APPENDIX C

Why No Immediate Mutual Annihilation

BACKGROUND OF THE PROBLEM

The Big Bang could only have resulted in equal amounts of matter and antimatter for the sake of the principle of conservation as presented in Appendix A1, *The Origin of Matter - Its Cause* with the assumption that there would have been a complete and almost instantaneous mutual annihilation.

Because that annihilation did not take place it has been hypothesized that the original symmetry was slightly skewed in favor of matter and that the universe is now all matter, all original antimatter having been annihilated with an equal amount of original matter. However that skewed balance conflicts with conservation in the Big Bang.

The Big Bang had to produce equal amounts of matter and antimatter and their total mutual annihilation did not occur because of the conditions there. Rather, while a moderate amount of initial matter / antimatter mutual annihilations may have taken place our present universe contains the remaining matter and antimatter in equal amounts, between some particles of which further mutual annihilations still occur at a modest rate.

The failure of comprehensive matter-antimatter immediate annihilation to occur develops as follows.

CONDITIONS AFFECTING MATTER / ANTIMATTER MUTUAL ANNIHILATION

What Is a Matter / Antimatter Annihilation ?

A positron-electron mutual annihilation, for example, is

(C-1) ${}_{1}e^{0} + {}_{-1}e^{0} \Rightarrow \approx + \approx$ where ≈ is a photon of gamma radiation

It happens as follows [per equation *2-6*].

(C-2)
$$\begin{aligned}({}_{1}e^{0}) + ({}_{-1}e^{0}) &= U_c \cdot \left[1 - \mathrm{Cos}(2\pi \cdot f_e \cdot t)\right] - U_c \cdot \left[1 - \mathrm{Cos}(2\pi \cdot f_e \cdot t)\right] \\ &= 0\end{aligned}$$

The two oscillations literally cancel. The annihilation occurs because the two are point-by-point inverses of each other. Such an annihilation is depicted in Figure C-1 on the following page.

In general for a particular particle and some particular anti-particle of it, their phases and frequencies will not be identical because of their different velocities and histories of relativistic frequency shifts. However, for them to mutually annihilate they must remain co-located for some brief moment sufficient for the event to occur.

For the particles to be co-located for a brief moment their positions and velocities must be identical, which means that their frequencies and their phases will also be identical.

The mutual annihilation energy is the conversion into energy of the entire mass of the two particles involved. The mass of each of the particles is its oscillation [there is nothing else to be the mass]. At annihilation the two particles' oscillations cease to exist by cancelling each other out. Since the center oscillations cease, the last waves of *Propagated Outward Flow* are followed by no waves at all from those centers.

E-M radiation is the propagation of changes in the *Propagated Outward Flow*, changes usually caused by velocity changes of charged particles. The ceasing at annihilation of the oscillations of the two particles involved [the largest change possible] causes a pair of gamma photons, equation `C-1`, to be propagated.

The photons carry off conservation maintaining energy and momentum. The frequency of each photon is the frequency of the oscillation that just ceased, which corresponds to the mass of the particle. In other words the photon energy, $W = h \cdot f$, is the energy equivalent of the entire mass of the of the particle annihilated.

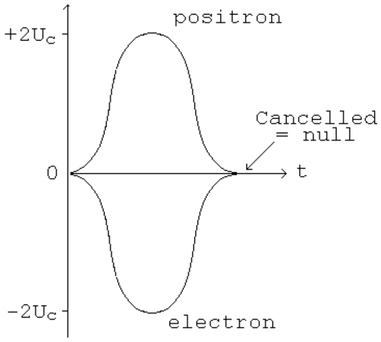

Figure C-1
A Mutual Annihilation

The first issue to investigate is the necessary conditions for a matter / antimatter annihilation to take place: how close must the particle and its antiparticle be and for how long must they remain in such sufficiently intimate contact ?

In addition to those two factors there is the more obvious requirement that the two particles involved be true antiparticles of each other [for example, a proton and an antiproton or an electron and a positron, but not a proton and a positron nor a proton and an electron]. Furthermore in general, particle / antiparticle annihilations are relatively unlikely between electrically neutral particles [for example, a neutron and an antineutron] because the only effects tending to bring the two together are their very weak gravitational attraction or chance encounter.

