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THE BALLISTIC THEORY OF LIGHT AND ITS IMPLICATIONS FOR SPACE TRAVEL

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An outline of the ballistic theory of light is given (for a full account see Waldron 1977). The theory is able to explain those phenomena of modern physics hitherto held to be explicable only by Einstein's theory of relativity, such as the mass defect of atomic nuclei, positron-electron annihilation and pair production, Doppler effect, Compton effect, etc. The theory is next applied to rocket travel, and it is shown that although it is possible in principle to accelerate a rocket to speeds greater than the velocity of light the ratio of payload to initial mass rapidly becomes small for quite modest increases in speed. It is concluded that even with technology far in advance of anything conceivable to-day, the region of the universe open to rocket exploration, while greater than would be expected if velocities were always less than that of light in accordance with the orthodox relativity theory, would not be more than an order of magnitude greater.

1. INTRODUCTION

ACCORDING TO THE THEORY of relativity nothing can travel faster than light. Thus if we are to send a spacecraft out to a star n light-years away, we must wait at least 2n years for its return. The visible part of the universe (out to a radius such that spectrum lines are red-shifted to zero frequency or, if the red-shift be interpreted as a velocity of recession, the radius at which this velocity becomes equal to the velocity of light) has a radius of some 16×10^9 light-years. It is evident that, if relativity theory is right about the limitation on velocity, only a small part of the visible universe can be explored in any reasonable time.

For a variety of reasons, however, there are still many scientists who do not accept the theory, either rejecting it completely or not accepting some of the conclusions drawn from it. My own position is that I reject the theory outright because I believe the postulate of the invariance of light to be untenable. My reasons for this belief lie outside the scope of this paper, but are fully discussed elsewhere (Waldron, 1977). But if the orthodox theory of relativity is not accepted, another theory must be proposed to explain the various experimental facts of modern physics, and it is conceivable that according to such a theory the restrictions on space travel may be less limiting than those deduced from the orthodox theory. In the above reference I have proposed an alternative theory; some account of it will be given below, and its implications for space exploration will be studied.

The orthodox theory, due to Einstein, is based on the principle of relativity and the postulate of the invariance of the velocity of light; from these, the Lorenz transformations are obtained, and these latter may be taken as the basis for predicting observable effects. Lorentz, on the other hand, had previously developed a theory based on Maxwell's equations and the interaction of charged particles with the aether. This led to the conclusion that a moving body is contracted in the direction of its motion by a factor $\sqrt{1 - v^2/c^2}$, where v is the velocity of the body with respect to the aether. Lorentz also found it necessary to define a 'local' time for the charged particles in the moving body, and this 'local' time is in fact identical with that obtained by Einstein in the Lorentz transformations. These results lead to the prediction of a null result for the Michelson-Morley experiment, which means that the velocity of light in the interferometer arms is measured to be c regardless of the state of motion of the apparatus with respect to the aether, i.e. they predict the invariance of the velocity of light.

Thus in Lorentz's theory the Lorentz transformations and the invariance of the velocity of light are given a physical basis in the interaction of charged matter with the aether. Einstein, however, explicitly denies the relevance of any such interaction, but his theory has the same structure as Lorentz's. Thus as far as any calculations that may be made are concerned, and for all observable effects, the two theories are identical, and the denial in Einstein's case of interaction between matter and aether is erroneous. There is only one theory, which has received two formulations. It is essentially a wave theory, depending on the propagation of fields through an aether.

Attempts to detect the aether, however, had all failed. The Einstein-Lorentz theory goes to great lengths to explain why an aether which must be present for the waves to propagate in could not be detected. Once one becomes dissatisfied with the Einstein-Lorentz theory, a fairly obvious step is to assume that the failure to detect the aether is due to the non-existence of the aether. Then a wave theory of light is untenable, and one is led to re-examine the ballistic theory of light, which has received little attention since the interference experiments of Young and the diffraction experiments of Fraunhofer and Fresnel, in the early nineteenth century, seemed to settle the question once and for all in favour of the wave theory.

At the centre of the Einstein-Lorentz theory is the assertion that the velocity of light will be measured by an observer as having the same value, c, regardless of any (uniform) motion he may have with respect to the source of that light. In view of the importance of this statement for the theory, it is highly desirable that there should be convincing direct evidence of its truth. There is in fact no direct evidence whatsoever for it. While it is true that all optical experiments designed to test the postulate give results in accordance with its predictions, the same results are predicted by the ballistic theory.

