Update on the Electrodynamics of Moving Bodies

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This paper considers experiments up to the present that have been concerned in independent ways with electrodynamic measurements. If electromagnetic energy generated on the Earth is considered to be approximately carried by its co-ordinate frame in its solar orbit, this, together with a reanalysis of classical electromagnetic theory retaining the small, but non-zero, term involving the electric conductivity of free space, leads to a satisfactory explanation of observed phenomena, and to a necessary reassessment of relativistic and cosmological physical theories developed during the last century.

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1. Introduction

Starting with the famous 1887 Michelson-Morley attempt to measure the absolute orbital speed of the Earth, various terrestrial experiments comparing return transit times of electromagnetic radiation over different paths can be considered to have pointed to a null result only if the criterion for non-nullity be the establishment of differences determined by translatory speeds of the order of at least the Earth's orbital speed. The 1903 Trouton-Noble experiment, entailing measurement of deflection of a freely suspended charged capacitor due to a generated magnetic force moving the plates to be parallel to the Earth's velocity, also provided a null result only on this premise; the maximum deflection observed was only a small fraction of that expected, and appeared unrelated thereto, so no further investigation was then undertaken. However, in 1913 Sagnac used a spinning disc on which light was sent in opposite directions around the circuit to arrive back at an interferometer; the resulting fringe shift was quite real, apparently indicating the effect of the spin on the speed of light traveling with or against it.

Analysis using electromagnetic theory, together with more recent experimental data of accuracy not available at the beginning of the last century, leads to a theoretical formulation that explains the phenomena without the use of theories that have been formulated since the initial experiments but prior to the availability of these data. The results of modern methods are consistent with a variation in return transit times depending upon the rotational, but not orbital, speed of the Earth, and this indicates that a satisfactory solution may be found on the basis of considering electromagnetic radiation generated on the Earth to be approximately carried, like other energy or particulate matter, by the Earth in its solar orbit. This requires a reassessment of the properties of the medium through which such radiation is transmitted.

The apparent non-symmetry between treatment of revolution and rotation can be understood when it is considered that the above carrying is, more precisely, an approximation obtained by considering the orbital reference frame to be approximately inertial, whilst taking into account the accelerating nature of the rotational frame at greater angular speed. Effects from the latter easily evidence themselves in many ways in terrestrial experiments: a signal example is the observed precession of the plane of motion of a Foucault pendulum – in the Northern Hemisphere clockwise – owing to its coriolis acceleration caused by the Earth's rotation. This coriolis acceleration, being minus twice the vector product of angular velocity and any additional linear velocity occurring in the rotating frame (whether that of a pendulum or of a light signal), is the appropriate measure of non-inertiality, rather than centrifugal acceleration relative to the center of revolution or rotation. The latter for the Earth in its orbit is 0.006 m s^{-2} as against typically three to four times this value for rotation of a point on the Earth's surface at mid-latitudes, hardly a sufficiently significant difference to determine departure from inertiality. If we wish to compare the two cases, we must evaluate the effects relative to axes fixed in the center of the Earth in *both* cases, and we see than the value applying to revolution is only about 1/366.26 (sidereal days in a year) of that applying to rotation, thus being negligible in comparison for an individual experimental determination. In effect, a gravitational (tidal) locking between the Sun and Earth can be thought of which permits, to the ratio above, complete slippage with respect to the Earth's inertial frame in the case of rotation, and zero slippage in the case of revolution; more precisely, locking due to the Moon's orbit (1/27.40) must also be included, being about 2.18 times that due to the Sun on account of the former's relative proximity notwithstanding its relatively smaller mass. The combined effect – obtained by summing the appropriately proportionated angular speeds – is a locking that decreases the perfect rotational slippage by about 2.6% and imparts an orbital one (in the opposite sense) amounting to about 10.5% of the Earth's annual angular speed, *i.e.* one with a period of about 38.62 sidereal days.

2. Review of Experimental Data

The bulk of now-available experimental data showing small variations in the measured light speed in relative motion may be classified as interferometric, astronomical, or electrical. The interferometric techniques separate into Michelson-Morley interferometric, and Michelson-Sagnac interferometric. Both use light or other electromagnetic energy emitted from a common source, different paths, and a comparator that can measure interference fringes. The astronomical observations include repeats of Römer's classic seventeenth-century measurements of the speed of light, essentially measuring a difference of opposing motion times, and studies of stellar aberration. The electrical experiments involve the Trouton and Noble principle.

The two interferometric methods compare, respectively, the sums of to-and-fro motion times along interferometer arms, and the difference of opposing motion times around interferometer circuits. To evince effects, the Michelson-Sagnac interferometric method requires significantly less precise equipment than does that of Michelson-Morley, as can be seen from the following argument. In the classic Michelson-Morley set-up, the sum of the forward and return times of light travelling with speed c_0 with the motion is compared with the sum of the to-and-fro motion 'crosswind'. That is, from a simple geometrical consideration of an interferometer whose (one-way) length is L and whose translatory speed is v, an evaluation is made of the time difference

$$\Delta t_+ = [L/(c_0 - v) + L/(c_0 + v)] - 2L/\sqrt{c_0^2 - v^2}$$

or

$$\Delta t_+ = 2L\gamma^2/c_0 - 2L\gamma/c_0 \tag{1}$$

where

$$\gamma = 1/\sqrt{1 - v^2/c_0^2} \tag{2}$$

is the Lorentz factor. In the Michelson-Sagnac set-up, however, the comparison is made between the return times of light in opposing motion around a circuit, so that, where in this case L represents the circuit length and v its rotational speed, an evaluation is made of the time difference

