The Æther, Inertia and Cosmology

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Assigning to the æther fluid a velocity-dependent refractive index can ensure that a spherical light wave remains spherical for all observers. Motion relative to zero-point radiation cannot be measured, suggesting identification with the æther. The divergent energy density U of zero-point radiation when added to self-gravitational potential energy density $\left(U/Kc^2\right)\phi(0)$*, where* $\phi(0) = -2\pi G\rho_o R^2/3$ *yields total energy density* $K\rho_o c^2$*, which is finite if* $2\pi G\rho_o R^2 = 3Kc^2$*. Because* $m\phi(0) = -Kmc^2$*, addition of mass m does not increase* ρ_o*. The uniformly dense sphere then becomes an exact cosmological model. Spontaneous matter creation is possible at any world point without affecting* ρ_o*. Duality of such a theory with de Sitter cosmology is claimed.*

The Æther Fluid

Length contraction and time dilation were originally postulated as physical effects due to æther motion in order to resolve the null results of æther drift experiments. However, these two effects by themselves do not ensure that a spherical light wave remains a spherical light wave for observers with uniform relative motions. Assignation to the æther of a refractive index $n(\mathbf{u})$ which depends on æther velocity $\mathbf{u}$ can, however, resolve the problem, as pointed out previously (Browne 1995a,b). The required expression for $n(\mathbf{u})$ can be obtained in several ways, the following being a particularly simple one.

Let a light ray have velocity $\mathbf{c}$ relative to the æther which has velocity $\mathbf{u}$, and let θ be the angle between $\mathbf{c}$ and $\mathbf{u}$. Adding the kinematical effects of æther drift, and assigning to the moving æther a refractive index $n(\mathbf{u})$ which is a function of $\mathbf{u}$ so that c is replaced by $c_n\left(=c/n\right)$, we expect that light velocity has components ($c_n\cos\theta + u$, $c_n\cos\alpha\sin\theta$), parallel and perpendicular to $\mathbf{u}$, where $\sin\alpha = u/c$. The $\cos\alpha$ factor arises because radiation must propagate slightly upstream in order to progress in the direction transverse to the flow. The condition that a spherical light wave should remain spherical is

$$c\cos\theta \to c_n\cos\theta + u = c\cos\theta'$$
$$c\sin\theta \to c_n\left(1-\frac{u^2}{c_n^2}\right)^{1/2}\sin\theta = c\sin\theta' \qquad (1)$$

where the angle between $\mathbf{c}$ and $\mathbf{u}$ now is θ'. Eliminating θ', we require that

$$\left(c_n\cos\theta + u\right)^2 + c_n^2\left(1-\frac{u^2}{c_n^2}\right)\sin^2\theta = c^2 \qquad (2)$$

which reduces to

$$c_n + u\cos\theta = c \qquad (3)$$

Defining $\beta_n = u/c_n = nu/c = n\beta$, (3) yields

$$n = \left(1-\vec{\beta}\cdot\hat{\mathbf{c}}\right)^{-1} = \left(1+\vec{\beta}_n\cdot\hat{\mathbf{c}}\right) \qquad (4)$$

where $\hat{\mathbf{c}} = \mathbf{c}/c$. Then, using (4) in (1) we obtain

$$\cos\theta' = \frac{\cos\theta + \beta_n}{1+\beta_n\cos\theta} \qquad \sin\theta' = \frac{\left(1-\beta_n^2\right)^{1/2}\sin\theta}{1+\beta_n\cos\theta} \qquad (5)$$

which will be recognized as the relativistic transformation of velocity components ($c_n\cos\theta$, $c_n\sin\theta$), or relativistic aberration of light.

There remains the question of the physical nature of the æther fluid. Let radiation be trapped by perfectly reflecting walls of a cylinder closed at one end by a piston. Let the piston have velocity v, and let the compression or expansion of radiation be adiabatic. Doppler effect for radiation incident at angle θ to the normal of the moving surface changes frequency from ω to ω', where

$$\frac{\omega'}{\omega} = 1 - 2v\frac{\cos\theta}{c} \qquad (6)$$

It is then simple to show (Browne 1995c) that radiant energy density per unit frequency band U_ω changes with the volume V of the cylinder according to

$$dU_\omega = \left[\frac{\omega}{3}\left(\frac{dU_\omega}{d\omega}\right) - U_\omega\right]\frac{dV}{V} \qquad (7)$$

a result due to Planck. Because zero-point radiation has the spectrum $U_\omega \propto \omega^3$, dU_ω/dV as given by (7) vanishes, so U_ω does not change with V, and hence the piston does no work. This unique property of zero-point radiation permits its identification with the æther. A detector comoving with the piston registers the same value of U_ω whatever its velocity v. Thus, zero-point radiation remains isotropic with respect to all reference frames in uniform relative motion, making it impossible for an observer to measure his state of motion relative to the fluid. By contrast, motion relative to the 2.7 K cosmic blackbody radiation gives rise to flux anisotropy which can be measured (Smoot *et al.* 1977).

