

EPR-B correlations: a physically tenable local-real model

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Abstract

We propose a classical, i.e., local-real physical model of processes underlying EPR experiments. The model leads to the prediction, that the visibility of the output signal will exhibit increasing variation as the coincidence window is increased, thus providing a testable criteria for its validity. If it can be sustained, this model undermines the claim that Nature has a fundamentally nonlocal feature or that irreal entities are required by quantum theory.

1 State of the argument.

Historically, the struggle to find an interpretation for the wave function in quantum theory led, *inter alia* by way of arguments made by Einstein, Podolski and Rosen (EPR), to examination of correlations of measurements on systems comprising two entities. As is well known and commonly accepted nowadays, analysis of such correlations seems to support the conclusion that at a fundamental level, Nature admits either “nonlocal,” or “irreal” aspects. The first of these alternatives constitutes a deep and serious rift between the two main theories of Physics, namely Quantum Mechanics and Relativity, because the latter demands “locality,” namely, that interaction must transpire between all entities at or below the speed of light. Accepting the alternative, irrealty, is, if anything, an even deeper break with occidental science, as it injects a role for human perception into the evolution of the universe (via observer induced collapse of wave packets), oblivious to the eons before humans appeared.

This situation has led some researches to critically reevaluate current experiments deemed to justify the orthodox interpretations, in particular the so-called EPR experiments and tests of ‘Bell-inequalities’ as carried out by Aspect, Weihs, etc. This writer, for example, has identified several generic arguments supporting the conclusion, that the correlations seen in these experiments do not result from structure unique to quantum mechanics, but appear already in the analysis by Stokes of polarized light at least 50 years before the need for quantum notions was recognized.[1] Moreover, this criticism of current thinking was under-girded with proposed simulations of EPR experiments, intended to demonstrate in detail that non local interaction is not needed to duplicate data commonly believed to require quantum (i.e., nonlocal) interaction for explanation.[2]

Such simulations are incisive insofar as they constitute counterexamples to the augment put forward by, for example, Bell, and subsequently dubbed a “theorem,” to the effect that EPR correlations absolutely cannot be taken into account without the employ of nonlocality. Demonstrating a simulation without nonlocality extinguishes that claim once and for all. Nevertheless, these simulations can be, and have been, criticized for making use of features that, although not quantum in their essential nature, are either impossible or implausible as physics. This writer’s simulation[2] silently assumes, for example, that photo detectors respond depending on the global character of the input signal (specifically, which of the two component states making up the ‘singlet state’ actually enters the detector).[3]

Less objectionably, the simulation proposed by de Raedt et al. proposes that, upon deflection or transmission at a beam splitter, a “photon” either suffers a random delay[4], or that beam splitters behave as “deterministic learning machines,”[5]. While such delays cannot be rejected *a priori*, at least this writer knows of no physical cause for such delays in beam splitters, in particular of the magnitude required by the simulation to duplicate data taken in actual experiments. Alternatively, “learning machine” effects, as proposed, require, for example, persistent polarization currents to be setup by one signal which persist to influence subsequent signals passing through the beam splitter, an effect for which explanation involves somewhat implausible, even extravagant hypothetical input.

It is the purpose here to propose a physical model for these experiments that accommodates the facts as observed in experiments. The model is simple, fully classical, local and real; it does not presume any quantum structure, not even the existence of “photons.”

First, factual characteristics of the data from the experiments that are to be modeled must be delineated.

2 EPR-B data “as it is.”

The overwhelming impression made by EPR-B raw data, is that it appears to be two (or four) streams of events occurring at essentially random times¹. The two or four streams represent what are called “photon detections,” at the detectors, either one (or two) on both the right and left of an EPR setup. These data streams do not give the impression to the eye of being temporally grouped or correlated. Thus, for the purpose of analysis of the EPR experiments, these streams are filtered in terms of a coincidence “window,” i.e., a time interval within which one event on the left is paired with one event on the right. Naturally, as this window is made more narrow, the number of resulting coincidences diminishes, but at the same time the closer the statistics of the selected pairs come to those predicted using quantum theory. At the other end, with a very wide window, the coincidence statistics more closely approach those expected from strictly classical analysis. The difference is, as is now well known, that the quantum statistics involve more coincidences than are expected from non quantum analysis. This is said to lead to “quantum correlations stronger than admitted by classical statistics.”

