A Note on the Energy of the Vacuum

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We consider that the vacuum has not any energy.

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From the first principle of the thermodynamics

$$dU = dQ - dW \tag{1}$$

where U is the energy, Q the heat and W the work, with $U = \rho V$, $W = FR = PSR = PV$, ρ being the energy density, V the volume, F the force, R the distance, P the pressure and S the surface; for the vacuum, an empty space where $dQ = 0$, $d\rho = 0$ and $dP = 0$, we would have that: $dU = \rho dV$, $dW = PdV$ and $dU = -PdV$, then $\rho dV = -PdV$, and

$$\rho = -P \tag{2}$$

If $\rho > 0$ (which implies that $U > 0$ because $U = \rho V$), then $P < 0$, and any particle that enters the vacuum would go to the center. As this would also happen in the adjacent vacuum, then the particles would recede, that is, there would be antigravity (repulsion), which would produce the expansion of the space. This would produce the redshift of the light by Doppler effect, but the light of the galaxies is redshifted because the light scatters the microwaves of the Cosmic Microwave Background Radiation (CMBR) losing energy (which implies also that there was not any Big Bang) [1, 2]. Then, ρ cannot be positive.

If $\rho < 0$ ($U < 0$), then $P > 0$, and any particle that enters the vacuum would go to the periphery. As this would also happen in the adjacent vacuum, then the particles would approach, that is, there would be gravity (attraction), which would produce the contraction of the space. This would produce the blueshift of the light by Doppler effect, but this has not been observed. Then, ρ cannot be negative.

Therefore, ρ would be zero ($U = 0$). And the vacuum has not any energy (which implies also, together with the no Big Bang, that the Higgs boson does not give a mass to the other particles, and the Casimir effect may also be explained without any vacuum energy [3]). In addition, P would be zero, which implies a static space.

This affects also to the quantum harmonic oscillator (QHO), and hence to the quantum field theory (QFT). The energy of the QHO is: $E_n = (1/2 + n)h\nu$, where n is the number of particles, h the Planck's constant and ν the frequency. Thermodynamically, it would be: $\langle E \rangle_T = (1/2)h\nu + h\nu/(e^{h\nu/kT} - 1)$, where $\langle E \rangle$ is the mean energy, k the Boltzmann's constant and T the temperature. In the vacuum, $n = 0$, which implies $T = 0$, it would be:

$E_0 = (1/2)h\nu$ and $\langle E\rangle_0 = (1/2)h\nu$, then the vacuum energy, or the zero (temperature) point energy, would not be zero. This anomaly can be solved redefining the energy of the QHO as: $E_n - (1/2)h\nu = nh\nu$, and $\langle E\rangle_T - (1/2)h\nu = h\nu/(e^{h\nu/kT} - 1)$.

In summary, we consider that the vacuum has not any energy.

[1] José Francisco García Juliá, A Brief and Elementary Note on Redshift, May 26, 2010.
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[2] José Francisco García Juliá, Cosmological and Intrinsic Redshifts, November 19, 2010. (Revised, December 13, 2010.)
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[3] José Francisco García Juliá, A Note on the Boson of Higgs, October 1, 2012.
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