The Problem of Big Bang Matter vs. AntiMatter Symmetry

Roger Ellman

Abstract

The Big Bang had to be smoothly spherically symmetrical in its particles, energy, and radiation emitted outward from the origin, and likewise for the emitted particles versus their antiparticles. The result should have been equal amounts of matter and antimatter with the expectation of their complete mutual annihilation.

A total annihilation did not take place as evidenced by the universe's existence. The currently favored explanation is that the universe is now all matter, all original antimatter having been annihilated with an equal amount of original matter, the total amount of the original matter having been greater than that of the original antimatter. That is, that the original symmetry was slightly skewed in favor of matter.

That conflicts with a purely symmetrical Big Bang and posits a condition, the skewed balance of original matter and antimatter, that is difficult to justify. Current investigations seek to detect an innate violation of matter / antimatter symmetry sufficient to justify the original matter being greater in amount than the original antimatter.

An alternative is developed, maintaining the original symmetry yet still resulting in our universe's existence. That involves showing that a total mutual annihilation of equal amounts of original matter and antimatter could not have occurred. The logic and mechanism of mutual annihilation and the conditions for it to take place are analyzed.

Our present universe still must contain large amounts of both forms of matter between some particles of which further mutual annihilations still occur at a modest rate.

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1 - Background of the Problem

It is generally deemed, and reasonably so, that the Big Bang had to be largely symmetrical and exhibit a smooth spherical uniformity in the pattern of particles, energy, and radiation emitted outward in all directions from the singularity source. That would also apply to the emitted particles versus their antiparticles and imply that the Big Bang should have resulted in equal amounts of matter and antimatter, for which the expectation would be their complete, almost instantaneous, mutual annihilation.

On the other hand, because a total mutual annihilation did not take place, as evidenced by our and our universe's existence, the general cosmological position currently favored holds that the universe is now all matter, all original antimatter having been annihilated with an equal amount of original matter, the total amount of the original matter having been greater than the amount of the original antimatter. That is, that the original symmetry was slightly skewed in favor of matter.

That contention is in conflict with a purely symmetrical Big Bang, of course, and posits a condition, the skewed balance of original matter and antimatter, that is difficult to justify. Experiments currently in process seek to detect an innate violation of matter / antimatter symmetry sufficient to justify the current thinking that the original matter was greater in amount than the original antimatter.

The following development presents an alternative showing that a total mutual annihilation of equal amounts of original matter and antimatter could not have occurred; that, 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.

2 - Conditions Affecting Matter / AntiMatter Mutual Annihilation

The first issue to be investigated 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 in *A New Look at the Neutron and the Lamb Shift*[1] which, among other analyses, investigates the decay of a neutron into a proton and an electron, a natural process with a mean lifetime before decay of about 887 seconds. [The Lamb Shift is a factor in this process because Coulomb's Law becomes non-linear when the two interacting charges are near each other, which effect is the cause of the Lamb

Shift]. 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.

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 able 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 and their state at lesser separation distance 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 results from the analysis of the neutron decay in *A New Look at the Neutron and the Lamb Shift*[1] are as follows.

(1) - 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:

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

where the precision for this separation distance is limited by the precision of Lamb Shift data as discussed in the above referenced paper.

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

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

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

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

quite near to the empirical value for the proton radius from equation *(2)* and the separation distance, S, of equation *(1)*. Thus the separation distance boundary between a proton and an electron as separate particles versus combined into a neutron is about *1* proton radius.

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 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

$$(4) \qquad \lambda_e = 2.426,310,6 \cdot 10^{-12} \text{ meters.}$$

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 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.

$$(5) \qquad {}_1p^1 + {}_{-1}p^1 \Rightarrow \gamma + \gamma \qquad \text{where } \gamma \text{ is a gamma photon}$$

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.

$$(6) \qquad f_{\gamma p} = m_p \cdot c^2/h$$

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

In communications theory it is shown that a sinusoidal oscillatory signal must be sampled twice per cycle for the signal to be correctly represented. That is, two data 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 should be the period of each of the resulting photons.

$$(7) \qquad \Delta t_{\text{proton / antiproton}} = T_{\gamma p} = 4.407,749,3 \cdot 10^{-24} \text{ seconds}$$

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

$$(8) \qquad \Delta t_{\text{electron / positron}} = T_{\gamma e} = 8.093,301,0 \cdot 10^{-21} \text{ seconds.}$$

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.

