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An Unprecedented View of Quantum Computers

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Abstract

Every discussion of quantum computing starts with wave-particle duality, to explain how qubits differ from bits. But what if wave-particle duality were wrong? How would we explain quantum computing then? A little-known science called the Theory of Elementary Waves (TEW) says that quantum particles follow zero-energy waves backwards. Wave-particle duality cannot be true if waves and particles travel in opposite directions. This article proposes the first-ever TEW theory of quantum circuits. Elementary waves emanate from measuring devices and travel backwards through the circuits, whereas qubits move forwards through the wires and gates following those waves backwards. Quantum computers are known to be reversible. After we present that way-of-thinking, we will explain some of the evidence that TEW is valid. There is a mountain of empirical evidence from outside information technology. TEW is a maverick theory, out-of-step with the consensus about how quantum computers work. At first TEW sounds counterintuitive. Its advantage is Occam's Razor: we present a simpler explanation of quantum circuits. We will present the quantum computer equivalent of saying that before the box is open Schrödinger's cat is already dead or alive, but not both. Observing the cat simply tells us what was already true before we looked.

ACM Computing Classification: F.0: General Theory of Computation

1. Introduction

Wave-particle duality is a cornerstone of quantum sciences and therefore of quantum computers and quantum information. But the model we will build will show qubits following backwards zero-energy waves coming from the measuring devices, inside quantum circuits. We will explain why we propose something that sounds preposterous. (1-15, 19-20, 22-23, 26-33, 37-40)

Time never goes backwards in this article. Particles, qubits, and Elementary Waves all travel forwards in time. Elementary Waves travel in the opposite physical direction as particles and qubits. Elementary Waves flow in the opposite direction as energy, surprisingly.

Wave-particle duality is said to be a solid fact, based on the Davisson-Germer and many other experiments. (17) But a little-known science named the Theory of Elementary Waves (TEW) advances a different explanation of the Davisson-Germer experiment and is supported by a mountain of empirical and mathematical data that is taller than the mountain that supports wave-particle duality.

TEW claims that quantum particles follow backwards zero-energy Elementary Waves coming from detectors. Such waves are everywhere, but the particles that our detectors see are the ones following backwards waves emanating from those same detectors. With respect to quantum circuits TEW says the waves are already inside a circuit before the qubits arrive. Qubits have no intrinsic wave-like properties but acquire such properties from the environment inside the circuit. The wave-like properties and the particle-like properties of the same qubit travel in opposite directions. (10-12, 26-28)

1.1 The Nature of Qubits

Because we reject wave-particle duality, we need to rethink what a qubit is. It turns out that this radical reconceptualizing of qubits simplifies and clarifies quantum circuits. It doesn't lead to any different algorithms. We will offer no improvement on Shor's, Simon's, or Grover's. But we will offer an improvement on IBM's Qiskit and Google A.I. Cirq circuits.

Our approach has three advantages. First, it encourages students to ponder what happens inside quantum circuits from a refreshing, mind-boggling perspective. Students often enjoy sci-fi. TEW is not sci-fi but has that same enjoyable quality of an unprecedented perspective. The second advantage is that this way of thinking is more compatible with how programmers habitually think, namely considering gates one-step-at-a-time. TEW helps programmers think better. Third, it is compatible with a mountain of data from non-computer sciences that we will review in the second half of this article.

Although mathematicians are trained to think in equations, it is more natural to think in pictures. Take children for example. They prefer books with pictures rather than simply text. And they prefer videos even more. Pictures are the "machine language" intrinsic to this author's brain. We will translate Dirac equations into two-dimensional pictures (see Figures 1 to 14).

We request suspended disbelief. The reader will only learn our viewpoint if the reader is willing to tolerate the cognitive dissonance of ideas that are unfamiliar. It is hard work to learn a drastically different way of thinking, as if awakening from a dream confused about which world you are in.

Because our approach requires a profound change in how one thinks, therefore some words change their meaning. Words that assume wave-particle duality become confusing. Since quantum circuits are known to be reversible, this should not be a wrenching change of assumptions.

The word “superposition” means two unrelated things. It can refer to the way waves add together, a well-known property of waves, because waves are linear partial differential equations. We endorse that. Or it can refer to the idea that qubits (regarded as particles) can occupy contradictory states until measured, like Schrödinger’s cat, an idea we reject. TEW says “superposition” is a word that can be applied to waves, but not to particles, qubits, or cats.

The word “qubit” also has two different meanings. TEW splits apart the intrinsic particle-like features from the wave-like features moving in the opposite direction. The confusion is evident when we say something like, “A qubit cannot be in a superposition of two incompatible states simultaneously.” That makes sense in TEW but not in QM.

We will present a step-by-step approach to how circuits work. We claim this idea is closer to the compiler embedded in the imagination of programmers. They are trained by classical binary computers. According to that way-of-thinking, each gate does something specific to a piece of information. The idea that no decisions are made until the very end, when the entire circuit is measured, at which time a featureless “superposition of qubits” collapses and becomes specific for the first time, is not the way programmers think. It’s impractical. It’s magical thinking.

TEW says that each shot traverses a circuit in a unique way, possibly different from the other shots. At a gate inside the circuit a qubit might bifurcate into two or three qubits on different wires, and those might merge with qubits already on that other wire. Similarly Elementary Waves, moving right-to-left often bifurcate and merge with other waves. With this crisscross dance, we explain entanglement and wave superposition.

Halfway through a circuit a Bloch sphere can have its vector pointing obliquely, so that $\boldsymbol{\theta}$ and $\boldsymbol{\varphi}$ can take peculiar values. We speak of such an oblique Bloch sphere as being “in a specific state.”

It is traditional to separate the “theory of measurement” (meaning mathematics stated by John von Neumann, Paul Dirac, and others) from “philosophy” (meaning metaphysics). We reject that bifurcation. How we think is inextricably entwined with what programmers think. As we said, we will attempt to draw pictures to clarify our unusual ideas.

In TEW each “shot” makes a unique contribution to the final histograms. This is parallel to the way conventional digital computer circuits work: gate-by-gate, step-by-step in a definite sequence that produces a unique outcome for each shot. A conventional computer is not said to suffer from “superposition collapse” when it is measured at the end.

1.2 The Second Half of This Article

This article will be speculative in the first half and scientific in the second half. The speculation arises because this is the first time anyone ever attempted to reimagine quantum information sciences from a TEW perspective. The scientific second half presents an abbreviated sketch of the mountain of evidence that TEW is true, evidence from outside the field of quantum information.

Elsewhere we have published that evidence in detail, in peer-reviewed scientific journals of mathematics, physics, and chemistry. Here is a list of some of the experimental evidence: the Davisson-Germer experiment, Stern-Gerlach, Bell-test, and double-slit experiments, the quantum-eraser, Wheeler *gedanken*, and optics experiments, several high-energy scattering experiments, and the Periodic Table of 118 elements. As we said, the mountain of evidence supporting TEW is taller than the mountain supporting wave-particle duality. But mainstream computer scientists never heard of it. (10-12)

2. Measurement

Measurement of a quantum state turns it into a classical bit. The superposition, entanglement, and wave interference all disappear and are replaced by an ordinary bit that can only take values of zero or one.

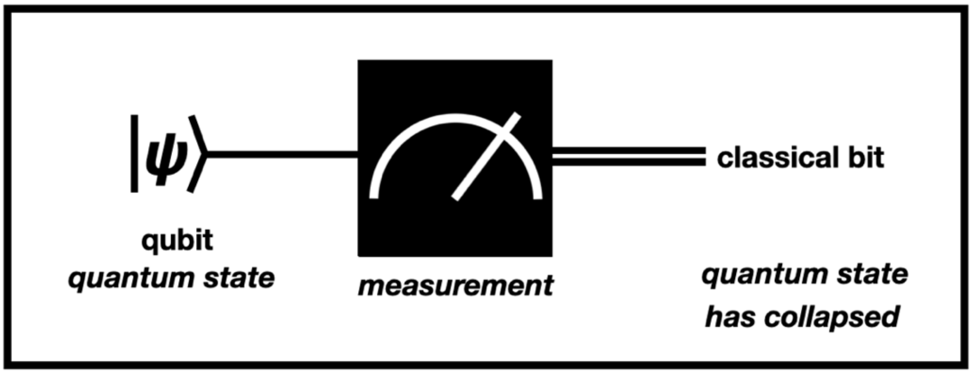


Fig. 1. This meter symbolizes a projective measurement (POVM) of a quantum system. Measurement transforms a qubit into a classical bit. We will not speak of bits that can take 3 or more values. (32)

As we said, TEW is based on an unorthodox theory. This theory was discovered in 1996 by physicist named Lewis Little. (26-28) Boyd, the author of this article, developed the theory, presenting it a dozen times to academic scholarly societies, and publishing more than two dozen scholarly, peer-reviewed articles on the subject. This is his first publication involving information theory. (10-12)

2.1 TEW's Picture of a Quantum Circuit

No one previously asked the question how quantum computers could work if TEW were true. There are no empirical studies, nor any scholarly articles about this. This article is unique.

We begin with the assumption is that waves start at detectors and quantum particles follow those waves backwards, which must mean that qubits do so also. At the end of this article, we will discuss how a qubit differs from a quantum particle. A qubit is a hybrid of a particle and a wave, and, as mentioned, we say those travel in opposite directions. The reader must get used to this weird idea since it is at the core of this article. That bi-directional assumption is what makes this article challenging, invoking a sci-fi-like unfamiliarity that might be fun or annoying.

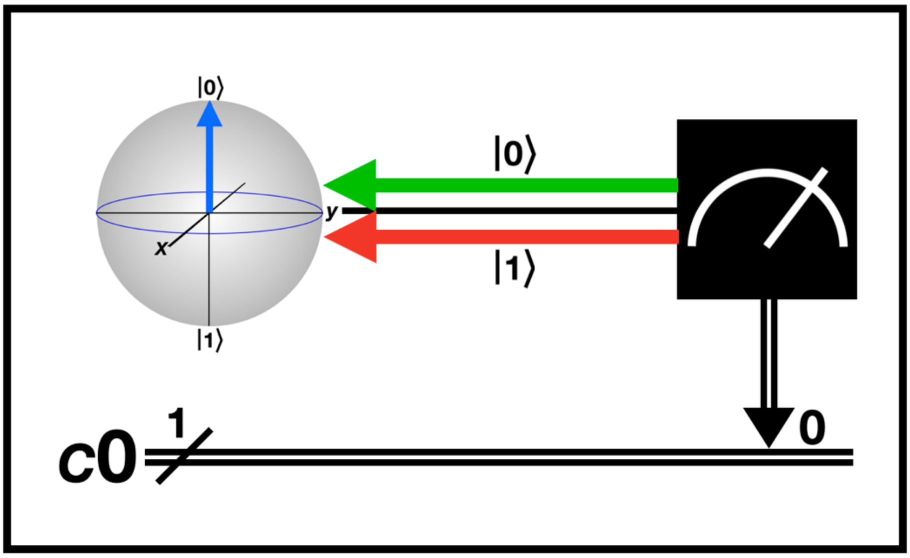


Fig. 2. This shows the TEW picture of a quantum circuit with no gates, using IBM Qiskit symbols. A Bloch sphere in the computational state, initialized to $|0\rangle$, enters the circuit on the left. It is following backwards Elementary Waves (green and red arrows) coming from the measuring device. When the sphere reaches the measuring device it yields a classical binary (0,1) measurement.

We are translating mathematical equations into two-dimensional color diagrams. We make this transition into pictures because this author tends to think in pictures, and videos.

In the Figure above, the green arrow represents $|0\rangle \equiv \begin{bmatrix}1\\0\end{bmatrix}$ and the red arrow represents $|1\rangle \equiv \begin{bmatrix}0\\1\end{bmatrix}$.

(1)

According to TEW, superposition, entanglement, and interference are characteristics of Elementary Waves as those waves pass from right-to-left through the labyrinth of a circuit. Those are not intrinsic characteristics of a qubit. For the remainder of this article, we will use the word "qubit" to refer to the particle-like characteristics of a qubit, and NOT the wave-like characteristics. We call the waves Elementary Waves, which are moving from right-to-left. A qubit follows such waves backwards moving from left-to-right. Elsewhere we present wave equations for how that might happen. (10-11)

Therefore, a qubit is like an American baseball that can rotate but cannot carry entanglement or interference inside. Our goal currently is not to prove this idea, but to introduce a visual way of displaying Dirac notation for the simplest IBM Qiskit circuit. The proof or evidence will be sketched in the second half of this article.

2.2 Single Qubit Circuits

Now let's consider what happens as a qubit passes through a Hadamard gate

$$H = \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\1 & -1\end{bmatrix}$$

(2)

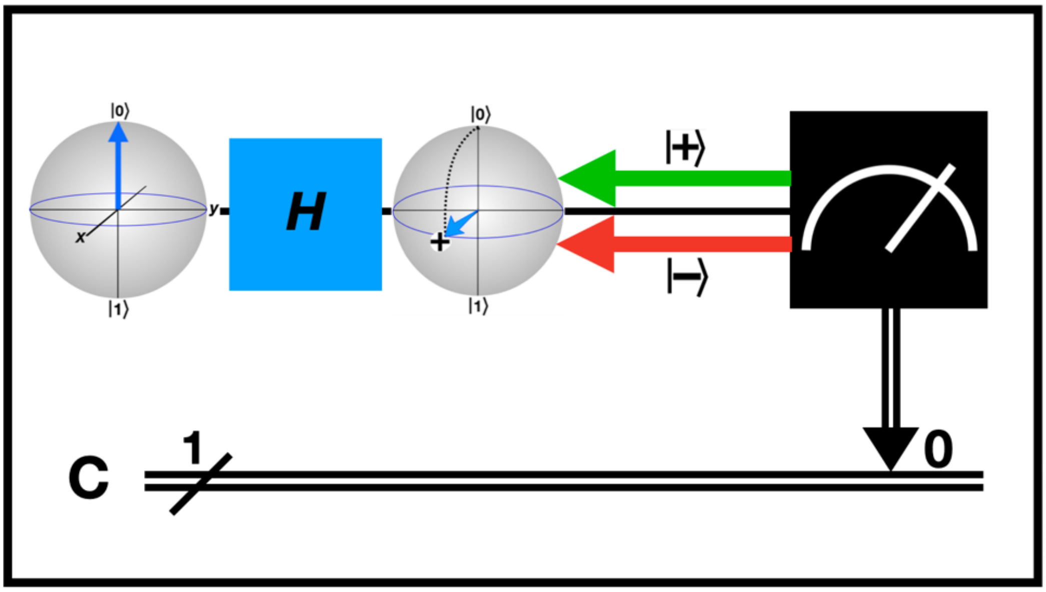


Fig. 3. The blue vector inside the Bloch sphere moves from a vertical to a horizontal position (along the "+" axis) in the middle sphere. This is one way to understand the Hadamard gate: it rotates the Bloch sphere by π/2 around the y axis (using the right-hand rule). Looking at this picture we see that it is unclear whether the middle Bloch sphere will be measured as having a value of "0" or "1". This shows how and why QM claims that measurement causes wave-function collapse, which could be "0" sometimes and with another shot it could be "1".

There is another way of picturing the impact of a Hadamard gate on a Bloch sphere. We prefer the next picture, because it clarifies that the qubit is in only one state at a time, not a superposition of two states. With a subsequent shot the qubit might be in the opposite state. Therefore, the final histograms will show 50% in the $|0\rangle$ state and 50% in the $|1\rangle$ state. Those histograms report what happens over thousands of shots. Any one shot cannot be in both states simultaneously, nor do the histograms say that.

We invoke Occam's razor. Our interpretation is closer to the empirical data. Occam's razor says, "Explanations with fewer entities are preferred." Our theory articulates what the histograms say. QM adds the idea of a "superposition of qubits", which is unobservable. Occam's razor says, "Why add an unnecessary metaphysical idea of 'qubit superposition' that is not intrinsic to the data?"

$$\text{The H matrix applied to ket } |0\rangle \text{ is: } \frac{1}{\sqrt{2}}\begin{bmatrix}1 & 1\\ 1 & -1\end{bmatrix}\begin{bmatrix}1\\ 0\end{bmatrix} = \frac{(|0\rangle + |1\rangle)}{\sqrt{2}} = \overset{\textbf{2 Bloch spheres}}{\overbrace{\frac{1}{\sqrt{2}}|0\rangle} + \overbrace{\frac{1}{\sqrt{2}}|1\rangle}}. \tag{3}$$

This can be pictured as the **sum of two Bloch spheres**, as shown below.

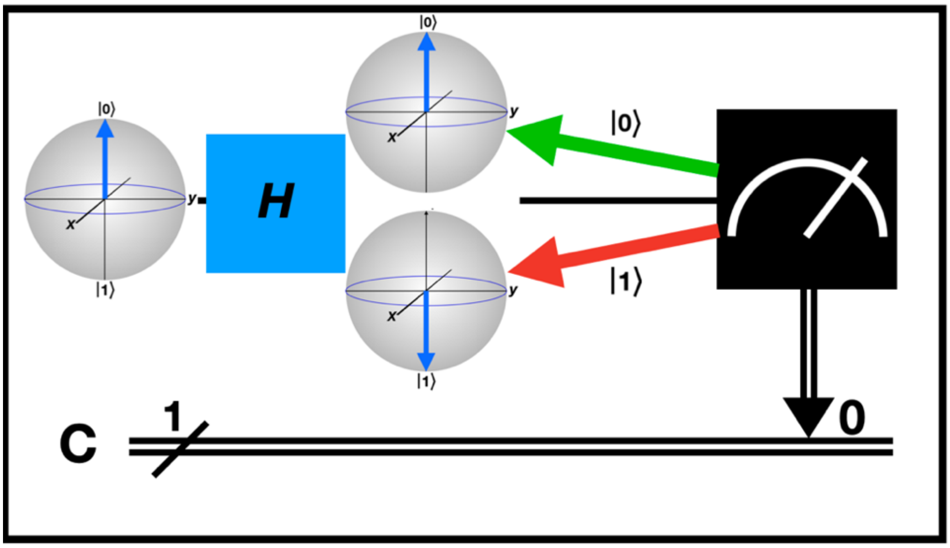


Fig 4. Hadamard gate produces one of two Bloch spheres as shown here, **but not both simultaneously.** The upper sphere shows what happens if the Bloch sphere on the far left follows the green $|0\rangle$ Elementary Wave backwards as it passes through the ***H*** gate and therefore takes the $|0\rangle$ position before it is measured. The lower sphere shows that the Hadamard gate turns the Bloch sphere to a $|1\rangle$ position if the red Wave is followed backwards as a pathway through the gate.

