On Dark Energy and Matter of the Expanding Universe

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At present the expanding universe is observed to be dominated by the not fully understood concepts of dark energy and matter, in a conceived almost flat Euclidian geometry. As one of the possible efforts to understand the global behaviour of the expanding universe, the present paper attempts to explain these concepts in terms of the pressure force and gravity of a spherical photon gas cloud of zero point energy, in a flat geometry. A difficult point of the conventional theory concerns the frequency distribution of the zero point energy oscillations which leads to the unacceptable result of an infinite total energy per unit volume. A modification of this distribution is therefore proposed which results in finite energy density. A corresponding equilibrium state is investigated, as well as small dynamic deviations from it, to form a basis for a model of the expanding universe. Provided that the crucial points of the present approach hold true, the model satisfies the requirements of cosmic linear dimensions, results in an estimated acceleration of the expansion being of the order of the observed one, presents a possible solution of the coincidence problem of dark energy and matter, and provides one of the possible explanations of the observed excess of high-energy electrons and positrons in recent balloon and satellite experiments.

1 Introduction

From being a speculative subject of discussion, the features of the universe have during recent years become more of an area of strict scientific analysis. After Hubble's discovery of the cosmic expansion and the Big Bang hypothesis by Gamow, astronomical observations and associated theoretical work have resulted in a number of new points of view, as summarized in recent reviews such as those by Linde [1], Hogan, Kirshner and Suntzeff [2], Luminet, Starkman and Weeks [3], Turner [4], Perlmutter [5], Riess and Turner [6], Crease [7] and Linder and Perlmutter [8]. In particular, this includes the concepts of dark energy and dark matter as well as the newly discovered accelerated expansion of the universe and its possible theoretical explanation.

The Hubble redshift has not only been interpreted as the result of a real cosmic expansion. Recently Rabounski [9] has reconsidered the Hubble redshift in terms of General Relativity, thereby finding that a photon loses its proper energy due to the work against the field of the space non-holonomity.

There have so far been reported a number of efforts to understand the global behaviour of the universe. This paper presents one of the alternatives to be investigated for such a purpose. Here an investigation is made on the possible rôle of the zero point energy of quantum mechanical vacuum fluctuations as an origin of dark energy and matter. A summary of recent observations of the expanding universe is first presented in Section 2, with corresponding theoretical so far made considerations in Section 3, followed by a description of the basic reasons for the present approach in Section 4. The frequency distribution of the zero point energy is then reconsidered in Section 5, the cosmic equilibrium of a zero point energy photon gas is elaborated in Section 6, and the acceleration of the expansion is estimated in Section 7. The implications of the present approach are finally given in Section 8, as well as in the summary and conlusions of Section 9.

2 Observations of an expanding universe

As early as in 1900 Schwarzschild [10] considered the possible non-Euclidian structure of space. For a closed elliptical configuration the lower limit of its permissible radius of curvature was found to be about $6{\times}10^{17}$ meters. At present it is often stated that observations indicate the universe just to be about flat on a scale of $R_0 = 10^{26}$ meters which is the radius of its observable parts [1], but the radius of the universe could be larger. With Hubble's discovery and the Big Bang model, a finite and growing radius can also form the basis of an expansion until the present time. Conventional wisdom says the universe is infinite, but it could be finite, merely giving the illusion of infinity [3]. On the other hand, a closed finite universe of curved space is certainly attractive from the conceptual point of view, but does not become reconcilable with an observed nearly flat geometry. The idea of a finite and flat universe runs then into its own obstacle of the apparent need for the "cut-off" at an edge defined by a radius $R \geqslant R_0$. Still these questions have not been settled, and will not be further touched upon in this paper.

In the 1990s it was realized that supernovae were promising candidates for measuring the cosmic expansion. This came out to be particularly fruitful when one kind of supernova, the type Ia, turned out to have the property of a "standard candle" [2, 5, 6, 8]. The method of surveying space-time with supernovae then became accurate enough even to measure the rate of change in the cosmic expansion. Many cosmologists had anticipated that the rate of expansion should slow down due to the attractive force of the mass of the universe. It therefore became a news of utmost interest when the supernova measurements indicated that the expansion was in fact accelerating [2, 5, 6, 8].

