Theoretical and observational arguments are listed in favor of a new principle of relativity of units of measurements as the basis of a conformal-invariant unification of General Relativity and Standard Model by replacement of all masses with a scalar (dilaton) field. The relative units mean conformal observables: the coordinate distance, conformal time, running masses, and constant temperature. They reveal to us a motion of a universe along its hypersurface in the field space of events like a motion of a relativistic particle in the Minkowski space, where the postulate of the vacuum as a state with minimal energy leads to arrow of the geometric time. In relative units, the unified theory describes the Cold Universe Scenario, where the role of the conformal dark energy is played by a free minimal coupling scalar field in agreement with the most recent distance-redshift data from type Ia supernovae. In this Scenario, the evolution of the Universe begins with the effect of intensive creation of primordial W-Z-bosons explaining the value of CMBR temperature, baryon asymmetry, tremendous deficit of the luminosity masses in the COMA-type superclusters and large-scale structure of the Universe.

1 Introduction

Unification of General Relativity (GR) and Standard Model (SM) is one of the last bastions of theoretical physics not won in the 20th century. Our idea of such a unification is a new principle of relativity - a relativity of units of measurements. This means that equations of motion become conformal-invariant ones, they do not depend not only on the data but also on the units of measurement of these data. In order to obtain the corresponding conformal unified theory (i.e., Conformal Relativity), it is sufficient to replace all masses, including the Planck mass in GR and Higgs mass in SM, with a scalar massless dilaton field [1–5]. It was shown that this Conformal Relativity takes the form of a relativistic brane where the dilaton field plays the role of the evolution parameter in the field space of events [3–5]. Conformal Relativity contains the conformal cosmology defined as a version of the standard cosmology where observables are identified with the conformal quantities (the coordinate distance, conformal time, running masses, and constant temperature). Due to this identification the role of the dark energy is played by an additional scalar field (conformal quintessence) with the stiff equation of state in agreement with observational data [5–7].

In this paper, we show how Conformal Relativity can describe numerous astrophysical data and answer the topical questions of modern cosmology.
2 Conformal-invariant theory

The first physical theory formulated by Newton was a representation of the Galilei group of automorphisms of the initial data for the Copernicus relativity of the position and velocity of the Earth. The next step was the Poincaré group that means the Einstein relativity of the Lorentz frames of reference [8, 9] given in the Minkowskian space of events \([X_0, X_i]\), where a particle in each frame is described by two times: the time as a variable \(X_0\) measured in the rest frame and the time as a geometric interval \(ds\) considered as a measure of the world line \([X_0(s), X_i(s)]\) of a particle (see Fig. 1). An additional datum \(X_0(s = 0) = X_{0I}\) was treated as the point of creation of a particle moving forward, or annihilation of a particle moving backward with the postulate of the vacuum as a state with minimal energy defined as the canonical momentum \(P_0\) of the time-like variable \(X_0\).

![Figure 1. The world line \([s]\) of a relativistic particle in the space of events \([X_0, X_i]\) with the initial data \([X_{0I}, q_i]\) treated as the point of creation of the particle.](image)

The Poincaré group of automorphisms of the initial data follows from symmetries of the Faraday – Maxwell electrodynamics that has one more symmetry – conformal [10, 11]. Conformal-invariant unified theories equivalent to GR and SM have been proposed by a lot of authors (see, for example [1, 2], and references therein), who replaced all masses with the scalar dilation field \(w\). One of such theories has the action [4]

\[
S = S_{GR} + S_{SM} + \int d^4x \sqrt{-g} w^2 \partial_\mu Q \partial^\mu Q,
\]

where \(S_{GR} = -\int d^4x \left[ \sqrt{-g} w^2 R(g) / 6 - w \partial_\mu (\sqrt{-g} \partial^\mu w) \right]\) is the Penrose – Chernikov – Tagirov action [12], \(S_{SM}\) is the Standard Model in that the Higgs mass is replaced with the dilaton \(y_h w\) \((y_h \sim M_h / M_{Planck} \approx 10^{-17})\), and the last term is included in the theory as one of the possible models of the dark energy.

