White Paper V

Why Has Orthodox Physics Neglected the Superluminal Velocities of de Broglie Pilot Wave Components?

by:

William A. Tiller, Ph.D.

The William A. Tiller Foundation

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Introduction

It can be readily shown, via calculation, that the pilot wave of de Broglie travels at a velocity equal to the velocity of the particle it is supposedly guiding. However, as shown here, the same type of analysis shows that the wave components that create the pilot wave, and pass through it from the rear to the front as it moves along, do so at velocities far exceeding the velocity of electromagnetic (EM) light, c. Why has orthodox physics chosen to neglect this fact?

In this "white paper", I provide two important perspectives on this issue. The first utilizes an approach by E.F. Schubert(1) who focuses on the group and phase velocity of waves as a precursor for discussing position and momentum space in quantum mechanics. The second starts with the same wave model but introduces the total relativistic energy content for the particle and leads to the same pilot wave conclusions as Schubert but much, much more for the pilot wave components(2).

The Wave Model

Consider a sinusoidal plane wave propagating along the x-axis without any distortion and represent it by the wave function(1),

$$\Psi(x,t) = A\cos(kx - \omega t), \qquad (1a)$$

where k=2π/λ is the wave number, λ is the wavelength and A is the amplitude. The locations of constant phase are given by

$$kx - \omega t = \text{constant}. \qquad (1b)$$

Differentiation of x with respect to t yields the phase velocity, *v*,

$$v = \frac{dx}{dt} = \frac{\omega}{k}. \qquad (1c)$$

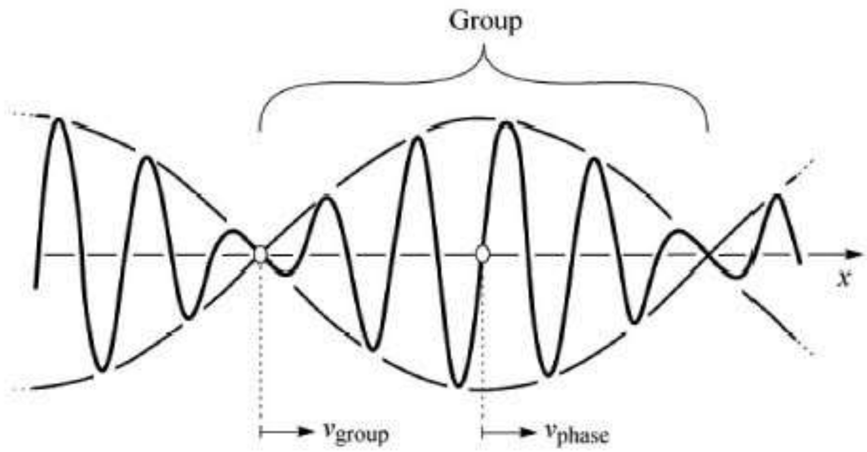

Figure 1. Example of a group of waves moving along the x-direction. The entire group of wavelets propagates with group velocity v_{group}. Individual wavelets propagate with phase velocity v_{phase}.

Figure 1 illustrates that, by superposition of two of these simple harmonic waves of very slightly different angular frequency leads to groups of waves (wave packets) propagating with velocities different from the phase velocity, *v*. Such a superposition can be represented mathematically by

$$\Psi(x,t) = A\cos(k_1 x - \omega_1 t) + A\cos(k_2 x - \omega_2 t), \quad (2a)$$

with

$\omega_1 = \omega - \Delta\omega$ and $\omega_2 = \omega + \Delta\omega$,
(2b)
$k_1 = k - \Delta k$ and $k_2 = k + \Delta k$. (2c)

Application of trigonometry yields

$$\Psi(x,t) = 2A\cos(\omega t - kx)\cos(\Delta\omega t - \Delta kx). \quad (2d)$$

with $\Delta\omega << \omega$, one can interpret the wave function as a rapidly oscillating term, $\cos(\omega t - kx)$, and a slowly oscillating term, $\cos(\Delta\omega t - \Delta kx)$, and this, in turn, modulates the amplitude of the rapidly oscillating term. The zeros of the rapidly oscillating term propagate with the phase velocity, $v = \omega/k$, as in Equation 1c. On the other hand, the phase of the slowly varying term, the wave group, propagates at the group velocity, $v_g=\Delta\omega/\Delta k$. In the limit of infinitesimal magnitudes for $\Delta\omega$ and Δk, one has

$$v_g = \frac{d\omega}{dk} \ . \qquad (3)$$

The group velocity, v_g, is the velocity at which the wave packets propagate in space. The phase velocity, v, can be smaller than, equal to or larger than v_g. In the latter case, $v > v_g$, the high frequency waves enter the group from the rear, pass through the group and exit the group from the front. In the opposite case that $v < v_g$, the direction of relative movement is reversed. For non-dispersive media, v is independent of the frequency of the wave and

$$v = v_g = \frac{\omega}{k} = \frac{d\omega}{dk} \ . \qquad (4a)$$

For dispersive media, $v \neq v_g$ and it can be shown that

$$v_g = v - \lambda \frac{dv}{d\lambda} \ . \qquad (4b)$$

For water, if one throws a stone into a pond, the curves of constant phase emanating from the impact site are concentric circles with $v/v_g \approx 2.0$, so water is a somewhat dispersive medium.