If we picture a qubit as a Bloch sphere, the qubit makes a choice whether to transit through each gate following the green or red arrow emanating from the measuring device.

TEW pictures "superposition collapse" happening deep inside the circuit. In Figure 4 it happens inside the **H** gate. Each qubit occupies only one state as it emerges from the **H** gate. In Figure 4 the qubit emerges in a state of being $|0\rangle$ **or** $|1\rangle$ **but not both.** If you want to get the whole picture, TEW says you must take thousands of shots and see how the histograms look after that. But each single shot only contributes to the histograms in one specific way. Every programmer knows that is what the data says. The data does require us to invoke a mystical "superposition of qubits" before measurement. That is a metaphysical idea not arising from the data.

That idea that each shot is unique gives us a more sensible picture of what is happening deep inside the guts of the circuit, than the standard view that each shot crosses the circuit as an eerie ghost-like superposition that only shatters into unique patterns as it enters the measuring devices.

According to TEW the decision maker inside a quantum circuit is the qubit. It chooses between Elementary Waves moving through each gate in the opposite direction. Sometimes a qubit chooses to cross a gate one way, sometimes another way. That decision is based on random chance, and it is also based on the strength (or intensity) of the different Elementary Waves incident to the gate.

Once a qubit has transited through a gate, that is a piece of history. The final measurement is determined step-by-step, gate-by-gate, so that each decision contributes uniquely to the final histograms.

2.3 Double Qubit Circuits

Now we'll consider the first Bell state, which is one of four maximally entangled states of two qubits. Since the circuit involves two qubits both initialized to $|0\rangle$, the combined initial state is traditionally written:

$$|00\rangle = \begin{bmatrix}1\\0\\0\\0\end{bmatrix} \tag{4}$$

Our circuitry starts with a Hadamard gate on the top wire, and Identity gate on the bottom wire:

$$(H \otimes I)\,|00\rangle = \frac{1}{\sqrt{2}}\begin{bmatrix}1\\0\\1\\0\end{bmatrix} \tag{5}$$

$$\text{We then apply a CNOT gate: } \begin{bmatrix}1&0&0&0\\0&1&0&0\\0&0&0&1\\0&0&1&0\end{bmatrix}\frac{1}{\sqrt{2}}\begin{bmatrix}1\\0\\1\\0\end{bmatrix} = \frac{1}{\sqrt{2}}\begin{bmatrix}1\\0\\0\\1\end{bmatrix} = \frac{(|00\rangle + |11\rangle}{\sqrt{2}} \text{ which is the first Bell state.} \tag{6}$$

The next **two** Figures translate those equations into our symbolism for Elementary Waves.

$$\text{The first Bell state can be summarized: } \frac{(|00\rangle + |11\rangle}{\sqrt{2}} = \overbrace{\frac{(|00\rangle)}{\sqrt{2}}}^{\textbf{Fig. 5}} + \overbrace{\frac{(|11\rangle)}{\sqrt{2}}}^{\textbf{Fig. 6}} \text{which represents the next 2 figures.} \tag{7}$$

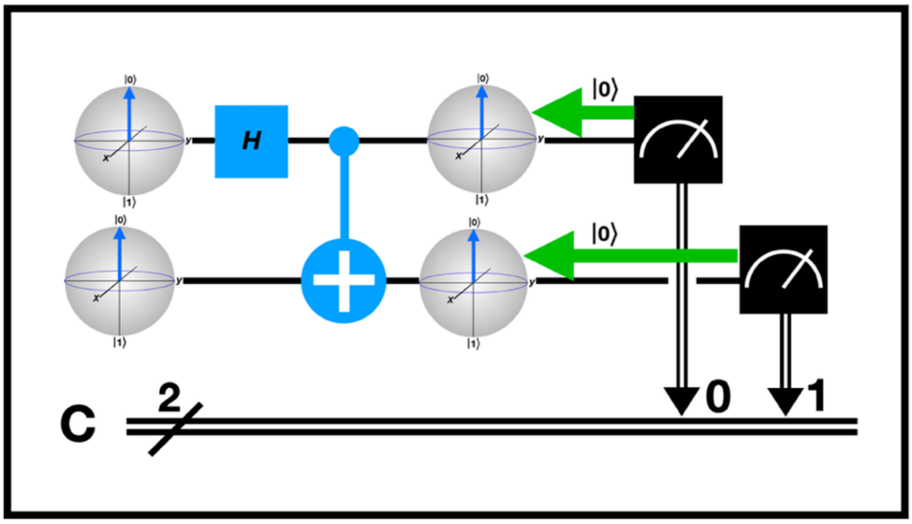


Fig. 5. This circuit represents the first Bell state $|00\rangle$. In this diagram both qubits are following backwards a green Elementary Wave in the $|0\rangle$ state as the qubits pass through the CNOT gate. If the reader says, "But the first Bell state $|00\rangle$ can also emerge from these two gates in the $|1\rangle$ state", then the reader is thinking correctly and anticipating our next picture.

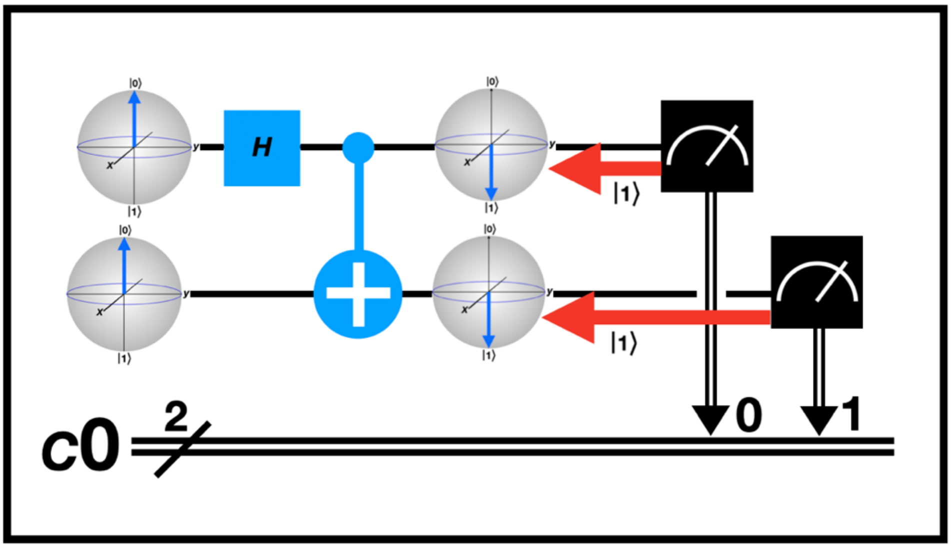


Fig. 6. If, on the other hand, the qubits have followed a red Elementary Wave backwards, the CNOT gate makes them agree to take the $|1\rangle$ state, so that the total picture is $|11\rangle$.

The entanglement we presented was that found in the circuit for the first Bell state. What makes it entangled is that the Hadamard gate produces a qubit in a mixed state of being sometimes $|0\rangle$ and other times $|1\rangle$. That entanglement cascades down through the CNOT gate to affect the second qubit. In TEW the word "entanglement" refers to the state of Elementary Waves, not to the state of a qubit, except insofar as the qubit is following entangled waves backwards.

To summarize, qubits (viewed as if they were particles) and waves traverse circuits in opposite directions. As they crisscross from wire to wire, circuits are awash in activity, like ocean waves swirling around rocks, so that one might consider the entire quantum circuit as being one very complicated gate that embodies a specific relationship between a set of outcome variables and a set of input variables.

2.4 Multiple Qubit Circuits in IBM's Qiskit

When there are many wires and many detectors, several detectors can be sending Elementary Waves from right-to-left toward any single gate. Those waves might "grope" their way backwards through a maze of circuitry before getting to a gate. This means that waves impinging on a gate may come from several different detectors competing for the attention of the qubit approaching the gate from the left. That competition leaves room for random chance as each qubit makes its decision about how to deal with this complicated situation. The qubit can choose to follow more than one incident wave, bifurcating into two qubits taking different paths.

The reversibility of quantum circuits is well-known. Reversibility is pertinent to our understanding of a multiple qubit circuit. The next Figure was copied from the literature (Thapliyal and Munoz-Coreas), but we changed the labels at the top and bottom. (34)

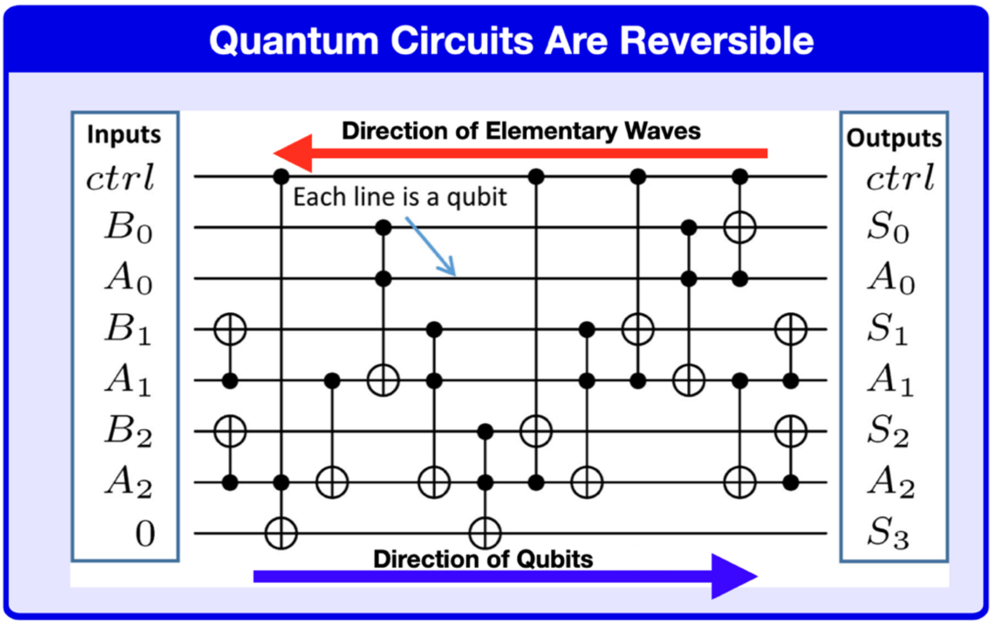


Fig. 7. Quantum circuits are reversible. TEW says that the waves (color red) travel from right to left, whereas the blue qubits (or shots) follow the waves backwards.

The red vector means something different in Figure 7 than in Figures 3, 4 and 6. In Figure 7 red means "any Elementary waves". In Figures 3, 4 and 6 a red vector meant $|1\rangle$.

Our model allows us to ponder issues that are not usually discussed in quantum circuit discussions. For example: is each qubit in one specific state after it has passed through the ith gate? Our answer is that probabilities govern each choice a qubit makes as it confronts each gate. Thus, the outcome is somewhat random, but within the realm of predictability.

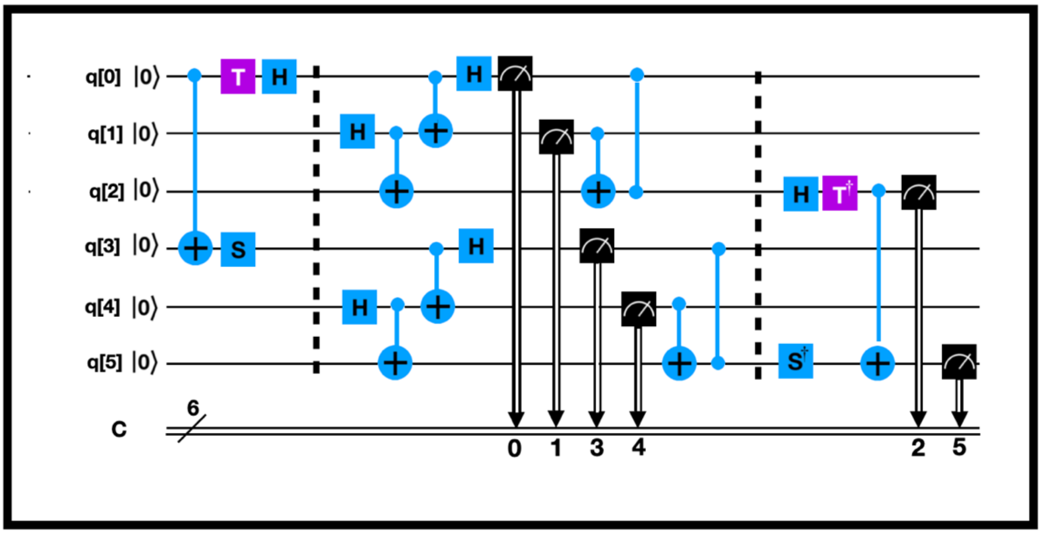


Fig. 8. In this circuit, the Elementary Waves emanate from the detectors on the right, traveling toward the qubits coming through the circuits from the left.

When we "take a shot", we initiate six qubits (q[0] to q[5]) simultaneously, and they work their way step-by-step across the maze of gates and wires from left toward the right. If it takes a certain amount of time "**t**" on average for the qubits to travel across the entire circuit, in ½**t** time the six qubits will be about halfway across. In the end we will measure the qubits, not the Elementary Waves. Therefore, the timing and movement of qubits is important. The Elementary Waves are always residing inside the circuit, and are not seen by our measuring devices.

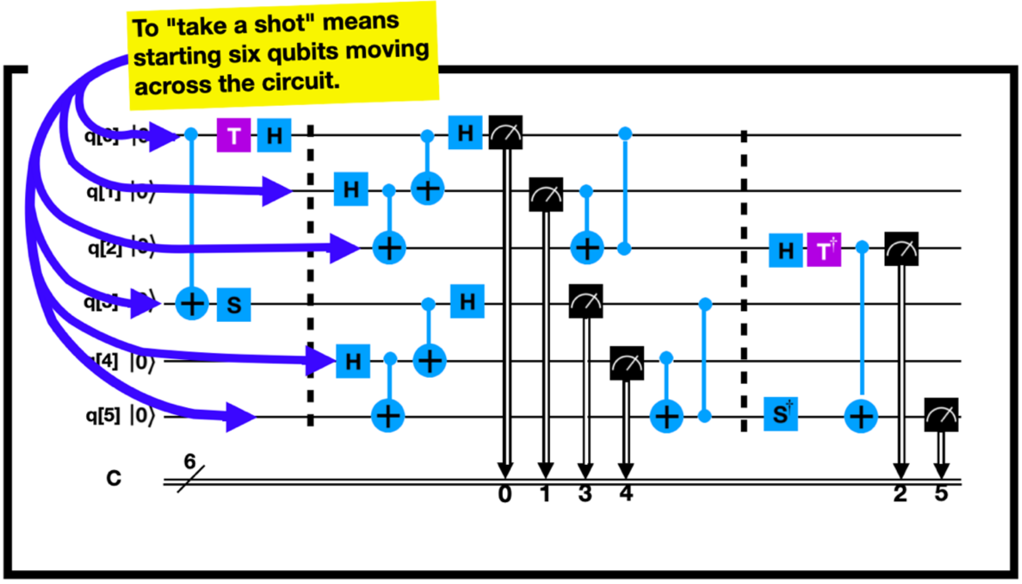


Fig. 9. When we “take a shot” at a quantum circuit, we initiate six qubits moving from the left. Those six qubits are traditionally named q[0] through q[5].

Each of these qubits is, according to TEW, following backwards Elementary Waves flowing through the wires and gates from the right. We will select the third detector (for no good reason) to show how this works.

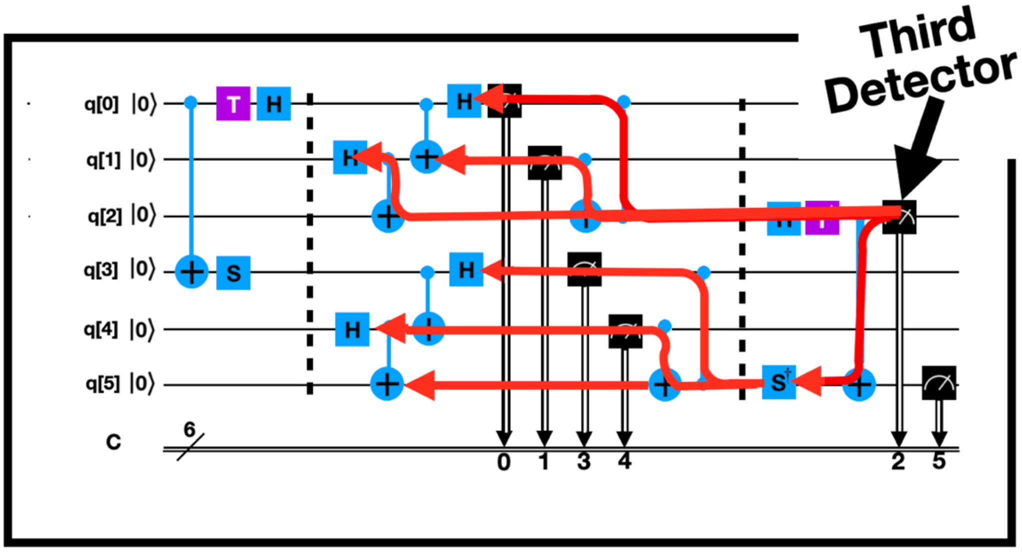


Fig. 10. The third detector is wired so it gathers information from qubits q[0] through q[5] as indicated by the red arrows. This labyrinthine web contains the entanglement and superposition of waves, as the zero-energy Elementary Waves travel from right-to-left, splitting into two or three red arrows at various gates (such as at CNOT gates).

The third detector (on wire q[2]) contributes information to all sixteen histograms: 000000, 000001, 000010, 000011, 001000, 001001, 001010, 001011, 010000, 010001, 010010, 010011, 011000, 011001, 011010, and 011011. To accomplish that work, the third detector sends out tentacles to inquire about the state of all six different qubits (q[0] through q[5]) as they approach from the left.

There is nothing unique about the third detector. All six detectors are connected to several gates and multiple qubits.

Just as the red arrows traveling leftwards can split at a CNOT gate into two arrows on two different wires, so also red arrows on two different wires can merge into the same one red arrow. Similarly, the qubits (shown in purple) moving into the maze from the left can split and merge with other qubits on other wires. The dance of red arrows leads to the dance of purple qubits.