Two dilatons \(X_0 = w \cosh Q\) and \(X_1 = w \sinh Q\) with signature (+, −) and four Higgs fields \(\Phi_{\text{Higgs}} = X_2^2 + X_3^2 + X_4^2 + X_5^2\) give a scalar sector of the action in the form of a relativistic Brane (with the metric \(G^{AB} = \text{diag}(+1, −1, −1, −1, −1)\)):

\[
S_{\text{BRANE}} = -\int d^4x \sum_{A, B = 0}^5 G^{AB} \left[ \sqrt{-g} X_A X_B \left( \frac{R}{6} - X_A \partial_\mu (\sqrt{-g} g^{\mu\nu} \partial_\nu X_B) \right) \right]
\]
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that is analogous to the action of a relativistic particle

\[ S_{\text{PARTICLE}} = -\frac{m}{2} \int_{t_0}^{t_1} dx_0 \left[ \frac{1}{\dot{\epsilon}} \left( \frac{dX_0}{dx_0^0} \frac{dX_0}{dx_0^0} \right) - \frac{dX_i}{dx_0^0} \frac{dX_i}{dx_0^0} \right] + \epsilon \]. (3)

The Conformal Relativity \(^1\) considered above can be easily converted into the conventional GR and SM by a scale transformation, so that the new dilaton field \( \tilde{w} \) coincides with its occasional present-day “datum” \(^2\)

\[ \tilde{w}(x) = \varphi_0 = M_{\text{Planck}} \sqrt{3/8\pi} \quad (c = 1, \ \hbar = 1). \] (4)

The defect of this choice of variables is the conversion of an occasional datum into the fundamental parameter of equations of motion\(^a\).

\[ \text{UNIVERSE} \]

Another choice of variables in Conformal Relativity \(^1\) is given by analogy of with the theory of a relativistic particle \(^3\) mentioned above. In a concrete frame of reference both the theories are invariant with respect to the reparametrizations of the coordinate “time” \( x^0 \rightarrow \tilde{x}^0 = \tilde{x}^0(x^0) \). This invariance, in theories of all relativistic systems (particle \(^8, 9\), string \(^13\) and General Relativity \(^14\)), means that this coordinate “time” is not observable. As we have seen above, there are two observable “times”: i) a “time” as a time-like dynamic variable in the field space of events, and ii) a “time” as an invariant geometric interval. Conformal symmetry allows us to choose such a time-like dynamic variable as the dilaton

\[ w(x^0, x^i) = \varphi(x^0) \] (5)

because it has the negative sign of its action. This choice (in contrast to naive fixation \(^11\)) keeps the relative units, and it reveals to us a motion\(^b\) of a relativistic universe along the world hypersurface in the field space of events \([\varphi|F]\) from a point \( \varphi_I \) to the present-day point \( \varphi_0 \) defined by Eq. (4) (see Fig.2).

\(^a\)This fixation of the dilaton date \( \varphi_0 \) looks like the Ptolemaeus absolutization of the Earth “initial datum” in the Newton mechanics.

\(^b\)The dilaton canonical momentum \( P_\varphi \) is considered as an energy \( E \) of events. Stability of a relativistic theory requires the postulate of the vacuum as a state with minimal energy \( E \). The vacuum postulate restricts the motion of the Universe in the field space of events and it means
3 Conformal observables

The relative units (5) mean that the dilaton as a cosmological scale factor $a = \varphi/\varphi_0 = 1/(1 + z)$ scales all masses. In the Conformal Relativity the conformal version of Friedmann cosmology arises without any assumption about homogeneity as averaging of an exact equation over the spatial volume (see Appendix A). In the conformal cosmology observational quantities are identified with the conformal ones: conformal time $d\eta$ (instead of the Friedmann one $dt = a(\eta)d\eta$), coordinate distance $r$ (instead of $R = r/(1 + z)$), running masses $m = m_0/(1 + z)$ (instead of the constant one $m_0$), and the conformal temperature $T_c(z) = T(z)/(1 + z)$ (instead of the standard one $T(z)$). In this case the red shift of the spectral lines of atoms on cosmic objects

$$\frac{E_{\text{emission}}}{E_0} = \frac{m_{\text{atom}}(\eta_0 - r)}{m_{\text{atom}}(\eta_0)} = \frac{\varphi(\eta_0 - r)}{\varphi_0} = a(\eta_0 - r) = \frac{1}{1 + z}$$

is explained by the running masses. The conformal observable distance $r$ loses the factor $a$, in comparison with the nonconformal one $R = ar$, therefore, the recent distance-redshift data from type Ia supernovae [15], in the conformal cosmological model [5], are compatible with the stiff state $p = \rho$ of the conformal quintessence (1) and the square root dependence of the scale factor on the conformal (i.e., observable) time $a(\eta) \sim \sqrt{\eta}$; this dependence can explain chemical evolution [16].

