Calculation of the energy density of space-time and study of zero energy states. A universe of matter, light and dark energy

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Abstract

Some researchers have recently suggested by studying the shape of the universe according to the most recent observations, that the possible origin itself has been from a state of zero energy or very close to zero. This seems to be in contradiction with the relativistic energy coming from its mass, m, which determines that its energy is equal to or greater than mc^2. However, the hypothesis of dark energy as a negative energy field, in a global energy balance and its enormous weight with respect to dark matter and baryonic mass, could make us think that the total energy of the universe could be zero or very close to zero. In this paper we work with this hypothesis, and the vacuum field is carefully studied by studying a wave function that represents it. This wave function is obtained from a Klein-Gordon type wave equation that is studied here. The excellent results obtained in terms of calculating the vacuum energy density, the vacuum as a physical state with its own mass and therefore capable of curving space-time, and the introduction of dark energy as an essential element in the universe, make this hypothesis and our vacuum model are more than just one more hypothesis to consider.

Keywords

vacuum energy density, vacuum field, dark energy.

1. Introduction.

Firstly, we carry out the following energy approach:

a) The universe is an isolated system, therefore its total energy is conserved
b) The total energy of the universe always has been and is equal to zero.

The total energy of the universe is the sum of the following energies, the dark energy plus the energy due to the photons plus the energy due to the masses, in this case dark matter and baryonic mass.
The energy due to the photons and the energy due to the masses are positive energies but the dark energy is a negative energy so that although all the components of the total energy are significant, the total sum of the energies can be equal to zero, that with a total energy equal to zero it is possible, energetically, the existence of our current universe. That is because this zero energy would be always its total energy. This necessarily implies the existence of the dark energy field; without it this energy balance would not be possible. This conclusion of zero energy agrees with the considerations made by Professor Fulvio Melia in relation to the shape of the universe and its possible energetic origin [1].

In this paper we will search for a wave function, solution of a relativistic wave equation, that represents the state of the vacuum in those circumstances of zero energy and we will study that solution carefully calculating with it the vacuum energy density in the space of definition of the wave function, the Minkowsky space, and later by means of a detailed mathematical calculation we will find the value of that vacuum energy density in Euclidean space, where the experimental measurements have been recently made, comparing the results. Finally, in the conclusions we will explain more extensively our hypotheses and the results obtained.

2. Search for the mathematical solution.

We are going to study a wave function that represents the vacuum field and with it we are going to determine the vacuum energy density.

To carry out a quantum study of the vacuum field we are going to use a Klein-Gordon type equation without potential, studying its solutions for zero energy.

**Special description of the title. (dispensable)

In the case of a problem with spherical symmetry the is:

$E\psi = -(h^2/8\pi^2 m)\ (\eth\psi/(\eth^2 r)) + mc^2\psi$

As it is a relativistic equation, we can very well consider its solution defined in the Minkowsky space. in our case R = ict + r

We study a wave function ϕ(R) and we are working in the International System of Units

$E\phi(R) = -(h^2/8\pi^2 m)\ \phi(R)`` + mc^2\phi(R)$

Setting the energy of the quantum state, E, equal to zero, E=0, result:

$0 = -(h^2/8\pi^2 m)\ \phi(R)``+ m^2c^2\ \phi(R)$
$\phi(R)`` = (m^2c^2 8\pi^2/h^2)\ \phi(R)$
$k^2 = m^2c^2 8\pi^2/h^2$
$k = 2{,}8\pi mc/h$
$\phi(R)`` = k^2\ \phi(R)$

A solution [2] of this differential equation is the following:
$\phi = e^{-kR}$ where R = ict + r

Normalization in Minkowsky space:
$\phi\ \phi^* = e^{-2kr}$
$1 = \int_o^\infty e^{-2kr} dr = 1/(2k)$
$k = 1/2$

So, the wave function defined in Minkowsky space found is as follows:
$\phi(R) = e^{-R/2}$; R = ict + r

$k = 1/2 = 2{,}8\pi mc/h$
$1 = (2.\ 2{,}8.3{,}14.3.10^8/6{,}63.10^{-34})\ m = 2{,}64.10^{42} m$
$m = 1/2{,}64.10^{42} = 0.38.10^{-42} Kg = 2{,}1.10^{-8}\ eV$

