QUANTUM VACUUM, BIG BANG, ENTROPY: WHICH IS THE STARTING POINT?

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The quantum vacuum is a material medium capable of polarization and equipped with its own electric permittivity, permeability and dielectric constant. It has been hypothesized that our Universe arose from a perturbation in the quantum vacuum, when an inflationary mechanism, correlated with a false vacuum state, led to the production of cosmic matter and to the huge expansion that took place 1^{-35} seconds after the Big Bang. Therefore, according to this framework, the vacuum endowed in our Universe is primitive to it.
In this brief note, we go through a different scenario. At the very beginning of 1^{-43} seconds after the Big Bang, our Universe was equipped with an energy $=10^{19}$ GeV and a temperature of 10^{32} K, while its horizon was 10^{-25} cm and the density 10^{96} kg/m^3. Therefore, at the very start, there was no place for the quantum vacuum state into our 4D spacetime cosmic manifold. Indeed, the quantum vacuum state stands for the zero-point field, where the energy is the lowest possible. At 10^{-36} seconds after the Big Bang, the energy lowered at 10^{16} GeV, while at 10^{-32} seconds the temperature decreased at 10^{28} K. The sudden decreases in energy and temperature led a part of the energy to randomly reach the low energetic levels of the quantum vacuum, that experienced an abrupt increase in volume. We can state that, from an initial, very high energetic state, a secondary, less energetic quantum vacuum state arose. Because the quantum vacuum is equipped with "dark energy", i.e., an unknown antigravitational force, the Universe underwent a rapid expansion so that, from an horizon diameter of 10^{-25} at 10^{-43} after the Big Bang, it reached the size of about one-meter diameter at 10^{-32} seconds.

The "real" cosmic particles (apart from some nuclei, that are very stable and almost eternal) are able to reach very low energetic levels, due to their interactions with other matter and energy. Below a given energetic threshold, they are "trapped", in form of quantum harmonic oscillators, in the quantum vacuum's medium. They cannot "escape" from the vacuum: just short-lived couples of "virtual" particles (standing for the variance of the field strength in the minimal energy state) reach high energetic levels, but they are rapidly annihilated and come back to the quantum vacuum's reservoir. The stepwise particles' trapping leads to a progressive increase of the quantum vacuum volume, while the quantum energy density per unit volume is kept constant (**Figure**). The vacuum energy density does not change, because the oscillations cannot approach one each other at the short Planck length distance. The quantum oscillations in the vacuum must repel one each other, otherwise the vacuum energy density would hugely increase. Therefore, the novel contributions to the vacuum (coming from the trapped particles) lead to an increase in the vacuum volume, but not of its energy density.

