Higgs Boson and Higgs Field in Fractal Models of the Universe: Active Femtoobjects, New Hubble Constants, Solar Wind, Heliopause

Valeriy S. Abramov

Abstract Theoretically the relationship between the main parameters of active femtoobjects and the Higgs boson in fractal models of the Universe was investigated. To describe the structure of the solar wind, heliopause, new Hubble constants are proposed. Estimates of the main parameters are conformed with the experimental data obtained by the Planck space observatory (based on Fermi-LAT and Cerenkov telescopes), UTR-2 and URAN-2 radio telescopes, Parker Solar Probe, Voyager 2 and Voyager 1. Within the framework of the anisotropic model, a description of the main characteristics of the model femtoobject and its relationships with the parameters of the Higgs boson and the Higgs field was performed. To take into account the stochastic behavior of the parameters of a model femtoobject (an active object with dimensions of the order of the classical electron radius), random variables are introduced. Using the example of a hydrogen atom, we estimated the radius of a proton, its mean square deviation, and compared it with an experiment. Estimates of the anomalous contributions to the magnetic moments of leptons based on the lepton quantum number are obtained.

Keywords Model femtoobject · Higgs boson and Higgs field · Fractal models of the Universe · Hubble constants · Structure of the solar wind · Heliopause · Hydrogen atom · Proton and electron radii · Magnetic moments of leptons

1 Introduction

To describe fractal cosmological objects (using binary black holes and neutron stars as an example), the model was proposed in [1, 2] that takes into account the relation between the parameters of the Higgs boson and relict photons, gravitons. Within the framework of this model, the possibility of radiation of gravitational waves from such cosmological objects in the superradiation regime is shown [2]. Higgs field accounting made it possible to propose an anisotropic model of fractal cosmology,

V. S. Abramov (✉)
Donetsk Institute for Physics and Engineering Named After A.A. Galkin, Donetsk, Ukraine
e-mail: vsabramov@mail.ru

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within the framework of which it is possible to describe the effect of accelerated expansion of the Universe [3]. In this case, a transition to the description of atomic defects, active nanoobjects, and neutrinos is possible [4, 5]. Active objects in fractal quantum systems have their own characteristic features of behavior [6–8]. In this case, superradiative states of active objects may appear [7]. When describing various physical fields (gravitational, electromagnetic, neutrino, deformation, stress) in fractal quantum systems, it is necessary to take into account the ordering effect of the corresponding operators [8]. Coherent laser spectroscopy methods and the modern development of nanotechnology make it possible to study active femtoobjects (protons, neutrons, atomic and muon hydrogens, leptons) in fractal quantum systems. Estimates of the characteristic sizes for the proton radius and Rydberg constant in atomic and muon hydrogens were obtained in [9–11]. Note that active femtoobjects such as leptons have anomalies in magnetic properties [12–14]. For neutrinos, the effect of oscillations (mutual transformations of the electron, muon neutrino and τ-neutrino into each other) is observed [13].

The relationships between the Higgs boson parameters and active nanoelements in fractal systems were studied in [15–17]. Features of the behavior of coupled states of a vortex–antivortex pair were considered in [16]. In [17], the description of the relations of the Higgs boson parameters with cosmological objects in the Universe was proposed. For the accelerated expansion of the Universe, within the framework of this model [17], the relationships of the Hubble constant (old value) with the parameters of the Higgs boson and relict radiation were obtained. The experimental data on the attenuation of gamma rays against an intergalactic background, obtained by the Planck space observatory (based on Fermi-LAT and Cerenkov telescopes), made it possible to determine new values of the Hubble constant and the density of matter in the Universe [18]. The authors explain these new values by the interaction of γ rays with relic photons. In this case, it becomes necessary to agreement the old and new values of the Hubble constants both within the framework of our model and with the cosmological model ΛCDM (plane cosmology). On the other hand, experimental data on the compound, structure, and behavior of the solar wind (flows of various particles) near the Sun [19–24], Earth [25] and in interstellar space (near the heliopause) [26–30] should also be associated with new values of the Hubble constant, the expansion rate, and the density of matter in the Universe.

The aim of this work is to describe the main characteristics of active femtoobjects, the solar wind, heliopause and their relationships with the parameters of the Higgs boson and the Higgs field in fractal models of the Universe.

2 Description of Model Femtoobject

The compound of the solar wind may include active nanoobjects [4–7] and femtoobjects. Based on the results of [1, 2, 4–7], we introduce the main parameters ξ_{2p}, Ω_{A0}, r_p of a model femtoobject

$$\xi_{2p} = \chi_0/n'_F = 1/(N'_p - N);\ \Omega_{A0} = n_{A0}E_e/E_{H0};\ r_p = 2r_e/(z'_\mu n_F), \quad (1)$$

which are related with the known parameters of quantum electrodynamics

$$\begin{aligned} &r_e = e^2/\left(m_e c_0^2\right);\ \hbar c_0 = e \cdot e_{\alpha 0};\ e_{\alpha 0} = e \cdot \alpha_0;\ \alpha_0 = \hbar c_0/e^2;\\ &E_e = m_e c_0^2 = e^2/r_e;\ r_{0p} = m_e r_e/m_p = e^2/E_p;\ E_p = m_p c_0^2 = e^2/r_{0p};\\ &\mu_B = e\hbar/2m_e;\ \mu_N = e\hbar/2m_p. \end{aligned} \quad (2)$$

