On the fundamental properties of matter

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Sixty years ago de Broglie conceived the idea of ascribing wave properties to particulate matter. His original concepts were soon absorbed into the somewhat different treatment by Schrodinger which evolved into the wave mechanics that is used to compute orbitals and other problems concerned with the probability of finding particles in a particular physical situation. Wave mechanics has told us little about the particles themselves although de Broglie has always maintained that his original treatment held the key to the fundamental structure of matter itself. Very recent work, stemming originally from research into the problem of how the units of length and time are preserved in the proper frame despite the effects of acceleration, has shown that the principles of phase-locked cavities may be combined with de Broglie's wave treatment to provide a unique description of a spinning particle. Various modes of the trapped wave system are available and the properties of rest mass, inertia (independent of Mach's Principle) and quantisation all appear simply as a result of the phaselocking and feedback process that is intrinsic to phase-locked particles. The sharp bounding of the spinning wave-mechanical packet has interesting relativistic properties which may indicate why the action of quantum phenomena are concentrated into particular space-time events and are not diluted over large regions of the Universe. This approach to the understanding of fundamental matter is radically different to the philosophy of highly energetic collisions where the exotic products of the collisional energy demonstrate the patterns available from ever increasing energies. It may do more to elucidate the fundamental properties of matter upon which the quantum hypothesis, Newton's laws and the concepts of charge, angular momentum, mass, length and time are based.

The enigmatic duality of particles and waves has influenced the development of science for hundreds of years. As with so many aspects in the history of science it has been influenced by the timing of discoveries and by the stature of the researchers. There is an old conundrum which poses the hypothetical question of what would have happened if Michelson and Morley had performed their experiment at the time of Copernicus - surely there was proof that Galileo's teachings were unscientific heresy! The nature of light has also swung between extremes of interpretation. Newton claimed that it was corpuscular, despite his experiments with prisms, and then Young demonstrated the interference from a double slit which appeared to show that it was waves. If the photo-electric effect had been discovered at about that time, Young would have been disgraced and all the development of wave theory in the nineteenth century would have taken a back place. Then in 1905 Einstein showed that light interacted with matter as if it were quantised according to the relation $E = h\nu$. It is often said that Einstein invented the photon but I do not believe this to be true. He proved, quite correctly, that the *interaction* was quantised; he did not unequivocally state that the light itself was particulate. Despite his unique contributions to the quantum theory Einstein was highly suspicious of its interpretation and campaigned against it for the remainder of his life.

The story turned full circle when, in 1925, Louis de Broglie showed that matter could be treated as waves. His remarkable discovery coincided with the birth of quantum mechanics dominated by the presence of Max Born in Germany and Niels Bohr in Copenhagen and so de Broglie's ideas were quickly absorbed into the somewhat different structure of wave mechanics developed by Schrodinger. This was much more compatible with the matrix mechanics of quantum theory but differed in considerable detail from the ideas of de Broglie. Wave mechanics became essentially a probability computation and did nothing to elucidate the nature of matter itself. For many decades scientists have been trying to solve the internal structure of the fundamental particles by colliding matter at ever increasing energies and studying the products of the collisional energy. But if de Broglie's original ideas were correct then there ought to be much cheaper and more effective ways of solving the mystery.

Mackinnon (1981, a, b) showed that de Broglie's wave equation, when viewed from an assemblage of observers, could give a solution of the form

$$\Psi = [(\sin kr)/kr]\exp[i\omega t - k_0 x] \quad (1)$$

which befits a non-dispersive wave packet for a free particle of mass m traveling in the + x direction at velocity v, where K_0 = mv/h and = m^2ch. He showed that this is consistent with a classical description of the particle and is equivalent to the electromagnetic form of a phase-locked cavity proposed by Jennison (1978). De Broglie's disciples Gueret and Vigier (1982) extended Mackinnon's work and also noted the similarity to the author's phase-locked cavities. Mackinnon's solution, however, does not have a finite distant boundary, whereas such a boundary is required to return the wave in a phase-locked cavity.