The postulate originated when Einstein tried to imagine what an observer would see if he travelled through the aether at the same velocity as a beam of light. According to pre-relativity ideas of relative motion, the beam should then appear as a spatially oscillating electromagnetic field at rest. This is something which is not observed. Einstein concluded that such a situation is impossible, and that the appearance of the beam must be the same whatever the speed of the observer. The conclusion is a non sequitur, however: one would expect that the phenomenon speculated on by Einstein would be observed only if an observer and a source of light were moving with respect to one another at the velocity of light, and no experimental situation in which such a relative velocity occurs has ever been established. This is why the behaviour has not been observed, and to conclude that such an observation is impossible is without justification. To go further and arrive at the invariance postulate is equally unjustifiable.

2. THE BALLISTIC THEORY

With the ballistic theory light is assumed to consist of beams of photons instead of waves. A photon is assumed to leave its source with velocity c with respect to the source; its velocity with respect to an observer is found by compounding c with the velocity of the observer with respect to the source. An attempt is made to explain the facts of modern physics while retaining as far as possible the laws of classical physics. It is found possible to retain Newton's three laws of motion and the principles of conservation of mass, of energy, and of momentum. Notice, both energy and mass are separately conserved, not the composite mass-energy of Einstein's physics. Moreover, mass is not velocity-dependent as Einstein asserts. Maxwell's equations also survive, but with the restriction that they are limiting forms true only in systems in which all the electrodes, coils, etc. which generate the fields are at rest with respect to one another.

Changes are found to be necessary only in the Lorentz force law and in Newton's law of gravitation.

In attempting to explain the facts of modern physics, care must be taken in deciding what a fact is. Facts are such things as readings of pointers on dials, or tracks in cloud chambers; what may be deduced from them is not necessarily a fact, no matter how strongly it is believed.

For example, Einstein asserts that the mass of a body increases with velocity according to the law

$$m = \frac{m_0}{\sqrt{1 - v^2/c^2}} \qquad \ldots(1)$$

where m_0 is the 'rest-mass' and m the mass as judged by an observer with respect to whom the body is travelling at velocity v. The only experimental evidence for this is that when a particle of mass m_0 and charge q falls through a potential difference V, the velocity of the particle is given by

$$qV = m_0 c^2 \left[\frac{1}{\sqrt{1 - v^2/c^2}} - 1 \right] \qquad \ldots(2)$$

It is equation (2) which must be explained, which represents a fact, not equation (1) which is an inference from equation (2) based on the assumption that the force on the particle is

$$F_e = qE \qquad \ldots(3)$$

regardless of the velocity of the particle. If we assume, however, that the mass of the particle is independent of the velocity, we find that the force is

$$F_e = qE(1 - v^2/c^2)^{3/2} \qquad \ldots(4)$$

On what basis do we choose between the interpreations represented by equations (1) and (4)? Firstly, there is no direct evidence for Eqn. (1). Secondly, Newton's laws of mechanics, plus conservation of mass, have a certain satisfactory feel about them; they have served well in the past, and should not be discarded unless a change is demonstrated to be necessary; since there is no direct evidence for Eqn. (1) - and in principle never could be, since a measurement of mass must essentially be made at rest - no demonstration of such necessity has been made. Thirdly, Maxwell's equations and the Lorentz force law represent the results of experimental observations, and in those experiments any relative motion between different parts of the apparatus was very slow. Thus there is no difficulty in taking them as being true only in the limiting case of zero relative velocity. To insert velocity-dependent factors as, for example, in Eqn. (4), does not change anything in classical physics; it extends the classical electrodynamic laws to the case of appreciable relative velocities where previously classical electrodynamic theory had been inapplicable.

Eqn. (4) gives the electric force on a charged body moving with velocity v parallel to an electric field. For a body moving perpendicular to an electric field the force becomes

$$F_e = qE\sqrt{1 - v^2/c^2} \qquad \ldots(5)$$

while for a body moving perpendicular to a magnetic field the force is found to be

$$F_m = qvB\sqrt{1 - v^2/c^2} \qquad \ldots(6)$$

Eqns. (4), (5) and (6) replace the Lorentz force law

$$F = q(E + v \times B) \qquad \ldots(7)$$

to which they reduce in the limit as $v \to 0$.