As it has been shown in [4, 7], when the Universe horizon coincides with the Compton length of the vector bosons $H_I = M_I$, there is an intensive cosmological creation of the primordial vector bosons from the vacuum (see Fig.3). This creation leads to a conformal temperature in the form of the integral of motion of the Universe in the stiff state $T_I = (M^2_I H_I)^{1/3}$ as a consequence of collision and scattering of these bosons.

These theoretical results are in satisfactory agreement with the value of temperature of Cosmic Microwave Background radiation as a final product of decays of the primordial bosons remembering the integral of motion

$$T_{\text{CMB}} \sim (M_I^2 H_I)^{1/3} = (M_{W0}^2 H_0)^{1/3} \sim 3K.$$  

(6)

The value of the baryon–antibaryon asymmetry of the Universe is followed from the axial anomaly and is frozen by the superweak-interaction with the coupling constant

$$X_{CP} = n_b/n_\gamma \sim 10^{-9}.$$  

(7)

The boson life-times [7] $\tau_W = 2H_I \eta_W \sim (\frac{M_W}{\alpha_W})^{2/3} \sim 16$, $\tau_Z \sim 2^{2/3}\tau_W \sim 25$ determine the present-day visible baryon density

$$\Omega_b \sim \alpha_g = \alpha_{QED}/\sin^2 \theta_W \sim 0.03.$$  

(8)

that for positive energy of events the Universe moves forward $\varphi > \varphi_I$, and the anti-Universe moves backward $\varphi < \varphi_I$, where $\varphi_I$ is the initial data treated in quantum theory as a point of creation, or annihilation, respectively. One can see that a universe with the positive energy of events does not contain the cosmological singularity $\varphi = 0$ that belongs to an anti-universe.
This baryon density as a final product of the decay of bosons with momentum \( q \) and energy \( \omega(\eta) = (M^2(\eta) + q^2)^{1/2} \) oscillates as \( \cos \left[ 2 \int_0^\eta d\tilde{\eta} \omega(\tilde{\eta}) \right] \) [7]. One can see [17] that the number of density oscillations of the primordial bosons during their life-time for the momentum \( q \sim M_l \) is of order of 20, which is very close to the number of oscillations of the visible baryon matter density recently discovered in researches of large scale periodicity in redshift distribution [18, 19] \[
[H_0 \times 128 \text{ Mpc}]^{-1} \sim 20 \div 25 \sim (\alpha_g)^{-1}. \tag{9}
\]

The results [5], [7], [8], [9] testify to that all visible matter can be a product of decays of primordial bosons with the oscillations forming a large-scale structure of the baryonic matter. The number \( N_s \) of superclusters can be estimated from Eq. [9]: \( N_s \sim (\alpha_g)^{-3} \). Each of them has gravitation radius of order of \( r_g \sim (\alpha_g)^4 H_0^{-1} \).

Cosmological perturbation theory [20] in Conformal Relativity (in contrast to the standard one [21]) does not contain the scalar metric component as a dynamic variable and contains the Yukawa-like form of interactions with the shift of the coordinate origin by a central gravitation field (see Eqs. (A.22) – (A.24)). Due to this shift the field of each supercluster can lead to the spatial anisotropy of fluctuations of the photon energy (A.27) and temperature of CMBR:
\[
\Delta T/T \sim |r_g'| = r_g \times H_0 \sim \alpha_g^4 \sim 10^{-5} \div 10^{-6}.
\]

