An open system thermodynamic pathway from Planck particles to hadrons

Dr. Alfred Bennun* and N. Ledesma
*Full Professor Emeritus of Biochemistry
Rutgers University

Abstract

The Universe Expansion evidences the possibility of thermodynamic dissipative structures, constituted by short-lived particles decaying and releasing energy, to form more stable ones during the period of 10^{-26} to 10^{-11} s. The thermodynamic of these processes favor the models, in which the cooling effects of expansion could be balanced by the temperature generated in the primordial absorption of bosons, particles decay and annihilation. The microscopic chronology during the state of plasma, maintains asymptotic freedom which allows multiple quark and antiquark aggregations, preventing massive annihilations. In the primordial quark-antiquark-gluon plasma emerges the Muons that show a 1% asymmetric annihilation, in the decay of B-mesons. This could be integrated into the cyclical elimination of antimatter, by incorporation into matter of the energy from environment bosons or pair annihilation. The self-duplication of pions provides such a mechanism because their constitutive quarks resist separation forces by generating gluons. Annihilation energy could be returned as a 99% that jointly with a 1% contributed by the resting mass of quarks, could create nucleons. The plasma evolved from pions and quarks annihilations, would have a large population of positrons, electrons and high energy photons. It is shown that coupling between reactions, allows nucleons cycles in which electrons, positrons and gamma radiation could be absorbed, generating neutrinos/antineutrinos. Hence, quantum chronology in a dynamics of open thermodynamics coupling becomes compatible with the description of the space-time like a continuum. In this, the universal constants, allows integrating dissipative potentials at different scales and within a large diversity of configurations, into the evolutive architecture of the universe.

Introduction

An open thermodynamic system allows a flow of energy-matter in the boundary of a region of space, but not in the case of a self-contained system [1, 2, 3, 4]. However, conceptually, openness could be not only a property of space, but also of time.

Hence, *the dynamics* of space-time [5, 6] allows continuous coupling between open states. These integrate, in a chronology that first allows the accretions of potentials by forming thermodynamic structures, which dissipate by conforming new ones, in a no-equilibrium made possible because of the efflux of the system of no-reversely reacting products.

The universe could be modeled as a self-contained system. In which, Inflation [7, 8] could be described as a process that allows a near-stationary state of entropy, with a cumulative increment of Planck particles. Hence, adding by their mutual spatial inter-foliation to an extending of the metric. The graphic of this cooperative increment of space, generates a sigmoid curve showing a rate higher than *c* [9].

At the micro level, the Expansion Era [10, 11, 12] would be characterized as a dissipative state of the energy potential, through which numerous short-lived particles decay generating other particles with longer half-life [13, 14]. The space increment modulates the relationship between temperature and permissibility of reactions.

Extending the open system characterization to the macro and local scales, a star could be described like a system of coupling of thermodynamic phases. A solar accretion phase, allows a potential that dissipates in the hydrogen fusion reaction, with the leak of neutrinos and radiation. The expansive tendency of the nuclear reaction, balances against gravity maintaining the system away from equilibrium. Exhausted the potential by the consumption of hydrogen, the system could no longer maintain the no-equilibrium and operates as closed. Consequently, gravity could then implosion the star.

Recently the astronomer Doug Finkbeiner recognized that the images from the NASA's Fermi Gamma-ray Space Telescope shows that perpendicular to the center to the Milky Way a bi-axial projection of relativistic particles, gamma and X radiation extending into two magnetic bubbles each of 25,000 light-years diameter [15].

This structure should be characterized as part of a black hole-accretion disk bubbles-system [16, 17] in an open thermodynamic structure. The accretion disk releases matter-energy into the black hole and eject into the bubbles particles-radiation, as angular momentum carriers [18, 19]. Their axial direction allows no-equilibrium with the accretion disk. Hence, it allows the continuous enlargement of the hole and the bubbles projected from the disk, over the history of the galaxy.

Examples that escape of the chemical equilibrium and maximized the potential of the substrate are: precipitate in the reaction media, gas emission, etc.

Sakharov [20, 21, 22] stated that from an initial symmetric state, a matter-antimatter a development of asymmetry within the primordial universe, involved: I: Violation of the baryonic conservation number. II: Violation of symmetry CP strong. III: Deviations from thermodynamic equilibrium.