Unit Fields

The validity of cosmology based on Newtonian-type gravitational fields in Minkowski space-time requires a digression about unit fields (Browne 1976). If units are defined by natural standards at a fixed world point x_o^α, then measurements of the surrounding scene are possible only by the Milne (1948) procedure of radar surveying. Radar coordinates are assigned to remote events from the time of outgoing and returning light signals as measured by a clock at x_o^α, with the assumption of constant light velocity c in all directions. Constant light velocity implies that the length unit cdt_o at x_o^a is used along the path to the reflection event. When the radar coordinates are plotted on a space-time, the geometry (as revealed by round-trip light paths involving more than one reflection) is not in general Euclidean. Thus, the curvature of space-time (a 4-dimensional hypersurface) is predetermined.

An alternative and equally valid units convention is to transport natural standards from fixed point x_o^a to all field points x^a, where they are used to measure local infinitesimal elements of the surrounding scene. Transport of units changes their values as dictated by the change of gravitational potential, but because the system being measured and the units are equally affected by changes of potential, the measures obtained are independent of gravity and hence obey the laws of geometry for flat space-time. We term such units "covarying."

"Covarying units" are obtained from constant units by application of special relativistic time dilation and length contraction appropriate for æther velocity field $\mathbf{u}(\mathbf{r},t)$, which is identified with "free-fall velocity" in $f(\mathbf{r},t)$ (velocity acquired in linear free fall to potential $f(\mathbf{r},t)$ from reference potential zero). By relating measures in terms of "covarying units" to measures in terms of constant units, we may transform the Minkowski metric for the former units into the appropriately curved metric for the latter units. The Schwarzschild and de Sitter metrics can be derived simply by this method (Browne 1976).

The convention of constant units transfers all information about gravitation to space-time geometry, and æther parameters remain implicit. On the other hand, the choice of "covarying units" transfers all information about gravitation to the four unit fields, and æther velocity becomes explicit. Specifically, æther velocity $\mathbf{u}(\mathbf{r},t)$ becomes a gravitational field variable.

We may relate $\mathbf{u}(\mathbf{r},t)$ to $f(\mathbf{r},t)$. First, construct a velocity 4-vector for the æther fluid $u^a \equiv (g\vec{b}, g)$, where $\vec{b} = \mathbf{u}/c$ and $g = (1-b^2)^{-1/2}$, and then define a gravitational potential 4-vector,

$$A^a = -u^a Kc^2 \tag{8}$$

where K is the ratio of inertial to gravitational mass. In 3-vector notation

$$A^a = (\mathbf{A}, f) = (Kc^2 g\mathbf{u}, gKc^2) \tag{9}$$

where $g = (1-u^2/c^2)^{-1/2}$. Since $(g-1)Kc^2 = -f(r) + f(0)$, we verify that $b = u/c$ is free-fall velocity in f.

Gravitational Inertial Force

Consider a particle moving with velocity $\mathbf{v}$ in the gravitational potential fields (8). The comoving derivatives of $(\mathbf{A}, f)$ are

$$\begin{aligned} \frac{\mathrm{d}\mathbf{A}}{\mathrm{d}t} &= \frac{d\mathbf{A}}{dt} + (\mathbf{v}\cdot\vec{\nabla})\mathbf{A} \\ &= \frac{d\mathbf{A}}{dt} + \vec{\nabla}(\mathbf{v}\cdot\mathbf{A}) - \mathbf{v}\times(\vec{\nabla}\times\mathbf{A}) \\ \frac{\mathrm{d}f}{\mathrm{d}t} &= \frac{df}{dt} + \mathbf{v}\cdot\vec{\nabla}f \end{aligned} \tag{10}$$

where we use a well-known vector identify for $(\mathbf{v}\cdot\vec{\nabla})\mathbf{A}$, noting that $\mathbf{v}$ = constant and $\mathbf{A} = \mathbf{A}(\mathbf{r},t)$.