In Conformal Relativity, galaxies and their clusters are formed by the Newton Hamiltonian with running masses \( E(\eta) = p^2/2m(\eta) - r_g(\eta)m(\eta)/2r \), where the Newton coupling \( r_g(\eta)m(\eta)/2 = r_g(\eta_0)m(\eta_0)/2 \) is a motion constant. One can see that the running masses lead to the effect of the capture of an object by a gravitational central field at the time when \( E(\eta_{\text{capture}}) = 0 \). After the capture the conformal size of the circle trajectories decreases as \( r(\eta) = R_{\text{circle}}/a(\eta) \), \( R_{\text{circle}} = \text{const} \).
In the stiff state, the running masses change the orbital curvatures [22]

\[ v_{\text{orbital}}(R_{\text{circle}}) = \sqrt{\frac{\tau_g}{2R_{\text{circle}}}} + 2(R_{\text{circle}}H)^2 \]

which can explain the tremendous deficit of the luminous matter \( M/M_L \sim 10^2 \), where \( M_L \) stands for the mass of luminous matter, in superclusters with a mass \( M \geq 10^{15}M_\odot \), \( R \gtrsim 5\text{Mpc} \) [23], where the Newton velocity becomes less than the cosmic one.

Conclusion

We listed arguments in favor of that the Conformal Relativity can explain problems of energy, arrow of time, cosmological singularity, homogeneity, origin of all visible matter from physical vacuum, CMBR conformal temperature, baryon asymmetry, large-scale structure of the universe expressed in terms of fundamental parameters of the SM. The listed arguments stimulate farther consideration of other topical problems of modern cosmology, including gravitational lensing, and fluctuation of the CMBR temperature, in terms of relative units.

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Appendix A: Hamiltonian approach to Conformal Relativity

The Hamiltonian approach to Conformal Relativity [11] in the relative units [5] is formulated in a frame of reference given by a geometric interval

\[ g_{\mu\nu}dx^\mu dx^\nu \equiv \omega_{(0)}\omega_{(0)} - \omega_{(1)}\omega_{(1)} - \omega_{(2)}\omega_{(2)} - \omega_{(3)}\omega_{(3)} \quad (A.1) \]

where \( \omega_{(a)} \) are linear differential forms [24] in terms of the Dirac variables [25]

\[ \omega_{(0)} = \psi^6 N_4 dx^0; \quad \omega_{(a)} = \psi^2 e_{(a)ij}(dx^i + N^i dx^0); \quad (A.2) \]

here triads \( e_{(a)ij} \) form the spatial metrics with \( \det |e| = 1 \). These forms are invariant with respect to the kinematical general coordinate transformations [26] \( \tilde{x}^0 = \tilde{x}^0(x^0), \tilde{x}^i = \tilde{x}^i(x^0, x^i) \). This invariance means that the frame of reference \( \tilde{\varphi} \) should be redefined by two “times”: the “time” as a variable \( \varphi \) in the field space of events \( [\varphi|F] \) (see Fig. 2) and the “time” as a geometric interval [13,14]

\[ d\zeta = N_0(x^0)dx^0; \quad \zeta(x^0) = \int dx^0 N_0(\tilde{x}^0), \quad (A.3) \]
where
\[ N_0(x^0)^{-1} = V_0^{-1} \int_{V_0} d^3x N_d^{-1}(x^0, x^i) \equiv \langle N_d^{-1} \rangle \]  \hfill (A.4)

is the averaging of the inverse lapse function \( N_d \) over spatial volume \( V_0 = \int d^3x \).

The Hamiltonian action in the field space \([\varphi|F]\) takes the form [20]
\[ S = \int d^4x \left[ -P_\varphi \partial_\varphi \varphi + N_0 \frac{P_\varphi^2}{4V_0} + \int d^3x \left( \sum_F P_F \partial_F F + C - N_d \psi^{12} T_0^0 \right) \right], \hfill (A.5) \]

where \( P_F \) is the set of the field momenta \( p_\varphi, p^i_\psi, p_\rho, p_Q \); the sum of constraints
\[ C = N^i T_0^i + C_0 p_\psi + C_{(a)} \partial_b e^b_{(a)} \hfill (A.6) \]

