Scale Expanding Cosmos Theory III - Gravitation

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In the Scale Expanding Cosmos (SEC) the gravitational potential is modified by the cosmological scale expansion. The range of the gravitational field rolls off close to the Hubble distance and the presence of matter modifies the gravitational vacuum field, which evaluated in the cosmological reference frame contains negative energy that should equal the gravitating mass energy mc^2. A freely falling particle never reaches the event-horizon, which could prevent the formation of black holes. Although the results presented in this paper are tentative, two definite conclusions may be made in the SEC model: 1. The event-horizon is a true singularity. 2. Any spherically symmetric solution (other than the cosmological line element) of the Einstein's equations necessarily must modify the vacuum energy-momentum tensor generating negative field energy.

Key words: Locally curved spacetime, Gravitational roll-off, Gravitational field energy, Black hole avoidance

1. Introduction.

The first paper in this series introduced the Scale Expanding Cosmos (SEC) theory showing that it resolves cosmological puzzles and that the theory's predictions agree with several observational programs including the supernova Ia observations and the Pioneer anomaly. The second paper discussed cosmic drag, a new property of the SEC, showing how it would explain galaxy formation, and the recently discovered discrepancies between optical observations and the planetary ephemerides.

This paper investigates how the gravitational potential is modified in the SEC by a "roll-off" function that diminishes the range of gravitation. This gravitational roll-off could generate negative field energy equal to $-mc^2$. It also appears that the formation of black holes is prevented in the SEC.

2. Schwarzschild's solution in the SEC.

The standard Schwarzschild solution may be derived from the line element:

$$ds^2 = n(r)\cdot dt^2 - l(r)\cdot dr^2 - r^2\cdot\left[dq^2 + \sin^2(q)\,dj^2\right] \tag{2.1}$$

The two functions *n(r)* and *l(r)*, corresponding to Schwarzschild's exterior solution, are familiar:

$$\begin{aligned} n(r) &= 1 - \frac{r_0}{r} \\ l(r) &= \left(1 - \frac{r_0}{r}\right)^{-1} \end{aligned} \tag{2.2}$$

This solution is obtained with the assumption that the energy-momentum tensor for vacuum disappears, i.e. that all its components equal zero. In the SEC the corresponding scale expanding line element is:

$$ds^2 = e^{2t/T}\left\{n(r)\cdot dt^2 - l(r)\cdot dr^2 - r^2\cdot\left[dq^2 + \sin^2(q)\,dj^2\right]\right\} \tag{2.3}$$

However, here the energy-momentum tensor for vacuum does not disappear; it equals the Cosmic Energy tensor of the SEC:

$$\begin{aligned} T_0^0 &= \frac{3}{K\cdot T^2}\cdot e^{-2t/T} \\ T_?^? &= \frac{1}{K\cdot T^2}\cdot e^{-2t/T} \;\; ; n = 1,\ 2,\ 3 \end{aligned} \tag{2.4}$$

K = Einstein's constant = $8pG/c^4$ or $8pG$ since $c = 1$.

Setting $n(r) = exp(N(r))$, $l(r) = exp(L(r))$ and denoting partial derivatives with lower indices, the GR equations for the line element (2.3) with Cosmic Energy Tensor (2.4) become:

Temporal $G_0^{\ 0}$ component:

$$e^{2t/T}G_0^0 = e^{-L}\left[\frac{L_r}{r} - \frac{\left(1-e^L\right)}{r^2}\right] + \frac{3\cdot e^{-N}}{T^2} = \frac{3}{T^2} \tag{2.5}$$

Radial $G_1^{\ 1}$ component:

$$e^{2t/T}G_1^1 = -e^{-L}\left[\frac{N_r}{r} + \frac{\left(1-e^L\right)}{r^2}\right] + \frac{e^{-N}}{T^2} = \frac{1}{T^2} \tag{2.6}$$

Angular $G_2^{\ 2}$ and $G_3^{\ 3}$ components:

$$e^{2t/T}G_{a}^{a} = -e^{-L}\cdot\left[\frac{N_{rr}}{2}+\frac{(N_r-L_r)}{2\cdot r}+\frac{N_r^2}{4}-\frac{N_r\cdot L_r}{4}\right]+\frac{e^{-N}}{T^2}=\frac{1}{T^2} \tag{2.7}$$

The exponential factor *exp(2t/T)* removes the factor *exp(-2t/T)* that results from raising one index in $G_{\mu\nu}$.