The number of particles resulting from the original Big Bang is estimated to have been about 10^{85} [2], 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 annihilate their Coulomb attraction must accelerate them into co-locating in the required time frame starting from their initially having 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 the Coulomb attraction can accelerate the two particles to the point of co-locating within the time frame of equation *(7)* [or equation *(8)* for an electron / positron case].

If, for their mutual annihilation, the proton or the antiproton is to travel its half of the separation distance, $\frac{1}{2} \cdot S_p$, in time $T_{\gamma p}$ <u>at constant velocity</u> it would require a speed of

(9)
$$v_p = \frac{\frac{1}{2} \cdot S_p}{T_{\gamma p}} = 0.5 \cdot c \qquad \text{[half light speed]}$$

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

(10)
$$v_e = \frac{\frac{1}{2} \cdot S_e}{T_{\gamma e}} = 0.5 \cdot c \qquad \text{[half light speed].}$$

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 *A New Look at the Neutron and the Lamb Shift*[1] shows that the attraction weakens drastically at close quarters per Figure 1, below, reproduced from that paper. [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 wavelength, λ_p.]

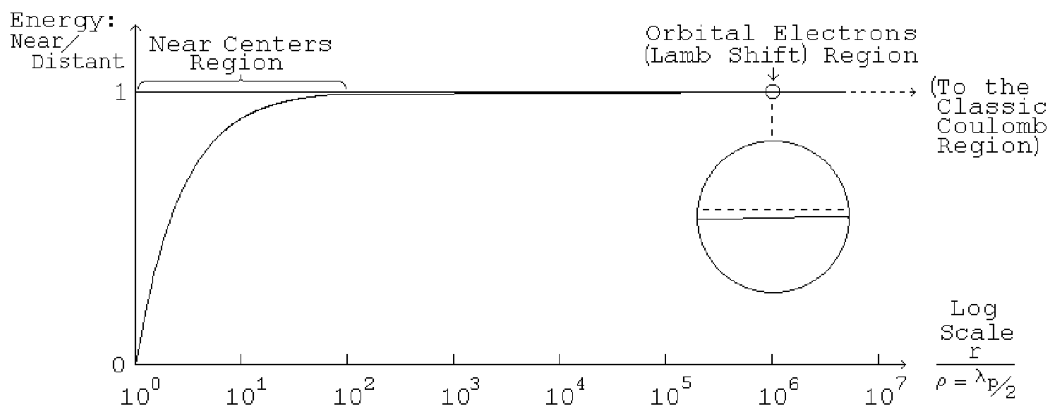

Figure 1
Coulomb Effect <u>Reduction Factor</u> When Charges Are Near to Each Other

The boundary-like significance of the Separation Distance, that when the two particles are separated by that distance or more they appear as the separate independent particles but when closer than that distance they appear as annihilated, must be taken into account. That would tend to indicate that the portion of the above figure for the region where $r < \lambda_p$ [or $r < \lambda_e$ for the electron / positron case] is probably inapplicable. What happens in that region would appear to be somewhat indeterminate so far as our knowledge can go, but is certainly not the usual Coulomb effect.

Finally, decisively, 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 negligible.

In summary:

- "adjacent" Big Bang product particles and their antiparticles,
- initially spaced optimally [as closely as possible]
- traveling outward at near light speed on essentially parallel paths [actually minutely diverging paths],
- are unable to accelerate toward each other, from essentially 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.

It would appear that in the case of the Big Bang mutual annihilation was much more difficult, and rare, than one might have assumed. And, thus it would appear that a large scale annihilation of matter and antimatter could not have taken place in the Big Bang with the result that the present universe must contain both matter and antimatter, most likely in equal amounts because of the original symmetry.

3 – A Universe Containing Both Matter Regions and AntiMatter Regions

Contemporary physics' position that there is now in the universe no antimatter from the Big Bang derives from the following reasoning.