In addition, there is a second phenomenon revealed in the data. It is this: the expected strict rotational invariance with respect to the input signals is imperfect. This defect is visible as a variation in the visibility of the output signal which oscillates so as to have minimums at the angles of $\pi/4 + n\pi/2$. To date, this anomaly remains under reported because it is unexplained.[6]

Thus, what a simulation, or model, of these experiments must reflect and explain goes beyond just the subset of the data which exhibit the peculiar quantum aspects; it must also explain the large amount of data filtered out which does not fully fit the quantum structure as revealed in calculations with solutions to the Schrödinger equation. In this regard, the two salient characteristics are:

1. the relative paucity of qualified pairs, and
2. the strict failure of rotational invariance as revealed by oscillating visibility.

The model proposed below covers both of these features.

3 The model: background motivation

In a study of EPR and GHZ (after Greenberger, Horn and Zeilinger, who famously considered experiments on higher order systems with three, four, etc. output events) correlations, this writer has shown that the observed coincidences can be accurately calculated using the *classical* variant of the coherence function.[7] For GHZ setups correlation calculations become quite unwieldy, and, therefore, are best carried out with a computer algebra program; here we use MuPAD. This tactic can be exploited also to lead directly to a very convenient display of the essential difference between the results of classical and quantum analysis of EPR (or GHZ if desired) experiments (see below).

1. See: [5] for a comprehensive description of data from a typical Bell-test experiment.

Consider a prototypical experiment to test Bell-inequalities. The signal² as generated in the source crystal in the quantum mechanical understanding of the setup constitutes a “singlet state” sent in opposed directions, such that if a vertical signal is detected on the left, a horizontal signal is detected deterministically on the right, or *visa versa*. Such singlet states or signals emitted by the crystal are considered to be essentially ambiguous in that they are the sum of both options in both directions, but that this ambiguity is resolved by whichever detector registers first, thereby causing a collapse of the quantum mechanical ψ -function (wave) for the pulses sent in both directions. The consequence is, that the mate to the first signal at the companion measuring station is *instantly* granted (by some mysterious nonlocal process not described by the dynamic equations of quantum mechanics) the opposite polarization. In non quantum renditions or simulations of these experiments, no such essential ambiguity is allowed; the paired signals are randomly selected to be one or the other anti-correlated possibility and are never the simultaneous sum in the form of the “singlet state,” a stipulation which constitutes an encoding of “reality” in such simulations. A singlet state must be considered “irreal” as it is supposedly the sum simultaneously of mutually exclusive alternatives — contrary to all logic.

For our model the calculation algorithm the source is encoded in terms of a source signal sent left $Sl(n)$ and one sent right $Sr(n)$, each a function of a random variable, n , taking on the values 0, 1 with equal probability. First, some initialization statements:

```
• reset(): Matrix:=Dom::SquareMatrix(2): vector:=Dom::Matrix():
```

Now, the source signals are encoded as functions of n , such that for each of its designated values, 0, 1, it produces one or the other of the component states constituting the singlet state :

```
• Sl:=n->vector(2,1,[n],[1-n]); Sr:=n->vector(2,1,[1-n],[n]);
```

These signals are then each sent, on both sides, through polarizing beam splitters (PBS). The axis of each beam splitter is separately variable, thus the encoding of the effect of such a beam splitter on each beam must be a function of its angular orientation. The operator corresponding to a PBS as a function of its angular orientation is the 2-dimensional projection operator:

```
• proj:=z->Matrix([[cos(z),sin(z)],[-sin(z),cos(z)]]);
```

The output signal from a PBS is then obtained by multiplying the source signal by the projection operator to obtain a two component vector, where each component represents a signal from each output port of the PBS.

```
• El:=(z1,n)->proj(z1)*Sl(n); Er:=(zr,n)->proj(zr)*Sr(n);
```

The output signals of the PBS, (El, Er), are electric fields and are sent to photo-detectors, where they can be used in the standard law to obtain the probability, P , of generating a photo electron, namely

$$P \propto E^2, \quad (1)$$

where P can be interpreted as a photo current, for high intensity.