The invariant,

$$\mathbf{A}_a v^a = gf - \frac{g\,\mathbf{v}\cdot\mathbf{A}}{c} = Kc^2 \tag{11}$$

has constant value Kc^2 provided that $v^a = u^a$ along the world line of any particle, so that

$$\vec{\nabla} f = \vec{\nabla}\left(\frac{\mathbf{v}\cdot\mathbf{A}}{c}\right) \tag{12}$$

Then (10) yields

$$\begin{aligned} -\frac{\mathrm{d}\mathbf{A}}{c\mathrm{d}t} &= -\frac{d\mathbf{A}}{cdt} - \vec{\nabla}f + \frac{\mathbf{v}}{c}\times(\vec{\nabla}\times\mathbf{A}) = \mathbf{f} \\ \frac{\mathrm{d}f}{\mathrm{d}t} &= \frac{\mathbf{f}\cdot\mathbf{v}}{c} \end{aligned} \tag{13}$$

where $\mathbf{f}$ is a gravitational Lorentz force on unit mass. In 4-vector notation, equations (13) are

$$\frac{\mathrm{d}\mathbf{A}_a}{c\mathrm{d}t} = (A_{m,a} - A_{a,m})v^m \tag{14}$$

where $\mathrm{d}t' = \mathrm{d}t/g$ is proper time.

On the righthand side of (13) we have a gravitational Lorentz force on unit mass with velocity $\mathbf{v}$. On the lefthand side we have inertial force on unit mass, because $-\mathrm{d}\mathbf{A}/c\mathrm{d}t = K\mathrm{d}(g\mathbf{v})/\mathrm{d}t$ from (9). Inertial force is due to regauging of the potentials in order to maintain (11).

The geodesic equations for a space-time with metric tensor g_{ab} can be written in Euler-Lagrange form

$$2\frac{\mathrm{d}(g_{am}v^m)}{\mathrm{d}t} = g_{nm,a}v^m v^n \tag{15}$$

where $v^a = \mathrm{d}x^a/\mathrm{d}t$. The total derivative of $g_{am}v^m$ along the world line of the particle is

$$\frac{\mathrm{d}(g_{am}v^m)}{\mathrm{d}t} = (g_{nm}v)^m_{,} v^n \tag{16}$$

Subtraction of (16) from (15) yields (14) if

$$A_a = g_{am}v^m Kc^2 \tag{17}$$

Renormalization of Energy Density of Zero-Point Radiation

One is now in a position to extend the Newtonian cosmology of McCrea and Milne (1934; McCrea 1951). The starting point is the Newtonian potential field $f(r)$ inside a sphere of radius R with constant mass density r_o. Poisson's equation,

$$\nabla^2 f(r) = -4pGr_o \tag{18}$$

subject to the boundary condition $f(R) = 0$ has solution,

$$f(r) = -\left(\frac{2pGr_oR^2}{3}\right)\left(1 - \frac{r^2}{R^2}\right) \tag{19}$$

It is proposed to identify Kr_oc^2 with the energy density of zero-point radiation after renormalization by inclusion of self-gravitational potential energy density. Because dU_w/dV in (7) vanishes there is no potential energy due to pressure of zero-point radiation, so that enthalpy density and energy density of zero-point radiation are equal, in agreement with (Browne 1994a) (but contrary to (Browne 1994b). Now the total electromagnetic energy density of zero-point radiation U is renormalized to $\pm K\rho_o c^2$, where

$$\begin{aligned}\pm K\rho_o c^2 &= U\left(1+\frac{\phi(0)U}{Kc^2}\right)\\ &= U\left(1-\frac{2\pi G\rho_o R^2}{3Kc^2}\right)\end{aligned} \tag{20}$$

In order that ρ_o should remain finite as $U\to\infty$, we require that

$$2\pi G\rho_o R^2 = 3Kc^2 \tag{21}$$

so that (19) becomes

$$\phi(r) = -Kc^2\left(1-\frac{r^2}{R^2}\right) \tag{22}$$

The total mass in a universe is $M = 4\pi R^2 \rho_o/3$. Hence, another form of (21) is $R = 2GM/2Kc^2$. Thus R is the Schwarzschild radius for isotropic coordinates (Atkinson 1962), and hence it has the significance of an event horizon for a black hole. Since interaction between the content of the black hole and external matter is severed, we are justified in cutting off ρ_o at $r = R$ in (19).

