Baryogenesis as a parallel to the non-biased (achiral) generation of only one of two identical energy isomers.

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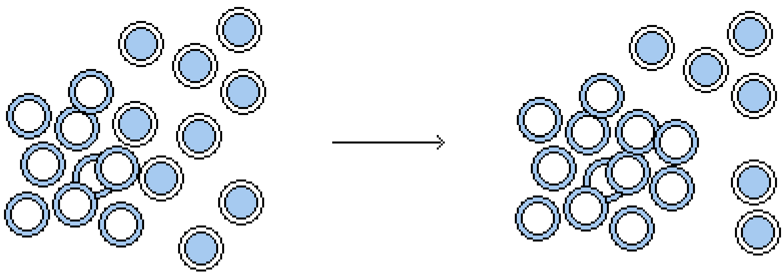
Abstract.
This paper suggests an alternative mechanism to account for the dominant abundance of matter over antimatter in our observed universe by looking at the production side of baryons and antibaryons in the very early universe. The Sakharov conditions appear to be met.

It is suggested that an aspect of baryogenesis may have been similar to the physics of randomly forming only one isomer from two possible identical energy isomers by non-biased (achiral) stimulus. Research is cited where random 100% one isomer (complete single chirality) is produced <u>without bias</u> from a mixture that should produce a 50%/50% mix of two isomers as they have equal energy and equal probability of being formed.

A similar <u>chance resolution</u> in the production of baryons and antibaryons to generate baryons as the majority might have applied in the very early universe.



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1. Introduction.

According to the laws of physics that we have discovered, when matter is created an equal amount of antimatter is also created [reference 1].

However, the amount of matter in our observed universe is far greater than the amount of antimatter [reference 2].

This paper offers a possible explanation of this inconsistency.
The suggestion is that in the very early universe production of baryon/antibaryon pairs may have been locally skewed towards the production by seeding of only baryons or antibaryons because of dense packing among random groupings of the same species of particle. Under these conditions baryon number would have been violated.

A process of seeding (baryon number violating) and annihilation (baryon number conserving) on the perimeter of a chance same species (all baryon or all antibaryon) grouping followed by further seeding might be a parallel to the non-biased (achiral) generation of only one of two identical energy isomers.

1.1 Key components in baryon/antibaryon formation.

To show a parallel between baryogenesis and the non-biased (achiral) generation of only one of two identical energy isomers we need the following hypothesis.

*-----
Hypothesis:
Among the components of a baryon and its antibaryon are a pair or pairs of key components common to both the baryon and its antibaryon.

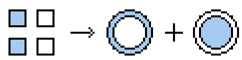
The pair or pairs of key components are arranged in two different ways, one way in the baryon and a different way in its antibaryon. The alternative arrangements of key components define the baryon and its antibaryon. In addition to the key components there are further components not common to both a baryon and its antibaryon.
*-----

To start with in this paper the depictions only show key components. Other components are required to produce a baryon/antibaryon and will be shown in later depictions.

Four basic reactions are needed in this picture of baryogenesis.

1. Standard pair production. (Only showing the key components).

free key components $\rightarrow$ baryon + antibaryon

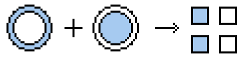


Baryon number (B) conserved: $0 = (+1) + (-1)$

Schematic depiction of the production from free key components of a baryon and its antibaryon.

2. Standard pair annihilation. (Only showing the key components).

baryon + antibaryon $\rightarrow$ free key components

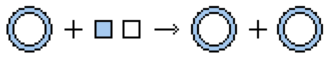


Baryon number (B) <u>conserved</u>: $(+1) + (-1) = 0$

Schematic depiction of the annihilation of a baryon and its antibaryon and the formation of free key components.

3. Hypothesised seeding reaction - production of one baryon. (Only showing the key components).

baryon + free key components $\rightarrow$ baryon + baryon

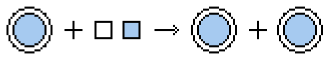


Baryon number (B) <u>violated</u>: $(+1) + 0 \neq (+1) + (+1)$

Schematic depiction of the seeded production from free key components of one baryon.