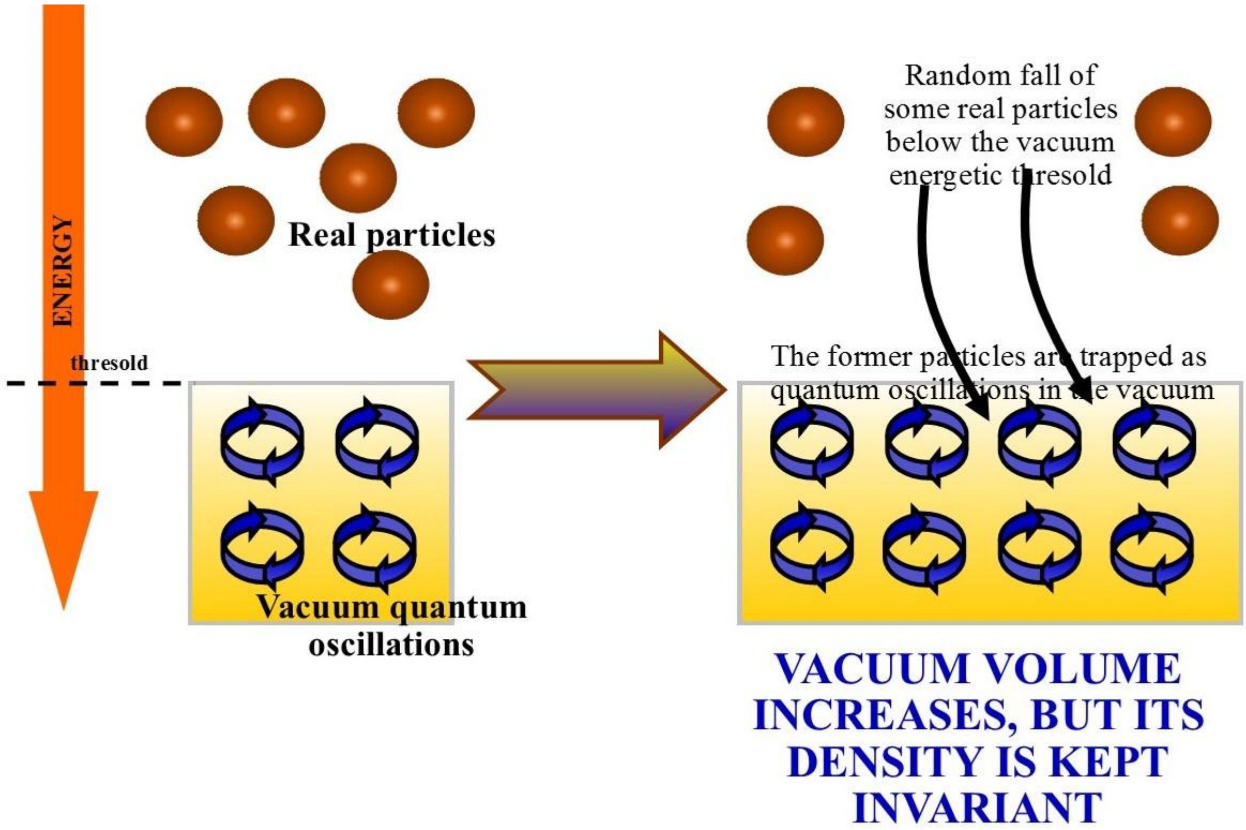

Figure. *Possible mechanisms of particles trapping in the vacuum. A few real particles, equipped with energy/matter, randomly cross an energetic threshold and fall into the low-energy vacuum levels, where they become quantum oscillations. The progressive intake of "former" real particles increases the vacuum's dimensions, while its energy density is kept constant. In the whole system (the "real" Universe plus the vacuum), the enthalpy is preserved, while the free energy (the real particles) decreases and the entropy (the energy stored into the vacuum) increases.*

The increase in vacuum volume leads to increase in dark energy, and consequently to an accelerated Universe expansion (currently, the visible horizon is 10^{29} cm, the cosmic density is 10^{-29} gr/cm^3, the matter corresponds to one atom/m^2 and the space is expanding at a speed of 74,3±2,1 km/sec per megaparsec). One of the possible explanations of the anti-gravitational strength of the quantum vacuum is the cosmological constant. Indeed, the quantum vacuum is believed to display a negative pressure (an anti-gravitational force) that equals its energy density and causes the accelerated expansion of the Universe. The cosmological constant displays a negative pressure: the amount of energy in a container full of vacuum increases when the volume increases. The dark energy amount stands for the 73% of the whole Universe: if it is encompassed in the vacuum (as proposed by some scientists), this means that the vacuum occupies the 73% of the Universe, and it is increasing. In sum, due to the increase in quantum vacuum which leads to cosmic accelerated expansion, the dark matter density is kept constant, and the density of "visible" matter and radiation is diluting.

Now we ask: how does the second law of thermodynamics enter in this framework? Could it be correlated with increases in quantum vacuum? We propose that the quantum vacuum, that “attracts” the falling particles, could be the source of the entropy increase occurring in our Universe. In the whole system encompassing both the “real” Universe and the vacuum, the total enthalpy is constant (the total mass-energy of the Universe consists of about 10^{69} Joule), while the free energy (standing for the real particles in our framework) decreases and the entropy (standing for the energy encompassed into the vacuum) increases, due to the continuous trapping of a large number of former particles into the quantum vacuum. Indeed, an increase in entropy might stand for an increase in vacuum dimensions, while the vacuum energy density is kept constant. Summarizing, free energy = real particles, and entropy = quantum vacuum.

We propose a change in the current paradigm. The latter states that the vacuum quantum fluctuations (dictated by the Heisenberg energy-time uncertainty principle) are able to cause, through an inflaton-based mechanism, the occurrence of the Big Bang and our Universe. In our framework, the opposite takes place: the very high energy at the beginning gave rise to the quantum vacuum that currently stands for the 73% of our Universe.

Some problems need to be solved by further studies:

a) The main problem is: why the most of the oscillations cannot escape from the quantum vacuum? Is there a barrier? In long times, due to the Heisenberg energy-time uncertainty principle, a quantum oscillation trapped in the vacuum cannot escape in order to become a real particle. Another possibility is that there must be in the vacuum something that traps the oscillations, preventing them to increase their energy and to become once again real particles. Therefore, we ask: which unknown factor traps the former real particles into the vacuum?
b) At our biological level of observation (say on the Earth), we do not experience that the cosmic vacuum dilates at the amazing speed of 74 km/sec. Our bodies are not dissolved, nor dilated, with time passing, even if the entropy increases also in our meso-level environment. Are there zones of local decrease in entropy? Is it feasible that high concentrations of “real” matter prevent the vacuum to increase in local areas, but do not prevent entropy to increase everywhere?

In conclusion, we draw some previsions, testable by future experiments:

1) If the quantum vacuum increases in volume, its total energy increases, although its energy density does not vary. The vacuum must take the energy from somewhere, e.g., from the real particles. This means that the cosmic matter is lowering. Is it possible to proof that the matter is decreasing in our Universe? A feasible experiment is to calculate (in a closed micro-system) the total matter/energy amount and to see whether it decreases with time, due to its partial annihilation. Remind that just a very tiny amount of annihilation is needed, e.g., possibly, just a few particles/ huge vacuum volumes.
2) Nuclei cannot annihilate, while particles such as photons are able to disappear into the vacuum. Therefore, in a future time, the observable Universe will be equipped with just the “real” matter that cannot decay (such as the simpler atoms). The cosmos will stop expanding, because the matter to “destroy” is finished and the anti-gravitational vacuum cannot further increase in volume.

3) In the vacuum, although the predicted energy is very high (10^{133} j/m^3), it might theoretically equal the zero, due to the reciprocal deletion of the opposite charges. However, the experimentally detected amount of vacuum energy is positive, although slightly (10^{-9} J/m^3). Why this feeble amount of energy is endowed in the vacuum, if we expect that it must be zero? The cause of this tiny amount could be due to the continuous, slight intake of energy from the real particles. In order to test this hypothesis, we might calculate how many real particles are trapped into the vacuum (that has a density of 10^{-17} kg/m^3) in every instant. How much increase of vacuum can be predicted, when the annihilation of just a single particle (of a known mass and energy) occurs? How much is the cosmic entropy production/sec, and does it match with the experimentally detected increase of intergalactic space expansion?