The primordial asymmetry [23, 24, 25] is analyzed as a function of the chronology and without quark-antiquark massive annihilation. Therefore, it is assumed: I. Baryon number conservation by increasing mesons and pions. II. Violation of electroweak CP-symmetry with a 1% cumulative residual matter. III. Deviations of thermodynamic equilibrium as a function of a no-null transition time for $W^{\pm}$ bosons [26, 27] and the no-electroweak-interaction of products with leak of neutrinos/antineutrinos [14, 28].

In a subatomic particle reaction the intermediate states or generated virtual particles ($W^{\pm}$) [26, 27] show a time differential for their decay, which allows the progress of the final state at a time that the initial one had dissipated, generating a unidirectional gradient that prevent microscopic reversibility.

Results

The Big-Bang as a process of the emergence of Planck particles evolving into a thermodynamic continuum

The initial state of the generation of energy potential within a self-contained universe, could be idealized within quantum-mechanic treatment as the emerging of a single Planck particle [13] of 1.6×10^{-33} cm, defining universal constants. Thus, h constant imposed the progressive emergence of 1.6×10^{60} Planck particles, accounting for a density of two atoms of hydrogen per cubic meter. The success horizons of these singularities integrate preventing the existence of matter and causality [13].

The half-life of Planck particle: 5×10^{-44} s, is the initial instant of chronology, that manifest a causality radiation sphere of about $\tau \approx 10^{-41}$ s. This one becomes constituted by bosons with a Hawking temperature: $T_H = \dfrac{\hbar c^3}{8\pi G m k_B}$, $T_H \approx 8.2\times10^{30}\,\mathrm{K} \approx 4\times10^{20}\,\mathrm{MeV}$, where m is mass of mini-black hole [18].

The increment of the Planck particles follows the Boltzmann statistics [29], with a distance of 10^{-29} cm between nascent particles according to the uncertainty's principle, with an increment rate by time unit: dn/dt, conforms a Hawking's sphere. In the boson-fermion transition the quantum fluctuations could no longer interact with evanescent state generator of Planck particles [9].

A plotting of the process gives a sigmoid curve with the main increment at 10^{-35} to 10^{-33} s, at the end of the Inflationary Era, when generated bosons uncoupled from quantum fluctuations. The created energy potential reaches dissipative state when the increment rate of Planck particle ended. In this process some of the emerging Planck particles, as mini black holes, may have survived as primordial entities in the universe [13]. At about 10^{-36} s the generated high energy bosons developed mass: m> 140 GeV/c^2 [30, 31].

The asymptotic and dissipative state of the symmetric quark-antiquark-gluon plasma and meson creations

A 10^{28} K ultra-hot plasma appears symmetrically at 10^{-36} s, which density of the 10^9 million tons per cubic centimeter with a composition: quark-antiquark [32], leptons/antileptons, photons and gluons which as the carrier of the strong nuclear force by color charge interact between quarks to confer mass [33, 34, 35, 36].

The decay of bosons can be in the form of lepton-antilepton pairs $\mathrm{W}^- = e^- + \bar{\nu}_e$ and $\mathrm{W}^+ = e^+ + \nu_e$, 33% of cases, and in the form of quark-antiquark pairs $\mathrm{W}^+ = q + \bar{q}$, $\mathrm{W}^- = q + \bar{q}$, in 67% of cases, where q is a quark and $\bar{q}$ an antiquark [37].

When the distance between quarks becomes very short, the intensity or interaction decreases. Hence, in between to 10^{-30} to 10^{-10} s the plasma quark-gluon would show asymptotic freedom. This mechanisms allows that each quark or antiquark to be in an unstable state of attraction with the others [13].

Starting a 10^{-25} s, the $2\text{x}10^5$ cm diameter universe, at 10^{23} K a generation of particles of very short-life consisting of two or more quark/antiquark, could be subject to asymptotic freedom, if the distance is smaller than a Fermi: 10^{-13} cm, allowing a continuous re-configuration.

If ordered by the half-life particles that arise in high-energy colliders such as LHC, and projecting these data could be simulated a cosmic chronology quark-gluon plasma evolving from particles with a low half-life to these with a higher one: boson $W^{\pm}$ y Z : 10^{-25} s, $\rho^{\pm}$, ρ^0, ω^0: 0.4×10^{-23} s, φ: 16×10^{-23} s, η’: 3×10^{-21} s, J/ ψ : 7.2×10^{-21} s, ϒ: 1.3×10^{-20} s, η: 5×10^{-19} s, π^0: 0.84×10^{-16} s, D^0: 4.10×10^{-13} s, B_c^+: 4.6×10^{-13} s, D_s^+: 4.9×10^{-13} s, D^+: 1.04×10^{-12} s, B_s^0: 1.46×10^{-12} s, B^0: 1.53×10^{-12} s, B^+: 1.63×10^{-12} s [38].

