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Wavemechanical inertia and the containment of fundamental particles of matter

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Abstract. It is shown that the form of a non-dispersive wavemechanical packet representing a rotating particle of matter has a sharp and finite boundary in the equatorial plane and is entirely consistent with earlier models of phase-locked cavities. The latter have been shown to possess the properties of inertia without the need of Mach's principle. Hence, it appears that the origin of inertia for all finitely bounded particles of matter lies in the feedback process that is intrinsic to phase-locked particles. The sharp bounding of the wavemechanical packet befits models of some elementary particles and may shed light on the remarkable process whereby the actions of quantum phenomena are concentrated into particular space-time events and are not diluted over large regions of the Universe.

Mackinnon (1981a, b) has drawn attention to a solution of the wavemechanical equation

$$\Box\psi = 0 \tag{1}$$

which has the form

$$\psi = [(\sin kr)/kr] \exp(\mathrm{i}\,\omega t - k_0 x) \tag{2}$$

and befits a non-dispersive wavepacket for a free particle of mass m travelling in the $+x$ direction at velocity v, where $k_0 = mv/\hbar$ and $\omega = m^2c/\hbar$. He shows 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). Gueret and Vigier (1982) have 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, phenomenologically, to include J_0 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.) 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 wavemechanical 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-state 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 $r = R = c/\Omega$ but the wavedistances in the cavity will correspond to measurements on the circular arc which has a maximum length of $S_{\max} = \frac{1}{2}\pi R$ and is related to r as an arc of a circle is to a chord

$$s = (c/\Omega)\sin^{-1}(\Omega r/c). \tag{3}$$

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 $\frac{1}{2}n\lambda$ where λ is the wavelength of the matter wave $= 2\pi c/\omega_{\text{wave}}$. The only systems which can be rotated therefore have

$$S_{\max} = n\pi c/\omega_{\text{wave}} \tag{4}$$

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 submultiples of ω_{wave}, thus $\Omega = \omega_{\text{wave}}/2n$.

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

$$\psi = \{[\sin(\omega_{\text{wave}}s/c)]/\omega_{\text{wave}}r/c\}\exp \mathrm{i}\omega_{\text{wave}}t \tag{5}$$

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 $1/r$. Successive shells of this function are, therefore, shed as Ω is increased from zero. The nonlinear form of equation (5) 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 (3) into (5) we have

$$\psi = \frac{\sin[(\omega_{\text{wave}}/\Omega)\sin^{-1}(\Omega r/c)]}{\omega_{\text{wave}}r/c}\exp \mathrm{i}\omega_{\text{wave}}t = \frac{\sin[2n\sin^{-1}(\Omega r/c)]}{2n\Omega r/c}\exp \mathrm{i}\omega_{\text{wave}}t. \tag{6}$$

This function, which is contained within the range $r = c/\omega$, is therefore applicable to the equatorial distribution of ψ in all simple rotating wavemechanical 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 utilised by Jennison (1983).

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 pinciple (Birch 1982).

Some comments on the properties of the rotating solution

It will be noted from (5) that if we follow de Broglie's concept in contradistinction to Schrödinger's interpretation and we identify $|\psi|^2$ with the distribution of mass, then the mass distribution in any shell decrcases 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 $1/R$, and 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 infinity. 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 by 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 wavemechanical 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 wavemechanical 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 wavemechanical 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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