At each gate each qubit makes a choice how to go through that gate. The choices made by qubits as they enter a gate are subject to random chance, but the probabilities also reflect the strength of the Elementary Waves impinging on the opposite side of that gate. More than one detector can be competing for the qubit's attention at each gate, but some Waves are stronger than others at that gate.

Our thinking about this subject is informed by our thinking about the decisions a particle makes in a double slit experiment as it leaves the gun. Those ideas will be explained in Section 7 below.

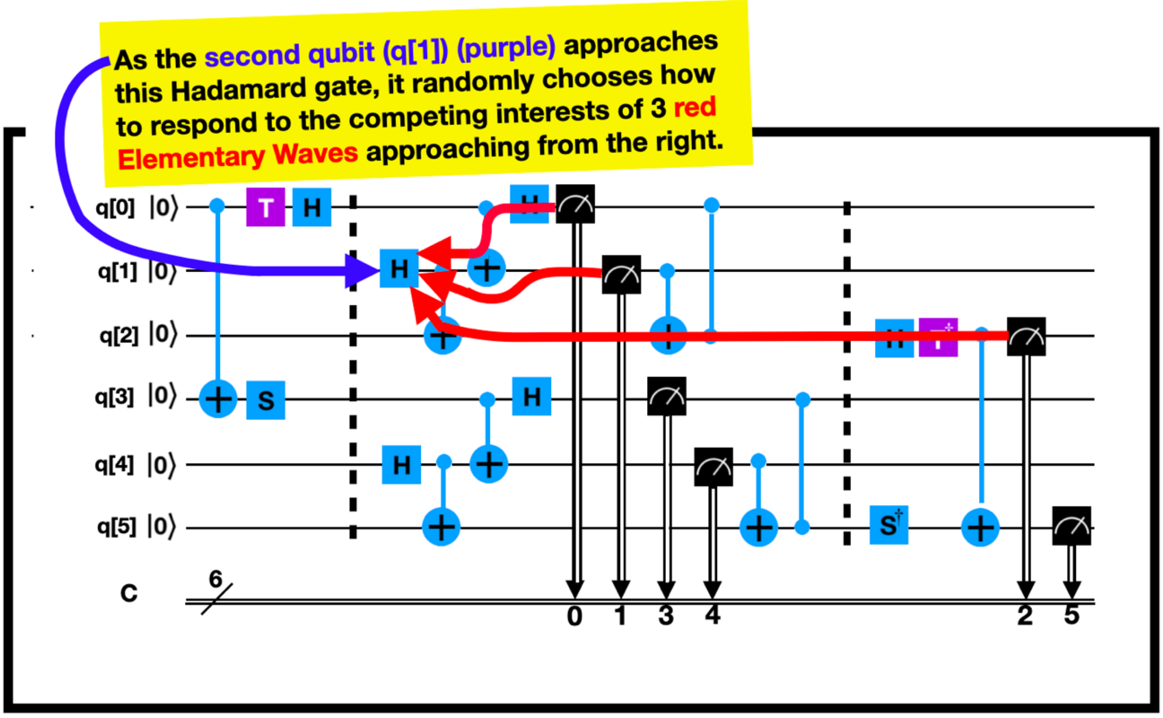

As the second qubit (q[1]) (purple) approaches this Hadamard gate, it randomly chooses how to respond to the competing interests of 3 red Elementary Waves approaching from the right.

Fig. 11. Elementary Waves (symbolized by red arrows) from three detectors all impinge on a gate (in this case an **H** gate). The qubit (symbolized by the purple arrow on the left) approaching that gate is subjected to the simultaneous influence of all three red waves as it decides how to pass through that gate. Perhaps the qubit will choose to follow all three of them simultaneously or behave in a way we don't expect. Under such circumstances a single qubit might split into two or three parts, any one of which might merge with other qubits on neighboring wires.

Inside the **H** gate in the Figure above, the qubit decides which Elementary Waves to follow backwards. Those decisions by the qubits as they transit through gates ultimately determine the height of the 16 histograms at the end of the experiment. Inside the gates is where the superposition, entanglement, and interference of Elementary Waves have their effect on any qubit attempting to cross the gate from left to right. The decision maker is the qubit, and the decisions are probabilistic. This concept is most evident in Section 7 about double slit experiments.

Our purpose is not to dissect exactly what happens inside each gate, which we don't know, and is too complicated to think about. Our purpose, rather, is to solve a "measurement problem" that has haunted QM for the past century. We are presenting the quantum computer equivalent of saying that before final measurement, Schrödinger's cat is either alive or dead, but not both (not in a superposition). That is what we mean when we say we are solving a "measurement problem." This is not just metaphysics. This is computer programming. We "think different" (as Steve Jobs said) but hopefully we think clearer.

To reiterate, TEW has no qubit superposition. Nothing extraordinary happens when a system is measured. Things just work in the normal and natural way. TEW says that at each gate something specific happens, so that the outcome is determined step-by-step at one gate after another. Halfway through the circuit, about half of the final data has been decided.

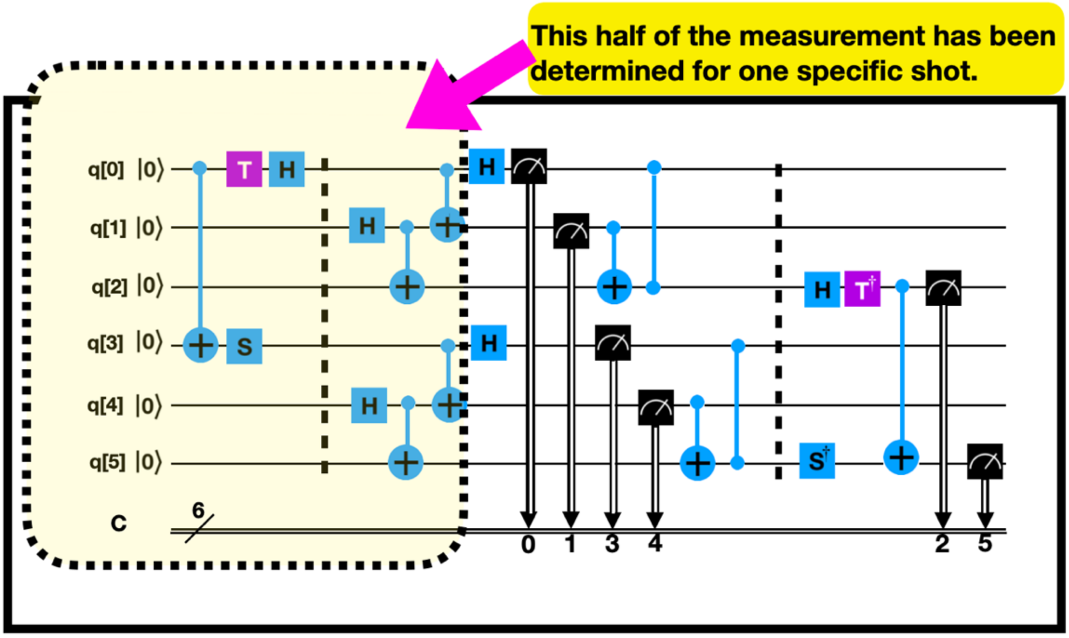


Fig. 12. If it takes approximately time "**t**" for each shot to transit through a circuit like this, the yellow box in the upper left crudely delineates how far that shot has reached after ½**t**. Each qubit has moved through each gate in a specific way. That history will not change when the qubits are measured at the end. Each qubit has followed a specific path through the maze, but it can vary slightly from one shot to another, based on probability. The final histograms are an average over thousands of shots.

2.5 Google's A.I. Cirq

Using the language Cirq we will restate the same ideas as we presented above for Qiskit. These are both Python languages.

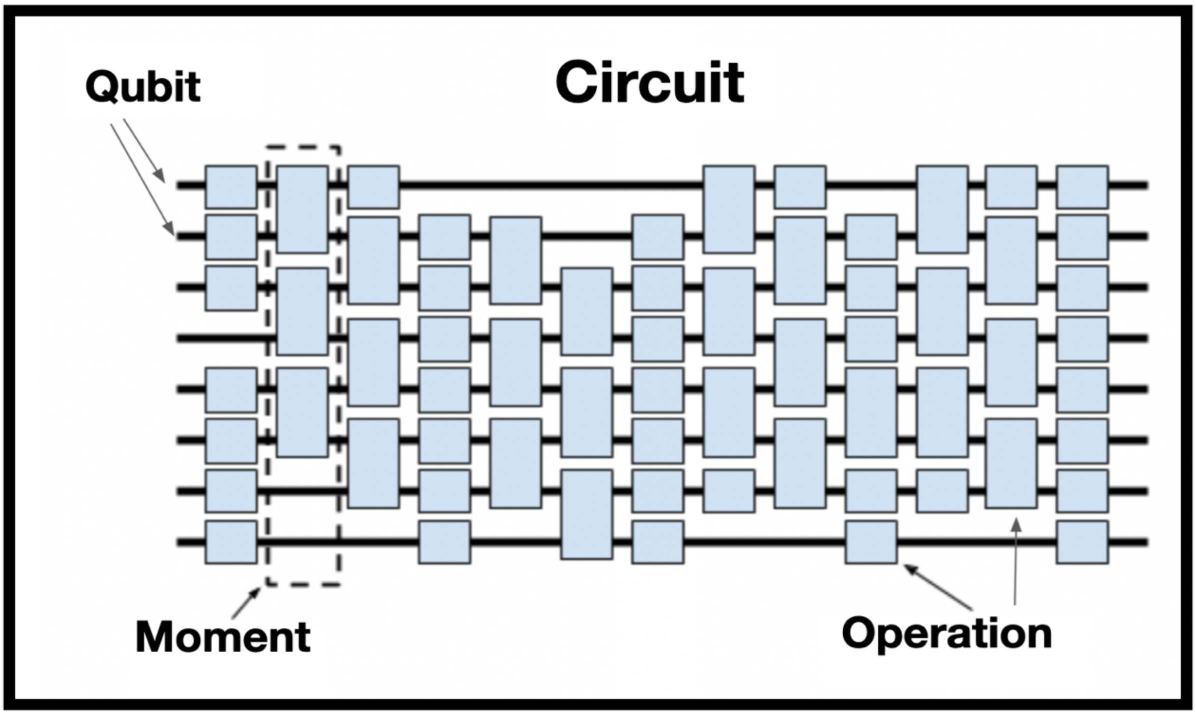


Fig. 13. A circuit diagram for a Google A.I. quantum chip.

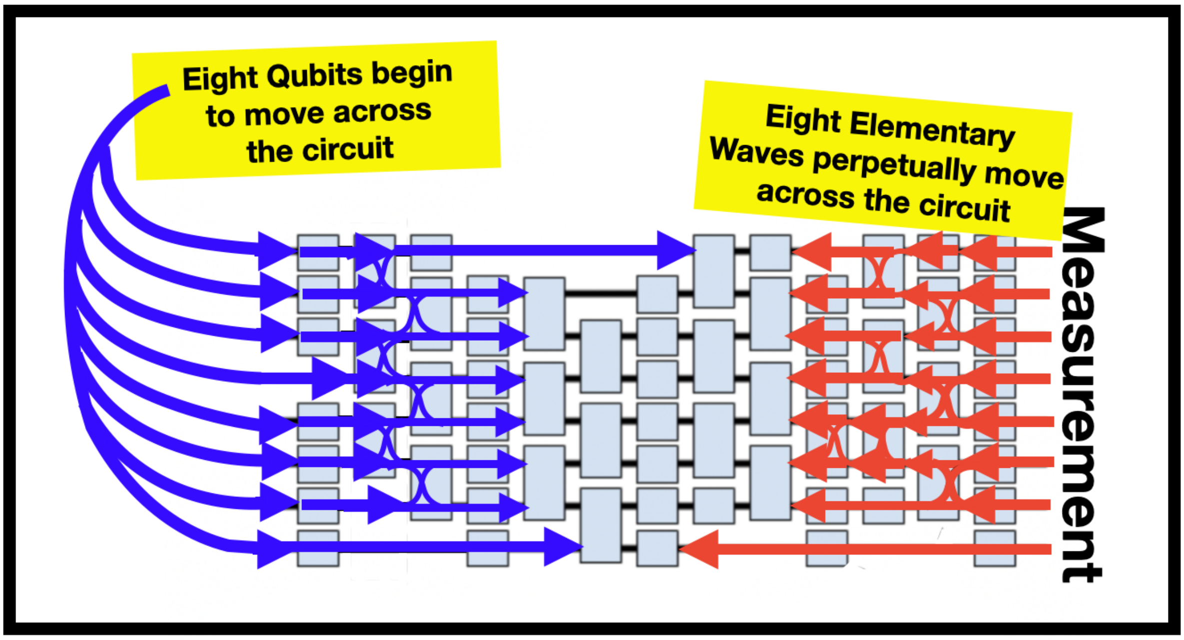


Fig. 14. How Elementary Waves (in red) coming from the measuring device guide the Qubits (purple arrows) across the circuit. The Elementary Waves are present inside the circuit before the Qubits arrive. The waves are always present. The "shots" are not. This arrangement is like Figures 9 and 10. Note that the arrows can split from one wire into two, or two adjoining arrows can merge.

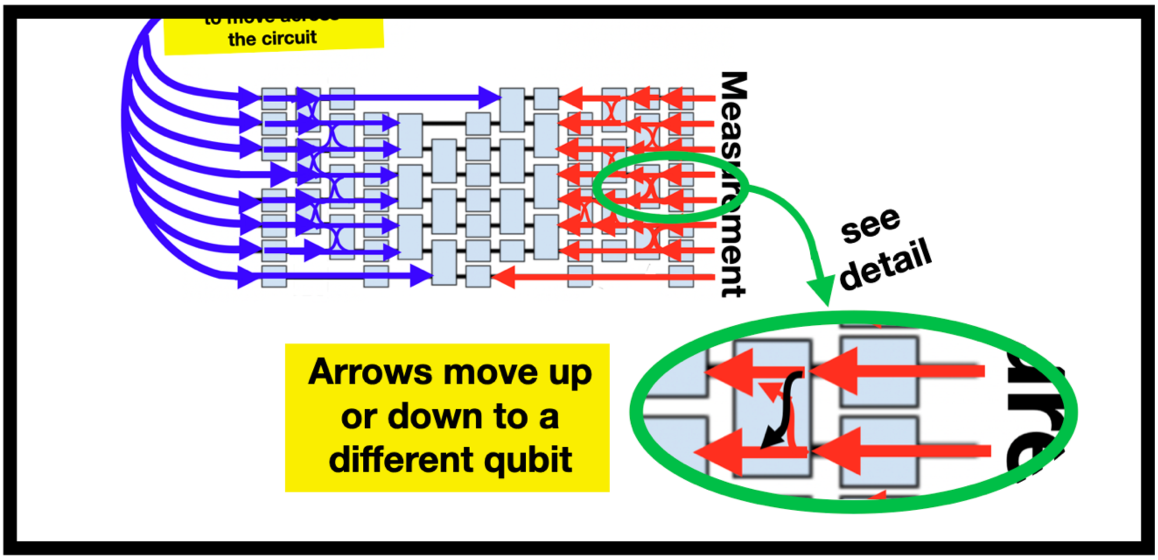


Fig. 15. This is a detail from the previous Figure, showing how Elementary Waves can split and then cross over onto a different wire and merge with a different red arrow in a Google Cirq diagram.

To repeat the same thing, the Google A.I. chip (Figures 13 to 15) likewise determines the final output data one moment at a time as qubits cross the circuit. Our teaching on this issue is more congruent with the subjective experience of programmers as they construct the Cirq code in conformity with the internalized Cirq compiler that resides in their skulls.

2.6 Printed Sheet Music as a Metaphor

Although we have emphasized that the qubits and Elementary Waves travel in opposite directions, on a practical level the best way to think is that the Elementary Waves with their superposition and entanglement are already living inside the circuitry before the qubits arrive. Consider the relationship between printed sheet music and the melody produced by an orchestra. The TEW viewpoint is that the sheet music is already on the music stands before the conductor arrives, and each sheet is unique to that instrument and is so arranged that the different instruments will be in harmony.

If an orchestra is playing, we notice that a piano, clarinet, drums, and double bass all interact in a way that is analogous to being "entangled." If we know the sheet music was already present before the music began, then we don't need to invoke the idea of nonlocality. We can say that the clarinet produces its own sound locally, while the double bass and piano produce notes in a self-contained way. The entangled dance of the instruments was already embedded in the printed sheets, which were individualized for each instrument by Elementary Waves. The printed sheets were present on the music stands before the musicians arrived. The Elementary Waves are like high school students who scurry across the stage half an hour before the concert, putting the sheet music on the corresponding stands.

3. Definition of Terms

We will now define three terms that we have used repeatedly: superposition, entanglement, and interference. Since "entanglement" is the most difficult, we will discuss it third.

3.1 Superposition and Wave Interference

Superposition means that two waves can add together when they overlap, the way water waves add when one wavefront crosses the other wavefront obliquely. The wave equations are linear differential equations that can add. When two peaks coincide the sum is constructive, so the height can be taller. When a peak of one wave coincides with a valley of another wave, they cancel each other, because the peak of one wave fills the valley of the other. That is destructive interference. It can produce flat water. This definition of wave superposition also defines wave interference.

Our thesis is that wave-particle duality is a mistaken idea because waves and quantum particles travel in opposite directions. Because we reject wave-particle duality, we say that particles are physical objects that are never in a superposition: the particles have no intrinsic wave-like properties. Schrödinger's cat is likewise never in a superposition. (10-12, 26-28)

We take this concept of wave-particles and apply it to qubits. The relationship of qubits to wave particles is discussed at the end of this article.