$$\Delta t_- = L/(c_0 - v) - L/(c_0 + v)$$

or

$$\Delta t_- = 2L\gamma^2 v/c_0^2 \tag{3}$$

The ratio is thus

$$\Delta t_+/\Delta t_- = [2L\gamma/c_0(\gamma - 1)]/2L\gamma^2 v/c_0^2 \tag{4}$$

which, upon binomial expansion with higher powers of v^2/c_0^2 ignored, yields

$$\Delta t_+/\Delta t_- \approx v/2c_0 \tag{5}$$

We can obtain a value twice this through successive measurements with the Michelson-Morley interfereometer rotated through 90^0, thus interchanging the two paths and thereby doubling the time difference given by Eq. (1). We note that the above analysis is for zero inclination of the interferometer to the direction of travel; in the more general case of an azimuthal inclination φ, an additional factor $1/\gamma_s$, the reciprocal of the Lorentz factor but with v replaced by $v\sin\varphi$, enters the first term of Eq. (1), the second term being the same but with the factor $1/\gamma_c$, where v is replaced by $v\cos\varphi$ in the Lorentz factor. This introduces a $\cos 2\varphi$ signature into the equation, indicating maximum difference at zero azimuth reducing to zero at 45^0 and increasing to maximum again (in the opposite sense) at 90^0. Considering the maximum difference, the reciprocal of Eq. (5) gives the ratio of effects to be expected using Michelson-Sagnac determination to those using Michelson-Morley. If we take, for example, attempted measurements of the Earth's rotational speed, of the order of 300 m s^{-1}, we see that the ratio $\Delta t_-/\Delta t_+$ is of the order of 10^6; for a circuit whose perimeter is of the order of thousands of meters undergoing a daily rotation on the Earth, the ratio is still of the order of 10^3. This is no doubt why Michelson-Sagnac experiments showed up such effects earlier than Michelson-Morley ones did. We also note that, for other parameters remaining constant, $\Delta t_+ \propto v^2$, whilst $\Delta t_- \propto v$, so that the ability to detect results as speed diminishes is more severely vitiated for the former case. In particular, the factor by which expected effects are divided in consideration of detecting the Earth's rotational speed relative to its orbital speed, of order 30 km s^{-1}, is 10^4 in the former case, but just 10^2 in the latter.

A. Michelson-Morley Interferometric Results

Michelson commenced his observations in 1881; these culminated in the classic 1887 experiment with Morley [1]. The result expected on the basis of detecting the Earth's orbital speed was 0.4 fringe shift. Observations were undertaken over just three contiguous days, and the experimenters concluded from the results that ''The actual displacement was certainly less than the twentieth part of this [0.4 fringe], and probably less than the fortieth part. But since the displacement is proportional to the square of the velocity, the relative velocity of the Earth and the ether is probably less than one sixth the Earth's orbital velocity, and certainly less than one-fourth'' (*ibid.*). In subsequent years, various researchers carried out more detailed and extensive tests, at various parts of the Earth's orbit cycle and sidereal times, to establish if any level of cosmic ether-drift could be detected; we note that in addition to the Earth's rotation and revolution, there is a motion due to that of the solar system within the galaxy of the order of 300 km s^{-1}.

Morley and Miller [2] conducted repeat experiments between 1902 and 1905, for which a detected speed of 8.7 ± 0.6 km s^{-1} was calculated; Miller (*ibid.*) between 1921 and 1926 performed experiments on Mount Wilson (on the assumption of less ether-entrainment at higher altitudes), and from calculation obtained a speed of 10.05 ± 0.33 km s^{-1}; Michelson with Pease and Pearson [3] thereupon performed repeat experiments and reported in 1929 a speed calculated from the results of the order of several times Miller's value. Miller's extensive Mount Wilson experiments (*op. cit.*) were used to determine, from analysis of epochal variations, a cosmic motion of the Earth on the assumption of reduction of this and the orbital component in the same proportion (giving the result 208 km s^{-1} directed to the apex having a right ascension of 4 h 54 min and a declination of - 70^0 33'). Further and detailed analysis of these experimental results, interpreted as non-null by the experimenters, has been undertaken by Tabanelli [4]. Miller's results have recently been reassessed in terms of reliability by DeMeo [5] and by Allais [6], and the 1955 critique of these results by Shankland *et al.* [7] as essentially due to temperature effects has been shown to be, at the least, unconvincing.

In 1932 Kennedy and Thorndike [8] reported sensing a daily effect, due to the Earth's rotation, with a Michelson interferometer constructed with arms of unequal length for the different paths. They concluded, however, that ''there is no effect corresponding to absolute time unless the velocity of the solar system in space is no more than about half that of the Earth in its orbit" (*ibid.*). In 1938, by analyzing experimental results to measure longitudinal and transverse Doppler effects, Ives and Stilwell [9] obtained a variation in light speed with direction that was interpreted as conflicting with the second postulate of Special Relativity Theory (SRT). It was not till 1963, however, that the experimental accuracy necessary to detect speeds of the order of hundreds of meters per second became available: then, Jaseja *et al.* [10] used the measured frequency shift of masers in a Michelson-Morley-type determination. A frequency change with 90^0 rotation of the device of about 250 kHz (somewhat less than that attributable to the Earth's orbital speed) was found, but was considered to be due to local effects such as the Earth's magnetic field. The probable errors of measurement were ± 4 kHz, and the change with the time of experiment of the observed frequency shift was estimated to be 1.6 kHz with probable error 1.2 kHz, leading to a result less than one thousandth of that expected on the basis of the Earth's orbital speed, or a translatory speed no greater than 950 m s^{-1}. On the assumption of east-west to north-south 90^0 rotation by the experimenters, this result was of an order of magnitude not inconsistent with an indication of the Earth's rotational speed.

