Can the energy density of gravitational field be interpreted as dark energy?

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Abstract

After a brief review of the Maxwell-like approach to gravity we consider the issue of the negative energy of gravitational field which is a consequence of the field approach to the phenomenon of gravitation. Due to the existence of the negative field energy within a mass body its total energy content is smaller than the positive energy assigned to its mass energy. We study the total energy content of a spherically symmetrical mass body having constant matter density, and show that its total energy content depends on its radius. We show that under certain circumstances, the total energy content of a mass body achieves negative values so that the force at its surface becomes repulsive. We apply this idea to the evolution of universe filled by matter and the negative energy density of its gravitational field. Since the negative energy density causes the negative pressure it might be considered as an agent which causes the acceleration of the universe.

KEYWORDS: Maxwell-like equations of gravity, negative field energy, Newton-like universe.

1 Introduction

An interesting development seems to take place in cosmology during the last few years. The evidence continues to mount that the expansion of the universe is accelerating rather than slowing down. Several astrophysical groups (Tonry et al. 2003 [1]; Barris et al. 2004 [2]; Riess et al. 2004 [3]) have recently updated the original supernova data of Riess et al.[16] and Perlmutter et al.[15]. The usual way to describe the structure and evolution of our observable universe is to assume that on the largest scales it is Friedmann-Lamaitre-Robertson-Walker (FLRW-universe), i.e. isotropic and spatially homogeneous. The observational parameters specifying the FLRW-universe are (i) the Hubble parameter $H$ (ii) the deceleration parameter $q$ (iii) the cosmological constant $\lambda$ (iv) the equation of state (v) the ratio $\Omega_m$ of the matter density to the critical matter density (vi) the spatial
curvature. New observation suggests a FLRW-universe that is light-weight ($\Omega_m < 1$), is expanding ($H > 0$), is cooling ($dT_U/dt < 0$), is accelerating ($q < 0$), and is flat ($\sum \Omega_i = 1$), where $i$ denotes the number of components occurring in the universe [15] [17] [18].

To account for cosmic acceleration it is necessary to take into consideration a new type of energy, the dark energy, a hypnotical form of energy which permeates all space and tends to increase the rate of expansion of the universe. It is usually modeled as the static cosmological constant, an energy density filling space homogeneously and the quintessence, a dynamical, spatially inhomogeneous form of energy with negative pressure [23].

Dark matter is causative agent of the current accelerating expansion. This agent (stuff) must have negative pressure, in order to produce acceleration of the cosmic scale factor. The essential properties of dark energy can be summarized in the following points: (a) It does not show its presence in the galactic space; (b) it is relatively smoothly distributed in cosmic space; (c) it does not emit and absorb elrm radiation; (d) it has large, negative pressure; (e) it forms approximately homogenous stuff.

An adequate and coherent cosmological theory, conform with recent observation, should give at least answers to the following problems [30]:

(i) The nature of the vacuum energy. In the literature, the vacuum energy is theoretically modeled by many ways, e.g., as (i) a very small cosmological constant (e.g.,[22]) (ii) quintessence (e.g.,[23]) (iii) Chaplygin gas (e.g.,[24]) (iv) tachyon field (e.g.,[25] [31] [32]) (v) interacting quintessence (e.g.,[26]), quaternionic field (e.g.,[27]), etc. It is unknown which of the said and the expected follow up models will finally emerges as the successful one.

(ii) The cosmological constant problem. The 'Λ-problem' can be expressed as discrepancies between the negligible value of Λ for the present universe and the value $10^{50}$ times larger expected by Glashow-Salam-Weinberg model or by GUT where it should be $10^{107}$ times larger.

(iii) The fine-tuning problem. It is a puzzle why the densities of dark matter and dark energy are nearly equal today when they scale so differently during the expansion of the universe. Assuming that the vacuum energy density is constant over time and the matter density decreases as the universe expands it appears that their ratio must be set to immense small value ($\approx 10^{-120}$) in the early universe in order for the two densities to nearly coincide today, some billions years later.

(iv) The flatness problem. Inflation predicts a spatially flat universe. According to Einstein’s theory, the mean energy density determines the spatial curvature of the universe. For a flat universe, it must be equal to the critical energy. The observed energy density is about one-third of critical density. The discrepancy between the value of the observed
energy density and the critical energy represents the flatness problem.

