

Chapter 17

“Teleportation”



Credit – Rose is Rose: “Deceptive Checkup” (need permission)

Ok, so we can't use a single EPR pair to send superluminal signals – Eberhard's impossibility proof holds. What *can* be done with a single EPR pair?

Let Alice and Bob share an EPR pair

$$\Psi_{12} = \frac{1}{\sqrt{2}} \{ |H\rangle_1 |V\rangle_2 - |V\rangle_1 |H\rangle_2 \} \quad (1)$$

Alice is also in possession of a qubit she wishes to share with Bob.

$$\Psi_3 = \{\alpha|0\rangle_3 + \beta|1\rangle_3\} \quad (2)$$

However, any attempt on her part to measure this qubit risks collapsing it into an eigenstate of whichever basis she used for the measurement. Unless it is already in such an eigenstate, its state will be destroyed upon a simple measurement.

So instead of using either the orthogonal basis (H & V) or the angled basis (D & S) she does something clever, she makes a joint measurement in the Bell basis.

$$\begin{aligned} |\Phi^+\rangle_{AB} &= \frac{1}{\sqrt{2}}\{|0\rangle_A \otimes |0\rangle_B + |1\rangle_A \otimes |1\rangle_B\} \\ |\Psi^+\rangle_{AB} &= \frac{1}{\sqrt{2}}\{|0\rangle_A \otimes |1\rangle_B + |1\rangle_A \otimes |0\rangle_B\} \\ |\Psi^-\rangle_{AB} &= \frac{1}{\sqrt{2}}\{|0\rangle_A \otimes |1\rangle_B - |1\rangle_A \otimes |0\rangle_B\} \\ |\Phi^-\rangle_{AB} &= \frac{1}{\sqrt{2}}\{|0\rangle_A \otimes |0\rangle_B - |1\rangle_A \otimes |1\rangle_B\} \end{aligned} \quad (3)$$

Instead of measuring one photon, she measures two, one of which is the one she wished to convey to Bob, the other is her half of the EPR pair she shares with Bob.

Since she is measuring two particles at once, she has four possible outcomes. She then shares these two bits of information with Bob via a classical communication channel. It is the use of this classical channel that limits the communication to sub-light speeds.

Once in possession of the two classical bits, Bob has four possible transformations he can perform on his entangled photon. After that transformation, Bob's photon (#2) has exactly the same state as Alice's (#3). She doesn't even have to know what the real state of photon 3 was, but Bob now has a faithful copy of it.

So, this isn't material teleportation in the sci-fi sense, photon 3 was not transported from Alice to Bob, but rather information teleportation.

Science has extended this to atoms, to distances in the hundred kilometer range over fiber, air, and vacuum. They have even teleported entanglement itself, doable if Alice and Bob share two EPR entanglements. The permutations abound and progress has been steady. These quantum manipulations are the foundation for quantum computing.

But no FTL.

Except, that some of the information went over a quantum channel, and according to quantum orthodoxy, this part of the communication was *instantaneous*. Nature is jealously keeping anything superluminal exclusively to herself. We are cut off.

Unless we can find a loophole.