Bell's inequality refuted irrefutably on Bell's own terms

Gordon Watson[1]

Abstract Consistent with claims that we've advanced since 1989, we refute Bell's 1964 inequality on Bell's own terms. In sum, in the context of the EPR-Bohm experiment, Bell-(14b) $\neq$ Bell-(14a).

1. Introduction

(i) Bell's theorem has been described as one of the most profound discoveries of science. (ii) Yet, despite this fame, Bell (1990:7) lived on the horns of a dilemma wrt the significance of his theorem. (iii) Here, using elementary mathematics as an introduction to its further use in Watson (2018e),[2] we refute Bell's inequality on Bell's own terms and respond to an interesting objection.

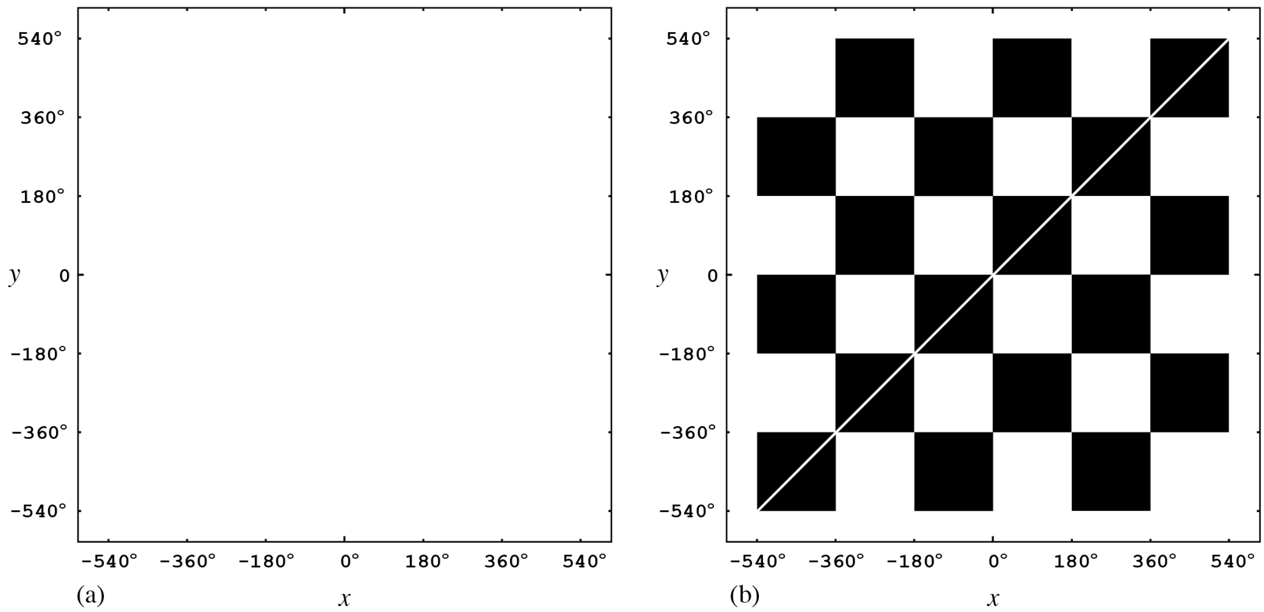

Fig.1. With $x = (\vec{a}, \vec{b})$, $y = (\vec{a}, \vec{c})$, two screen-shots show the difference between our irrefutable relation (6) and (7), Bell's inequality, Bell-(15). (a) shows (6) true, its upper-bound of 0 not breached. (b) shows (7) widely false, its upper-bound of 0 breached regularly; see (16). nb: (7) is true on the line $[x = y; \text{ie}, (\vec{a}, \vec{b}) = (\vec{a}, \vec{c})]$, and on four similar $\cos(\vec{a}, \vec{b}) = \cos(\vec{a}, \vec{c})$ lines not shown; each being a set of points of zero probability.

(iv). Bell (1964) is available free-online, see References; it helps to have it on hand. Let Bell-(1) be short for Bell 1964:(1); etc. Let Bell-(14a), (14b), (14c) identify the three expressions between Bell-(14) and Bell-(15). Then, based on our elementary mathematics, Fig.1 introduces our results graphically upon two opaque-white screens; akin to archeological sieves, one might imagine them shaken randomly with displacements equal to the least-positive real. For each screen is set to catch all positive reals $\forall\, \vec{a}, \vec{b}, \vec{c}$, with $(\vec{b}, \vec{c}) = (\vec{a}, \vec{c}) - (\vec{a}, \vec{b})$ for simplicity. Thus all non-positive real numbers pass through and lie beneath the screen, hidden from view. Put simply, under our simplified but valid conditions: white-space on screen (a) shows where relation (6) is true; on screen (b) it shows where (7) is true, (6) being true all over, per (a).