Especially interesting is the problem of acceleration of the expansion of the universe which is generally solve by assuming a vacuum energy. According to Glimer [28] the vacuum energy must satisfied the following requirements: (i) It should be intrinsically relativistic quantity having the dimension of the energy density. (ii) It should be smoothly distributed throughout the universe. (iii) It should cause the speedup of the universe. (iv) It should balances the total mean energy density to \( \Omega = 1 \).

As is well-known the FLRW cosmological model constitutes the standard paradigm of present day cosmology. Its 4-curvature is determined from the various contributions to its total energy-momentum tensor, mainly in form of matter energy, radiation pressure and cosmological constant. The cosmological constant contribution to the curvature of space-time is represented by the \( \lambda \) term which enters the gravitational field equations in the form

\[
R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = 8\pi G \tilde{T}_{\mu\nu},
\]

(1)

where \( \tilde{T}_{\mu\nu} = T_{\mu\nu} + g_{\mu\nu}\Lambda(t) \). \( T_{\mu\nu} \) is the ordinary energy-momentum tensor associated to isotropic matter and radiation. When modeling the expanding universe as perfect fluid with velocity 4-vector field \( U^\mu \), we have

\[
T_{\mu\nu} = -pg_{\mu\nu} + (\rho + p)U^\mu U^\nu,
\]

(2)

where \( p \) is the isotropic pressure and \( \rho \) is the proper energy density of matter. With the generalized energy-momentum tensor, and in the FLRW metric (\( k=0 \) for flat, \( k = \pm 1 \) for spatially curved universe)

\[
ds^2 = dt^2 - R^2(t) \left( \frac{dr}{1 - kr^2} + r^2d\theta^2 + r^2\sin^2\theta d\phi^2 \right)
\]

(3)

the gravitational field equations turns out to be the Friedman-Lamaitre equation

\[
H^2 \equiv \left( \frac{\dot{R}}{R} \right)^2 = \frac{8\pi G}{3} (\rho + \lambda) - \frac{k}{R^2}
\]

(4)

and the dynamical field equation for the scale factor gets the form

\[
\ddot{R} = -\frac{4\pi G}{3}(\rho + 3p - 2\lambda)R
\]

(5)

The baryonic contribution to the total matter content is far smaller than the total amount of matter detected by dynamical means, namely \( \Omega^0_b \approx 5 \) per cent of critical density. The total amount of matter detected by dynamical means is \( \Omega^0_M \approx 30 \) per cent of critical density. Therefore the bulk of the matter content must be in the form of unknown kind of cold (non-relativistic and non-baryonic) invisible component. Significant amount
of hot (relativistic) dark matter are excluded because it would not fit with the models of structure formation. So the radiation part at present boils down to an insignificant fraction of neutrinos plus an even more negligible contribution of very soft photons entering at the level of one ten-thousandth of critical density.

On the other hand, the astrophysical measurements tracing the rate of expansion of the university with high-z Type Ia supernovae indicate that $\Omega_\Lambda^0 \approx 70$ per cent of critical energy density of the universe is cosmological constant or another dark energy candidate with a similar dynamical impact of the evolution of the expansion of the universe. Specifically, the cosmical constant values found from Type Ia supernovae at high $z$ is:

$$\Lambda_0 = \Omega_\Lambda^0 \rho_c^0 \approx 6h_0^2 \times 10^{-47} GeV^4.$$ 

Independent from these supernovae measurements, the CMB anisotropy, including the recent data from WMAP satellite, lead to $\Omega_0 = 1.02 \pm 0.02$. As a first observation, it is obvious that this result leaves little room for our universe to be spatially curve. As a second observation, when combining this result with the dynamically determined values of the matter density, the complete energy bookkeeping leads us to the conclusion: the rest of the present energy budget must be encoded in the parameter $\Omega_\Lambda^0$.