The Closeness Criterion

Indication of how close the two participating particles must be for their annihilation to take place can be found from the decay of a free neutron [not one that is part of an atomic nucleus] into a proton and an electron, a natural process with a mean lifetime before decay of about 881.5 seconds. For the neutron decay to be successful the proton and electron product particles must derive from the parent neutron not only their rest masses but also sufficient kinetic energy so that they are at escape velocity relative to each other, else they would be attracted back together and recombine. [One can neglect the also emitted electron anti-neutrino which is of zero or negligible mass.]

The escape velocity of the two particles is, at first consideration, an awkward problem because the separation distance of the two particles, which appears in the denominator of the expression for their Coulomb attraction, would seem to be required to be as small as zero. That is, at first consideration the escape velocity required is infinite. But, since infinite escape velocity is impossible yet the escape occurs, then the starting point, the minimum separation distance that can occur must be greater than zero. In other words, the neutron decay products, a proton and an electron, exist as such only when separated by some minimum Separation Distance, S, and their state at lesser separation distances appears as their parent neutron.

Therefore, since if the proton and the electron are separated by less than that minimum distance they do not exist as proton and electron but rather as the neutron, and at separation distances greater than that minimum they are the pair of separate particles, then that Separation Distance is a measure of how close a proton and an electron must be to unite into a neutron and is indicative of the spacing at which a particle and its antiparticle mutually annihilate.

The point is that the excess of the mass of the neutron over that of a proton plus that of an electron must supply the proton and electron relativistic kinetic masses needed to escape the decaying neutron. The detailed analysis and relativistic calculations can be found in Appendix A-1, *The Neutron.* The results are as follows.

(C-3) - The escape velocities:

$$v_e = 275{,}370{,}263. \text{ meters per second}$$

$$= 0.918{,}536{,}33\cdot c$$

$$v_p = 379{,}350.6975 \text{ meters per second}$$

$$= 0.001{,}265{,}378\cdot c$$

- The minimum Separation Distance:

$$S = 1.3\cdot 10^{-15} \text{ meters}$$

Some years ago experiments involving measurement of the scattering of charged particles by atomic nuclei, yielded an empirical formula for the approximate value of the radius of an atomic nucleus to be

(C-4) $\text{Radius} = [1.2\cdot 10^{-15}]\cdot[\text{Atomic Mass Number}] \text{ meters}$

which formula would indicate that the radius of the proton as a Hydrogen nucleus (atomic mass number $A = 1$) is about $1.2\cdot 10^{-15}$ meters.

The mass of the proton can be expressed as an equivalent energy, $W_p = m_p\cdot c^2$, and that as an equivalent frequency, $f_p = m_p\cdot c^2/h$, or as an equivalent wavelength, $\lambda_p = c/f = h/m_p\cdot c$. That wavelength (not a "matter wavelength") for the proton is

(C-5) $\lambda_p = 1.321{,}410{,}0\cdot 10^{-15}$ meters

quite near to the empirical value for the proton radius from equation (C-4) and the Separation Distance, S, of equation (C-3). Thus the Separation Distance boundary between a proton and an electron as separate particles versus combined into a neutron is about 1 proton radius, the equivalent wavelength for the proton mass per equation (C-3).

Then for a proton and an antiproton the boundary between their being the two separate particles and their mutually annihilating is a proton radius, a Separation Distance of $S_p = \lambda_p = 1.321{,}410{,}0 \cdot 10^{-15}$ meters. At that boundary if their velocities have a sufficient net component directly toward each other [per the time criterion, below] they would seem to be able, and likely, to mutually annihilate, and otherwise the annihilation would seem not possible.