This sequence allows to infer that the decay of particles produced news ones, gradually more stable. In addition, residual high-energy photons, trying to separate the quark-antiquark inside mesons, allows an increment of mesons number.

At 10^{-10} s started the Quark Era. Annihilation rather than acting to decrease the matter/radiation ratio increases the amount of energy that could be confined with quarks. Hence, functions as a mechanism that allows consuming radiation and preventing that any massive primordial quark-antiquark annihilation immerses the universe in gamma radiation.

This re-confinement of the energy allows to enhance the 1% electroweak CP-asymmetry, reported for the decay of mesons pair [39, 40], as a pathway for the predominance of matter.

Pions decay

The short lived particle decays [37, 41] favor that the released energy becomes substrate of subsequent reactions with eventual duplication of pions. This process prevents accumulation of high energy photons and favors the increase in the population of quarks versus antiquarks, which conforms the quark-gluon plasma at 10^{-10} s. Hence, allowing an event chronology in which the recycling of energy potencies any asymmetric quark-antiquark state plus a residue of lower energy photons.

The pions $\pi^{\pm}$ show zero spin have a mass of 139,6 MeV/c^2 and a half-life of $2{,}6 \times 10^{-8}$ s. Disintegrating in

I.a.1. $\pi^+ \to \mu^+ + \nu_\mu$, where $\pi^+ : u\bar{d}$

I.a.2. $\pi^- \to \mu^- + \bar{\nu}_\mu$, where $\pi^- : \bar{u}d$

The combination $d\bar{d} / u\bar{u}$ constituted a ligature state: π^0, mass of 134,97 MeV/c^2, and a half-life of 8.4×10^{-17} s, principal disintegration $\pi^0 \to 2\gamma$.

The pions: π^- / π^+, can be formed from a quark: $d/\bar{d}$, respectively, plus one photon: $d + \gamma \to u + \pi^-$ or $\bar{d} + \gamma \to \bar{u} + \pi^+$. In addition, can be formed from a quark: $u/\bar{u}$, plus one photon: $u + \gamma \to d + \pi^+$ or by symmetry $\bar{u} + \gamma \to \bar{d} + \pi^-$.

Muons decay

The lepton Era: the annihilation of muons at 9×10^{-5} s [37, 41].

I.b.1. Positive muon: $\mu^+ \to e^+ + \nu_e + \bar{\nu}_\mu$

I.b.2. Negative muon: $\mu^- \to e^- + \bar{\nu}_e + \nu_\mu$

The muon-antimuon pair's annihilation is 1% asymmetry [40]. This allows inferring reactions progresses from a primordial CP-violation process, at constant total energy capable to increment the relationship matter/radiation at differences steps of the chronology.

Integration of reactions and asymmetry

The residual asymmetry quark-antiquark would restrict the generation of nucleons at 4×10^{-5} s the generation of antiproton and antineutron. At this time the temperature drops from 10^{12} K to 10^{10} K and density from $10^{14} - 10^{4}$ [g/cm^3].

Unlike the electron-positron pairs, which are abundant when the temperature is higher than their mass, protons and neutrons appear only at a temperature well below its mass (100 MeV = 10^{12} K), being that mass (≈ 938 MeV) corresponds to 10^{13} K.

II.a. $n^0 + \gamma \to p^+ + e^- + \bar{\nu}_e$

II.b. $n^0 + e^+ \to p^+ + \bar{\nu}_e$

II.c. $p^+ + e^- \to n^0 + \nu_e$

II.d. $p^+ + \gamma \to n^0 + e^+ + \nu_e$

The first reaction shows how weak interaction is able to shift the charge of a particle. Neutron/antineutron conversion into proton/antiproton occurs with the release of antineutrinos/neutrinos restricting microscopic reversibility. The antineutrinos emission increase as *handedness* [42] carriers favors the decrease of antimatter.