Although the standard cosmological hot model describes successfully many features of the evolution of the universe the problem of the cosmic acceleration requires its revision in that one adds to it some new phenomenological components such as static cosmological constant or quintessence scalar field. Here the question arises whether there exists an alternative cosmological model based on Newtonian physics in form of the Maxwell-like equations in flat space-time which can describe the cosmic evolution in a comparable way as nowadays cosmological models without any implanted phenomenological parameters. The aim of this account is to give a simple exposition of the gravitation described by means of Maxwell-like equations especially with respect to the negative energy of the gravitational field. We show that Since the negative energy is linked with the negative pressure we show that it might be the agent that causes the acceleration of the rate of cosmic expansion. For the description of the dynamical evolution of the universe we use the simplest isotropic and homogenous cosmological model in its Newtonian analogue. General relativity reduces to Newtonian gravity locally but when spatial uniformity exists then local structure is equivalent to global structure [12]. We study the action of the negative pressure due to the negative energy of gravitation field and show that it might be a further component of the universe having similar properties as the dark energy. As the initial condition of the beginning of the cosmic expansion we consider the extremely comprised unstable mass object with huge density of the negative gravitation energy. The dynamical instability of this object causes the uniformly dispersion of its matter with extremely large velocity. This we consider as the beginning of big bang. Finally, we
describe the further fate of the expanding universe and show that the negative energy can be taken as important agent in the evolution of the universe.

2 The problem of negative energy in the Maxwell-like gravitation

Maxwell, at the end of a paper entitled *A dynamical theory of electromagnetic field* added a brief *Note on the attraction of gravitation*. There was suggested that the energy density of a gravitational field might be $-(8\pi)^{-1}R^2$ where $R$ is the 'intensity' of gravitational field, but Maxwell rejected the idea of negative energy of the gravitational field, and insisted that it negative value must be balanced by existence of an unknown intrinsic positive energy in masses [4]. The same rejection again the negative energy of gravitational field showed also Helmholtz [10]. In electrostatics, one derives an expression for the energy density of the electrostatic field by calculating the work done in assembling a charge distribution from elements of charge that are initially in a dispersed state. A similar situation in classical Newton theory leads to a strange conclusion that the energy density of gravitational field is necessarily negative.

Recently, motivated by these facts, there has been much interest paid to the consistent field equations for the gravitational interaction in an analogy to the extended Maxwell elm theory. In this approach the interaction energy of a mass body occurs, similarly as in elm, in its neighboring space and is necessarily negative. The quantitative characteristics of this field obey the Maxwell equations. As is well-known the standard Maxwell equations applied to gravity have the form [27]

$$\nabla \times \vec{B} - \frac{\partial \vec{E}}{\partial ct} = \frac{4\pi}{c} i$$

(6a)

$$\nabla \times \vec{E} + \frac{\partial \vec{B}}{\partial ct} = 0$$

(6b)

$$\nabla \vec{E} = \rho,$$

(6c)

where $\vec{E}$ and $\vec{B}$ represent the familiar vector field variables with the difference that the source of gravitational field $\rho$ and $i$ are purely imaginary quantity (We refer to article of Ulyrch [7] where the relevant references concerning the Maxwell-like gravity theories are presented.) It has been shown that the simplest way how to cross over from elm to gravitation consists either in substituting for the electrical charge $e$ the imaginary 'gravitational charge' $i\sqrt{G}M$ ($i = \sqrt{-1}$) [5] or in taking the elm equations with the negative permittivity $\varepsilon = -1$ [6]. In both cases all measurable quantities of gravitational interaction are real and obey Maxwell-like equations but necessarily with opposite sign.
For example, in gravitostatics, Gauss's law in spherically symmetrical case turns out to be
\[ \nabla E_g = 4\pi i \sqrt{G} \rho(r) \] (6d),
whose solution is
\[ E_g = \frac{4\pi \sqrt{G} i}{r^2} \int r^2 \rho(r) dr. \]
For the sake of simplicity, we illustrate this situation only for an idealized model case with \( \rho = q = \text{const.} \). The solution of Eq.(6d) has the simple form
\[ E_g = \frac{4\pi i}{3} \sqrt{Gqr} \]
and the corresponding field energy density becomes
\[ E_f = \frac{1}{8\pi} (E_g)^2. \] (7)