Similarly, the mass of the electron or the positron can be expressed as the equivalent energy, $W_e = m_e \cdot c^2$, and that as its equivalent frequency, $f_e = m_e \cdot c^2 / h$, or equivalent wavelength, $\lambda_e = c/f = h/m_e \cdot c$. That wavelength (not a "matter wavelength") for the electron / positron is

$$\text{(C-6)} \quad \lambda_e = 2.426{,}310{,}6 \cdot 10^{-12} \text{ meters.}$$

Then for an electron and a positron the boundary between their being the two separate particles and their mutually annihilating is a Separation Distance of $S_e = \lambda_e = 2.426{,}310{,}6 \cdot 10^{-12}$ meters. At that boundary if their velocities have a sufficient net component directly toward each other [per the time criterion, below] they would seem to be able, and likely, to mutually annihilate, and otherwise the annihilation would seem not possible.

Then, what is that sufficient net velocity ?

The Time Criterion

The mutual annihilation of a particle and its antiparticle is symbolized as in the following example for a proton and an antiproton.

$$\text{(C-7)} \quad {}_1p^1 + {}_{-1}p^1 \Rightarrow \gamma + \gamma \quad \text{where } \gamma \text{ is a gamma photon}$$

In the present case of a proton and an antiproton the mass of each of the protons is converted into the energy of the related γ photon. The frequency and period of each of those two photons is as follows.

$$\text{(C-8)} \quad f_{\gamma p} = m_p \cdot c^2 / h$$

$$T_{\gamma p} = 1/f_{\gamma p} = h/[m_p \cdot c^2] = 4.407{,}749{,}3 \cdot 10^{-24} \text{ seconds}$$

In communications theory it is shown that a sinusoidal oscillatory signal must be sampled at least twice per cycle for the signal to be correctly represented. That is, two independent datums are required so as to determine the value of the oscillation’s two absolute parameters, its amplitude and its frequency. [It’s phase is relative, not absolute.] That implies that the time duration of a proton / antiproton mutual annihilation must be the period of each of the resulting photons.

$$\text{(C-9)} \quad \Delta t_{\text{proton / antiproton}} = T_{\gamma p} = 4.407{,}749{,}3 \cdot 10^{-24} \text{ seconds}$$

Similarly for an electron / positron mutual annihilation, the time duration would be

$$(C\text{-}10)\quad \Delta t_{electron\ /\ positron} = T_{\gamma e} = 8.093{,}301{,}0 \cdot 10^{-21}\ \text{seconds.}$$

While those are very brief times they are not instantaneous.

In the case of a particle and its antiparticle coming together from significantly far apart, the particles will have accumulated significant velocity toward each other by the time they arrive at Separation Distance S because of having been accelerated by their mutual Coulomb attraction. However, the situation was different for the Big Bang.

WHY THE CRITERIA FAILED IN THE CASE OF THE BIG BANG

The number of particles resulting from the original Big Bang is estimated to have been about 10^{85} [Appendix B, *The Limitation of the Original Envelopes*], and those particles emerged on paths that were initially radially outward. The event was overall spherically symmetrical on the large scale, but at the local particle level perfect symmetry was impossible because of the nature of finite particles versus a smooth non-particulate substance. Initially all of the particles were on divergent paths although for two adjacent particles the amount of the divergence was minute.

For a proton and an adjacent antiproton in the Big Bang to be separate [not annihilated] at the instant of being projected outward in the Big Bang, they had to be separated by at least the above-developed $S_p = 1.321{,}410{,}0 \cdot 10^{-15}$ meters. For them to then annihilate their Coulomb attraction would have had to accelerate them into co-locating in the required time criterion starting from their initially zero velocity toward each other. [Actually they would have had non-zero but minute velocities away from each other because each follows its own outward radial path.] The issue is whether their Coulomb attraction can accelerate the two particles to the point of co-locating within the time frame of equation C-9 [or equation C-10 for an electron / positron case].

