What is the de Broglie Wave? Revisiting the famous thesis of 1923

De Broglie's insight that a massive particle has associated wave characteristics was crucial to the formulation of quantum mechanics. But under the current orthodoxy, the de Broglie wave makes no physical sense: it is of unknown origin and ontology and has a superluminal velocity that becomes infinite as the particle comes to rest.

Yet while such a velocity is not that of any physically reasonable wave, it is characteristic of the modulation of an underlying carrier wave. There is a significant literature that began with the writings of the late Milo Wolff that asserts that this is indeed the true nature of the de Broglie wave. According to this view, the Broglie wave is not a true wave, but the relativistically-induced modulation of an underlying wave structure that is itself evolving through space at the classical velocity of the particle. In the rest frame of the particle, this underlying structure has the form of a standing wave, and it is easily demonstrated that when considered from any other frame, a standing wave does indeed acquire a modulation having the superluminal velocity and characteristics of the de Broglie wave. Considered in this way, this modulated waveform *is* the particle, thereby resolving the mystery of wave-particle duality in favour of a waveform that simulates the behaviour of a particle.

Less well-known is the support for this interpretation to be found in de Broglie's own thesis of 1923. The de Broglie wave is clearly identifiable as a modulation in de Broglie's depiction of the wave in Minkowski spacetime, as also in his modelling of the wave by an array of oscillating springs. Although de Broglie did ultimately conclude that the wave is a wave in its own right, there is, as I will show, a discontinuity in the "harmonizing of phases" by which he reached that conclusion. He began by proposing that a particle is surrounded in its rest frame by a spatially extended "periodic phenomenon". But when he went on to consider how this extended waveform would change under a Lorentz transformation, he confined his attention to a single point in the waveform. In effect, what he derived was not a spatially extended wave, but a record through space and time of the varying phase of a moving and oscillating point.

Considered as a modulation, the de Broglie wave acquires an origin consistent with special relativity and well understood in classical wave theory. And unlike the de Broglie wave considered alone, the full modulated wave is a covariant relativistic object capable of taking its place in the tensor equations of relativistic physics.

Once the existence of the underlying wave structure is recognized, it becomes apparent why the wave functions of quantum mechanics have seemed so mysterious. The Schrödinger and other wave equations from which those wave functions emerge have known only the de Broglie modulation. But while it is the modulation that identifies the energy and momentum of the particle, it is the full modulated wave structure that shows why that is so and defines the position and trajectory of the particle.

References

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