Now, whatever else is true or false, it is a fact, that the classical second order correlation function corresponds to the same correlation as computed with ostensible quantum algorithms. To execute this calculation we need to form the ratio of difference over the sum of two other sums, of the form:

$$\frac{\sum_{ijkl} El_i^*(\theta_l)Er_j^*(\theta_r)Er_k(\theta_r)El_l(\theta_r) - \sum_{ijkl} El_i^*(\theta_l)Er_j^*(\theta_r + \pi/2)Er_k(\theta_r + \pi/2)El_l(\theta_r)}{\sum_{ijkl} El_i^*(\theta_l)Er_j^*(\theta_r)Er_k(\theta_r)El_l(\theta_r) + \sum_{ijkl} El_i^*(\theta_l)Er_j^*(\theta_r + \pi/2)Er_k(\theta_r + \pi/2)El_l(\theta_r)}, \quad (2)$$

2. Herein the term “signal” refers to the pair of opposed “pulses” generated so as to have anti-correlated polarization. Each pulse is taken to have just enough total energy to evoke one electron by the photoelectric effect in a detector. As is customary, the “singlet” state is considered to be a mysterious quantum entity comprised of the sum of two such ‘signals’ of opposite polarization orientation, which randomly “collapses” to one or the other component signal whenever one of the pulses encounters a detector.

where all the indices take on the values 1 and 2 as there are two components representing the two output channels of a PBS.

In this expression one sees the definition of a fourth order correlation of electric field magnitudes, which for certain of these products equal second order correlations of the field energy intensities, or, calling on the theory of photo current generation, i.e., on the formula $I \propto E^2$, of the correlation of the number of photo (electron) detections.

The encoded numerator of this expression is given by:

```
• Num:=(n,c,i,j,k,l,zl,zr)->(-1)^c*El(zl,n)[i]*Er(zr+c*PI/2,n)[j]*
Er(zr+c*PI/2,n)[k]*El(zl,n)[l];
```

$$(n, c, i, j, k, l, z_l, z_r) \mapsto (-1)^c \text{El}(z_l, n)_i \text{Er}\left(z_r + \frac{\pi c}{2}, n\right)_j \text{Er}\left(z_r + \frac{\pi c}{2}, n\right)_k \text{El}(z_l, n)_l$$

where the indicated sums are then executed by:

```
• sum(sum(sum(sum(sum(Num(n,c,i,j,i,j,zl,zr),
i=1..2),j=1..2),k=1..2),l=1..2),n=0..1),c=0..1);
```

$$8 (\cos(z_l) \sin(z_r) - \cos(z_r) \sin(z_l))^2 - 8 \left(\cos\left(\frac{\pi}{2} + z_r\right) \sin(z_l) - \sin\left(\frac{\pi}{2} + z_r\right) \cos(z_l) \right)^2$$

```
• simplify(%);
```

$$- 8 \cos(2z_l - 2z_r).$$

The denominator, $\sum_{ijkl} \text{El}_i^*(\theta_l) \text{Er}_j^*(\theta_r) \text{Er}_k(\theta_r) \text{El}_l(\theta_r) + \sum_{ijkl} \text{El}_i^*(\theta_l) \text{Er}_j^*(\theta_r + \pi/2) \text{Er}_k(\theta_r + \pi/2) \text{El}_l(\theta_r)$, is computed with the same statements with exception of the factor of $(-1)^c$, which is replaced with $(+1)^c$:

```
• Den:=(n,c,i,j,k,l,zl,zr)->(+1)^c*El(zl,n)[i]*Er(zr-c*PI/2,n)[j]*Er(zr-
c*PI/2,n)[k]*El(zl,n)[l];
```

```
• sum(sum(sum(sum(sum(Den(n,c,i,j,i,j,zl,zr),
i=1..2),j=1..2),k=1..2),l=1..2),n=0..1),c=0..1): simplify(%);
```

8.