If, for example, for their mutual annihilation, the proton or the antiproton is to travel <u>at constant velocity</u> its half of the separation distance, $\tfrac{1}{2} \cdot S_p$, in time $T_{\gamma p}$, so as to be co-located with its antiparticle at the end of that time, it would require a speed of

$$(C\text{-}11)\quad v_p = \frac{\tfrac{1}{2} \cdot S_p}{T_{\gamma p}} = 0.5 \cdot c \quad \text{[half light speed]}$$

and if the electron or the positron, for their mutual annihilation, is to travel its half of the separation distance, S_e, in time $\tfrac{1}{2} \cdot T_{\gamma e}$ <u>at constant velocity</u> it would require a speed of

$$(C\text{-}12)\quad v_e = \frac{\tfrac{1}{2} \cdot S_e}{T_{\gamma e}} = 0.5 \cdot c \quad \text{[half light speed].}$$

The achieving of that speed, if even only by the very end of the extremely short time period of the acceleration and travel, 10^{-21} seconds or less, would be difficult. The particles moving continuously at that <u>constant velocity</u> throughout their travel from separated to co-located is impossible in that they commence their travel of distance S from essentially zero velocity toward each other.

Furthermore, the analysis of the Coulomb interaction at close separation distances presented in Appendix A-1, *The Neutron* shows that the attraction weakens drastically at close quarters per Figure C-2, below, reproduced from that appendix. [The figure shows the form of the reduction in the Coulomb attraction as a function of the charge separation radial distance relative to a proton mass equivalent wavelength, λ_p.]

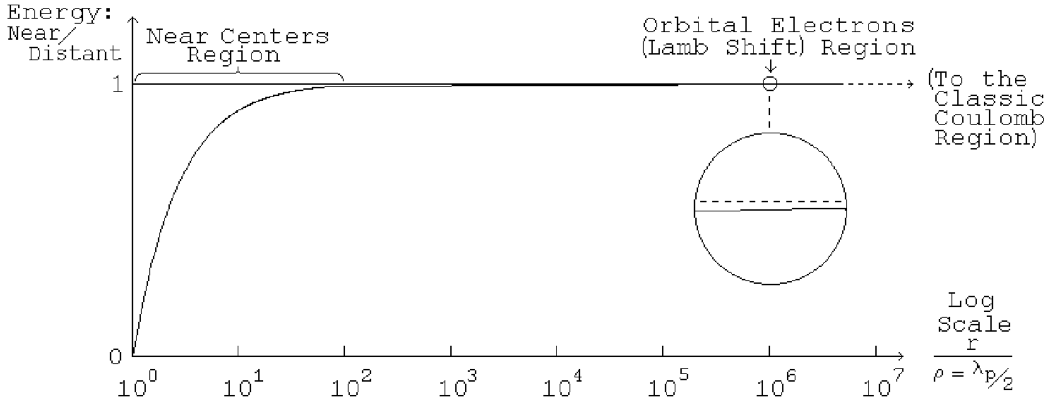

Figure C-2
Coulomb Effect <u>Reduction Factor</u> When Charges Are Near to Each Other

Finally, the posited particle and its antiparticle, emerging from the Big Bang, with spacing adjacent to each other as closely as possible, and on radially outward paths, were not alone. They were surrounded by a more or less uniform, symmetrical, large group of like particles and antiparticles. Any Coulomb tendency to unite the posited particle pair was largely offset by the similar tendency of each member to unite with the adjacent particle on its other side. The net Coulomb action on a specific particle or antiparticle was certainly insufficient to produce enough acceleration to enable the particle to transit its half of the Separation Distance in the required gamma photon period.

In summary:

- Adjacent Big Bang product particles and their antiparticles,
- Initially spaced optimally for co-locating [as closely as possible yet independently separate],
- Traveling outward at near light speed on essentially parallel paths [actually minutely diverging paths],
- Are unable to accelerate toward each other, from zero initial such velocity, quickly enough for their annihilation to produce the known actual gamma photons that would have to result from their mutual annihilation.
- That is, they cannot travel to the point of annihilation in time for the annihilation gamma photons to be the correct frequency to carry off the energy equivalent of the input particles, the pre-annihilation proton / antiproton or electron / positron.

In other words a Big Bang mutual annihilation was much more difficult, and rare, than one might have assumed. A large scale annihilation of matter and antimatter could not have taken place in the Big Bang. The result is that the present universe contains both matter and antimatter in equal amounts because of the original symmetry.

