How the Nazis Split the Foundations of 20th Century Physics

Alan M. Kadin
(Retired)
Princeton Junction, NJ
amkadin@alumni.princeton.edu
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Summary

- De Broglie first derived quantum waves in 1924, directly from special relativity, and Einstein approved.
- But in Germany in 1930s, the Nazis viewed relativity or anything related to Einstein as subversive “Jewish Physics”.
- I argue that German physicists obscured the relativistic basis for quantum mechanics, in order to avoid dismissal or worse.
- Early German QM textbooks led to a split in the foundations of physics that has continued to the present.
- An alternative “quantum relativity” picture could reunify physics, but has never been considered.

De Broglie Waves

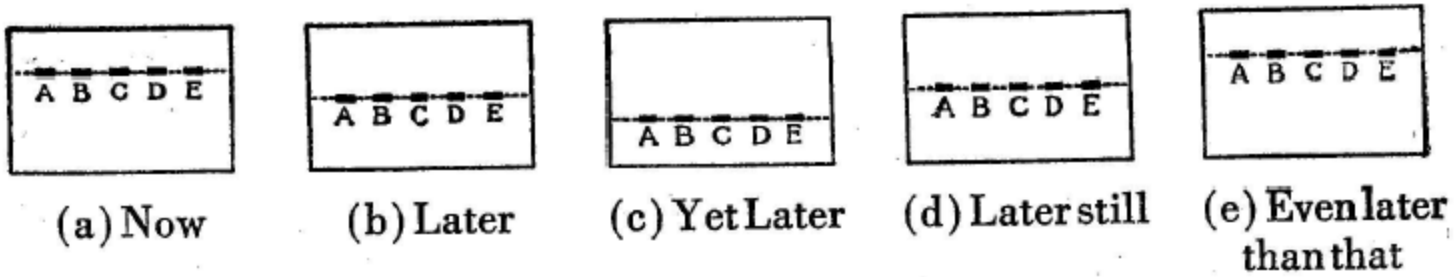
- De Broglie in 1924 assumed a relativistic particle given by
  $E = \gamma mc^2$ and $p = \gamma mv$, [or $E^2 = (pc)^2 + (mc^2)^2$]
  associated with a distributed oscillation
  $\omega = \omega_0 = mc^2/\hbar$ in its rest frame.
- Lorentz-transform to moving reference frame, time delays lead to wave with $\lambda = h/p$, de Broglie wave with $\omega^2 = (kc)^2 + \omega_0{}^2$.
- He then showed that group velocity of wave packet $v_g = \partial\omega/\partial k$ is same as particle velocity $v = \partial E/\partial p$, so they move together.
- De Broglie always believed in the reality of both a point particle and a distributed wave packet that move together.
  - (I am partial to a purely wave picture with no point particles.)

Relativity and Simultaneity

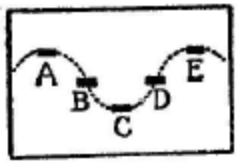
- In classical physics, events simultaneous in one reference frame are also simultaneous in other reference frames.
  - For example, simultaneous wave crests define the wavelength λ of a sound wave, so λ remains the same in all reference frames.
- But this is NOT true for relativistic waves because of space-time mixing.
  - Simultaneous events such as wave crests are NOT simultaneous in other reference frames, leading to time-shifts and changes in wavelength.
  - For example, the wavelength of an EM wave can be red-shifted or blue-shifted by changing reference frames.
- De Broglie waves are relativistic even for v<<c.
  - $\lambda = \infty$ in rest frame, and h/p in moving frame.
  - ***Without Lorentz transforms, these quantum waves would not exist!***

Picture of de Broglie Wave

- Taken from description of de Broglie's theory in "The Strange Story of the Quantum", Banesh Hoffmann, 1947
  - Hoffmann was Math Prof at CUNY, colleague of Einstein, who also wrote biography of Einstein.
- Rest Frame: Phase vs. position for various times



- Moving Frame: Lorentz transform yields wave



- Could this be Einstein's picture of de Broglie wave?

