Universes, Black Holes and Elementary Particles

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The divergence in the energy density of zero-point radiation can be removed by addition of self-gravitational potential energy density, provided that the resulting finite energy density closes the universe at radius R. Gravitational renormalization removes also the divergence of the self-energy of the electron. The black hole condition is satisfied at r = R, for both internal and external motion. Extended Newtonian cosmology in flat space-time is valid only with coordinate-dependent units. The equivalent Einstein cosmology (with constant units) is that of de Sitter space-time. Being a black hole, the universe is perfectly isolated from the rest of the cosmos, and is one of an infinity of universes. A universe is to be regarded as an isolated system surrounding any test mass m whose boundary surface adjusts so as to produce at m in the rest frame of m a constant gravitational potential irrespective of the distribution of surrounding matter.

1. Vacuum Fluctuations

Vacuum fluctuations are often regarded as a purely quantum mechanical effect without classical analog. However, papers extending over a number of years (Weisskopf 1939, Welton 1948, Marshall 1963, Power 1966, De la Pena-Auerbach and Garcia-Colin 1968, Boyer 1978) have shown that it is possible to regard vacuum fluctuations as classical electron motion driven by zero-point radiation. In taking this viewpoint, remarkable insights into the meaning of quantum mechanics are achieved.

Classically, zero-point radiation has energy $\hbar\omega/2$ per standing wave mode of frequency ω, of which there are $\omega^2 \mathrm{d}\omega/\pi^2\sigma^3$ in unit volume in frequency range $\omega \to \omega + \mathrm{d}\omega$. Thus the energy density of zero-point radiation in $\omega \to \omega + \mathrm{d}\omega$ is $U_\omega \mathrm{d}\omega$ and over all frequencies is U_0, where

$$U_0 = \int U_\omega \mathrm{d}\omega = \int \frac{\hbar\omega^3}{2\pi^2 c^3}\mathrm{d}\omega = \frac{\hbar\omega^4}{8\pi^2 c^3} \tag{1}$$

Adding the zero-point radiation to blackbody radiation for temperature T, one obtains (Marshall 1963)

$$U_\omega(T) = U_\omega \frac{1+x}{1-x} \tag{2}$$

where $x = \exp(-\hbar\omega/kT)$, and where U_ω is given by (1). Zero-point radiant energy is not measurable because the most sensitive detector is already in equilibrium with zero-point radiation. Only finite temperature is detectable.

One notes from (1) that $U_0 \to \infty$ as $\omega \to \infty$. It is proposed to renormalize U_0 by inclusion of the gravitational self-energy of the zero-point radiation. We distinguish gravitational mass m from equivalent inertial mass Km by the constant K, which has dimensions although it is usual to assign value unity to K by choice of the gravitational constant G. The Newtonian gravitational potential within a universe of finite radius R containing uniform mass density ρ_0 is

$$\phi(r) = -2\pi G\rho_0 R^2\left(1 - \frac{r^2}{3R^2}\right) \tag{3}$$

A universe specified by the finite radius R constitutes a perfectly isolated system within an infinite cosmos for reasons that will transpire below. The gravitational mass density associated with zero-point radiation having energy density U_0 is $4U_0/3$ (enthalpy density), because pressure $p = U_0/3$ does work $p\mathrm{d}V$ when the volume of zero-point radiation increases by $U_0\mathrm{d}V$ (see Tolman 1934), which requires that we assign mass to stored potential energy in addition to rest energy (as in a compressed spring). Adding gravitational self-energy, the total energy density of zero-point radiation becomes

$$\begin{aligned} K\rho_0 c^2 &= U_0 + \frac{\left(4U_0/3Kc^2\right)\phi(0)}{2} \\ &= U_0\frac{1-4\pi G\rho_0 R^2}{3Kc^2} \end{aligned} \tag{4}$$

where a factor of ½ ensures that contributions to interaction potential energy are not counted twice. In order that ρ_0 remain finite, we require that

$$4\pi G\pi_0 R^2 = 3Kc^2 \tag{5}$$

which is the condition for ρ_0 to close the universe at radius R.

Now consider a particle with electromagnetic mass m^* and gravitational potential energy $m^*\phi(r)$ at radius r in the Newtonian universe. Following the same procedure, its mass m^* is renormalized to $m(r)$, where

$$Km(r)c^2 = Km^*c^2 + m^*\phi(r) = -\left(1 - \frac{r^2}{R^2}\right)\frac{Km^*c^2}{2} \tag{6}$$

Thus, $m(r) = -\left(1 - r^2/R^2\right)m^*/2$. Now no factor ½ enters the $m^*\phi(r)$ term.

