Can this description of physical reality be considered complete?

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Abstract

To the question 'It from Bit or Bit from It?' this essay replies, 'It from Bit *and* Bit from It.' Bringing fun and substance to Wheeler's famous phrase, this wording and emphasis is backed by the creation of a new particle—the *first* It *from* Bit—*and* by the link that ends the EPR-Bell era—fusing EPR's missed Bit with Bell's missed It. Then—proving material objects more fundamental than information—a fresh big Bit from phantasmic It. That is, 'collapse'—so-called, and problematic in QM—is but a short-cut in a new mechanics, wholistic mechanics, wm, with its commonsense philosophy of wholistic-local-realism (WLR) and its aversion to subjectivity (replacing probability with prevalence). WM delivers a whole new particle family, while WLR itself, claiming its EPR-Bell birthright—uniting local-causality *(no causal influence propagates superluminally)* and physical-realism *(some physical properties change interactively)*—revives local causality in line with the early hopes of folks like Aspect, Bell, Clauser, Einstein, Podolsky, Rosen. Among findings reported from analysis judged fit for well-taught highschool seniors: Naive realism is a doctrine of limited value, being false in spin-entangled contexts; EPR is vulnerable to a naive-realistic interpretation; Bell's theorems and inequalities are constrained by their basis in naive realism; correlated tests on correlated particles produce correlated results—absent nonlocality, spooky-actions, mystery; like other valued shortcuts, QM wavefunctions and their collapse are abstractions; eliminate collapse, farewell nonlocality, predict with certainty the value of a physical quantity—for there exist elements of physical reality creating that quantity. Suggesting that WLR will feature in the future of physics, that wm will benefit from any and all comments and critiques, this essay invites us to join in the creative fun that goes with such research; and boldly requests: *Please respond critically.* In a word: Enjoy!

1 Notes to the Reader

> 'In the interest of clearness, it appeared to me inevitable that I should repeat myself frequently, without paying the slightest attention to the elegance of presentation,' Einstein (1916). May this essay bring you many happy hours of fun and critical thinking.

1. About: This essay is released early to allow extra time for public discussion and feedback, a missing link in the story so far. So please join the conversation, noting: (i) I learn best from my mistakes. (ii) I welcome and generally reply to all critical correspondence. As a rule, such will be best begun openly via the associated FXQi facilities, hopefully encouraging reticent others to also engage. (iii) Taking maths to be the best logic, rambling discourse is not expected. (iv) This is a working document, hyperlinking (see *References*) to key texts, commenting thereon. Such links minimize the need to repeat details in the essay, and allow sources to speak for themselves. (v) All results here accord with the sound experimental findings of others, none of which accord with Bell or related inequalities.
2. Errors: Errors and typos bug me, so please let me know of them all. I will report errors ASAP.
3. Conventions: If $\mathbf{u}$ and $\mathbf{v}$ are vectors, $(\mathbf{u};\mathbf{v})$ denotes the angle between them, $(\mathbf{u}:\mathbf{v})$ the swept angle $\mathbf{u}\to\mathbf{v}$. Given the maths emphasis here, once a term has a defined notation or abbreviation, such may be used in subsequent text. WM/wm (say *WHAM/wham*) and WLR are distinguishing marks.
4. Figures: Saving space/time/face, promoting discussion via FQXi, Figures are here left as exercises. I look forward to your creative responses; and my own when I learn how to draw in this environment.
5. Testing: Keen to test the waters? See discussion at equation (9): A new way to look at QM's *collapse* – a maths shortcut in the real physical dynamics of wm – makes *nonlocality* nonsensical.
6. Controversy: I cordially invite clear expressions of disagreement, dissent, etc; especially re the maths. This work will benefit from such, and I'm keen to soften the conditional in this early comment: *A remarkable result if true.*

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2 Introduction

> Einstein argues that 'EPR correlations can be made intelligible only by completing the quantum mechanical account in a classical way,' after Bell (2004:86). So let's do just that.

As an engineer, I'm keen to advance the science of understanding — the discipline that should IMO dominate the space between epistemology and ontology — a science astray in my view since local causality was taken by so many, post-Bell (1964), to be a lost cause. Thus, challenged by the question *It from Bit or Bit from It?*(FQXi 2013), replying, *It from Bit* ***and*** *Bit from It*, this essay will give facts to back that answer. It will also respond to the challenge seen here: "The past century in fundamental physics has shown a steady progression away from thinking about physics, at its deepest level, as a description of material objects and their interactions, and towards physics as a description of the evolution of information about and in the physical world,"(FQXi 2013).