Here r_e and r_{0p}, m_e and m_p, E_e and E_p are classical radii, rest masses, rest energies for electron and proton, respectively; c_0 is limited speed of light in vacuum; $\hbar$ is Planck's constant; e is electron charge; α_0 is fine structure constant; $e_{\alpha 0}$ is renormalized electron charge; μ_B is Bohr magneton; μ_N is nuclear magneton. Next we will use the numerical values $E_e = 0.51099907$ eV, $m_p/m_e = 1836.152701$, $E_p = 938.2723226$ eV, $r_e = 2.81794092$ fm, $r_{0p} = 1.534698568$ am. Note that in this work, model femtoobjects are active objects with sizes of the order of the classical electron radius r_e. Model attoobjects with sizes of the order of the classical proton radius r_{0p} describe the internal structure of nucleons (the presence of a core and scalar, vector clouds [12]). In fractal quantum systems (such as atomic and muon hydrogen), model attoobjects can lead to a change in the main parameters (1), anomalies in magnetic properties (2) and stochastic behavior [8] of model femtoobjects and leptons. In our model, the main parameters of the model femtoobject are related to the resting energy of the Higgs boson E_{H0}, the main parameter n_{A0} for black holes [1, 2], the number of quanta n_F, n'_F of the fermionic field ($n_F + n'_F = 1$) from the anisotropic model (taking into account the presence of the Higgs field) [3], and the cosmological redshift z'_μ [1, 2], the effective susceptibility χ_0 in the absence of the Higgs field [4–7] and the effective number N in the Dicke superradiation model [2]. The numerical values of these parameters are: $E_{H0} = 125.03238$ GeV, $n_{A0} = 58.04663887$, $n_F = 0.945780069$, $n'_F = 0.054219931$, $z'_\mu = 7.18418108$, $\chi_0 = 0.257104198$, $N = 17.0073101$. Using formulas (1), we find the numerical values of the main parameters of the model femtoobject $\xi_{2p} = 4.741876161$, $\Omega_{A0} = 237.232775 \cdot 10^{-6}$, $r_p = 0.829458098$ fm and $N'_p = 17.21819709$.

To take into account the stochastic behavior of the parameters of the model femtoobject, we introduce a random variable $\hat{\xi}_{rp}$ with two possible values ξ_{1p}, ξ_{2p} and their corresponding probabilities P_{1p}, P_{2p}, and expected value $M(\hat{\xi}_{rp}) = 1$. Based on the parameters ξ_{2p}, Ω_{A0} from (1) we find the probabilities P_{1p}, P_{2p}, possible value ξ_{1p}, variance $D(\hat{\xi}_{rp})$, standard deviation $\sigma(\hat{\xi}_{rp})$

$$P_{1p} = \xi_{2p}/(\xi_{2p} + \Omega_{A0});\ \ P_{2p} = \Omega_{A0}/(\xi_{2p} + \Omega_{A0});\ \ P_{1p} + P_{2p} = 1$$

$$\xi_{1p} = (1 - \xi_{2p}P_{2p})/P_{1p};\ \ D(\hat{\xi}_{rp}) = (\xi_{2p} - \xi_{1p})^2 P_{1p}P_{2p};\ \ \sigma(\hat{\xi}_{rp}) = D^{1/2}(\hat{\xi}_{rp}). \quad (3)$$

The values of these parameters from (3) are equal: $P_{1p} = 0.999949973$, $P_{2p} = 50.027 \cdot 10^{-6}$, $\xi_{1p} = 0.999812796$, $D(\hat{\xi}_{rp}) = 700.495 \cdot 10^{-6}$, $\sigma(\hat{\xi}_{rp}) = 0.026466865$.

Next, we introduce a random variable $\hat{r}_p = r_p \cdot \hat{\xi}_{rp}$ with two possible values r_p^*, r_e^* and their corresponding probabilities P_{1p}, P_{2p}. If r_p is a constant value, then the possible values r_p^*, r_e^*, expected value $M(\hat{r}_p)$, variance $D(\hat{r}_p)$, standard deviation $\sigma(\hat{r}_p)$ are found by the formulas

$$\begin{aligned} &r_p^* = \xi_{1p}\, r_p;\;\; r_e^* = \xi_{2p}\, r_p;\;\; M(\hat{r}_p) = r_p^* P_{1p} + r_e^* P_{2p} = r_p; \\ &D(\hat{r}_p) = (r_e^* - r_p^*)^2 P_{1p} P_{2p};\;\; \sigma(\hat{r}_p) = D^{1/2}(\hat{r}_p) \end{aligned} \tag{4}$$

The numerical values are equal: $r_p^* = 0.82930282\,\text{fm}$, $r_e^* = 3.933187582\,\text{fm}$, $D(\hat{r}_p) = 481.936 \cdot 10^{-6} (fm)^2$, $\sigma(\hat{r}_p) = 0.021953046\, fm$. Our calculated value of the proton radius r_p^* almost coincides with the new experimental value of 0.8293 fm for the proton radius in the hydrogen atom, obtained by 2S-4P spectroscopy (based on quantum interference) [11].

Based on the anisotropic model [1, 2, 4], we find the relationship of the radii r_p, r_p^* with other characteristic parameters r_p', x_p, y_p, $r_{p\tau}$, $r_{p\tau}^*$, $r_{p\mu}$

$$\begin{aligned} &r_p' - r_p = x_p;\;\; x_p = r_p\, \mathrm{sn}(u_\mu;k_\mu);\;\; y_p = r_p\, \mathrm{cn}(u_\mu;k_\mu);\;\; x_p^2 + y_p^2 = r_p^2; \\ &r_p - y_p = 3(r_p' - r_{p\tau});\;\; r_{p\tau}^* = r_{p\tau}\, n_{F\tau};\;\; 2r_{p\mu} = r_p'(1 - S_{1u} - S_{2u}) - 4(r_p - r_p^*). \end{aligned} \tag{5}$$

The parameter $\mathrm{sn}(u_\mu;k_\mu) = \sin\varphi_\mu = 0.057234291$ is related to the angle φ_μ [1, 2]; quantum numbers $n_{F\tau} = 0.950987889$, $n_{F\tau}' = 1 - n_{F\tau}$ are related with the lepton quantum number $\Omega_{\tau L} = (n_{F\tau}')^2 = 0.002402187$ from [5]; parameters $|S_{1u}| = 0.046741575$, $S_{2u} = 0.033051284$ defined in [4]. Further, based on expressions (5), we find the numerical values of the characteristic parameters: $r_p' = 0.876931544\,\text{fm}$, $x_p = 0.047473446\,\text{fm}$, $y_p = 0.828098429\,\text{fm}$, $r_{p\tau} = 0.876478321\,\text{fm}$, $r_{p\tau}^* = 0.833520268\,\text{fm}$, $r_{p\mu} = 0.841841587\,\text{fm}$. Our calculated values r_p' and $r_{p\mu}$ practically coincide with the values of 0.8768 fm (the CODATA value) and 0.84184 fm (determined on the basis of fine and ultrafine splitting in the framework of quantum electrodynamics) [9], respectively. Our calculated value $r_{p\tau}^*$ practically coincides with the value of 0.8335 fm for muonic hydrogen [10]. Our anisotropic model [1, 2, 4] also makes it possible to estimate the measurement error δr_p, $\delta r_p'$ using the formulas