We note that $m(0) = -m^*/2$. Because all masses interact with the zero-point radiation of the universe, their renormalized values will all be negative. However, this raises no difficulty, because all forces and interaction energies between local masses are quadratic in gravitational mass. Inertial force and inertial mass represent interactions between a local mass m and universe mass ρ_0, which are unique in that the signs of m and ρ_0 are opposite. The opposite signs have the consequence that m gravitates outwards rather than inwards in the potential field (3). If m is released from rest at the origin, then at radius r its outward radial velocity will be v, where

$$\begin{aligned}\frac{Kmv^2}{2} &= m\left[\phi(0)-\phi(r)\right]\\ &= \frac{m2\pi G\rho_0 r^2}{3} = \frac{Kmc^2r^2}{2R}\end{aligned} \tag{7}$$

from which follows

$$\frac{v}{c} = \frac{r}{R} \tag{8}$$

The interpretation of this result is deferred until sections 3 and 4.

2. Electron Self-Energy

Electromagnetic energy density in the external field of an electron provides gravitational mass density which is the source of a gravitational field. The gravitational field, in turn, provides energy density which makes a further contribution to the source of the same field (*i.e.* a self-source term). The problem is to calculate the total energy in both fields integrated down to a radius ε, which we shall allow to approach zero. The present treatment differs from that due to Arnowitt *et al.* (1960).

The electrostatic energy W' in the field of an electron with charge q [which can be either Coulomb charge q or bare charge $(\hbar c)^{1/2}$] is given by

$$W' = \int_\varepsilon^\infty \frac{E'^2}{8\pi}4\pi r^2\,\mathrm{d}r = \frac{q^2}{2\varepsilon} \tag{9}$$

where $E' = q/r^2$. The energy density in both fields E' and E'' is the source of the field E''. We convert from energy density to gravitational mass density ρ by dividing by Kc^2, and then to gravitational charge density $\bar{\rho}$ by multiplying by $G^{1/2}$. Introducing $\alpha = G^{1/2}/Kc^2$, we obtain

$$\bar{\rho}(r) = \frac{\alpha\left(E'^2 - E''^2\right)}{8\pi} \tag{10}$$

By Gauss's theorem,

$$4\pi r^2 E'' = -4\pi\int_0^r \bar{\rho}(r)4\pi r^2\,\mathrm{d}r \tag{11}$$

After substituting (10) into (9), writing $\bar{m}(r) = E''r^2$, differentiating, and introducing $u = 1/r$, we obtain

$$\frac{\mathrm{d}\bar{m}}{\mathrm{d}u} = \frac{\left(q^2-\bar{m}^2\right)\alpha}{2} \tag{12}$$

The solution is

$$\begin{aligned}\frac{\bar{m}}{q} &= \tanh\left(\frac{a}{2r}+C\right)\\ E'' &= \frac{\bar{m}(r)}{r^2}\end{aligned} \tag{13}$$

where

$$a = \frac{G^{1/2}q}{Kc^2} = 1.62\times 10^{-33}\quad \mathrm{cm} \tag{14}$$

and where $q = (\hbar c)^{1/2} = 137^{1/2}e$, C being an integration constant. At $r=0$ we find $\bar{m}(0) = q$, and at $r=\infty$ we find $\bar{m}(\infty) = q\tanh C \cong qC$. If $\bar{m}(\infty) = G^{1/2}m$, where m is the observed electron mass, then $C = \bar{m}/q$. Note that $\bar{m}(r)$ begins to deviate significantly from $\bar{m}$ when $2r < a/C = aq/\bar{m}$.

It remains to obtain the total energy in both the electrostatic and gravitational fields of the electron. We shall obtain a finite result by integrating total energy density down to $r=0$. The energy W' in the electrostatic field is

$$W' = \int_0^\infty \frac{E'^2}{8\pi}4\pi r^2\,\mathrm{d}r = -\left[\frac{q^2}{2r}\right]_0^\infty \tag{15}$$

The energy in the gravitational field is

$$\begin{aligned}W'' &= -\int_0^\infty \frac{E''^2}{8\pi}4\pi r^2\,\mathrm{d}r = \int_0^\infty \frac{\bar{m}^2}{2r^2}\mathrm{d}r\\ &= \frac{q^2}{a}\int_\infty^C \tanh^2 x\,\mathrm{d}x = \frac{q^2}{a}\left[x-\tanh x\right]_\infty^C\end{aligned} \tag{16}$$

where $x = a/2r + C$. As $r\to\infty$, $x\to C$ and as $r\to 0$, $x\to\infty$ and $\tanh x\to 1$.

The divergent terms in (15) and (16) cancel when we take the total energy:

$$\begin{aligned}W = W' + W'' &= \frac{q^2}{a}\left[\tanh x\right]_\infty^C\\ &= \left(1-\frac{\bar{m}}{q}\right)\frac{q^2}{a} \cong \frac{q^2}{a}\end{aligned} \tag{17}$$

where we use $\tanh(\bar{m}/q) \cong \bar{m}/q$.