contains the weak Dirac constraints\(^5\) of transversality and the minimal space-like surface \([25]\)
\[ \partial_t e^a_{(a)} \approx 0; \quad p_\psi = \frac{8\varphi^2}{N_d} \left( (\partial_0 - N^i \partial_i) \ln \psi - \frac{1}{6} \partial_i N^i \right) \approx 0, \hfill (A.7) \]

respectively, with the Lagrangian multipliers \( C_0, C_{(a)} \):
\[ T_{00}^0 = \frac{1}{\psi^{12}} \left[ 6 p_{(ab)} p_{(ab)} - \frac{16}{\varphi^2} p_\psi^2 \right] \quad \frac{\varphi^2}{6\psi^5} \left[ (^3 R(e)) \psi + 8 \Delta \psi \right] + T_{00}^{0(SM)}, \hfill (A.8) \]
\[ T_{kk}^0 = -p_\psi \partial_k \psi + \frac{1}{6} \partial_k (p_\psi \psi) + p^i_\psi \partial_k e^i_{(b)} + T_{k(SM)}^0 \hfill (A.9) \]

are the total components of the energy - momentum tensor in terms of momenta \( p_{(ab)} = \left[ p^i_{(a)} e^j_{(b)i} + p^j_{(b)} e^i_{(a)j} \right] / 2 \).

The gauge-invariant lapse function \( N_d/N_0 = N \) and the spatial metric determinant \( \psi \) can be determined by their equations for both the zero Fourier harmonic \( F \) and the nonzero ones \( \mathcal{F} = F - \langle F \rangle \):
\[ \left\langle N_d \frac{\delta S[\varphi]}{\delta N_d} \right\rangle = 0 \implies \varphi'^2 = \rho_t, \quad \left\langle N_d \frac{\delta S[\varphi]}{\delta N_d} \right\rangle = 0 \implies \frac{\rho_t}{N} = \mathcal{N} \mathcal{H}_t, \hfill (A.10) \]
\[ \left\langle \psi \frac{\delta S[\varphi]}{\delta \psi} \right\rangle = 0 \implies (\varphi'^2)' = 3(\rho_t - \rho_v), \quad \left\langle \psi \frac{\delta S[\varphi]}{\delta \psi} \right\rangle = 0 \implies \mathcal{A}\mathcal{N} = 0, \hfill (A.11) \]

where \( \varphi' = d\varphi/d\zeta, \rho_t \equiv \langle \mathcal{N} \mathcal{H}_t \rangle = \langle N^i \psi^{12} T_{00}^0 \rangle \) and \( \rho_v = \langle N^i \psi^{12} T_{kk}^0 \rangle / 3 \) are the energy density and pressure of all fields, respectively; \( \mathcal{H}_t = \psi^{12} T_{00}^0 \), and \( \mathcal{A} \) is a differential operator defined by identity:
\[ \mathcal{A}\mathcal{N} \equiv \frac{2\varphi^2}{3} \left[ (^3 R(e)) \psi^5 + 8 \psi^7 \Delta \psi \right] + \partial_j [\psi^2 \partial^j (\psi^b N)] + \psi^{12} [3 T_{00}^{0(SM)} - T_{k(SM)}^0] N. \]

Eqs. \( A.10, A.11 \) show us that their zero harmonics coincide with the conformal version of the Friedmann equations with the scale factor \( a = \varphi/\varphi_0 \).

\(^5\)We impose the strong constraint \( \int_{V_0} d^3x p_\rho \equiv 0 \) to remove the double counting of the spatial metric determinant and keep the number of variables of GR (in contrast with the standard cosmological perturbation theory [21]).
The energy constraints \( A.10 \) have solutions \( P_\varphi(\pm) = \pm 2V_0\varphi' = \pm 2V_0(\sqrt{\mathcal{H}}) \), \( \mathcal{N} = \langle \sqrt{\mathcal{H}} \rangle / \sqrt{\mathcal{H}_t} \). If we substitute these solutions into the action \( A.3 \), we obtain, in the case of the positive energy of events, the reduced Hamiltonian action

\[
S_+[\varphi_1|\varphi_0]|_{\text{energy constraint}} = \int d\varphi \left\{ \int d^3x \left[ \sum_P P_F \partial_\varphi F + \tilde{C} - 2\sqrt{\mathcal{H}_t} \right] \right\}, \quad (A.12)
\]