Thus, this calculation delivers the same result as does the quantum algorithm for the correlation. Like many such quantum algorithms, the physical interpretation is less than obvious. But, for present purposes, an interesting point of entry is the numerator of the correlation. The result obtained above, namely

$$(\cos(z_l) \sin(z_r) - \cos(z_r) \sin(z_l))^2 - 8 \left(\cos\left(\frac{\pi}{2} + z_r\right) \sin(z_l) - \sin\left(\frac{\pi}{2} + z_r\right) \cos(z_l) \right)^2, \quad (3)$$

offers a propitious venue for interpretation of the physics involved by expanding each term, i.e.,

$$\cos^2(z_l) \sin^2(z_r) - 2 \cos(z_l) \sin(z_r) \cos(z_r) \sin(z_l) + \cos^2(z_r) \sin^2(z_l) + \Upsilon, \quad (4)$$

where Υ is the expansion of the second term in Eq. (3). The first and third terms of Eq. (4) are the standard expressions for correlations of events on each side from each of the variant signals put out by the source; but, the middle term is not standard. It does not fit the law of photo current generation, i.e., $P \propto E^2$; because it is the product from four different fields, giving the amplitudes of electric fields for four different photo electron source events — all of which appears to mean that it cannot be associated with the generation of a photo electron current.

In short, it is this middle term that requires a model or interpretation if the mystical aspects of EPR correlations are to be explained without recourse to preternatural phenomena.

4 A new model for EPR correlations

The motivation for the model proposed here is provided by the most conspicuous feature of that data from EPR experiments data, namely, that data exhibiting the so-called quantum correlations is just a subset of the total data stream which has been filtered out in terms of a “coincidence window.” The narrower, the window, the closer the coincidence pattern approaches the ideal as calculated using the quantum algorithm.

This fact suggests the following structure, which shall be taken as the hypothetical input for our model. The source crystal under stimulation of the driving input beam at various emission centers in the crystal independently produces two types of anti corrected output signals, one with a vertically polarized pulse to the right and a horizontally polarized pulse to the left, and one in which the signal has switched polarization orientations. It is taken that the separate pulses in each pair have an intensity just sufficient (statistically) to elicit one photo electron.³ Nevertheless, it is not taken that the matched pulses, one in each arm, necessarily elicit photo electrons exactly simultaneously; as is well known they can be separated by some random time interval, compatible with the coherence length of the pulses. Now, filtering the data to fit within a “window,” selects those coincidences of one detection on each side engendered by these two types of signal pairs that happen to have evoked photo electrons coincidentally within the window. Such coincidences arise from two distinct situations: one, when each of the photo electron detections is elicited by the same signal, and, two, when an event on each side is elicited by oppositely polarized signals. The first sort correspond to the first and third terms in Eq. (4).

But, there are still additional coincidences possible if two separate signal types from the crystal are timed such that a coincidence can arise between single detections evoked one by each signal. In terms of classical physics, this assumes that two such signals, one of each variant, arise at separate locations within the crystal. Coincidences of this sort, which can be considered “illegitimate,” obviously, can be involved only if these two coincidences fall within a very short interval, shorter than the expected interval between coincidences generated by “legitimate” pairs, thereby forming a closer time association than the underlying legitimate events. When the window is narrow these illegitimate coincidences are counted along with a certain number of legitimate ones, whereas, with a broad window, additional coincidences are counted which arise only from legitimate pairs, i.e., from signals that are not coincident with the opposite variant. These extra, legitimate counts dilute the selected data sample by adding relatively more coincidences not corresponding to the cross terms in Eq. (4).

