# The arrow of time and the avoidance of primordial annihilation

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## Abstract

The predominance of matter over antimatter, leads to develop an alternative conjecture, which does not violate the primordial symmetry of particle-antiparticle pairs, resulting in annihilation. To be able to predict a phenomenon that could generate a greater number of particles over antiparticles, we resorted to a mechanism capable to transfer out of the system, the antimatter characteristics. The mass's action law indicates that if a reactant or product escapes the reaction mixture, is left without any action over the equilibrium. For example, gas emission, precipitate formation, etc. Hence, if annihilation is not completed during inflation, the reactions in the quark-gluon plasma, would allow that the generated neutrinos and antineutrinos, would be able to elude annihilation and transfer the antimatter characteristics out of the system. It was assumed that neutrinos and antineutrinos becomes "transparent" or escape at a greater decoupling temperature than 1 MeV. The antineutrinos preserve the antimatter characteristics, because of the near null interaction with other particles. Therefore, becomes isolate from the matter system. Hence, there is not initial violation of CP symmetry (charge and reflect-on parity). The problems to detect neutrinos or antineutrinos, explain the non-observation of antimatter and the failure to be exposed to very large quantities of lethal gamma radiation, the product of annihilation. These leptons, along the cosmic chronology, remain without interaction and the reactions irreversibility become determinant of the time arrow. In a primordial open system, trough the separation of pathways, reactions could be thermodynamically structured to avoid conservation of symmetric interactions, and function to maintain the arrow of time.

## Introduction

The universe shows a larger excess of particles over antiparticles [1]. Studies of meson K disintegrations, which involve the weak interaction, where shown by Cronin James and Fitch Van, that only 2 disintegrations of each 1000 violated CP symmetry [2, 3].

Sakharov [4] suggested that could be expected that at the strong interaction level a CP-violation, which would result in annihilation with a remaining of a little excess of matter.

The Noether's theorem proposes invariance of the form of physical law, with respect to any transformation preserving the referent system and its physical quantities. Hence, could be expected an origin of the universe preserving CP symmetry, with respect to the generation-annihilation, of equal parts of matter-antimatter, conforming to Dirac's prediction [3, 5, 6, 7, 8].

From the quantum perspective, Physical limitations became the Planck's dimensions. That allows excluding a non-dimensional point, like the initial cosmological condition. The latter, should be the Planck particle, which is a quantum of maximum energy density [2, 9].

Any manifestation of energy, previous to the emergence of the Planck's dimensions, would not be dimensionable in term of critical energy. Tacking in account the latter and the fundamental constants was developed a conjecture of quantum inflation and expansion [9].

Hence, an alternative proposition to Guth's inflationary mechanism was adapted for a self-contained universe. In this one, inflation is consequent to cooperativity between two processes. The progressive quantization from a non-predictable state of energy, resulting in accumulative increment of quanta, associated with a simultaneous elongation of the particle-wave function [10].

The conformation of the plasma of quark-gluon, in which the creation of particle-antiparticle pairs goes on, generates the conditions which exclude antimatter from the environment of annihilation [2, 11, 12].

It is important that inflation could accumulate potential energy because inflows into an open-system, supporting the black body emission. This acts as a gradient of dissipative energy between the higher and the lower energy of the photons within each spectrum. Hence, the splitting of photon of high energy allows generating photons of lower energy.

This allows concatenate spectra of decreasing emission temperature. The dissipation from higher to lower emission temperature constitutes a gradual black body emission and the energy flow which keeps the expansion-system away from equilibrium [13]. This constitute a thermodynamic arrow of time, which also entails the exclusion from equilibrium of neutrinos, antineutrinos and which contribute to the vacuum state system or zero point [14].

## Results

### Neutrinos escape

It is assumed that in the course of inflation the progressing dissipation of the Planck energy density allows to generate particles-X and anti-X, ending inflation at $10^{-32}$ seconds. Each boson-X (or anti-X) has associated a large mass ($10^{18}$ MeV) which allows their disintegration in a rain of quark and leptons (or antiquark and leptons) [2, 5, 8].

Hence, the appearance of the quark-gluon plasma decreases the probability of collision between the "free" particles. This concept is relative because quarks transfer but the environment compresses other quarks, which maintain the particles related as groups.