[1] Correspondence welcome. email: eprb@me.com Ex: Watson (2018d)-12. Ref: Watson (2018d)-13. Date: 20180816.

[2] All results here are independent of Watson (2018e), which simply delivers new results with similar mathematics.

2. Analysis

(i) Via Bell-(1) and LHS Bell-(2), the functions required to analyze Bell's work are straight-forward: result A is given by $A(\vec{a}, \boldsymbol{\lambda}) = \pm 1$, etc; expectation value $P(\vec{a}, \vec{b})$ is the average over the product of paired-results $A(\vec{a}, \boldsymbol{\lambda})$ and $B(\vec{b}, \boldsymbol{\lambda})$, etc. (ii) Thus—using clearly-identified facts at one with mathematics, quantum theory (QT), observation and true local realism (as in Watson 2018e)—we have via Bell-(1)-(2):

$-A(\vec{a}, \boldsymbol{\lambda}) = \pm 1,\quad B(\vec{b}, \boldsymbol{\lambda}) = \pm 1, C(\vec{c}, \boldsymbol{\lambda}) = \pm 1$ represent Bellian result functions, (1)

with $-1 \leq P(\vec{a}, \vec{b}) \leq 1,\quad -1 \leq P(\vec{a}, \vec{c}) \leq 1, -1 \leq P(\vec{b}, \vec{c}) \leq 1$ the related expectations. (2)

Then, since $y \geq xy$ is a fact (by observation) if $x \leq 1$ and $0 \leq y$: so, via (1)-(2), (3)

$1 + P(\vec{a}, \vec{c}) \geq P(\vec{a}, \vec{b})[1 + P(\vec{a}, \vec{c})]$ is also a fact [with others] for all $\vec{a}, \vec{b}, \vec{c}$. (4)

Then, editing (4) – ready for comparison with Bell-(15) (5)

here's a new fact: $0 \geq \Big[P(\vec{a}, \vec{b}) - P(\vec{a}, \vec{c}) - 1\Big] + P(\vec{a}, \vec{b})P(\vec{a}, \vec{c})$ (6)

versus Bell's claim: $0 \geq \Big[\,|\,P(\vec{a}, \vec{b}) - P(\vec{a}, \vec{c})\,| - 1\Big] - P(\vec{b}, \vec{c})$ for his famous Bell-(15). (7)

And if $(\vec{a}, \vec{b}) = (\vec{a}, \vec{c})$: then $P(\vec{b}, \vec{c}) = P(\vec{b}, \vec{b}) = -1$ per Bell-(13). So (6) & (7) hold and (8)

all's well. However : Bell's start-point [P...] might exceed ours; since $\pm x \leq |\pm x|$. So, (9)

aware of (8) : let's study high start-points where a breach of (7) is likely. (10)

Now : as Bell (1964) well-knows via QT [but see ¶2(iv)] as at (11)

Bell-(2)-(3): $P(\vec{a}, \vec{b}) = -\cos(\vec{a}, \vec{b})$, etc. [Or see Watson 2018e:(19).] So, with (8) now, (12)

it is: if $\cos(\vec{a}, \vec{b}) \neq \cos(\vec{a}, \vec{c})$, Bell needs $-P(\vec{b}, \vec{c}) \leq P(\vec{a}, \vec{b})P(\vec{a}, \vec{c})$ for (7) to hold: (13)

else (7) could be > 0, exceeding its claimed upper-bound. But, via (13), see (25): (14)

if $\cos(\vec{a}, \vec{b}) \neq \cos(\vec{a}, \vec{c})$, Bell needs $\sin(\vec{a}, \vec{b}) \sin(\vec{a}, \vec{c}) \leq 0$ for (7) to hold; which (15)

leads to a new fact : (7) is false for $\cos(\vec{a}, \vec{b}) \neq \cos(\vec{a}, \vec{c})$, $0 < \sin(\vec{a}, \vec{b}) \sin(\vec{a}, \vec{c})$; (16)

see Fig.1(b). So (7) > 0 for some $\vec{a}, \vec{b}, \vec{c}$ and Bell's upper-bound of 0 is breached. So, (17)

as claimed in 1989 : Bell-(15) is false, his theorem refuted at its source: *QED.*■ (18)

for Bell-(14b) = (7) $\neq$ (6) = Bell-(14a); ie, in Bell 1964: (14b)$\neq$(14a). *QED.*■ (19)