The decay reaction **II.a**: $n^0 \to p^+ + e^- + \bar{\nu}_e$, with half-life of free neutron is 886 s, but could be activated by interaction with the energy of the environment, according to the sequence:

$$\begin{array}{c} n^0 + e^+ \to p^+ + \bar{\nu}_e \\ e^- \to \ e^- \\ \hline n^0 + e^+ + e^- \to p^+ + e^- + \bar{\nu}_e \\ \hline n^0 + \gamma \to p^+ + e^- + \bar{\nu}_e \end{array}$$

This pathway shows as a feedback [43] the modulator effect of energy since the rhythm of gamma photon production controls the decay rate of neutrons.

The following reactions are obtained by charge symmetry and anti-matter quality, thus, replacing the (+) by (–) and vice versa, or a particle “*x*” for its anti “ $\bar{x}$ ”, and vice versa [32].

III.a. $\bar{n}^0 + \gamma \to p^- + e^+ + \nu_e$

III.b. $\bar{n}^0 + e^- \to p^- + \nu_e$

III.c. $p^- + e^+ \to \bar{n}^0 + \bar{\nu}_e$

III.d. $p^- + \gamma \to \bar{n}^0 + e^- + \bar{\nu}_e$

It could be diagram a sequence of reactions allowing a matter survival system:

IV.a. $p^+ + p^+ \to \pi^+ + p^+ + n^0$

IV.b. $\pi^+ + p^- \to K^- + \pi^+ + \Lambda^0$

IV.c. $K^- \to \pi^- + \pi^0$

IV.d. $\Lambda^0 \to n^0 + \pi^0$

K^- kaon decays in 1.24×10^{-8}, Λ^0 neutral Hyperon with a strange quark 1,115 MeV decays in 2.6×10^{-10} s.

As shown in figure 1 the symmetric reactions in the lines **II** and **III**, are interconnected. Two protons interact to generate a pion π^+ proton p^+ and a neutron n^0 (**IV.a)**. A pion π^+ and antiproton p^- generates K^-, a pion π^+ and neutral hyperon Λ^0 (**IV.b**). The kaon K^- decays into a minus pion π^- and a neutral pion π^0 (**IV.c.**). The Λ^0 hyperon decays into a neutron n^0 and a neutral pion π^0 (**IV.d.**). In order to simplify figure 1, the decay of pions $\pi^\pm$, were not included, but are computed to show a residual: p^+, p^-, 3 e^-, 3 e^+, cancelable by pairs annihilation and matter survival: 4 n^0 / 2 $\bar{n}^0$, plus: 7 ν_e, 7 $\bar{\nu}_e$.