The acceleration of the radius R_0 of the observable universe can be determined from the measurements of redshift, relative intensity of light, and relative distance [2,5]. Here we consider very distant supernovae, near the radius of visibility where the redshift $z = \Delta\lambda/\lambda \cong 1$, $\Delta\lambda$ is the shift in wavelength, and λ stands for the wavelength of the light emitted by the supernova at its position. For a given intensity of light, the diagrams of the observations [2, 5] then yield a redshift $z_a \cong 0.8$ for an accelerated expansion instead of $z_0 \cong 1$ for a constant one. This shows that high-redshift supernovae are fainter than would be expected for a constant expansion [5]. The deviation of the redshift due to the acceleration thus corresponds to an additional increment $\Delta v = (z_0 - z_a)c$ in velocity where c is the velocity of light. With a linear scale of $R_0/2$ relative to the universe of today [5], the corresponding time of passage becomes $\Delta t \cong R_0/2c$. This yields an acceleration $\Delta v/\Delta t = 2(z_0 - z_a)c^2/R_0 \cong 4\times10^{-10}$ m/s^2 of the radius R_0.

Recent experiments with high-altitude balloons and satellites [11, 12] have further spotted an excess of high-energy electrons and positrons. These can become a possible signature of a decay of dark matter.

3 Theories on the present expansion

The period of acceleration has not prevailed during the entire expansion of the universe, but appears to have started about 5 billion years ago [8]. In order to account for the present acceleration, about 75 percent of the mass-energy content is then considered to be made of some weird gravitationally repulsive substance called dark energy [8], i.e. a "cosmological antigravity" which can drive the universe apart [2]. The remaining 25 percent has attractive gravitational interaction, but $5/6$ of this is not even normal matter but rather some additional unknown substance called dark matter [5].

An alternative description of the global behaviour of the universe has been presented by Rabounski [9]. In this theory the empirical Hubble law is explained in a static universe, as being due to the redshift produced by the global non-holonomity of the isotropic space in which a propagating photon loses its energy. Also the nonlinearity of the Hubble law which is observed at large distances is explained by the deduced form of the redshift.

A candidate to explain the effect of dark energy is further the vacuum energy which is mathematically equivalent to the cosmological constant introduced by Einstein in 1917. However, it appears to be a remarkable and implausible coincidence that the mass density, just in the present epoch, is within a factor of two of the vacuum energy density. This would need some kind of accelerating dark energy that, unlike the cosmological constant, does not become constant [5]. In addition, there are problems with the zero-point vacuum energy of the quantum fluctuations. Thus the standard model of particle physics has no place for a vacuum energy density of the modest magnitude required by astrophysical data, because the simplest estimates predict a vacuum energy being 10^{120} times greater [5]. We shall later return to this crucial point.

4 Exposition of reasons for the present approach

The investigation in this paper on the optional and possible rôle of the zero point energy as an origin of dark energy and matter, in particular during the later stages of the expansion, can be justified as follows:

- The concept of an expanding universe is accepted as a working hypothesis.
- The mass-energy content is mainly due to dark energy in the form of antigravity and to dark matter accounting for the attractive gravitational interaction, thereby dominating the general dynamics of the universe.
- From the observations the universe is here interpreted to have a nearly flat geometry. This supports a simple Euclidian approach in a first approximation, without the introduction of the curved space effects of General Relativity. This would not only hold for a strictly flat space, but also as an approximation for the limited observable part of a closed elliptical or spherical universe with a very large radius of curvature.
- The zero point energy represents the lowest quantum mechanical state. This is a "dark state" having no line radiation.

5 The zero point energy and its frequency distribution

We now turn to the zero point vibrational energy, as discussed by Terletskii [13], Milonni [14] and Loudon [15] among others. This energy can hardly be discarded since its effects have been revealed experimentally. Its infinite total amount per unit volume, as obtained from conventional theory, is on the other hand unacceptable and presents a so far unsolved dilemma.

5.1 Conventional deductions

It is known from quantum mechanics that the energy of a linear harmonic oscillator with the frequency ν only assumes the values [13–15]

$$E_k = h\nu\left(k + \frac{1}{2}\right) \qquad k = 0, 1, 2, \ldots \tag{1}$$

Utilizing the partition function and the Gibbs-Helmholtz equation [13], the mean energy of the ensemble of oscillators of all k-values, also including $k = 0$, then becomes

$$\bar{E} = \frac{1}{2}\,h\nu + \frac{h\nu}{\exp(h\nu/kT) - 1}\,, \tag{2}$$

where kT is the mean energy of a classical oscillator in thermal equilibrium at the temperature T.