where \( \tilde{C} = C/\partial_0\varphi \) and \( \varphi_1 \) is an initial datum. The action \( A.12 \) gives the evolution of fields directly in terms of the redshift parameter connected with the scale factor \( \varphi \) by the relation \( \varphi = \varphi_0/(1+z) \). Using the reduced action \( A.12 \) one can get the probability to find the Universe at the point \( \langle \varphi_1, F_1 \rangle \), if the Universe was created at the point \( (\varphi_0, F_0) \) determined by the causal Green function:

\[
G(\varphi_1 F_1|\varphi_0 F_0) = G_+(\varphi_1 F_1|\varphi_0 F_0)\theta(\varphi_0 - \varphi_1) + G_+(\varphi_0 F_0|\varphi_1 F_1)\theta(\varphi_1 - \varphi_0), \quad (A.13)
\]

where \( G_+ \) can be given by the Faddeev – Popov (FP) functional integral

\[
G_+(\varphi_1 F_1|\varphi_0 F_0) = \int \prod_{F=a,\psi,i} \frac{(dpdFdF)}{2\pi} \delta(T_0^i)\delta(p_\psi)\delta(\partial_\varphi^i) D\epsilon^{S_+|\varphi_1|\varphi_0}, \quad (A.14)
\]

here \( D \) is the FP determinant of the matrix \( D_{(b)(a)}F_{(b)} = \partial_{(b)}\partial_{(a)}F_{(b)} \). The vacuum postulate (defined like for relativistic particle one on page 10) restricts a motion of a universe forward \( \varphi_0 \geq \varphi_1 \) for a positive energy \( E = P_\varphi = 2V_0\varphi' \geq 0 \), and backward \( \varphi_0 \leq \varphi_1 \) for a negative energy \( E \leq 0 \) treated as annihilation of a universe at the point \( \varphi_1 \), so that the geometric time \( A.3 \) as a solution of \( A.10 \) is always positive

\[
\zeta(\varphi_0|\varphi_1) = \theta(\varphi_0 - \varphi_1) \int^{\varphi_0}_{\varphi_1} \frac{d\varphi}{\rho_1(\varphi)} + \theta(\varphi_1 - \varphi_0) \int^{\varphi_0}_{\varphi_1} \frac{d\varphi}{\rho_1(\varphi)} \geq 0. \quad (A.15)
\]

Conformal Relativity gives a new cosmological perturbation theory

\[
\omega_{(0)} = (1-\Phi_N)\eta_1, \quad \omega_{(a)} = (1+\Phi_N)(dx_1) + h_{TT} dx^i + \partial_{(a)}\sigma d\eta + N_{(T)}\eta), \quad (A.16)
\]

where the metric components are defined in the class of functions with the nonzero Fourier harmonics \( \Phi(k) = \int d^3x \Phi(x)e^{ikx} \). In the approximation \( \rho_0 = \langle T_0^0|_{\text{SM}} \rangle \gg T_0^0 = (T_0^0|_{\text{SM}}| - T_0^0), \quad 3p_s = \langle T_k^k|_{\text{SM}} \rangle \gg T_k^k = (T_k^k|_{\text{SM}} - T_k^k), \quad T_0^0 = \mu_0 \langle T_0^0|_{\text{SM}} \rangle \), the equations of the theory for the scalar, vector, and tensor components take form

\[
\begin{align*}
\tilde{T}_0^0 &= \frac{2\varphi^2 k^2}{3} \Phi_h + 2\rho_s \bar{\Phi}_N, \quad (A.17) \\
\tilde{T}_0^0 + \tilde{T}_k^k &= +9(\rho_s - p_s)\Phi_h + \left( \frac{2\varphi^2 k^2}{3} + 5\rho_s + 3p_s \right) \Phi_h, \quad (A.18) \\
T_0^0(T) &= -\frac{\varphi^2}{12} N_k^T; \quad T_k^T &= -\frac{\varphi^2}{12 \sqrt{\mathcal{H}}} \left[ -\Delta_k^{TT}(TT) + \frac{(\varphi^2 h_{kk}^{TT})'}{\varphi^2} \right], \quad (A.19)
\end{align*}
\]