Analogously, those experimental facts which are generally held to be explicable only by the general theory of relativity can also be explained by velocity-dependent laws of gravitational force, although this question will not be pursued further in this paper.

3. THE PHOTON MODEL

With classical mechanical principles plus velocity-dependent force laws, a new and simple picture of the universe can be built up, giving insights into processes where on the orthodox theory only the initial and final states are described. An interesting example of fundamental importance is the annihilation of a positron and an electron to give a pair of γ rays – or γ particles as it is preferable to call them, seeing that they are photons.

An electron may be thought of as a fluid drop of charge, tending to fly apart under electrostatic repulsion but held together by some constraint whose nature need not concern us here. Locked up in the electron is that energy of repulsion, and calculated according to the ballistic theory (i.e. with velocity-dependent force laws) it is found to be $\frac{1}{2}m_ec^2$, where m_e is the mass of the electron. Likewise, the positron has an internal energy of $\frac{1}{2}m_ec^2$. There is also the energy of attraction of the two particles; this turns out to be m_ec^2. Thus the total energy of the system is $2m_ec^2$; this is converted to the energy of the two γ particles, m_ec^2 each in accordance with the orthodox theory. Energy has been conserved. Likewise, mass is also conserved; each γ particle has mass m_e – and this holds good at all velocities, it does not fall to zero at zero velocity. The mass of the electron and positron has not been converted to energy. What has happened is that half the matter of the electron and half that of the positron have gone into each γ particle, so that the γ particle has a mass m_e and equal and opposite charges which leave it electrically neutral overall. There is no annihilation of matter; the matter of which the positron and electron are composed is rearranged, and a γ particle then appears as a material particle – it is made of the same stuff as ordinary matter. No such insight is given by the Einstein-Lorentz theory, which moreover fails to account for the energy of Coulomb attraction between the positron and electron – according to this theory, in the annihilation reaction the masses of the positron and the electron suffice to give the energy of the γ particles, so what happens to the Coulomb energy?

Pair production can also be seen in terms of the electric 'fluids', positive and negative. It is noteworthy that pair production occurs only in the neighbourhood of a massive nucleus which enables excess momentum to be mopped up.

But the nucleus does more than that. In the neighbourhood of the nucleus is a strong inhomogeneous electric field, which polarises the γ particle so strongly that it eventually splits into two parts, one composed of all the positive charge from the γ particle and the other of all the negative charge. Again a rearrangement of matter, understandable as such in the light of the ballistic theory. The Einstein-Lorentz theory gives no such insight, nor does it explain how, when the energy of a γ particle of energy $2m_ec^2$ 'creates' the mass of an electron plus a positron, they are able to separate against their Coulomb attraction.

This discussion of the 'annihilation' reaction gives us a picture of a γ particle as a particle made up of equal parts of positive and negative electricity. The Coulomb energy of attraction can be calculated in accordance with Eqn. (4) and is found to be $\frac{1}{2}m_ec^2$. Kinetic energy of translational motion isgiven by the classical formula according to the ballistic theory and so, in the present case, is $\frac{1}{2}m_ec^2$, making a total of m_ec^2. There is no reason to regard the γ particles resulting from an 'annihilation' reaction as different from other photons, so we now picture a photon as having mass m and equal charges +q and -q, where the ration 2q/m is equal to the charge-to-mass ratio for an electron. The Coulomb interactions within the photon give an internal energy $\frac{1}{2}mc^2$. There is additionally the kinetic energy $\frac{1}{2}mc^2$ for a photon moving with velocity c. The momentum is mc.

In the beam of photons, the ratio of total energy to momentum is $mc^2/mc = c$, in accordance with measurements of radiation pressure.

4. APPLICATIONS OF THE PHOTON MODEL

The photon model arrived at in Section 3, together with velocity-dependent force laws and classical mechanical principles, can be used to explain many of the phenomena occurring when electromagnetic radiation interacts with ordinary matter. A photon which strikes a material particle – electron, atomic nucleus, surface of an extensive body such as a mirror – may interact in either of two ways. It may merely bounce off, in which case only the kinetic energy of the photon comes into play; the structural energy plays no part in the interaction. Or it may be absorbed, in which case it gives up its total energy, kinetic plus structural.