The number of virtual field oscillators per unit volume with frequencies in the range $(\nu, \nu + d\nu)$ further becomes

$$dn(\nu) = (8\pi/c^3)\nu^2\, d\nu\,. \tag{3}$$

On the average the oscillators then have the energy density

$$du(\nu) = \bar{E}\, dn(\nu) = (8\pi\bar{E}/c^3)\nu^2\, d\nu \tag{4}$$

in the same range. The total energy density then becomes

$$u = u_0 + u_p \tag{5}$$

where

$$u_0 = \int_0^\infty (4\pi h/c^3)\nu^3\, d\nu\,, \tag{6}$$

$$u_p = \int_0^\infty (8\pi h/c^3)\frac{\nu^3}{\exp(h\nu/kT) - 1}\, d\nu\,, \tag{7}$$

(here u_0 is the infinite zero point energy contribution, and the finite contribution u_p originates from Planck's radiation law).

To obtain a finite total zero point energy, it has sometimes been suggested that the integral (6) should be truncated at a cut-off frequency corresponding either to the Planck length or to a high energy of 100 GeV. As compared to the magnitude of astrophysical data, this still leads to an excessive vacuum energy density being about 10^{120} or 10^{55} times greater than that which is required. The choice of cut-off also appears not to be rigorously motivated.

Even if the integral (6) leads to a physically unacceptable result, a straightforward illustration of vacuum effects can be obtained from a cavity configuration. In the latter a finite change in energy is obtained from the difference between two infinite integrals of forms being similar to that of equation (6). Thus, in 1948 a theoretical analysis was reported by Casimir [16] in which it was shown that two metal plates at narrow distance will attract each other slightly, due to the electromagnetic quantum fluctuations of the zero point energy. This force is due to the low-frequency part of the zero point energy pressure, because only the small high-frequency modes are allowed to squeeze in between the plates. Later, in 1997, the theory was experimentally confirmed within 5 percent accuracy by Lamoreaux [17] who used a torsional pendulum to measure the corresponding Casimir force between a spherical and a plane metal surface. He found that this generated a force up to about 10^{-9} N on a plate having a diameter of 2.54 centimetres, and at separation distances in the range 0.6 to 6 μm. The corresponding energy density was up to about 6×10^{-6} J/m^3. An experimental confirmation of Casimir's theory for parallel metal plates was further reported by Bressi et al. [18] who measured the force between a cantilever and a rigid surface. From data of the oscillating cantilever they obtained agreement with the calculated Casimir force with 15 percent accuracy for separation distances in the 0.5 to 3 μm range. Other experimental attempts to verify Casimir's prediction have also been reviewed by the same authors.

Consequently, the low-frequency part of the zero point frequency distribution has to be accepted as an experimental fact, whereas there arises a crucial problem with the high-frequency part.

5.2 A revised form of the high-frequency distribution

Several investigators have thrown doubt upon the conventional theory of vacuum energy and its related frequency distribution [6, 19]. Here the following points can be taken as an indication that some fundamental part of the theory may be lacking:

- In the conventional analysis the probability that an oscillator is excited to its k-th state is given by a Boltzmann factor. In this factor, however, the zero point energy cancels and disappears when expression (1) is substituted into the deductions [15];
- The energy values which an oscillator can assume at a given frequency ν are determined by expression (1), whereas expression (2) represents the mean energy values which an oscillator adopts in thermal equilibrium. Here $\bar{E}$ differs from E_k for $k \geqslant 1$ of the Planck radiation part which adapts itself to a probability distribution being in thermodynamic equilibrium at a temperature T. For the zero point energy part $k = 0$, however, conventional theory yields $\bar{E}_0 = E_0 = \frac{1}{2}h\nu$, which corresponds to the same probability for all frequencies ν. Such a distribution could be questioned and requires further investigation and explanation;
- In the conventional deduction of Planck's law, a finite mean energy kT of the oscillators is introduced as a given and independent parameter, as well as the resulting finite total energy. In the case of the zero point energy, a corresponding introduction becomes unclear in terms of the conventional theory. In other words, the Planck law part of equation (2) includes the disposable and independent parameter kT of the photon mean energy. However, for the zero point energy part of the same equation, the analogous situation is not fully determined because there is no corresponding and independent parameter which determines the average photon energy;
- In the limiting case $T = 0$ of a pure zero point energy photon gas, one would thus have to study an ensemble of continuous states, to search for the most probable distribution of frequency among the oscillators at a given total and finite energy per unit volume.