$$\begin{aligned} &\delta r_p = \chi_{32}\, r_p' = r_{p\chi}\, \mathrm{sn}(u_\mu; k_\mu)[1 + \mathrm{sn}(u_\mu; k_\mu)];\; r_{p\chi} = 2r_e\, \chi_{11}/(z_\mu'\, n_F); \\ &\delta r_p' = r_{d\tau} S_{2u};\;\; r_{d\tau} = |\chi_{ef}| r_{F\tau};\;\; r_{F\tau} = n_{F\tau}\, r_p'. \end{aligned} \tag{6}$$

Taking into account $\chi_{11} = 0.181800122$, $\chi_{32} = 0.010405201$, $|\chi_{ef}| = 0.250425279$ from [1, 2] and expressions (6) we find estimates of measurement errors $\delta r_p = 0.009124649\,\text{fm}$, $\delta r_p' = 0.006902512\,\text{fm}$, which do not disagree the experimental estimates of 0.0091 fm from [11], 0.0069 fm from [9], respectively. In this case, the calculated value of the radius $r_{d\tau} = 0.208842481$ fm in our model is near the mean square radius of the electric charge distribution in the core of nucleons equal to 0.21 fm [12]. The radius $r_{F\tau} = 0.833951278$ fm is related with the characteristic radii $r'_{F\tau}$, $r_{\tau L}$ and the value $\Omega'_{\tau L} = 0.97597813$ by the expressions

$$r'_{F\tau} = n'_{F\tau} r'_p;\ (r'_{F\tau})^2 + (r_{\tau L})^2 = (r'_p)^2;$$
$$r^2_{\tau L} = \Omega'_{\tau L}(r'_p)^2;\ \Omega'_{\tau L} = 1 - \Omega_{\tau L} = n_{F\tau}(1 + n'_{F\tau}). \quad (7)$$

The values of these radii are equal: $r'_{F\tau} = 0.042980266$ fm, $r_{\tau L} = 0.866334751$ fm. Anomalies in the magnetic moments of leptons can be determined by the influence of CMB radiation. In this case, relict radiation can lead to effects of renormalization of the initial parameters: fine structure constant α_0, electron charge e, limiting speed of photon propagation in vacuum c_0; rest masses m_e, m_μ, m_τ and magnetons μ_B, $\mu_\mu = e\hbar/2m_\mu$, $\mu_\tau = e\hbar/2m_\tau$ for electron, muon, τ-lepton, respectively. The magnetic moments of leptons $< \hat{\mu}_e >$, $< \hat{\mu}_\mu >$, $< \hat{\mu}_\tau >$ for an electron, muon, τ-lepton, respectively, are determined by the expressions

$$2 < \hat{\mu}_e >= (2 + \Omega_{\mu e})\mu_B;\ 2 < \hat{\mu}_\mu >= (2 + \Omega_{\mu\mu})\mu_\mu;\ 2 < \hat{\mu}_\tau >= (2 + \Omega_{\mu\tau})\mu_\tau. \quad (8)$$

Anomalous contributions to magnetic moments and renormalization effects are described by parameters $\Omega_{\mu e}$, $\Omega_{\mu\mu}$, $\Omega_{\mu\tau}$ for electron, muon, τ-lepton, respectively, based on the lepton number $\Omega_{\tau L}$

$$\Omega_{\mu e} = \Omega_{\tau L} - \Omega_{HL};\ \Omega_{HL} = E_{HL}/E_{H0};\ E_{HL} = n'_{H3}E_e;\ N' = 17.21088699; \quad (9)$$

$$\Omega_{\mu\mu} = \Omega_{\tau L} - \Omega'_{NL};\ \Omega'_{NL} = E'_{NL}/E_{H0};\ E'_{NL} = N'E_e;\ (N' - N) \cdot \chi_0 = n'_{\mu F}; \quad (10)$$

$$\Omega_{\mu\tau} = \Omega_{\tau L} - 0.5(\Omega_{HL} + \Omega_{GL});\ \Omega_{GL} = E_{GL}/E_{H0};\ E_{GL} = n_G E_e. \quad (11)$$

Additional contributions Ω_{HL}, Ω'_{NL}, Ω_{GL} are determined based on the energies E_{HL}, E'_{NL}, E_{GL} and the resting energy of the Higgs boson E_{H0}. From (9–11) it follows that these additional energies are determined by the numbers of quanta n'_{H3}, N', n_G and the rest energy of the electron E_e. Wherein

$$n'_{H3} = n_{H3}/(1 + \Omega_{0\nu});\ 1 + \Omega_{0\nu} = 1 + (n'_F)^2 = 1 + (N'_p - N)^2 \cdot \chi_0^2; \quad (12)$$

$$n_{H3} = Q_{H3}n_{h2} = 0.5Q_{H3}\,n_{A0};\ n_{A0} = z'_\mu(z'_\mu + 1) - n_Q/n_g;\ n_Q = 2n_G. \quad (13)$$

Here $n_g = 8$, $n_Q = 6$, $n_G =< \hat{c}_G\hat{c}^+_G >= 3$ and $n'_G =< \hat{c}^+_G\hat{c}_G >= 2$ can be interpreted as the numbers of quanta of the gluon, quark, excited, and ground states of the gravitational fields, respectively; neutrino density $\Omega_{0\nu} = 0.002939801$ [4]. Based on (13) we find $n_{H3} = 20.33926863$. Further, taking into account (12, 10), we obtain $n'_{H3} = 20.27965049$, $n'_{\mu F} = 0.052340473$. Based on Eqs. (9–11) we find the energies $E_{HL} = 10.36288254\,\text{MeV}$, $E'_{NL} = 8.794747246\,\text{MeV}$, $E_{GL} = 1.53299721\,\text{MeV}$; additional contributions $\Omega_{HL} = 82.88159067 \cdot 10^{-6}$, $\Omega'_{NL} = 70.33975716 \cdot 10^{-6}$, $\Omega_{GL} = 12.26080164 \cdot 10^{-6}$. The found parameters $\Omega_{\mu e}/2 = 1159.652705 \cdot 10^{-6}$, $\Omega_{\mu\mu}/2 = 1165.923621 \cdot 10^{-6}$, $\Omega_{\mu\tau}/2 = 1177.307902 \cdot 10^{-6}$ coincide with the data [14] for anomalies of the magnetic moments of leptons.