The theory of the photo-electric effect enables us to associate a frequency with the total energy of the photon, thus

$$h\nu = mc^2 \qquad \ldots(8)$$

The corresponding wavelength can be introduced:

$$\frac{hc}{\lambda} = mc^2 \qquad \ldots(9)$$

and λ can be measured by means of a diffraction grating.

When light is observed that originates from a source moving with respect to the apparatus, what is observed will depend on the way the light interacts with the apparatus. In the case of diffraction from a slit, the light, after passage through the slit, will diverge from the slit. This will enable it to be properly focussed by a following optical system and so permit observations. Such light must therefore be captured by the material walls of the slit and reradiated. On reradiation, the velocity will be c with respect to the slit, which constitutes a new source, whatever it may have been before the photon reached the slit.

If we now imagine a source of light approaching us with velocity v, the velocity of a photon will be c + v with respect to us, in accordance with the Galilean transformations. Its internal energy is $\frac{1}{2}mc^2$ and its kinetic energy is $\frac{1}{2}m(c+v)^2$. Its total energy is

$$W = \tfrac{1}{2}mc^2 + \tfrac{1}{2}m(c+v)^2 = mc^2(1 + v/c + \tfrac{1}{2}v^2/c^2) \qquad \ldots(10)$$

If this photon now strikes the slit of a spectrometer and a new photon is reradiated with velocity c, the new photon will have a mass m' such that

$$W = m'c^2 = mc^2(1 + v/c + \tfrac{1}{2}v^2/c^2) \qquad \ldots(11)$$

To an observer at rest with respect to the source, the wavelength is given by

$$\frac{hc}{\lambda_0} = mc^2 \qquad \ldots(12)$$

in accordance with Eqn. (9). To us, the wavelength is given by

$$\frac{hc}{\lambda} = m'c^2 \qquad \ldots(13)$$

whence

$$\frac{\lambda}{\lambda_0} = \frac{m}{m'} = 1 - \frac{v}{c} + \frac{\frac{1}{2}v^2}{c^2} \qquad \ldots(14)$$

which may be compared with the Einstein-Lorentz Doppler formula

$$\frac{\lambda}{\lambda_0} = \sqrt{\frac{1-v/c}{1+v/c}} = 1 - \frac{v}{c} + \frac{\frac{1}{2}v^2}{c^2} - \frac{\frac{1}{2}v^3}{c^3} - \qquad \ldots(15)$$

Eqns. (14) and (15) agree as far as the term v^2/c^2, and to this accuracy have been confirmed experimentally (Ives and Stilwell, 1938). There is a difference in the term in v^3/c^3, but this has not been checked experimentally. Thus the Ives-Stilwell experiment does not discriminate between the ballistic theory and the Einstein-Lorentz theory and so does not, as is generally supposed, confirm the latter.

Compton scattering can be treated as a Newtonian collision between two particles, one an electron of mass m_e at rest, the other a photon of mass m, velocity c, kinetic energy $\frac{1}{2}mc^2$ and momentum mc. The internal energy plays no part in the interaction and can be ignored. The result obtained for the change of wavelength as a function of the scattering angle is identical with that given by orthodox theory. However, whereas in the latter case there is a change of frequency from ν to ν' while the photon velocity remains c, the ballistic theory requries that the photon mass m remain constant while the velocity changes from c to c', where $c' < c$.

In optics, if a mirror is moving with respect to the source, Snell's law of reflection no longer applies. If the mirror is moving with velocity v with respect to the source, in a direction normal to its plane, the angle of reflection φ is related to the angle of incidence θ by

$$\varphi \doteq \theta(1 - 2v/c) \qquad \ldots(16)$$

for small θ. Refraction, too, is modified. If a lens has a focal length f_0, this becomes

$$f = f_0(1 - v/c) \qquad \ldots(17)$$

if the object is approaching the lens with velocity v. Effects such as these can cause shifts of interference fringes in diffraction experiments, and in this way the ballistic theory enables experimental observations to be explained that have hitherto been held to be explicable only by the Einstein-Lorentz theory.

A full description of the ballistic theory is given by Waldron (1977).