This can be understood in terms of the probabilities of detection. For each detection of a photo electron resulting from a pulse (assumed to have energy sufficient for only one photo electron) the probability that this electron is lifted into the conduction band after a time dt equals dt/l where l is the pulse length. The probability of a coincidence with the lifting of a photo electron in the companion measuring station is then equal to $(dt/l)^2$, i.e., the probability of the coincidence of the two events is the product of their probabilities. Now, for the coincidence of photo electrons engendered by “illegitimate” combinations, the probability equals $(dt_1/l)(dt_2/l)$ where the subscripts indicate that two distinct signals are under consideration, i.e., an “illegitimate” coincidence. Clearly, to conform to the calculation described above, which is fully symmetric in the admitted combinations (as encoded by selection of indices) over which the sum is carried out, these two probabilities must be equal. This can arise only when $dt_1 \equiv dt_2$, that is, when the two signals from the crystal are by chance simultaneous because then the two intervals will be equal, or nearly so, only when they have essentially identical initial instants, which applies tautologically for coincidences that are virtually simultaneous i.e., when selected under a very narrow coincidence window. However, for illegitimate coincidences, there is likely an offset in the starting instants for the dt_i as they pertain to separate, uncoordinated, independent signal pairs. The extent to which the data includes coincidences admitted by a wide filter, it the extent to which the quantum pattern is corrupted.

A central issue is: can these ‘illegitimate’ coincidences be related to the cross terms in Eq. (4)?

3. The absolute anti-correlation of detections in the output channels of a beam splitter at the one photo electron level is considered nowadays to reflect quantum structure. However, behaviour at a PBS is irrelevant to the quantum structure of coincidences. Moreover, there are also non quantum models for beam splitters, e.g., [8], that can purge this last vestiges of quantum structure from the analysis of EPR correlations.

At first glance, this would seem to be impossible because the form of this term does not admit a straightforward interpretation in terms of the law of photo electron generation, which requires electric field amplitudes squared. Just here, however, another possibility enters. It is this. If it is allowed, that coincidences can arise from the occasions on which there is a temporal overlap of elementary signals, one of each variant, then there is a formal equivalence between the number of additional coincidences and the cross terms in Eq. (4). The essence of this equivalence consists in the fact, that formally seen, the cross terms in Eq. (4) correspond to physically sensible terms of the form:

$$E_i(zl)^2 E_j(zr)^2, \quad (5)$$

obtained with the substitutions:

$$\cos(x + \pi/2) = -\sin(x); \quad \sin(x + \pi/2) = \cos(x), \quad (6)$$

that convert the four-factor, cross terms in Eq. (3) to the form of Eq. (5), which does admit physical interpretation in terms of photo electron generation. The phase shifts of $\pi/2$ in the arguments here are related to the fact that the two factors on each side, pertain to opposite variants of the source signals, which must take into account the difference between the polarization orientation of the input pulses entering the beam splitters.

Physically, this correspondence take coincidences into account which arise from a photo electron generated on the left from one of the variants with a detection on the right from the opposite variant which happens to overlap temporally. The number of such coincidences corresponds to the number arising from source signals comprised of correlated (in stead of anti-correlated) pairs. This poses a challenge for a physical interpretation of these experiments because the phase matching conditions imposed on the non-linear generation processes in the crystal produces only anti-correlated output pairs. This challenge (for formulating a model) is overcome, however, by positing that such correlated pairs are comprised of detections on each side matched with detections on the other side from a distinct signal of the opposite variant.

It is to be stressed, that the significance of Eqs. (6) is *not* strictly physical. It represents mostly a formal correspondence rendering the quantum algorithm in accord with a feasible physical process.

In other words, detections are considerably different if two different but overlapping signals are present. Then, it becomes possible, that the two photo electrons closest in time have arisen from different pairs. That means, that in the total population of detected pairs, as identified by proximity of detection times, among pairs selected by narrow window criteria, there will be some pairs formed corresponding to the cross terms in Eq. (4). But as the window width is increased, so as to capture additional pairs, the number of such illegitimate pairs is not greater than the number found using a narrow window. In other words, the total data set grows in size with increasing window width but the number of illegitimate pairs or pairs corresponding to the cross terms remains the same. This explains just why experimenters must strive to reduce the window width as much as feasible; and, it explains why only the statistics of a subset of data taken with a narrow coincidence window width conform with those computed using so-called quantum algorithms.