To investigate whether any solution pair *n* and *l* that satisfies both (2.5) and (2.6) also satisfies the angular relations (2.7), relation (2.6) may be differentiated to obtain N_{rr}. After repeated application of (2.5) and (2.6), the angular relation (2.7) becomes:

$$-\frac{1}{T^2}\cdot\left[0.5\cdot e^{L}-e^{L-N}+2\cdot e^{-N}-1.5\right]- \frac{r^2}{T^4}\cdot 0.5\cdot\left[3\cdot e^{L-N}-2\cdot e^{L-2N}-e^{L}\right]+e^{-N}\frac{1}{T^2}=\frac{1}{T^2} \tag{2.8}$$

Any pair of functions *n(r)* and *l(r)* that exactly satisfies the two equations (2.5) and (2.6) will not satisfy the third equation (2.7) (not counting the trivial $n = l = 1$). *There is no simultaneous solution to all three equations*. Therefore, any pair of functions *n(r)* and *l(r)* necessarily modifies the energy-momentum tensor.

Thus, the presence of matter modifies the SEC energy-momentum tensor for vacuum and induces gravitational field energy.

Although the analysis of these equations by no means is complete, a few interesting observations may be made at this time. Let's assume that the two metric functions are selected so that:

$$n(r)=\frac{1}{l(r)}=1-\frac{r_0}{r}f(r) \tag{2.9}$$

This choice is made since it eliminates the large term $(e^{-L}-1)/r^2$ in (2.5) and (2.6) leaving small rest terms of order $1/T^2$. Also, in section 4 I will show that this choice yields gravitational field energy that equals $-mc^2$.

Substituting (2.9) into (2.5)-(2.7):

$$e^{2t/T}G_0^0 = \frac{r_0}{r^2}f_r + \frac{3}{T^2}e^{-N} \tag{2.10}$$

$$e^{2t/T}G_1^1 = \frac{r_0}{r^2}f_r + \frac{1}{T^2}e^{-N} \tag{2.11}$$

$$e^{2t/T}G_2^2 = G_3^3 = \frac{r_0}{2r}f_{rr} + \frac{1}{T^2}e^{-N} \tag{2.12}$$

In the far field we have:

$$\frac{1}{T^2}\left(e^{-N}-1\right) \approx \frac{r_0}{T^2 r}f \tag{2.13}$$

Equations (2.5)-(2.7) become:

$$\frac{1}{r}f_r = -\frac{3}{T^2}f \tag{2.14}$$

$$\frac{1}{r}f_r = -\frac{1}{T^2}f \tag{2.15}$$

$$\frac{1}{2}f_{rr} = -\frac{1}{T^2}f \tag{2.16}$$

The solutions to these equations are:

$$f_0 = e^{-1.5\left(\frac{r}{T}\right)^2} \tag{2.17}$$

$$f_1 = e^{-0.5\left(\frac{r}{T}\right)^2} \tag{2.18}$$

$$f_2 = f_3 = \cos\left(\frac{\sqrt{2}r}{T}\right) \tag{2.19}$$

There is no solution common to all three GR equations. A possible approach to selecting "a best" roll-off function *f(r)* is presented in the next section.

3. The SEC action integral

The GR equations were derived by David Hilbert using the action:

$$I_H = \int L_H \cdot dV = \int R \cdot \sqrt{-g} \cdot dx^4 \tag{3.1}$$

R is the Ricci scalar and *L=RÖ-g* the Lagrangian.