4. Hypothesised seeding reaction - production of one antibaryon. (Only showing the key components).

antibaryon + free key components $\rightarrow$ antibaryon + antibaryon

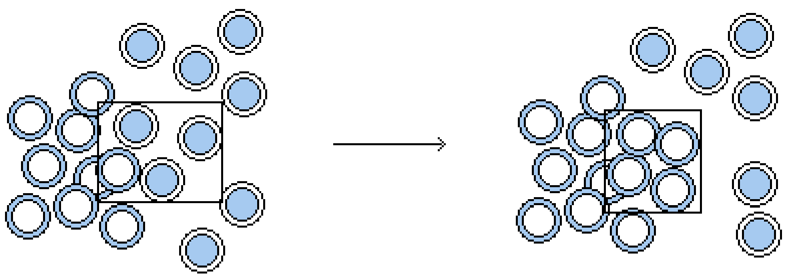


Baryon number (B) <u>violated</u>: $(-1) + 0 \neq (-1) + (-1)$

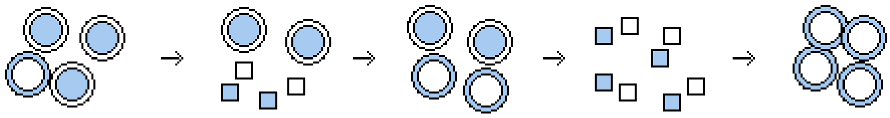
Schematic depiction of the seeded production from free key components of one antibaryon.

1.2 What might cause baryon number violation?

Seeding might occur when a chance larger concentration (domain) of particles of one baryon number {+1 or -1} could partially annihilate on its perimeter with a smaller domain of particles of the opposite baryon number {-1 or +1} and then by copying its own structure (seeding) use the material from the annihilation to increase the size of its own baryon number {+1 or -1} domain. This is in addition to the increase of a domain by seeding directly from free key components.



In the boxed region of the above depiction, an example conversion process might follow these stages:



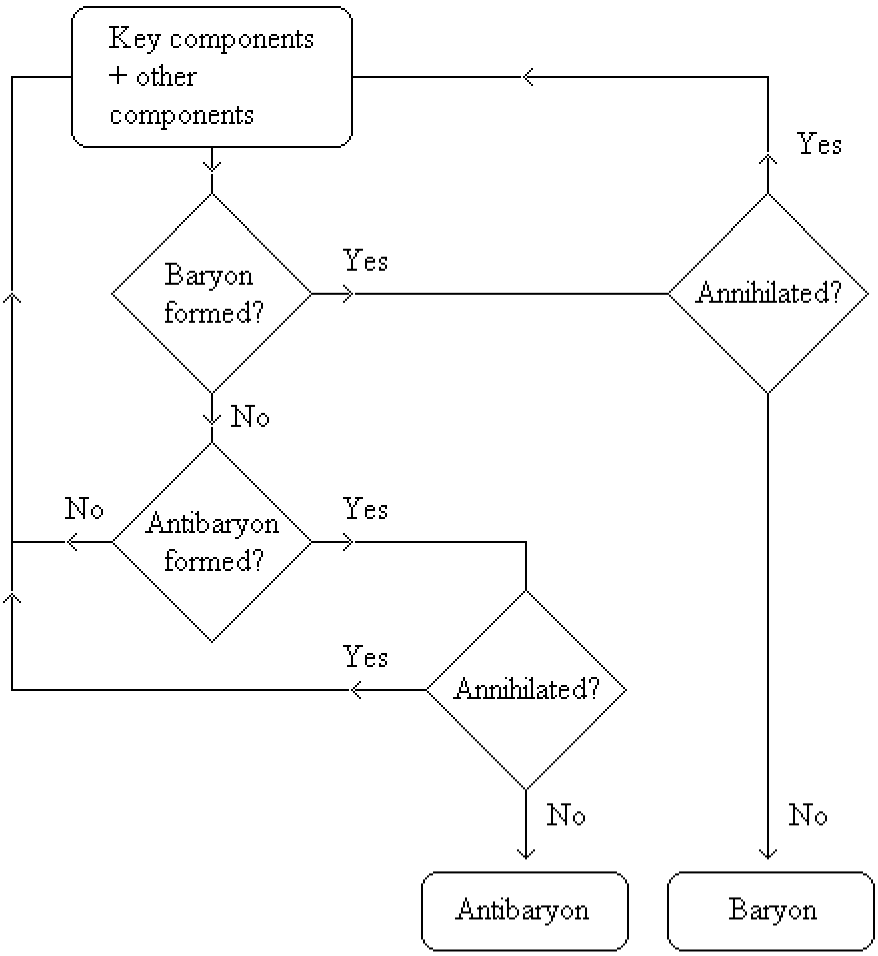
annihilation seeding** annihilation seeding**