3 New Hubble Constants

The parameters of active nanoobjects and femtoobjects are related with cosmological parameters. To describe accelerated expansion of the Universe in model I [17] and the anisotropic model [1, 2, 4], the Hubble constants H_{01}, H_{02}, H_0, characteristic distances L_{01}, L_{02}, L_0, speeds υ_{01}, υ_{02}, υ_0 were introduced

$$H_{01} = c_0/L_{01} = \upsilon_{01}/L_0;\;\; H_{02} = c_0/L_{02} = \upsilon_{02}/L_0;\;\; H_0 = \upsilon_0/L_0;\;\; H_0 = \upsilon_0/L_0. \tag{14}$$

The values $L_0 = 1\text{Mpc}$, $H_{01} = 73.2\,\text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}$, $L_{01} = 4.0954948\,\text{Gpc}$ (distance to supernova type 1a), $\upsilon_{01} = 73.2\,\text{km}\cdot\text{s}^{-1}$ and $L_{02} = 4.2574359\,\text{Gpc}$ (event horizon), $H_{02} = 70.415674\,\text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}$, $\upsilon_{02} = 70.415674\,\text{km}\cdot\text{s}^{-1}$ were obtained on the basis of the analysis of supernova type 1a [3] and measurements by Cepheids, respectively. The Hubble constant $H_0 = 67.83540245\,\text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}$, velocity $\upsilon_0 = 67.83540245\,\text{km}\cdot\text{s}^{-1}$ were introduced in [1, 2, 4] to describe the radiation of gravitational waves, relict photons from binary black holes, neutron stars based on the expression

$$\upsilon_0 = \upsilon_{01}/\Omega_{tH};\;\; \Omega_{tH} = Q_{H0} + |S'_{01}|;\;\; Q_{H0} = \upsilon_{01}/\upsilon_{02} = H_{01}/H_{02} = L_{02}/L_{01}. \tag{15}$$

Here are $Q_{H0} = 1.039541282$, $|S'_{01}| = 0.039541282$. New experimental data on the attenuation of γ-rays against an intergalactic background [18] make it possible to introduce a new Hubble constant H_0^*, velocity υ_0^*, and matter density Ω_m based on expressions

$$H_0^* = \upsilon_0^*/L_0;\;\; \upsilon_0^* = \upsilon_{01}/\Omega_{tH}^*;\;\; \Omega_{tH}^* - \Omega_{tH} = S_{012};\;\; S_{012} = |S'_{01}| - S'_{02}. \tag{16}$$

Here is $S'_{02} = 0.03409$. The numerical values of $H_0^* = 67.49443576\,\text{km}\cdot\text{s}^{-1}\cdot\text{Mpc}^{-1}$, $\upsilon_0^* = 67.49443576\,\text{km}\cdot\text{s}^{-1}$, $\Omega_m = (n'_F + \Omega'_{c1})/2 = 0.141145722$ (the parameter $\Omega'_{c1} = 0.228071512$ is related to the gap in the energy spectrum of relict photons) are close to the experimental data from [18]. From [16] it follows the connection of parameters H_{01}, υ_{01} for the accelerated expansion of the Universe with new parameters H_0^*, υ_0^*. Our parameters H_0, υ_0 and new parameters H_0^*, υ_0^* are close to the main parameters H_0', υ_0' of the model ΛCDM (plane cosmology). In our model H_0', υ_0' are defined by expressions

$$H_0' = \upsilon_0'/L_0;\ \upsilon_0' = \upsilon_{01}/\Omega_{tH}';\ \Omega_{tH}' = \Omega_{tH}^* + \Omega_{0\nu} + n_g\Omega_{A0}/n_{A0}. \quad (17)$$

Values $H_0' = 67.30995226\,\mathrm{km}\cdot\mathrm{s}^{-1}\cdot\mathrm{Mpc}^{-1}$, $\upsilon_0' = 67.30995226\,\mathrm{km}\cdot\mathrm{s}^{-1}$ are close to the parameters of the planar cosmology model.

4 Solar Wind and Heliopause

The Sun is the source of solar wind (flows of photons and various particles) [19]. Photons achieve the Earth after 8 min, and high-energy particles arrive with a delay of 100 min [20]. To estimate the characteristic distances and times, we use

$$L_{ES}' = L_{ES}/Q_{H0} = c_0 t_{ES} = \upsilon_{H0}\, t_{ES}';\ n_{H0} = Q_{H0}^2 = (1+|S_{01}'|)^2 = \upsilon_{01}^2/\upsilon_{02}^2, \quad (18)$$

where $\upsilon_{H0}^2 = c_0^2/n_{H0}$. Taking into account the numerical values of the distance from the Earth to the Sun $L_{ES} = 1\,\mathrm{au} = 1.495995288\cdot 10^8\mathrm{km}$, the limiting speed of light in a vacuum $c_0 = 2.99792458\cdot 10^5\mathrm{km\,s^{-1}}$, we find estimates of the refractive index of the medium $n_{H0} = 1.080646077$, the speed of photon propagation in the medium $\upsilon_{H0} = 2.883891801\cdot 10^5\mathrm{km\,s^{-1}}$, the distance $L_{ES}' = 0.961962759\,\mathrm{au}$, and the times of arrival of photons to the Earth from the Sun in vacuum $t_{ES} = 480.0293392\,\mathrm{s}$ and in the medium $t_{ES}' = 499.0103147\,\mathrm{s}$.