Finally, Brillet and Hall [11] reported in 1979 the use of equipment (a servo-stabilized laser in an isolated Fabry-Perot interferometer) with an accuracy four thousand times better than that of Jaseja *et al*., indicating a null value (half a millionth of the expected result on the basis of the Earth's orbital speed, or a translatory speed no greater than 21 m s^{-1}), but only after rejecting as spurious a 17 Hz signal at the second harmonic of rotation. In Aspden's analysis [12], the indication was, in reality, correct to within 3%, of the rotational speed of the location (Boulder, Colorado), 355 m s^{-1}, and although the original analysis has also been legitimately questioned by Hayden and Whitney [13], it would require repeat experiments of this accuracy undertaken in different locations to resolve the question definitively. Our analysis in terms of effects depending upon *angular* speed, *i.e.* the determinant of departure from inertiality of reference frame, would, in any case, in conjunction with gravitational locking show an effect due to the Earth's revolution of only about $1/38.62^2$ of that due to its rotation in an individual experiment of the Michelson-Morley type.

B. Michelson-Sagnac Interferometric Results

Sagnac's original experiment of 1913 [14, 15] involved the use of a spinning disc in the laboratory; the uncertainty has been estimated as 1:100, and the results showed a fringe displacement determined by the speed of the disc, typically 0.07 for a speed of around 2 s^{-1}. If the circumference be substituted for L in Eq. (3), it is seen, as γ is approximately unity, that the time difference is proportional to angular speed ω, the constant of proportionality being $4A/c_0^2$, where A is the enclosed area, being about 0.09 m^2 in Sagnac's case. In 1925, Michelson and Gale [16] reported the construction of a closed circuit of piping whose perimeter was of the order of two thousand meters, relying upon the rotation of the Earth to impart the necessary spin to be analogous to a Sagnac apparatus with area equal to the circuit area projected onto the equatorial plane. They measured a fringe shift of 0.230 ± 0.005 on average, against a theoretical value of 0.236 ± 0.002 based upon the rotational speed of the location. This location (Clearing, Illinois) was in the Northern Hemisphere, and the results correctly showed a retardation of the anticlockwise beam of light, *i.e.* that traveling in the same sense as the Earth. Agathangelidis [17] has shown that the small negative discrepancy can be fully accounted for by superimposing on a gravitational drag model as first proposed by Stokes the action of tidal locking to the Sun and Moon; as noted from such considerations above, these orbital effects amount to only about 1/38.62 of that due to the Earth's rotational angular speed in the Sagnac formula. That light generated in the laboratory remained in its coordinate frame, and did not take up that of a spinning Sagnac disc, was shown by Dufour and Prunier [18] as reported in 1942; they obtained no experimental deviation when the light traveling around the disc was, intermediate between source and interferometer, beamed at and reflected by successive mirrors fixed stationary in the laboratory.

In 1963 came the ring-laser; then, Macek and Davis [19] performed a Sagnac-type experiment using lasers, and verified Sagnac's results to $1:10^{12}$. The retardation of electromagnetic radiation traveling with the Earth's spin (*i.e.* eastwards in the Northern Hemisphere) as against that traveling against it (westwards) was shown by Saburi *et al*. [20] in 1976 by comparing recorded times of reception of radio signals at remote stations with those of atomic clocks. The Sagnac effect was again shown by Marinov [21, 22], who between 1979 and 1986 studied the photoelectric effects caused by two beams of differing wavelength; Silvertooth [23] obtained a similar result in 1987, but by using a standing-wave sensor, interpreting this as a detection of linear, or nearly linear, rather than rotational, motion. Confirmation of the Michelson-Gale results to as accuracy better than $1:10^{20}$ was performed with ring-laser tests on a fixed circuit by Bilger *et al*. [24] as reported in 1995; in this case, clockwise retardation was evinced, correct for the Southern Hemisphere (the tests were carried out in Christchurch, New Zealand).

It is thus seen that an optical gyroscope can be constructed from a Sagnac-type apparatus, and can be employed, as Sagnac suggested in 1914 [15], to measure deviations in the speed of a ship carrying it, yaw, pitch, and roll being determinable from rotation of the apparatus about a vertical axis and horizontal axes across and along the vessel. This has now been done: ring-laser optical gyroscopes, rather than mechanical ones, are now fitted to the latest generation of civil aircraft. The operation of these devices requiressome not-insignificant mentaljuggling to explain whilst holding to SRT, which would appear to predict that they should show no effects and thus not work; Langevin [25] and subsequently some others, for example Anandan [26] and Vigier [27], have attempted this with the aid of General Relativity Theory(GRT), Anandan endeavoring to reconcile this with SRT and with non-relativistic derivations. Studies of electromagnetic radiation in accelerated systems, such as the general equations derived by Anderson and Ryon [28], are in general consonance with the results here analyzed; our additional consideration of dissipation in the medium (introduced below to establish a coherent theory) is not necessary to account for the Sagnac effect, which can be derived as in the argument leading to Eq. (3) above. Kelly [29] has used the Sagnac effect as the basis of analysis, together with other available experimental results, to indicate the necessity of a new theory of the behavior of light and relative motion, entailing light being carried by the Earth's co-ordinate frame in its solar orbit, but not diurnal rotation. From our comparison of the respective levels of non-inertiality of these reference frames when the motion of a point on the Earth's surface is referred in both cases to axes fixed in its center of the Earth, and including effects such as gravitational locking, we obtain the postulate approximately amounting to this, as here used, for non-inertiality is the measure of departure from congruence of the motions of light and the Earth's co-ordinate frame.