Gravitational renormalization is not to be confused with renormalization of electron self-energy in quantum electrodynamics. The Dirac vacuum modifies contributions to electron self-energy, as analyzed by Weisskopf (1939). In electron theory, integration of the electrostatic field energy density down to radius ε produces an ε^{-1} divergence; in positron theory, this is weakened to a logarithmic divergence. In electron theory, the energy in the magnetic and solenoidal electric fields cancels; in positron theory they add, yielding ε^{-2} divergence. In electron theory, the energy in the vacuum fluctuations diverges as ε^{-2}; in positron theory energy in the vacuum fluctuations cancels to within a logarithmic divergence the ε divergence created in the magnetic and solenoidal electric fields. Thus, for the sum of contributions, positron theory gives a logarithmic divergence.

3. The Black Hole Universe

Matter in a universe expands because the potential field (3) implies gravitational field $\nabla\phi = -4\pi G\rho_0\mathbf{r}/3$. Thus, negative mass experiences an outward radial force and positive mass an inward radial force. The gain in kinetic energy of a particle moving radially outward is due to loss of gravitational potential energy so that renormalized mass decreases, reaching zero at $r=R$ in accordance with (7). This is the condition for the surface of the universe to be the event horizon of a black hole.

The total mass of zero-point radiation in a universe is $M = 4\pi R^3\rho_0/3$. Another form of (5) then is

$$\frac{GMm}{R} = Kmc^2 \tag{9}$$

which expresses that the rest energy of a mass m which approaches a universe from the outside has gravitational potential energy sufficient to cancel its rest energy at the radius of the universe, again the condition for a black hole. A universe, therefore, behaves as a black hole for both an internal and an external observer. The black hole horizon at $r = R$ severs connection between regions $r < R$ and $r > R$, in which sense a universe becomes a perfectly isolated system in an infinite Cosmos.

Expansion in accordance with (8) is not universe expansion in the sense of the conventional "Big Bang" cosmology, because velocity is not relative to a Euclidean reference reference frame R_E, but relative to the aether fluid, which is assigned the free-fall velocity $\mathbf{v}_g(\mathbf{r},t)$. The Euclidean frame is available only for flat Minkowski space-time. The two references for velocity give rise to two Doppler shifts. We call the Doppler shift relative to the Euclidean frame a normal Doppler shift, and that relative to the aether fluid a generalized Doppler shift. If the source is at rest relative to the Euclidean frame, it still has motion relative to the aether fluid, and the Doppler shift due to this motion is called a "gravitational redshift." Thus, a generalized Doppler shift is a superposition of gravitational redshift and normal Doppler shift. The redshift due to universe expansion (8) is *wholly a gravitational redshift.*

4. The Equivalent Einstein Cosmological Model

In order to understand universe expansion in the present sense, it is necessary to consider the equivalent cosmological model in Einstein's theory. There are two distinct and independent descriptions of gravitation, which stem from the two possible interpretations of the aether drift experiments which led to Einstein's special theory of relativity. On the one hand, Lorentz, Fitzgerald, Poincaré (L-F-P) and others explained the null results of aether drift experiments by contraction of all lengths parallel to aether velocity $\mathbf{v}_g = \beta_g c$ by a factor $\gamma_g^{-1} = \left(1-\beta_g^2\right)^{1/2}$ and dilation of all clock periods by the factor γ_g. On the other hand, Einstein evaded explaining the results by postulating that (i) light velocity is constant relative to the observer and (ii) the laws of physics have the same form with respect to all frames of reference in uniform relative motion. One approach is as good as the other, although only that of Einstein became fashionable. It can be demonstrated that the same mathematical results follow from the L-F-P approach (see Ehrlichson 1973, Selleri 1993).

In special relativity only uniform motion of the aether fluid is considered. When a gravitational field is introduced, aether velocity becomes non-uniform; that is, we have a velocity field $\mathbf{v}_g(\mathbf{r},t)$. Now the contraction of lengths and dilation of time periods are functions of the coordinates in the L-F-P approach. A convention with regard to the units in which lengths and times are measured becomes imperative. If measurements on an infinitesimal system are quantified in terms of natural standards local to the system, then the units will be affected by gravity in the same way as the system under observation, with the consequence that the measures obtained are independent of gravity. Such measures obey the laws of geometry for the flat Minkowski space-time of special relativity. Information about gravity resides wholly in the unit fields, which are determined by the velocity field $\mathbf{v}_g(\mathbf{r},t)$.

On the other hand, if measurements in the infinitesimal system are quantified in terms of units of a fixed world point, then the measures obtained will obey the laws of geometry for a curved space-time. Information about gravity is transferred from the unit fields to the geometry of space-time. Einstein followed this approach by assuming constant units.

When we say that the universe expands in flat Minkowski space-time in accordance with (8), the expansion is relative to an aether fluid which acts as the reference for zero velocity. Thus, an equally valid interpretation of (8) is that the aether fluid contracts.