The total negative field energy of within the sphere of radius \( R \) and mass \( M \) assumes the form
\[ U_g = \int_0^R E_f^2 4\pi r^2 dr = -kGq^2 R^5 = -\kappa \frac{GM^2}{R}, \] (8)
where \( k = 1.27 \) and \( \kappa = 0.1 \). The energy content in this sphere is according to Eq.(7) negative while that of \( M \) is positive. The sum of the positive and negative energy containing in mass object is
\[ U_t = Mc^2 + U_g = Mc^2 \left( 1 - \kappa \frac{\lambda}{R} \right) \quad \lambda = \frac{GM}{c^2}. \]
If we denote the effective mass of \( M \) by symbol \( M^{(eff)} \), where \( M^{(eff)} = U_t/c^2 \), then the force at the surface of this mass object acting on test mass \( m \) is given as
\[ F = -\frac{GM^{(eff)} m}{r^2} = -\frac{GMm}{r^2} \left( 1 - \kappa \frac{\lambda}{R} \right). \] (9)

We see that the force law (9) changes its sign when \( 1 - \kappa \frac{\lambda}{R} < 0 \). If \( U_t = 0 \) then the radius of this spherical body is \( R_0 = \kappa R_S = 0.05 R_S \), where \( R_S \) is the Schwarzschild radius. In this case, a spherical body with constant density of radius \( R_0 \) has its total energy just equal to zero and no gravitational field outside of it exists. The total energy of a spherically symmetrical mass body can become even negative. This happens when \( R < R_0 \). In that case the mass body becomes unstable. The thee main consequences of the field approach to gravity are:
(i) The gravitational mass of gravitating body depends generally on its shape.
(ii) If taking into account that the (negative) energy density of the gravitational field is a source of the gravitational field itself, then one obtains a slightly modified force law for
the gravitationally interacted bodies. In the simplest case of a point-like gravitational source this leads to the equation

$$F'(r) + \frac{2}{r} F'(r) = -\frac{G^2 M^2}{c^2 r^4}$$

(10)

whose solution is

$$F'(r) = -\frac{GM^2}{r^2} + \frac{G^2 M^2}{c^2 r^3}.$$

We see that to Newton’s law is added a further term which modifies the force law between gravitationally interacting bodies.

(iii) The negative energy represents a kind of anti-gravitational force similar as the dark energy in standard cosmology.

3 The negative energy in the cosmology-the Newton-like cosmological model.

The fully relativistic Friedman equation for homogeneous and isotropic universe has the form

$$\frac{1}{R^2} \left( \frac{dR}{dt} \right)^2 = \frac{8\pi G \rho}{3} - \frac{k}{R^2},$$

(11a)

where $\rho$ is the density of matter and $k = \pm 1$ or 0. As first noted Milne and McCrea in their classical article [11], the Newtonian equation governing the evolution of a particle with mass $m$ and total energy $E$ located a distance $R$ from the center of a homogeneous and isotropic sphere of matter with density $\rho(t)$ which expresses the conservation of energy is

$$\frac{1}{R^2} \left( \frac{dR}{dt} \right)^2 = \frac{8\pi G \rho}{3} - \frac{(-2E/m)}{R^2}.$$

(11b)

If we set $(-E/m) = k$, then equations (11a) and (11b) are identical.

Instead of deriving Eq.(11b) using the energy conservation, we start with the familiar Newtonian force law. One picks an arbitrary point in space as the origin of coordinates, and considers the gravitational force acting on a test body $m$ a distance $R$ from this center. The Newtonian force law leads to the rule that for a spherically symmetrical mass distribution, only the mass inside the sphere of radius $R$ has a net gravitational effect, and so the force acting on $m$ is

$$m\ddot{R} = -\frac{GMm}{R^2},$$

or using $M = (4\pi/3)\rho R^3$,

$$\ddot{R} = -\frac{4\pi \rho}{3} R.$$

(12)
Assuming that the density varies \( R \) as \( \rho = \rho_0 R_0^3/R^3 \), then by inserting this expressing for \( \rho \) into Eq.(12) and multiplying by \( \dot{R} \), the the results can be integrated to obtain an equation identical to Eq. (11b), but with a different integration constant.

