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NEW COSMOLOGY II

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The cosmological model first proposed in 1978 on the basis of the Generalised Field Theory (GFT) is discussed in more detail. It is shown that the model requires a nonzero cosmological constant different from the de Sitter one, admits no horizons within the parts of the universe smoothed out by the geometrical symmetry condition, and predicts a negative deceleration parameter allowed by GFT. It is also considered what role the model may play as an empirical test of the field theory.

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1. Introduction

The number of cosmological models that have been proposed in the past is probably as large as that of unified field theories of gravitation and electromagnetism. The only difference, is that in the former case there is a considerable body of empirical evidence about the universe in which we live; in the latter there is little apart from intellectual curiosity and a dissatisfaction with the foundations of General Relativity. Current observations have been able to eliminate some of the ideas about the world at large. Thus, for example, Steady State theories are in disfavour because they seem to predict something which is not observed. A Big Bang origin of the expanding universe is now generally accepted and there is extensive speculation about the state of matter in the early stages of the expansion as well as about the resulting abundance of elementary particles or of the elements. This of course, always presupposes that nuclear processes during the hadron or the radiation era were the same as today. Perhaps we cannot assume anything else, just as for lack of an acceptable alternative, we must interpret the extragalactic red shift as a Doppler effect.

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However, empirical evidence appears to be insufficient to discriminate between many cosmologies which still survive. Most of these are based on some form of a cosmological principle which is superimposed onto a general relativistic background and serves to select this or that solution of the field equations as the metric of the universe. The only exceptions to this rule are the models in which a presupposed anisotropy of matter plays the part of the principle, the GFT model which I am going to discuss in this article, and perhaps the de Sitter universe. The latter is, of course, just the unique, spherically symmetric solution of the general relativistic equations with a cosmological constant but a source-less field. The model, I shall consider, bears some resemblence to the de Sitter world.

I have shown in several publications [1–4] that the nonsymmetric unified field theory which will be referred to as GFT (generalised field theory) predicts a unique cosmological model. Several questions raised especially in the conclusions to Ref. [2] can be answered now and it is the purpose of this article to give an account of the relevant results.

One of the major difficulties in observational cosmology is to disentangle those data which can be interpreted independently of any theory which we may care to assume. Clearly, only these data can be unambiguously used as a test of the theory itself. The importance of the GFT cosmological model lies in that it represents at present the most likely means of providing an hitherto elusive, empirical verification of GFT.

Now, all observations are from a cosmological point of view local while they refer to events immensely distant both in space and in time. All evidence too, arrives by hypothesis along radial null geodesics. Again this is the only reasonable hypothesis we can make. It follows that the first problem to be solved is to decide what should be regarded as the correct time and (radial) distance coordinates or parameters. In spite of appearances, the choice of these parameters is not entirely arbitrary. Moreover, according to General Relativity (and GFT), physically meaningful quantities ought to be defined in a coordinate independent, invariant way. However, such apparently significant quantities as mass or volume of a space-like section of the world are invariant only if additional assumptions are made, for example, that the space-time is asymptotically flat. In the case of our new cosmology, the continuum is not flat at infinity and the choice of the correct parameters of primitive measurement becomes particularly pertinent.

Once the choice has been made, the formulae involving red shift and deceleration parameters of cosmology become well determined irrespective of the distribution of matter in the universe. Indeed, we must recall that it was the main aim of GFT to eliminate an energy-momentum tensor from the mathematical description of the fundamental, physical fields. Such tensor must exist but instead of postulating its form in terms of energy-density, pressure, stress and the like (which can only be done as Einstein put it, on the basis of prerelativistic physics), it is to be calculated when the field equations have been solved. In particular, we are not entitled to assume a priori that the matter in the universe behaves as a perfect fluid. Whether it does or not, is a consequence of the mathematical structure of the world and not the starting point of its derivation. This change of outlook is perhaps the most significant factor distinguishing our new cosmology from the standard, relativistic models.