The GR equations follow from this action by setting the variation of the metrical coefficients equal to zero. Taking into account the possibility of discrete scale increments I will consider the following action:

$$I_{SEC} = \int S^2 \cdot \left(G - K \cdot T_{SEC}\right)\sqrt{-g} \cdot dx^4 \tag{3.2}$$

S is the scale factor and *G* the trace of Einstein's tensor. T_{SEC} is the trace of the SEC Cosmic Energy Tensor. The product $S^2 \cdot T_{SEC}$ does not depend on the metrics and may be considered constant when varying the metrical components. In the Standard Cosmological Model (SCM), based on the big bang, where the scale is constant and where there is no vacuum energy, this action coincides with the Hilbert action since the trace of Einstein's tensor is the negative of the Ricci scalar *G = -R*.

The SEC action may be viewed as a generalization of the Hilbert action, which also takes into consideration discrete scale variation. The scale is regarded as an independent parameter, which changes in discrete increments during the piecewise continuous cosmological expansion. This means that the variation of the SEC action has two independent parts that both must equal zero:

$$d\,I_H = S^2 \cdot \int d\left\{G \cdot \sqrt{-g}\right\} dx^4 + \cdot \int \Delta S^2 \cdot \left\{\left(G - K \cdot T_{SEC}\right)\sqrt{-g}\right\} \cdot dx^4 = 0 \qquad (3.3)$$

The first part is the Hilbert action and the second part implies:

$$G - K \cdot T_{SEC} = 0 \qquad (3.4)$$

The increment ΔS^2 models both discrete scale expansion and oscillatory scale modulation. This will have important consequences in the next paper in this series, where I propose that quantum mechanical wave functions correspond to modulation of the scale *S*. Relation (3.4) is trivially satisfied by the SEC (vacuum) line element, but in the presence of matter it will add a constraint to the gravitational vacuum field. This constraint can be used to find the "roll-off" function *f(r)* of the previous section.

Applying relation (3.4), making use of the GR equations (2.5)-(2.7) and relations (2.10)-(2.12), results in the following differential equation applicable in the far-field:

$$G - K \cdot T_{SEC} = 0 \rightarrow \frac{r_0}{r} f_{rr} + \frac{2r_0}{r^2} f_r + \frac{6}{T^2} e^{-N} - \frac{6}{T^2} = 0 \qquad (3.5)$$

We get using (2.13):

$$\frac{r_0}{r} f_{rr} + \frac{2r_0}{r^2} f_r + \frac{6}{T^2} \frac{r_0}{r} f = 0$$

or (3.6)

$$f_{rr} + \frac{2}{r} f_r + \frac{6}{T^2} f = 0$$

Another form of this equation is:

$$\nabla^2 f + \frac{6}{T^2} f = 0 \quad (3.7)$$

This familiar differential equation (Helmholtz's equation) has a simple closed form solution:

$$f_a = \frac{\sin(u)}{u}; \quad u = \frac{\sqrt{6}}{T} r \quad (3.8)$$

The action roll-off function f_a looks like a compromise between (2.17), (2.18) and (2.19). These roll-off functions are shown in Figure 1.

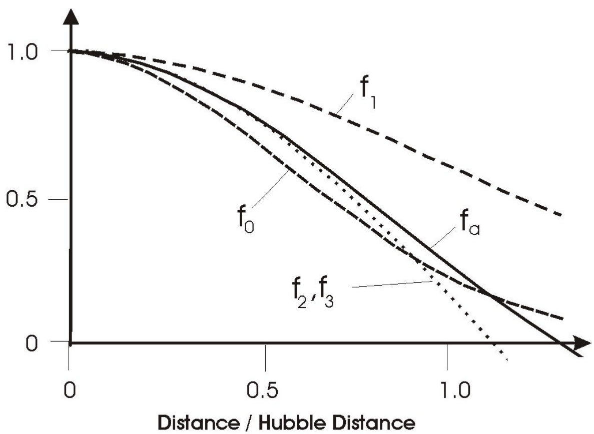

Figure 1: Gravitational roll-off functions

With the action roll-off function (3.8) the first order terms in the GR relations (2.5)-(2.7) are in the far field:

$$e^{2t/T}G_0^0 - \frac{3}{T^2} \approx \frac{r_0}{T^2 r} \tag{3.9}$$

$$e^{2t/T}G_1^1 - \frac{1}{T^2} \approx -\frac{r_0}{T^2 r} \tag{3.10}$$

$$e^{2t/T}G_2^2 - \frac{1}{T^2} = e^{2t/T}G_3^3 - \frac{1}{T^2} \approx 0 \tag{3.11}$$