5 The rotational invariance anomaly

A crucial feature of EPR data to be explained by any model is the evidence of a breakdown of rotational invariance. Previous analysis of this matter by this writer led to the conclusion that this break down should be complete, i.e., that the visibility of the signal should actually approach null for certain angular settings of the polarizers in the detection stations.[6] This conclusion, however, resulted from the assumption that individual signals are exclusively of one variant or the other. As described above, in the model proposed herein, such pure signals are indeed the majority, except for that small subset of data filtered out when the detection window width approaches null. These selected events in this special case comprise events corresponding to the cross terms from the overlay of both variants of source signals, and, as such, under optimum conditions, constitute a rotationally independent sum. Each signal variant under rotation compensates the other as they are exactly out of phase. This means that the small variations in visibility still seen in the data result from the fact that the window width is still sufficiently wide to admit a less than an ideal set of coincidences, that is, it contains a relative deficit of cross terms so that the statistics of this data set exhibit some portion of rotational variance.

This effect can be quantitatively depicted by redefining Eq. (4) so that the legitimate terms are multiplied by a factor, which when greater than 1, represents the excess in their number whenever the coincidence window is widened:

$$\bullet \text{ cor} := (z_l, z_r, y) \rightarrow -\cos(z_l)^2 \cos(z_r)^2 + \cos(z_l)^2 \sin(z_r)^2 - y^{-1} * 4 * \cos(z_l) * \cos(z_r) * \sin(z_l) * \sin(z_r) + \cos(z_r)^2 \sin(z_l)^2 - \sin(z_l)^2 \sin(z_r)^2;$$

$$(z_l, z_r, y) \mapsto \left(\left(\cos(z_l)^2 \sin(z_r)^2 - \cos(z_l)^2 \cos(z_r)^2 \right) - \frac{4 \cos(z_l) \cos(z_r) \sin(z_l) \sin(z_r)}{y} \right) + \cos(z_r)^2 \sin(z_l)^2 - \sin(z_l)^2 \sin(z_r)^2$$

This expression is the result of multiplying all terms for legitimate coincidences in both the numerator and denominator and is therefore the absolute correlation function as a function of y , the excess factor of legitimate coincidences resulting from non ideal filtering. By now substituting this into the expression for CHSH discriminator:

$$\bullet S := (x, xx, z, zz, y) \rightarrow \text{cor}(x, z, y) - \text{cor}(x, zz, y) + \text{cor}(xx, z, y) + \text{cor}(xx, zz, y);$$

and then defining, for convenience, the function:

$$\bullet SS := (w, v, y) \rightarrow S(w, w+2*v, w+v, w+3*v, y);$$

which is defined in terms of the values of the orientations of the polarizers which have been determined to maximise the violation of a Bell-inequality. $SS(w, v, y)$ can be plotted directly:

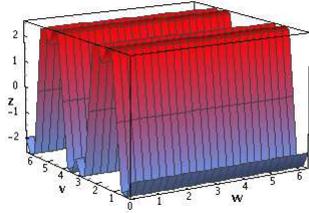


Figure 1.

Fig. 1 shows the variation of the function S in terms the variables v , the displacement between the angular settings on both sides in the various experiments contributing terms to the CHSH discriminator when $y = 1$, i.e., for an ideal subset of data. If the source signals are rotationally invariant, then the values for v have no absolute meaning, which implies that variation of w has no effect on S . Fig. 2 illustrates just how much rotational invariance is destroyed by a 10% increase in the number of legitimate coincidences in the total data stream.

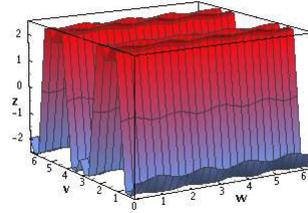


Figure 2.

The existence of this effect is strong evidence that the source signals are not, as envisioned in orthodox quantum theory, comprised of singlet states; rather, the singlet state structure is mimicked only in the (ideal) subset of data filtered out with a small coincidence window.