Knowing the aether velocity field $\mathbf{v}_g(\mathbf{r},t)$, it is possible to obtain the metric of the equivalent Einstein space-time by a units transformation (Browne 1976a). We introduce spherical polar coordinates (r,θ,ϕ,t) and define $d\sigma^2 = d\theta^2 + \sin^2\theta\, d\phi^2$. If $(\delta\bar{r}, \bar{r}\delta\bar{\sigma}, \delta\bar{t})$ are measures in terms of the coordinate-dependent units, we have the Minkowski metric.

$$ds^2 = c^2 d\bar{t}^2 - d\bar{r}^2 - \bar{r}^2 d\bar{\sigma}^2 \tag{19}$$

On the other hand, if $(\delta r, r\delta\sigma, \delta t)$ are measured in terms of constant units which are related to coordinate-dependent units by

$$\delta t = \gamma_g \delta\bar{t}, \quad \delta r = \gamma_g^{-1}\delta\bar{r}, \quad r\delta\sigma = \bar{r}\delta\bar{\sigma} \tag{20}$$

then by substitution of (20) into (19) and use of $\beta_g = \mathbf{v}_g / c = r/R$ we obtain

$$ds^2 = \left(1-\frac{r^2}{R^2}\right)c^2 dt^2 - \left(1-\frac{r^2}{R^2}\right)^{-1} dr^2 - r^2 d\sigma^2 \tag{21}$$

The metric (21) is that of a curved space-time (that of de Sitter) because there exists no integrable transformation which will convert it to (19). Now de Sitter space-time contains uniform mass density ρ_o, whereas its derivation from the Einstein equations requires it to be empty. The resolution of this contradiction emerges in section 6.

The geodesic equations for radial motion $(d\sigma = 0)$ in space-time (21) are:

$$\begin{aligned} r: &\quad \frac{dr}{c\,dt} = \pm\frac{r}{R}\left(1-\frac{r^2}{R^2}\right) \\ t: &\quad \frac{dt}{c\,d\tau} = \left(1-\frac{r^2}{R^2}\right)^{-1} \end{aligned} \tag{22}$$

where $ds = c\,d\tau$, τ being proper time (measured by a comoving clock). The velocity of a radial light ray follows from (21) by putting $ds = d\sigma = 0$:

$$c(r) = \left(1-\frac{r^2}{R^2}\right)c \tag{23}$$

By substituting (23) into (22)

$$\frac{dr}{dt} = \pm\frac{r}{R}c(r) \tag{24}$$

which corresponds to (8) in the extended Newtonian model. Note that $c(r)$ reverts to c if we introduce measures in terms of coordinate-dependent units. The redshift for coordinates (r,t) can be shown to be

$$\frac{\nu_2}{\nu_1} = 1 - \frac{r}{R} \tag{25}$$

where ν_1 is frequency at source and ν_2 frequency at the detector. Defining $dr/dt = v$ we can express (25) as

$$\frac{\nu_2}{\nu_1} - 1 = \frac{v}{c(\tau)} \tag{26}$$

This redshift is to be interpreted as a gravitational redshift, which is the non-Euclidean part of a generalized Doppler effect.

Now we change the reference system by introducing Robertson coordinates by

$$\bar{r} = r\left(1-\frac{r^2}{R^2}\right)^{-\frac{1}{2}} \exp\left(-\frac{ct}{R}\right)$$
$$c\bar{t} = ct + \tfrac{1}{2}R\ln\left(1-\frac{r^2}{R^2}\right) \tag{27}$$

In terms of $(\bar{r},\bar{t})$ the metric (21) takes the form

$$\mathrm{d}s^2 = c^2\mathrm{d}\bar{t}^{-1} - \exp\left(\frac{2c\bar{t}}{R}\right)\left(\mathrm{d}\bar{r}^2 + \bar{r}^2\mathrm{d}\sigma^2\right) \tag{28}$$

Now the geodesic equations for radial motion are

$$\bar{r}: \quad \frac{\mathrm{d}\bar{r}}{\mathrm{d}\bar{t}} = 0$$
$$\bar{t}: \quad \frac{\mathrm{d}\bar{t}}{\mathrm{d}\tau} = 1 \tag{29}$$

Now the universe does not expand, because the coordinate transformation has changed the velocity field. With respect to $(\bar{r},\bar{t})$ coordinate matter remains at rest. The same conclusion can be reached by integration of the radial motion (22), which yields (27) with $\bar{r} =$ integration constant. With respect to $(\bar{r},\bar{t})$ coordinates the velocity of a radial light ray is

$$c(\bar{t}) = c\exp\left(-\frac{c\bar{t}}{R}\right) \tag{30}$$

and the redshift formula becomes

$$\frac{\nu_2}{\nu_1} = \exp\left(-\frac{\ell}{R}\right), \qquad \ell = c\left(\bar{t}_2 - \bar{t}_1\right) \tag{31}$$

The interpretation of this redshift is that the refractive index of the aether varies with epoch $\bar{t}$, being larger at the time $\bar{t}_2$ of reception than at time $\bar{t}_1$ of emission of a wave crest.