QM and Relativity

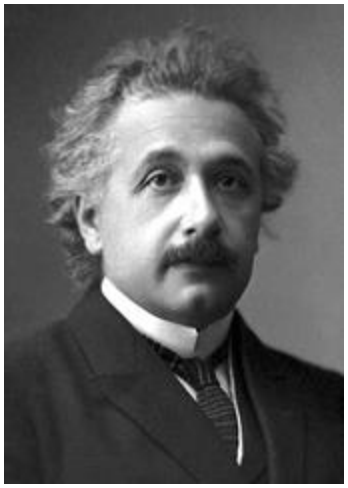
- All QM is actually based on Relativity
  - NOT just "relativistic quantum mechanics" for motion near speed of light c.
  - Even non-relativistic Schrödinger equation is based on de Broglie waves.
- This viewpoint should have been included in physics textbooks by the 1930s. It was not then, or since. Why?
- First, QM had its separate history, going back to Planck's quantum in 1900, and Bohr's (old) atomic theory in 1913.
- Second, relativity was still controversial in 1930s.
  - Even Einstein's Nobel Prize, issued in 1922, was officially for photons and the photoelectric effect.
- But the hostility to Einstein and relativity by the Nazis may have been the most critical.

Einstein and the Nazis

- In 1930, German physics was the best in the world.
- Einstein was the most famous German physicist, but the Nazis viewed him as a dangerous Jewish subversive, and viewed his physics as equally subversive.
  - Einstein fled Germany for Princeton in 1933, when Hitler became Chancellor of Germany.
- But opposition to Einstein was also widespread among pro-Nazi German physicists.
  - Nobelists Philipp Lenard and Johannes Stark led a movement known as "German Physics" or "Aryan Physics", as opposed to "Jewish Physics". https://en.wikipedia.org/wiki/Deutsche_Physik
  - Espousing Relativity was dangerous, and QM was suspect.
- Other German physicists likely understood the relativistic basis for quantum waves, but left it out of the textbooks.
  - This made QM less politically suspect, and enabled German universities to teach it.

Einstein and QM

- Einstein was one of the originators of the photon (in 1905).
- But by the 1930s, Einstein was actively opposed to the prevailing Copenhagen interpretation of QM.
  - Einstein objected to both fundamental randomness and entanglement.
- This enabled German physicists to claim that QM and relativity were really two distinct fields.
  - That attitude still prevails in textbooks.
- A unified conceptual picture of QM and relativity could have been presented in the 1930s.
  - This is not related to Einstein's goal of a "unified field theory" of EM and gravity.



Einstein and Entanglement

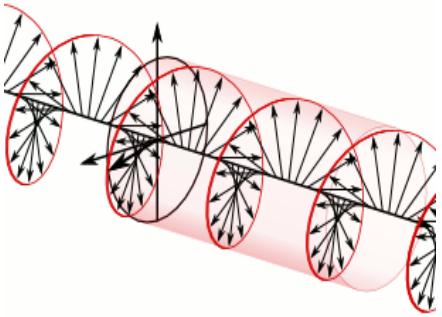
- Entanglement of quantum waves entered QM with Pauli's 1925 "exclusion principle" of only 1 electron in any quantum state.
  - For 2 states ψ_A and ψ_B, the combined state is $\psi_A(1)\ \psi_B(2) - \psi_A(2)\ \psi_B(1)$.
  - If ψ_A and ψ_B are the same, the combined state cancels out.
  - Electrons 1 and 2 are NOT in definite states A and B, even if far apart. Measurement of one immediately changes the state of the other.
- Einstein referred to this as "spooky action at a distance", inconsistent with special relativity.
  - In 1935, Einstein, Podolsky, and Rosen published EPR paradox on entangled quantum states.
- Also in 1935, Erwin Schrödinger wrote paper on paradox of micro-macro coupled "Cat States".
  - Anti-Nazi Austrian, left Germany 1933, Austria 1938 when Nazis took over.
- Neither Einstein nor Schrödinger ever accepted entanglement.
  - They were mostly ignored by colleagues, especially in Germany.