**The seeding is biased by the close proximity of the domain of baryons (shown on the left of the previous picture).

The process of seeding could continue until:
all available matter/antimatter in the region had been converted to the dominant type of matter/antimatter with baryon number {+1 or -1}; or
the conditions for seeded production ceased.

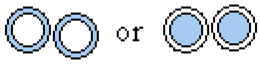
If we assume the seeding mechanism in the very early universe then the chance dominant type of matter/antimatter happened to be composed of baryons rather than antibaryons, the result of which we observe today.

1.3 Baryon/antibaryon production and annihilation reactions.

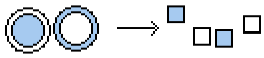


1.4 External stability/instability.

Notice that in this key component formulation;
<u>external stability</u> occurs when <u>like</u> shielding/external key components are juxtaposed:



and <u>external instability</u> (annihilation) occurs when <u>unlike</u> shielding/external key components are juxtaposed.



2. Baryon/antibaryon assumptions.

In the following:
n is an integer; and nx and ny denote key components; and

z(a) and z(b) denote components other than the key components nx and ny. z(a) and z(b) include <u>particle/antiparticle pairs to allow for charge and spin conservation</u> in creation and annihilation reactions as shown in section '3. Baryon/antibaryon reactions'.

a <u>baryon</u> has components nx and ny in a particular configuration where the properties of nx dominate or shield the properties of ny (shown below as: nx(ny)z(b)); and similarly an <u>antibaryon</u> also has components nx and ny, but in this case the properties of ny dominate or shield the properties of nx (shown below as: ny(nx)z(a)).

x may be composed of more than one kind of particle, i.e. x is $n_{x1}x_1$, $n_{x2}x_2$, $n_{x3}x_3$, …
and in that case $n = n_{x1} + n_{x2} + n_{x3} + \ldots$ $\quad (n = \sum n_{xi})$
and
 y may be composed of more than one kind of particle, i.e. y is $n_{y1}y_1$, $n_{y2}y_2$, $n_{y3}y_3$, …
and in that case $n = n_{y1} + n_{y2} + n_{y3} + \ldots$ $\quad (n = \sum n_{yi})$

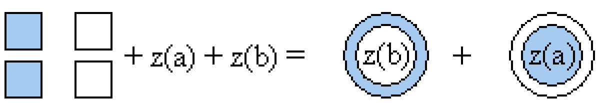
The numbers of each subcomponent have to be equal: $n_{x1} = n_{y1}$, $n_{x2} = n_{y2}$, $n_{x3} = n_{y3}$, ...

3. Baryon/antibaryon reactions.

This section shows the same reactions as section 1.1 but with the extra components z(b) and z(a) not common to both a baryon and its antibaryon.

3.1 Baryon number <u>conservation</u>: creation of baryon + antibaryon.

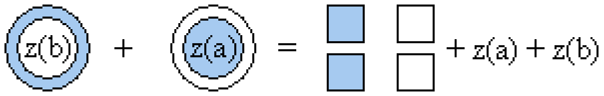
2nx + 2ny + z(a) + z(b) = nx[ny z(b)] + ny[nx z(a)]



Baryon number:
  0 + 0 + 0 + 0 = +1 + -1
  0 = 0

3.2 Baryon number <u>conservation</u>: annihilation of baryon + antibaryon.

nx[ny z(b)] + ny[nx z(a)] = 2nx + 2ny + z(a) + z(b)



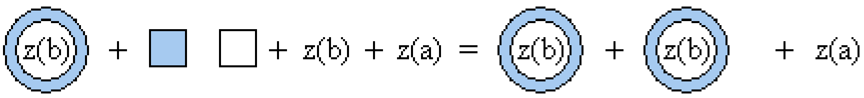
Baryon number:

+1 + -1 = 0 + 0 + 0 + 0

0 = 0

3.3 Baryon number <u>violation</u> (seeding): creation of one baryon.

nx + ny + z(b) + z(a) = nx[ny z(b)] + z(a)



Baryon number:

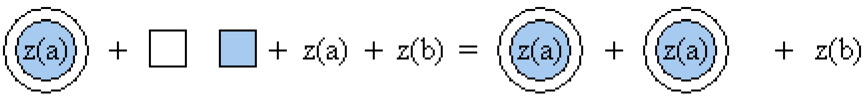
+1 + 0 + 0 + 0 + 0 $\neq$ +1 + +1 + 0

+1 $\neq$ +2

[Please note: z(a) is shown in this reaction as z(a) and z(b) may involve particle/antiparticle pairs.]

3.4 Baryon number <u>violation</u> (seeding): creation of one antibaryon.

ny + nx + z(a) + z(b) = ny[nx z(a)] + z(b)



Baryon number:

-1 + 0 + 0 + 0 + 0 $\neq$ -1 + -1 + 0

-1 $\neq$ -2

[Please note: z(b) is shown in this reaction as z(a) and z(b) may involve particle/antiparticle pairs.]

4. Baryon/baryon affinity and antibaryon/antibaryon affinity.

Possible support for the idea of baryons seeding further baryons may come from baryon/baryon affinity in the atomic nucleus. Neutrons and protons coexist in a strongly bound state in the nuclei of atoms of mass number A greater than 1.

The same could apply to antibaryons seeding further antibaryons because of assumed antibaryon/antibaryon affinity in the atomic nucleus of antimatter. Antineutrons and antiprotons may coexist in a strongly bound state in the nuclei of anti-atoms of mass number A greater than 1.

This affinity may signal an environment in which additional baryonic/antibaryonic components are forced in conditions of high energy and density into duplicating the neighbouring baryons or antibaryons rather than forming baryon/antibaryon pairs.

5. Baryon/antibaryon comparison with chiral isomers.

In this section I indicate processes involved in the production of isomers and then comment (*in italics*) on what might have applied as a parallel to very early universe baryon/antibaryon production.

5.1 What are chiral isomers?

Chiral comes from the Greek word for hand: χειρ (transliteration: 'cheir' or 'kheir'). Hands have the same components but different arrangements. While a left hand in a mirror looks like a right hand, in reality a left hand cannot be superimposed on a right hand and appear the same. Similarly a right hand cannot be superimposed on a left hand and appear the same.

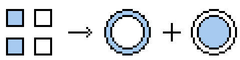
The possible parallel between chirality and baryogenesis lies in alternative arrangements of the same components. Two chiral isomers have exactly the same components but for baryon/antibaryon pairs it is suggested that <u>only the key components are the same</u>.

Isomers or structural isomers are molecules of the same chemical compound (same atoms in the molecule) but with different spatial arrangements of the atoms making up the compound.

Chiral isomers are a subset of structural isomers. They 'have a definite handedness and can't be superposed on their mirror images.' [reference 3 page 1 column 1 lines 7-8.]

'Energetically, left-handed and right-handed isomers are identical and should form with the same probability.' [reference 3 page 1 column 1 lines 26-29.]

<u>For baryogenesis</u> to have parallels with isomer production we need pairs of components common to both a baryon and its antibaryon which form one way in the baryon and a different way in its antibaryon.



These key components that define a baryon in one arrangement and its antibaryon in another arrangement are <u>not the only components</u> in the baryon or antibaryon.

The suggested parallel between baryon/antibaryon and structural isomers is limited to the key components. <u>Other components not common to both</u> a baryon and its antibaryon are required to complete the construction of these particles.

Restating the above paragraph in a different way: a baryon and its antibaryon are not fully structural isomers since at least some of their components are not the same. For example a proton contains, amongst other particles, two up quarks and one down quark whereas an antiproton contains, amongst other particles, two antiup quarks (two up antiquarks) and one antidown quark (one down antiquark).