The metric (31) is said to apply to a steady state universe because it is invariant under the further transformation

$$\bar{t}' = \bar{t} - \bar{t}_0, \qquad \bar{r}' = \bar{r}\exp\left(\frac{c\bar{t}_0}{R}\right) \tag{32}$$

which changes the time origin from 0 to $\bar{t}_0$. This property allows a frequency decay ("tired light") interpretation of (31) because we can maintain light velocity constant between source and detector by a sequence of infinitesimal changes of time origin. Then, instead of variation of light velocity at constant frequency we have constant light velocity at variable frequency, with in each case variable wavelength.

Now we are in a position to understand universe expansion. With respect to the (r,t) reference system the universe expands in accordance with (24), and the redshift (26) has a Doppler-gravitational interpretation. However, with respect to the $(\bar{r},\bar{t})$ reference system, the universe is at rest, and the redshift (31) receives a tired light interpretation (see Browne 1962, 1964). One reference system is as good as another in a generally covariant theory. Whilst any observable effect must emerge for all reference systems, it may emerge in very different guises.

The universe which we have described both in the extended Newtonian approach with coordinate-dependent units and in the Einstein approach with constant units is in a steady state because the radius R is constant. We have expansion given by (8) relative to an aether fluid in the Newtonian approach. In the extended Newtonian approach the aether velocity field emerges explicitly as a gravitational field variable; it is the free-fall velocity field corresponding to a given Newtonian potential field. In the Einstein approach we obtain expansion relative to the (r,t) reference system, but no expansion relative to the $(\bar{r},\bar{t})$ reference system. Again, the expansion is not absolute, because reference to external matter is impossible for a perfectly isolated system (Browne 1979).

The two approaches to gravitation are independent, and should not be mixed. The Newtonian theory obtained by extending the L-F-P explanation of aether drift experiments is not superseded by Einstein's theory, nor is it an approximation to Einstein's theory. It is based on a different convention regarding units.

5. Hierarchical Cosmology

The description of gravitation in flat space-time normally requires only the Newtonian gravostatic field based on the inverse square law of force between point gravitational masses m_1 and m_2, or point "gravitational charges" $\overline{m}_1$ and $\overline{m}_2$, where $\overline{m} = G^{\frac{1}{2}}m$. Because like gravitational charges attract, whereas like electrical point charges q_1 and q_2 repel, the analogous force laws are

$$\mathbf{F}' = \frac{q_1 q_2 \hat{\mathbf{r}}}{r^2}, \qquad \mathbf{F}'' = \frac{\left(i\overline{m}_1\right)\left(i\overline{m}_2\right)\hat{\mathbf{r}}}{r^2} \tag{33}$$

where $i = \sqrt{-1}$. It is well known (Page and Adams 1940) that the complete theory of electromagnetism can be developed from electrostatics and special relativity. It follows that an analogous theory for gravitation can be developed from gravostatics based on invariant gravitational charge $i\overline{m}$.

A gravitational vector potential has been postulated from time to time in order to account for inertia (Sciama 1953, Browne 1977). If $\mathbf{a}$ is the acceleration of mass m, then in the rest frame of m the universe has acceleration $-\mathbf{a}$ and the element of universe mass $\rho_0\mathrm{d}V$ at distance $\mathbf{r}$ from m provides the inductive gravitational field $\mathrm{d}\mathbf{E}''$, where for transverse propagation

$$\mathrm{d}\mathbf{E}'' = \frac{i\rho_0\mathrm{d}V}{rc^2}\hat{\mathbf{r}}\times\left(\mathbf{a}\times\hat{\mathbf{r}}\right) \tag{34}$$

where $\hat{\mathbf{r}} = \mathbf{r}/r$. The vector $\hat{\mathbf{r}}\times\left(\mathbf{a}\times\hat{\mathbf{r}}\right)$ is the component of $\mathbf{a}$ normal to $\mathbf{r}$ in the plane containing $\mathbf{r}$ and $\mathbf{a}$ with magnitude $a\sin\theta$, where θ is the angle between $\mathbf{a}$ and $\mathbf{r}$. At the position of m we must again resolve this transverse field parallel to $-\mathbf{a}$, introducing a second $\sin\theta$ factor. Thus

$$\begin{aligned}\mathbf{E}'' &= i\rho_0 c^{-2}\mathbf{a}\int_0^R r^{-1}\sin^2\theta\,\mathrm{d}V \\ &= \frac{4\pi}{3}i\rho_0 R^2 c^{-2}\mathbf{a}\end{aligned} \tag{35}$$

If this inductive gravitational field is responsible for inertial force, then we must have

$$i\overline{m}\mathbf{E}'' = -Km\mathbf{a}, \qquad K = \frac{4\pi G \rho_0 R^2}{3c^2} \tag{36}$$

The result (36) agrees with (5). The inductive field actually propagates outwards from m to be absorbed by the universe as an advanced field of $\rho_0 \mathrm{d}V$ (Browne 1969), being regarded as a transverse disturbance in an aether fluid. Because ρ_0 is a constant, K is a constant, and can be assigned value unity by choice of G, though K has dimensions. Inertial force is quadratic in mass like local gravitational forces.