Von Neumann and Hilbert Space

- John von Neumann was Hungarian mathematician in Germany, established Hilbert-space formalism of QM operators & entanglement, based on linear algebra.
  - His 1932 book "The Mathematical Foundations of Quantum Mechanics" (in German) was highly influential.
  - He left Germany for Princeton in 1933, due to Jewish ancestry.
  - He was a colleague of Einstein, but they seldom interacted – there are no photos of the two together.
  - He later led a program that established the standard architecture of the first digital computers, in the late 1940s.
- In the absence of clear physical foundations based on relativity, QM textbooks focused on math. foundations.
  - Hilbert-space model became universally believed, even while it was never verified experimentally.

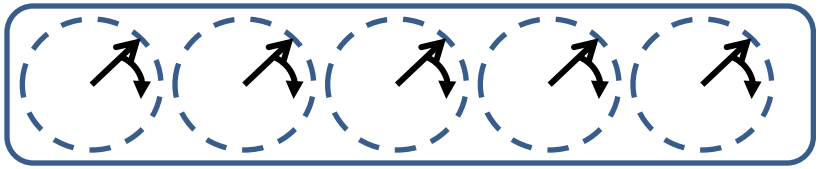
EM Waves and Spin

- Spin is central to QM, but is already present in classical circularly polarized (CP) EM waves
- A CP EM wave has helical E-field rotating at ω, and distributed angular momentum ($\mathcal{L}$), energy ($\mathcal{E}$), and momentum ($\mathcal{P}$)
  - From Maxwell's equations, $\mathcal{L} = \mathcal{E}/\omega$, $\mathcal{E} = \mathcal{P}c$.
- Consider coherent CP wavepacket with total spin L = $\hbar$. Then E= $\hbar\omega$ and p= $\hbar$k follow automatically.
  - This is a real-space wave picture of a photon with quantized spin.
  - Multiphoton state with L = n$\hbar$ would have larger amplitude.
- Note that L is Lorentz-invariant, so the total spin is the same in any reference frame.
  - The photon is red-shifted or blue-shifted, but spin remains the same.

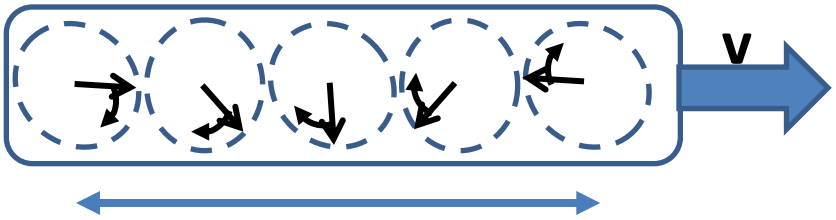


Electron Waves and Spin

- If an electron quantum wave is a real relativistic wave, why not rotating vector field like CP EM wave?
  - But here one can Lorentz Transform to rest frame with v=0.
  - Distributed Fermion field with S = $\hbar/2$, rotating at f = $mc^2/h \sim 10^{21}$ Hz.
  - Opposite spin corresponds to rotation in opposite direction.
- This is NOT a rotating solid body, and there is no point particle.
  - Spin, energy, and charge are distributed over a wave packet.
- Spin is in addition to orbital angular momentum associated with motion of wave.
  - Magnetic moment associated with both spin and orbital ang. mom.
- Note that a real rotating field about a fixed axis maps onto a complex scalar field rotating in the complex plane
  - Suppressing carrier wave at 10^{21} Hz yields Schrödinger equation.