This is the best possible far field fit of the functions n and l, since (2.9) implies $G_1{}^1 = G_0{}^0$. (However, the same (lowest order) far field fit is also obtained with $f = \exp[-(r/T)^2)]$. As mentioned above the choice (2.9) is motivated by the elimination of the larger terms containing $(r_0/r^3)f$ in (2.5) and (2.6). However, there is another motivation for the choice (2.9); with any "reasonable" roll-off function f the gravitational field energy of a spherically symmetric field generated by a central mass m equals $-mc^2$.

4. Gravitational field energy.

The subject of gravitational field energy has been lively debated ever since Einstein's introduction of GR in 1916. The energy-momentum tensor of GR specifies an energy density, which usually is considered to be the source for the spacetime field as given by Einstein's tensor G_{mn}. It seems that this field should contain gravitational field energy. However, in GR it is always possible to find a local Minkowskian coordinate system in which the energy-momentum tensor disappears, which suggests that there is no *absolute* gravitational field energy; the energy density depends on the chosen coordinate system. This is puzzling, since the gravitational field ought to have negative energy.

This motivated Einstein and other investigators (for example Tolman, Landau/Lifshitz, Møller and Weinberg) to try to find ways of modeling gravitational field energy using "pseudo-tensors", which are tensor-like objects that do not transform like tensors. Nowadays one realizes that these different pseudo-tensors all are related by gauge symmetry (Neto and Trajtenberg, 2000) and that energy density modelled by the pseudo-tensors may be nullified at any point by local variable transformation.

On the other hand, other investigators, for example Lorenz in 1916 and Levi-Civita in 1917, suggested that Einstein's tensor implicitly defines gravitational field energy density. With this interpretation Einstein's equations is an identity that simply says that the gravitational field energy density is such that it always matches the source energy field, but with opposite sign. Quoting Levi-Civita (Loinger, 2002):

"The nature of ds^2 is always such as to balance all mechanical actions; in fact the sum of the energy tensor and the inertial (spacetime) one identically vanishes."

This reminds us of Newton's third law of action and reaction and d'Alembert's principle. Also, we are familiar with this situation when gravitational forces and kinetic energy disappear in a freely falling particle's reference system. This interpretation suggests that the energy-momentum tensor of GR in vacuum actually models gravitational field energy relative to the selected coordinates, and that little is gained by introducing various gravitational pseudo-tensors.

In the SCM the energy-momentum tensor for vacuum disappears; there is no gravitational field energy in vacuum. This is consistent with that there is no cosmological reference frame in the SCM. Since energy is not invariant in GR, but depends on the choice of coordinates, the energy-momentum tensor for vacuum would depend on this choice unless it disappeared. For consistency the absence of a reference frame implies that the energy-momentum tensor must disappear in vacuum.

However, in the SEC theory, where there is a cosmological reference frame and a preferred line element – the SEC line element, the situation is different. It permits the definition of gravitational field energy by the following postulate:

Gravitational vacuum field energy density is defined by the energy-momentum tensor evaluated in the cosmological reference frame.

Accordingly, gravitational field energy density in vacuum may be defined by:

$$E_d = T_0^0 - T_1^1 - T_2^2 - T_3^3 = K^{-1}\left(G_0^0 - G_1^1 - G_2^2 - G_3^3\right) \tag{4.1}$$

Again, this energy density is well-defined in the cosmological reference frame. The total field energy for a spherically symmetric field is then given by:

$$E_T = \int_0^\infty E_d \cdot dV = \int_0^\infty 4\pi r^2 \left(T_0^0 - T_1^1 - T_2^2 - T_3^3\right)\sqrt{-g} \cdot dr \tag{4.2}$$

In the SEC universe this energy is always finite.