> If there are in the universe regions of antimatter as well as regions of matter, then at the boundaries between the two different type regions antimatter should come in contact with the matter. That should result in major amounts of mutual annihilations and the production of major amounts of gamma photons. Such major amounts of gamma photons not having been detected it is presumed that there are no antimatter regions of space.

Of course, an alternative explanation of such major amounts of gamma photons not having been detected would be that the mutual annihilations are not occurring in significant amounts for reasons similar to their not having so occurred in the original Big Bang or for other reasons. That alternative must now be investigated.

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 at the point of the separation distance, S, with no initial velocity toward each other. 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 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 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; however, the rate of occurrence of such events is so low that nothing approximating a detectable extensive "gamma flux" could be produced.

Separation of Matter and AntiMatter In the Universe

The original, spherically symmetrical Big Bang, in spite of its symmetry developed over a period of time into the present universe which has a substantial amount of non-symmetrical structure. The "clumping" that produced the current structure of various cosmic bodies would have operated equally on both matter and antimatter and on the two intermixed. The result should be cosmic structures of various mixtures of matter and antimatter which ultimately developed into purely one or the other.

In regions of space where the particle density became greater, with young stars gradually assembling particles from their surroundings, there must have been a significant amount of matter / antimatter mutual annihilation. Depending on the local relative amounts of the two the resulting star would have developed into one of pure matter or of pure antimatter via mutual annihilations that eliminated the locally non-dominant form.

But the developed star, residing in its share of interstellar medium, would be able to continue its existence as a pure matter star or a pure antimatter star, essentially shielded or protected by its surrounding interstellar medium. In that manner the present universe should consist overall of equal amounts of matter and of antimatter, the two types residing in their pertinent stars, sufficiently "insulated" from each other by the vast and sufficiently empty interstellar medium such that their mutual annihilation with their matter-type opposite should be a relatively rare event.

Indications of Matter / AntiMatter Mutual Annihilations

The most likely indication of our detection of cosmic matter / antimatter mutual annihilations is that of Gamma Ray Bursts [GRB's]. These are brief, extremely high energy bursts of gamma rays and are detected by satellites. They appear to come from all directions. They appear to come exclusively, or dominantly, from outside of our Milky Way Galaxy. Their source and cause are currently not well understood and hypotheses in those regards are under investigation. They are detected at an average rate of about one per day.

The energy given off by GRB's is on the order of a solar rest-mass if the radiation of its gamma rays is isotropic as should be the case for cosmic body matter / antimatter mutual annihilations. That is, the energy output rate is comparable to the conversion to energy of the entire mass of our sun in a few tens of seconds. Such a conversion is consistent with the concept of cosmic body matter / antimatter mutual annihilation.

While alternative, and not necessarily mutually exclusive, hypotheses for GRB's are being developed, there would appear to be no way of validating a particular hypothesis by observations and measurements. At present, however, those various hypotheses neglect matter / antimatter mutual annihilations on the *a priori* assumption that the universe is now all matter, all original antimatter having been annihilated with an equal amount of original matter, the original matter / antimatter symmetry having been slightly skewed in favor of matter, which assumption is shown above to be invalid.

1 – Conclusion

The current assumption, that an original skewed balance of the amounts of matter and antimatter produced in the Big Bang account for our universe having survived an original massive mutual annihilation of original matter and antimatter, is difficult to justify. Current investigations seeking to detect an innate violation of matter / antimatter symmetry sufficient to justify the original matter being greater in amount than the original antimatter have not had success. The concept is contrary to the natural condition that the Big Bang had to be smoothly spherically symmetrical in its particles of both matter and antimatter, energy, and radiation emitted outward from the origin.

The alternative proposed in the present paper requires no questionable assumptions and is in comfortable agreement with known physics and astrophysics. It therefore merits consideration and acceptance in place of the skewed balance concept.

References

[1] R. Ellman, *A New Look at the Neutron and the Lamb Shift*, Los Alamos National Laboratory Eprint Archive at http://xxx.lanl.gov, physics/9808045.

[2] This paper is based on development in R. Ellman, *The Origin and Its Meaning*, The-Origin Foundation, Inc., http://www.The-Origin.org, 1997, in which the development is more extensive and the collateral issues are developed. [It may be downloaded from http://www.The-Origin.org/download.htm].