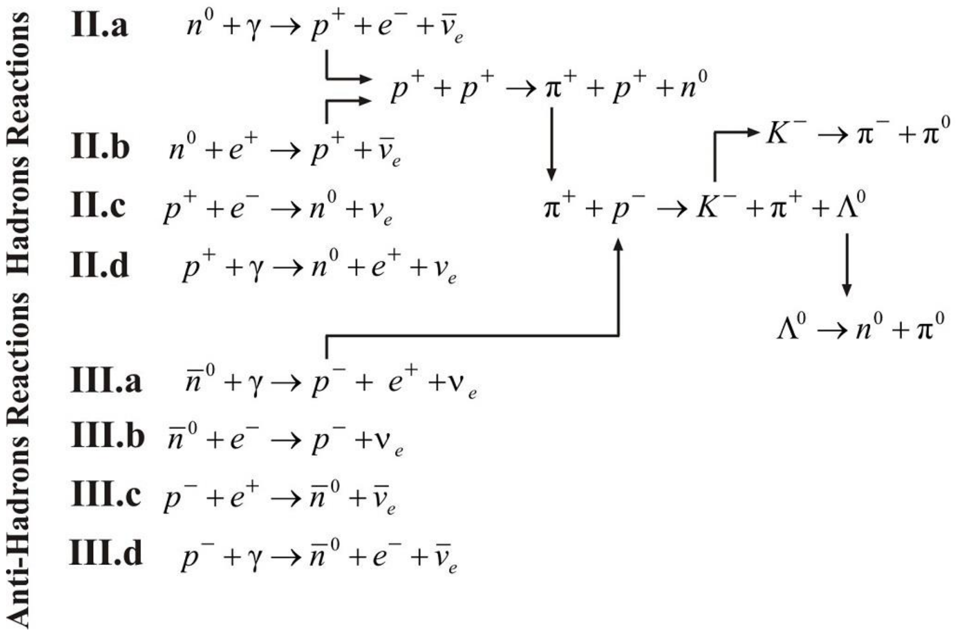

Figure 1: The emission of neutrinos and antineutrinos as carriers of handedness. *The scheme allows predicting the unidirectional flow of reactions. In III.d and II.d the gamma radiation generated in annihilation could be absorbed generating other particles, plus neutrinos and antineutrinos, which preventing reversibility. The sequence of reactions could be shown in hadron/antihadron balance. The reactions for hadrons: neutron (n^0) and proton (p^+), are indicated by [II]. The ones for antihadrons: antineutron ($\bar{n}^0$) and antiproton (p^-), are indicated [III].*

Annihilation of the nucleon-antinucleon pairs persists until 20 MeV and the resultant photons at a temperature greater than 7×10^9 K could generate electron-positron pairs [44].

The annihilation of electron-positron pairs start at activation temperature 0.511 MeV at 4 seconds. The pairs are no longer relativistic and annihilate as photons increasing their temperature: $T = \left(\frac{11}{4}\right)^{1/3} T_\nu$. The numeric resolution for a Boltzmann equation for annihilation electron-positron shows that the equilibrium lost starts at $T = m_e$ continuing to $T = m_e/25$, where m_e is electron mass. This process leaves a negligible positron residue as a cold fossil and the electrons resulting from the matter-antimatter asymmetry. When $T = m_e/10$, only remains 1 per 1000 initial pairs [13].

Cycle interaction of hadrons (o antihadrons)

The flow of reactants and products could be organized cyclically. If there is quantitative difference between matter and antimatter, the former could be maximized as a function of the cycle turnover. The relationship between usually accepted total numbers of neutrinos 10^{87} versus number of baryons 10^{78} suggests that the neutrinos excess may be related to turnover number, favoring the increment of matter over antimatter.

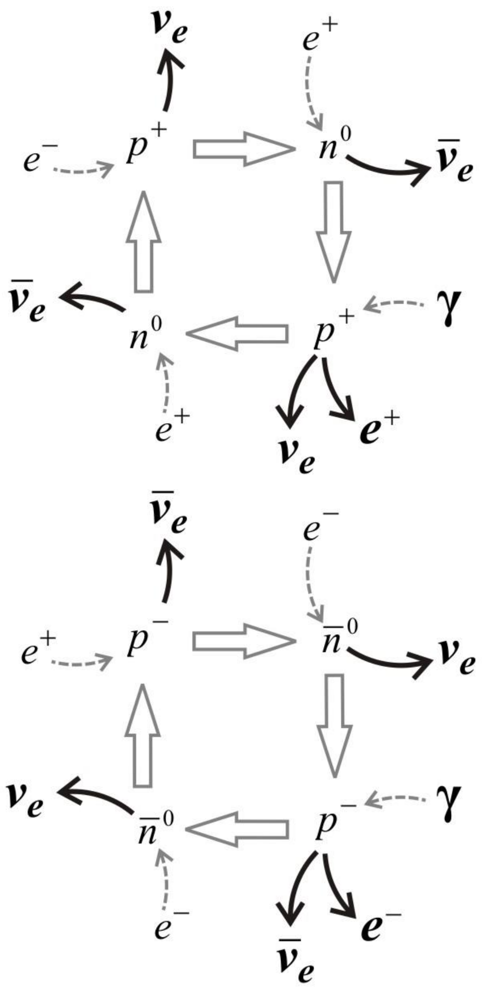

__Figure 2:__ Coupling between reactions allows cycles; this one shows that one electron and one positron are consumed to absorb gamma radiation, generating neutrinos and antineutrinos.

Figure 2 shows that an excess of electrons and positrons that required 10^{-7} s to reach annihilation could instead be absorbed as hadrons or antihadrons with a production of neutrinos and antineutrinos. Also the photons could be consumed in quantities much higher than the hadrons presents in the system. The hadrons/antihadrons recycling could support a near stationary state of the ratio: $n_p / n_n = e^{1.29/0.7} \approx 6.25$ [13].

However, starting at 2 seconds free neutron decay: $n^0 \to p^+ + e^- + \bar{\nu}_e$, in proton, electron and antineutrino to achieve stability through the synthesis of deuterium, 200 s:

$n_p / n_n = e^{1.29/0.7} \approx 7.7$ [13].

