated SN explosions would happen in short succession within such a small region, but about 20% of all SNe originate in OB star associations, and are therefore strongly clustered in time and space." We will discuss these "OB associations" later.

One clue to the affect of supernovae on the Local Bubble involves the radioactive nucleus ^{60}Fe. This isotope ^{60}Fe, with half-life $t_{1/2} = 2.62 \times 10^6$ years, is produced inside supernova precursors and ejected into space during the explosions (Rugel et al., 2009; Wallner et al., 2015b). The 2.6 million year half-life caused astronomers to expect that some amount of ^{60}Fe should survive the light-years of long-distance travel and be deposited on Earth when supernovae debris arrived.

What clues are there for which supernovae carved-out the Local Bubble? There is an emitter of pulsed radio signals, a pulsar, named "Geminga" which is about 250 parsecs from Earth (Faherty et al., 2007). The precursor of Geminga pulsar was initially favored as a candidate star, but it does not seem to fit the evidence. Breitschwerdt et al. (2016) sought to identify these supernova candidates by modeling the motion of radioactive ^{60}Fe expelled from hypothetical supernovae. This would help explain where the ^{60}Fe detected in seafloor sediments originated (Knie et al., 2004; Koll et al., 2019). Uncertainties in the history of local gas densities make these simulations difficult. Nevertheless, based on computer simulations, Breitschwerdt et al. proposed an aggregate of candidates including two with location shown in Figure 7 which hypothetically exploded 2.3 and 1.5 million years ago. The supernovae remnants of such great age would have long since dispersed, so Breitschwerdt et al. were not discouraged

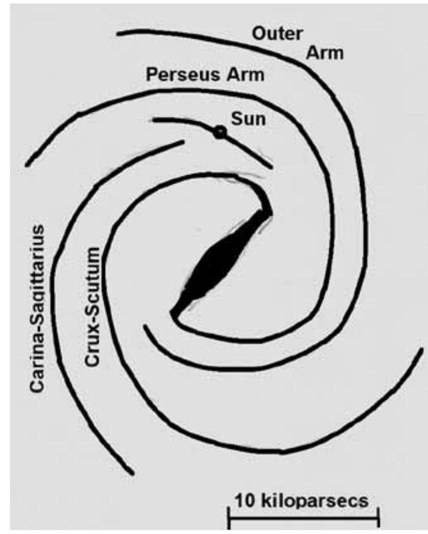

Figure 6. A sketch if the Milky Way Galaxy showing the Sun in relation to the know arms (Perseus Arm, Carina-Sagittarius Arm, Crux-Scutum Arm, and Outer Arm) of the spiral structure. The Sun is in the Orion-Cygnus Arm.

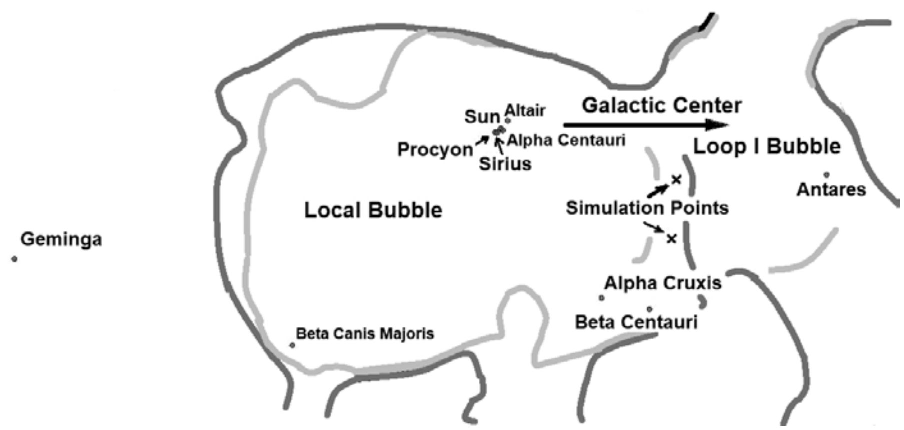

Figure 7. The Local Bubble and Loop I Bubble viewed in the galactic plane. These are regions of the Milky Way Galaxy, including the Sun, where the density of gas is low compared to surrounding space within the galactic disk. Precise data for gas density contours, upon which this sketch is based, may be found in Sfeir et al (1999). Two hypothetical points identified by Breitschwerdt et al. (2016) are labelled "simulation points" in the figure, denoting where some exploding stars were located.

by the lack of anything to be detected at those locations.