At about the same time as Mackinnon's publication, Jennison (1981) had generalised his inertial analysis, phenomenalogically, to include J. particles - all particles or regions of space containing trapped wave energy of any type (no longer restricted to the electromagnetic case), wherein the requisite echo effect for feedback could occur at velocity c. (The insignia 'J_0' particle referred to the rest energy in Joules.) These particles possess the property of inertia without the need for Mach's principle and they respond in a quantised manner in response to a classical wave without the need for the wave itself to have quantum properties. It is of interest to see what further information may be obtained by comparing or combining these two very different approaches.

Consider the equatorial plane of rotation of a wave-mechanical phase-locked cavity containing a very large number of wavelengths. Let this rotation be measured against a non-rotating inertial frame in which light paths are straight lines. For very small values of rotational angular velocity (Ω) there will be distant parts of the system ($r \to \infty$) where the rotation will create a tangential velocity approaching the velocity of light. Applying (Ω) equally to all points in the matter-wave system, the steady-gate geometry becomes the inverse case of that discussed by Jennison (1963), the rotating radius now lying on a circular arc relative to the straight line radius in the inertial system. The whole system will become closed at a radius of r = R = c/Ω but the wave distances in the cavity will correspond to measurements on the circular arc which has a maximum length of S_{max} = π/2R and is related to r as an arc of a circle is to a chord

$$S = \frac{c}{\Omega}\sin^{-1}\frac{\Omega r}{c} \quad (2)$$

From the phase-locking principle, there must be an integral number of half waves in the cavity (assuming no phase reversals at the ends). S_{max} can therefore only have integral values of n $\lambda/2$ where λ is the wavelength of the matter wave = $2\pi c/\omega_{wave}$. The only systems which can be rotated therefore have

$$S_{max} = n\pi c/\omega_{wave}t \quad (4)$$

where n is an integer.

If Ω is now increased, the physical size of the matter wave system must therefore reduce in successive steps to preserve phase-locking at the boundary and, from the limiting relationship $\Omega R = c$, the value of Ω must correspondingly increase in successive steps which are integral sub-multiples of ω_{wave}, thus $\Omega = \omega_{wave}/2n$.

Consider a matter wave distribution of the form discussed by Mackinnon. In the rest frame $\omega_{wave} = m_0c^2/n$ and we may substitute $k = \omega_{wave}/c$. If this is rotated, we have the non-linear form in the equatorial plane:

$$\Psi - \frac{\sin(\omega_{wave}s/c)}{\omega_{wave}r/c}\exp i\omega_{wave}t \quad (4)$$

where we have replaced r in the argument of the sin function by the measure s, the r in the denominator is not affected since the divergence is dependent on l/r. Successive shells of this function are therefore shed off as Ω is increased from zero. The non-linear form of equation (4) corresponds to the real particle within $0 < r < c/\Omega$. [The double solution envisaged by de Broglie and Vigier may include $c/\Omega < r < \infty$. Substituting $\Omega s/c = \sin^{-1}\Omega r/c$ from (2) into (4) we have

$$\Psi = \frac{\sin\left[\frac{\omega_{wave}}{\Omega}\sin^{-1}\frac{\Omega r}{c}\right]}{}\exp i\omega_{wave}t = \frac{\sin(2n\sin^{-1}\Omega r/c)}{2n\Omega r/c}\exp i\omega_{wave}t \quad (5)$$

This function, which is contained within the range $r = c/\omega$, is therefore applicable to the equatorial distribution of Ψ in all simple rotating wave-mechanical phase-locked cavities. The radius to the first minimum corresponds to a half wavelength from the centre at twice the Compton frequency, i.e. half the pair-production wavelength pivoting about the centre. The circumference through the first minimum corresponds to the Compton wavelength. This double role is significant for the interpretation of the conversion process in annihilation and pair production. Furthermore, the formation of a real particle phase-locked to the Compton dimensions defines a combined proper measuring rod and proper clock of fundamental significance, as predicted by Jennison and Drinkwater (1977) and utilized by Jennison (1 983).

It should be noted that if a phase reversal can occur at the central node then another series of modes is possible, based upon an odd number of quarter waves pivoting about the centre. The fundamental solution (n = 1) in this case gives a uniform distribution of Ψ within the limiting radius $R = c/\omega$.