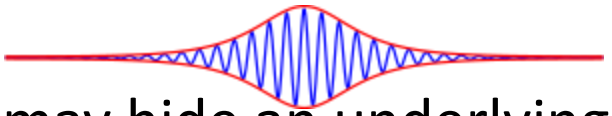
Single Electron at Rest, showing in-phase rotation of vector field



Moving single electron, showing phase-lag of de Broglie wave

Solitons and Electron Waves

- The central paradox of QM is wave-particle duality.
- But a simple way out of the paradox is to regard electrons as soliton-like excitations of a ***nonlinear*** wave equation.
  - Solitons are localized wave packets that act like particles, maintaining their amplitude and their integrity – they cannot split, merge, or disperse.
  - For an appropriate nonlinear equation, the nonlinearities cancel out for a soliton, making it otherwise appear linear.



- Schrödinger equation is linear, but this may hide an underlying nonlinearity that quantizes spin.
  - Exclusion Principle with single electron per quantum state would be obeyed automatically, ***without*** requiring Pauli's anti-symmetrized products.
- Multi-electron state would be sum of single-electron states, ***not*** an entangled product state.
- Soliton picture is ***NOT*** an alternative interpretation of QM; it is a different theory that may be tested experimentally.

Quantum Waves, Time and Space

- Relativistic matter waves in rest frame define characteristic time and length τ and Λ
  - $\tau = h/mc^2$, $\Lambda = c\tau = h/mc$ (Compton wavelength)
- From microscopic viewpoint, electron quantum oscillations DEFINE time and space.
  - Clocks and rulers depend on speed, reproduce time dilation and length contraction for any object made of quantum waves (all matter!).
- Alternative fully realistic picture of *special* relativity.
  - No need for 4D spacetime or 4-vectors – all due to dispersion relation for wave: $\omega^2 = c^2k^2 + \omega_0^2$, where $\omega_0 = mc^2/\hbar$.
  - There is NO abstract time and space – just the microscopic waves.

Quantum Waves and Gravity

- The microscopic quantum waves are also affected by gravity, due to gravitational time dilation and length contraction.
- This alters local clocks and rulers, which alters trajectories.
- Alternative fully realistic picture of *general* relativity.
  - No need for curved 4D spacetime
  - Trajectories calculated using classical Hamiltonian – bending of light, precession of orbits.
  - This is an alternative interpretation of standard GR theory.
- This is NOT related to modern theories of "quantum gravity" that would quantize the gravitational field.

“Quantum Relativity”

- Einstein’s vision was that quantum mechanics should be based on locally real objects in real space, consistent with special relativity.
  - He objected to a probability wave with non-local correlations.
- A real rotating relativistic electron wavepacket with quantized spin satisfies these requirements.
- Such a wavepacket defines local time and space, providing a real microscopic basis for relativity.
- Electron Soliton in a nonlinear equation (yet undefined) enables Exclusion Principle without entanglement.
  - A multi-electron state is a sum of waves, not a sum of products.
- Unified picture of quantum relativity could have been proposed in the 1930s, if the close connection between relativity and quantum waves had not been suppressed.

Possible Implications of Quantum Relativity

- Hilbert space theory may be wrong, testable in table-top lab experiments.
- Entanglement-based predictions, such as those for quantum computing, may be suspect.
- Singularities in orthodox theories, such as point particles or event horizons, may be mathematical artifacts.
- Fundamental “particles” (electrons, photons, quarks) are really waves, while composite particles (nucleons, atoms) are not waves at all.
- Accurate simulations of complex quantum systems may be achieved using conventional computers.

Conclusions

- Relativity should properly be at the heart of QM, and vice versa.
- Nazi opposition to Einstein prevented this natural unity from being taught, distorting the evolution of physics.
- Instead, the focus was on incompatible abstract formalisms: 4D space-time vs. Hilbert space.
- Einstein's criticisms of QM (non-locality and randomness) were largely ignored.
- This foundational split was established in early textbooks, and never corrected.
- A simple unified picture of real relativistic quantum waves, which should have been proposed in the 1930s, provides a clear foundation both for physics education and for future theories.

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