2. *Time and distance*

The space-time metric relation of the GFT model is [3]

$$ds^2 = \gamma dt^2 - w^2\gamma^{-1}dr^2 - wr^2 d\Omega^2, \tag{1}$$

where

$$\gamma = 1 - \frac{2m}{r}, \quad w = \frac{r_0^2}{r_0^2+r^2}, \quad d\Omega^2 = d\theta^2 + \sin^2\theta d\phi^2,$$

and m and r_0 are constants with

$$2m < r < r_0. \tag{2}$$

I have shown in particular [1] that when r is very much greater than $2m$ but equally very much less than r_0 (this presupposes, of course, that

$$2m \ll r_0),$$

one obtains from the expression (1) an approximate form of the Hubble law of expansion. In Ref. [3], r_0 was identified as the finite (limiting) radius of the universe. Indeed, it is easily seen from (1) that if $r_0 \to \infty$, the metric becomes just the standard Schwarzschild metric of General Relativity (this can be imagined as the view of a spherically symmetric universe "from outside"). Similarly, if $r \to \infty$, the model collapses into an Euclidean sphere of radius r_0 with an absolute time measure [5]. The parameters r and t have been tacitly assumed in all the previous articles as representing respectively the radial distance from an observer and time. Is this, however, their correct interpretation?

In trying to answer this question, let us first transform the metric expression (1) into a form in which the coefficient of dt^2 becomes unity. The resulting form allows a ready comparison to be made with the constant curvature models of the Robertson-Walker cosmologies. Let

$$\xi = t + h(r), \quad \tau = t + g(r) \tag{3}$$

be new coordinates with the functions (of r only) h and g given by

$$\frac{dh}{dr} = \pm\frac{w}{\gamma\sqrt{1-\gamma}}, \quad \frac{dg}{dr} = \pm\frac{w\sqrt{1-\gamma}}{\gamma}, \quad \left(\frac{dh}{dr}\frac{dg}{dr} = \frac{w^2}{\gamma^2}\right). \tag{4}$$

We easily find that

$$ds^2 = d\tau^2 - R^2 d\xi^2 - P^2 d\Omega^2, \tag{5}$$

where

$$R^2 = \frac{2m}{r} = 1-\gamma, \quad P^2 = wr^2 = \frac{4m^2}{\lambda^2+R^4}, \quad \lambda = \frac{2m}{r_0}. \tag{6}$$

If we now put (a quasi-"retarded time")

$$T = \tau - \xi, \tag{7}$$

equations (4) give immediately

$$\frac{dT}{dr} = \pm \frac{r_0^2}{\sqrt{2m}} \frac{\sqrt{r}}{r_0^2+r^2}, \tag{8}$$

or

$$\frac{dR}{dT} = \pm \frac{\lambda^2+R^4}{4m}. \tag{9}$$

The sign in the equations (4), (8) and (9) can be determined by the calculation of mass and volume in the next section. It is of course, important for drawing observable consequences from the GFT model but at the moment all we need to know is that the components R^2 and P^2 of the metric tensor are well defined functions of T only. It is convenient to use the coordinate system

$$(x^0, x^1, x^2, x^3) \equiv (T, \xi, \theta, \phi), \tag{10}$$

in which the metric relation is

$$ds^2 = dT^2+2dTd\xi+Q^2d\xi^2-P^2d\Omega^2, \tag{11}$$

with

$$Q^2 = \gamma = 1-R^2.$$

We can easily calculate the corresponding Christoffel brackets:

$$\begin{Bmatrix} 0 \\ 0\;1 \end{Bmatrix} = -\frac{R'}{R}, \quad \begin{Bmatrix} 0 \\ 1\;1 \end{Bmatrix} = -\frac{Q^2R'}{R}, \quad \begin{Bmatrix} 0 \\ 2\;2 \end{Bmatrix} = \begin{Bmatrix} 0 \\ 3\;3 \end{Bmatrix} \operatorname{cosec}^2\theta = -\frac{Q^2RP'}{R^2},$$