C. Astronomical Results

Römer's 1673 observations of the times of eclipse of one of the moons of the planet Jupiter when the Earth is successively at positive and negative syzygy relative to the Sun and Jupiter enabled a determination of the one-way speed of light. These observations also enabled determination of what might be termed the true period of the moon, T_0, critical for the next series of observations. Measurements made in 1676 entailed determination of the varying periods of eclipse of the moon when the Earth is in successive positive and negative quadrature relative to the Sun and Jupiter. They also provide the light-speed result, but this time the relative velocity of approach and recession of the Earth has to be taken into account *on the basis of respective Galilean addition to and subtraction from the speed of the approaching light*. It is seen that this latter method is essentially a determination of the difference of forward and return transit times of light from Jupiter to the Earth, Δt_-, which may be expressed as

$$\Delta t_- = c_0 T_0 / (c_0 - v) - c_0 T_0 / (c_0 + v)$$

giving
$$c_0 \approx 2 v T_0 / \Delta t_- \tag{6}$$

An independent astronomical measurement of c_0 was undertaken in 1728 by Bradley, using the principle of aberration. This principle, entailing the use of resolved translatory and light velocities, is, of course, consistent with the Galilean composition thereof. Here, owing to the translatory speed of the Earth, v, a telescope to observe a star at an altitude of θ must be displaced forward in the direction of the Earth's travel, say an angle α; trigonometric consideration gives the relationship

$$c_0 \sin\alpha = v \sin(\theta - \alpha) \tag{7}$$

This is a sufficient analysis of a phenomenon due to the motion of the observing telescope during the time it takes the observed light to travel down the tube, and is said to have occurred to Bradley while noticing the varying angle of the wind incident on a boat in which he was traveling on the Thames as the boat's velocity (speed or direction) changed. It is not simply a reciprocal phenomenon (as has been shown, for example, in observations of binary stars), which might be inferred from relativistic derivation: no telescope motion during the light passage through it leads to no aberration effect when the star, not the observer, is moving. It may also be noted that the starlight, unlike light generated on the Earth, is not carried in the Earth's co-ordinate frame in its solar orbit. Aberration due to the Earth's orbital motion, amounting to a maximum displacement over a year of 20.5′′ of arc, is sometimes referred to as *annual* aberration to distinguish it from the very much smaller aberration (at mid-latitudes about one hundredth of the above) that results from the Earth's rotation. Expressing the formula in terms of the aberration angle, rather than new apparent altitude, also yields an explanation of a hitherto puzzling phenomenon: the observed fact that the aberration angle is unchanged when the light speed is changed, for example by filling the observation telescope with water [1], as performed by Airy in 1871. What is happening is that the reduction in light speed by the factor of the water's refractive index, which should lead to an increase in aberration angle, is exactly compensated in Eq. (7) by the reduction of the ratio of the sines of refracted and incident rays by this factor, in accordance with Snell's law. Put more simply, the added refraction due to the water just provides the necessary additional angular displacement of the rays without a further tilt of the telescope.

A distinction is to be observed between one-way measurements such as the above, and later terrestrial measurements of the type originated by Fizeau in 1849. These latter measure the two-way speed, c_M, a kinematic determination (return path length ÷ time duration), or, using the terminology of Eq. (1),

$$c_M = 2L / (\Delta t_+)_1 \tag{8}$$

where the numerical subscript refers to the first term on the right-hand side of the equation, that determining the sum of forward and return times in the direction of the motion. The electromagnetic speed, c_0, however, is

$$c_0 = 2L\gamma^2 / (\Delta t_+)_1 \tag{9}$$

so we have the relation

$$c_M = c_0 / \gamma^2 \tag{10}$$

As predicted by this result, experimental determinations of the kinematic speed of light as determined by two-way observations are always less than those of its electromagnetic speed as determined by one-way observations, as shown by Monti [30]; the second postulate of Einstein's formulation of 1905 [31], on the contrary, puts forth an identity between these two speeds. Noting that it is the rotational speed of the Earth that will show up in kinematic determinations, Eq. (10) predicts that the kinematic speed will be less than the electromagnetic by the order of one part in 10^{12}. In the more general case of non-zero azimuth of measurement, the factor γ_s defined above enters on the right-hand side of Eq. (10). The kinematic speed in this case will be less than the electromagnetic by the above amount at zero azimuth, and the difference will decrease for non-zero values, being, however, still one half of this at 90^0.

Modern investigations using radar observations of the planet Venus have been undertaken by Wallace as reported in 1969 [32] and Tolchelnikova-Murri as reported in 1991 [33], and these have shown that the non-constancy of measured values of transit time can be accounted for by the relative motion between the Earth and Venus at the times of observation, in accordance with Δt_- determination. Detection by anisotropic electromagnetic means of the Earth's motion at 400 km s^{-1} through the background cosmic radiation has also been effected [34]. Astronomical observations thus per-mit the detection of motion relative to co-ordinate systems of less locality, such as those of the Sun and the observable Universe, and indicate anisotropy in electromagnetic transmission dependent upon relative motion.

