Commentary

# On Aspect's Bell Inequality Experiment

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**In this short note, we explain the untenability of a recent claim in the technical literature purportedly proving that Aspect's experiment testing the Bell inequality is based on a statistical flaw.**

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## 1. Introduction

In a recent article [1], Han Geurdes claims that Aspect's experiment, as described in [2], is based on the incorrect application of some basic mathematical concepts, which purportedly renders it wrong as a consequence of what Geurdes terms *bad statistics.*

Since Allan Aspect is one of the 1922 Nobel Prize physics awardees, along with Anton Zeilinger and John Clauser, for their work devoted to empirically testing the Bell inequality and contributing to the development of quantum information science, it would be quite puzzling that such a blunder could pass unnoticed by the physics community and the committee in charge of awarding one of the most prestigious scientific recognitions.

As is usually the case in such instances, experts in the field tend to ignore claims that seem explicitly incorrect; however, to set the record straight and clarify the issue for the general audience, we shall analyze Geurdes's main argument and explain why it does not stand up to rational analysis.

In section 2 we first present a quick review of the Bell-CHSH inequality [3] and in section 3 we explain why Geurdes's argument is incorrect.

## 2. The Bell-CHSH inequality

The Bell-CHSH inequality is written,

$$-2 \leq \langle A_1 B_1 \rangle + \langle A_1 B_2 \rangle + \langle A_2 B_1 \rangle - \langle A_2 B_2 \rangle \leq 2 \tag{1}$$

Where $< A_i B_k >$ is the mean of of the joint measurements $A_i B_k; i, k \in \{1, 2\}$ with $A_i \in \{-1, +1\}$ representing the result of Alice's spin measurement in direction $i$ and analogously for $B_k$ representing the result of Bob's measurement in direction $k$. Thus, the experiment consists of a series of four different possible combinations of measurements in directions $i$ and $k$ giving the results $A_i B_k = \pm 1 \pm 1 \in \{-1, 1\}$.

Setting $x_j; j \in \{1, 2, 3, 4\}$ for the four possible angles between directions $i$ and $k$ and putting $\langle A_i B_k \rangle = R(x_j)$, we can write (1) as

$$|R(x_1) + R(x_2) + R(x_3) - R(x_4)| \leq 2 \tag{2}$$
$$-1 \leq R(x_j) \leq 1 \tag{3}$$

If $P(x, ++)$ represent the probability of obtaining the values $A_i = 1, B_k = 1$ when the angle of measurement between directions $i$ and $k$ is $x$ and analogously for $P(x, +-), P(x, -+), P(x, --)$,

$$R(x) = P(x, ++) + P(x, --) - P(x, +-) - P(x, -+) \tag{4}$$
$$= P(x, =) - P(x, \neq) \tag{5}$$

Where the $P(x, =)$ and $P(x, \neq)$ represent probabilities of finding equal or different values in one run of joint measurements.

If $\vec{a}_i$ and $\vec{b}_k$ are unitary vectors in directions $i$ and $k$ respectively, quantum mechanics predicts,

$$\langle A_i B_k \rangle = -\vec{a}_i \cdot \vec{b}_k \tag{6}$$
$$R(x) = -cos(x) \tag{7}$$

where $x$ is the angle between $\vec{a}_i$ and $\vec{b}_k$.

## 3. Analysis of Geurdes's Claims

Geurdes's notation includes some typos that are nevertheless irrelevant to the main argument. We shall rectify them in our analysis; thus, in the following discussion, we amend the following points:

- In [1], (7) reads $R(x) = \cos x$ instead of $R(x) = -\cos x$
- Formula (7) is valid for $1/2$ spin particles, while Aspect's experiment is with photons. As in [1], we keep the analysis within the scope of spin 1/2 particles.
- $P(x, \neq) = \sin^2(x/2)$ should read $P(x, =) = \sin^2(x/2)$

Geurdes's claim of *bad statistics* consists in the purported existence of negative probabilities in Aspect's model. This conclusion arises as a consequence of writing $\sin^2(x/2)$ as the integral

$$P(x,=) = \sin^2(x/2) = \int_0^x \frac{1}{2}\sin(y)dy, x \in [0, 2\pi) \tag{8}$$

This expression suggests interpreting $\rho(y) = 1/2\sin(y)$ as a density probability and reinterpreting the discrete probability $P(x,=)$ for the angle value $x$ as a cumulative distribution function that we write $P([0,x],=)$ to distinguish it from the discrete probability $P(x,=)$,

$$P([0,x],=) = \int_0^x \frac{1}{2}\sin(y)dy \tag{9}$$

Since in the range $y \in (\pi, 2\pi)$, $\rho(y) < 0$, Geurdes asserts that Aspect's statistical model of the Bell-CHSH inequality implies negative probabilities.