$$\begin{Bmatrix} 1 \\ 0\;1 \end{Bmatrix} = \frac{R'}{R}, \quad \begin{Bmatrix} 1 \\ 1\;1 \end{Bmatrix} = \frac{R'}{R}, \quad \begin{Bmatrix} 1 \\ 2\;2 \end{Bmatrix} = \begin{Bmatrix} 1 \\ 3\;3 \end{Bmatrix} \operatorname{cosec}^2\theta = \frac{PP'}{R^2},$$

$$\begin{Bmatrix} 2 \\ 0\;2 \end{Bmatrix} = \frac{P'}{P}, \quad \begin{Bmatrix} 2 \\ 3\;3 \end{Bmatrix} = -\sin\theta\cos\theta, \quad \begin{Bmatrix} 3 \\ 0\;3 \end{Bmatrix} = \frac{P'}{P}, \quad \begin{Bmatrix} 3 \\ 2\;3 \end{Bmatrix} = \cot\theta, \tag{12}$$

dashes denoting differentiation with respect to T.

Let us now consider the Killing equations. If

$$(X_0, X_1, X_2, X_3)$$

denotes the components of a Killing vector X_μ, these are

$$X_{0,0} = 0, \quad X_{0,1}+X_{1,0}+2\frac{R'}{R}(X_0-X_1) = 0,$$

$$X_{0,2}+X_{2,0}-\frac{2P'}{P}X_2 = 0 = X_{0,3}+X_{3,0}-\frac{2P'}{P}X_3,$$

$$X_{1,1}+\frac{R'}{R}(Q^2X_0-X_1) = 0, \quad X_{1,2}+X_{2,1} = 0 = X_{1,3}+X_{3,1},$$

$$X_{2,2}+\frac{PP'}{R^2}(Q^2X_0-X_1) = 0 = X_{2,3}+X_{3,2}-2\cot\theta X_3,$$

$$X_{3,3}+\sin\theta\cos\theta X_2+\frac{PP'}{R^2}(Q^2X_0-X_1) = 0. \tag{13}$$

It is easily seen that the only separable solution of these equations is given by

$$X_\mu = (1, Q^2, 0, 0). \tag{14}$$

This is a timelike vector which can be transformed into

$$X_\mu = (Q^2, 0, 0, 0) \tag{15}$$

by the transformation

$$t = \int \frac{dT}{Q^2}+\xi, \quad r = \xi, \quad \theta = \theta, \quad \phi = \phi \tag{16}$$

when the metric relation becomes

$$ds^2 = Q^2dt^2-Q^2R^2d\varrho^2-P^2d\Omega^2, \tag{17}$$

in which

$$\varrho = t-r, \tag{18}$$

and $Q^2 = \gamma$ is a function of ϱ only. We must note that t in the last three equations is a new parameter which is different from that originally used in the metric (1). This new t appears as the correct time coordinate but this choice is still not free from an ambiguity.

Let us indeed recall again the fact that information about distant events is received, in the view of a local observer, along radial null geodesics only. This is an hypothesis which is forced on us by our way of thinking itself rather than by any considerations resulting from empirical knowledge, being thus psychological rather than physical. It does not determine the geometry of the world but once the geometry is determined for some other reasons consequences of it become important in assessing the meaning of further observations.

Now in either of the coordinate systems

$$(\tau, \xi, \theta, \phi) \quad \text{or} \quad (t, \varrho, \theta, \phi),$$

the radial null geodesics are given by the equation

$$\frac{d\xi}{d\tau} = -\frac{1}{R} \quad \text{or} \quad \frac{d\varrho}{dt} = -\frac{1}{R}, \tag{19}$$

choice of sign being decided since light received from a distant event is necessarily emitted in the past of the observer. In the first of the equations (19), R is a function of $T = \tau-\xi$

and in the second, of $\varrho = \tau - r$, and

$$\frac{d\varrho}{dR} = \pm \frac{4m}{(1-R^2)(\lambda^2+R^4)}. \tag{20}$$

However, empirical measurements can determine only the velocity $\frac{d\xi}{d\tau}$ or $\frac{d\varrho}{dt}$ but not which of the two coordinate systems is the more "appropriate". If we want to decide this question, other criteria than direct measurement must be sought, if there are any at all.