6 Conclusions

In the introduction characteristics of the data taken in EPR experiments that a physical model of the underlying physical phenomena must explain were identified. It was noted that the data taken in these experiments differs considerable from the ideal data predicted by conventional analysis based on current quantum orthodoxy. A viable physical model should explain all the data taken, that is, the empirical facts, rather than just a sub portion, however significant it may be considered.

The three salient features of the data are explained by the model as follows:

1. *The most obvious feature of EPR data streams is that there are very few obvious, ideal coincidences.*

The proposed model incorporates or explains this feature as a consequence of the distribution of emission time of photo electrons. In this case it is taken that the emission time of the photo electron in a detector is displaced naturally and randomly within a pulse length or coherence length of the signal impinging on the detector. It is a well know fact that electromagnetic pulses, while they can stimulate virtually instantaneous emission of photo electrons, in fact for an ensemble of such pulses, the actual exact emission times are distributed over the pulse length. Thus, the emission times on opposite sides of an EPR setup usually do not exactly coincide, even when generated by the same signal or pulse pair.

2. *The population of coincidences that exhibit the pattern as calculated using algorithms from quantum mechanics must be filtered from the total data set by selection using “coincidence circuitry” with as narrow a time interval window as possible.*

Data subsets selected with a wider than optimum window, while they may exceed limits considered to obtain from non quantum regimes, nevertheless deviate from the ideal quantum pattern and approach that for non quantum systems. Specifically, the curve of the CHSH discriminator function exceeds 2 but is significantly less than $2\sqrt{2}$.

In terms of the proposed model, these features are explained as follows: It is taken that occasionally two pairs of signals of opposite polarization character overlap temporally. For these cases, it might happen that the closest coincidences involve detections from each signal because the actual displacement of the truly paired events (i.e., from the same signal) are displaced at larger intervals by cause of the effect considered in point 1. above than these “illegitimate” coincidences. These extra, illegitimate, coincidences are the excess that correspond to the cross terms in Eq. (3), so that the manipulations in the quantum algorithm yield the observed patterns coincidentally, even while these algebraic expressions as such do not correspond to direct application of known physics principles, here the photoelectric effect.

The corruption of the data set as the coincidence window is broadened is then a consequence of the fact, that the “illegitimate” coincidences represent relatively rare events that cannot occur for well separated signal variants. They occur only for nearly simultaneous sums of both variants. Therefore as the window is increased, the set of events considered for analysis includes ever increasing numbers of coincidences formed from legitimate pairs, and the statistics approach those for classical particulate systems.

3. *The filtered data sets for even narrow windows exhibits a variation in visibility that should not occur for the data set envisioned in terms of quantum analysis (i.e., for the singlet state, which is perfectly rotationally invariant).*

This phenomenon in terms of the model proposed herein is a result of the fact, that no matter how narrow the coincidence window is taken, the statistics can only approach the ideal which is mathematically codified with the singlet state. If this model is faithful to the actual physical facts of the EPR experiments, then it is to be expected that the degree of violation of rotational invariance, and therefore the visibility, is a function of the window width — a testable proposition.

If this model is empirically sustainable, then it has been shown, that claims that EPR experiments and experimental tests of “Bell’s theorem” prove that Nature at a fundamental level involves nonlocal interaction, cannot be maintained. Likewise, it would show, that “irreal” states (i.e., states composed of the sum of mutually exclusive options, for example the singlet state) do not have ontological status. They are artifacts of the formalism for which statistical parameters are valid for ensembles, but that cannot be applied to the individual entities constituting the ensemble. This conclusion follows directly from the fact that, were the input variant signals actually singlet states in each individual case, the statistics would be essentially invariant with respect to the coincidence window width because all signals would have equal probability of producing “illegitimate” coincidences.

Of course, it is in principle possible that some other true “quantum” system in which singlet states arise in fact exists. Experiments on such a system might then verify the current understanding of the issues around nonlocality; but, until such experiments on such systems are carried out, these issues remain open.

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