D. Electrical Results

Trouton and Noble's 1903 attempt [35] to measure the torque on the plates of a suspended capacitor resulting from the magnetic force generated by virtue of the Earth's motion produced a non-zero value of maximum deflection of 3.6 mm, very small compared to the value expected on the basis of observing the Earth's orbital speed, up to 68 mm. In this case, the torque is determined by the element of the Lorentz force caused by the magnetic induction:

$$\mathbf{F} = q\mathbf{v} \times \mathbf{B} \tag{11}$$

where $\mathbf{F}$ is the force, q the charge on the capacitor, $\mathbf{v}$ its translatory velocity, and $\mathbf{B}$ the magnetic induction. It is seen that the effect should be proportional to the second order of the speed, essentially as is Δt_+ of Eq. (1), rather than Δt_- of Eq. (3), because $\mathbf{B}$, in accordance with the Biot-Savart law, as well as $\mathbf{F}$ varies directly as velocity $\mathbf{v}$.

Modern repeats of Trouton and Noble's experiment using high voltages generated by Wimshurst machine were carried out by Cornille *et al*. [36] in 1998. It is argued that effects only become noticeable when voltages in excess of 40 kV are employed, so that moving charges *inside* (as well as on the surface of) the plates can contribute to the effect (Trouton and Noble used about 2 kV). The experiments clearly showed an observable torque; a hyperlinked video recording can be viewed via the Internet [37].

3. Theoretical Formulation of Wave Equation

Maxwell's equations for electric and magnetic field intensities $\mathbf{E}$ and $\mathbf{H}$ in the linear, homogeneous, isotropic medium of free space in the absence of free charge are:

$$\nabla \cdot \mathbf{E} = 0, \quad \nabla \cdot \mathbf{H} = 0 \tag{12,13}$$

$$\nabla \times \mathbf{E} + \mu_0 \partial \mathbf{H} / \partial t = 0 \tag{14}$$

$$\nabla \times \mathbf{H} - \varepsilon_0 \partial \mathbf{E} / \partial \mathrm{t} = \sigma_0 \mathbf{E} \tag{15}$$

where ε_0 is the electric permittivity of free space, μ_0 its magnetic permeability, and σ_0 is the electric conductivity of (let us here use the term) the ether, and we have used the vector relationship of Ohm's law to equate current density to the last term of Eq. (15). It is to be noted that the term σ_0, like ε_0 and μ_0, is an integral part of Maxwell's complete theoretical formulation [38]. Most analyses subsequent to Maxwell have arbitrarily reduced his conductivity term to zero in considering wave propagation in free space. Following Monti [29], this arbitrary modifycation is here reversed.

Consider now the identity for any vector $\mathbf{\Psi}$:

$$\nabla \times (\nabla \times \mathbf{\Psi}) \equiv -\nabla^2 \mathbf{\Psi} + \nabla(\nabla \cdot \mathbf{\Psi}) \tag{16}$$

where ∇^2 is the Laplacian operator. Successively taking the curl of Eq. (14) and (15), and employing Eq. (12) and (13), we obtain Maxwell's electromagnetic wave equation for both electric and magnetic field intensities $\mathbf{E}, \mathbf{H} = \mathbf{\Psi}$ in any given system of spatial co-ordinates and at time t:

$$\nabla^2 \mathbf{\Psi} = \varepsilon_0 \mu_0 \partial^2 \mathbf{\Psi} / \partial t^2 + \sigma_0 \mu_0 \partial \mathbf{\Psi} / \partial t \tag{17}$$

The electromagnetic speed of propagation is

$$c_0 = 1 \Big/ \sqrt{\varepsilon_0 \mu_0} \tag{18}$$

and if we define the etheric wave resistance to be

$$R_0 = \sqrt{\mu_0 / \varepsilon_0} \tag{19}$$

Eq. (17) may be written as

$$\nabla^2 \mathbf{\Psi} = c_0^{-2} \partial^2 \mathbf{\Psi} / \partial t^2 + R_0 \sigma_0 c_0^{-1} \partial \mathbf{\Psi} / \partial t \tag{20}$$

The second term on the right-hand side of Eq. (20) is equal to the *non-vanishing* D'Alembertian $\Box^2 \mathbf{\Psi} = (\nabla^2 - c_0^{-2} \partial^2 / \partial t^2) \mathbf{\Psi}$; it represents the (very small) dissipation of energy during wave propagation; if there be no luminiferous ether, as in the first postulate of Einstein's formulation of 1905 [31], then $\sigma_0 = 0$, this term disappears, and we obtain the simple wave equation with no dissipation. In such a case, the dielectric rigidity of the ether (the maximum potential gradient that can exist without the creation of a discharge) is infinite [30]. A non-infinite value of dielectric rigidity was indicated through the vacuum-decay effect in 1897 by Trowbridge [39], but his experiments have yet to be repeated with modern equipment. As what is called free space is a sustainer not only of displacement currents of electricity but also of conduction currents, it follows that the conductivity is not zero and the rigidity is not infinite, even though these quantities may be, respectively, vanishingly small and exceedingly large.