In the next section, we shall find that consideration of the distribution of matter in the universe and especially of the possible values of a cosmological constant give some indication of what the final choice may be.

3. *Volume and mass*

Let us consider first the volume of an hypersurface

$$\tau = \text{constant}, \tag{21}$$

using the metric relation (5). This is given by

$$V = 4\pi \int_{\xi_0}^{\xi_1} RP^2 d\xi \tag{22}$$

with R and P now regarded as functions of ξ only, and with ξ_0 corresponding say, to

$$R = 1$$

and ξ, to

$$R = 0.$$

On the hypersurface

$$d\xi = -dT,$$

and so, we must take

$$\frac{dR}{dT} = + \frac{\lambda^2+R^4}{4m}, \tag{23}$$

and

$$V = -4\pi \int_{T_0}^{T_1} RP^2 dT$$

$$= 128\pi m^3 \int_0^1 \frac{RdR}{(\lambda^2+R^4)^2}$$

$$= 4\pi r_0^3 \left(\tan^{-1}\frac{1}{\lambda} + \frac{\lambda}{1+\lambda^2}\right). \tag{24}$$

The hitherto undeterminable sign of the relation (9) is thus fixed by the requirement that the volume of the above 3-section of the world should be positive. We may notice also that for small λ

$$V \simeq 2\pi^2 r_0^3$$

which is the same as the total volume of an Einstein universe. The above calculation, however, is not coordinate independent because of the arbitrary choice of the section (21). This is inevitable in GFT especially since the energy-momentum tensor is to be calculated rather than predetermined as in standard General Relativity. This, after all, was one of the motivations behind the present theory. Thus, although we can define

$$T_{\mu\nu} = -\frac{1}{k} G_{\mu\nu} = -\frac{1}{k}(R_{\mu\nu} - \tfrac{1}{2} a_{\mu\nu}(R - 2\Lambda)), \tag{25}$$

where the geometrical Ricci tensor $R_{\mu\nu}$ is constructed from Christoffel brackets formed with the components $a_{\mu\nu}$ of a metric tensor (and R of course, is $a^{\mu\nu}R_{\mu\nu}$), we should not presuppose a physical interpretation of the individual components of $T_{\mu\nu}$. On the other hand, one can expect the results of the comprehensive theory to bear some relation to classical data. We, therefore, write heuristically

$$T_{\mu\nu} = (\varrho_0 + p)u_\mu u_\nu - a_{\mu\nu}p, \tag{26}$$

with u_μ being a covariant velocity vector, ϱ_0 — mass density and p — the pressure. For "slow" matter, we then have, as usual,

$$T_{00} = \varrho_0, \quad T_{11} = -a_{11}p, \quad T_{22} = T_{33}\operatorname{cosec}^2\theta = -a_{22}p. \tag{27}$$

We have considered in the previous section, three "likely" coordinate systems (i.e. three choices of the time):

$$S_1 \equiv (T, \xi, \theta, \phi); \quad S_2 \equiv (\tau, \xi, \theta, \phi); \quad S_3 \equiv (t, \varrho, \theta, \phi). \tag{28}$$

We now have (putting $k = 1$)

