Bell's Theorem and Retrocausality

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Abstract

Bell's Theorem, which is of course true, is shown to be bypassed in a Bell experiment using retrocausality where antiparticles are travelling backwards in time.

Introduction

The version of retrocausality in this paper, that of antiparticles travelling backwards in time with backwards causation, is very limited in scope and does not apply to any macroscopic bodies and only to antimatter particles, for example, positrons. Also, antimatter is very sparse which makes retrocausality very limited. Antiparticles are generally believed **not** to travel backwards in time because of physics such as general relativity, and the properties of spin 2 gravitons, but in this paper they are assumed to travel backwards in time with backwards-in-time causation effects.

Results of Bell experiments which show that Bell's Theorem is contravened in the laboratory has led to speculations such as multiverses or instantaneous transmission of information via entangled particle pairs. Retrocausality is a solution to the problem of Bell's Theorem's and is a solution that counters the usual implication of nonlocality. Bell's Theorem is a major player in undermining belief in realism and locality in the quantum sphere.

Bell's Theorem

There is much written elsewhere about Bell's Theorem but this paper gives an alternative to the normal viewpoint and is based on retrocausality, or more specifically the backwards-in-time motion of antiparticles. Bell's Theorem is correct but, here, this different viewpoint dodges the Bell roadblock and bypasses the Bell's Inequalities by re-casting the physics of a Bell experiment and making it very different to what is normally assumed.

Appendix A of Ref. # 1 (Fearnley, 2017) shows two correlation coefficients, calculated in a computer simulation of a Bell experiment, on two paired sets of numbers. The first of the two paired sets has real number values lying between +1.0 and -1.0, that is, non-integer decimal numbers which cannot actually be measured in a real Bell experiment. The second of the paired sets has integer numbers which were obtained by rounding any decimal to the nearest integer, that is to either +1 or -1, which corresponds to allowable measurements in a Bell experiment. One million pairs of numbers were used in each calculation and the correlations were 0.499454164 (for integers) and 0.707258632 (for non-integer decimals). The first number (0.5) gives the absolute value of the empirical calculation of the classical limit of the correlation as is theoretically derived for Bell's Theorem. This correlation often appears as a value S = 4*0.5 = 2 in the CHSH statistic which is the maximum absolute (expectation) value of the correlation coefficient available under normal mathematical and macroscopic physics methods. This is to be expected as the measurements made in a Bell experiment can only take integer values (either +1 or -1).

A spooky element enters the scene as, in a real run of a Bell Experiment, the empirical (absolute) value of the correlation coefficient can reach 0.707, that is cos(45^o), which corresponds to the earlier calculation of 0.707258632 which was based on exact decimal values. This is a quasi-magical occurrence which is a main driver towards seemingly eccentric ideas such as instantaneous transmission of information/non-locality of particles/lack of reality on the microscopic scale/Everett's multiverse.

The lower correlation coefficient of 0.5 corresponds to an attenuated correlation. It is a lower correlation because, in the rounding of the exact decimal values, precision has been lost and this loss of precision means that there can no longer be the exact correlation of 0.707, that is, cos(45^o). It is unreal, or wishful thinking, to believe that one can lose precision in the values being correlated and yet still obtain an exact correlation as if there had been no loss of precision. Defeating Bell's Theorem empirically by obtaining the higher correlation (absolute) value is a quasi-magical effect which requires a re-evaluation of physical reality at the microscopic level. There must be some current understanding of physical nature on the microscopic level that needs to be revoked.

MALUS'S LAW

Computer simulations in Fearnley (Ref. #1, 2017) assumed that the particle hidden variables were generated as static vectors in random directions on a sphere/circle. This is a natural assumption for pairs of particles emitted at random from a source/oven in a simulation of a Bell's Theorem experiment, where the known condition is that particle spins must add to zero because of conservation of angular momentum within an emitted particle pair, with no other information available about spin vector directions. This randomness seems appropriate in a Bell's Theorem experiment as the measurements are all made on randomly polarised pairs of particles. That is, the joint spin vector axis for a pair of particles is simulated at random. As already noted in Ref. #1, static hidden variables in computer simulations did not lead to a breaking of the constraint of the Bell correlation coefficient size.

The next step was to test if this static picture accorded with Malus's Law. It was found in Fearnley (Ref. #2, 2019) that there was a theoretical duality between Bell and Malus calculations despite Malus's Law not taking randomised polarisations as input to its formula. Although Malus's Law does not meet the conditions of a Bell experiment, it did allow for an insight into the nature of hidden variables and a basis for future investigation of the Bell experiment.

A further step was taken in Fearnley (Ref. #3, 2020). In that paper a toy model was made of the physical properties of the hidden variable of a particle. That model was reverse engineered by differentiating Malus's equation to give intensities at specific angles, whereas Malus's Law gives cumulative intensity between the polarisation angle and any other angle. That is, say, the angle between a first and a second polarising filter. The Malus intensity, which is a two-hundred year old empirical law, falls away steeply as the angle increases. So the use of a static or constant hidden vector for a particle needed to be rejected.