Schubert then goes on to say that, in the classical limit, v_g is identical to the propagation velocity of the classical particle described by the de Broglie wave packet (pilot wave), so that $v_g=v_{classical}$, and that this requirement is called Bohr’s “Correspondence Principle”. The correspondence principle postulates a detailed analogy between quantum mechanics and classical mechanics. Specifically, it postulates that the results of quantum mechanics merge with those of classical mechanics in the classical limit, where large quantum numbers obtain. Using the definitions of group velocity and of the classical velocity for a particle, one obtains

$$\frac{d\omega}{dk} = \frac{p}{m} \qquad (5a)$$

where p is the momentum of a particle and m is its mass. Substitution of k by using the de Broglie relation, $p = \hbar k$, and subsequent integration yields the famous Plank relationship

$$E_{kinetic} = \hbar\omega = p^2 / 2m \, . \qquad (5b)$$

Schubert goes on to state that the Planck relation further illustrates the dualism of particles and waves; i.e., a particle with momentum p oscillates at an angular frequency, ω, given by the Planck relation. On the other hand, a wave with angular frequency ω has a momentum p. The kinetic energy of the particle, $p^2/2m$, coincides with the quantum energy, $\hbar\omega$, of the wave representing the particle.

This author (Tiller) is unhappy with Schubert's treatment, which is standard for the orthodox physics community, for a number of reasons:

(1) All the waves cognitively accessed by human sense organs are not of the type described by Equations (1a), (2a) and Figure 1 but rather are all modulations of particle densities and particle flux densities,

(2) Equation (4a) applies for non-dispersive media like vacuum and approximately air and this assumption is used to gain Equation (5a). Yet, even an air/water interface wave packet system is found to be dispersive ($v/v_g \approx 2.0$), and

(3) Practically nothing substantive on an atom/molecule size-scale level has been provided to convince one that such a wave packet could sufficiently interact with a mass particle to loosely/tightly bind the particle to the wave packet so that the pilot wave could guide the particle's trajectory.

On the other hand, Eisberg[(2)] combines de Broglie's two postulates with the total relativistic energy of the particle. De Broglie postulated that the wavelength, λ, and frequency, ν, of the pilot waves associated with a particle of momentum, p, and total relativistic energy, E, are given by the equations

$$\lambda = \frac{h}{p} \quad and \; \nu = \frac{E}{h} \, , \qquad (6)$$

and that the motion of the particle is governed by the wave propagation properties of the pilot waves. The propagation velocity, w, of the pilot wave components associated with a particle is

$$w = \nu\lambda = \frac{E}{h}\frac{h}{p} = \frac{E}{p}. \qquad (7a)$$

The first relationship is the usual one uses for any wave and the rest comes from Equation (6). Using the total relativistic energy, E, of the particle, we obtain from Equation (7a)

$$w = \frac{\sqrt{c^2p^2 + \left(m_0c^2\right)^2}}{p} = \frac{c\sqrt{p^2 + \left(m_0c\right)^2}}{p} = c\sqrt{1 + \left(m_0c/p\right)^2}. \qquad (7b)$$

It should be noted that w/c>1. Since the particle velocity, *v*, must be less than c from Relativity Theory (RT), on the surface it seems that the particle could not keep up with its own pilot wave. However, using the same wave model that led to Figure 1, one can realize that, for such a moving <u>group</u> of waves, it is necessary to distinguish between the velocity, v_g, of the group and the velocity, w, of the individual oscillations of the waves. Furthermore, v_g must be less than w. This is encouraging but one must prove that v_g is equal to the velocity of the particle.

To do this, we start with Equation 1a but in sinusoidal form (just a phase difference of $\pi/2$), so that

$$\Psi(x,t) = \sin 2\pi\left(\frac{x}{\lambda} - \nu t\right), \qquad (8a)$$

and follow a similar thought process as Schubert to lead to

$$\Psi(x,t) = 2\cos 2\pi\left[\frac{dk}{2}x - \frac{d\nu}{2}t\right]\sin 2\pi\left[\frac{(2k+dk)}{2}x - \frac{(2\nu+d\nu)}{2}t\right]. \qquad (8b)$$

Since $d\nu<<2\nu$ and dk <<2k, this is

$$\Psi(x,t) \approx 2\cos 2\pi\left[\frac{dk}{2}x - \frac{d\nu}{2}t\right]\sin 2\pi(kx - \nu t). \qquad (8c)$$

A plot of $\Psi(x,t)$ as a function of x for fixed $t=t_0$ is shown in Figure 2.