	T_{00}	T_{11}	T_{22}
S_1	$\frac{\gamma+2}{r_0^2} - \Lambda$	$\gamma\left(\frac{3\gamma}{r_0^2} - \Lambda\right)$	$p^2\left(\Lambda - \frac{\gamma}{r_0^2}\right)$
S_2	$\frac{\gamma+2}{r_0^2} - \Lambda$	$(1-\gamma)\left(\Lambda + \frac{2-3\gamma}{r_0^2}\right)$	$p^2\left(\Lambda - \frac{\gamma}{r_0^2}\right)$
S_3	$\gamma\left(\frac{3\gamma}{r_0^2} - \Lambda\right)$	$\gamma(1-\gamma)\left(\Lambda - \frac{\gamma}{r_0^2}\right)$	$p^2\left(\Lambda - \frac{\gamma}{r_0^2}\right)$

(29)

It follows that unless we have T_{22} everywhere negative

$$\Lambda \neq 0. \tag{30}$$

For the universe expressed in any of the coordinate systems S_i, matter cannot be "slow" if the perfect fluid relation (26) is to hold because clearly

$$a^{11}T_{11} \neq a^{22}T_{22}.$$

Hence the nonvanishing of the cosmological constant Λ is the only conclusion we can draw legitimately up to this point.

Let us now consider the values of T_{00} (*i*) on the critical surface

$$r = 2m, \quad \text{or} \quad \gamma = 0,$$

and (*ii*) at infinity ($\gamma = 1$), respectively for the three most likely values of Λ:

$$\Lambda_1 = \frac{1}{r_0^2}, \quad \Lambda_2 = \frac{2}{r_0^2} \quad \text{and (de Sitter)} \quad \Lambda_3 = \frac{3}{r_0^2}.$$

These are

$\gamma = 0$	Λ_1	Λ_2	Λ_3
S_1	$1/r_0^2$	0	$-1/r_0^2$
S_2	$1/r_0^2$	0	$-1/r_0^2$
S_3	0	0	0

$\gamma = 1$	Λ_1	Λ_2	Λ_3
S_1	$2/r_0^2$	$1/r_0^2$	0
S_2	$2/r_0^2$	$1/r_0^2$	0
S_3	$2/r_0^2$	$1/r_0^2$	0

(31)

If $\Lambda = \Lambda_3$, the negative mass density on the critical surface (I have shown in Ref. [3] that unlike the corresponding case of the Schwarzschild solution, a Szekeres-Kruskal type of transformation does not shift the resulting singularity of the metric) is difficult to understand. Also, taking

$$T_{00} = \varrho_0,$$

the relative mass of a spatial section of the universe (in S_2) is easily seen to be given by

$$M = \frac{64\pi m^3}{k} \int_0^1 \frac{\left(\frac{3}{r_0^2} - \Lambda - \frac{x}{r_0^2}\right) dx}{(\lambda^2 + x^2)^2}$$

$$= \frac{4\pi r_0^2}{k}\left(\frac{3}{r_0^2} - \Lambda\right)\left(\tan^{-1}\frac{1}{\lambda} + \frac{\lambda}{1+\lambda^2}\right) - \frac{4\pi r_0 \lambda}{k(1+\lambda^2)} \quad (32)$$

and would be negative for the de Sitter choice of Λ.

We now observe that only for the S_2 choice of time and distance, we have

$$T^{00} = T_0^0 = T_{00}. \quad (33)$$

It cannot be a priori decided in GFT which of these components should represent mass density and therefore the equality (33) strongly suggests that S_2 is the correct choice being also allowed by the empirical considerations embodied in the equations (19). If in addition, we choose

$$\Lambda = \Lambda_2 = \frac{2}{r_0^2}, \tag{34}$$

vanishing of the mass density on the critical surface may be interpreted as meaning that in the initial (and presumably recurring) explosion, all of the primeval fire-ball blew up.