Bell's Theorem assumes the particle pairs to be generated at random by a source or oven. This means that the beam of pairs is not a polarised beam. Malus's Law on the other hand requires that the beam to be measured is polarised, which is why Malus has no direct equivalence to a Bell experiment. Fortunately, Malus's Law shows that a polarised beam is more concentrated in the direction of polarisation than elsewhere.

One possible interpretation of the physical hidden variable is that the beam's polarisation angle or polarisation vector is a constant value which is merely the average value of the hidden variable vector, which varies over time as in gyroscopic precession. Say the polarisation average vector is in the |up> state, then the varying, precessing vector (or phase vector) [for the electron] varies over time and covers the whole upper hemisphere where |up> is pointing at the North pole. It points up more often than it points anywhere else.

Applying this model to a simulation of a Bell experiment unfortunately gave an absolute correlation of approximately 0.35. This disappointing finding was not reported in that paper. The constant polarisation vector model would have given the classical or saw-tooth correlation of 0.5. A Bell correlation of 0.707 was and is of course impossible in such simulations.

For a Bell experiment using antiparticles moving backwards in time and having backwards causation, the calculations needed to give the Bell correlation coefficient in a computer simulation are simply those using the 200-year old Intensity Law given by Malus as is seen below. The paper in Ref. #3 (2020) found the Bell correlation (absolute value) of 0.707 but the method shown used calculations on the toy model of variable phase vectors about a constant polarisation vector for an individual particle. Also, the Appendix to Ref. #3 gave a listing for a computer program to produce results for Malus's Law intensities using local hidden variables in a particle-at-a-time simulation.

In the sub-section below, the correlation coefficient of 0.707 has been obtained by the much simpler calculation taken direct from only the 200-year-old Malus's Law.

RETROCAUSALITY AND BELL'S THEOREM

Retrocausality allows Bell's Theorem to be circumvented in a Bell's Theorem experiment. This allows the experiment's outcome correlation to be higher (in absolute value) than the lower, classical correlation which is restricted by the Bell Inequalities

The retrocausal simulation starts with incoming antiparticles to detectors A (Alice's) and B (Bob's), which have detector angle settings of 0^0 and 45^0, respectively. Of the total number of antiparticles, Alice receives 50% and Bob receives 50% and they make measurements of +1 or – 1 per particle using Stern-Gerlach detectors. These incoming antiparticles are travelling backwards in time and have random polarisations but leave Alice and Bob as polarised particles with recorded measurements of either +1 or -1 in the lab book of measurement results where +1 indicates passing through the detector in accordance with the detector setting and -1 indicates passing through the detector at the opposite settings, namely: 180^0 and 135^0, respectively. The four outgoing polarised beams each contain 25% of the antiparticles making their intensities 0.25 of the total for later use in the Malus' Law calculations. This part of the simulation is illustrated in Figure A, with the antiparticles (positrons) travelling backwards in time.

FIGURE A First stage of a retrocausal Bell simulation. Where antiparticles travel backwards in time to the 'Source' from Alice and Bob

Thermodynamic arrow of time →
← time for antiparticles (positrons}

```
                                   ALICE
POLARISED 0⁰ - - - - - < - - - - - - - [[  A = +1  ]]   \
                                                          \  - - - - - - < - - - - - -   INCOMING RANDOM POLARISATION
                                                          /
POLARISED 180⁰  - - - - - < - - - - - [[  A = -1  ]]    /

                                    BOB
POLARISED 45⁰ - - - - - < - - - - - - - [[  B = +1  ]]  \
                                                          \  - - - - - - < - - - - - -   INCOMING RANDOM POLARISATION
                                                          /
POLARISED 135⁰  - - - - - < - - - - - [[  B = -1  ]]    /
```

[[ ]] is a measurement station and measurement result

The measurements in the first stage are on randomly polarised antiparticles and not on entangled particles. This fact is the reason why Bell's Theorem is by-passed in a retrocausal simulation.

The incoming (backwards in time) antiparticles or positrons from Alice [or Bob] give rise at the oven or source to the electrons travelling forwards in time to the other researcher, Bob [or Alice]. These electrons are flipped in polarisation angle by the oven to conserve total angular momentum. It is sometimes written that the positrons bounce back in time to become electrons, but that is not the case in this model as positrons never travel forwards in time and electrons never travel backwards in time.