5.2 Biased (chiral) isomer production.

Later we move on to non-biased (achiral) symmetry breaking but first let's have a look at the biased (chiral) version using a seed crystal of single chirality (homochiral). Experiments have been performed with sodium chlorate ($NaClO_3$).

'In aqueous solution, sodium chlorate's Na^+ and ClO_3^- ions are not chiral, but the crystals they form are. The chirality manifests itself in how the crystals transmit light.' [reference 3 page 1 column 3 lines 31-35.]

'Left by itself, a solution of sodium chlorate would precipitate roughly equal numbers of left-handed and right-handed crystals. But back in 1898, Frederick Kipping and William Pope discovered that if they dropped a single seed crystal into a supersaturated solution, all subsequent crystals shared the same chirality. Of course, using an already-homochiral seed can't account for the emergence of homochirality itself.' [reference 3 page 1 column 3 lines 42-53.]

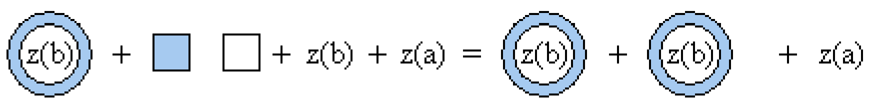
<u>For baryogenesis</u> dense packing of the assumed key components of baryon/antibaryon pairs may be seen as a parallel to a supersaturated solution of isomer components.

Baryon/baryon affinity and antibaryon/antibaryon affinity noted in section 4 appear as a parallel to seeding in a supersaturated solution with a crystal of defined chirality in that baryon/antibaryon key components are forced into the same structure as existing baryons or antibaryons.

* -----
The following two reactions are the assumed baryon/antibaryon equivalents of isomer seeding.

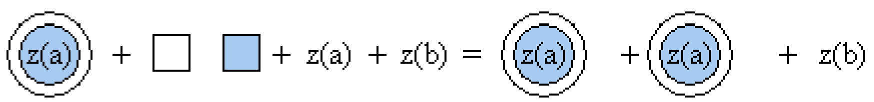
Key components and other components in the immediate proximity of an existing <u>baryon</u>:

$$nx + ny + z(b) + z(a) = nx[ny\ z(b)] + z(a)$$



Key components and other components in the immediate proximity of an existing <u>antibaryon</u>:

$$ny + nx + z(a) + z(b) = ny[nx\ z(a)] + z(b)$$



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5.3 Chiral symmetry breaking by non-biased (achiral) stimulus - 1.

D. K. Kondepudi et al [reference 4] experimented with sodium chlorate crystals and 'tried to find an achiral stimulus that would trigger symmetry breaking. One day, when he was watching a crystal form, he noticed it fall to the bottom of the flask. On a whim, he stirred the solution. To his astonishment, the stirring caused all subsequent crystals to adopt the same chirality as the original crystal.' [reference 3 page 1 column 3 line 54 and page 2 column 1 lines 1 to 8.]

'Kondepudi explained his results in terms of primary and secondary nucleation.' reference 3 page 2 column 1 lines 15 to 17.

'Left-handed and right-handed crystals have the same chance of forming.' [reference 3 page 2 column 1 lines 23 to 25.]

'In secondary nucleation, solute crystallizes on the surface of an existing crystal. Newly added material assumes the chirality of the surface.' [reference 3 page 2 column 1 lines 26 to 29.]

The handedness of the first crystal which formed in the first quote was the result of a 50%/50% chance since 'Left-handed and right-handed crystals have the same chance of forming' as shown in the third quote. In this sub-section this first crystal to form was the result of primary nucleation.

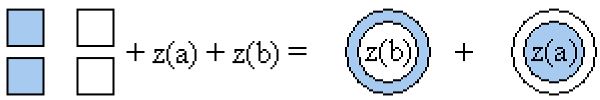
In the first quote in this sub-section 'the stirring caused all subsequent crystals to adopt the same chirality as the original crystal' was the result of secondary nucleation.

<u>For baryogenesis</u> the equivalent of stirring would be the agitation in the highly energetic, compact and chaotic environment of the very early universe.