Believing that any challenge to the science of understanding is best addressed from one's own comfort zone in the company of critical friends, let's see if we can together develop a united response to this It-Bit business, starting with a preface that's comfortable for me: Given FQXi's on-line facilities, our effort should be suited to well-taught highschool seniors — which means: in the company of teachers that understand the simplicity of the content here — *forever subject of course to our response being judged error-free.* Our work would then be accessible to a diverse, well-educated but non-specialist audience if they engage step-by-step with the maths and use FQXi facilities when required.

So, studying the interaction of tiny material objects (Its) in the fashion of *old physics* — creating new information (Bits) in the manner of *old maths* — let's together lift the locally causal hopes of many via the simple constructive model of Bell's dreams. For surely, with wholistic mechanics (wm; Watson 1998; 1999) — (i) embracing wholistic-local-realism (WLR) with its fusion of local-causality *(no causal influence propagates superluminally)* and physical-realism *(some physical properties change interactively);* (ii) endorsing EPR's (1935:777) condition of completeness, *Every element of the physical reality must have a counterpart in the physical theory;* (iii) rejecting the naive realism associated with EPR's *elements of physical reality;* (iv) surprising with its soon-to-be-seen particle family $p(\lambda_{wn+i})$ — we can deliver Bell's (2004:167) hope for the future of physics.

> "To those for whom nonlocality is anathema, Bell's Theorem finally spells the death of the hidden variables program.[31] But not for Bell. None of the no-hidden-variables theorems persuaded him that hidden variables were impossible," Mermin (1993:814). (#31: "Many people contend that Bell's Theorem demonstrates nonlocality independent of a hidden-variables program, but there is no general agreement about this.") "Indeed it was the explicit representation of quantum nonlocality [in de Broglie-Bohm theory] which started a new wave of investigation in this area [of local causality]. Let us hope that these analyses also may one day be illuminated, perhaps harshly, by some simple constructive model. However that may be, long may Louis de Broglie continue to inspire those who suspect that what is proved by impossibility proofs is lack of imagination," (Bell 2004:167).

So, from the lively interplay of It+Bit+imagination, with maths our best logic, let's build such a model — fully formulated mathematically in local-realistic terms, physically precise. For surely natural physical variables[1] alone (without mystery) account for the correlated results produced by correlated tests on correlated things. Taking information[2] to be less fundamental than material objects, let's go after Bell's own analyses, especially Bell (1964). Let's go on to reveal the dynamics that underpin QM's abstractions, to thus eliminate *collapse*, mystery, nonlocality and spooky-actions from QM and deliver that great Planck-Einstein-Bohm-Bell goal in our own terms: The quantum is classical.

3 Bell's 1964:(2) theorem

$$\textbf{If } A(\mathbf{a},\lambda)=A^{\pm}=\pm1,\ B(\mathbf{b},\lambda)=B^{\pm}=\pm1, \int d\lambda\rho(\lambda)=1, \tag{1}$$

$$\textbf{then } \langle AB\rangle \equiv \int d\lambda\rho(\lambda)A(\mathbf{a},\lambda)B(\mathbf{b},\lambda)\neq -\mathbf{a}.\mathbf{b}. \tag{2}$$

Deferring *What-is and What-is-not Bell's theorem (BT),* let's agree that (1)-(2) represent a fair reading of Bell's 1964:(2) theorem: $A^{\pm}$ and $B^{\pm}$ anticipate our use of such; $\langle AB\rangle$ replaces Bell's $P(\mathbf{a},\mathbf{b})$ notation to avoid confusion with probability functions; $\neq$ is a Bell-inequality with generous conditions, ie,

[1]Unlike *observables,* natural physical variables are *beables* – elements of reality, things which exist, their existence independent of *measurement* and *observation* – after Bell (2004:174).

[2]Not confusing primordiality with importance, just wondering out loud: Isn't information all about correlations too?

for Bell and his λ, "It is a matter of indifference ... whether λ denotes a single variable or a set, or even a set of functions, and whether the variables are discrete or continuous," Bell (1964:195). With a later phrasing – "let λ denote any number of hypothetical additional complementary variables needed to complete quantum mechanics in the way envisaged by EPR," Bell (2004:242). NB: the only constraint on *our* $\boldsymbol{\lambda}$ will be its basis in a beable.

To derive his inequality, Bell goes beyond (1)-(2) and invokes **c** (a third unit vector) in the unnumbered equations that follow his 1964:(14). If we number them (14a)-(14c), Bell equates (14b) to (14a). So let's now see the unphysical restriction required for this Bellian equality to go through.