A UNIVERSE CONTAINING BOTH MATTER REGIONS AND ANTIMATTER REGIONS

Why Matter and AntiMatter Regions Are Able to Co-Exist

Of course, matter / antimatter mutual annihilations in general are not as awkward as they were for the original Big Bang with its peculiar initial conditions. Of interest here, however, is the case of the interstellar medium. It is the interstellar medium that must be examined because it is the natural boundary between regions of matter and regions of antimatter; where, if they are to occur, the anticipated matter / antimatter annihilations should be occurring and yielding their looked-for gamma ray flux.

In the interstellar [and intergalactic] medium the particles and antiparticles start from being significantly separated, residing in the vacuum of interstellar space, which vacuum, while not devoid of competing particles, has a much lower particle density than the original Big Bang. They do not suffer the disadvantage of being in a dense milieu of particles and antiparticles whose Coulomb attractions tend to cancel out their effects. And, they avoid the disadvantage of always starting their mutual Coulomb attraction toward each other with no initial velocity. Without regard for any mutual attraction between particular particles and antiparticles, they all move with significant velocities.

However, those velocities are in general not oriented toward the combination of a pair. Rather, the velocity directions are a combination of [a] some component distributed randomly over the particles in essentially all possible directions, and [b] some amount corresponding to a general flow direction.

Table C-1, below summarizes the particle [and antiparticle where applicable] content of interstellar space. The density of the particles, and their related mean distance apart are such as to militate against any significant number of encounters, whether aided by Coulomb attraction or not. [Excepting solar wind, which is local to star’s nearby environment, most of the interstellar medium is Hydrogen atoms, not ions.] [Gravitation can be ignored here, it being decades of orders of magnitude weaker than Coulomb attraction.]

Region	Size	Particle	
		Density [/cc]	Energy
Our Solar Wind	Sun Neighborhood	10.	0.001- 0.004 × c
Our Local Cloud	60 Light Years	0.1	~ 7,000 °K
Our Local Bubble	300 Light Years	0.001	~ 1,000,000 °K
Intergalactic Space	[The Universe]	0.000 … ?	?

Table C-1 – The Interstellar Medium

As has been pointed out in analyses of our solar wind, with typically `1 atom` in each `10 cm`^{3} of interstellar gas in our local cloud and `10 ions` in each `cm`^{3} of our solar wind, the particles are so far apart that the solar wind and interstellar gas flow through each other without being disturbed by collisions. On that basis, the even less dense regions of the interstellar medium such as ones like our local bubble, those within galaxies in general, and those in intergalactic space are even less conducive to particle / antiparticle encounters.

Another factor bearing on the likelihood of matter / antimatter mutual annihilations occurring in interstellar space is as follows. Because gravitational and Coulomb field attraction communicate at c, particles are attracted to where the attractor was, not where it is. That tends to produce orbital motion or “sling shot” non-collision passages rather than direct collisions. For example, a proton traveling at $0.000,001 \cdot c$ [only 300 $^{meters}/_{second}$] and at a distance of 0.001 millimeter from another charged particle [compare that distance with the spacing implied by the densities of the above table] will travel a distance equal to 757 of its proton radii during the time that its Coulomb field communicates at velocity c to the other charged particle its then Coulomb attraction impulse.

All of these various factors taken into account, matter / antimatter collisions must be quite infrequent events in the interstellar medium. When such mutual annihilations occur the appropriate gamma photons are emitted.

Indications of Some Matter / AntiMatter Mutual Annihilations

A most likely indication of our detection of cosmic matter / antimatter annihilations is Gamma Ray Bursts [GRB’s].

GRB’s are flashes of gamma rays coming from seemingly random places in deep space at random times. GRB’s last from milliseconds to minutes, and are often followed by "afterglow" emission at longer wavelengths. Gamma-ray bursts are detected by orbiting [*Swift*] satellites about two to three times a week. All known GRB’s come from outside our own galaxy. Most GRB’s come from billions of light years away [as much as $z = 6.3$ or more].

Under the assumption that a given burst emits energy uniformly in all directions, some of the brightest bursts correspond to a total energy release of 10^{47} joules, nearly a solar mass converted into gamma-radiation in a small amount of time. No candidate process other than a significant matter-antimatter annihilation is able to liberate that much energy so quickly.