3.2 Entanglement

Entanglement is a difficult concept because it is a property of the quantum world that we don't observe in the large-scale world of everyday experience. As everyone knows, the idea emerged from a debate around the so-called EPR paper of 1935, in which Einstein, Podolsky, and Rosen (EPR) said that QM was "incomplete" because it could not account for some features of two spinning particles moving apart, if the particles were mirror images of each other and shared the same origin. (18)

In 1964 John Bell said that the EPR paper made it clear that in subtle ways classical and quantum equations for two spinning particles contradict one another. Bell's Theorem led to the idea that it would be possible to design experiments to determine which of the two contradictory theories was correct. (5-6)

Spinning particles moving apart are impractical in a lab. As everyone knows, Clauser, Horne, Shimony, and Holt (CHSH) published an experimental design in 1969 that explored the Einstein-Bell controversy using two photons that were emitted from a 2-photon source, and tested by hypothetical observers Alice and Bob, using polarizers and detectors. (15)

CHSH provided a mathematical definition of the term "entanglement" according to this equation: ***"Entanglement"*** is defined by the parameter "**S**" in this CHSH equation:

$$S \equiv E(a,b) - E(a,b') + E(a',b) + E(a',b') \tag{8}$$

Here "E" is the coincidence rate of Alice and Bob's data, and "a, a', b, and b'" are random angles at which their polarizers might be positioned. That which they call "coincidence" we rename "probability."

$$\textbf{Entanglement means} \quad 2 < S \leq 2\sqrt{2}. \tag{9}$$

Entanglement means that quantum processes in one place and time are not separable from quantum processes in another place and time. They can only be understood as two parts of the same whole. In other words, a single quantum state can exist simultaneously in two places. Entanglement means that the values in the middle of an X-Y matrix are not simply the product of the marginal values of X and the marginal values of Y.

After CHSH defined entanglement, Alain Aspect et. al. built the equipment below to test the CHSH hypothesis, with randomizers inserted (blue rectangles C_1 and C_2). Here is a diagram of the 1982 experiment for which Aspect received the 2022 Nobel Prize. (1,2,23)

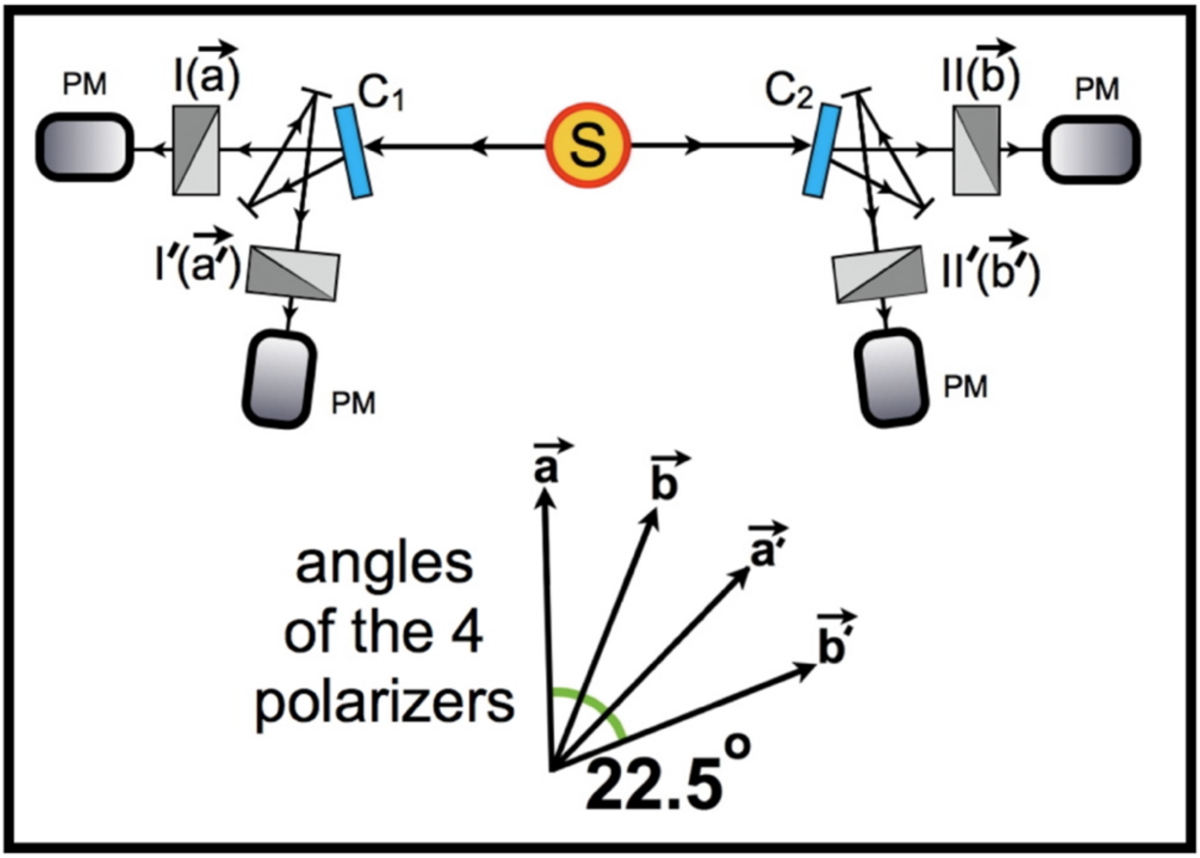


Fig. 16. In 1982 Alain Aspect's team built the experiment designed by CHSH, adding a time-varying randomizer consisting of waves on a pool of water (shown in blue). A calcium source was used to generate two entangled photons. (1,2)

Since 1982 dozens of sophisticated experiments have shown that entanglement persists even when all "loopholes" have been closed. This means that Albert Einstein's denial of entanglement is not tenable. Those loopholes are not discussed in this article since our theory sides with QM, not with Einstein.

Einstein called this "spooky action at a distance." Quantum communication networks today use that kind of spooky action.

Later, in Section 8, we will demonstrate that TEW can replicate the sinusoidal equations of the CHSH idea of a Bell test experiment. Our explanation will demonstrate that TEW rejects Einstein's picture of local reality. Therefore, the sixty years of elegant experiments to "close the loopholes" are not relevant to this article because we simply don't accept Einstein's "local realism." TEW does not have any corresponding loopholes that need to be closed.

The bedrock upon which quantum information networks rests is entanglement. As everyone knows, in 2022 a Nobel Prize was awarded to the founders of entanglement, John Clauser, Alain Aspect, and Anton Zeilinger: "for experiments with entangled photons, establishing the violation of Bell inequalities and pioneering quantum information science." (23)

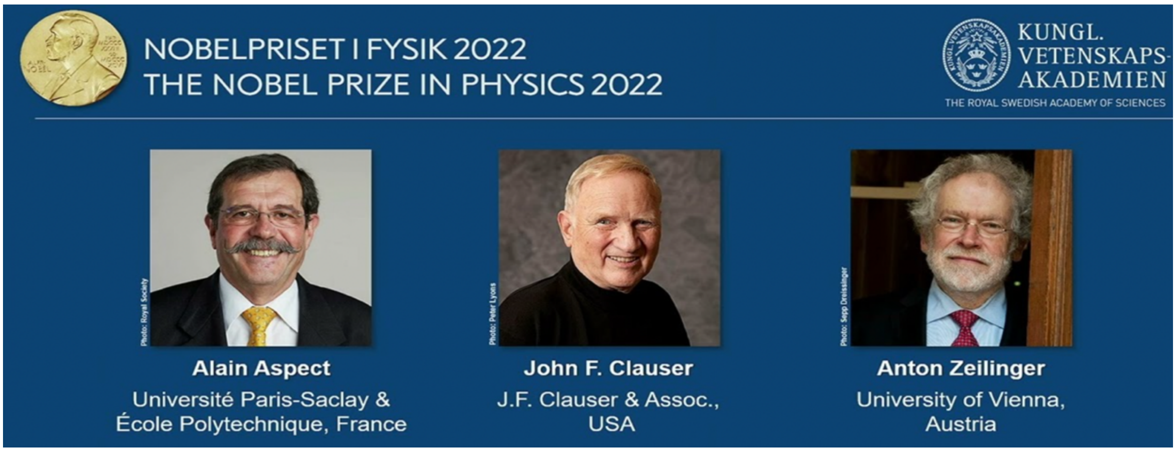
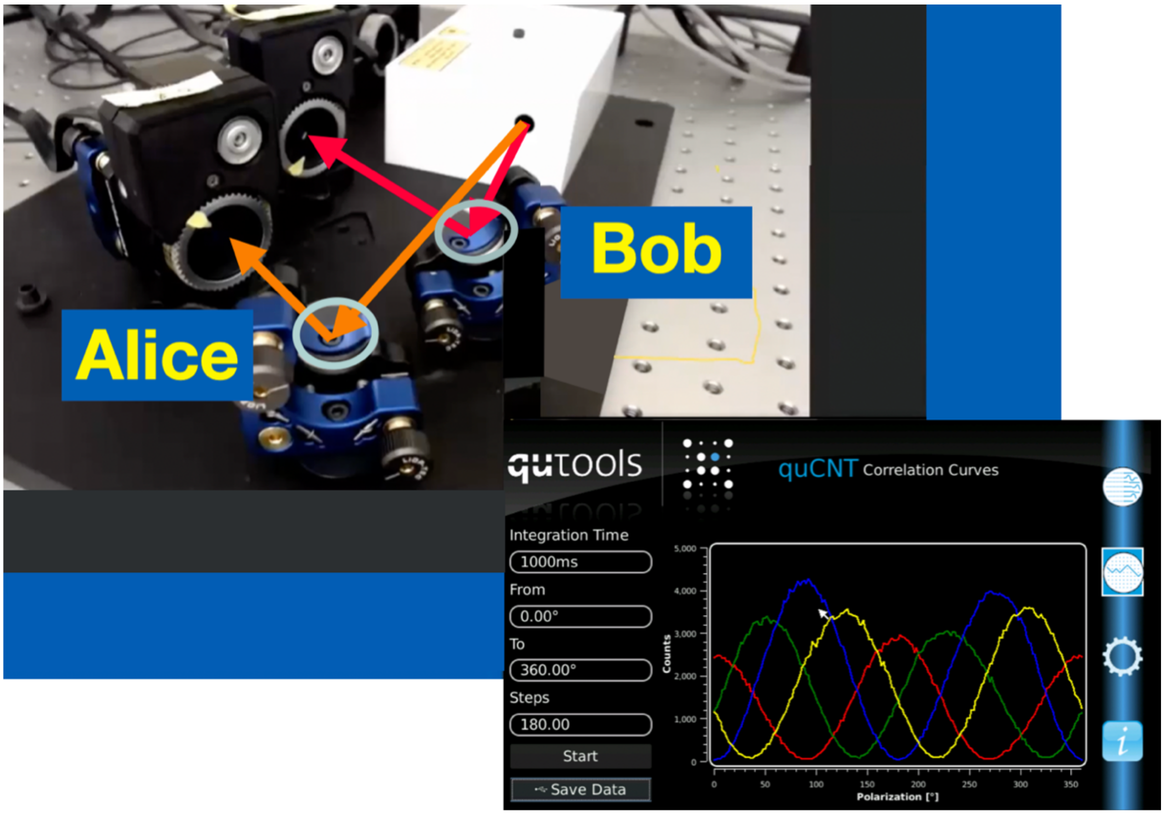


Fig. 17. The 2022 Nobel prize for the founders of entanglement and quantum information theory.

The reason John Bell did not receive a Nobel Prize is that he was dead.

Since entanglement is something that does not occur in the everyday world, it is difficult to teach it to students. However, we have a solution to that.

If you are a teacher, the next diagram gives you a straightforward way to give your students a hands-on experience of entanglement. A German company named quTools (with whom the author has no financial connection and no vested interest) makes available equipment designed to precisely reproduce the CHSH experiment. (31)



Integration Time
1000ms
From
0.00°
To
360.00°
Steps
180.00

Fig. 18. The CHSH experiment is implemented by quTools equipment. Inside the white rectangle (in back) is a β-barium-borate (BBO) crystal that emits two entangled photons (orange and red) that travel to the equipment of Alice and Bob in the foreground. The photons are reflected to two detectors, after they pass through polarizers that can be rotated to different angles.

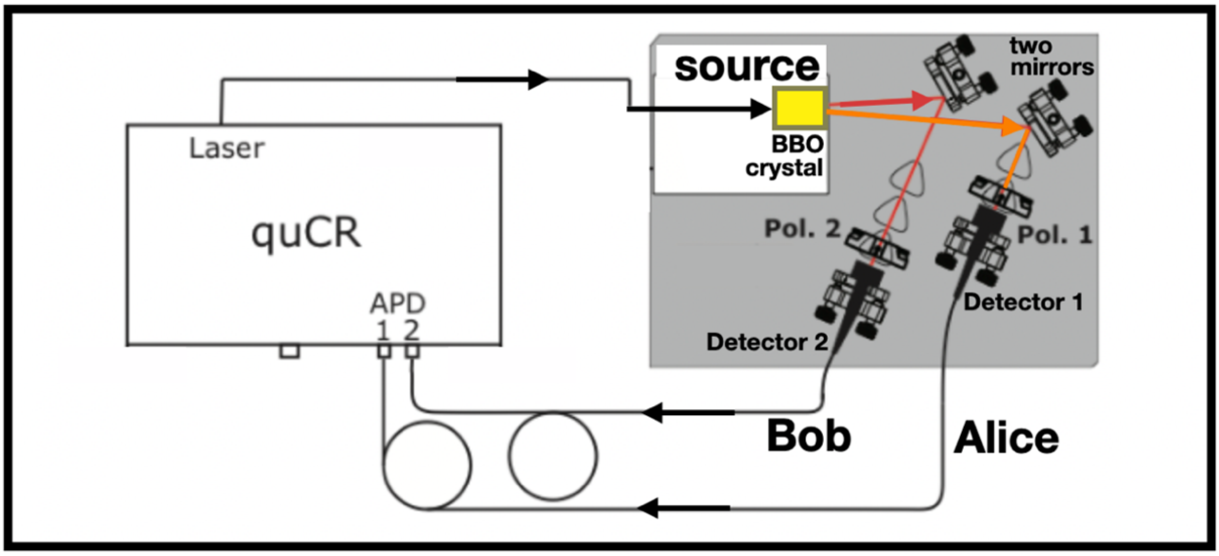


Fig. 19. Diagram of the equipment from the previous figure. On the left, a white rectangle named quCR (built by the company quTools) sends a laser beam, which passes through a BBO crystal (in yellow), splitting into two entangled photons. Those two photons are reflected by mirrors in the upper right and pass-through polarizer 1 or 2 (Pol. 1 & Pol. 2) to strike detectors 1 or 2.

The key to using this quTools equipment is getting your school to buy it. It's not cheap. (31)

4. Transition to the Second Half of the Article

We have explored a nonstandard way of thinking about what happens inside a quantum computer.

So far, we have focused on IBM's Qiskit and Google's Cirq. This is not because we consider the Qiskit or Cirq approach better. It's because we had to start somewhere, and those are the systems about which we know a little bit.

If there is merit to our ideas, other scholars can translate our ideas into other types of quantum computers. For readers who want an overview of different varieties of quantum computers, we recommend Dominic Walliman's 34-minute video, his 4-minute, or 12-minute video. Anastasia Marchenko also has a YouTube video comparing Qiskit and Cirq as languages for the IBM or Google AI computers. (14, 29, 32, 37-38)

What we turn to now is experimental data from areas outside computer science, that gave birth to the TEW viewpoint. We have published extensive reviews of this experimental data and wave functions in scholarly peer reviewed articles in mathematics, physics, and chemistry journals. Anyone interested is referred there. We will not repeat most of what was already published. Here we will limit our discussion to sketching those experiments needed by the reader to understand this article. (10-12)

TEW is a new theory that embodies all the strengths of QM but is free of Schrödinger's cat and other weirdness. It helps programmers to think more clearly. It also perks up the interest of STEM students so that they would be more likely to choose a career in quantum information. The field needs students. Jobs and training programs can't find enough applicants. One way to attract STEM students is to amuse them with an outrageous theory that challenges the status quo and invites them to dabble in their love of sci-fi. Possibly this might motivate students to tackle the otherwise tedious task of learning linear algebra and Python.

Part II. Experimental Evidence Supporting TEW

5. Davisson-Germer Experiment

The Davisson-Germer experiment of 1927, which experts say "proves wave-particle duality" does no such thing. Clinton Davisson and Lester Germer shot electrons at a crystal of nickel and measured the electrons rebounding. This was in the 1920's when physicists were debating wave-particle duality as a way to understand the Schrödinger equation. Davisson and Germer were at Bell labs. At that time the Bell Labs were in Manhattan, not New Jersey. (17)

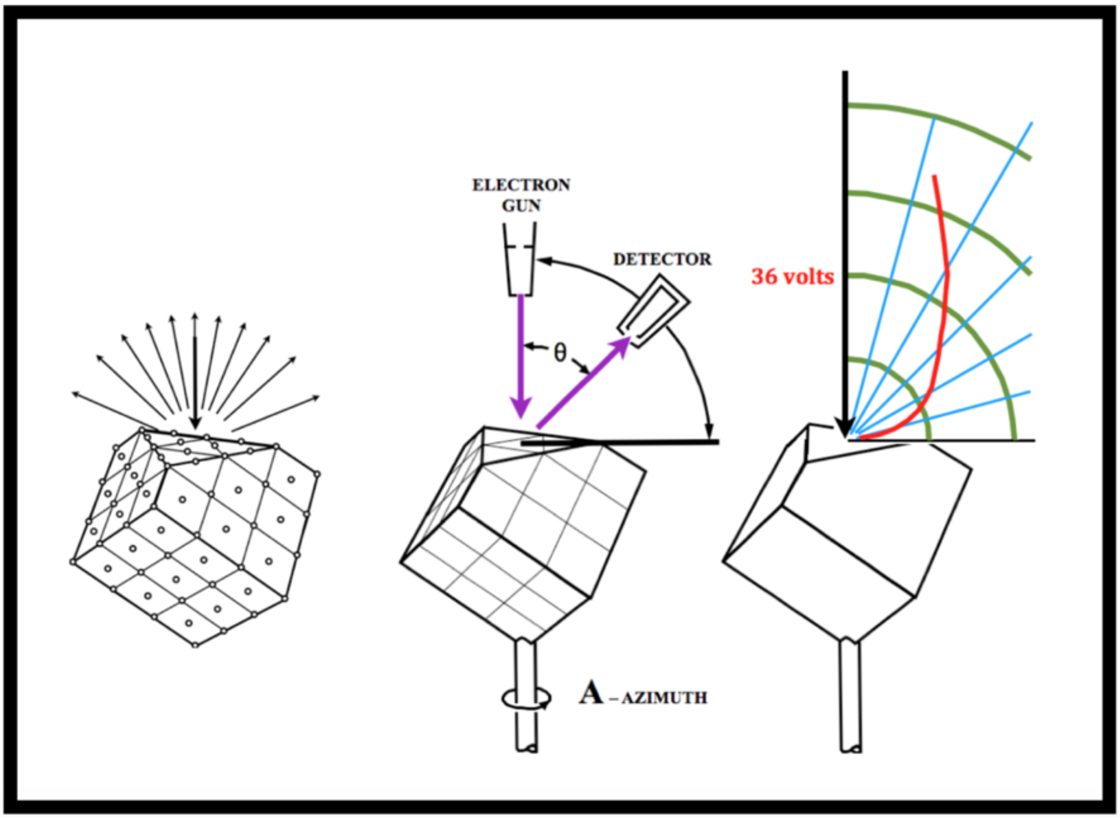


Fig. 20. The Davisson-Germer experiment. Left: a crystal of nickel, off which electrons ricochet. Middle: Electron gun shoots electrons at a nickel crystal and they are detected at angle *θ*. Right: polar coordinates for the number of electrons detected when the electrons are fired with a voltage of 36 volts..