3. Vacuum energy density calculated.

The radius of the sphere that corresponds to the unit of volume is r = 0.62 According to this, the probability of finding the boson in a unit of Minkowsky volume is given by:

$\int_0^{0,62} e^{-r}$dr =[-e^{-r}]$_0{}^{0,62}$ = 0,46

The energy density ρ* per unit volume in Minkowsky space will be given by:
$\rho_\wedge$* = 0,46. 0,38.10^{-42} = 0,17.10^{-42} Kg/ unit volume in Minkowski space

The conversion factor between the unit volume modulus in Minkowsky space (*) and a unit volume in Euclidean space is obtained as follows, (we are working in the International System of Units) :

Let be an interval between two points in Minkowsky space Δl* and between two points in Euclidean space Δl:

$\Delta l^{*2} = -c^2\Delta t^2 + \Delta l^2$; $\Delta l^{*2}/\Delta t^2 = -c^2 + \Delta l^2/\Delta t^2$

The volume element in our Minkowsky V* space is expressed by V* =Δl*Δl* = Δl^{*2}, the element of volume in Euclidean space v is expressed by v =Δl^3

$V^*\Delta l = -c^2\Delta l + v$,   if V* = 1 and Δl =1;   v=Δl^3 =1,

so, this equation in this case has a solution if the coefficient that multiplies v is (c^2+1). So (c^2 +1) volumes of 1m^3 in Euclidean space equal 1 volume in Minkowsky space, so the density in Euclidean space in Kg/m^3 is (c^2+1) times greater than that obtained in Minkowsky space.
$\rho_\wedge$ = (c^2+1). $\rho_\wedge$*
$\rho_\wedge$ = 0,17.10^{-42}. (c^2+1) = 1,5.10^{-26} Kg/m^3
recent measurements of the value of vacuum energy density [3] have determined a value of
$\rho_\wedge$ = (0.603 ± 0.013) × 10^{-26} kg/m^3

	Vacuum energy density calculated	Vacuum energy density measured
	$\rho_\wedge$ = 1,5.10^{-26} Kg/m^3	$\rho_\wedge$ = (0.603 ± 0.013) × 10^{-26} kg/m^3

4. Conclusions. Behavior of vacuum as a physical system.

4.1. The wave equation used.

The wave equation used to obtain the wave function that has served us to calculate the energy density of the vacuum has been a simplified Klein-Gordon type equation. A term representing the relativistic energy at rest has been added to the potential-free Schrödinger equation, and a solution has been sought for a zero energy E=0,: this is in contradiction with the concept of relativistic energy that, having a mass always has to be greater than mc^2, but it is not in contradiction with the initial hypothesis of a vacuum, that is, a region where initial energy starts from zero. This ambiguity that will be explained throughout these conclusions and the introduction in the calculation of the value of zero energy, has been very useful when determining the energy density of the vacuum, since it seems that it can be calculated correctly with these hypothesis. The resulting wave function leads to describe a physical state that meets the Heisenberg uncertainty relationships, being able to determine the half-life of said state based on them.

In accordance with the Heisenberg uncertainty relations the half-life of the particle turns out to be:

$(\Delta E).\ (\Delta t) \geq h$

$(\Delta E) = mc^2 = 3{,}4.10^{-26}$ Joules

half-life of the physical state of the vacuum

$\Delta t \ \geq\ h/mc^2 \ \geq\ 1{,}95.10^{-8}$ sec = 19,5 nanoseconds

The particular analytical solution of the wave function of the wave equation seems to be valid in principle to describe the behavior of the vacuum in some important questions, such as the curvature of space-time when assigning a mass to the physical state of the vacuum and the existence of the field of dark energy, as we will discuss later in these conclusions. . There we will see how this zero energy value E=0 is consistent with the existence of positive masses and with the existence of a negative energy field, dark energy. We will explain it later.