**The Explanation**: Geurdes's reinterpretation of the discrete probability $P(x,=)$ corresponding to a single value $x$ as the cumulative distribution $P([0,x],=)$ does not apply to the Bell theorem nor to Aspect's statistical model. In a continuous distribution, the probability for any single value is null, which contradicts (6) and (7) that would also vanish according to (4) and (5).

As shown in (2), in Aspect's experiment, the angles between joint measurements have only four possible values $x_1, x_2, x_3,$ and $x_4$. When working with spin $1/2$ particles, typical values are $x_1 = x_2 = x_3 = 1/4\pi, x_4 = 3/4\pi$(Fig. 1.) Reinterpreting that discrete set of values as continuous probability distributions is not meaningful and contradicts the quantum prediction (7).

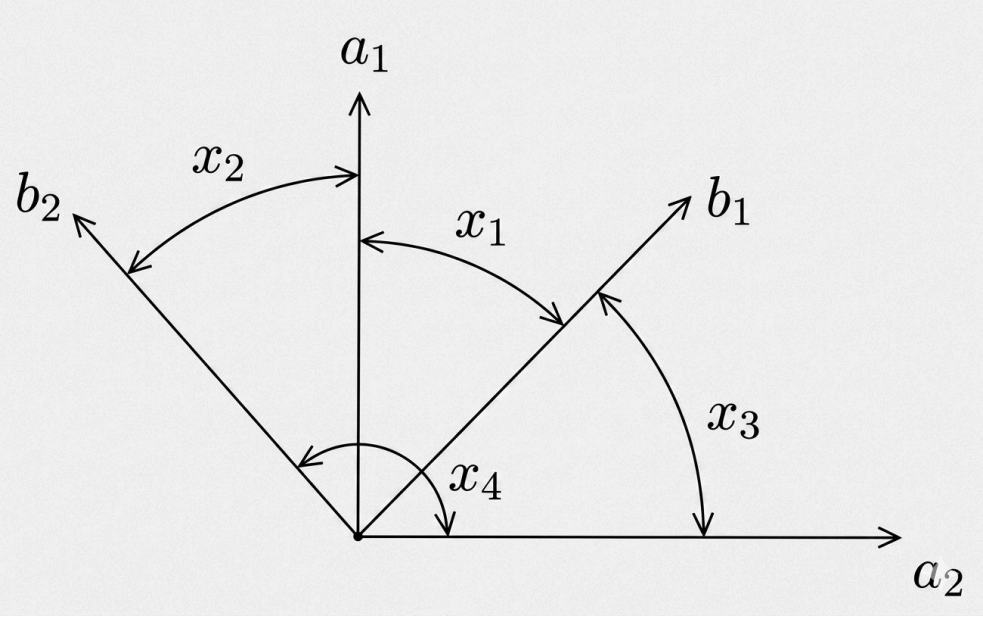



**Figure 1.** $a_1$ and $a_2$ are Alice's settings. Analogously, $b_1$ and $b_2$ for Bob's.


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Furthermore, even though the inclusion of a continuous angle distribution lacks direct physical meaning in Aspect's experiment, the appearance of negative probabilities in (8) is a consequence of including angles outside the interval $[0, \pi]$, which already exhausts the angle meaningful values.

## 4. Conclusions

We have shown that Geurdes's reinterpretation of the formulas used in Aspect's experiment does not apply to the Bell-CHSH inequality nor to the statistical model tested by Aspect's experiment; therefore, claims of erroneous statistical underpinning and *bad statistics* are based on an incorrect reinterpretation of the quantities being tested; therefore, they are unjustified.

## References


1. [a], [b], [c] *Geurdes H (2026). "Conclusion of the Aspect Paradigmatic Experiment Is Based on a Statistical Flaw." J Stat Theory Appl. **25**(27). doi:10.1007/s44199-026-00183-w.*
2. [^] *Aspect A, Grangier P, Roger G (1982). "Experimental Realization of Einstein-Podolsky-Rosen-Bohm Gedan kenexperiment: A New Violation of Bell's Inequalities." Phys Rev Lett. **49**:91–94. doi:10.1103/PhysRevLett.49.91.*
3. [^] *Clauser JF, Horne MA, Shimony A, Holt RA (1969). "Proposed Experiment to Test Local Hidden-Variables T heories." Phys Rev Lett. **23**(15):880. doi:10.1103/PhysRevLett.23.880.*


### Declarations


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