We consider the universe as a sphere of the radius \( R_u \) in the flat space filled by homogenous and isotropic matter governed by the force law (9). Such a cosmological model we shall call as the Newton-like universe. Its total matter content \( M_u \) does not vary with time while its total negative mass content amounts

\[
M_g = -\frac{GM_u^2}{c^2 R_u} = -\frac{M_u L_u}{R_u} \quad \text{and} \quad L_u = \frac{\kappa G M_u}{c^2}.
\]

This follows from Gauss’s law for a spherical body \( M \) of radius \( R \) with isotropic and homogeneous matter density. Accordingly, the total energy of the universe is given as

\[
E_t = M_u c^2 - \frac{\kappa G M_u^2}{R_u}
\]

and the force acting on mass \( m \) located a distant \( R \) from the center of sphere is

\[
F = m \ddot{R} = -mG \left( \frac{M}{R^2} - \frac{\kappa G M_u^2}{c^2 R^3} \right) = -mG \frac{M}{R^2} \left( 1 - \frac{L_u}{R} \right), \quad (13)
\]

where \( M = (4\pi/3)\rho R^3 \), \( \rho \) being the matter density in this sphere. First integral of Eq.(13), expressing the conservation of energy, gets the form

\[
\frac{1}{2} (\dot{R})^2 = \frac{GM}{R} - \frac{G^2 M^2}{2c^2 R^2} - \left( \frac{E}{m} \right) = \frac{GM}{R} - \frac{GML}{2R^2} - \left( \frac{E}{m} \right).
\]

Accordingly, we have

\[
\dot{R} = \sqrt{2(T_1(R) + T_2(R) + T_3)},
\]

where

\[
T_1(R) = \frac{GM}{R}, \quad T_2(R) = -\frac{\kappa G^2 M^2}{c^2 R^2} = \frac{GML}{R^2} \quad \text{and} \quad T_3 = -\left( \frac{E}{m} \right).
\]

The first term \( T_1 \) represents the gravitational attraction, the second term \( T_2 \) the gravitational repulsion and the third term \( T_3 \) the total energy divided by \( m \). According to the relations among \( T_1 \), \( T_2 \) and \( T_3 \) the velocity \( \dot{R} \) is decreasing or increasing. The velocity \( \dot{R} \) assumes maximal value for \( R_{\text{max}} = \kappa R_S/2 \), where \( R_S \) is the Schwarzschild radius of matter containing in the sphere of radius \( R \).

The scenario of the proposed Newton-like cosmological model can be briefly sketched as follows. At the big bang, the whole matter content of the universe was extremely comprised in a sphere of radius \( R_0 \ll R_S \) so that the negative energy considerable prevailed the positive energy of \( M_u c^2 \). ( \( R_0 \) and \( M_0 \) we take the initial conditions for the beginning of cosmic evolution). The large repulsive force acting on the individual
spherical mass shells of $M_u$ depends, according to Eq.(13), on $R$. The largest force acted on the surface mass shell. As a consequence of this force the matter was uniformly spread outwards starting a kind of cosmic inflation. The acceleration at the beginning of cosmic evolution was extremely large and then, in course of time, it became zero. This happened when $R = GM/(2c^2)$. Then the acceleration switched to deceleration.

Given $\rho$, Eq.(13) can be re-written as

$$\ddot{R} = -\frac{4\pi}{3}G\rho R + \left(\frac{4\pi}{3}\right)^2 \frac{G^2 \rho^2 R^3}{c^2} = -\left(\frac{4\pi}{3}\right)GR\rho \left(1 - \left(\frac{4\pi}{3}\right)\frac{G\rho R^2}{c^2}\right).$$

or

$$\ddot{R} = -\frac{4\pi}{3}G(\rho - \rho L)R,$$

where

$$L(\rho, R) = \frac{4\pi G\rho R^2}{3c^2}.$$

$L$ is a dimensionless quantity. If one takes a point in the Newton-like universe as the origin of coordinates, then for a spherically symmetrical mass distribution only the mass equivalent to total energy inside the radius $R$ has a net gravitational effect, therefore $\ddot{R}$ is negative for $L < 1$. For example, the mean mass density in the present day universe $\rho \approx 10^{-29}\, gr.cm^{-3}$. When taking into account that $G / c^2 \approx 10^{-28}\, cm.gr^{-1}$, the repulsive prevails the attractive force at the distance $R_a \approx 10^{27} - 10^{28}\, cm$. This distance approximately corresponds the distance from where the rate of cosmic expansion begins to be accelerated. For $R \ll R_a$, the first term $GM/R$ in Eq.(13) becomes larger than $G^2M^2/(c^2R)$ so that in the sphere of this radius the rate of expansion is similar as in standard cosmological model.

The formula for $\ddot{R}$ in the Friedman cosmology for matter dominated era is

$$\ddot{R} = -\frac{4\pi G}{3}(\rho_M - 2\Lambda)R$$

The comparison of Eq.(16) and Eq.(15) yields

$$\Lambda = \frac{L\rho}{2},$$

i.e. $\Lambda$ is proportional to $\rho$. However, $\Lambda$ does not represent the static cosmological constant because it is a function of $R$.