The close formal analogy between Maxwell's field equations and gravitational field equations has been discussed previously (Browne 1977), and it suggests unified field equations

$$F^{\mu}_{\alpha\ ,\mu} = 4\pi i\alpha T_{\alpha\beta} v^{\beta}, \qquad F^{*\mu}_{\alpha\ ,\mu} = 0 \tag{37}$$

where $F_{\alpha\beta} = F'_{\alpha\beta} + iF''_{\alpha\beta}$ is a complex Maxwell field tensor and $F^{*}_{\alpha\beta}$ is its dual, and where $T_{\alpha\beta}$ is the Maxwell stress tensor

$$T_{\alpha\beta} = \tfrac{1}{2}\left(F_{\alpha\mu}F^{\mu}{}_{\beta} + F^{*}_{\alpha\mu}F^{*\mu}{}_{\beta}\right) \tag{38}$$

with v^{β} being the 4-velocity of the charge which samples the field.

In the static field approximation, such field equations give sensible results. Applying them to the static field of the electron by writing $E = E' + iE''$, we have to solve the complex Poisson equation

$$r^{-2}\frac{\mathrm{d}\left(r^2 E\right)}{\mathrm{d}r} = \frac{i\alpha E^2}{2} \tag{39}$$

Noting that $E^2 = E'^2 - E''^2 + 2iE'E''$, we see that the source of the gravitational field is $E^2 - E''^2$ and the source of the electrostatic field is $2E'E''$. The solution of this equation is

$$E'r^2 \cong \frac{q}{1 = a^2/4r^2} \qquad E''r^2 \cong \frac{m - qa/2r}{1 + a^2/4r^2} \tag{40}$$

where a is given by (14). The approximation $\overline{m}/q << 1$ which is used in obtaining (4) is well justified. If $r = a/2$, (40) yields $E' = -E'' = q/2a^2$, so electrostatic and gravostatic fields have equal strengths.

Despite the close formal analogy between the electromagnetic and gravitational fields there appear to be fundamental differences in status between the two types of phenomena. Thus, (i) there does not exist a fundamental imaginary charge $i\overline{m}$ of equal strength to the electron charge e, or perhaps bare charge $(\hbar c)^{1/2}$; (ii) the universe contains gravitational charge apparently of only one sign, whereas real charges of both signs are present in equal numbers; and (iii) energy density in both fields is a source of the gravitational field, but not of the electromagnetic field.

Remarkably, it is possible to remove all differences of status between gravitation and electromagnetism by a single hypothesis. The hypothesis is that there exists within an infinite Cosmos a hierarchy of isolated systems—universes for an internal observer and elementary particles for an external observer—each isolated system being specified by a charge q_i and a radius a_i (alternately real and imaginary) in the geometric series

$$\begin{aligned} &\ldots iq_{-1},\ q_0,\ iq_{+1}\ \ldots \\ &\ldots ia_{-1},\ a_0,\ ia_{+1}\ \ldots \end{aligned} \tag{41}$$

We identify q_i and a_i with the electron constants

$$\begin{aligned} q_0 &= (\hbar c)^{1/2} = (137)^{1/2} e \\ a_0 &= a = K^{-1}\left(\frac{G\hbar}{c^3}\right)^{1/2} \end{aligned} \tag{42}$$

where the value for a is that given by (14) with $q = (\hbar c)^{1/2}$, and we identify q_{+1} and a_{+1} with the universe constants

$$\begin{aligned} q_{+1} &= i\overline{M} = iG^{1/2}\rho_0\frac{4\pi R^3}{3} = iG^{-1/2}RKc^2 \\ a_{+1} &= R \end{aligned} \tag{43}$$

The geometric series for q_i has the same common ratio $i\beta$ as that for a_i. Thus it follows from (42) and (43) that

$$\overline{M} = i\beta(\hbar c)^{1/2}, \quad R = i\beta a \tag{44}$$

We expect the ratio $i\beta$ to be applied to the quantities of dimensional analysis. Associated with each structure is a time scale defined by a_i/c.

Our observations are confined at the upper bound by the radius R of the universe, a finite isolated system within an infinite Cosmos, and at the lower bound by the Planck radius of the electron a, another finite isolated system. Although equal complementary status can be assigned to gravitational and electromagnetic phenomena in the Cosmos, the one based on attraction between likes and the other on repulsion between likes, within the limited scale range between a_{-1} and a_{+1} gravitational and electromagnetic phenomena will exhibit different status. Our existence seems to depend on the asymmetrical viewpoint which stems from limitation of scale range of observable phenomena.