From relations (2.5)-(2.7) we see that terms containing $1/T^2$ cancel in the two energy expressions above. Therefore, to simplify the writing I will introduce primed Einstein tensor components as follows:

$$\begin{aligned} G'^0_0 &= e^{2t/T} G_0^0 - \frac{3}{T^2} e^{-N} \\ G'^\alpha_\alpha &= e^{2t/T} G^\alpha_\alpha - \frac{1}{T^2} e^{-N}; \qquad \alpha = 1, 2, 3 \end{aligned} \tag{4.3}$$

We then have:

$$E_d = e^{-2t/T} K^{-1} \left(G'^{0}_{0} - G'^{1}_{1} - G'^{2}_{2} - G'^{3}_{3} \right) \tag{4.4}$$

These primed tensor components coincide with the standard components that yield the solution (2.2) when T goes to infinity. These preliminaries permit the following observations.

Observation 1:

Under quite general assumptions the gravitational field energy equals –mc^2.

To show this, assume that the function *f(r)* in (2.9) satisfies:

$$f(0) = 1;\ f(\infty) = 0;\quad \lim_{r\to\infty}(r \cdot f_r) = 0;\ \lim_{r\to 0}(r \cdot f_r) = 0 \tag{4.5}$$

Setting:

$$E'^{a}_{a} = \int_0^\infty K^{-1} G'^{a}_{a}\, 4p\, r^2 dr \tag{4.6}$$

We get:

$$E'^{0}_{0} = E'^{1}_{1} = \int_0^\infty \left[\frac{r_0}{r^2} f_r \right] \cdot K^{-1} 4p\, r^2 dr =$$

$$= \left| r_0 f \cdot K^{-1} 4p \right|_0^\infty = -4p\, r_0 = -mc^2 \tag{4.7}$$

The last equality follows from:

$$r_0 = \frac{2mG}{c^2}; \qquad K^{-1} = \frac{c^4}{8p\, G}$$

For the angular components:

$$E'^{2}_{2} = E'^{3}_{3} = \int_0^\infty \frac{r_0}{2r} f_{rr} K^{-1} 4p\, r^2 dr \tag{4.8}$$

Integrating by parts:

$$\int_0^\infty \frac{r_0}{2r} f_{rr} K^{-1} 4\pi r^2 dr =$$

$$\left| r_0 \cdot f_r K^{-1} 2\pi r \right|_0^\infty - \int_0^\infty r_0 \cdot f_r \cdot K^{-1} 2\pi \, dr = 0 + \frac{mc^2}{2}$$

The gravitational field energy becomes:

$$E'_f = E'^0_0 - E'^1_1 - E'^2_2 - E'^3_3 = -mc^2 + mc^2 - 2\left(\frac{mc^2}{2}\right) = -mc^2 \quad (4.9)$$

In the SEC the epoch $t = 0$ may be chosen so that it always corresponds to present time, which means that the exponential scale factor may be ignored in the results so that $E = E'$. Therefore the field energy equals $-mc^2$, *which suggests that the gravitational field energy in general cancels the mass energy of the gravitating matter.* This would be a pleasing result, since the total energy of the universe then would be zero.

Observation 2:

The total gravitational field potential from all matter in the universe is finite.

The gravitational potential is the work of moving a (unity) test mass to infinity:

$$P(r) = -\frac{c^2}{2}\int_r^\infty \Gamma^1_{00} dx = -\frac{c^2}{2}\int_r^\infty \frac{n_r}{l} dx \approx -\frac{c^2}{2}\left[n(\infty) - n(r)\right] =$$
$$-\frac{c^2 r_0}{2}\frac{1}{r} f = -\frac{Gm}{r} f \quad (4.10)$$

The contribution from all matter in the universe becomes:

$$P_T \approx -\int_0^\infty \frac{G}{x} \cdot f \cdot 4p\, x^2 \mathbf{r}\, dx = -\int_0^\infty G \cdot f \cdot 4p\, x\, \mathbf{r}\, dx \qquad (4.11)$$