Davisson and Germer find a remarkable "spur" or "hump" that can only be explained if electrons are interacting with waves of 1.67 Å. The "spur" shown in the next Figure is what everyone found so remarkable in their data.

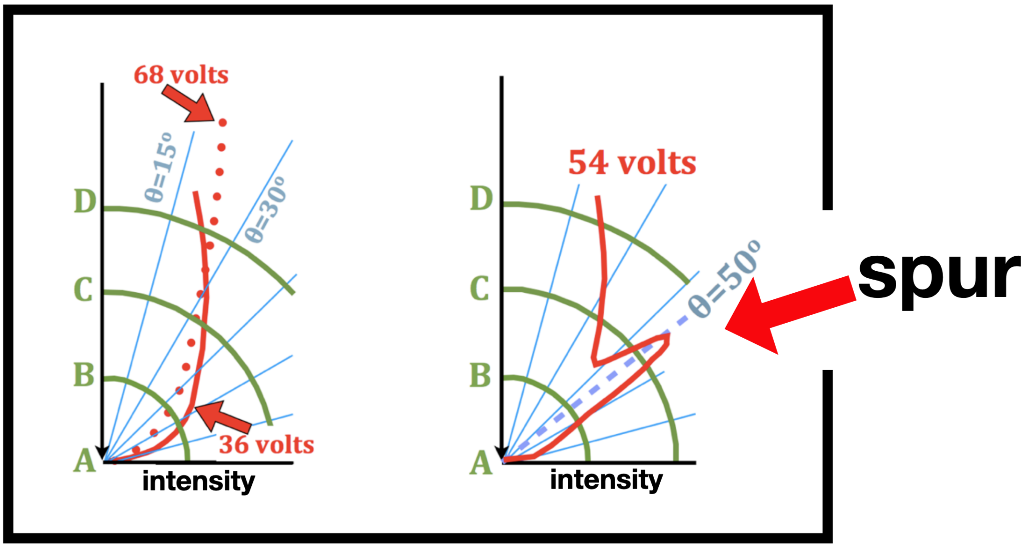


Fig. 21. Polar coordinate graphs of electrons coming off a nickel crystal at various voltages show an unusual spur at 50° and 54 volts. It indicates electrons are interacting with waves of 1.67 Å.

TEW can explain the data: Elementary Waves with a wavelength of 1.67 Å start at the detector, refract backwards through the crystal up into the gun, then electron particles follow the waves backwards, producing that spur in the data. The experiment can be explained by either theory. The experiment does not provide information that would allow us to determine which of the two is the correct interpretation. The data do not tell us which direction the waves are traveling.

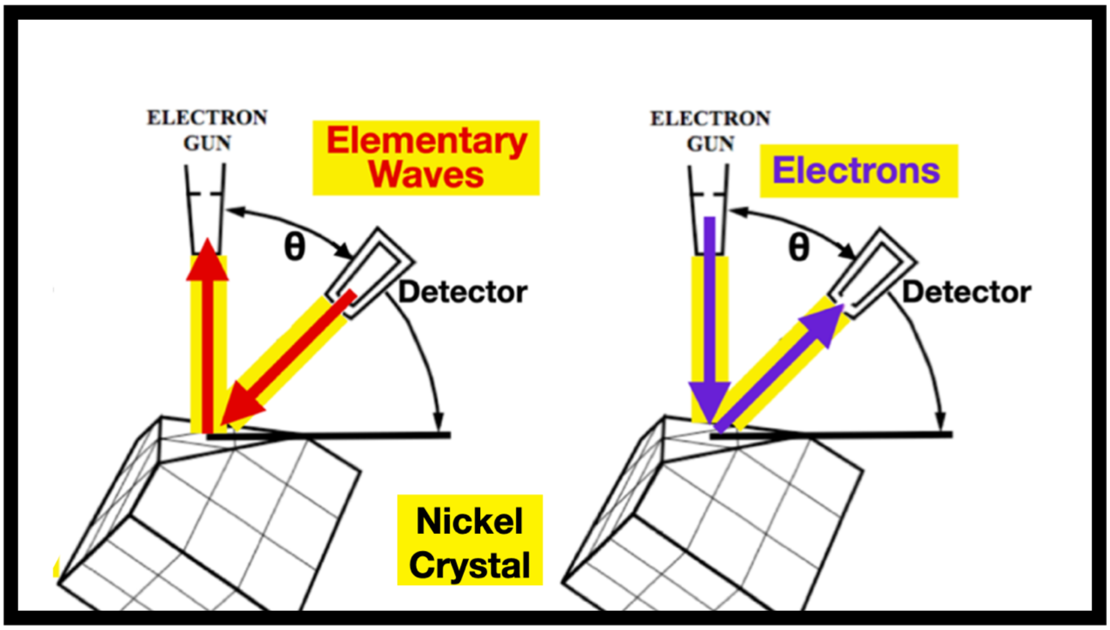


Fig. 22. First, Elementary Waves from the detector refract through the crystal and travel up into the gun. Then, right, electrons follow those waves backwards. This explains the data equally well, without wave-particle duality. Therefore, the statement "Davisson-Germer **proves** wave-particle duality" is **false**.

The next experiment does tell us which direction the waves are traveling.

6. A Neutron-Interferometer Experiment That QM Cannot Explain

A neutron-interferometer published in *Physical Review A* in 1992 cannot be explained by QM. Experts often say, "QM can explain all experimental data," but that is not true. Here is an experiment that QM cannot explain. The researchers themselves said QM cannot explain these data. (10-11, 16, 24)

This experiment is incompatible with wave-particle duality. Although this experiment is not about quantum information systems, it introduces a new perspective on quantum computers, networking, and communication systems. This is the strongest evidence we have that TEW is correct.

In this experiment the amount of wave interference diminishes as more and more bismuth is added inside a neutron interferometer (Figure 23). Bismuth, the 83^{rd} element, slows neutrons. With enough bismuth all interference abates. However, when a nearly perfect (NP) silicon Analyzer Crystal is inserted outside and downstream from the interferometer (red arrow), robust wave interference is restored upstream and inside the interferometer. That research team says QM cannot explain it. They attribute it to "Wheeler's smoky dragon" – a mythical creature that John Wheeler invoked when quantum experiments contradict quantum theory.

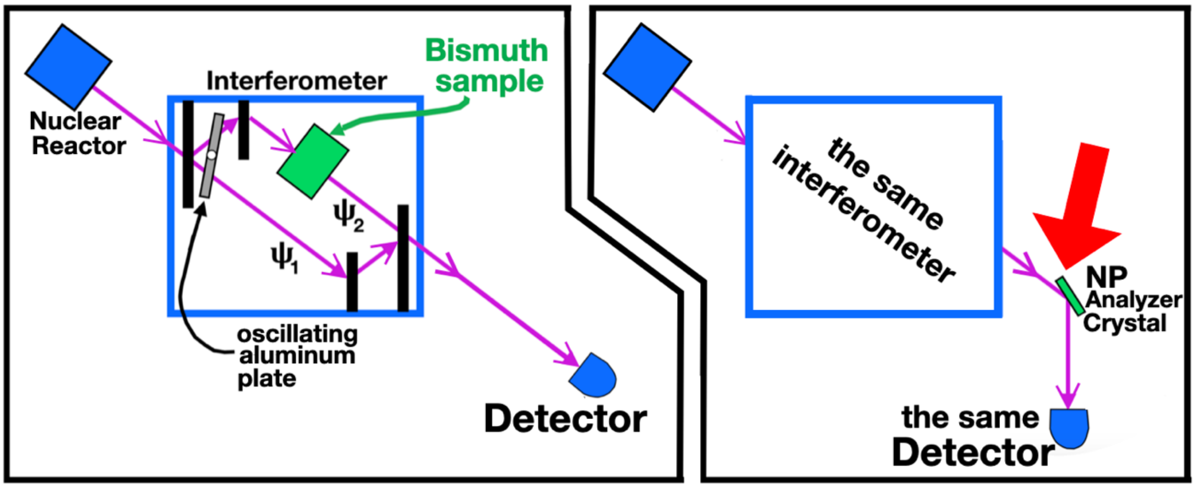


Fig. 23. A perfect-silicon-crystal Neutron Interferometer (NI) with two arrangements of the detector. Left: an incoming beam of neutrons is divided by silicon blades (black) inside the NI into two beams (ψ_1 and ψ_2 are purple

arrows). An oscillating (±1°) aluminum plate induces a phase shift so when ψ_1 and ψ_2 are recombined, the ^3He detector records a sinusoidal curve. A sample of bismuth of varying thickness is inserted (green), slowing ψ_2 but not ψ_1. When they are recombined, interference diminishes (flattening sine waves, measured as decreasing relative contrast). Right: A "nearly-perfect" (NP) silicon-crystal is inserted (red arrow) outside and downstream.

The NP Analyzer Crystal is placed in the 111 anti-parallel position, Bragg angle $\theta_A = -22°$ full width at half maximum, mosaic width $\eta_A = 0.00015$ rad.

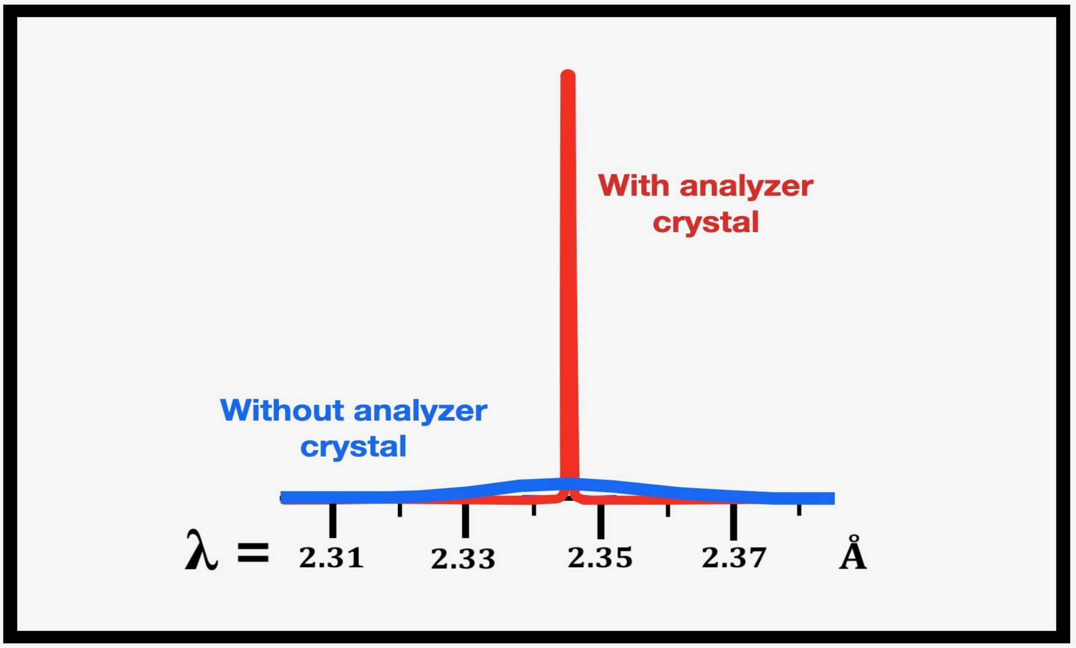


Fig. 24. The wavelength of the beam of neutrons is focused by the NP Analyzer Crystal. The variance narrows and Gaussian heightens. (Data from Table 1 top and bottom rows, p. 36 of Kaiser)

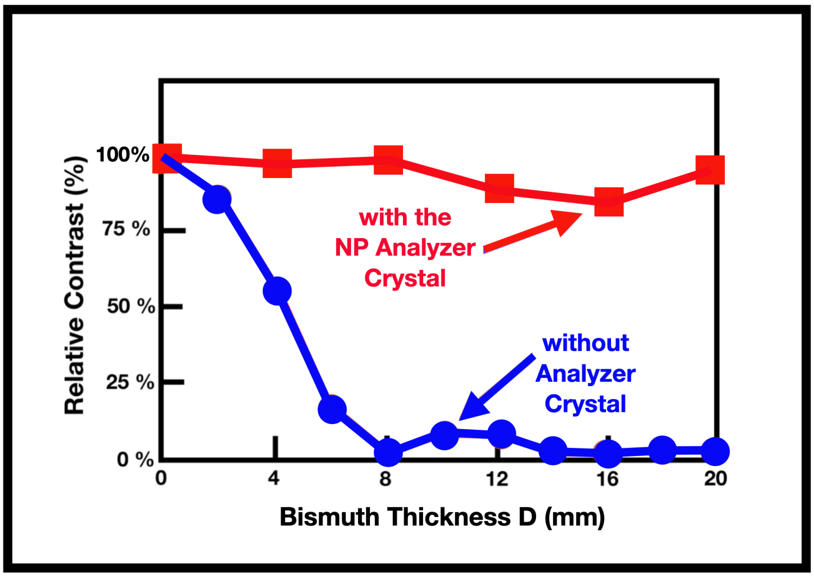


Fig. 25. This graph compares the height of wave interference if the NP Analyzer Crystal is absent versus present. The blue curve shows that with an increasing thickness (D) of bismuth across the horizontal axis, the sine waves representing wave interference flatten out (Relative Contrast decreases on the vertical axis). The red curve shows that when an NP Analyzer Crystal is inserted downstream, robust interference is restored. (Data from Figure 9 top and bottom, from p. 40 of the article by Kaiser, et.al.)(24)

Somehow the NP Analyzer Crystal reinstates full-bodied interference even though it is downstream! The researchers say neither they nor QM can explain this.

The experiment presents astonishing results. Figure 26 (blue sinusoidal curves) shows the dampening effect of bismuth on the wave interference inside the interferometer. Figure 27 (red sinusoidal curves) shows that somehow, against all reason, the NP Analyzer crystal at the red arrow in Figure 23, restores robust wave interference (tall sine waves), as if the bismuth were invisible. Table 1 gives you statistics from the article, which say the same thing.

Table 1. Relative height of the interferogram **(% Relative Contrast)**

Bismuth width D	Without Analyzer Crystal	With NP Analyzer Crystal
$0.00\ mm$	100%	100%
$4.01\ mm$	$57.3 \pm 1.0\%$	$97.1 \pm 5.1\%$
$12.26\ mm$	$8.0 \pm 0.8\%$	$89.6 \pm 4.4\%$
$16.5\ mm$	$1.8 \pm 0.8\%$	$86.0 \pm 4.8\%$
$20.08\ mm$	$2.9 \pm 0.6\%$	$95.2 \pm 5.2\%$

(from Tables III & VI, pp.38-39)(28)

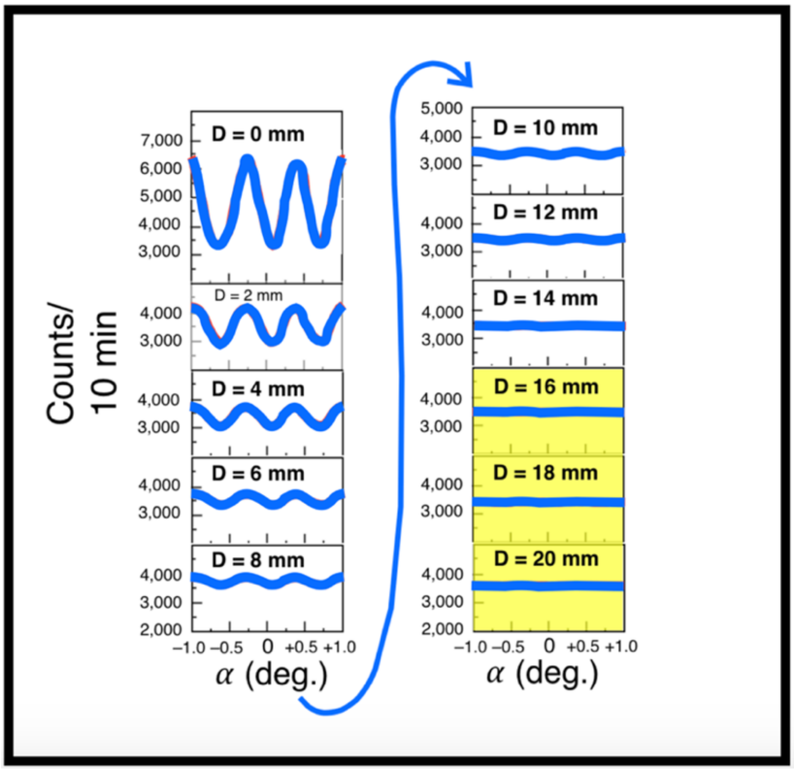


Fig. 26. This shows the interferograms with no Analyzer Crystal. We added the yellow highlight to call attention to the loss of Relative Contrast with enough bismuth. (Data from p.37, Figure 8, "Direct C2")(24)

When a Nearly Perfect (NP) Analyzer Crystal is inserted outside and downstream from the interferometer, robust interference is restored upstream, no matter how much bismuth is used. The experimenters say that neither they nor QM can explain these data.