Reintroducing Einstein's constant k and the speed of light c, the mass of the universe for small λ, becomes

$$M = 2\pi^2 T_0/c^2 k. \tag{35}$$

Finally, we may note that if

$$a^{\mu\nu} u_\mu u_\nu = 1, \tag{36}$$

the resulting mass distribution of the world may be regarded as a perfect fluid moving with the four-velocity

$$u_\mu = \pm \left(\frac{1}{\sqrt{\gamma}}, \frac{-(1-\gamma)}{\sqrt{\gamma}}, 0, 0 \right), \tag{37}$$

under a pressure

$$p = \frac{2-\gamma}{kr_0^2} \tag{38}$$

and having a relative mass-density

$$\varrho_0 = \frac{3\gamma - 2}{kr_0^2}. \tag{39}$$

4. *Cosmic observables*

The discussion of the preceding section, whatever its theoretical importance may be, does not lead to any results which could be either measured or observed. Its value is solely to establish the concrete model of the universe as predicted by GFT. I have shown in the quoted references that the GFT universe admits isotropy and expansion which are the two facts of which we are least uncertain in cosmology. Apart from my remarks about information from distant sources, however, most of empirical evidence concerning the structure of universe at large is derived from measurement of the (red) displacement of spectral lines. Empirical verification or otherwise (i.e. of GFT which predicts the model subject to the restriction imposed by the limited nature of the static, spherically symmetric solution) of the new cosmology is likely to arise from relations involving the red shift. Some of these will now be obtained.

Although τ (or perhaps t) represents the "correct" time parameter, it is the quantity.

$$T = \tau - \xi, \tag{7}$$

which is the argument of the components of the metric tensor and is presumably measured by an observer's clock. It has the appearance of the retarded time.

Starting with the *T-R* equation

$$\frac{dT}{dR} = \frac{4m}{\lambda^2+R^4} = \frac{P^2}{m} \tag{40}$$

we define the redshift z by the standard formula (e.g. Ref. [5])

$$z = \frac{R_a}{R} - 1, \tag{41}$$

R_a denoting the value of R at the observer (i.e. at the arrival time of the signal).

Hence

$$\frac{dz}{dT} = -\frac{\lambda^2(1+z)^4+R_a^4}{4mR_a(1+z)^2}, \tag{42}$$

or, writing

$$\Delta T = T_a - T,$$

$$\frac{R_a^3(1+\nu^2)}{4m}\Delta T = z+(1-2\mu^2)z^2+\tfrac{1}{3}(1-14\mu^2+16\mu^4)z^3+o(z^4), \tag{43}$$

where

$$\nu = \frac{\lambda}{R_a^2}, \quad \mu^2 = \frac{\nu^2}{1+\nu^2}.$$

Choosing units of time so that the Hubble constant is 1, or equivalently writing

$$\frac{R_a^3(1+\nu^2)}{4m}\Delta T = \delta T,$$

we find that

$$z = \delta T(1+(2\mu^2-1)\delta T+\tfrac{1}{3}(5+2\mu^2+8\mu^4)\delta T^2+o(\delta T^3)). \tag{44}$$

The above formulae depend only on purely geometrical quantities whereas in the classical cosmologies they involve parameters of mass and pressure, that is a priori assumptions about the state of matter in the universe for which there can be little empirical justification or rather, whose justification is theory dependent.

It is a somewhat different question whether they can constitute an empirical verification of the present theory. Perhaps one possibility may be to compare the predicted forms of the coefficients of δT and δT^2 in the equation (44) especially since they depend on the single parameter μ.

One thing can be immediately obtained from the above formula. The deceleration parameter

$$q = -\frac{RR''}{R'^2} = -\frac{P^2R^4}{m^2}, \tag{45}$$

and therefore, is necessarily negative. In the general relativistic cosmologies this possibility is usually rejected on the grounds that it must necessarily imply a negative energy density. This is not the case in GFT where the latter is independently calculated from the definition (25). From (45) we find that at the observer (which, after all, is the only place we are really interested in)

$$q_a = -\frac{4}{1+v^2}. \tag{46}$$

In the present theory, it is rather difficult to decide where the observer is situated but perhaps the most reasonable assumption is that at "a"

$$r \sim 2m,$$

since the region

$$r < 2m,$$

is definitely excluded. Then

$$\lambda \sim v \sim R_a \sim 1$$

and

$$q_a \sim -2. \tag{46}$$

This then is an inevitable conclusion of the present theory.