The second stage of the simulation is illustrated in Figure B

FIGURE B **Second stage of a retrocausal Bell simulation. Where electrons travel forwards in time from the 'Source' to Alice and Bob**

Thermodynamic arrow of time →
Time for electrons → {partner particles = electrons}

BOB

(POSITRON SPIN REVERSED AND ENTANGLED) / [[B = -1]] - - - - - - - - > - - - - - - - - OUTGOING ELECTRON
ELECTRON POLARISED 180^0 - - - - - >- - - -/
(A=+1) \
\ [[B = +1]] - - - - - - - - > - - - - - - - - OUTGOING ELECTRON

BOB

(POSITRON SPIN REVERSED AND ENTANGLED) / [[B = +1]] - - - - - - - - > - - - - - - - - OUTGOING ELECTRON
ELECTRON POLARISED 0^0 - - - - - >- - --- -/
(A=-1) \
\ [[B = -1]] - - - - - - - - > - - - - - - - - OUTGOING ELECTRON

ALICE

(POSITRON SPIN REVERSED AND ENTANGLED) / [[A = -1]] - - - - - - - - > - - - - - - - - OUTGOING ELECTRON
ELECTRON POLARISED 135^0 - - - - - >- - - -/
(B=+1) \
\ [[A = +1]] - - - - - - - - > - - - - - - - - OUTGOING ELECTRON

ALICE

(POSITRON SPIN REVERSED AND ENTANGLED) / [[A = +1]] - - - - - - - - > - - - - - - - - OUTGOING ELECTRON
ELECTRON POLARISED 45^0 - - - - - >- --- -/
(B=-1) \
\ [[A = -1]] - - - - - - - - > - - - - - - - - OUTGOING ELECTRON

[[ ]]   is a measurement station and measurement result

The raw data of paired A and B values of +1 and -1 can be tabulated in a 2x2 table of outcomes. When the data are expressed as proportions, each row and column sums to 0.5 while the grand total is 1.0. This table has only one degree of freedom, so that knowing the value in one cell allows the values in the other three cells to be known automatically (See Table 1). There are four beams entering Figure B after leaving the oven/source so each beam has an initial intensity of 0.25. The detectors then split each beam into two more beams, so there are eight beam intensities to be calculated in the simulation. Say we take the cell which contains A = 1 and B = -1: there are two beams in this cell, one where A measures positrons and the other where A measures electrons.

A = +1 based on positrons with B = -1 based on electrons:
Intensity of beam, using Malus's Law, $= 0.5*\cos^2\{(180^0 - 135^0)/2\}$
$= 0.5*\cos^2(22.5^0)$
$= 0.2134$

A = +1 based on electrons with B = -1 based on positrons:
Intensity of beam, using Malus's Law, $= 0.5*\cos^2\{(45^0 - 0^0)/2\}$
$= 0.5*\cos^2(22.5^0)$
$= 0.2134$

The total intensity in the cell for A = 1 and B = -1 is 0.4268
By subtraction from 0.5, the intensity in the cell for A = 1 and B = +1 is 0.0732

correlation coefficient = 4 * probability (A=1 and B=1) - 1 (a shortcut formula for correlation)
correlation coefficient = 4 * 0.0732 - 1 = 0.2928 – 1 = -0.707 = - $\cos(45^0)$
which exceeds, in absolute value, the classical correlation coefficient of -0.5.

Table 1 Correlation results for electrons/positrons with 45^0 polarisation angle between detectors (correlation coefficient = -0.707)

Measurement outcome intensities as proportions	B = 1	B = -1	Total
A = 1	0.0732	0.4268	0.5
A = -1	0.4268	0.0732	0.5
Total	0.5	0.5	1.0

It is true that the measurement events in Figures A and B for a pair of partner particles were made at the same time and that, between 'Source' and the detectors, the pairs of particles were entangled, but the antiparticles are measured with random polarisations and not with entangled polarisations.

Bell's Theorem has been very important for over fifty years in forcing physicists to look for an alternative reality for elementary particles than the reality for macroscopic bodies. The solution shown here is for antiparticles to travel backwards in time. This does not defeat the Bell Inequalities, which is impossible, but re-configures the Bell experiment analysis in a way that the inequalities do not apply. This shows that the experimental results for Bell experiments can reach a correlation coefficient of -0.707 and yet be consistent with a theoretical retrocausal model where antiparticles travel backwards in time.

ANTIPARTICLES ARE TRAVELLING BACKWARDS IN TIME

The consensus is that antimatter has positive mass: both gravitational and inertial mass. Particle-antiparticle pairs attract one another electrically which implies either the mass or the charge on an antiparticle is reversed in sign compared to the particle properties. It appears that the electric charge is reversed but not the mass as otherwise the antiparticle would repel the particle electrically. This still leaves the question of whether the antiparticle is genuinely travelling backwards in time, or not. I have not thought of a way of detecting this difference in an experiment. An antiparticle travelling backwards in time would enter the detector with (say) random polarisation and leave the detector polarised in the direction of the detector setting. This means that (say) positrons when measured in a Bell experiment are not yet entangled with their paired partner electrons.

Feynman and Stuckleberg (Ref. #5) have both pronounced on properties of antiparticles. It is generally accepted that a positron can be viewed as an electron moving backwards in time, but only as a mathematical contrivance. My view is that a positron is an electron moving backwards in time and that it is a physical necessity that observations on it can only be made from a forwards-in-time point of view by macroscopic instruments and observers. So the backwardness is assumed here to be real while the forwardness viewpoint is merely the best we can do to observe an antiparticle. This model works to bypass all the Bell's Theorem inequality restrictions as the pairs are not entangled at detector

References

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