With these points in mind, it is here concluded that the zero point energy requires a separate statistical treatment. We thus limit the analysis to a state of zero temperature, in which there is an ensemble of photons, each having an energy E_0 of equation (1). The number of possible states of oscillation is as before given by equation (3) in the range $(\nu, \nu + d\nu)$. Here the population of zero point energy photons due to the conventional theory is on the other hand put in question, as well as their corresponding average energy.

A simple proposal is now made to find a distribution in statistical equilibrium which results in a finite average photon energy. Following Kennard [20], the probability of any state of energy $E_0(\nu) = \frac{1}{2} h\nu$ becomes proportional to a Boltzmann factor

$$P_B = \exp(-E_0/\bar{E}) = \exp(-\nu/\bar{\nu}) \tag{8}$$

where

$$\bar{E} = \frac{1}{2}\, h\bar{\nu} \tag{9}$$

now stands for a finite average energy of a photon, and $\bar{\nu}$ is the corresponding average frequency. With this proposal the revised form of the density (4) of the zero point energy becomes

$$du(\nu) = (4\pi h/c^3)\nu^3 \exp(-\nu/\bar{\nu})\, d\nu \tag{10}$$

It results in a finite total energy density

$$u = 24\pi h\bar{\nu}^4/c^3 \tag{11}$$

where the frequency $\bar{\nu}$ is a so far undetermined quantity, like the arbitrary mean energy kT of the states for $k \geqslant 1$.

It is desirable to extend the studies on the Casimir effect also on the experimental side. Investigations on smaller plate distances do not become an easy task, and may involve advanced nanotechnological methods. Here we can only speculate about the possibility of deposing an extremely thin layer of insulating material on a flat metal plate, and placing another such plate on top of it. With layer thicknesses being much smaller than the so far studied plate distances in experiments, considerable mutual forces are expected to arise, as long as equation (4) applies. Observed deviations from this which reveal a smaller or even a saturated force, could provide a test of various theoretical approaches, also that of equations (10) and (11).

6 Equilibrium of a photon gas in its gravitational field

In a gas cloud of photons of zero point energy, there is an antigravity force due to the photon gas pressure gradient, and a gravitation force due to the intrinsic mass of the same photons as determined by the total energy according to Einstein's mass-energy relation. We now proceed to the steady-state balance of an isotropic photon gas of zero point energy, in which the pressure force is balanced by the gravitational force. A restriction is made to spherical symmetry in a flat space, as supported by the points given in Section 4, and based on the proposed model of frequency distribution given in Section 5.

With the radial coordinate r in a spherical frame of reference, the energy density u of equation (11) and the corresponding average photon energy $\bar{E}$ and frequency $\bar{\nu}$ of equation (9) then become functions of r only. The radially outward directed pressure force is given by

$$f_p = -\frac{dp}{dr} = -\frac{1}{3}\frac{du}{dr}\,. \tag{12}$$

With an average total mass $\bar{E}/c^2$ of each photon, the integrated mass of the photon gas within the radius r becomes

$$M(r) = \int_0^r 4\pi r^2 (u/c^2)\, dr = (4\pi/c^2)\int_0^r r^2 u\, dr\,. \tag{13}$$

This leads to a radially inward directed gravitational force

$$f_g = -\,GMnm_p/r^2 = -\,GMu/c^2r^2 \tag{14}$$

where $G = 6.673\times10^{-11}$ m^3/kg·s^2 is the Newtonian constant of gravitation.

A steady equilibrium is now determined by $f_p + f_g = 0$ which results in

$$-\frac{1}{3}\frac{du}{dr} = \frac{4\pi G}{c^4 r^2}\, u \int_0^r r^2 u\, dr\,. \tag{15}$$

This equation is normalized by introducing $\rho = r/r_c$ where r_c is a characteristic radius, and $u = u_c U(\rho)$ with u_c as a characteristic photon energy density. Multiplying eq. (15) by r^2/u and taking the derivative with respect to r,

$$\frac{d^2U}{d\rho^2} + \frac{2}{\rho}\frac{dU}{d\rho} - \frac{1}{U}\left(\frac{dU}{d\rho}\right)^2 + 2C_0U^2 = 0\,. \tag{16}$$

This relation includes the dimensionless characteristic parameter

$$C_0 = 6\pi G u_c r_c^2/c^4 = 3\pi n_c r_c^2 L_p^2/\bar{\lambda}\,. \tag{17}$$

Here $L_p = (Gh/c^3)^{1/2}$ is the Planck length, $n_c = u_c/\bar{E}$ a characteristic photon density, and $\bar{\lambda} = c/\bar{\nu}$.