When the universe cooling reach $2.5\times10^{12}$ K, at $4\times10^{-5}$ seconds after the Big-Bang the quarks plasma allowed formation of hadrons. The quarks "u" and "d" were confined as protons and neutrons (table 1) in a much greater volumes than the ones required by their inertial mass. The strong interaction mediates by gluons kept the quarks bound staled their disintegration.

***Table 1: Configuration of baryons***

| | |
|---|---|
| Proton: $p \leftrightarrow \mathrm{uud}$ | Anti-proton: $\overline{p} \leftrightarrow \overline{\mathrm{uud}}$ |
| Neutron: $n \leftrightarrow \mathrm{udd}$ | Anti-neutron: $\overline{n} \leftrightarrow \overline{\mathrm{udd}}$ |

The black body radiation as a function of time $\mathrm{T}(t) = 1.52\times10^{10} \times t^{-1/2}$ [1], $[\mathrm{T}(t)] = \mathrm{K}$, $[t] = \mathrm{s}$, allows to calculate a temperature of $10^{12}$ K at $10^{-4}$ seconds. Below this temperature the particle physics, indicate that the universe contained a particle mixture of photons$\gamma$, electron-positron pairs, electronic neutrinos $\nu_e$, muon neutrinos $\nu_\mu$ and their antiparticles ($\bar{\nu}_e$ and $\bar{\nu}_\mu$) [2, 15]. The presence of neutrinos and antineutrinos could be directly related to the poor tendency to react between themselves or with matter or antimatter particles.

The temperature for uncoupling of neutrinos and antineutrinos of the $T_d$ > 1 MeV, allows these to move away from the reactions soup, but at any moment the reactions which generate antineutrinos were capable to significantly reverse the direction sense because the kinetic order favor antineutrinos emission. The following reactions generated antineutrinos dissipating the antimatter characteristic.

***Table 2: Neutrinos and Antineutrinos generation***

| | |
|---|---|
| [a] | $n^0 \rightarrow p^+ + e^- + \bar{\nu}_e$ |
| [b] | $n^0 + e^+ \rightarrow p^+ + \bar{\nu}_e$ |
| [c] | $\overline{n} \rightarrow \overline{p} + e^+ + \overline{\nu}_e$ |
| [d] | $p^+ + e^- \rightarrow n^0 + \nu_e$ |

In reaction [c], a positron is created but it could be coupled to be consumed in reaction [b], the sequence generates one proton and therefore has the tendency to decrease antimatter and generate matter.

$$\bar{n}^{0} \rightarrow p^{-} + [e^{+}] + \bar{\nu}_e$$
$$\downarrow \qquad [2]$$
$$[e^{+}] + n^{0} \rightarrow p^{+} + \bar{\nu}_e$$

CP symmetry allows predicting generation of neutrinos and antineutrinos to preserve to energy and angular momentum. However, the previous examples allow that annihilation became an unlikely event, along the primordial chronology of the universe.

After the plasma quark period, an average energy for a particle when T< 1 MeV, may support that photons (γ) generates electron ($e^-$) and positron ($e^+$). However these photons do not have the energy to generate heavier particles. The electron and positron would have the tendency to collision the respective antiparticle, to generate γ-photons. Hence, it is more probable that were generating at earlier times from reactions that involve hadrons.

Hence, it could be suggested a shared symmetry or slowing-down annihilation, not from the generation of matter and antimatter pairs, but from their generation in different reactions. These may be synchronized like concatenate reactions, until the time that antineutrinos emission out of the system reduces the rate of annihilation.

The Pauli interpretation predicts the existence of the neutrino and antineutrino as necessary to preserve de physical quantities or symmetry of the system. Both do not have electrical charge and their masses are very small. They are not subject to the electromagnetic or the strong forces, for which their interactions with the rest of matter should be very weak.

The 15 minutes stability of a free neutron $n^0$, results in disintegration into a proton, an electron and an antineutrino: $n^0 \rightarrow p^+ + e^- + \bar{\nu}_e \uparrow$ *[3]. Where, the antineutrino plays a role for the conservation of energy and angular moment within the reaction.

This relation [3] is not reversible, but when a titanic-star turns into a supernova, the large energy and densities generates allows an electron to react with a proton to generate a neutron in ligation state. However, this is not a true reversal of the substrate-product of the reaction [3] because a neutrino is emitted [4]. Hence, in the reaction [4] the neutrino is preserving different quantities of internal symmetry than the antineutrino: $p^+ + e^- \rightarrow n^0 + \nu_e \uparrow$ * [4]. *The symbol $\uparrow$ is used to show tendency to escape from the system, hence that the neutrinos do not participate in any equilibrium state.