The finite boundary condition has important consequences for inertia, for it provides an essential requirement for a phase-locked particle, that there shall be an outer boundary from which information may return to produce the requisite feedback in the system. Thus we can identify the closed systems of matter waves discussed in this paper with the J_0 types of phase-locked cavity and expect them to possess the various properties that have been discussed in that context. In particular, such particles of matter possess inertia corresponding to their rest mass and independent of the rest of the Universe (Jennison, 1981 etc). This is currently of especial importance in view of the recent discovery of a possible rotation of the Universe and the resulting inapplicability of Mach's principle (Birch, 1982).

SOME COMMENTS ON THE PROPERTIES OF THE ROTATING SOLUTION

It will be noted from (4) that if we follow de Broglie's concept in contra-distinction to Schrodinger's interpretation and we identify $|\Psi|^2$ with the distribution of mass, then the mass distribution in any shell decreases as $1/r^2$ along a single radial line and as $1/r$ for successive complete rings in the equatorial plane. The angular momentum for a ring is, however, proportional to the mass in that ring, the square of the radius of the ring and the angular velocity of rotation. For a system defined by the limiting radius $r = R = c/\Omega$, $mR^2\omega$ becomes mRc but we have seen that m varies as 1/R, the angular momentum for the interior shells therefore increases precisely to compensate for those shells which are discarded as the system is spun up. *Within the limiting radius, the angular momentum of the total system is conserved as Ω increases in integral steps.*

The excess angular momentum is, conversely, shed in equal quantised steps as Ω increases and R_{max} progresses inwards in discrete steps from ∞. A perfect detent mechanism therefore operates at the boundary to maintain a quantised state by shedding quanta of angular momentum from the system as its angular velocity is increased. If the system is born in a rotating state, as might correspond to the circumstances in the process of pair production, then the solution simply indicates that a rotating mass results, the angular momentum of which is conserved and quantised in the manner indicated.

The properties of the boundary formed from the rotating transformation are remarkable and probably of some importance to the interpretation of measurements in particle physics. The boundary represents an onset of matter with a tangential velocity at the velocity of light. The formation of a mechanical system with a boundary rotating at this velocity would be quite impossible in macroscopic classical physics but in this case it is simply constructed from the component matter waves so that the usual mechanical constraints are inapplicable, indeed the mechanical system appears to correspond closely with the electromagnetic models discussed in Jennison 1978. In that paper it was shown that the Compton energy and momentum equations could be derived classically for such a system whilst Ashworth and Jennison 1974 showed that the angular scattering could be treated classically. Ashworth (1978) showed that the angular distribution of the scattering could be expressed in a form directly compatible with a specular reflection and with the Jennison 1978 energy and momentum treatment. In these treatments it is usual to transform from the laboratory frame to that of the particle and then back again. It is assumed that a fundamental observer at the particle could apply the usual laws of physics and that Snell's law and the usual conservation laws apply.

From the present analysis we now ascertain a number of very remarkable facts relevant to such a particle observer. If the reflection occurs at a surface which is rotating at or very close to the velocity of light then the scale size of the Universe will be vanishingly small. (This effect has been discussed in Ashworth and Jennison 1976.) If this observer receives radiation, then, as the Universe has been reduced to vanishing dimensions, the remainder of the wavefront which strikes him is contained in the encounter at the rotating observer's point in space-time. We can speculate that it may therefore disappear, or strictly, never appear, as far as all other observers are concerned. Furthermore the apparent specular reflection encountered in the Compton effect may be a simple outcome of the curious rotating geometry at this boundary. If this is the case, the communicating properties of fundamental particles in space-time are out of this world but still amenable to physical understanding.

No attempt has been made in the paper to discuss wave-mechanical models for the system which embrace the axial dimension and I have ignored the possibility of co-related electromagnetic phenomena, whereas many fundamental particles having rest mass also have electromagnetic properties. This paper has been concerned entirely with the wave-mechanical system but it invites the speculation that the boundary, rotating at the velocity of light, may behave as a ring displacement current, giving rise to an axial dipole magnetic field which may well constrain the polar component of the matter waves. I repeat that this is entirely speculation but the present treatment has taken one so far down the road in providing a wave-mechanical description of a discrete fundamental particle that one suspects that the final axial closure must come about in an equally simple manner.

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