Outline of an Experiment to test Retrocausal versus Superluminal Interpretations of a Digital Protocol over a Quantum Channel

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Abstract

There is an interpretation of Quantum Mechanics gaining ground that had its roots in Feynman-Wheeler absorber theory, which has lead to the Watanabe Two-state vector /Cramer Transactional-Interpretation/ /Sutherland viewpoint of Retrocausality. It seems that fantastical notions of superluminal effects are to be abhorred for equally fantastical notions of retrocausality. Noting that physics is the science of natural philosophy, we add to the argument with an outline of an experiment to settle the matter, by a blocking protocol where future actions would be limited by actions in the past (and hence the future) or not at all if the hypothesis is false.

1. Introduction

Physics wishes to be causal; it probably has to be for anything to be said to be "understood". Through the synthesis of classical physics and quantum mechanics, physics explains itself by wave equations – energy (photons or force carriers) as well as matter (leptons and quarks). These equations, of course, relate differential changes in space and time to the potential of interest defining the phenomena; propagation through space occurs at a definite speed, with an ultimate limiting speed of light. The general feature of these equations is their 2nd order nature permitting two solutions, one going forward in time, the other backwards. This feature and the reversibility of classical mechanics (classical electromagnetism[1] too) but with the preferential direction of time, was know but is slightly beyond the scope of this present discussion([2] in the conclusion).

Physics has embraced some apparent non-causality in the classical realm via statistical mechanics and chaotic dynamics. In the first instance this is understood as making probabilistic predictions to a system when all the microstates are not known; this was the flavour of classical thermodynamics anyway[3-4]. Latterly, chaotic dynamics[5] can show the *possibility* (or even the probability) of bizarre system behaviour but it would be hard to show direct causality from a set of state vectors, given the loss of information and the growth of computational errors when an un-integratable system is simulated. However it is entirely reasonable to see, despite this, that causal micro-processes underlie this at any instant in time.

Quantum mechanics introduces, perhaps, a fundamental non-causality via the measurement problem, though some believe this mystery to be another multi-body effect similar in spirit to statistical mechanics and thermodynamics via Decoherence Theory[6]. Perhaps then a quantum system of equations has an ansatz similar to a non-integratable Newtonian system, by which the issue of wavefunction collapse is then hopefully "washed away" with then the same problem of not being able to know all the microstates (of the measuring apparatus and the environment), presents quantum mechanical measurement as similar to a mean-field, statistical theory.

That thorny issue slightly aside, quantum mechanics throws another curved ball of entanglement from multi-particle systems, which is possibly an inevitable result of the quantum postulates (measurement applied to a system of particles constrained by conservation laws which is in an initially indeterminate state before measurement). Early on it was asked if such a phenomenon was faster than light and whether that made any sense[7]. Bell quizzed and answered in the affirmative[8] that the phenomenon could be real. Aspect et-al[9] proved experimentally beyond doubt that it was and Zbinden et-al[10] raised the intriguing fact that the a-posteriori correlations appeared to have occurred extremely quickly (at least 10,000c). The author[11] enquired if this phenomenon could be used to send information, with the author coming up with a disproof[12-13] of the No-communications Theorem[14-15] and a particularly simple experimental arrangement (appendix 1).

According to Relativity theory nothing can travel faster than the speed of light. What then is the interpretation of EPR type events or even the sending of data by such means? Some in the physics community, not wishing or even being able to contemplate Relativity failure, have come up with notions of Retrocausality (Wheeler-Feynman absorber theory, [16-18]). This may seem a metaphysical debate or even just a matter or opinion, science ought to provide an objective test of this. Figure 1 illustrates this debate on a space-time diagram. Two parties at rest in a frame (A and B) agree to send a signal. If the signal from A is superluminal (or nearly so) it is shown as a horizontal line. A speed of light signal is constrained to move on light cones which are 45 degree lines, clearly here, B can only receive a signal from the future self A'.

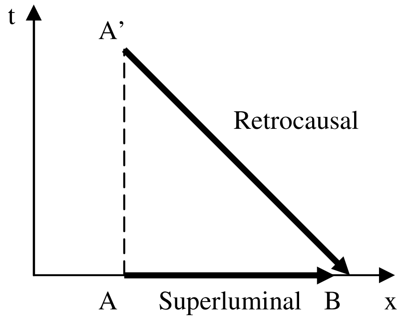

Figure 1 – Superluminal or Retrocausal?

2. A protocol to test between these alternatives

We shall set up a thought experiment where the parties, A and B, are initially together and aim to synchronise clocks by the following procedure: A and B synchronise clocks. A sets out slowly so that the minimal time resolution unit of the clocks is not affected by time dilation. A achieves a separation from B of many time units such that A is separated from B by a space-like interval. Accordingly, if A can message B by a superluminal signal, then A and B are both in the *absolute present* but such notions are meaningless in Relativity anyway.

A and B agree to perform an experiment several time units from when A initially set out and came to rest at a space-like interval from B. Their clocks are zeroed. The protocol for the experiment is that A will send a superluminal/retrocausal signal (by the apparatus in appendix 1, [11, 19]) to B at time zero (which B would receive at time zero), whilst B will choose to thwart the process by sending a conventional light-speed signal at time "minus one", which A on receipt, will then not send the superluminal signal at time zero (in its frame of reference). Figure 2 illustrates this.

3. Conclusion

The argument in figure 2 would hoist notions of relativistic non-simultaneity and non-absolute time (and then) retrocausality on their own petard. Essentially the light-speed limited "no-send" signal can't race a genuinely superluminal signal and the retrocausal light-speed limited signal argument would be bust. It only remains to do this experiment.