A. Solution of the Wave Equation with Dissipation

If we define Minkowskian co-ordinates

$$x_1 = x, \;\; x_2 = y, \;\; x_3 = z, \;\; x_4 = ic_0 t \tag{21}$$

where x, y, z are Cartesian spatial co-ordinates and $i = \sqrt{-1}$, Eq. (20) can be written in scalar form for constant-argument Ψ as

$$\sum_{i=1}^{4} \partial^2 \Psi / \partial x_i^2 = i R_0 \sigma_0 \partial \Psi / \partial x_4 \tag{22}$$

A solution may be obtained for the quantity Ψ by the method of separation of variables, positing that

$$\Psi(x_1, x_2, x_3, x_4) = \prod_{i=1}^{4} X_i(x_i) \tag{23}$$

and substituting this for the function in Eq. (22). This yields

$$\sum_{\substack{i=1 \\ i \neq j}}^{4} X_i'' \prod_{j=1}^{4} X_j = iR_0\sigma_0 X_4' \prod_{i=1}^{3} X_i$$

where the primes represent differentiation of each function with respect to its independent variable; we thus have, dividing through by the function,

$$\sum_{\substack{i=1 \\ i \neq j}}^{4} X_i'' \prod_{j=1}^{4} X_j \Big/ \prod_{i=1}^{4} X_i = iR_0\sigma_0\, X_4' \prod_{i=1}^{3} X_i \Big/ \prod_{i=1}^{4} X_i$$

and consequently

$$\sum_{i=1}^{4} X_i'' / X_i = iR_0\sigma_0 X_4' / X_4 \tag{24}$$

Eq. (24) can hold generally only if

$$X_i'' / X_i = -m_i^2, \quad i = 1,2,3 \tag{25}$$

$$-X_4'' / X_4 + iR_0\sigma_0 X_4' / X_4 = -\sum_{i=1}^{3} m_i^2 \tag{26}$$

where the m_i are constants. Eq. (25) defines simple harmonic motion; the solutions are of the form

$$X_i = k_i \cos(m_i x_i + \varphi_i), \quad i = 1,2,3 \tag{27}$$

where the k_i, φ_i are arbitrary constants depending upon the boundary conditions. Eq. (26), however, defines simple harmonic motion with damping proportional to the rate of change of the function; it reduces to simple harmonic motion only when $\sigma_0 = 0$ (the negative sign of the first term and imaginary quantity in the second have been introduced owing to the change of variable from t to $ic_0 t$). The solution, in terms of t, is

$$X_4 = k_4 \exp(-R_0\sigma_0 c_0 t / 2)\cos(pt + \varphi_4) \tag{28}$$

where again there appear arbitrary constants depending upon the initial conditions, and

$$p^2 = c_0^2 \sum_{i=1}^{3} m_i^2 - (R_0\sigma_0\, c_0 / 2)^2 \tag{29}$$

We obtain from Eq. (23) the complete solution to the wave equation with dissipation term included. The dissipation factor, d_Ψ, on field intensity at distance $r = c_0 t$ from the source is the exponential term, which governs the envelope of the decaying periodic wave; we may thus write

$$d_\Psi = \exp(-R_0\sigma_0 r / 2) \tag{30}$$

which applies to either $\mathbf{E}$ or $\mathbf{H}$. The energy flow in the direction of propagation of the electromagnetic wave is, however, determined by the Poynting vector $\mathbf{E}\times\mathbf{H}$: the flux of energy through a surface S, or, using Gauss's divergence theorem, the energy lost per unit time through a volume V is

$$\iint_S (\mathbf{E}\times\mathbf{H})\cdot \mathbf{dS} = \iiint_V \nabla\cdot(\mathbf{E}\times\mathbf{H})dV \tag{31}$$

The factor governing energy dissipation is thus $d_{EH} = d_\Psi{}^2$, which can be written as

$$d_{EH} = \exp(-r / r_d) \tag{32}$$

where we have defined a *dissipation distance*

$$r_d = 1 / R_0\sigma_0 \tag{33}$$

being the distance whereat the propagated energy has decreased to $1/e$ of its initial value. It is to be noted that putting $\sigma_0 = 0$ in the above analysis leads to an exponential term of unity in Eq. (28) and thus a purely periodic, un-attenuated solution, and to an infinite value of dissipation distance from Eq. (33), and thus an infinite distance required to be traversed by light for any energy dissipation at all to occur.

4. Galactic Spectroscopic Red-Shifts

Amplitude exponential decay through the envelope of a decaying periodic wave, yielding the dissipation factor of Eq. (32), indicates loss of energy of the individual quanta making up the energy stream. Using Planck's law relating energy quanta and frequency (as suggested by the law of the photoelectric effect), we see that such loss of energy would entail a reduction in frequency, *i.e.* a shift towards the red end of the spectrum. Galactic spectroscopic red-shifts can be attributed in this way to energy dissipation rather than to an expanding Universe, thus making the Big Bang Theory an unnecessary hypothesis. Proceeding further, we can obtain from cosmological observations of spectral red-shifts and galactic distances, together with the known value $R_0 = 376.74\ \Omega$ [40], the result that

$$\sigma_0 = (2.85 \pm 0.15)\times 10^{-29}\,\mathrm{S\ m^{-1}} \tag{34}$$

and thus

$$r_d = (9.31 \pm 0.49)\times 10^{25}\,\mathrm{m} \tag{35}$$

or about 10^{10} light-years. By equating the total energy of electron-positron pairs to that across the dielectric space at breakdown, the value of dielectric rigidity has been estimated as $4 \times 10^{20}\,\mathrm{V\ m^{-1}}$ (*ibid.*). The dissipation attribution is essentially equivalent to the so-called *tired-light* hypothesis, postulated in 1935 by Hubble and Tolman [41, 42], and discussed by various authors in recent decades, *e.g.* Sandage (*ibid*).