A consequence of (22) is that a mass m has zero total energy,

$$E = \phi(0) + Kmc^2 = 0 \tag{23}$$

Thus, an arbitrary distribution of matter may be superimposed on zero-point radiation without any change of ρ_o. A uniformly dense sphere as a cosmological model is exact, not approximate.

Because a single physical constant (ρ_o or R) suffices to specify a perfectly isolated system (a "universe"), and because generally covariant equations can be applied to only a perfectly isolated system, the source term in the Einstein field can be only the cosmological $-\Lambda g_{ab}$. The conventional source term kT_{ab} must be omitted. The curvature invariant then becomes a constant 4Λ. The modified field equations have solution

$$\begin{aligned}ds^2 &= \gamma^{-2}c^2dt^2 - \gamma^2 dr^2 - r^2\left(d\theta^2+\sin^2\theta\, d\phi^2\right)\\ \gamma &= \left(1-\frac{a}{r}-\frac{\Lambda r^2}{3}\right)^{-1/2}\end{aligned} \tag{24}$$

where a is an integration constant and $\Lambda = 3/R^2$.

There arises the possibility of spontaneous matter creation at any point without an additional source of energy. Presumably matter represents excitations in the form of standing waves in the æther fluid. Standing waves require a boundary condition, the simplest being a vortex ring. Development of pairs of vortex rings may represent spontaneous creation of electron positron pairs, presumably the ultimate building blocks for matter. If matter is treated as an excitation in a fluid, then only motion of matter relative to the fluid is physically significant. Standing waves in vortex rings might provide a physical basis for string theory.

Conclusions

1. A spherical light wave remains spherical with respect to an æther which has refractive index $n = \left(1-\vec{\beta}\cdot\hat{\mathbf{c}}\right)^{-1}$, where $\vec{\beta}c$ (= u) is æther velocity and $\hat{\mathbf{c}} = \mathbf{c}/c$, and c is ray velocity.
2. Motion of an observer relative to zero-point radiation cannot be measured, unlike motion relative to the cosmic 2.7 K blackbody radiation, because no work is done in compressing or expanding zero-point radiation.
3. There exists a duality between extended Newtonian gravitation (ENG) in flat space-time with covarying unit fields, and general relativistic gravitation (GRG) with constant units. ENG transfers information about gravity to the unit fields, which are specified by æther velocity field $\mathbf{u}(\mathbf{r},t)$.
4. Defining gravitational 4-potential by $A^a = Kc^2u^a$, it is necessary to continuously regauge A^a at the position x^a_A of a particle with velocity v^a so that $u^a\left(x^m_A\right) = v^a$. This condition leads to an equation of motion in which dA_a/dt due to regauging is balanced by a gravitational Lorentz force. Equivalence to the geodesics of GRG is demonstrated.
5. Cosmology for ENG is investigated. The divergent energy density U of zero-point radiation is renormalized to $K\rho_o c^2$ by addition of self-gravitational potential energy $U\phi(0)/Kc^2$, where $\phi(0)$ is potential at $r = 0$ due to a uniformly dense sphere of radius R. The condition for ρ_o to be finite is $2\pi G\rho_o R^2 = 3Kc^2$. Then $\phi(r) = -Kc^2\left(1-r^2/R^2\right)$.
6. Because $Kmc^2 + m\phi(0) = 0$, addition of matter to the zero point radiation adds nothing to the mass density ρ_o. The uniformly dense sphere becomes an exact cosmological model. Then ρ_o (or R) specifies a universe. The material energy source term must be omitted from Einstein's equations, and the cosmological term treated as source. The solution is then de Sitter space-time, in agreement with what is obtained from a units transformation (Browne 1976).
7. Since rest mass is always canceled by gravitational potential energy, matter can be created spontaneously at any point without additional energy. Creation of matter is envisaged as the development of structure in the zero-point radiation (or equivalent graviton fluid), the first step of this development being appearance of vortex pairs which may represent electron-positron pairs. A steady state is envisaged, with matter appearing at a rate sufficient to balance its rate of decay. The picture to emerge is of an infinite, eternal Cosmos within which "universes" with black hole properties are finite, isolated systems in a steady state.

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