Let us next consider cosmic distances as determined by the apparent size of an observed object. If the extremities of the latter are assumed to be at the same radial distance from the observer obtainable by integrating the first of the equations (19), and subtend an angle $\delta\theta$, its diameter, that is the local separation of its extremities, is given by [5]

$$l = P\delta\theta. \tag{47}$$

In terms of the redshift, the angular diameter is

$$\frac{l}{P} = \frac{l}{2m}\sqrt{\lambda^2 + \frac{R_a^4}{(1+z)^4}}. \tag{48}$$

Hence, as z varies from 0 to infinity, the angular diameter varies between the limits

$$\frac{l}{2m}\sqrt{\lambda^2 + R_a^4} \quad \text{and} \quad \frac{l}{r_0}$$

respectively.

Now, equation (19) can be rewritten as

$$\frac{d\xi}{dz} = \frac{4m(1+z)^3}{R_a^4 + \lambda^2(1+z)^4}, \tag{49}$$

so that

$$\xi = \frac{m}{\lambda^2}\ln\frac{R_a^4 + \lambda^2(1+z)^4}{\lambda^2 + R_a^4}. \tag{50}$$

It follows that there are no horizons in any finite part of the universe which is occupied by matter or fields and this is another definite conclusion of the GFT cosmology.

For small red shifts

$$\xi = \frac{4m}{\lambda^2+R_a^4} z \left(1+ \frac{3R_a^4-\lambda^2}{2(R_a^4+\lambda^2)} z\right) + o(z^3) \tag{51}$$

but it must be observed that close to an observer, the formula (48) must be replaced by l/ξ which becomes infinite at $z = 0$ as seems to be conceptually required.

Finally, for most of the universe, we have

$$R \gg \sqrt{\frac{2m}{r_0}} = \sqrt{\lambda}\,. \tag{52}$$

If we therefore, introduce a new "coordinate" given by

$$r = \sqrt{\frac{\lambda}{R}}, \tag{53}$$

we get

$$r \ll 1,$$

while

$$\frac{dT}{dr} = -\frac{4}{\lambda^{3/2}} \frac{r^2}{1+r^4}\,. \tag{54}$$

Hence, again for "most" of the universe, and to a high degree of accuracy

$$R \simeq \left(\frac{4m}{3}\right)^{1/3} (T_a - T)^{-1/3},$$

T_a being the "retarded" time of the arrival of a signal.

5. Conclusions

The "new cosmology" predicted by GFT differs in several respects from the classical, general relativistic models of the universe. As we have seen, it demands a nonzero value of the cosmological constant, gives a definite value of the deceleration parameter and asserts that there should be no horizons in any observable part of the world. This last conclusion, of course, depends on the validity of the somewhat artifical solution from which the present model is derived, namely a static spherically symmetric geometry. Since the latter may be easily upset by local conditions, it does not follow for example that black holes cannot exist in this theory. The horizons which are disallowed are any which would arise from purely cosmological considerations, that is anything that is consistent with the geometrical restrictions of the overall structure of the world.

The fields which are admitted by the GFT are the macroscopic gravitation and electromagnetism but a special characteristic of the theory, which in fact is one of its basic aims, is the elimination of energy-momentum terms from the field equations which determine both the physical laws and the geometrical structure of the space-time. This leads to certain difficulties in arriving at physically meaningful conclusions. Although the components of an energy-momentum tensor can be readily calculated assigning to them a physical interpretation is necessarily arbitrary. Strictly speaking, the only assumption made in this respect is identification of T_{00} with mass, or energy density.

An unsolved problem of the theory which reflects on the likelihood of the cosmological model considered herein, is the validity (or otherwise) of Birkhoff's theorem. If the latter is not valid then it is possible that an evolving, time-dependent model may represent a more realistic cosmology.

On the other hand, if the theorem holds, the model we have been discussing must be considered to be a crucial empirical test of GFT.

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