A particular solution of eq. (16) can be found by means of the ansatz $U = \rho^{-\alpha}$ which leads to $2C_0 = \alpha\rho^{\alpha-2}$ and becomes satisfied when $\alpha = 2$. This yields $C_0 = 1$ and

$$u(r) = u_c\,(r_c/r)^2\,. \tag{18}$$

The equilibrium condition $C_0 = 1$ corresponds to a characteristic radius

$$r_c = \left(c^4/6\pi G u_c\right)^{1/2}\,. \tag{19}$$

The integrated mass at the distance r further becomes

$$M(r) = 2c^2 r/3G \tag{20}$$

from combination of relations (13), (18), and (19). The obtained results are now discussed as follows:

- In some respects the present analysis also applies to the equilibrium of a photon gas in the regime of Planck's radiation law at nonzero temperature;
- When being observed from the Earth, the surrounding parts of the universe appear on the average to be rather uniformly distributed over the sky. This is here taken as an indication that the position of the Earth and of an observer is deep inside the cloud of the universe, i.e. far

away from its "boundary". Consequently we take $r = r_c$ as the position of the Earth where the energy density has the characteristic value u_c, and have $r = R_0 \gg r_c$ as the radius of the observable parts of the universe. Due to relation (18) this implies that the energy density $u(r)$ decreases from u_c at $r = r_c$ to $u_c(r_c/R_0)^2 \ll u_c$ at $r = R_0$. A "halo" extending beyond the radius R_0 can also exist, as introduced in many cosmological versions [1];

- The Planck length $L_p \cong 4.05\times10^{-35}$ m is the smallest length appearing as a basic parameter in physics. To satisfy the equilibrium condition $C_0 = 1$, it is seen from eq. (17) that the characteristic radius r_c of eq. (19) has to be of cosmic dimensions for moderate values of u_c;
- Equation (19) further shows that a high energy density u_c requires a small radius r_c for a state being close to equilibrium, and does not lead to excessively large cloud dimensions;
- At the origin $r = 0$ the total mass (20) vanishes. The divergence at $r = 0$ of the energy density u in equation (18) can here be taken as a remnant of the earliest stage of a Big Bang. Further, even if each of the forces (12) and (14) diverges at $r = 0$, the total force vanishes at the origin in equilibrium;
- The mass (20) increases linearly with r, to $M(R_0) = 2c^2 R_0/3G$ at the radius of the observable universe. This value is analogous to the solution by Einstein [21] for a steady quasi-Euclidian universe.

The parameter C_0 represents the ratio $|\, f_g/f_p \,|$ between the gravitation and pressure forces. Here f_g is proportional to u^2, and f_p to u. Small deviations from an equilibrium can in a first approximation be represented by values of C_0 which differ slightly from unity. This implies that $C_0 < 1$ corresponds to pressure-dominated accelerated expansion, and $C_0 > 1$ to gravitation-dominated accelerated compression. The deviations of C_0 from unity can therefore be used to identify the acceleration without considering a detailed equation of state as discussed elsewhere [4, 8]. This has some resemblance to the energy principle in fluid dynamics, where stability is studied in terms of virtual changes in energy, without analysing the dynamics of the corresponding normal modes in detail.

7 A simple discussion on the dynamics of the expansion

During the later stages of the expansion the equilibrium solution of Section 6 could provide a starting point also for a simple discussion on the related dynamics. As a working hypothesis we here adopt the often accepted view of a balance between the dark energy and matter forces corresponding to a constant expansion rate, whereas a force unbalance leads to an accelerated or retarded expansion. Only a crude estimation is made here of the order of the acceleration in the case of a slight deviation from the equilibrium treated in Section 6.