The decay of particles and systems irreversibility

The Feynman schemes [45, 46, 47] show that bosons $W^{\pm}$ change the flavor of decaying particles preserving the parity of electrical charge through the emission of electron/positron: $W^{\pm} \to e^{\pm} + \nu_e / \bar{\nu}_e$ and handedness by emission of neutrino/antineutrino. The bosons $W^{\pm}$ are the intermediate vectors of the weak force with a range of 10^{-18} m.

Treating the systems in terms of activation energy [48, 49] allows illustrating the kinetics and thermodynamics of the conversion neutron→proton trough the transition $d \to u$. In the figure 1 the solid line curves represent peaks of activation energies which are delocalized in successive steps of the reactions. In these coordinates the time is a function of progress of the reaction. The intermediate W^- decays in 10^{-25} s allowing the formation of products: electron and antineutrino, but not its reverse reaction. This one requires a larger time than the half-life of W^-.

Hence, energy of activation by W^- by decaying during formation of products do not allow is reverse reaction. The ordinate axis shows the energy release during exothermic conversion $d \to u$ involves a loss of resting mass 5.6 MeV→2.3 MeV, which appears as kinetic energy added as inertial mass of the emitted electron.

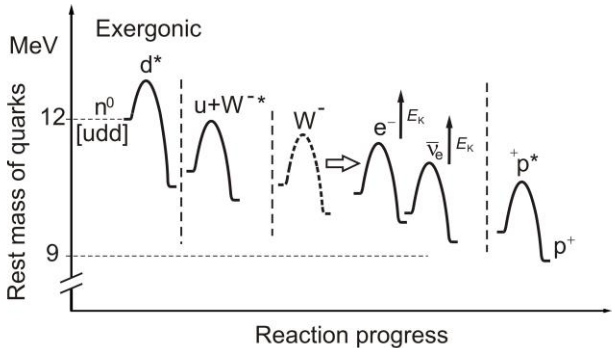

Figure 3: *Illustrates the intermediate reaction $d \to u + W^- \to u + e^- + \bar{\nu}_e$. The transition states involves the reactions of one quark u plus boson W^- which decays in products: proton, electron and*

antineutrino. W^- confers transition energy (activation) and asymmetry. A dotted curve indicates a much shorter half-life of the transition states which in this context prevents the reversibility of products into substrate. The very short half-life of $W^{\pm}$ allows that the transition-activation energy dissipate and prevents reaction equilibrium. Symmetry quantity $n \leftrightarrow \bar{n}$ *would yield a similar representation of the disintegration of antineutron:* $\bar{n}^0 \rightarrow p^- + e^+ + \nu_e$ ($\bar{d} \rightarrow \bar{u} + W^+ \rightarrow \bar{u} + e^+ + \nu_e$) *(involve the vector boson W^+) and therefore is not illustrated. The scale is based on the resting mass of two down quarks (d) of 5 MeV each and one up (u) of 2 MeV. (*) Excited or transitions states. The arrow ↑ indicates that the emission of electrons and antineutrinos escape from the system.*

When a Titanic star becomes a neutron star and later on a supernova the enormous energy density allows an electron to react with a proton as illustrated in figure 4 to generate neutrons strongly bounded between them.

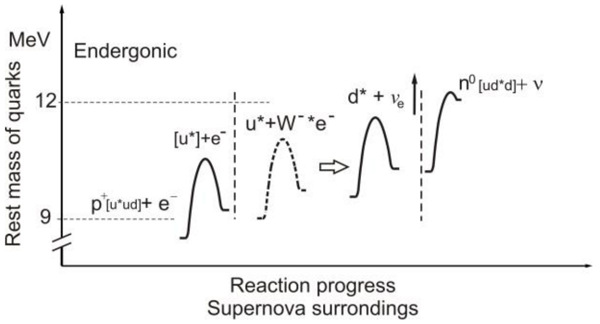

Figure 4: *Illustrates the endergonic reaction:* $p^+ + e^- \rightarrow n^0 + \nu_e$*, the combination of a proton and an electron to generate a neutron and a neutrino. The surrounding energy could generate a virtual W^- increasing the no-relativistic resting mass of quark u by incorporation of 3 MeV to form a quark d. Such reactions are produced in the extreme conditions of the formation of neutron stars. The reaction follows the statistical distribution of Fermi-Dirac:* $f(p) = 1/[e^{(E-\mu)/T} + 1]$*, for fermions and photons-electrons at same temperature* $T_{e^-} = T_\gamma$*. Symmetric reaction* $p^- + e^+ \rightarrow \bar{n}^0 + \bar{\nu}_e$*, from antiproton to antineutron, may require the boson W^+ and could be possible in the primordial quark-hadrons Era, but would not be observable in the present time, if we accept that there are not antimatter stars. The emergence of neutrinos and their escape generates a non-equilibrium system.*