The gauge treatment allows interpreting as mirror symmetry, the relationship of matter-antimatter. The mirror image preserves the angular momentum of helicity as opposite for in neutrino-antineutrino. Hence, when the spin is aligned with the direction of movement is positive and in reverse negative. This is a form to preserve quirality to avoid superposition in the same direction of the space-time [3]. Opposite sense for the reaction [3] and [4] required differentiable pathways to secure the energy conservation, angular momentum and quirality.

## Dissipative thermodynamics of Planck-CMB system

CPT symmetry conservation could be examined as if concurrent with a thermodynamic homogeneous local space, which does not allow a non-equilibrium system. The characterization of a universe dominated by the arrow of time, requires estimation if primordial state reactions were a function of a homogeneous thermic system. This assumption does not respond to the relation between the initial energy potential of Planck aggregating to generate critical energy and the dissipative thermodynamic potential of CMB.
Figure 1 shows temperature variations of CMB. This phenomenon could be described by a Boltzmann's distribution like a black body emission. This one, correspond to relation between wavelength versus radiation intensity, concordant with the subjacent quantum structure.

Observations lead to think that the universe is on very large scale close to isotropic. But, if radially homogeneous would be independent of distance of observers. But if not homogeneous, it could occupy a special locus in contradiction with Copernican's principle [16].

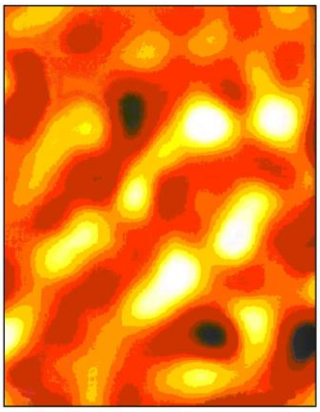

***Figure 1: CMB observation in one sky direction.*** *Obtain by the anisotropic cosmic telescope of Cambridge Mullard Radio Astronomy Laboratory/SPL. The color variation represents different temperatures, interpreted as revealing thermic differentiable structures. Hence, is could be assumed that a space characterized as uniform, allows a quantum structure to contain a non-homogeneous thermic distribution.*

Håvard Alnes and Morad Amarzguioui studying the alignment of CMB-anisotropies which look from outside the center slightly hotter in one direction than in the other seen to correspond to an inhomogeneous symmetric sphere, which could be interpreted as corresponding to a lumpy universe. These small fluctuations of CMB appear to align in a specific direction, explained by some investigators in terms of our displacement from the center of a void [17].

CMB allows evaluating expansion as quantum structure, but in itself a non-homogeneous thermic distribution. It could be assumed that results from the continuum cooling of the black body emission spectrum source. The first emitted photons would be more energetic and by temperature decay; the latter ones would be less energetic.

CMB-photons are characterized by elongation of wavelength requiring a larger temporal and spatial locus, which allows a correlation between the dissipation of the energy potential and space expansion. A decay of potential could be described as associated to the multiplication of photons. A factor supporting non-equilibrium and time-dependent elongation as a bottleneck controlling entropy increase.

CMB-system could be predicted with uniform distribution along the cosmic chronology, but generate voids-structures differentiable from the galactic one. This disparity results from quanta-multiplication been unaffected by gravity, even if does curve the trajectory of these photons.

The gravity exerted by the galactic cumulus, allows that galaxies remain filaments-aggregated, but as a function of the galactic distances subtracts from the rate of local expansion. Hence, results in voids that as a function of time become much larger than cumulus [18]. The same relationship was obtained when simulating quantum expansion as a function of distance and from which was possible to calculate the Hubble’s constant [19].

**Expansion arrow**

The universe total energy could not originated at a single locus, but that Planck particles integrate as a conjuncts of coupled states, which in the inflationary period accumulate with a minimum increment of entropy. At the end of this Era, starts a period of adiabatic expansion with an energy density decrease at half-life rate of initial dissipative potential.

A local system could be thermodynamically open by receiving matter and energy. Hence, the accumulative transition kinetics from pre-quantum to quantum supports inflation. This restricts the tendency to equilibrium, allowing the chronology to events, trough non-equilibrium.