The universe becomes an elementary particle of charge q_{+1} and radius a_{+1} in a superuniverse in the same way as the electron is the elementary particle of a universe, the implication being that all matter is constructed from electrons and positrons. Similarly, the electron becomes a subuniverse based on a subelectron, with charge q_{-1} and radius a_{-1}. The hierarchy of structure continues on both the upward and downward scales *ad infinitum*. The philosophical implications are indeed profound.

6. Universes Redefined (and Physical Constants)

The hierarchy hypothesis provides a rationale for some remarkable relationships between physical constants (Browne 1976b, 1977). In particular, a theoretical value for the Hubble constant emerges.

We must envisage a universe as that system of matter surrounding a test mass m (particle-observer) which provides gravitational potential $3Kc^2/2$ at m in the rest frame of m irrespective of the distribution of surrounding matter, where K is a constant. The potential has this constant value as surrounding matter changes with motion of m irrespective of the distribution of surrounding matter, where K is a constant. The potential has this constant value as surrounding matter changes with motion of m. Moreover, it has the same for any other test mass which will be surrounded by a different distribution of matter. The boundary surface of the universe adjusts like a horizon so as to maintain the constancy of K. The boundary adjusts automatically in the sense that the matter included is that which completely absorbs the disturbance which m creates in the aether fluid when it is accelerated, this disturbance being the advanced gravitational fields of universe matter as in the Wheeler-Feynmann absorber theory for radiation reaction (Wheeler and Feynmann 1945, Browne 1969).

Einstein's equations, because of their general covariance, are applicable only to a system which is perfectly isolated from its surroundings. The treatment of inertia (equations 34-35) shows that nothing less than a universe is inertially isolated, because the universe is the absorber for disturbances from m when a local force accelerates m. Thus, Einstein's equations describe only one system, a universe. It follows that the source term in the equations can have as independent, arbitrarily specified parameters only a single constant. The conventional source term $-\kappa T_{\alpha\beta}$, where $T_{\alpha\beta}$ is the stress tensor for an arbitrary fluid and κ is a constant, does not meet this requirement. Only the cosmological term $-\Lambda g_{\alpha\beta}$ in the Einstein equations meets the requirement. It is proposed, therefore, that the $T_{\alpha\beta}$ term be omitted from the equations, which then involve only purely geometrical terms. Specifically, they reduce to

$$R_{\alpha\beta} = \Lambda g_{\alpha\beta} \tag{45}$$

where $R_{\alpha\beta}$ is the Ricci tensor. Since $R = g^{\alpha\beta} R_{\alpha\beta} = 4\Lambda$, the equations now specify a space-time of constant curvature irrespective of the matter distribution. The variable boundary condition ensures this simplicity. Matter can enter the description only through singularities and constants of integration.

The static, spherically symmetric solution of these equations is (Tolman 1934)

$$\mathrm{d}s^2 = \gamma_g^{-2} c^2 \mathrm{d}t^2 - \gamma_g^2 \mathrm{d}r^2 - r^2 \mathrm{d}\sigma^2$$

$$\gamma_g = \left(1 + \frac{a_{-1}}{r} - \frac{r^2}{a_{+1}^2}\right)^{-1/2} \tag{46}$$

where a_{-1} is an integration constant and $a_{+1}^2 = 3/\Lambda$. For $a_{-1} = 0$ and $a_{+1} = R$ we obtain de Sitter space-time. For $a_{+1} = 0$ and a_{-1} equal to the Schwarzschild radius we obtain Schwarzschild space-time.

Let the constants a_{-1} and a_{+1} be chosen to be the radii of the subelectron and superelectron, respectively, in the series (41). That is, $a_{-1} = \beta^{-1} a$ and $a_{+1} = \beta a = R$, where a is given by (14). We note that γ_g is real if $r > r_0$ and is imaginary if $r < r_0$, where $a_{-1}/r_0 = r_0^2/a_{+1}$, which yields

$$r_0 = \left(a_{-1} a_{+1}^2\right)^{1/3} = \beta^{1/3} a \tag{47}$$

It is proposed to identify r_0 with the classical electron radius $d = e^2/Kmc^2 = 2.82 \times 10^{-13}$ cm. Then we obtain

$$\beta = \left(\frac{d}{a}\right)^3 = 5.30 \times 10^{60} \tag{48}$$

and it follows that

$$R = \beta a = 8.56 \times 10^{27} \text{ cm} \tag{49}$$

which implies a theoretical Hubble constant $H = c/R =$ 108 km s^{-1} Mpc^{-1}.

If we could find a theoretical relationship between the two dimensionless constants β and $\alpha\left(= e^2/\hbar c = 1/137\right)$, then all physical constants would be derivable from the constants (41) specifying the hierarchy. By using β as a cut-off to remove the logarithmic divergences of positron theory (Weisskopf 1939), a relationship of the following type is suggested:

$$\beta \cong \exp\left(\alpha^{-1}\right) = \exp(137) = 3.27 \times 10^{59} \tag{50}$$

A calculation which does not employ perturbation theory is required in order to make this relationship accurate.