Discussion

The processes of asymptotic freedom, pair annihilation and photon absorption allow re-confinement of energy within particles of increasingly longer half-life. This could maximize CP-asymmetry beyond the 1% reported by Fermilab's team for the disintegration of mesons-B [40]. Hence, it could be diagram reactions sequences for the eventual predominance of matter. These mechanisms could avoid massive annihilation and/or that gamma radiation could be cyclically absorbed generating particles.

The no-equilibrium thermodynamic results from systems' effluents pathways, such as leak of neutrinos/antineutrinos, accumulation along the chronology of zero-point-energy (ZPE) [50, 51], the decrease of the temperature of the emission spectra of cosmic background radiation (CMB) [52].

A microscopic chronology becomes manifest from the properties of the aggregate of particles, by equations bases in the density and pressure. ZPE becomes uncoupled from the thermodynamic system to become coupled to expansion rate "*a*" by iteration data of the system [53].

ZPE pressure could have an analogous role to the cosmological constant Λ in Friedmann's equations: [1]

$$\frac{\ddot{a}}{a} = -\frac{4\pi}{3}(\rho + 3p) + \frac{\Lambda}{3}, \qquad [2]:$$

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi}{3}\rho - \frac{\varepsilon}{a^2} + \frac{\Lambda}{3}$$

[13, 53, 54]. Where, ρ is density of mass, p pressure and ε curvature sign: 0, 1, -1.

Operating the expressions [1] and [2] it is obtain the density derive: $\dot{\rho} = -3(\rho + p)\frac{\dot{a}}{a}$, as independent of the Λ parameter [13, 54]. Thus, it could be infer that as a function of expansion ZPE express an invariant density: ρ_{ZPE}.

The densities species-structures thermodynamically coupled during expansion: $\sum_i \rho_i$, plus ρ_{ZPE}, that uncouples, verify: $\sum_i \rho_i + \rho_{ZPE} = \rho_{total}$. Operating, it is obtain $\frac{\sum_i \rho_i}{\rho_{total}} + \frac{\rho_{ZPE}}{\rho_{total}} = 1$, in where effluent ZPE tends to become dominant: $\frac{\rho_{ZPE}}{\rho_{total}} \to 1$ and $\frac{\sum_i \rho_i}{\rho_{total}} \to 0$ tends to a minimum.

By total energy conservation, the density of the system of space-time [54] becomes redistributed between a variety a dissipative structures and effluents. The common potential: ZPE allows a state in which the system potential could not enter in equilibrium while the dominant density is greater than ρ_{ZPE}. Hence, it could have the role of a flatness feedback. Einstein predicted that fields in the space-time system when temperature approached zero, would show a basal oscillatory remnant or frequency [55].

The interfolding of Planck particles expands the metric in the primordial state, the boson multiplication by Hawking's radiation effect and the temperature decrease coupled to expansion, allows a correlation between the De Broglie's wavelength increments with ZPE adding. The algorithmic development will depend of the dynamics between dissipative thermodynamic versus gravitation [53]. At the large scale this systematic correlation predicts conformation of voids- superclusters.

Conclusions

It was developed a quantum model within a chronological continuum of open thermodynamic systems, coupling the dissipative states of microscopic and macroscopic structures, into a single chronology. The symmetric surging of matter-antimatter particles decay and the annihilation energy could be naturally integrated by the temperature-expansion parameter. This treatment allows evidencing a pathway for energy to drive the predominance of matter and its stabilization as hadrons.

The quark-hadron-antihadrons maximize a CP-asymmetry electroweak of 1%. The release of the electroweak force integrates particles reactions into unidirectional pathways. Hence, leaving matter as the only resultant from the absorption of photons generated by annihilation. These processes are in no-equilibrium through the open system affluent pathways: phase transitions, particle decays, releases neutrinos/antineutrinos, fossil radiation (CMB), ZPE, etc.

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