Comment on the incompatibility of the relativity of simultaneity with superluminal signalling*

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Abstract

Westmoreland and Schumacher (quant-ph/9801014) argue that standard models of quantum mechanics are not consistent with the superluminal transmission of classical information. In their argument, they show that it is inconsistent to assume that quantum dynamics can apply in a reference frame in which classical information is received before it is transmitted. In this comment, I point out that it is actually inconsistent to assume that *any dynamics whatsoever* can apply in such a frame.

Introduction

In special relativity, the Lorentz transformation tells us how we should relate the space and time coordinates used in different uniformly moving reference frames. In particular, it defines which spatially separated events are simultaneous in a given frame, and so it defines what constitutes a set of simultaneous initial data in that frame.

Not all conceivable dynamical laws have simple transformation properties under the Lorentz transformation. Here we will show that any dynamics which allows the transmission and use of superluminal signals cannot be transformed at all into some Lorentz frames—in particular, into frames in which the causal order of some events is reversed. Our argument will be informational: the simultaneous initial data in such a disallowed frame is missing some information that was present in the original frame. If some initial data is missing in a frame, no dynamics whatsoever acting on incomplete data can reproduce the same set of events that occur in the space-time history of the original frame.

This observation is related to the recent note by Westmoreland and Schumacher (quant-ph/9801014), in which they point out that if there are superluminal signals, quantum mechanics can't operate in some frames. This is in fact just a particular instance of the general impossibility for any dynamics.

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An example

We will specify initial data in one particular Lorentz frame, and then discuss what simultaneous initial data is available in another frame.

Consider the following Gedanken experiment. At a particular time, we specify that the universe we're imagining is empty except for a mechanism sitting at the origin that can store a message, and some superluminal signal that contains a message heading towards the origin. The storage mechanism initially holds a blank message. A dynamics is specified which can evolve our initial data in time. Going forward, this dynamics causes the signal to reach the origin and be stored in the mechanism there. We'll assume that this dynamics is invertible, so that we can fill out the entire space-time history of this universe: going backwards from our initial data, the storage mechanism remains blank, and the signal recedes from the origin.

Since the signal is traveling faster than light, we can choose another Lorentz frame in which the signal first interacts with the storage mechanism, and subsequently travels away through space. In this frame, all slices of simultaneous initial-data that correspond to moments before the mechanism "emits" the signal have no intersection with the signal at all: the signal is not present in these slices. Thus it is not possible to reproduce the same time history that we saw in the original frame starting from initial data on such a slice. No dynamics whatsoever can make the message appear in the storage device when it isn't present in the initial data.

Information processing

Consider an information processing system in which some communication paths involve superluminal signalling. For simplicity, let's assume that there is just one such superluminal communication path (SCP). Suppose that in our original frame each bit in the system is specified independently. In particular, as one bit enters the SCP, a distinct bit that entered earlier leaves it.

Now consider the frame in which the SCP is instantaneous. The bit entering and the bit leaving are now the same: there is thus at least one bit of information that is missing from our state in this frame. If the SCP is faster than instantaneous, then the situation is even worse: the last few bits that have come out are bits that have not yet entered at the other end, and so several bits in our system contain redundant data. Thus there are several bits of missing data. We can therefore conclude that the dynamics in this second frame can't, in general, reproduce the processing history (suitably transformed) that we would have seen in the original frame.

Conclusion

For any dynamics that allows the superluminal transmission and subsequent processing of information, it is not possible to transform the dynamics into a Lorentz frame in which the causality of any of the superluminal signals is reversed.