The average radial extent of our bubble is about 100 parsecs (Sanders et al. 1977; Snowden et al. 1990; Sfeir et al. 1999), although it is not spherical. The Sun is relatively near to the edge of this bubble and to a neighboring bubble called the "Loop I Bubble."

Some stars are found in OB associations, such as the nearby Scorpius-Centaurus Association. The letters OB refer to spectral classes O and B. Antares, a name meaning "the enemy of Mars," is the brightest star in Scorpius, and resides inside the Loop I bubble (Figure 7). Associations such as this are thought to be responsible for a significant fraction of all Galactic supernova progenitors. An increase in supernova frequency would be expected near these associations.

Melott (2017) revised the presumed distance to the primary source of the ^{60}Fe to about 50 parsecs based on the simulations of Fry et al. (2016). This is about a factor of two smaller than Breitschwerdt et al.'s values of 91 and 96 parsecs. Melott said that the sources were "probably originating within the Tuc-Hor stellar group, which may have been at the appropriate distance at the appropriate time." This Tuc-Hor group was explored by Krauss et al. (2014). The fact that a factor of two difference in distance estimates is possible shows that there is not very much accuracy in these simulations.

Davies (2007) gave the following description of a typical supernova remnant (SNR):

> The diameter of a mid-sized SNR can be as much as twenty parsecs. To put this size into perspective, the distance from the Earth to the star Alpha Centauri is about three-fourths of a parsec. An average SNR is therefore sufficiently large to potentially contain a star cluster containing thousands of stars within its extended volume.

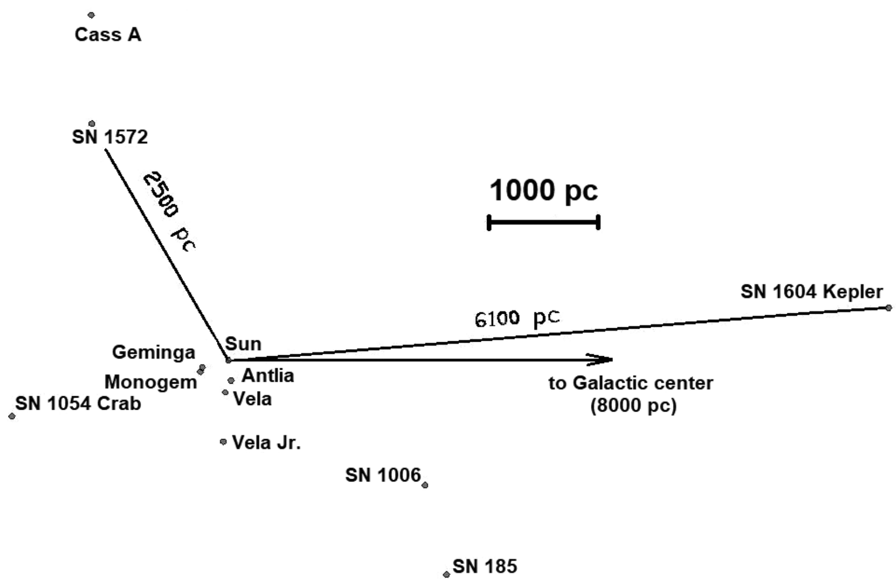

Figure 8. The positions of historic nearby supernovae and remnants projected onto the galactic plane.

Davies went on to discuss models of supernova remnant expansion (Davies, 1994, p. 243): "Using a sample ISM density of n=0.001 gives an expected largest diameter of around 140 parsecs." This largest diameter would be for a remnant of near 6,000-year age, which the Crab Nebula has not reached, currently being only 20 parsecs in diameter.

Davies (1994, p. 175) described two types of supernova remnants, plerions or "filled center" types and shell types. Furthermore, he wrote:

> The shell type comprise those objects distinguished by the conspicuous boundaries that are formed by the expanding cloud of stellar debris as they cause a "snow-plow" effect through the interstellar medium (I.S.M.).