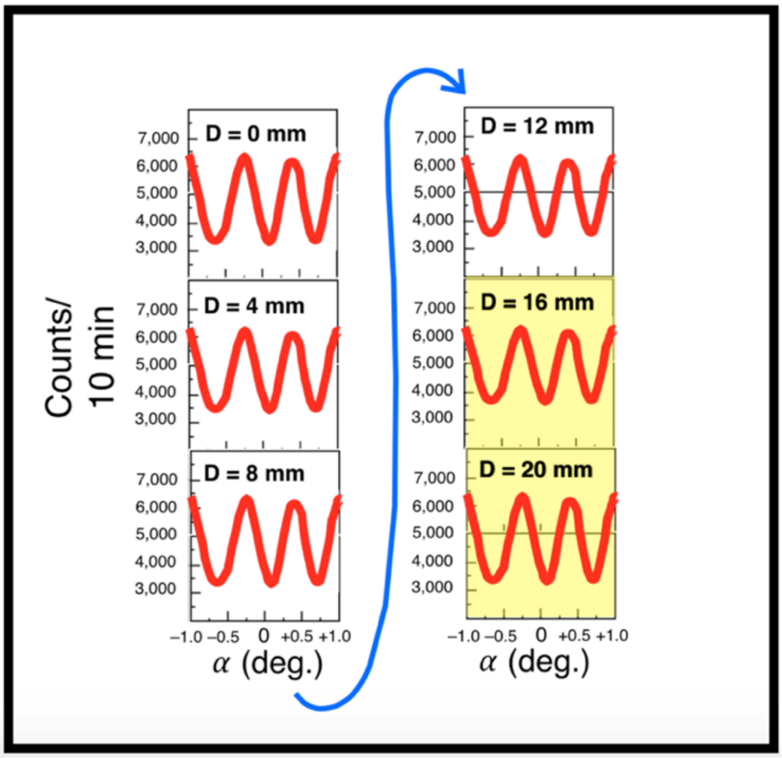


Fig. 27. This shows the robust interferograms after an NP Analyzer Crystal is inserted outside and downstream from the interferometer. This diagram is dramatically different from the preceding one. We added the yellow highlight to call attention to the robust interference, even with a maximum sample of 20 mm of bismuth. (Data from Figure 9 top and bottom, p. 40)

The only known explanation of this experiment is that zero-energy waves start at the detector, flow backwards through the interferometer into the nuclear reactor. Neutrons from disintegrating atoms then follow the waves backwards to the detector. The waves are traveling in the opposite direction as the neutrons.

It is obvious **why** the bismuth would appear to become almost invisible. The NP Analyzer Crystal increases the coherence length of a wave-packet from 86.2 Å to 3450 Å. A maximum sample of bismuth only delays a wave-packet by 435 Å.

It has now been three decades since this experiment was published. During that time there has been one and only one explanation of these data, namely the TEW explanation just stated.

An Elementary Wave is defined as a zero-energy wave which a quantum particle follows backwards. As we said, wave equations and path integral equations for how this could happen have been published by us elsewhere. These are very peculiar waves that are apparently everywhere in space traveling at lightspeed in all directions.

7. Double-Slit Experiments

Just as TEW is the only available explanation of that neutron interferometer experiment, TEW is also the only coherent explanation of complementarity in double-slit experiments. Richard Feynman says double-slit experiments contain the "central mystery of QM." TEW is the only known way to make these experiments non-mysterious.

Complementarity means: if we observe which slit a particle went through then the wave pattern on the target screen vanishes.

Why would an experiment produce different results depending on whether humans observe it? If the laws of nature are the same everywhere, then how can experimental results depend on the presence or absence of human observers? Nature has existed for 14 billion years and across billions of galaxies. It is exceedingly rare to have human observers. Nature behaves the same with or without observers. When we compare different theories of nature, QM requires a human observer, while TEW does not. (10-11)

We will show that TEW can explain complementarity based on mathematical rules alone. First we will teach you the unfamiliar way that TEW conceptualizes double slit experiments, then state a rule of partial differential equations (**PDEs**) that explains some of the behavior of Elementary Waves, and then we will show that the **PDE** rule explains complementarity without any need for "observers."

According to TEW, zero-energy waves travel from each point **Z** of the target screen (detector), travel backwards through the two slits, to the particle gun, whereupon a particle randomly selects one-and-only-one to follow backwards with a probability of one, going through one-and-only-one slit (it doesn't matter which slit) and inevitably striking that point **Z** from which its Elementary Wave continues to flow. Figure 28 shows the first half of this process.

Each point on the target screen emanates zero-energy Elementary Waves of all frequencies in all directions. We ignore most of them because they don't interact with physical reality. We restrict our attention to waves with a frequency corresponding to the de Broglie frequency of the particle that will soon be emitted. After passing backwards through the two slits, the waves coming from **Z** through slit **A** interfere with those coming from **Z** through slit **B** (see Figure 28).

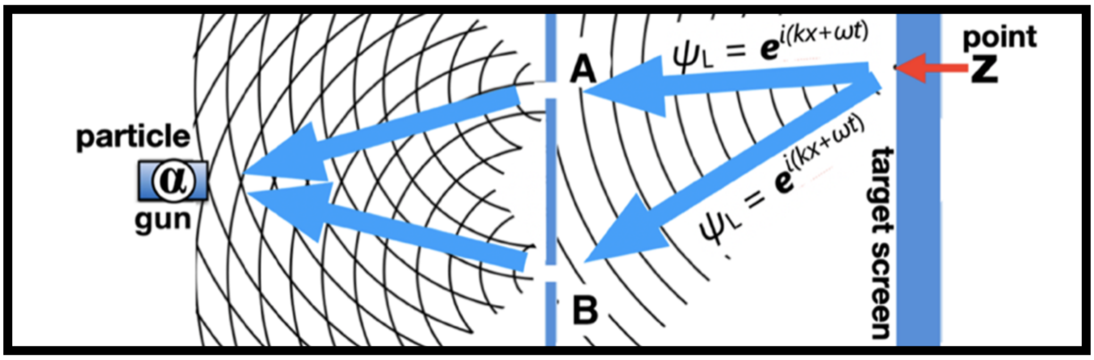


Fig. 28. Each point **Z** on the target screen (right) in a double-slit experiment, emanates Elementary Waves that pass backwards through the two slits (**A** and **B**) interfering as they approach the particle gun on the left. The interference affects the amplitude of the wave striking the gun, which affects the probability that particle ***α*** will select that incoming wave, to follow backwards.

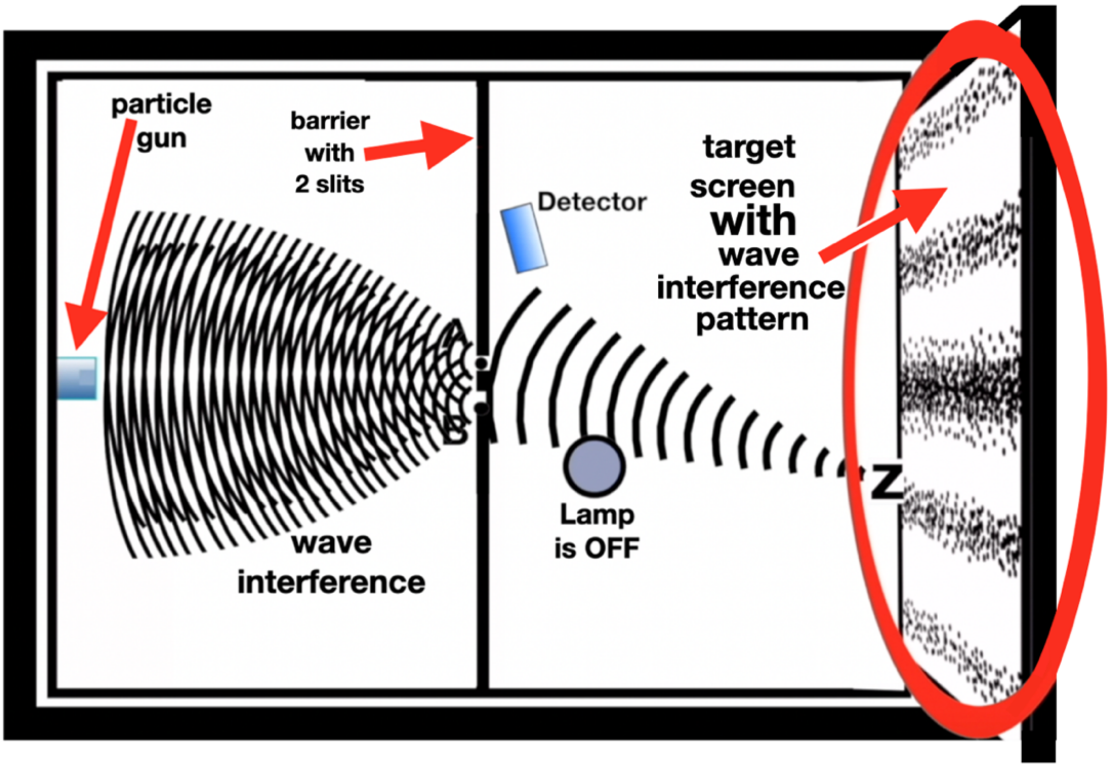


Fig. 29. When a particle ***α*** in the gun makes its random choice, this turns into a deterministic experiment. After leaving the gun ***α*** follows one-and-only-one wave backwards, going through one-and-only-one slit (it doesn't matter which slit) and inevitably strikes that point **Z** on the target screen from which that specific Elementary Wave comes. For this reason, the interference of waves in proximity to the gun indirectly creates the wave pattern on the target screen. We present the math in other articles. (10-11)

The particle ***α*** in the gun sees a zillion in-coming Elementary Waves, one from each point on the target screen. At random ***α*** chooses one-and-only-one wave to follow backwards. That choice constitutes wave-function-collapse. The experiment changes from probabilistic to deterministic as the particle leaves the gun. This is different from what you've been taught in the past.

Thomas Young said in 1801 that the relevant wave interference is that which occurred in proximity to his living room wall. We disagree. We say the important wave interference is on the proximate side of the double slit barrier. The pattern on the target screen is produced indirectly by that.

We are going to repeat ourselves. The important paragraph is the one that reads, "According to TEW, zero-energy waves travel from each point **Z** of the target screen (detector), backwards through the two slits, to the particle gun (see Figure 28), whereupon a particle randomly selects one-and-only-one incident wave to follow backwards with a probability of one, going through one-and-only-one slit (it doesn't matter which slit) and inevitably striking that point **Z** from which its Elementary Wave continues to flow."

This is hard to understand because it is a different way of thinking. That's what makes TEW enjoyable. This is a self-consistent explanation of why the wave interference near the particle source is the origin of the wave pattern on the target screen, in contradiction to Thomas Young's 1801 explanation. We have given the equations elsewhere that prove that this mechanism creates the same wave pattern that you expect. (10, 11)

7.1 Complementarity Explained

Complementarity is caused by mathematical rules that are stated in the next two sentences, not by human observation. The linear partial differential equations (**PDE**s) in this experiment can be added together if and only if they originate from the same point **Z** on the target screen. **PDE**s from two different points (like $\mathbf{Z_1}$ and $\mathbf{Z_2}$) cannot add together.

To discover which slit a particle uses, researchers insert a lamp and a detector (Figure 30). The energy from the lamp is infinitely more than the zero-energy of the Elementary Waves passing through the lamplight. It changes the Elementary Waves, so they forget that they originated at point **Z**. If subjected to lamplight, the waves traveling through slit **A** act as if they originate at slit **A**. Waves passing backwards through slit **B** act as if they originate at slit **B**. Since the waves act as if they had different points of origin, therefore their PDEs cannot add together. Therefore, there is no wave interference.

To reiterate: lamplight causes there to be no wave interference near the gun, because the lamplight has a detrimental effect on the zero-energy Elementary Waves, causing them to forget their point of origin. The waves through slits **A** and **B** now act as if they had different points of origin (**A** and **B**). Therefore, according to the **PDE** rules, those waves can no longer be added together.

To summarize: If-and-only-if there is interference in proximity to the photon source, will the target screen display a wave interference fringe pattern. This is evident in Figures 29 and 30.

In Figure 29 the Lamp is OFF, and therefore the Elementary Waves from point **Z** through slit **A** add into a superposition with those from **Z** through slit **B**, because of the **PDE** rules. But when we compare that to Figure 30, we discover what happens when we turn the lamp ON. The small amount of energy from the lamp is infinitely more than the zero-energy waves traveling through the lamplight. That energy modifies the Elementary Waves, making them forget their birthplace.

Therefore, in Figure 30 the **PDE** rules cause the target screen to act differently. The Elementary Waves from point **Z** through slit **A** no longer add into a superposition with those from **Z** through slit **B**. Why? Because of the poisonous effect of the lamplight the waves traveling through slit **A** believe they were born at slit **A** and are not siblings of the waves traveling through slit **B**, which believe they were born at slit **B**. We apologize for the repetition here, but many readers have trouble following our logic.

When we study the **PDE** rules, it says that waves can be added together if and only if they originate from the same point of origin. **PDE**s from two different points of origin (like **A** and **B**) cannot add together. Therefore, there is no wave interference in proximity to the particle gun, as shown in the next picture. And that lack of interference indirectly causes the target screen to show no wave interference. In other words, the target screen accurately tells us what is happening inside the experiment.

To put it crudely, QM tells us that if we know which slit was used, then the target screen tells a lie and says there was no wave interference. In general TEW says that detectors always tell the truth. If the detector says that there was, or was not wave interference, then that means there was or was not wave interference. Detectors don't try to deceive us.

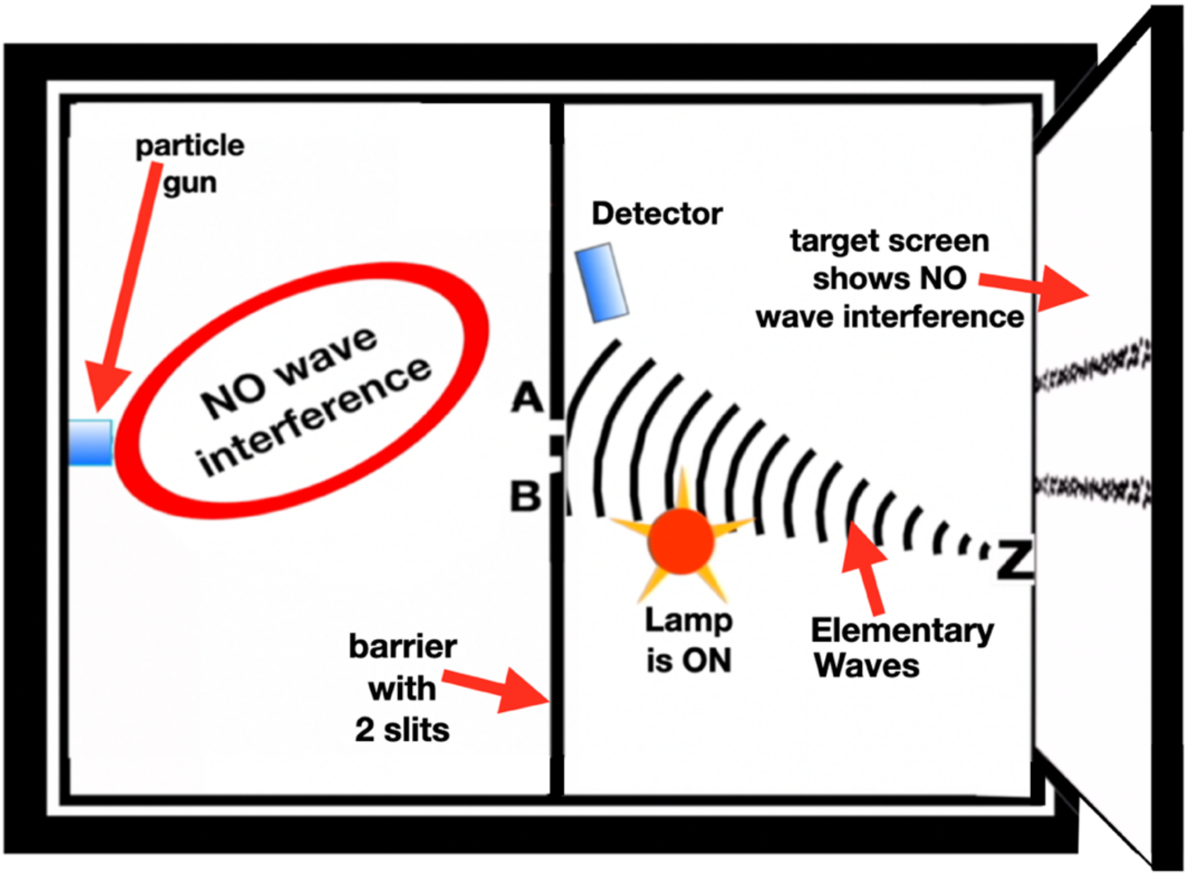


Fig. 30. Elementary Waves from point **Z** do not interfere after passing backwards through the two slits because the energy from the lamp modifies them. The wave through **A** acts as if it originated at **A**. The other as if it originated at **B**. Because of the **PDE** rules they do not interfere. The absence of wave interference in proximity to the gun indirectly causes an absence of a wave pattern on the target screen.

The last two figures explain "Complementarity" without needing to invoke human observers. We have explained Complementarity by means of mathematical rules governing the **PDE** rules governing Elementary Waves.

Elsewhere we show that Robert Pfleegor and Leonard Mandel, using a variant of a double-slit experiment, disprove wave-particle duality. We also demonstrate elsewhere the math that shows how our explanation of the double-slit experiment will reproduce the expected wave-interference-fringe pattern on the target-screen. (10,11)

8. Bell-Test Experiments

We will now briefly explain how TEW accounts for the mathematics of Bell test experiments. This description focuses only on the simple Bell test experiments such as described by CHSH. We do not discuss any of the elegant "loophole-closing" experiments of the past fifty years. Our description makes it clear that we disagree with Einstein's view of reality, and therefore the fifty years of "loophole-closing" experiments is not relevant to TEW.

As we said, TEW says there are zero-energy Elementary Waves everywhere in space, carrying no energy, traveling at lightspeed in all directions and at all frequencies. Most of these waves do not interact with physical nature. This worldview is assumed in the TEW explanation of double-slit experiments. (10-11)

That implies that every Elementary Ray has a mate, namely an identical ray that is coaxial, traveling at lightspeed in the opposite direction. This combination is called a Bi-Ray. Photons can follow such a Bi-Ray. Our explanation of the Bell test experiments is that entangled photons each follow the same Bi-Ray in opposite directions, as shown in Figures 31 and 32.

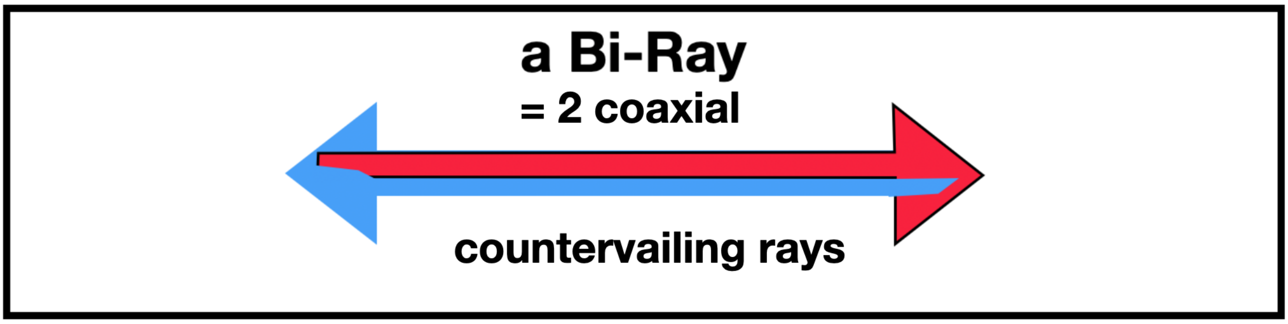


Fig. 31. A Bi-Ray is two coaxial, countervailing Elementary Rays.