To estimate the delay time t_{0m} of particles, arriving on the Earth from the Sun, we use the expressions

$$2\,t_{0m} = \tau_{0\gamma}\ln N_{0m};\ \tau_{0\gamma} = \tau_{0\alpha}/n_{0\alpha};\ \tau_{0\alpha} = \nu_{0\alpha}^{-1};\ n_{0\alpha} = 1.5 + |\xi_{0H}|^2;$$

$$\ln N_{0m} = 2n_{0\alpha}\ln N_{0\alpha};\ Q_{H2}N_{0\alpha} = 0.5 + \Omega_{c1}' + n_{F\tau}';\ \nu_{0\alpha} = \nu_{H0}/N_{0A}. \quad (19)$$

Expressions (19) were obtained in the framework of the Dicke theory of superradiance and describe the main parameters $\tau_{0\gamma}$, t_{0m} of the superradiance pulse in a medium from a state with the number of particles N_{0m}.

Based on the numerical values $N_{0A} = 3.557716045\cdot 10^5$, $\nu_{H0} = 50.182731\,\mathrm{Hz}$, $|\xi_{0H}|^2 = 0.181800122$, $Q_{H2} = 1/3$, $n_{F\tau}' = 0.049012111$ we find estimates of the frequency $\nu_{0\alpha} = 141.0532217\mu Hz$, relaxation time $\tau_{0\alpha} = 118.1587096\,\mathrm{min}$, fractal parameter $n_{0\alpha} = 1.681800122$, coherent spontaneous relaxation time $\tau_{0\gamma} =$

70.25728449 min, effective numbers of active particles $N_{0\alpha} = 2.331250869$ and $N_{0m} = 17.23047995$, delay time $t_{0m} = 100.0101199$ min.

To estimate the characteristic parameters for the region near the boundary of the heliopause, we first find the relationships between the rest energies E_{0E} and E_{H0}, rest masses M_E and m_{H0}, the gravitational radii of Schwarzschild R_{GE} and R_{H0} for the Earth and the Higgs boson, respectively, by the formulas

$$E_{0E}/N_a E_{H0} = M_E/N_a\, m_{H0} = R_{GE}/N_a\, R_{H0} = n_{0E};\ \ E_{H0} = c_0^2 m_{H0};$$

$$m_{H0} = c_0^2 R_{H0}/2GN_a;\ \ R_{GE} = A_G E_{0E};\ \ A_G = R_{H0}/E_{H0} = 2GN_a/c_0^4;$$

$$R_{GE} = N_{GE} L_{ES} = n_{0E} N_a R_{H0};\ \ M_E = 5.977 \cdot 10^{27}\text{g}. \tag{20}$$

Based on (20) we find the parameters of the theory $A_G = 0.960836162$ fm (eV)$^{-1}$, $n_{0E} = 73.87419814$, $R_{GE} = 5.347530124 \cdot 10^{18}$km, $N_{GE} = 3.574563481 \cdot 10^{10}$.

Taking into account (18) in the framework of the anisotropic model [4] we find the characteristic velocities υ_{hS}, υ'_{hS}, distances L_{hS}, L'_{hS}, time of arrival of the signal from the heliopause to the Earth t_{hS} from the expressions

$$\upsilon'_{hS} = Q_{H0}\, \upsilon_{hS} = |\chi_{ef}|\upsilon_{01};\ \ L_{hS} = N_{hS} L_{ES};\ \ L'_{hS} = N'_{hS} L_{ES};\ \ L^*_{hS} = L_{hS}/Q_{H0};$$

$$N'_{hS} = n_{H0} N_{hS};\ \ L_{hS}/R_{GE} = \upsilon_{hS}^2/c_0^2;\ \ L_{hS}/L_{ES} = t_{hS}/t_{ES}. \tag{21}$$

Based on (18–21), the values $|\chi_{ef}| = 0.250425279$ from [4], we find the estimates $\upsilon_{hS} = |\chi_{ef}|\, \upsilon_{02} = 17.63386481$ km s^{-1}, $N_{hS} = 123.6734916$, $N'_{hS} = 133.6472735$, $L_{hS} = 1.850149607 \cdot 10^{10}$km, $t_{hS} = t_{ES} N_{hS} = 16.49080679$ hour. The speed υ_{hS} is close to the speed $\upsilon_{V2} = 17.5$ km s^{-1} of the V2 probe; the distance $L^*_{hS} = 118.9692932\, au$ is near the distance to the heliopause boundary $L_{V2} = 119$ au from [26].

To describe the transition region near the boundary of the heliopause, we introduce the times t_1, t_2, t_3, distances L_1, L_2, L_3. Next, we find the characteristic time intervals t_{31}, t_{21}, t_{32} by the formulas

$$t_{31} = t_3 - t_1 = 1/\nu_{31};\ \ \nu_{31} = (1 - \psi_{02})\nu_{H0} S_{2u}/N_{0A};\ \ t_{21} = t_2 - t_1 = t_{31} P_\tau;$$

$$t_{32} = t_3 - t_2 = t_{31} P'_\tau;\ \ P_\tau + P'_\tau = 1;\ \ P'_\tau = 1/(2 + S'_{03}). \tag{22}$$

Using the parameters $\psi_{02} = 0.984494334$, $S'_{03} = 0.460458718$ from [4], we obtain numerical values: frequency $\nu_{31} = 0.072287263\mu Hz$; probabilities $P_\tau = 0.593571722$, $P'_\tau = 0.406428278$; time intervals $t_{31} = 160.1122188$ day, $t_{21} = 95.03808539$ day, $t_{32} = 65.07413336$ day. The obtained values of the intervals t_{21}

and t_{32} practically coincide with the time intervals of 95 days and 65 days for the transition region near the heliopause boundary from [26, Fig. 1a].