For this purpose we consider a volume element of thickness dr at the radius $r = R_0$. With the local force densities (12) and (14) the total forces on the layer become

$$(dF_p, dF_g) = 4\pi R_0^2 (f_g, f_p)\, dr\,. \tag{21}$$

From equations (12), (18) and (19)

$$f_p \cong 2u_c r_c^2/3R_0^3 \cong c^4/9\pi G R_0^3 \tag{22}$$

for small deviations from the equilibrium defined by $dF = dF_p + dF_g = 0$ and where

$$dF = (2\delta - 1)\, dF_p\,. \tag{23}$$

Here the fraction δ of the total mass-energy content is due to the pressure force dF_p, and δ is not far from the equilibrium value $\delta = 1/2$. The mass of the volume element further becomes

$$dM \cong (2c^2/3G)\, dr \tag{24}$$

due to equation (20). The acceleration of the radius R_0 is then roughly given by

$$d^2 R_0/dt^2 \cong (2\delta - 1)\, dF_p/dM \cong (2\delta - 1)(2c^2/3R_0)\,. \tag{25}$$

In a rigorous dynamical approach the question would arise whether the photon gas cloud can be considered as a closed system or not, i.e. if the region $r > R_0$ of an undisturbed "background" has to be included in the analysis.

8 Implications of present approach

An attempt has been made here to understand at least part of the features of the expanding universe at its later stage. Among the obtained results, the order of magnitude of the characteristic radius (19) should first be mentioned. The experiments by Lamoreaux indicate that the possible "saturation" at a finite average frequency $\bar{\nu}$ of equations (9)–(11) would at least take place above an energy density of the order of 6×10^{-6} J/m^3. With $u_c \geqslant 6\times10^{-6}$ J/m^3 at the position $r = r_c$ of the Earth, we then have $r_c \lesssim 10^{24}$ m $= 0.01 R_0$ with R_0 as the radius of the observable universe. Provided that there is not an excessively large average frequency $\bar{\nu}$ as compared to the frequency range in the experiments by Lamoreaux, and that the form (11) holds true, the linear dimensions of the present photon gas model should thus be consistent with cosmical dimensions. Since f_p is proportional to u and f_g to u^2, very large energy densities result in very small radii, and not in very large ones.

Concerning the present stage of an accelerated expansion, the radius of the outermost parts of the universe has been observed to expand at an acceleration of about 4×10^{-10} m/s^2 for a fraction $\delta = 0.75$, as described in Sections 2 and 3. The corresponding estimation (25) yields an acceleration of the order of 3×10^{-10} m/s^2, being of the same order as the observed value.

The generally discussed coincidence problem may have a solution in terms of the present theory. The vacuum energy density (dark energy) and its mass density (dark matter) are coupled here, because they originate from the same photon cloud. This coupling both exists in an equilibrium state, and in an accelerated state where the acceleration of the expansion is of the order of the ratio between the net pressure force and the mass of the cloud.

The spotted excess of high-energy electrons and positrons in recent balloon and satellite experiments [11, 12] may, among other possible explanations, also be due to electron-positron pair formation through the decay of energetic zero point energy photons. The latter then belong to the high-frequency part of the distribution, even in the proposed case of expression (10). The photon decay could be caused by impacts with other charged particles [22].

9 Summary and conlusions

The present expansion of the universe is dominated by the so far not fully understood concepts of dark energy and matter. An attempt has been made in this paper to explain these concepts in terms of the pressure force and gravity of a spherical photon gas cloud of zero point energy, treated in flat quasi-Euclidian geometry. Such an analysis requires a reconsideration to be made of the conventional concept of zero point energy and its frequency distribution, because this leads to an unacceptable infinite energy density. For this purpose a modified statistical approach has been proposed which results in a finite energy density. An equilibrium solution has then been found for a zero point energy photon gas confined in its own gravitational field. This also outlines the main behaviour of small dynamic deviations from an equilibrium, i.e. from a constant to an accelerated expansion of the universe.

A crucial point of the present analysis is the required finite energy density of the vacuum field. Provided that the present approach holds true, it would lead to the following features:

- The obtained linear dimensions seem to be consistent with observed cosmical ones;
- The observed and estimated values obtained for the acceleration of the present expansion are of the same order of magnitude;
- The generally discussed coincidence problem of dark energy and dark matter appears to have a solution, because these concepts originate from the same photon cloud in the present model;
- The observed excess of high-energy electrons and positrons in balloon and satellite experiments have one possible explanation in the decay of high-energy photons of the vacuum field.

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