7. Conclusions

The conclusions reached are as follows:

(i) Zero-point radiation, which pervades all space (although radiation detectors cannot reveal it), has energy density which diverges as frequency ω tends to infinity. The divergent energy density is converted to a finite value $K\rho_0 c^2$ by inclusion of gravitational self-potential energy density, provided that ρ_0 satisfies the universe closure condition, $4\pi G\rho_0 R^2 = 3Kc^2$.

(ii) When gravitational potential energy of a mass m^* in a Newtonian universe of radius R with constant mass density ρ_0 is added to rest energy Km^*c^2, the mass m^* is renormalized to $m(r)$, where $m(0) = -m^*/2$ and $m(R) = 0$. Such a mass gravitates outward, attaining velocity v at radius r, where $v/c = r/R$.

(iii) Gravitational renormalization also removes the divergence of the self-energy of the electron. When the energy density in both electrostatic and gravitational fields of the electron is integrated down to zero radius, a finite energy is obtained, specifically q^2/a for an electron of charge q, where $a = G^{1/2} q/Kc^2$.

(iv) Universes with constant mass density ρ_0 and finite radius R are black holes because gravitational potential energy cancels rest energy at their boundary surface. Thus, matter outside radius R does not contribute to the Newtonian potential within R, providing a finite isolated system.

(v) A convention regarding units for dimensional quantities is arbitrary, such quantities having axiomatic status. Cosmology can employ either one of two independent "languages" based on distinct conventions. One is extended Newtonian theory, employing flat space-time and coordinate-dependent units. The other is Einstein theory (general relativity) based on constant units. When properly developed, each language affords a complete and accurate description independently of the other language. Whilst it is useful to compare descriptions of the same phenomenon available in the two languages, the languages should not be mixed.

(vi) The geometry of space-time is arbitrary to the extent that the convention for unit fields is arbitrary. A description in flat space-time is valid, provided that units of time and length are suitably coordinate dependent. Special relativistic dilation of clock periods and contraction of measuring rods appropriate for aether velocity field $\mathbf{v}_g(\mathbf{r}, t)$ specifies the unit fields, where $\mathbf{v}_g(\mathbf{r}, t)$ is the free fall velocity field for a given Newtonian potential field.

(vii) Transformation from the coordinate-dependent units used in the extended Newtonian description to the constant units used in the Einstein description converts the metric of flat Minkowski space-time into the metric of curved de Sitter space-time. Effects found for extended Newtonian cosmology all have their counterpart in de Sitter cosmology.

(viii) De Sitter space-time with constant mass density is the solution of Einstein's field equations for static, spherically symmetric conditions only if the conventional source term is replaced by the cosmological term $-\Lambda g_{\alpha\beta}$, a step justified because a single constant specifies an inertially isolated system.

(ix) Universe expansion has been a confused topic because of failure to recognize two references for zero velocity. In extended Newtonian description a Euclidean reference frame is available, and it is common to restrict Doppler effect to motion relative to such a Euclidean reference. However, if motion is referred to the aether fluid, the Doppler effect will be different, the difference being called a gravitational redshift. The Doppler effect accompanying the expansion of (8) is of the latter type, and it is a wholly gravitational redshift because universe matter is at rest relative to the Euclidean frame. In the Einstein description, no Euclidean frame of reference is available, and we find expansion of matter relative to the (r,t) reference frame, but no expansion relative to the $(\bar{r},\bar{t})$ reference system. The (r,t) reference curves are at rest relative to the aether fluid, and the $(\bar{r},\bar{t})$ reference curves are at rest relative to matter. With the former choice, the Hubble redshift is a gravitational redshift, and with the latter choice the Hubble redshift (now in exponential form) is a "tired" light effect caused by loss of gravitons to the zero-point radiation permeating all space (Browne 1962, 1994). Graviton scattering is to be regarded as the mechanism of gravitational redshift, since the choice of reference frame is arbitrary.

(x) By postulating an infinite geometric series of elementary charges, alternately electromagnetic (real) and gravitational (imaginary), of which the electron and the universe are consecutive members, it is possible to assign equal complementary status to gravitation and electromagnetism in the Cosmos, but in not in a universe. Such a hypothesis permits unification of the gravitational and electromagnetic fields in a complex Maxwell field. In this scenario universe matter is constructed from electrons and positrons as sole elementary particles. What constitutes a universe from an internal viewpoint is an elementary particle in a superuniverse from an external viewpoint. Similarly, what constitutes an electron from an external viewpoint constitutes a sub-universe from an internal viewpoint. The hierarchy of structures based on the constants (41) continues *ad infinitum* both upwards and downwards.

(xi) Relationships between physical constants follow from the hierarchy hypothesis. A theoretical value for the universe radius is obtained, $R = 8.56 \times 10^{27}$ cm. The corresponding Hubble constant (which expresses the redshift as a Doppler effect, even if it is not) is $H = c/R = 108$ km s^{-1} Mpc^{-1}.

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