5. TRAVEL BY ROCKET

Classically, if a rocket of mass m, travelling with velocity v, propels itself forward by shooting out mass backwards at

TABLE 1. Ratio of Payload m_4 to Initial Mass m_O for Return Journey n Times as Fast as Light.

n	1	2	3	4	6	8	10	20	30	44.4	50
m_4/m_O	0.0183	$3.35.10^{-4}$	$6.14.10^{-6}$	$1.125.10^{-7}$	$3.78.10^{-11}$	$1.266.10^{-14}$	$4.25.10^{-18}$	$1.805.10^{-35}$	$7.67.10^{-53}$	$7.0.10^{-78}$	$1.384.10^{-87}$

the rate $-$ dm/dt, with velocity $-$ u with respect to the rocket, the motion of the rocket is found by solving the equation

$$m\frac{dv}{dt} = u\frac{dm}{dt} \qquad \ldots(18)$$

Eqn. (18) and its solutions are in accordance with Newtonian mechanics, and hold good, according to orthodox thought, only when u and v are both very small compared with the velocity of light c. The ballistic theory requires no such limitation $-$ Eqn. (18) and its solutions hold good whatever the values of v and u.

To minimise the time taken on a rocket journey the thrust must be maximised, and Eqn. (18) shows that this means that u must be maximised. An upper bound to the value of u is c. Values of u approaching c could be realised in principle by dividing the propellant into positive and negative ions and accelerating these by electrostatic fields. The fields are set up by electrodes carried by the rocket, so the velocity of an ion with respect to the electrodes is the same as its velocity with respect to the rocket. Eqn. (4) shows that the limiting value of this velocity is c, for then the force on an ion falls to zero and no more acceleration occurs. If we therefore take u to be c in Eqn. (18) we shall obtain limiting solutions which can be approached but not realised.

For minimum time of travel, taking u to be c, the rocket should accelerate as rapidly as possible to a maximum velocity, coast at this velocity, and then decelerate as rapidly as possible to zero velocity. A return journey would be made in a similar manner. If m_0 is the initial mass of the rocket, m_1 its mass while coasting, m_2 its mass after stopping at its destination, m_3 its mass while coasting on the return journey, and m_4 its mass after stopping at the earth, it is found that if v is c throughout the journey (with infinite accelerations), we must have

$$\frac{m_0}{m_2} > e^2 \quad \text{and} \quad \frac{m_0}{m_4} > e^4 \qquad \ldots(19)$$

Thus to make a rocket journey to a distant star and return to the earth, with a stop at the star to make observations and a stop on return to earth to enable data to be collected, and to take no longer than light over the outward and return journey, we have to accept that the final payload will be less than $1/e^{4n}$, or less than 1.83%, of the initial mass leaving the earth.

If we wish to make the round trip much faster, we must accept a much smaller payload. If the velocity of coasting is to be nc, the ratio of payload mass m_4 to initial mass m_0 becomes $1/e^4$. To halve the time, n = 2 and the ratio becomes 0.0335%. For various values of n, the mass ratio for a return journey is shown in Table 1. It is seen that as the time is reduced (n is increased) by quite modest factors the payload gets small very rapidly.

There is a limit to the smallness of the ratio of payload to initial mass that can be realised; no matter what technological advances may be made in the future, this absolute limit is not likely to be even approached closely. And if it were, it would involve such a large rearrangement of all the matter in the universe that our space probe would no longer be studying the same object.

Eddington concluded that the total number of particles (protons plus electrons) in the universe is $1.4.10^{79}$. Accepting this figure, and pairing off each electron with a proton, the universe consists of 7.10^{78} hydrogen atoms. If we now imagine that we make a rocket in which the whole of the rest of the universe is used as propellant for a payload of one hydrogen atom, the maximum velocity we can impart to an atom while coasting on a return journey is seen from Table 1 to be about 44 times the velocity of light. Even if Eddington's figure is varied by many orders of magnitude, the maximum velocity probably lies somewhere in the range from 30 to 60 times the velocity of light. The precise figure is only of academic interest; the important point is that no matter what developments may take place in future rocket technology, there is no possibility of exceeding a few tens times the velocity of light. The distance we can expect to be able to send a space probe from the earth, if it is to return in one man's professional lifetime of some fifty years, is thus limited to at most a few hundred light-years $-$ an order of magnitude or so, but no more, greater than the distance given by the orthodox theory. To reach the limits of the visible universe, a journey time of at least the order of 10^9 years would be necessary.

It appears, then, that although the ballistic theory does not restrict velocities to less than that of light, the practicalities of rocket travel will always imprison mankind within some hundreds of light-years of the earth, and even to penetrate so far would require technology far beyond anything we can imagine at present.

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