If f=exp[-a(t/T)2]:

$$P_T = -\frac{GM}{2aT}; \quad M = \frac{4p\, T^3 \mathbf{r}}{3} = \text{matter within r<T} \qquad (4.12)$$

With the action roll-off function (3.8):

$$P_a(r) = -\int_0^r \frac{G4p\mathbf{r}\, x^2}{x} \frac{\sin\left(x\sqrt{6}/T\right)}{\left(x\sqrt{6}/T\right)} dx = \qquad (4.13)$$

$$-\frac{G4p\mathbf{r}\, T^2}{6}\left(1-\cos\left(r\sqrt{6}/T\right)\right) = -\frac{GM}{2T}\left(1-\cos\left(r\sqrt{6}/T\right)\right)$$

Define an average limit by:

$$\overline{\lim}\, F(r) = \lim_{r\to\infty} \frac{1}{r}\int_0^r F(r)dr \qquad (4.14)$$

The total potential becomes:

$$\overline{P_a} = \overline{\lim} P_a(r) = -\frac{GM}{2T} \qquad (4.15)$$

Thus, the gravitational potential in the SEC is finite. This would resolve a longstanding puzzle since the time of Newton. The action roll-off is oscillatory but will satisfy conditions (4.5) if we apply the average limiting operation (4.14). For example:

$$\overline{\lim}_{r\to\infty}\left(r \cdot f\left(r\right)\right) = \overline{\lim}_{r\to\infty}\left[\cos\left(\frac{r\sqrt{6}}{T}\right) - \frac{T}{\sqrt{6}} \frac{\sin\left(r\sqrt{6}/T\right)}{r}\right] = 0$$

5. The near field solution

This section investigates the near field solution to the equations (2.5)-(2.7) based on the assumptions:

$$\lim_{r\to r_0} n(r) = 0 \text{ and } l^{-1}(r_0) \text{ is finite} \tag{5.1}$$

Thus, I will assume that the temporal metric approaches zero at the event horizon. This means that very close to the event horizon using equations (2.5) and (2.6):

$$e^{-L} \cdot \left[\frac{L_r}{r}\right] \cong -\frac{3 \cdot e^{-N}}{T^2} \tag{5.2}$$

$$e^{-L}\left[\frac{N_r}{r}\right] \approx \frac{e^{-N}}{T^2} \tag{5.3}$$

Thus:

$$r \approx r_0 \rightarrow l = n^{-3} \tag{5.4}$$

Very close to $r = r_0$ the near field metrics become:

$$n(r) \approx \left\{\frac{2}{T^2}\left[r^2 - r_0^2\right]\right\}^{1/4} \tag{5.5}$$

$$l(r) \approx \left\{\frac{2}{T^2}\left[r^2 - r_0^2\right]\right\}^{-3/4} \tag{5.6}$$

In GR inner products are preserved under variable transformation. Consider the scalar product for the momentum:

$$p_m p^m = m_0^2 = g_{mn} p^n p^m \tag{5.7}$$

Assuming radial motion we get with the line element (2.3):

$$m_0^2 = e^{2t/T}\left[n\left(p^0\right)^2 - l\left(p^1\right)^2 + 0\right] \tag{5.8}$$

p_0 is a constant of motion. Lowering the indices for $(p^0)^2$ we get:

$$\begin{aligned} m_0^2 &= e^{-2t/T} p_0^2 / n - e^{2t/T} l\left(p^1\right)^2 \\ \left(p^1\right)^2 &= \frac{e^{-4t/T}}{l \cdot n} p_0^2 - \frac{m_0{}^2 e^{-2t/T}}{l} \end{aligned} \tag{5.9}$$

In the SCM we have from (2.2):

$$\left|p^1\left(r_0\right)\right| = p_0 \tag{5.10}$$

A particle may fall through the event horizon and be swallowed by a black hole. But, in the SEC we get from (5.5), (5.6) and (5.9):

$$\left|p^1\left(r_0\right)\right| = e^{-2t/T} p_0 \cdot n\left(r_0\right) = 0 \tag{5.11}$$

Particles on geodesics will not cross the event horizon as long as relations (2.5) and (2.6) hold. This suggests that black holes might not form in the SEC.