In the case of a supernova occurring within the Local Bubble prior to the Genesis Flood, one would expect the current size of the remnant to be close to Davies' maximum size of 140 parsecs. Thus, the shell would have merged with the edges of the Local Bubble and would be difficult to distinguish from it. The Sun would now be encompassed by this large, very diffuse remnant, and one wonders whether observational data could test this conclusion.

One could consider whether our part of the Galaxy is special. If this pulse of neutrinos reached Earth at the time of the Genesis Flood, then we have said that the larger acceleron field in our neighborhood would remain for ten to a thousand years or so, with a resulting change in nuclear decay rates. In other parts of the Galaxy there may have been no such change because no supernova was nearby. Is there evidence for this? Figure 8 shows the distribution of nearby historic supernova and supernova remnants near the Sun.

While this variation in nuclear decay with galactic position is a matter for future study via observational astronomy, one might point to statements regarding galactic structure by Ward and Brownlee (2000, p. 29; 2002, p. 96), Gonzalez, Brownlee, and Ward (2001a, 2001b), and Gonzalez and Richards (2004).

The center of our galaxy, the "bulge," is a much more violent region laced with ionizing radiation, higher supernova frequency, and the danger from the 4-million solar mass black hole (Ghez [now a Nobel prize winner] et al., 2003, 2005), whereas points farther from the galactic center than the Sun have fewer heavy elements than our location. Thus isotope abundances do vary from place to place in the Galaxy. One could also point to data which show variations in ^{26}Al (half-life 710,000 years according to Parrington et al., 1996) concentration from place to place in the Galaxy (Prantzos and Diehl, 1996; Diehl et al., 2006). Prantzos and Diehl (2006, pp. 52–55) point to "hotspots" in the 1.8 MeV gamma ray intensity from ^{26}Al. The same variation is known for ^{44}Ti (The et al., 2006) and ^{244}Pu (Wallner et al., 2015a). The half-life of ^{44}Ti is 128 years, and in most models is one of the isotopes produced abundantly by core-collapse supernovae. It emits a characteristic 1.157 MeV gamma-ray line. The et al. (2006) wrote:

> In this paper we estimate what the gamma-ray sky of ^{44}Ti sources would be expected to look like by adopting an average ^{44}Ti source model having a characteristic source event recurrence rate, ^{44}Ti yield per event, and spatial distribution.We compare this to the present-day gamma-ray survey and find apparent and serious conflicts.

There were not enough Galactic supernova remnants detected. In fact the one called Cas A was the only one with appreciable gamma ray intensity that could be identified with ^{44}Ti. Cas A is at a distance of 3,400 parsecs and the remnant observed on Earth is thought to be 340 years old. Here SN1987A is discounted since it did not occur in the Galaxy but in the Large Magellanic Cloud satellite. ^{44}Ti was subsequently also detected in the Vela Jr. supernova remnant (Delahaye et al., 2010, p. 29), shown in Figure 8.

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Appendix A

When I repeat the calculations of Resnick, Sundaresan, and Watson (1973), I find the following.

$$\Gamma(\phi \to 2\gamma) = \frac{g^2_{\emptyset e\bar{e}}}{4\pi}\left(\frac{e^2}{4\pi}\right)^2 \frac{m_\emptyset}{4\pi^2}\left(\frac{m_\phi}{m_e}\right)^2 \left|\frac{1}{3}\right|^2$$

$$\frac{g^2_{\emptyset e\bar{e}}}{4\pi} = \frac{1}{2\pi} m_e^2 \frac{G_F}{\sqrt{2}}$$

Apparently, $(e^2/4\pi)^2$ stands for the square of the fine structure constant α (alpha in Heaviside Lorentz units), $(1/137.036)^2$.

$$G_F(\frac{e}{4\pi})^2 = 1.166x10^{-23}eV^{-2}\left(\frac{1}{137.036}\right)^2 = 6.209x10^{-28}eV^{-2}$$

$G_F(e/4\pi)^2/(3157.06) = 1.9667x10^{-31}$

$$\Gamma(\phi \to 2\gamma) = (1.9667x10^{-31}eV^{-2})m_\phi^3$$

$$\tau = \frac{h}{\Gamma} = \frac{6.582173x10^{-16}eV.s}{1.9667x10^{-31}eV^{-2}m_\phi^3}$$

$$= 3.35x10^{15}m_\phi^{-3}$$

This is smaller than Sato and Sato's 6.6×10^{16} m_f^{-3}.