4.2. The vacuum as a physical state with mass and therefore capable of bending the space-time.

Our study has led us to a wave function that represents the physical state of the vacuum with a certain mass at rest, this mass leads, treated mathematically, to determine the value of the vacuum energy density with a result close to the experimental value. Thus, it seems that this representation of our wavefunction of the physical state of the vacuum is reasonably acceptable. The wave equation and the particular solution that we have sought predict an inherent mass in the vacuum state, an associated mass that, coinciding with the experimental value [3] of the vacuum energy density, would bend space-time in the value that It is observed experimentally through the measurement of its energy density. Our physical model of the vacuum, defined through the wave function found, agrees quantitatively and qualitatively with the experimental measurements related to the curvature of space-time.

4.3. A possible origin of dark energy.

Another aspect to consider that our model resolves is the possible origin of dark energy.

In physical cosmology, dark energy is a form of energy that would be present in all space, producing a pressure that tends to accelerate the expansion of the universe, resulting in a repulsive gravitational force [4]. Recent observations in reference to the expansion of the universe show that for 6145 million years the expansion of the universe has been accelerating, this is in contradiction with what could be supposed according to a primitive explosion, the Big Bang, in what refers to the fact that the rate of expansion would decrease over time due to the gravitational pull. The dark energy field would explain this acceleration since it supposes the existence of a negative energy field, uniform throughout all space that causes a repulsive force contrary to the attraction of gravity. Since the force of gravity is inversely proportional to the square of the distance, as the universe expands it would lose importance, on the other hand, since the dark energy field (negative energy) of uniform intensity in space would be dominant at some point. and it would contribute to accelerating the expansion of the universe from a certain time, according to observations from 6145 million years ago.

In the standard model of cosmology, dark energy contributes almost 70% of the total mass-energy of the universe.

Recently disclosed information based on the work carried out by the Planck spacecraft on the distribution of the universe, obtained a more precise estimate of this in 68.3% dark energy, 26.8% dark matter and 4.9% of ordinary matter [5].

Our vacuum model according to the energetic approach that we have carried out in this paper gives a possible origin of the dark energy field, its uniformity in space and its consequences.

We have assumed, when we have raised the wave equation, that contrary to what is expected in relativity, the total energy of the system was equal to zero E=0, we have also predicted the existence of a vacuum as a physical system with a certain mass, as we make compatible these two assumptions, because only assuming the existence of a negative energy field that compensates the positive energy field created by the masses and that leads to a value of the total energy equal to zero, this negative energy field extended throughout the entire space predicted here is the dark energy field. Thus, our zero-energy model gives rise to a physical vacuum system in which positive energy fields exist simultaneously whose value is equal to or greater than the mass multiplied by the square of the speed of light in vacuum and the existence of a field of negative energy that would offset this positive energy resulting in a total energy equal to zero. In addition, the solution found with our wave function has led us to determine a value of the vacuum energy density very close to the experimental value [3]

From an energetic point of view, we propose a general equation for the energy of the universe as follows:

$E = 0 = E_{de} + E_{photons} + E_{matter}$

E is the total energy.

E_{de} it is the dark energy.

$E_{photons}$ is the energy due to electromagnetic radiation.

E_{matter} is the energy due to the rest of the masses of the universe (dark matter and baryonic masses).

The first term E_{de} would be negative and the other two would be positive, compensating each other and giving an initial energy equal to zero [1], which is what we are working with in our wave equation.

The necessarily existence of a particle of positive mass "m" in the vacuum field as required by the solution wave function of the wave equation studied here and the hypothesis of a total energy equal to zero necessarily energetically implies the existence of a negative energy field whose physical form is not determined here but whose existence is deduced from what is studied; we identify this negative energy field as dark energy. This field would be uniform throughout the space.

Energy density of the dark energy field:

Energy/Minkowski unit of volume = $-mc^2 = -0{,}17.c^2 = -1{,}5.10^{-26}$ Joules/Minkowski unit of volume

Energy/$m^3 = -1{,}5.10^{-26}.(c^2+1) = -1{,}4.10^{-9}$ Joules/m^3

Thus, our model explains dark energy, the existence of a vacuum as a physical system with a certain mass, capable of bending space-time, and determines the value of the vacuum energy density with a value close to the value [3] recently experimentally determined. Our simple model successfully explains simultaneously three aspects of reality in which other models partially fail, so we believe that it may be positive to make it known through this publication so that it can be improved by other scientists interested in it.

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