This is preserved by the continuous decay of temperature of emission, when an initial spectrum losses the higher energy photons splitting into two. The resultant lower energy photons integrate into one subsequent spectrum. The increasing entropy during expansion may not affect openness if released as a collateral contribution to the increment of zero-point energy.

Thus, the space expansions do not allow that the Planck produced rain of particles became homogenous, but rather generates a spectrum stratified particles of different energy.

At the end of inflation, every energetic entity characterized as incrementally corpuscular. A coulombic walls behavior resulted in the primitive universe from the elevated number of particles collision at high energy.

These walls were dynamics an expansion produced a diminishing of energy density since by distribution in increasing volume, with entropy increase at lower and lower temperature levels.

In the period where temperature decreases from $10^{32}$ to $10^{12}$ K, the space phase associated to quantum inflation-expansion, the mechanisms of SPDC could be used to simplify a model of the potential energy dissipation. Energy decreases by factor ½ per n-cycle, which $E = 2^{-n} E_0$, this decay could be described as a function of half-life: $E = E_0 \; e^{-\mathrm{In}[2] \; n}$.

During this period the universe is dominated by radiation, with some particles, neutrinos, antineutrinos, electrons, positrons and small concentration of protons and neutrons (in a ratio of 1 nucleon per $10^9$ particles).

The constant increment of the time lapse required by sequencing a decreasing potential by half, is reflected in λ-elongation. Therefore, time became a bottleneck that restricts the decay rate. This, illustrated mathematically in terms the of Zenon's paradox, avoids that the potential dissipates suddenly and allows that the non-equilibrium state could approach slowly the equilibrium state.

Entropy S will be in constantly increasing in an expansion volume. The relation $H = E_T - \mathrm{S} \times \Delta\mathrm{T}$ represents a temperature gradient, between the photon of greater a lower energy, within each of the consecutive emission spectra. When $\Delta\mathrm{T} \rightarrow 0$ approached zero, the total energy of the system would be entropy and it could no longer contribute to expansion. In an open system, a quantum dissipative potential as a function of emission, allows that $\Delta\mathrm{T}$ diminished with continuous, increment of entropy and its dispersion as zero point state [ZPS] like a limit.

Thus, in a self-contained system an exit for entropy could result from the latter contribution of ZPS. The analogy is that a steady state $\Delta\mathrm{T} \neq 0$, could be maintain as long that relates a two compartment system and the temperature of the surroundings to the system decreases even more or faster.

Hence, it could be expected that a $\Delta\mathrm{T}$ gradient maintain its dissipative state link to decrease of energy density as a function of half time. This could be achieving by a relationship within a compartmentalized system, between emission spectra with a residual state of zero point. Hence, a thermodynamic continuous of expansion allows that the amount of S, configured by capacitance, increases but also its enclosing volume, according to the common property of S and ZPS of increasing with volume.

## Discussion

What theoretically is required, to configure an open-system within a single close universe, is a bifurcated thermodynamic capacitance, for the relationship between enthalpy and entropy. The latter, does not interact with the dissipative system by having no-returnable properties, also attributed to ZPE, or, vacuum fluctuations, etc.

Sakharov assumes that when the densities of energy are very high, to allows the production of pairs of particle-antiparticles, CP symmetry could be violated and annihilation allows a left-over of baryons.

These predictions were confirmed by statistical cyclotron studies of the weak force dependent disintegration of mesons K. These, showed that two disintegrations violated CP symmetry per each thousand and therefore survived annihilation.

## Conclusions

The equations that described interactions of quarks, leptons, atoms, molecules, mass, etc., should be intrinsically symmetric with regard to space-transfer. A sequence of nuclear or molecular restructuration could be characterized like invariant with regard to their point of equilibrium or constant.

Since neutrinos move away from the reaction locus, a symmetric return, restoring equilibrium becomes theoretical possible as a function of time symmetry. However, the universe is ruled by the arrow of time and a primordial reaction in a backward time arrow improbable.

The literature assumed that matter remnant of about $1/10^9$ from matter-antimatter annihilation, but is possible to seek alternatives solutions which do not involve a primordial annihilation. The antimatter property could be assimilating within antineutrinos. However, these do not interact by a reverse of reaction sequences, thus generated a unilateral direction, allowing that the antimatter characteristics appears as not reactant and as difficult to locate as neutrinos.

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