where \( \partial_T T_k^{(TT)} = T_{ii}^{(TT)} = 0, \quad \partial_\varphi T_k^{0(T)} = 0 \). The Dirac minimal surface constraint \( A.7 \) defines the longitudinal shift vector \( A.16 \) \( \Delta\sigma = \frac{1}{4} \mathcal{H} \). In the Newton case
\( p_s, \rho_s \ll \varphi^2 k^2 \), we obtain standard classical solutions with the Newton constant \( G \):

\[
\tilde{\Phi}_h = \frac{4\pi G}{k^2} \tilde{T}_0^0; \quad \tilde{\Phi}_N = \frac{4\pi G}{k^2} \left[ \tilde{T}_0^0 + \tilde{T}_k^k \right]; \quad G = \frac{3}{8\pi \varphi^2}.
\]  

(A.20)

In the case of point mass distribution with the zero pressure \( T_k^k = 0 \) and the density

\[
\rho_s = \sum_j \frac{M_j}{V_0} = \alpha \Omega_b H_0^2 \frac{\varphi_s^2}{V_0^2};
\]

(A.21)

\( \tilde{T}_0^0 = \sum_j M_j \left[ \delta^3(x - y_j) \right. - \left. \frac{1}{V_0} \right] \),

solutions of Eqs. (A.17), (A.18) take the form:

\[
\tilde{\Phi}_h(x) = \sum_j \frac{r_{gJ}}{2r_J} \left[ 1.15e^{-\sqrt{11.25}\mu(z)r_J} - 0.15 \cos[\sqrt{3.75}\mu(z)r_J] \right],
\]

(A.22)

\[
\tilde{\Phi}_N(x) = \sum_j \frac{r_{gJ}}{2r_J} \left[ 0.95e^{-\sqrt{11.25}\mu(z)r_J} + 0.05 \cos[\sqrt{3.75}\mu(z)r_J] \right],
\]

(A.23)

where \( r_{gJ} = 2GM_J, r_J = |x - y_J|, \) and \( \mu(z) = \sqrt{\Omega_b H_0(1 + z)^{1/2}} \). The minimal surface (A.7) gives the shift of the coordinate origin in the process of evolution:

\[
N^i = \sum_j \frac{3r_{gJ}}{8} \frac{(x-y_j)^i}{|x-y_j|} \left[ 1.15e^{-\sqrt{11.25}\mu(z)r_J} - 0.15 \cos[\sqrt{3.75}\mu(z)r_J] \right].
\]

(A.24)

The obtained conformal interval

\[
ds_c^2 = (1 - 2\tilde{\Phi}_N) d\eta^2 - (1 + 2\tilde{\Phi}_h)(dx^i + N^i d\eta)^2
\]

(A.24)

determines an equation for the photon momenta

\[
p_\mu p_\nu g^{\mu\nu} \approx (p_0 + N^i p_i)^2(1 + 2\tilde{\Phi}_N) - p_0^2(1 - 2\tilde{\Phi}_h) = 0,
\]

(A.25)

from which we obtain a photon energy

\[
p_0 \approx -N^i p_i + \left[ 1 - (\tilde{\Phi}_N + \tilde{\Phi}_h) \right] |p|; \quad |p| = \sqrt{p_0^2}.
\]

(A.26)

This formula shows us the relative magnitude of spatial fluctuations of a photon energy in terms of the metric components (the potential \( \tilde{\Phi} \) and shift vector \( N^i \))

\[
\frac{p_0 - |p|}{|p|} = -[N^i n_i + (\tilde{\Phi}_N + \tilde{\Phi}_h)]; \quad n^i = \frac{p_i}{|p|}.
\]

(A.27)

The appearance of spatial anisotropic fluctuations of the photon energy in the flow of photons is the consequence of the minimal surface (A.7) that leads to the hermitian Hamiltonian in the field space of events \([\varphi|F]\). The cosmological perturbation theory in Conformal Relativity does not require its convergence to be proved because the perturbations are in a different class of functions (with nonzero Fourier harmonics) than the cosmological dynamics described by the equations in the zero harmonic sector.
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