2: Teleportation Through the Wormhole - Susskind, Zhao

The characters in this *gedanken* story are Alice, Bob, Charlie and Eve.

Charlie produces two identical bits of information, with the rule that both the bits are either 0 or 1. Let's call these bits **A** and **B** respectively.

Charlie hands over **A** and **B** to Alice and Bob respectively. He then asks them to go far apart, and they obey readily.

Now Alice has another bit **T** in addition to **A**, which she wishes to send to Bob. So she sends a message through some communication channel. If the message says *same*, Bob retains the state of **B** and if it says *different*, he flips the state. Hence, Bob always ends up with **B** in the configuration same as that of **T**.

But Eve wants to know what **T** is. She tries to intercept the communication. But since the message only says *same* or *different*, she cannot have any information about the state of **T**. But she has ways and means. She can try to coax Charlie, and extract from his memory the configuration of the bits he had created. Even if Charlie's memory had been erased, the information in his brain has been emitted into the environment (maybe as gravitational radiation ..., you get the gist). Hence, Eve could *in principle* detect that information.

So much for classical information.

$$|0\rangle_A|0\rangle_B + |1\rangle_A|1\rangle_B$$

This in the entangled state of qubits that Charlie produced. Again, he hands over **A** and **B** to Alice and Bob respectively. Alice has **T** which has the state

$$|\Phi\rangle_T \equiv \Phi(0)|0\rangle_T + \Phi(1)|1\rangle_T$$

.

The two qubits that Alice has is a linear combination any one of the following (Bell Basis) :-

$$\begin{aligned} |1\rangle &= |00\rangle + |11\rangle \\ |x\rangle &= |10\rangle + |01\rangle \\ |y\rangle &= |10\rangle - |01\rangle \\ |z\rangle &= |00\rangle - |11\rangle \end{aligned} \tag{2.0.1}$$

Measurement gives Alice one of the outcomes $(1, x, y, z)$. She writes this up and sends it to Bob, who applies the corresponding operator on his qubit. Hence, his qubit is always

$$|\Phi\rangle_B \equiv \Phi(0)|0\rangle_B + \Phi(1)|1\rangle_B$$

ie. the same as **T**.

But, can Eve intercept the message and find out about **T**? No! Bell's basis states are maximally entangled. Entanglement is monogamous, in the sense that if **A** and **B** are maximally entangled. they *cannot* be correlated with any other factors - Charlie's brain, gravitational radiation, or anything else.

But if one believes ER = EPR, then these maximally entangled EPR pairs should be connected by a microscopic Einstein-Rosen bridge.