To: *C. M. Caves*
From: *C. M. Caves*
Subject: **Comment on "Quantum entanglement and the nonexistence of superluminal signals" by M. D. Westmoreland and B. Schumacher** (`arXiv.org e-print quant-ph/9801014`)
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This paper shows, as the abstract says, that "ordinary quantum mechanics is not consistent with the superluminal transmission of classical information." The way the authors get at the conclusion is to show that if there were superluminal transmission of classical information, then quantum teleportation could be used to clone a quantum state, at least for some period of time in some reference frames. Since the no-cloning theorem is a consequence of ordinary quantum mechanics (i.e., linear, unitary evolution), they conclude that superluminal communication is inconsistent with ordinary quantum mechanics. I don't have any trouble with the conclusion, but relying on the no-cloning theorem to reach the conclusion seems to me to be very problematic.

The stage is set for teleportation by having Alice and Bob share an EPR pair and having Alice possess a third quantum system C in an arbitrary quantum state. As the authors say, teleportation consists of the two events:

I. Alice makes a joint measurement on A and C in the "Bell basis" and communicates the (classical) result of the measurement to Bob.
II. Bob receives the message from Alice and performs a conditional unitary operation on his half of the EPR pair.

Everything being done right, the result is that the arbitrary quantum state of C is transferred to B. The authors' argument really consists of two parts:

1. If event II precedes event I, then in the interval between II and I, there are two copies of the arbitrary state, one at C and one at B.
2. If there is superluminal communication of classical information, then there are references frames in which II precedes I.

Since ordinary quantum mechanics prohibits cloning, the conclusion is that superluminal communication of classical information is inconsistent with ordinary quantum mechanics.

The weakness of this argument, it seems to me, is how no-cloning gets into the picture. Having event II precede event I is by its very nature inconsistent with ordinary quantum mechanics. Ordinary quantum mechanics is simply unable to handle a situation in which the results of a measurement are used to perform operations before the measurement is made; in other words, ordinary quantum mechanics can't assign a state to A, B, and C during the interval between II and I. So how does one know that there are two copies of the arbitrary quantum state during this interval? It seems to me that one could avoid cloning altogether by saying that ordinary quantum mechanics, of which no-cloning is one consequence, is inconsistent with having II precede I and, therefore, superluminal communication of classical information is inconsistent with ordinary quantum mechanics.

One can try to do better by guessing what sort of statistical predictions would apply to the interval between II and I. Suppose that during this interval one measures the spin component of C along some axis. After the measurement, C is projected into the state corresponding to the measurement result. This post-measurement state is teleported from Alice to Bob. Thus B is left in this same state after event II, which precedes the measurement. A measurement of the same spin component on B during the interval between II and I yields the same result as the measurement on C. Since the axis was arbitrary in this discussion, one concludes that measurements of the same spin components on C and B during the interval between II and I have perfectly correlated results. This perfect correlation is nothing like what one would get by assuming that C and B are both in the original arbitrary quantum state during the interval between II and I. Indeed, there is *no* quantum state that is consistent with this perfect correlation (the spin singlet has perfectly anti-correlated results). It seems to me that this traditional "killing-your- grandmother" type of argument is more convincing than the authors' cloning argument, and it shows that the inconsistency between ordinary quantum mechanics and superluminal communication has nothing special to do with cloning.