[nb: LHS Bell-(14a) $= P(\vec{a}, \vec{b}) - P(\vec{a}, \vec{c})$ which gives fact (4), and thus (6).] So (20)

Bell's (1964:196-7) : "not possible" and "contradiction" are unjustified; *QED.*■ (21)

Bell's conclusion also – Bell (1964:199) − see Watson 2018e:¶5 too. Finally: *QED.*■ (22)

$\forall\, \vec{a}, \vec{b}, \vec{c}$ in (4)-(6): $0 \geq P(\vec{a}, \vec{b}) - P(\vec{a}, \vec{c}) - 1 + P(\vec{a}, \vec{b})P(\vec{a}, \vec{c})$; whereas for Bell in (7) (23)

for some $\vec{a}, \vec{b}, \vec{c}$: $\frac{1}{2} \geq |\,P(\vec{a}, \vec{b}) - P(\vec{a}, \vec{c})\,| - 1 - P(\vec{b}, \vec{c})$; as surmised at (14). *QED.*■ (24)

(iii) nb, wrt (13)-(15): with $(\vec{b}, \vec{c}) = (\vec{a}, \vec{c}) - (\vec{a}, \vec{b})$ from ¶2(ii) and using(12): if $\cos(\vec{a}, \vec{b}) \neq \cos(\vec{a}, \vec{c})$,

$$\text{Bell needs: } \cos[(\vec{a}, \vec{c}) - (\vec{a}, \vec{b})] - \cos(\vec{a}, \vec{b}) \cos(\vec{a}, \vec{c}) = \sin(\vec{a}, \vec{b}) \sin(\vec{a}, \vec{c}) \leq 0, \text{ as in (15).} \quad (25)$$

(iv) Now some physicists object, saying that our use of $P(\vec{a}, \vec{b}) = -\cos(\vec{a}, \vec{b})$ in (12) is invalid because Bell (against QT) wanted to keep open the possibility that this "quantum correlation" was false. Given Bell's "impossibility" claim below Bell-(3)—with its implication that a standard mathematical formulation for an average won't work in the EPR-Bohm experiment (EPRB): tho it does, see Watson 2018e:¶4—we find merit in this suggestion: for it helps explain Bell's acceptance of a result that is clearly false under QT. However, as stated in (12), and certainly consistent with our acceptance of QT: at Watson 2018e:(19) we derive this "quantum correlation" without QT. So, while (12) may be unavailable to Bell under his belief-system: (12) is clearly available to us, with QT's endorsement (and via that alone if necessary—see next—to allow our focus on Bell's errors to continue).

(v) So—and still "on Bell's terms"—we have the following Bellian analysis invoking QT:

'... . Thus $P(\vec{b},\vec{c})$ cannot be stationary at its minimum value (-1 at $\vec{b}=\vec{c}$) and cannot equal the quantum mechanical value $-\cos(\vec{b},\vec{c})$ from Bell-(3),' after Bell (1964:198).

(vi) Against this—and meeting all the quantum mechanical values—we again beat Bell's QT comparison. For our (6) reduces, via our (12) or Bell-(3), to another observationally-significant fact:

$$\forall\,\vec{a},\vec{b},\vec{c}: \cos(\vec{a},\vec{c})-\cos(\vec{a},\vec{b})-1+\cos(\vec{a},\vec{b})\cos(\vec{a},\vec{c}) = -4\sin^2\frac{(\vec{a},\vec{b})}{2}\cos^2\frac{(\vec{a},\vec{c})}{2} \le 0. \quad \textit{QED.}\blacksquare \quad (26)$$

(vii) With other Bellian errors corrected, see Watson (2018e), we rest our analysis here and conclude.

3. Conclusions

(i) Whatever the justification for Bell's (14b), it is mathematically false: for, given our hope that matters of fact here might be confirmed by observation, it leads to Fig.1(b). Note that, point-by-point, the performance of each screen may be audited with a hand-held calculator and the relevant relation, (6) or (7).

(ii) Moreover, whatever the triggering assumption, Bell-(14b) is also unwarranted. For, against Bell here, Watson (2018e) delivers—via true local realism—the same results as QT and observation; thus showing, independently, that Bell-(2) does equal Bell-(3) as we allowed in (12)-(13).

(iii) Further, under EPRB—ie, the context for Bell (1964)—Bell's (14b) is unphysical: akin, see Watson 2018e:¶7, to falsely inferring that naive-realism might succeed in Bohm's highly-correlated EPR/quantum setting: and not then dropping naive-realism when it failed.

(iv) So, in the context of our elementary mathematics, and on Bell's own terms, we rest our case:

Using irrefutable fact (3), Bell's famous Bell-(15) is refuted irrefutably. *QED.*■ (27)

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