The characteristic distance L_3 for interstellar space (outside the heliopause at $L_3 > L_2$) is determined from the expressions

$$L_3 = N_{L3} L_{ES};\ \ N_{L3} = (1 - \Omega_{hL} - S_{2u}) N_{hS}. \tag{23}$$

Using the parameters $\Omega_{hL} = 0.000118617$ from [4, 5], N_{hS} from (21), we find the value $N_{L3} = 119.5712542$ and the estimate of the distance $L_3 = 119.5712542$ au. To estimate the distance L_1 (inside the heliosphere for $L_1 < L_2$), we use the characteristic distances $L_{\mu e}$, $L_{\mu\mu}$, $L_{\mu\tau}$ for e, μ, τ-leptons, respectively, determined by the expressions

$$L_{\mu e} = N_{\mu e} L_{ES};\ \ N_{\mu e} = n_{\mu e} N_{hS};\ \ n_{\mu e} = (2 + \Omega_{\mu e}) - (1 + S_{1u});$$

$$L_{\mu\mu} = N_{\mu\mu} L_{ES};\ \ N_{\mu\mu} = n_{\mu\mu} N_{hS};\ \ n_{\mu\mu} = (2 + \Omega_{\mu\mu}) - (1 + S_{1u});$$

$$L_{\mu\tau} = N_{\mu\tau} L_{ES};\ \ N_{\mu\tau} = n_{\mu\tau} N_{hS};\ \ n_{\mu\tau} = (2 + \Omega_{\mu\tau}) - (1 + S_{1u}). \tag{24}$$

Using the parameters $\Omega_{\mu e}$, $\Omega_{\mu\mu}$, $\Omega_{\mu\tau}$ from (9–11), based on (24) we find the estimates of distances $L_{\mu e} = 118.1796344$ au, $L_{\mu\mu} = 118.1811855$ au, $L_{\mu\tau} = 118.1840014$ au. For search of the characteristic distance L_2 (as the heliopause boundary), we consider a random variable $\hat{L}_2$ with two possible values L_3 from (23), $L_1 = L_{\mu e}$ from (24) and their corresponding probabilities $P_{\psi 01}$, $P'_{\psi 01}$. For expected value $M(\hat{L}_2)$, variance $D(\hat{L}_2)$, deviation $\sigma(\hat{L}_2)$, we have

$$\begin{aligned} M(\hat{L}_2) &= P_{\psi 01} L_3 + P'_{\psi 01} L_{\mu e} = L_2;\ \ D(\hat{L}_2) \\ &= (L_3 - L_{\mu e})^2 P_{\psi 01} P'_{\psi 01};\ \ \sigma(\hat{L}_2) = D^{1/2}(\hat{L}_2); \end{aligned}$$

$$P_{\psi 01} + P'_{\psi 01} = 1;\ \ P'_{\psi 01} = \psi_{01}/(1 + S'_{03} + \psi_{01});\ \ \psi_{01} = 1.015268884. \tag{25}$$

The numerical values of the distance $L_2 = 119.0005661$ au and space intervals $L_{32} = L_3 - L_2 = 0.57068813$ au, $L_{21} = L_2 - L_{\mu e} = 0.8209317$ au practically coincide with the characteristic values of 119 au, 0.57 au, 0.82 au, respectively, from [26, Fig. 1a]. Based on (22), (25), we find the average values of the velocities υ_{21} (inside the heliosphere), υ_{32} (outside the heliopause), the jump in velocities $\delta\upsilon_{21}$ (at the heliopause) and the ratio of velocities $\upsilon_{32}/\upsilon_{21}$

$$\begin{aligned} \upsilon_{21} &= L_{21}/t_{21} = L_{31} P_{\psi 01}/t_{31} P_\tau;\ \ \upsilon_{32} = L_{32}/t_{32} \\ &= L_{31} P'_{\psi 01}/t_{31} P'_\tau;\ \ L_{31} = L_3 - L_1; \end{aligned}$$

$$\delta\upsilon_{21} = \upsilon_{32} - \upsilon_{21};\ \ \upsilon_{32}/\upsilon_{21} = \psi_{01} = \varepsilon_{01}/E_{H0} = \nu_{01}/\nu_{H0}. \tag{26}$$

The numerical values are equal: $\upsilon_{21} = 14.95635805\,\mathrm{km\,s^{-1}}$, $\upsilon_{32} = 15.18472495\,\mathrm{km\,s^{-1}}$, $\delta\upsilon_{21} = 228.366896\,\mathrm{m\,s^{-1}}$. We note, that the probabilities $P_{\psi 01}$ and P_τ are coupled through a conditional probability $P_{\psi\tau}$, and the ratio of the velocities and the jump in velocities allow us to introduce probabilities P_ψ, P'_ψ using expressions of the type

$$P_{\psi 01} = P_\tau P_{\psi\tau};\ P_{\psi\tau} = (2 + S'_{03})/(1 + S'_{03} + \psi_{01}) = 1/(1 + n_{01});\ P_\psi + P'_\psi = 1;$$

$$P_\psi = 1/\psi_{01} = \upsilon_{21}/\upsilon_{32};\ P'_\psi = \delta\upsilon_{21}/\upsilon_{32};\ n_{01} = (\psi_{01} - 1)/(2 + S'_{03}). \tag{27}$$

From (27) it follows, that n_{01} is a function of two arguments ψ_{01} and S'_{03}. If the Higgs field is absent ($\psi_{01} = 1$), then from (27) we obtain: $n_{01} = 0$; probabilities $P_{\psi\tau} = 1$, $P_{\psi 01} = P_\tau$, $P_\psi = 1$, $P'_\psi = 0$; jump in speed $\delta\upsilon_{21} = 0$ and equality of speeds $\upsilon_{21} = \upsilon_{32}$. The presence of the Higgs field ($\psi_{01} \neq 1$) leads to the appearance of a velocity jump, when crossing the heliopause boundary. Replacing the parameter S'_{03} in (27) with other parameters S'_{0x}, S_{xu} ($x = 1, 2, 3, 4$) of the energy (frequency) spectra leads to a change in the probabilities and stochastic behavior of the velocities υ_{21}, υ_{32}.