The Hubble relativistic linear law of 1929 relating distance to normalized change of wavelength, z, obtained theoretically from retention in the Taylor-series expansion of only the first-order term in z, is

$$r = c_0 z / H \tag{36}$$

where H is the Hubble constant. The Maxwell law may be derived by noting that

$$z = \Delta\lambda / \lambda = (\lambda_r - \lambda_0) / \lambda_0 = \lambda_r / \lambda_0 - 1 \tag{37}$$

where subscripts refer to respective values at the origin and at a distance r of wavelength λ. As frequency ν is inversely proportional to wavelength λ, and by Planck's law energy is proportional to frequency, Eq. (37) may be rewritten using Eq. (32) as

$$z = \nu_0 / \nu_r - 1 = \exp(r / r_d) - 1 \tag{38}$$

The solution is thus

$$r = r_d \ln(z+1) \tag{39}$$

Comparison of Eq. (36) with (39) shows two basic things: First, whilst the Hubble linear law is unbounded, so that $dr / dz = c_0 / H$, remaining constant as $z \to \infty$, the Maxwell logarithmic law is bounded, so that $dr / dz = r_d / (z + 1) \to 0$ as $z \to \infty$. Secondly, in analyzing cosmological data using the Hubble law there is a necessity, absent from analysis using the Maxwell law, to postulate extraordinarily increasing values of luminosity of quasars and galaxies whose apparent magnitudes and red-shifts have been measured. If we take an estimated value of H of the order of 50 km s^{-1} Mpc^{-1}, we find that this gives a value of 1.6×10^{-18} m s^{-1} m^{-1}, or, expressing this in terms of r_d from Eq. (35), of 1.5×10^8 m s$^{-1} \times r_d^{-1}$ or about $0.5 \times c_0 r_d^{-1}$, and ever-increasing recession speeds. On the basis of this law an upper limit to the age of the Universe is obtained from H^{-1} of the order of 1.9×10^{10} years. Figure 1 shows a comparison of distance *vs.* red shift predicted by the two laws. For a value of $z = 1$, there is a ratio of 8.4:1 in luminosities (proportional to the square of distance) predicted by the two laws; at $z = 4$, this becomes 25:1. Using the modified Hubble law for recession speed as a fraction of light speed so as to avoid values equal to or greater than the latter, *i.e.* $[(1 + z)^2 - 1]/[(1 + z)^2 + 1]$, the respective values for the above two cases are 0.60 and 0.92, and so on. Overall, it can be concluded that the logarithmic law shows a better fit against observed data, in addition to presenting no problems with matters such as the postulated limited age of the Universe and explaining the observed (Olbers effect) illumination of the black vault of the sky at 2.7 K.

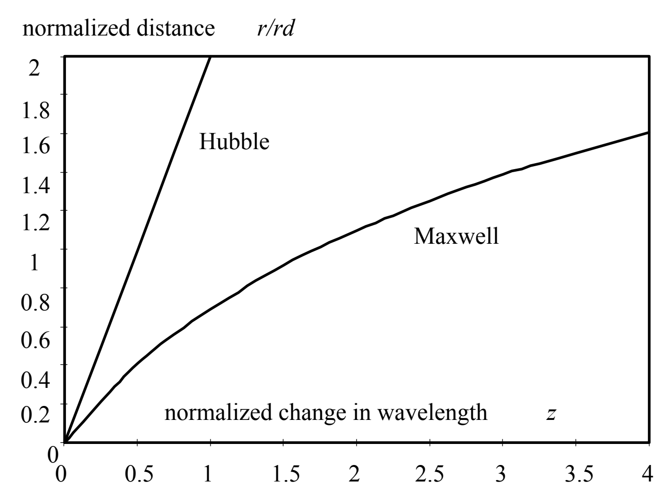

Figure 1. Comparison between Hubble and Maxwell laws of distance *vs.* red-shift.

5. SRT, GRT, and the Big Bang Theory

In considering the transmission of electrical or gravitational energy, it was established early that the speed of light was not a limiting factor: the current in a circuit (not rate of diffusion of electrons, an exceedingly slow phenomenon by comparison) and the gravitational interaction of masses travel much faster than electromagnetic energy, as established experimentally by the middle of the nineteenth century [43, 44]. By the end of the century, following the theoretical work of Maxwell and Lorentz, the focus of analysis had moved to electromagnetic transmission of energy.