A Bi-Ray spans from Alice to Bob. A pair of entangled photons is emitted into the center by a 2-photon source.

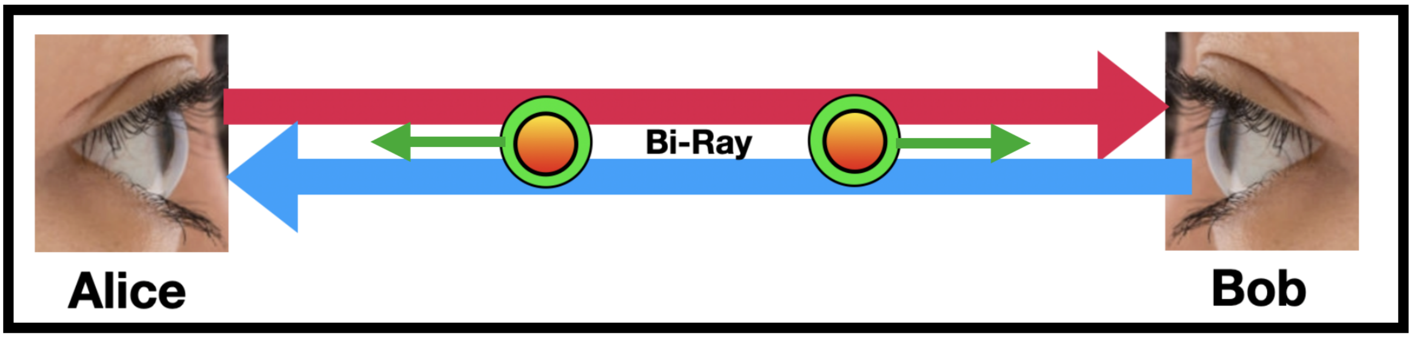


Fig. 32. A 2-photon source (not shown) emits a pair of entangled photons into a Bi-Ray.

5.1 Mathematics of the Bell-Test Experiments

Only two assumptions are needed for TEW to explain the Bell test experiment results. First, what makes the countervailing Elementary Rays coherent is a photon following both rays. Second, the probability of each photon following a Bi-Ray is the amplitude of it following one ray times the amplitude of it following the countervailing ray.

Based on the equations we are about to derive, we will show that the probability for Alice and Bob both seeing a photon simultaneously is $P = \cos^2 (\varphi_2 - \varphi_1)$ or $P = \sin^2 (\varphi_2 - \varphi_1)$, where "*P*" means "probability." In the Bell test experiment literature, they call the metric "coincidence rate" instead of *P*.

The difference between cosine and sine in the final data depends on what technology is used to generate two entangled photons. For example, in Alain Aspect's experiment they used a calcium cascade source to generate 2-photons with the same polarization, and therefore the coincidence rate they discovered was $P = \cos^2 (\varphi_2 - \varphi_1)$. If Aspect had used a different source (such as a BBO crystal) that generated photons orthogonal to one another, then his coincidence rate would have been $P = \sin^2 (\varphi_2 - \varphi_1)$.

One experiment (from the University of Innsbruck) found a coincidence rate of $\sin^2 (\theta + x)$, where the variable "x" varied depending on the time of the day, as the temperature of their equipment changed. The variable $\theta = \varphi_2 - \varphi_1$. That entire family of sinusoidal squared curves violates Bell's inequality.

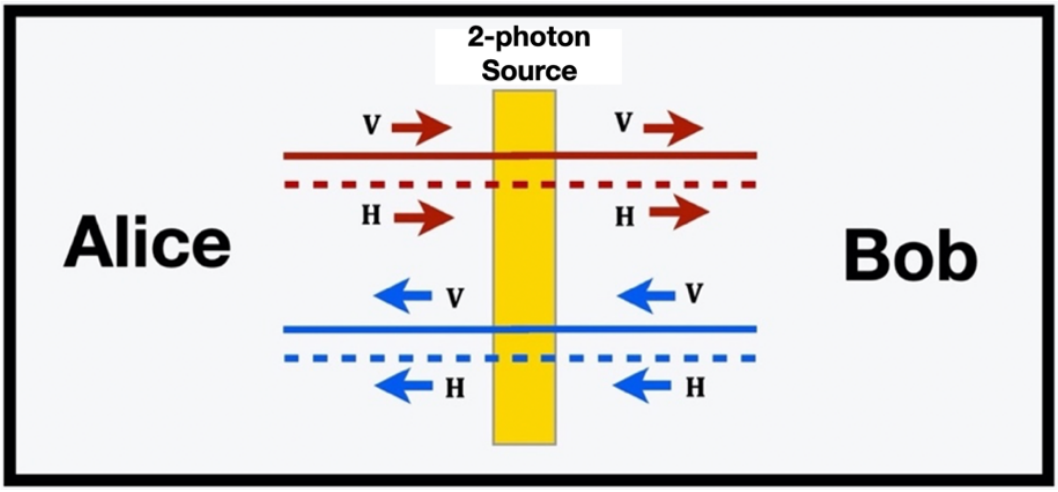


Fig. 33. Using vertical (solid lines) and horizontal (dashed lines) eigenstates of elementary waves, we re-draw Figures 31 and 32. We will use red to denote an elementary ray travelling to the right, and blue for one travelling to the left. These are eigenstates of the individual Elementary Rays, not Bi-Rays.

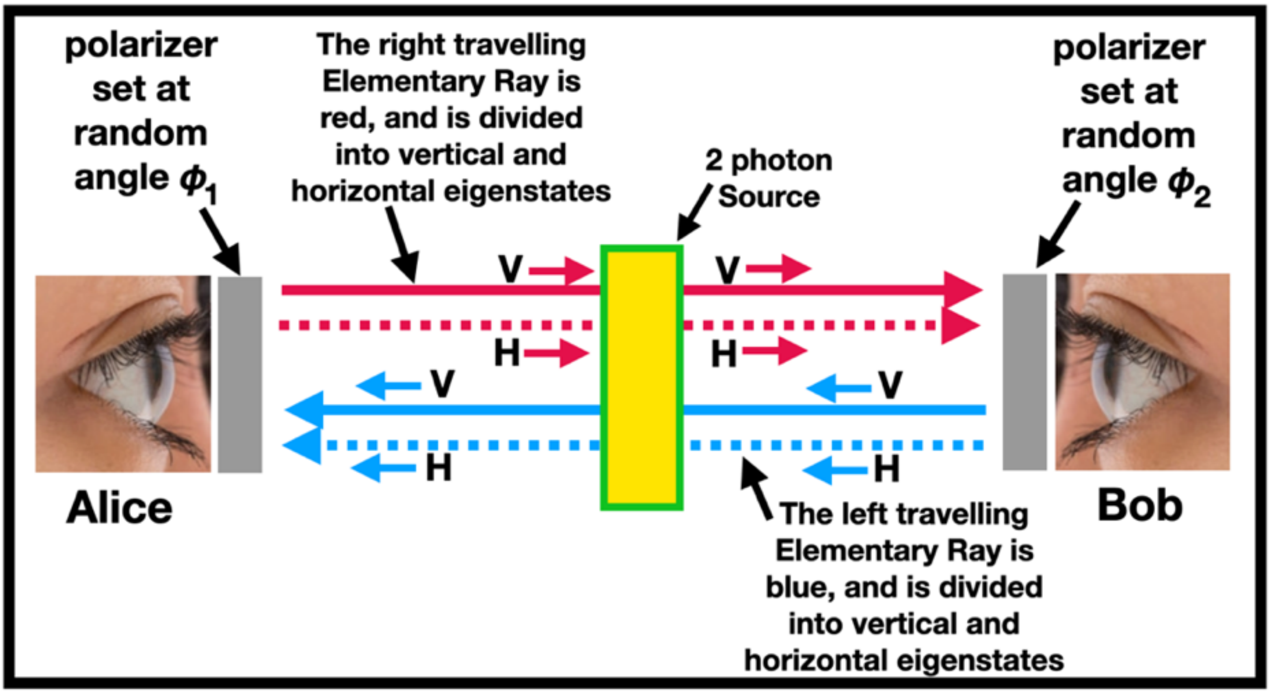


Fig. 34. This elaborates the previous Figure. Each photon follows both Elementary Rays, i.e., each photon follows all the red and all the blue arrows. Notice that the vertical and horizontal eigenstates (V, H, V and H) of the four Elementary Rays, are different than the eigenstates of the Bi-Rays, which we will name (***α***, ***β***, ***γ*** and ***δ***) in the next Figure.

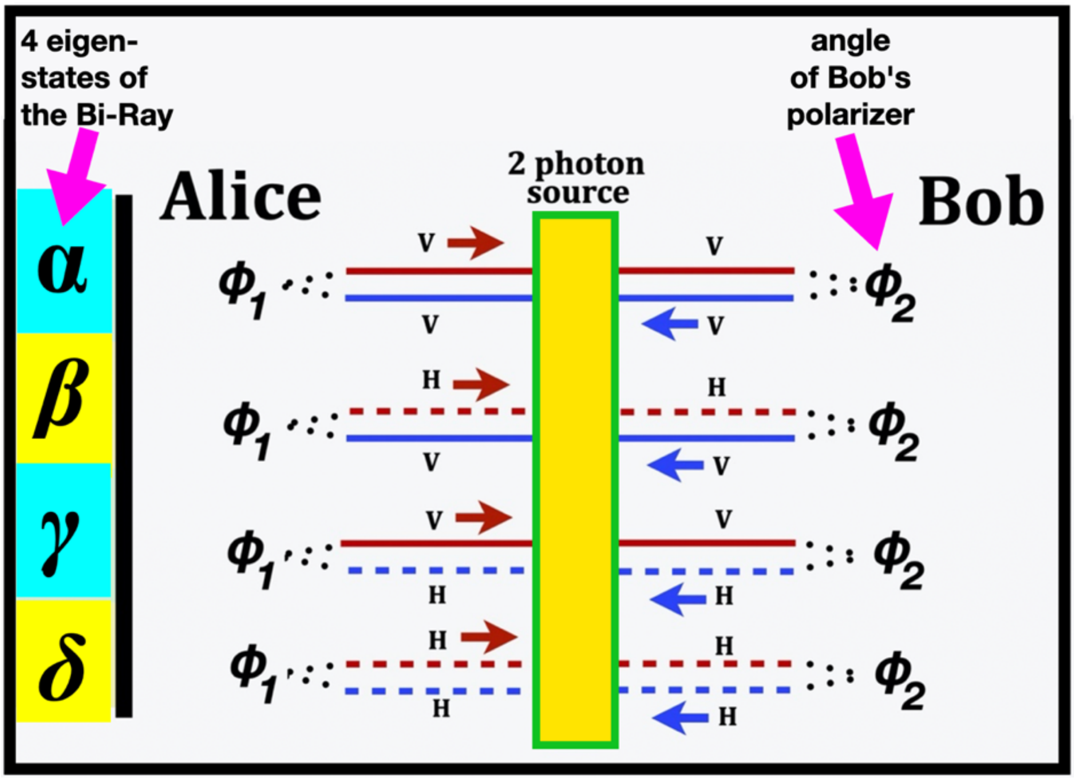


Fig. 35. We define four new eigenstates (α, β, γ and δ) of the Bi-Ray between Alice (whose polarizer is set at random angle Φ_1) and Bob (polarizer set at Φ_2).

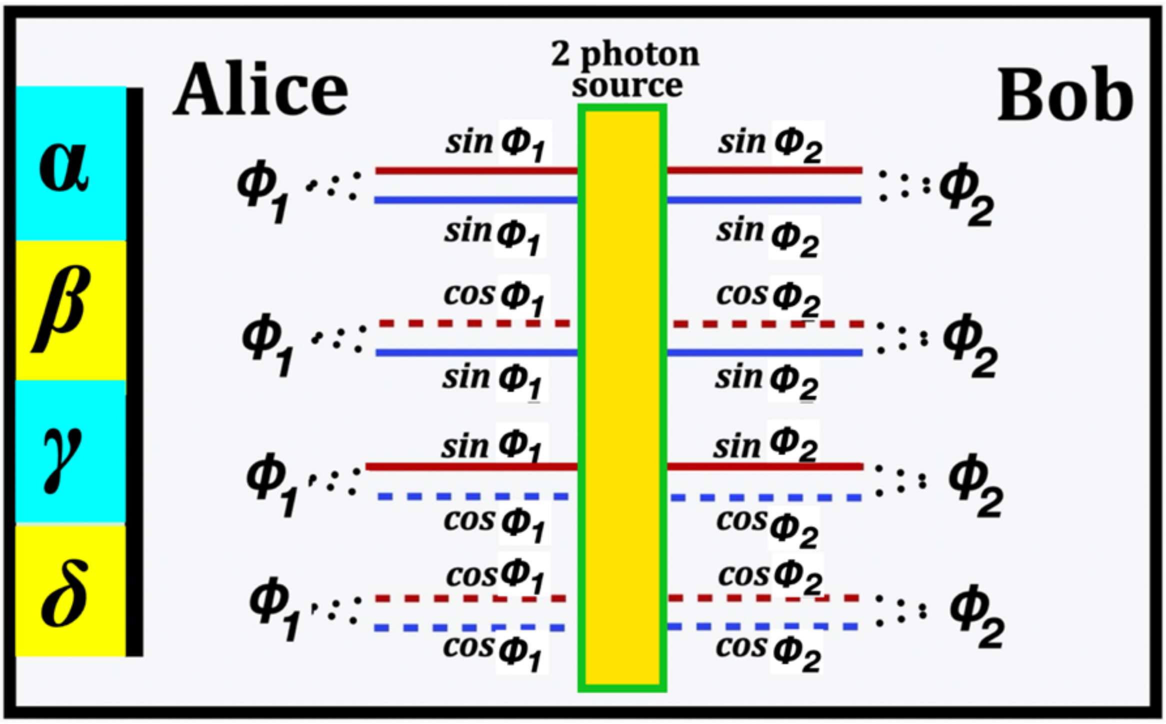


Fig. 36. These sines and cosines show the amplitude for a photon from the source being detected by Alice or Bob in a specific eigenstate. The diagram implicitly shows that Alice and her equipment never know anything about Bob's photon, nor about Bob's equipment, and vice-versa.

The probability of both Alice and Bob simultaneously seeing a photon (the so-called "coincidence rate") in the ***α eigenstate*** is the probability of Alice seeing a photon (*sin*(Φ_1) *sin*(Φ_1)) ***times*** the probability of Bob seeing a photon (*sin*(Φ_2) *sin*(Φ_2)). This provides the first line of the next equation:

$$P = \sin(\phi_1)\ \sin(\phi_1)\ \overset{\text{location of the 2-photon Source}}{\mathrm{x}}\ \sin(\phi_2)\ \sin(\phi_2)\ \ldots$$

To find the probability of Alice and Bob simultaneously seeing a photon we add together the probability in each of the four of the eigenstates (***α, β, γ*** and ***δ***) in Figure 36:

$$\begin{aligned}P &= \sin(\Phi_1)\ \sin(\Phi_1)\ \mathrm{x}\ \sin(\Phi_2)\ \sin(\Phi_2) \leftarrow (\text{within eigenstate } \alpha)\\ &+ \cos(\Phi_1)\ \sin(\Phi_1)\ \mathrm{x}\ \cos(\Phi_2)\ \sin(\Phi_2) \leftarrow (\text{within eigenstate } \beta)\\ &+ \sin(\Phi_1)\ \cos(\Phi_1)\ \mathrm{x}\ \sin(\Phi_2)\ \cos(\Phi_2) \leftarrow (\text{within eigenstate } \gamma)\\ &+ \cos(\Phi_1)\ \cos(\Phi_1)\ \mathrm{x}\ \cos(\Phi_2)\ \cos(\Phi_2) \leftarrow (\text{within eigenstate } \delta)\end{aligned} \tag{10}$$

When we add those four lines together, the result can be factored:

$$\begin{aligned}&= [\sin(\Phi_1)\ \sin(\Phi_2) + \cos(\Phi_1)\ \cos(\Phi_2)]\\ &\mathrm{x}\ [\sin(\Phi_1)\ \sin(\Phi_2) + \cos(\Phi_1)\ \cos(\Phi_2)]\end{aligned} \tag{11}$$

There is a trigonometry relationship that allows us to compress that into:

$$= \cos(\Phi_2 - \Phi_1)\ \mathrm{x}\ \cos(\Phi_1 - \Phi_1) \tag{12}$$

$$= \cos^2(\Phi_2 - \Phi_1) \tag{13}$$

This is how TEW accounts for the Bell test data. Our prediction is that the coincidence rate will be $P = \cos^2(\Phi_2 - \Phi_1)$. If the 2-photon-Source were changed so it emitted photons orthogonal to one another, then the final coincidence rate would be

$$P = \sin^2(\Phi_2 - \Phi_1). \tag{14}$$

Wave-function collapse (which is located at the 2-photon source and consists of entangled photons attaching themselves to the same Bi-Ray) occurs as the photons are emitted, not when the photons are measured by Alice and Bob. Nothing interesting happens upon measurement. Elsewhere we show that **when** you start the stopwatch timing a Bell test experiment, has a surprising impact on whether you believe that entanglement travels through space at superluminal speeds. Our conclusion is that entanglement is limited by the speed of light. (10-11)

5.2 Quantum Entanglement, Communication, and Networking

Our goal in the discussion of Bell test experiments was to show that the theory of bi-rays is capable of generating the kind of equations that Bell test experiments yield. That means that the TEW approach is compatible with the growing field of quantum communications and networking.

Bell states are the backbone of quantum communication and networking.