The anisotropic model [4] and expressions (1, 4) allow us to obtain relationships of velocities υ_{32}, υ_{21} with characteristic velocities $\upsilon_{\psi u}$, υ_{eu} (active nanoobjects, femtoobjects that are part of the solar and galactic wind) of the type

$$\upsilon_{32} = n'_F\,\upsilon_{\psi u} = \chi_0\,\upsilon_{eu} = \psi_{01}\,\upsilon_{21};\ \upsilon_{\psi u} = \xi_{2p}\,\upsilon_{eu};\ \xi_{2p} = r^*_e/r_p. \tag{28}$$

Based on (28) we find the velocity estimates $\upsilon_{eu} = 59.04358906\,\mathrm{km\,s^{-1}}$, $\upsilon_{\psi u} = 279.9773874\,\mathrm{km\,s^{-1}}$. On the other hand, the characteristic solar wind velocity $\upsilon_{\psi u}$ is related to the Hubble constants H_{01} and H_{02}, H_0, H^*_0, H'_0, velocities υ_{01} and υ_{02}, υ_0, υ^*_0, υ'_0 for models from (14, 15, 16, 17), respectively, by expressions of the type

$$0.5\upsilon_{\psi u} = 2\upsilon_{02} - \upsilon_{0A} = \upsilon_W - \upsilon_q - \upsilon_{0A};\ \upsilon_q = \upsilon_{01} - \upsilon_{02} = \upsilon_W - 2\upsilon_{02};$$

$$\upsilon_W = \upsilon_{01} + \upsilon_{02} = \upsilon_0\,\Omega_{tH} + \upsilon_{02} = \upsilon^*_0\,\Omega^*_{tH} + \upsilon_{02} = \upsilon'_0\,\Omega'_{tH} + \upsilon_{02};\ \upsilon_{0A} = c_0/N_{0A}. \tag{29}$$

Values of speeds are equal: $\upsilon_{0A} = 0.84265426\,\mathrm{km\,s^{-1}}$, $\upsilon_W = 143.615674\,\mathrm{km\,s^{-1}}$, $\upsilon_q = 2.784326\,\mathrm{km\,s^{-1}}$.

The velocity υ_{hS} from (21) is related to the characteristic velocities of relict photons υ_{ra}, υ^*_{ra} and the velocities υ_{02}, υ^*_0, $\upsilon_{0\rho}$, υ_W, $\upsilon_{h\rho}$ by expressions of the type

$$2\,\upsilon_{hS}\,\upsilon_{ra} = \upsilon^*_{ra}\,\upsilon_{02};\ \upsilon_{ra} = c_0/N_{ra};\ \upsilon^*_{ra} = 2|\chi_{ef}|\upsilon_{ra};$$

$$\upsilon^*_{ra}\,\upsilon_{0\rho} = \upsilon_{ra}\,\upsilon^*_0;\ \upsilon^2_W = \upsilon^2_{0\rho} + \upsilon^2_{h\rho};\ N_{ra} = 1041.293475; \tag{30}$$

Values of speeds are equal: $\upsilon_{ra} = 287.9039053\,\text{km}\,\text{s}^{-1}$, $\upsilon_{ra}^{*} = 144.1968316\,\text{km}\,\text{s}^{-1}$, $\upsilon_{0\rho} = 134.7596298\,\text{km}\,\text{s}^{-1}$, $\upsilon_{h\rho} = 49.65182785\,\text{km}\,\text{s}^{-1}$.

The experimental data obtained by the Wind probe (the interval of solar wind speed changes of 600–300 km s^{-1}, Fig. 6 from [25]), on the UTR-2, URAN-2 radio telescopes (Fig. 5 from [25]) showed, that the solar wind in orbit and beyond the Earth's orbit consists of a set of particle flows with different velocities and densities. The structure of these flows depends on time and solar activity [19, 20]. An analysis [25] of intermode (intramode) interactions of particles of different flows was performed by the interplanetary scintillation method based on the behavior of space and time correlation functions for radiation intensity. The velocities $2\,\upsilon_{0\rho}$, $\upsilon_{\psi u}$ and υ_{ra} are close to the characteristic velocities of 270, 280 and 290 km s^{-1} of separate solar wind modes from [25]. The detailed analysis of the multimode structure of the solar wind in our model is possible based on spectra of type $\upsilon_{\psi ux} = 2\,\upsilon_{\psi u} S_{xu}$ and $\upsilon_{rax} = 2\,\upsilon_{ra} S_{xu}$. From (30) it follows that the velocities $\upsilon_{0\rho}$ and $\upsilon_{h\rho}$ can be interpreted as both the radial and transverse components of the total velocity υ_W. The presence of transverse components $\pm\,\upsilon_{h\rho}$ of the solar wind near the Sun is confirmed by experimental data collected by the Parker Solar Probe [21–24]. The behavior of the transverse component (Fig. 2 from [22]) is stochastic and varies in the range from 50 to –50 km s^{-1}. In [24], such a behavior of the slow solar wind is associated with the presence of equatorial coronal holes in the Sun. A fast solar wind with speeds $2\,\upsilon_{0\rho}$ occurs near the poles of the Sun.

In our model, it is also possible to describe the multimode structure of the solar and galactic winds at the crossing of the heliopause based on the velocities υ_{eu} from (28), υ_W from (29), υ_{ra}^{*} from (30) and the corresponding velocity spectra. The experimental data (Fig. 4d from [27], Fig. 2 from [29]) confirm the stochastic behavior and change in the velocity of solar wind particles when the heliopause crosses from 150 km s^{-1} to 100 km s^{-1}. The complex dynamic behavior of the plasma components (Figs. 3, 4 from [29]) with velocities near υ_{eu}, $2\,\upsilon_{eu}$ inside the heliosphere indicates the presence of a boundary layer near the heliopause.

To estimate the characteristic energies ε_{0A}, E_{0A}, $\varepsilon_{\lambda A}$, effective wavelength λ_A, effective number N_{0n} of particles, we use expressions of the type

$$E_{H0}/\varepsilon_{0A} = E_{0A}/E_G = N_{0A};\;\; E_{H0}/E_{0A} = \varepsilon_{0A}/E_G = N_{0n};$$

$$E_{H0}/E_G = N_{HG} = N_{0n} N_{0A};\;\; \varepsilon_{\lambda A}^2 = \varepsilon_{0A} E_{0A} = E_{H0} E_G;\;\; \lambda_A = a_\lambda/\varepsilon_{\lambda A}. \qquad (31)$$

Taking into account $N_{0A} = 3.557716045 \cdot 10^5$, $N_{HG} = 1.031830522 \cdot 10^{16}$, a_λ from [6] we find the estimates: $\varepsilon_{0A} = 351.4400206\,\text{keV}$, $E_{0A} = 4.311073329\,\text{eV}$, $\varepsilon_{\lambda A} = 1.230887363\,\text{keV}$, $\lambda_A = 1.007114093\,\text{nm}$, $N_{0n} = 2.900261036 \cdot 10^{10}$.