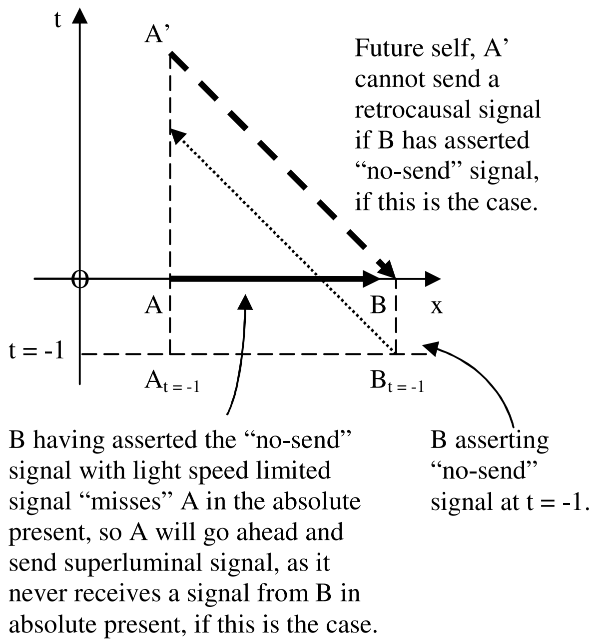

Figure 2 –Resolving the paradox

The author is of the opinion that EPR type signals are genuinely superluminal and not light-speed limited and retrocausal. This is based on the practically instantaneous a-posteriori correlations observed by Zbinden et-al[10]. The author believes that a radical re-think of space-time is required where relativistic effects are seen as emergent and simply based on the Doppler effect, time dilation and length contraction caused by mass gain by motion through a medium[20], such that the constancy of the speed of light is observed. This view is almost Galilean, with a universal frame at absolute rest and far from gravitating sources. Everything else in motion or in a gravity field is time dilated/length contracted by an underlying field that gives mass to particles. This can explain length contraction too (evanescent waves in the bound state will have mass, so bond lengths contract[20]) and even co-moving frames, whereby the underlying mass giving field can cause frames to be apparently receding by length contraction.

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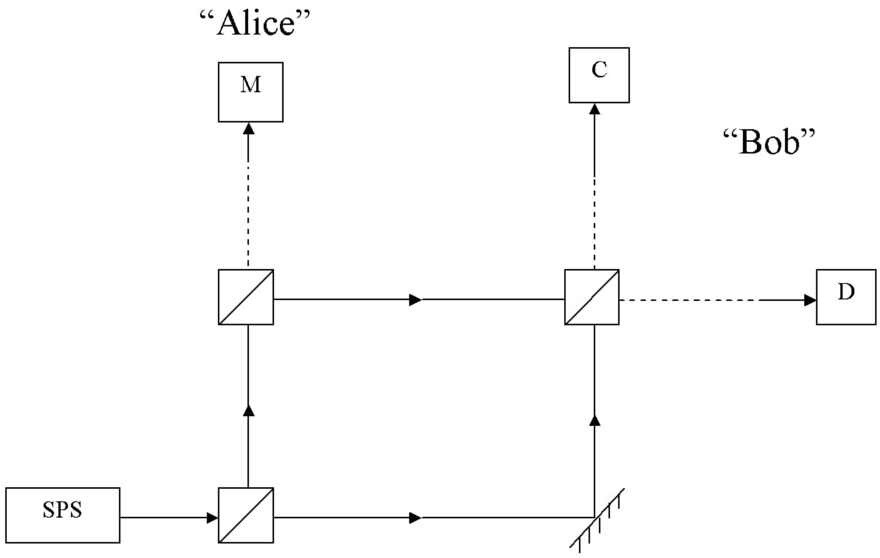
Appendix 1

A single photon source (SPS) is incident on a Mach-Zehnder type interferometer with 50:50 beamsplitters. Alice's measurements discerned over space-like separations by Bob at his detectors C (constructive) or D (destructive). Many single photons (a spot from a beam-expander is used with an attenuator on a laser source) are used to represent one bit.



This is the fundamental law of Quantum Mechanics:-

If the paths can be distinguished then add probabilities

else if the paths can't be, then add amplitudes before calculating probabilities

Thus when Alice measures, both of Bob's paths to his detectors become distinguishable.

Alice sends	Bob receives
Binary 0: No measurement	Binary 0: Min signal, destructive interference from pure state at D
Binary 1: Measurement	Binary 1: Max signal from mixed state at D

$$P\left(Bob\ few\ photons, binary\ 0 \,|\, Alice\ no\ measurement\right) = \left|\frac{i}{\sqrt{2}}\right|^2 + \left|\frac{e^{i\theta}}{\sqrt{4}}\right|^2 + 2\left|\frac{i}{\sqrt{2}}\right|\left|\frac{e^{i\theta}}{\sqrt{4}}\right|\cos\theta$$

$$= 0.5 + 0.25 + \frac{1}{\sqrt{2}}\cos\theta$$

$$\simeq 0.75 \pm 0.707\cos\theta$$

$$\simeq 0.043 \text{ minimum}$$

$$P\left(Bob\ lots\ of\ photons, binary\ 1 \,|\, Alice\ measurement\right) = \left|\frac{i}{\sqrt{2}}\right|^2 + \left|\frac{i}{\sqrt{4}}\right|^2$$

$$= 0.5 + 0.25$$

$$= 0.75$$