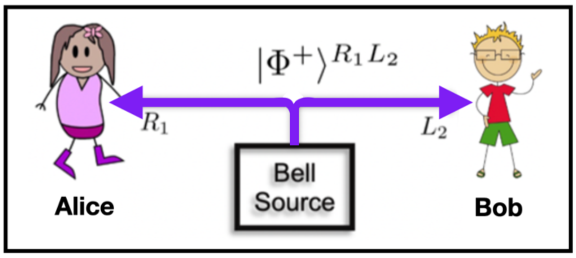


Fig. 37. Alice and Bob establish entangled communication using the four Bell states.

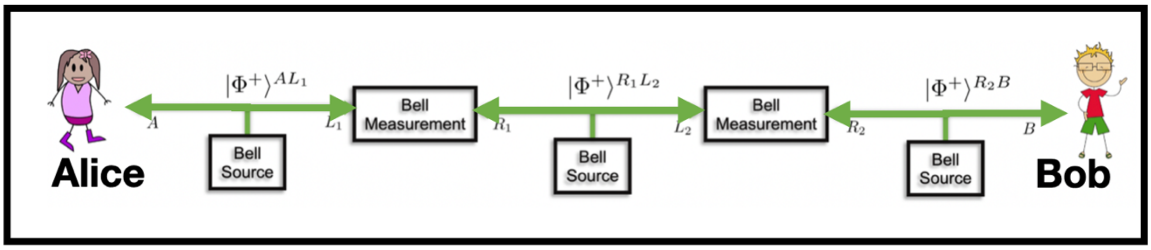


Fig. 38. **Long-distance** entanglement using a network linked by entanglement swapping.

We have demonstrated that TEW provides a foundation for the technology of quantum networking, communication, and cryptography. Such networks have already been established across hundreds of kilometers, and Micius—a low-orbit Chinese satellite with quantum capabilities—lays the groundwork for a satellite-based quantum communication spanning thousands of kilometers.

9. Other Experiments Supporting TEW

As we said, elsewhere we have published a review of other experiments that are erroneously said to "prove" wave-particle duality. As we said before, the mountain of experimental evidence supporting TEW is taller than the mountain that allegedly "proves" wave-particle duality. Here are some of the experiments that support the TEW approach: the Davisson-Germer experiment, a neutron-interferometer, quantum-eraser, Wheeler *gedanken*, and double-slit experiments, optics experiments, Bell-test experiments, Stern-Gerlach, and several high-energy scattering experiments. (10-11) The Periodic Table of the 118 elements is also compatible with TEW. (12)

10. Conclusion

Thomas Kuhn said, in his book *Structure of Scientific Revolutions*, that every paradigm shift faces the same obstacle, which is that scientists trained in the old paradigm consider the new idea to be unintelligible gibberish. (25)

Many people say that TEW is unintelligible gibberish. They say zero-energy waves cannot accomplish anything, because they have no energy. Even Einstein said that. Scientists today also say that particles and waves must travel in the same direction, not opposite directions. Furthermore this theory does not come from leading universities, nor from Nobel prize winners. It comes from the periphery, from beyond the horizon, from an outsider.

In the history of science paradigm shifts make no sense. If they made sense, they would not be paradigm shifts. They may not be logical, but they explain empirical data that cannot otherwise be explained. TEW, for example, can explain quantum circuits in a way that is more congruent with the pattern of programmers' thinking, and can explain the Kaiser neutron interferometer data that QM cannot explain. There is, after all, at least one experiment that QM cannot explain, and that is a decisive issue.

The struggle of paradigm shifting ideas is illustrated by the history of the idea of "continental drift" in the twentieth century.

10.1 The History of Plate Tectonics

In 1911 Alfred Wegener was the first to publish the idea that there had once been a continent that he named Pangaea, derived from Ancient Greek pan (πᾶν, "all, entire, whole") and Gaia or Gaea (Γαῖα, "Mother Earth, land"). Pangaea split apart. The fragments drifted to become the continents we know today. His idea of "continental drift" was rejected on the grounds that it was not logical.

In those days no one knew much about the seafloor. They called the bottom of the ocean the "dark abyss." They didn't know there were mountains down there. It was clear to every geologist and to all thinking people that there was no force on earth powerful enough to move continents. The assumption was that the flat ocean floor was covered with sand, and the idea of continents "plowing through the sand" made no sense. Pangaea was as illogical and preposterous in 1911 as TEW appears to be today.

Wegener could not explain how and why the continents would drift. He was dismissed as a fool.

Wegener's Pangaea was denounced, rejected since it was clearly not part of science. Pangaea was not mentioned in textbooks during the first half of the twentieth century.

Arthur Holmes invented the idea of "seafloor spreading" in the 1930's, but that idea was dismissed since there was almost no evidence for such an absurd idea.

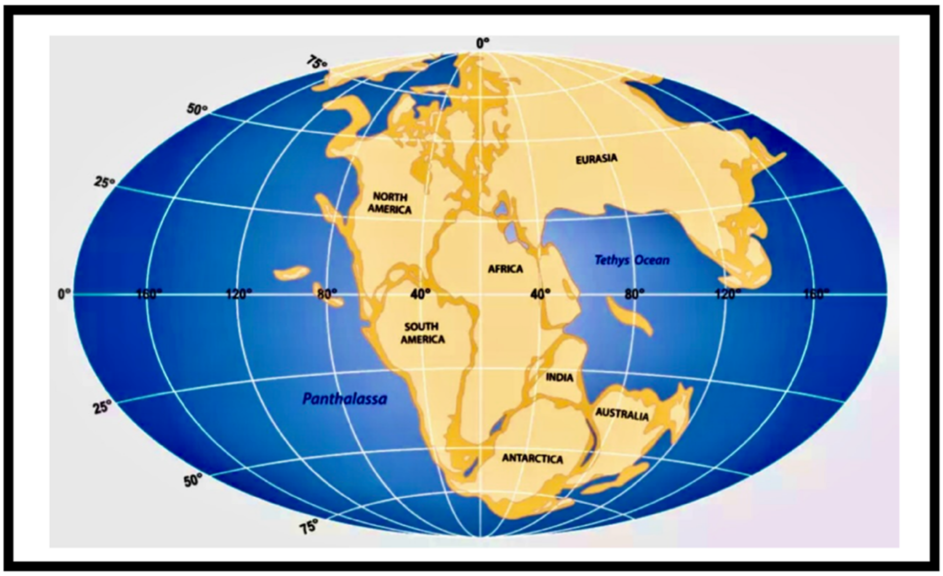


Fig. 39. Pangaea, an idea first published by Alfred Wegener in 1911 in his book, *Origin of Continents and Oceans*. Just as scientists tell us that TEW is unintelligible nonsense, so also scientists told Wegener that Pangaea was unintelligible nonsense, they said, there is no force strong enough to move continents.

The tipping point came from submarine warfare during World War II. Sonar allowed sailors to see beneath the surface of the waves for the first time. The leading Princeton geologist Harry H. Hess became captain of a US Navy attack transport ship named the USS Cape Johnson, equipped with sonar. He discovered the mid-Atlantic ridge in 1946. He remained active in the Naval Reserve after the war, and reached the rank of Rear Admiral. In 1959 Hess theorized that Holmes was correct, the seafloor was spreading. He wrote, "molten rock (magma) oozes up from the Earth's interior along the mid-oceanic ridges, creating new seafloor that spreads away from the active ridge crest and, eventually, sinks into the deep oceanic trenches." The force moving continents was convection currents of the magma. We've all seen boiling water come to the top of a pot in the center, then sink down along the edges. Hess said that same process was occurring in the molten magma beneath our continents, and the magma flows were carrying along continents floating on the surface. (21, 35)

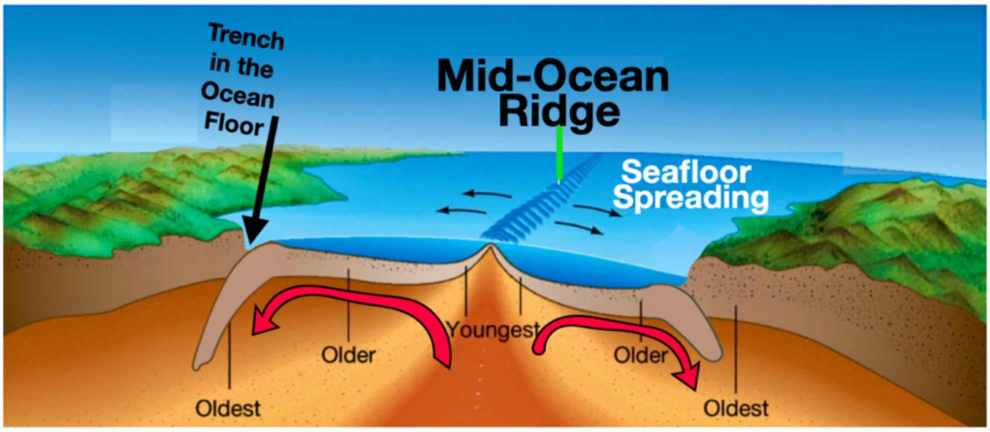


Fig. 40. Hess' theory of seafloor spreading caused by magma convection currents. This theory also explained ocean floor trenches such as the one found next to Chile on western South America.

Inspired by the idea of seafloor spreading, other geologists discovered zebra stripe-like magnetic patterns embedded in the rocks on the Pacific Ocean floor. The earth's magnetic poles reverse directions from time to time, and the direction of magnetism is recorded in the molten magma, then locked in place in the seafloor rock as it cools. In Figure 42 you can see that they graphed the magnetism of the seafloor basalt around the East Pacific Rise in a 1963 publication. (36)

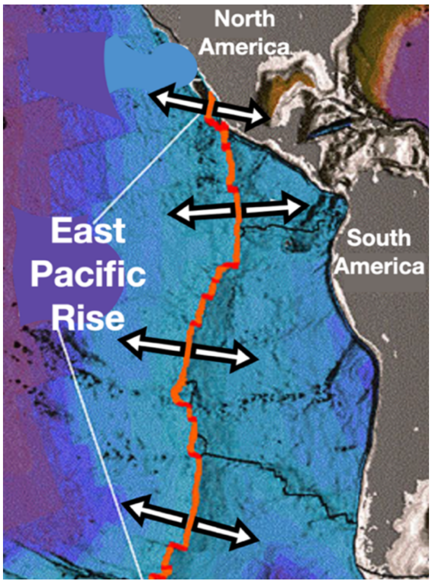


Fig. 41. East Pacific Rise is the upwelling of magma that creates new seafloor. It causes the seafloor trench besides Chile where the Pacific plate slides underneath the Andes Mountains.

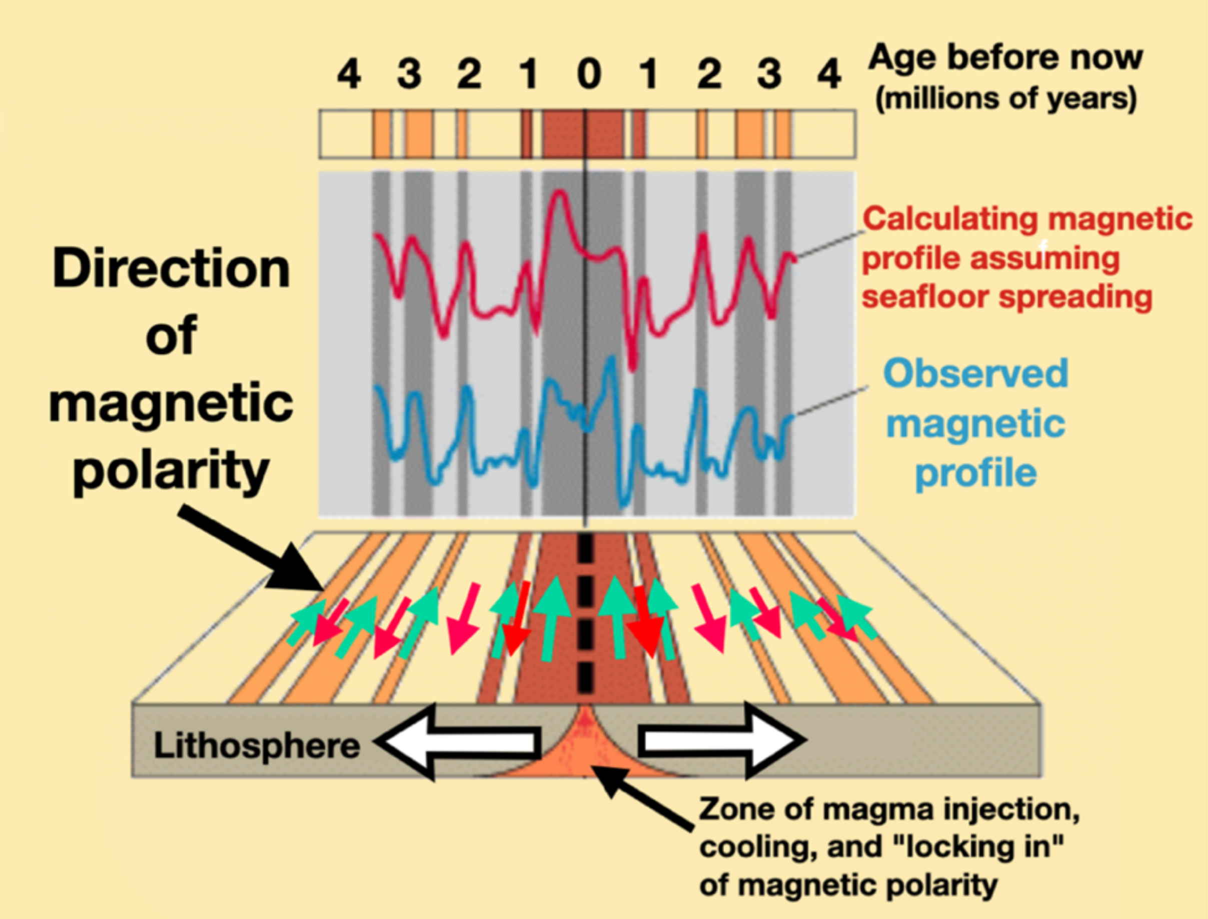


Fig. 42. Magnetic stripes symmetrical around the East Pacific Rise, caused by periodic reversals of the earth's magnetic poles. This confirmed seafloor spreading and therefore it initiated plate tectonics.

If you think about the earth from the viewpoint of everyone prior to 1960, plate tectonics made no sense whatsoever. Since science is ruled by logic, plate tectonics was not welcome in the sciences any more than TEW is welcome today.

10.2 Is a Qubit a Particle?

Whether TEW is valid or not is not the only issue. More important is to ask whether it helps programmers think better. Furthermore, our theory solves a difficult problem, which is that not enough young STEM students are attracted to quantum computer science, because they find it opaque and not engaging.

That means there is an advantage to assigning students to study a weird and dissenting theory like TEW. Students love renegade theories that debunk orthodoxy. TEW makes quantum information less daunting, less tedious, and more interesting. Students tend to love sci-fi, and TEW has a sci-fi-like quality even though it is not sci-fi. One way to use this article is to assign it to STEM students, and say, “Prove that this idea is wrong!”

Here is an example of the kind of issue this article might provoke for your students. Consider the question, **“What is a qubit?”**

Is it a quantum particle?

Probably not.

A qubit and a Bloch sphere are abstractions that are useful ways of symbolizing what happens inside a computer. But a qubit is not a particle in the real world. A qubit, for example, might be countervailing flows of quasi-particles after a photon breaks a Cooper pair inside a Josephson junction, which electrical engineers have harnessed to influence other Josephson junctions.

Like the IBM chip, the Google AI chip must be maintained at almost absolute zero (–273° Celsius) to utilize superconductivity. The IBM chip and Google chip are available in the cloud. This author has programmed and used an IBM quantum processor but not a Google processor.

Our point is that a qubit is not a particle, and in fact it is a fuzzy concept that differs in different circuitry. For example, a Canadian company named D-Wave uses an approach to qubits unlike others. D-Wave uses quantum annealing, in which the system begins in the lowest-energy eigenstate of the initial Hamiltonian. And there are dozens of different architectures for what a qubit is, almost none of them picturing a qubit as being a quantum particle moving through a circuit.

Among the companies offering different architectures for qubits are Quantuum, D-Wave, Google A.I., Rigetti, Psiquantum, Coldquanta, Ionq, Pasqal, Quera, Silicon Quantum Computing, Ust (of China), Alibaba Quantum Laboratory, Amazon, Raytheon BBN, Intel, Northrop Grumman, Xanadu, Orca Computing, Alpine Quantum Technologies, Oxford Ionics, Qsout, International Iberian Nanotech Lab, and dozens of others, not counting startups whose names we have not yet heard.

The question “What is a qubit?” is like asking why we use language. We use language because it helps organize our thinking and facilitates communication with other people. Language sometimes refers to real things. Sometimes it doesn’t. Take, for example, a transmon inside a computer. Transmons are not particles, but the absence of a particle (like a vacancy in a sea of electrons). Transmons are valuable in quantum circuits because they are less vulnerable to environmental noise.

If a qubit is not actually a quantum particle, then we can ask what it means to say that the wavefunction inside a quantum computer moves in the same direction as, or in the countervailing direction as the “shots” moving through a circuit. Does it make any difference which way they travel, given that everyone agrees that quantum computers are reversible?

We claim that Elementary Waves are already present before the qubits arrive, like sheet music already present on the stands of different musicians in an orchestra.

We propose a test for what is the most useful way of thinking about quantum circuits: what theoretical contraption is most compatible with the simulator embedded in the imagination of programmers? In other words, what is a productive way to think? What would help programmers think better? We claim that the TEW view of quantum circuits is closer to the subjective reality of programmers, than is the conventional wisdom about how circuits work. It is comfortable. QM theory of quantum circuits is like a shoe that doesn’t quite fit.

11. Author Biography

The author has an undergraduate degree in mathematics from Brown University, and training in Quantum Science, Networking, and Communications from the University of Chicago. He is a member of IEEE. During his decade working at the National Institutes of Health (NIH) in Bethesda, Maryland USA, he programmed the IBM mainframe for a computerized study involving 18,000 subjects assessed on three different occasions. The author had a compiler for a computer language named “SAS” embedded in his brain and wrote a manual for use inside NIH about how to program SAS. Boyd published more than two-dozen scholarly articles on TEW in the *Journals of Advances in Mathematics, Physics, and Chemistry* during the years 2011-2022. Boyd has also received advanced degrees, with diplomas from Harvard University, Yale University and Case Western Reserve University. He had a long and productive medical career serving at a Yale teaching hospital.

Fig. 43. The author, Dr. Jeffrey H. Boyd.

Conflict of Interest: The author has no conflict of interest about anything in this article.

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