The presence of a multimode structure of the solar and galactic wind, the Higgs field leads to the replacement $\varepsilon_{\lambda A}$, λ_A by $\varepsilon_{\lambda A}^{*}$, λ_A^{*} by the formulas

$$\varepsilon_{\lambda A}^{*} = \psi_{rc}\varepsilon_{bb};\;\; \lambda_A^{*} = a_\lambda/\varepsilon_{\lambda A}^{*} = 2R_{\lambda A};\;\; E_{\lambda A} = R_{\lambda A}/A_G;$$

$$\varepsilon_{bb} = \varepsilon_{0A}(|\, S_{1u}\,| + S_{2u});\;\; \psi_{rc} = 2\Delta_{rc}/E_{0A} = (\varepsilon_{01} - \varepsilon_{02})S_{1u}/\varepsilon_{02}S_{2u}. \tag{32}$$

The values are equal: $\varepsilon_{bb} = 28.042404\,\text{keV}$, $\psi_{rc} = 0.04420725$, $\Delta_{rc} = 95.290347\,\text{meV}$, $\varepsilon^*_{\lambda A} = 1.239677565$ keV, $\lambda^*_A = 0.999972933\,\text{nm}$, $E_{\lambda A} = 0.520365996\,\text{MeV}$. The energy $E_{\lambda A}$ (for solar wind particles inside the heliosphere) is associated with the energy $E_{\lambda L}$ (for galactic wind particles behind the heliopause)

$$E_{\lambda A} = (\Omega_{\tau L} + n_g\Omega_{0G})E_{\lambda L};\;\; \Omega_{0G}N_{0A} = 1.5 + \Omega'_{c1} + n'_{F\tau};$$

$$E^2_{rc} = E^2_{0A} - 4\Delta^2_{rc};\;\; (E'_{rc})^2 = E^2_{0A} + 4\Delta^2_{rc}. \tag{33}$$

The numerical values are equal: $\Omega_{0G} = 4.99501253 \cdot 10^{-6}$, $E_{\lambda L} = 213.0772532\,\text{MeV}$, $E_{rc} = 4.306858745\,\text{eV}$, $E'_{rc} = 4.315283797\,\text{eV}$. The energy estimates ε_{bb}, $E_{\lambda L}$ obtained in our model are consistent with the energies of 28 keV, 213 MeV from [26], and the energy $E_{\lambda A}$ is consistent with the energy of 0.5 MeV from [28].

The magnetic characteristics of solar and galactic wind particles have features of the behavior at the intersection of the heliopause: a jump in the magnetic field from 0.42 to 0.68 nT is observed (Fig. 1a from [27]); components of the magnetic field can have different signs (Fig. 3 from [27]); the presence of a magnetic barrier (Fig. 4a from [27]); a change in the direction of the magnetic field components (Fig. 6b, c from [27]). In our model, to estimate the components of magnetic fields $B_{y\beta x}$, $B^*_{y\beta x}$ we use frequency spectra of the type

$$\nu_{y\beta x} = \gamma_n B_{y\beta x}/2\pi = 2\nu_{y\beta}S'_{0x};\;\; \nu^*_{y\beta x} = \gamma_n B^*_{y\beta x}/2\pi = 2\nu_{y\beta}S_{ux};\;\; y = 0, 1, 2;$$

$$\nu_{y\beta} = \nu_{0y}/N_{ra};\;\; B'_{2\beta 1} = B^*_{2\beta 1}/(1.5 + n'_{zg} + S_{012});\;\; \nu_{00} = \nu_{H0};\;\; \nu_{02} = \psi_{02}\nu_{H0}. \tag{34}$$

Here we use the well-known nuclear gyromagnetic ratio $\gamma_n/2\pi = 0.6535\,\text{MHz/kO}$ for the deuteron (^{2}H) [4, 12]. Based on (34) we find estimates: frequencies $\nu^*_{2\beta 1} = 4.4353480\,\text{mHz}$; jump of magnetic fields from $B'_{2\beta 1} = 0.4190147\,\text{nT}$ to $B^*_{2\beta 1} = 0.6787067\,\text{nT}$ at the intersection of heliopause. The numerical values of the fields deviations of the type $\delta B = B_{0\beta 1} - B_{0\beta 2} = 0.0804015\,\text{nT}$, $\delta B^* = B^*_{0\beta 1} - B^*_{0\beta 2} = 0.2019195\,\text{nT}$ and the sum of the deviations $\delta B + \delta B^* = 0.282321$ nT are characteristic of the stochastic behavior of the magnetic field on time inside the heliosphere (consistent with data Fig. 6 from [27]).

5 Conclusions

In fractal quantum systems the model femtoobjects, as active objects with sizes of the order of the classical electron radius, are considered. The main parameters of the model femtoobject, which are coupled with the known parameters from quantum electrodynamics and the Higgs boson, are introduced. To take into account the stochastic behavior of the parameters, random variables with two possible values and the corresponding probabilities are introduced. It was shown, that the obtained estimates of the proton radius, measurement errors using the example of the hydrogen atom, and estimates of the anomalies in the magnetic moments of leptons are consistent with the experimental data.

The parameters of active nanoobjects and femtoobjects are coupled with cosmological parameters, with new values of the Hubble constants. These active objects can determine the compound, structure and behavior of the solar wind (flows of various particles) near the Sun, Earth and in interstellar space (near the heliopause). The relationships of such active objects with the parameters of the Higgs boson and the Higgs field are determined. Estimates of the main parameters are conformed with the experimental data, obtained by the Planck space observatory (based on Fermi-LAT and Cerenkov telescopes), UTR-2 and URAN-2 radio telescopes, Parker Solar Probe, Voyager 2 and Voyager 1.

The results can be used to find a solution to the problem associated with the Covid-2019 virus (based on active femtoobjects and nanoobjects), in cosmic medicine.

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