The well-known Whitrow-Randal relation [13] [14] one derives putting $U_t = 0$ which yields

$$\frac{\kappa GM_u^2}{R_u} \approx M_u c^2$$

Taking $M \approx 10^{56} - 10^{58} g$ and $R = 10^{26} - 10^{28} cm$ we find that

$$R_u \approx \frac{GM_u}{c^2} \approx \frac{R_S}{2},$$

(a)
where $R_S$ is the Schwarzschild radius of the Universe. Eq. (a) expresses that at present time the negative gravitational energy is approximately equal to its total positive energy.

The Newton-like field approach to gravity can be applied also to astrophysics. It is generally accepted that when a star run out of nuclear fuel, the only force left to sustain it against gravity is the pressure associated with the zero-point oscillation of its constituent fermions. This is valid if the gravitational force obeys Newton’s law. If one takes, instead of Newton’s, the Newton-like force law (13) then the force at the surface of a star depends on its total (negative and positive) energy. When the star is shrinking to a sufficiently small volume the gravity at its surface is weakening until it completely ceases. The weakening of force near to the gravity center in the Newton-like field approach makes possible the existence of star-like objects in equilibrium which are more collapsed than neutron stars (see [29]).

As is well-known general relativity offers the possibility of stable end state of collapsing mass body called black hole representing a mass object from which elm radiation can not escape. The black hole in its general form is conditioned with the cosmic censorship hypothesis which is not proved so far [8]. This censorship hypothesis represents the major unsolved problem of classical general relativity today [9]. The question, whether an event horizon will be formed around any singularity to screen it from the outside world is until now not answered. If cosmic censorship were not true, there see to be nothing in general relativity (and in Newton’s gravity) to prevent that a star can finally come to rest only in a configuration of zero volume. In this process an infinity amount of gravitational energy were pumped into kinetic energy of star’s matter as well as into its thermal energy. In absent of a protective event horizon, all of this energy will be released to outside world. It is often argued that a certain confirmation for the existence of cosmic censorship for the general non-symmetrical collapse is the fact that such an event would be with certainty notified by astronomers during the whole period of the astronomical observation. However, this argument can be reversed, i.e. such an event (the unlimited release of energy by mass collapse) has not been observed because the end state of gravitational collapse is not an object screened by horizon of event but an object smaller then neutron star, the energy release of which is at its collapse limited.

Interestingly, the gravitostatics can be straightforwardly extended to a complete gravitation Maxwell-like field theory describing by a whole set of the Maxwell-like equations - gravitodynamics. Singh (see [7]) has shown that the tree main post-Newtonian solar system experiments can be also explained in the frame of gravitodynamics.
4 Conclusions

(i) The Maxwell-like field approach to gravity leads necessarily to the existence of the negative gravitational field energy.

(ii) The gravitational mass of gravitating bodies is given by the total energy containing in them.

(iii) Application of the Maxwell-like gravity field equations to cosmology leads to the Maxwell-like universe described essentially by two components: the positive matter energy and the negative gravitation field energy.

(iv) The cosmic evolution began by an explosion-like uniform dispersion of a initial very comprised piece of the spherically symmetrical matter $M_0$ with the radius $R_0 \ll R_S$, where $R_S$ denotes the Schwarzschild radius assigned to $M_0$. This process resembles the cosmic inflation.

(v) The gravitational negative field energy exhibits some similar properties as dark matter, namely it has negative pressure and it is smoothly distributed in cosmic space.

(vi) The ‘cosmological term’ $\Lambda = (\rho L)/2$ is proportional to $\rho$ which might resolved the fine tuning problem [33] [34].

(vii) The negative energy of gravitational field within the star-like object causes that its shrinking leads, in the idealized case, not to its zero volume but to its stable end state having approximately the radius equal to its Schwarzschild radius.

The initial conditions for cosmic evolution are the total mass $M_u$ and $R_0$. The subsequent cosmic evolution is essentially given by these two quantities.

The aim of this article was only to outline the basic ideas concerning the Maxwell-like field theory of gravitation and its application to cosmology. This is why everything is simplified and many important issues remained open.

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