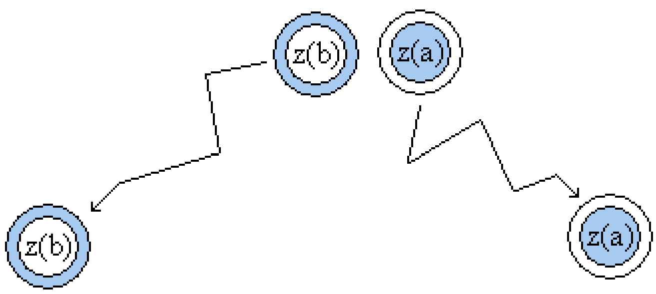
Primary nucleation for baryons/antibaryons could come from the spatial separation of baryons and antibaryons after production in the baryon number <u>conserving</u> reaction shown in subsection 3.1.

Production:

$$2nx + 2ny + z(a) + z(b) = nx[ny\ z(b)] + ny[nx\ z(a)]$$



Then separation:



The secondary nucleation for baryons/antibaryons would be the baryon number <u>violating</u> reactions shown in subsections 3.3 and 3.4.

5.4 Chiral symmetry breaking by (non-biased) achiral stimulus - 2.

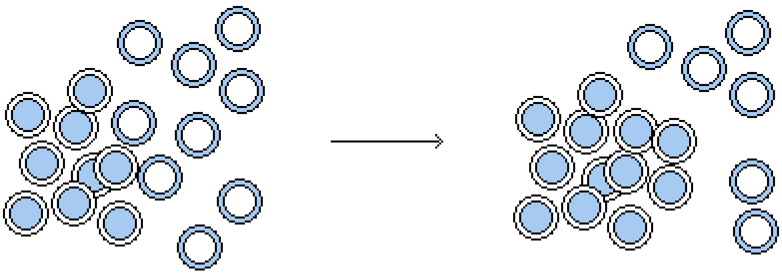
C Viedma [reference 5] showed 'that an initially equal mix of chiral crystals in solution can achieve complete homochirality thanks to the mundane action of grinding and stirring the crystals.' [reference 3 page 1 column 2 lines 6-10.]

'Viedma started instead with a supersaturated solution that contains a fifty-fifty mix of chiral crystals. Like Kondepudi, he stirred the solution, but in the presence of glass marbles. Crushed between the marbles, any crystals that have just formed are broken down. Meanwhile, others form and the cycle repeats - but not in a chiral steady state.' reference 3 page 2 column 2 line 23 to column 3 line 1.

'Viedma found that if he left his samples grinding away for several hours, one chiral form would steadily predominate. The dominant form was random, but the result was the same: complete chiral purity.' [reference 3 page 2 column 3 lines 2-7.]

'To understand the results, one needs to add another ingredient: Ostwald ripening. In 1896, Wilhelm Ostwald observed that big crystals grow at the expense of little crystals thanks to the big crystals' greater thermodynamic stability. In Viedma's experiment, one would expect left-handed and right-handed crystals to grow and dissolve at the same rate. But if there's a slight, chance preponderance of one chiral form, then Ostwald ripening, amplified by secondary nucleation, will shift the chiral balance.' [reference 3 page 2 column 3 lines 8-21.]
'Viedma's experiment ... converts an achiral mixture into a homochiral one ...' [reference 3 page 2 column 3 lines 22-24.]

<u>For baryogenesis</u> the parallel to Viedma's experiment is that already formed baryons/antibaryons may be broken down (by the baryon number conserving annihilation reaction in section 3.2) into their key components and reassembled (by the baryon number violating reactions in section 3.3 and 3.4) so as to increase the amount of locally dominant baryons or antibaryons.



<u>For baryogenesis</u> the parallel to Ostwald's observation that larger crystals have greater thermodynamic stability than smaller ones is that heavier atomic nuclei (an aggregation of baryons) are more stable than lighter ones up to the dominant isotope of iron ($^{56}Fe_{26}$) [reference 6].

The binding energy per nucleon (proton or neutron in the atomic nucleus) represents a loss of energy and therefore increased thermodynamic stability. It increases on average with increasing number of nucleons (baryons) although there are exceptions, for example, the dominant isotope of Helium on Earth ($^{4}He_{2}$) has an anomalous high binding energy indicating strong stability.