The postulates of SRT, following the work of Voigt, Lorentz, Fitzgerald, Larmor, and Poincaré, extended the classical principle of Newtonian relativity for inertial frames of reference from dynamics to all branches of physics, and posited a constant observed speed of light independent of any relative translatory motion. It should be noted that the latter positing is somewhat arbitrary, not being the only possible substitution for the law of light propagation in the derivation of the Lorentz transformation [45]. Most importantly, the postulates originated in a scientific environment that lacked the precise results that have subsequently emerged from experiments using modern equipment. The Lorentz transformation was extended from electrodynamics to ordinary dynamics to replace the Galilean transformation, an extension upon which, as we saw, the accuracy of experimental data available at the beginning of the last century was unable to pronounce definitively. In any case, the invariance of Maxwell's equations under Galilean transformation can be shown by following Hertz and using the *total* time-derivative instead of merely the *partial* time-derivative, the additional term to be added being the scalar product of diffusion velocity and gradient of the function [46]: *e.g.*, in Cartesian co-ordinates the operator $D / Dt = [\partial / \partial t + (dx / dt)\partial / \partial x + (dy / dt)\partial / \partial y + (dz / dt)\partial / \partial z]$, rather than merely $\partial / \partial t$. The Lorentz transformation in electrodynamics can thus be thought of as an adjustment tool to preserve invariance, required if this diffusion term be omitted from the analysis. It is to be noted, however, that the effective reciprocity of electromagnetic induction between magnet and coil, entailing just relative motion, holds despite experiments that appear to show otherwise. Apparent nonreciprocity has been shown by Kelly [47] to be essentially due to secondary induction in connecting conductors taking current back from the coil, thus counteracting the induced current where there is relative motion between the magnet and the conductors when the magnet rather than the coil is in motion, and leading to the (rather surprising) induction when there is no relative motion between magnet and coil when both rotate together.

The generalization of SRT in GRT [48] has also become subject to further and fresh analysis in the light of developments since its formulation and apparent validation early in the twentieth century. Some discussion of this, following propositions here put forward, has taken place [49, 50]. The theoretical solution of the geodesic equations for the gravitational field outside an isolated spherically symmetric static body – leading to the Schwarzschild or Kerr solution in terms of Killing vectors [51] – provides a metric ds^2 in terms of spherical polar co-ordinates r, θ, φ:

$$ds^2 = (1 - r_S / r)c_0^2 dt^2 - (1 - r_S / r)^{-1} dr^2 - r^2(d\theta^2 + \sin^2\theta d\varphi^2) \quad (40)$$

where
$$r_S = 2GM / c_0^2 \quad (41)$$

is the Schwarzschild radius for the Sun, G being the universal gravitational constant and M being the solar mass. This metric leads to a Lagrangian that can be used via the Euler-Lagrange equations to calculate planetary precession ($3\pi r_S$ / semi-latus-rectum of orbit) and gravitational bending of light ($2r_S$ / radius of the Sun); but there are other possible choices leading to other metrics. In fact, the rotation of the Sun's inner core faster than its surface, possibly allied to the additional gravitational effect due to the presence of a uniform distribultion of dust about it, may be a sufficient explanation for planetary precession when added to that which Newtonian dynamics predicts for planets revolving about oblate stars. Moreover, a non-constant value of refractive index of the solar atmosphere coupled with mass-energy gravitational attraction can account for the bending of light observed by Eddington during the 1919 solar eclipse, half of which is predicted by Newtonian dynamics. And Einstein's equivalence of inertial and gravitational masses can be taken to imply merely an equal acceleration by a macroscopic gravitational field of microscopic gravitational masses [30]. It may be noted that the predictions in the early part of the last century that confirmed values of quantities then extant require reanalysis in the light of upward estimates of secular planetary precession (*ibid.*). Furthermore, the use of scale factors in comparison with the control (involving differences of the order of only hundredths of a millimeter) in conjunction with analysis of the astrographic plates of the 1919 eclipse taken in W. Africa (Principe Island, Gulf of Guinea), whilst discounting those taken in S. America (Sobral, Brazil) as not of the right order and therefore of necessity otherwise affected (*e.g.* by temperature effects) [52], casts doubt on the objectivity of the analysis, notwithstanding the eminence of the researchers and the endorsement by the then Astronomer Royal, Sir F.W. Dyson.

The expanding Universe and Big Bang Theory were introduced to account for observed phenomena on the basis of what by the time had become accepted theory. The latter was Gamow's term for Lemaître's 1927 zero-time extrapolation of de Sitter's earlier theoretical expansion model (or, in some accounts, Hoyle's intending pejorative coinage). It was to avoid these that Einstein at first introduced the cosmological constant term into his field equations, but later withdrew it.

It may be noted finally that neither the increase of mass with speed, nor the equivalence of mass and energy, interdependent phenomena both predictable and predicted independently of relativity [53, 54], need be subject here to reconsideration because of our present review of electrodynamic phenomena. The gravitational red-shift, for example, may be predicted by writing the conservation of energy equation or Hamiltonian as the constant sum of kinetic and potential energies for photons of mass m and frequency ν, for both source and observer (subscripts respectively 0 and r), where h is Planck's constant:

$$h\nu_0 = (m - m_0)c_0^2 - GMm / r_0 \quad (42)$$

and

$$h\nu_r = (m - m_0)c_0^2 - GMm / r_r \quad (43)$$

On division, these equations give the fractional change of wavelength. Taking m_0, the photon rest-mass, to be zero:

$$z = (1 - r_S / 2r_0) / (1 - r_S / 2r_r) - 1 \quad (44)$$

in agreement with existing theory and observations.

6. Conclusion

In conclusion, a satisfactory explanation of the small effects recorded in attempting to measure absolute motion and of the spectral red-shifts observed for distant celestial bodies results from the following considerations: First, the various and independent electrodynamic experimental data now available; secondly, the postulation of the approximate carrying of electromagnetic energy generated on the Earth by its co-ordinate frame in its solar orbit; and thirdly, a rigorous investigation using electromagnetic theory including the non-zero electric conductivity of free space. This provides further validation of results that have suggested the necessity of revision of basic physical and cosmological theories that have been developed during the twentieth century.

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