The rest term of (2.8) gives sharply negative energy density close to the event horizon. Consider the two terms:

$$\begin{aligned} &\frac{1}{T^2} e^{L-N} \approx \frac{1}{T^2} e^{-4N} \sim \left[r^2 - r_0{}^2\right]^{-1} \\ &\left(\frac{r}{T^2}\right)^2 e^{L-2N} \approx \left(\frac{r}{T^2}\right)^2 e^{-5N} \sim r^2\left[r^2 - r_0{}^2\right]^{-5/4} \end{aligned} \tag{5.12}$$

The gravitational field energy density from each of these terms is negative and its volume integral diverges when r approaches the event horizon r_0. This might prevent gravitational collapse, a conjecture that gains further support from the fact that the event horizon is a truly singular surface.

Consider the Riemann curvature tensor:

$$R_{abnm} = \frac{1}{2}\left[g_{an,bm} - g_{am,bn} + g_{bm,an} - g_{bn,am} \right] \tag{5.13}$$

Let the first term be $g_{11,00} = 4g_{11}/T^2$. With $g_{11} = exp(2t/T)\cdot l = exp(2t/T) \cdot n^{-3}$ this term becomes infinite at $r = r_0$. The other three terms are finite. Thus elements of the Riemann tensor are singular at the event horizon.

Therefore, the SEC scale expansion could both limit the range of the gravitational potential in the far field and prevent the formation of black holes in the near field. However, these observations are not yet conclusive since there is no exact solution to the GR equations in the SEC. However, two definite statements may be made at this time:

1. The event horizon at $r = r_0$ is a true singularity in the SEC.
2. Any spherically symmetric solution pair n and l (other than $n = l = 1$) necessarily must modify the vacuum energy-momentum tensor generating negative field energy

6. Discussion and summary.

If the line element that yields Schwarzschild's solution in the SCM is modified by applying the exponential scale factor of the SEC theory and the SEC vacuum energy-momentum tensor is taken into account, Schwarzschild's exterior solution is altered in very interesting ways. Instead of the traditional gravitational potential that decreases inversely proportional to the radial distance, a gravitational roll-off function appears, and in the far field the potential assumes the form:

$$P(r) = -\frac{Gm}{r} f(r)$$

The roll-off function *f(r)* restricts the range of gravitation at a distance comparable to the Hubble distance.

In the SEC no exact simultaneous solution to all GR equations exists, which means that any "solution" necessarily must modify the vacuum energy-momentum tensor, *i.e.*, *the presence of matter induces negative vacuum energy evaluated in the cosmological reference frame*. The observations of section 4 suggest that the vacuum energy approximately (and probably exactly) equals $-mc^2$, which means that positive matter energy is balanced by corresponding negative gravitational field energy. This is a desirable feature, since the total energy of the SEC universe then would be zero and the presence of matter would not change the vacuum energy-momentum tensor other than locally.

In the SCM the gravitational potential from all matter in the universe is infinite, but in the SEC it is finite. The gravitational potential from all matter in the universe equals $-GM/(2T)$, where T is the Hubble distance and M matter within this distance. This would resolve a longstanding conundrum since the time of Newton.

At small radial distances approaching what in the SCM would be a black hole's event horizon the vacuum energy in the SEC diverges sharply, which means that a falling particle may never reach the event horizon. This would prevent the formation of black holes; the event horizon is a true singularity. It is intriguing that a very small vacuum energy density with zero net gravitating energy, which is generated by the cosmological scale expansion, both might limit the far-field action of gravitation and prevent the formation of black holes in the near-field.

If the formation of black holes is prevented in the SEC something quite dramatic must happen at gravitational collapse, which in the SCM would lead to the formation of a black hole. This could account for the AGNs and be the engine of quasars. Prevention of black holes might also explain the enigmatic gamma ray bursts, which could be generated in the sudden gravitational collapse of massive stars.

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