6. What might the components x, y, and z be?

6.1 Are x, y left/right pairs?

Could the x and y components be pairs of left and right handed particles? If x is left-handed then y is right-handed or the opposite way round: if y is left-handed then x is right-handed.

6.2 Are z selected because of matching/opposing handedness?

If one group (x or y) encloses the other group (y or x), are the z components selected because they have a handedness matching or opposing the handedness of the enclosed group?

7. The Sakharov conditions.

The three Sakharov conditions necessary for baryogenesis [reference 7] are:
7.1 Baryon number (B) violation.
7.2 C-symmetry violation and CP-symmetry violation.
7.3 Interactions out of thermal equilibrium.

7.1 Baryon number (B) violation.

For this condition to be met we require at least one process that produces more baryons than antibaryons.

$$\begin{array}{lccccc} & P & \rightarrow & Q & + & R \\ \text{Baryon number:} & 0 & \rightarrow & 0 & + & (>0) \end{array}$$

Where P and Q are particles with zero baryon number and R are particles with a baryon number excess (B > 0).

The baryon number violating (seeding) reaction in subsection 3.3 meets this condition as it violates baryon number.

7.2 C-symmetry violation and CP-symmetry violation.

C-symmetry and CP-symmetry require that matter/antimatter reactions have the same rate (width). Therefore matter creating reactions would be balanced by antimatter creating reactions. For an excess of baryons we need C-symmetry and CP-symmetry to be violated.

For example: if a baryon number violating reaction P → Q + R proceeds at a given rate, then its C-conjugate reaction (changing the reactants and products from matter to antimatter) /P → /Q + /R will also proceed at the same rate. Any excess baryons (R) would be countered by an equal number of antibaryons (/R) and no excess of baryons or antibaryons would result.

CP-symmetry changes charge and handedness in particles which also leads to baryon production equalling antibaryon production.

The baryon number violating (seeding) reactions in subsections 3.3 and 3.4 of this paper might appear to bypass the C-conjugate and CP-conjugate reactions thorough the <u>isolation of baryons or antibaryons in the seeding environment</u>.

7.3 Interactions out of thermal equilibrium.

This condition may have been met in the very early universe as indicated in the following quote from a work shown in the references.

'One of the conditions for a successful baryogenesis, the departure from thermal equilibrium, is naturally achieved at the stage of preheating after inflation.' [reference 8].

8. Conclusion.

Seeded production of matter/antimatter may add to the discussion of accounting for the dominance of matter over antimatter in the observed universe.

References.

[1] Matter/antimatter asymmetry. CERN Press Office, CH - 1211 Geneva 23, Switzerland. http://press.web.cern.ch/backgrounders/ matterantimatter-asymmetry {as at 25th August 2014.}

"Matter and antimatter particles are always produced as a pair and, if they come in contact, annihilate one another, leaving behind pure energy."

[2] Matter/antimatter asymmetry. CERN Press Office, CH - 1211 Geneva 23, Switzerland. http://press.web.cern.ch/backgrounders/ matterantimatter-asymmetry {as at 25th August 2014.}

"The big bang should have created equal amounts of matter and antimatter in the early universe. But today, everything we see from the smallest life forms on Earth to the largest stellar objects is made almost entirely of matter. Comparatively, there is not much antimatter to be found. Something must have happened to tip the balance. One of the greatest challenges in physics is to figure out what happened to the antimatter, or why we see matter/antimatter asymmetry."

"If matter and antimatter are created and destroyed together, it seems the universe should contain nothing but leftover energy. Nevertheless, a tiny portion of matter – about one particle per billion – managed to survive. This is what we see today."

[3] http://pendientedemigracion.ucm.es/info/investig/divulgacion/

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[7] A. D. Sakharov (1967). "Violation of CP invariance, C asymmetry, and baryon asymmetry of the universe". Journal of Experimental and Theoretical Physics **5**: 24–27., republished as A. D. Sakharov (1991). "Violation of CP invariance, C asymmetry, and baryon asymmetry of the universe". Soviet Physics Uspekhi **34** (5): 392–393.

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Page 1, lines 12 to 14 (lines 2 to 4 in the abstract):
'One of the conditions for a successful baryogenesis, the departure from thermal equilibrium, is naturally achieved at the stage of preheating after inflation.'

End of paper.