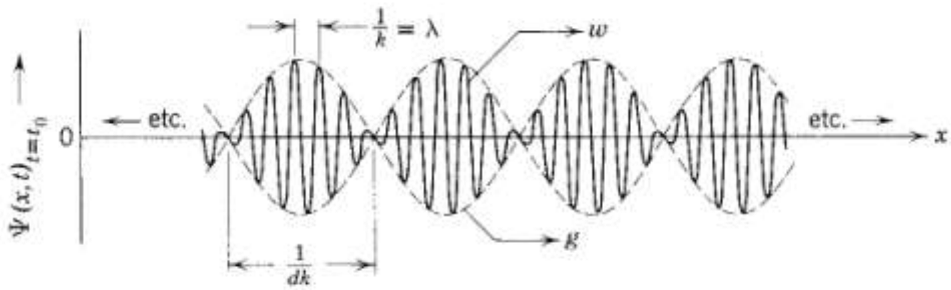

Figure 2. The sum of two sinusoidal waves of slightly different frequencies and wave numbers.

Here, we see that two waves of somewhat different frequency and wave number alternately interfere and reinforce in such a way as to produce an infinite succession of groups. It can be shown that, for an infinitely large number of waves combining to form one moving group, the dependence on w, v_g, ν, k and $d\nu/dk$ is exactly the same as the simple case we have considered. Proceeding with the above, one finds that the following equations have general validity.

$$w = \frac{\nu}{k} \quad and \quad \mathrm{v}_g = \frac{d\nu/2}{dk/2} = \frac{d\nu}{dk}. \tag{9a}$$

From Equations (6), we have

$$\nu = \frac{E}{h} \quad and \quad k \equiv \frac{1}{\lambda} = \frac{p}{h},$$

so

$$d\nu = \frac{dE}{h} \quad and \quad dk = \frac{dp}{h}$$

and

$$\mathrm{v}_g = \frac{d\nu}{dk} = \frac{dE}{dp}. \tag{9b}$$

Since the total relativistic energy, E, of a particle is

$$E^2 = c^2 p^2 + \left(m_0 c^2\right)^2 ,$$

we have

$$2EdE = c^2 2pdp$$

and, from Equation (9b),

$$\mathrm{v}_g = \frac{c^2 p}{E} . \qquad (10)$$

Since we also have

$$E = mc^2 \quad and \quad p = m\mathrm{v}_p \quad with \quad m = \frac{m_0}{\sqrt{1-\mathrm{v}_\mathrm{p}^2 / c^2}} ,$$

where m is the total relativistic mass and v_p is the velocity of the particle, we have the satisfying result that

$$\mathrm{v}_g = \frac{c^2 m\mathrm{v}}{mc^2} = \mathrm{v}_p . \qquad (11)$$

The velocity of the group of pilot waves, v_g, is just equal to the velocity of the particle, v_p, whose motion they are supposed to govern. Thus, de Broglie's postulate is internally consistent.

From Equations (7a) and (10), one finds that the following relation holds between the wave velocity, w, and the group velocity, v_g,

$$w=c^2/\mathrm{v}_g.$$

And, since Equation 11 tells us that $\mathrm{v}_g=\mathrm{v}_p$, we have our final important result

$$\boxed{w = \frac{c^2}{\mathrm{v}_p}}. \qquad (12)$$

Since $\mathrm{v}_p < c$, always, via Relativity Theory, w>c, always, via Equation 12 and the individual waves are constantly moving through the group from the rear to the front, just as occurs in water waves. However, it is the magnitude of w that is important to us.

Here, we see a set of waves moving faster than the speed of light, c, creating and directing a wave group moving at a speed slower than light which, in turn, is directing a positive mass particle which is also traveling at $v_p = v_g < c$. The de Broglie particle/pilot wave process has been confirmed experimentally and truth is always in the experimental data, so what must be operating in nature to allow such waves to interact with a particle across the relativistic light barrier at $v=c$? Calling such waves "information waves" and thereafter avoiding the concept does not help because, in a natural process where information increases, thermodynamic entropy decreases. Thus, a thermodynamic free energy exchange process is occurring here and this appears, on the surface, to violate a sacred constraint of Relativity Theory.

The high frequency waves of Figure 2 moving into and out of the wave packet at $w>c$ are non-physical "ghosts" in the relativistic sense and yet they drive an incredibly important physical process. What must be postulated by scientists to allow such a ghost-like process to become an operational reality? This author (Tiller) has postulated(3) that at a higher dimensional level of nature, a moiety exists that is outside the constraints of Relativity Theory and can travel at velocities greater than or less than c so as to be able to interact with both mass particles moving at $v_p<c$ and information waves moving at $w>c$ so as to allow the de Broglie particle/pilot wave process to become experimentally operational. I have labeled the moieties constituting this "coupling" agent deltrons(4).

A final important point of this white paper for the reader to think about is "Why have orthodox physicists not paid attention to Eisberg's(2) calculations published almost 50 years ago?"

References

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