4 Difference: Bell's missed It

Since A, B, C are discrete, Bell's integrals may be replaced by sums. Further, as we recall:

> It's a matter of indifference hereunder "whether λ denotes a single variable or a set, or even a set of functions, and whether the variables are discrete or continuous," Bell (1964:195).

So let's rewrite Bell's 1964:(14a) in these new terms. For generality, let λ be a random unit vector in 3-space; a uniform distribution with consequent probability zero that two λs or two particle-pairs are the same, though we'll tend not to comment on such probabilities henceforth. Then, with index i denoting the particle number, let n be such that, to an adequate accuracy hereafter,

$$\text{Bell's (14a)} = \langle AB\rangle - \langle AC\rangle = -\frac{1}{n}\sum_{i=1}^{n}[A(\mathbf{a},\lambda_i)A(\mathbf{b},\lambda_i) - A(\mathbf{a},\lambda_{n+i})A(\mathbf{c},\lambda_{n+i})] \tag{3}$$

$$= \frac{1}{n}\sum_{i=1}^{n} A(\mathbf{a},\lambda_i)A(\mathbf{b},\lambda_i)[A(\mathbf{a},\lambda_i)A(\mathbf{b},\lambda_i)A(\mathbf{a},\lambda_{n+i})A(\mathbf{c},\lambda_{n+i}) - 1]. \tag{4}$$

(4) is the discrete form of Bell's (14a). And Bell's (14c) is a valid conclusion from (14b). So, if (14b) = (14a), the related components of (4) and (14c) should be equal. Let $\stackrel{?}{=}$ identify Bell's suspicious equality under these conditions. Then,

$$\text{from Bell's (14c): } \langle BC\rangle \equiv -\frac{1}{n}\sum_{i=1}^{n} A(\mathbf{b},\lambda_i)A(\mathbf{c},\lambda_i) = -\frac{1}{n}\sum_{i=1}^{n} A(\mathbf{b},\lambda_{n+i})A(\mathbf{c},\lambda_{n+i}) \tag{5}$$

$$\stackrel{?}{=} -\frac{1}{n}\sum_{i=1}^{n} A(\mathbf{a},\lambda_i)A(\mathbf{b},\lambda_i)A(\mathbf{a},\lambda_{n+i})A(\mathbf{c},\lambda_{n+i});\ \text{from (4)}. \tag{6}$$

To support Bell's (14a) = (14b) — and remove our **?** from (6) — we would require the impossible $\lambda_i = \lambda_{n+i}$. For by definition, physical context, and from Bell's own λ-license: $\lambda_i \neq \lambda_{n+i}$. So here's a new Bell-inequality: (14b) $\neq$ (14a)! For

$$-\frac{1}{n}\sum_{i=1}^{n} A(\mathbf{a},\lambda_i)A(\mathbf{b},\lambda_i)A(\mathbf{a},\lambda_{n+i})A(\mathbf{c},\lambda_{n+i}) \neq -\frac{1}{n}\sum_{i=1}^{n} A(\mathbf{b},\lambda_i)A(\mathbf{c},\lambda_i). \tag{7}$$

So that famous inequality in (2), the source of many others, is just a slip like many make in maths. Indeed most, arriving at Bell's conclusions, would revisit the maths *tout de suite*. But there it is, the difference between pass and fail: Particle $p(\lambda_{n+i})$ is Bell's missed It; (7) is the Bellian community's missed Bit. But let's be cautious: An alternate route via *naive realism* might mask Bell's mistake — for Bell-inequalities do flow from that assumption — so let's feature a fine definition of naive realism in physics and take that route to Bell's next misstep.

5 Naive realism defined

In the context of the $\neq$ in (7), and going beyond the impossible $\lambda_i = \lambda_{n+i}$, here's Bell's (2004:147) endorsement of naive realism in physics: "To explain this dénouement without mathematics I cannot do better than follow d'Espagnat (1979; 1979a). Let us return to the socks for a moment. ..."

> 'One can infer that in *every particle-pair* [in every pair of socks], one particle [one sock] has the property A^+ and the other has the property A^-, one has property B^+ and one B^-, and one has property C^+ and one C^-. Such conclusions require a subtle but important extension of the meaning assigned to our notation A^+ . Whereas previously A^+ was merely one possible outcome of a measurement made on a particle [made on a sock], it is converted by this argument into an attribute of the particle [the sock] itself,' paraphrasing d'Espagnat (1979:166); [text] inserted to provide continuity.

That is, in our terms, Bell's $\lambda \in \{A^\pm B^\pm C^\pm\}$. With $|\{A^\pm B^\pm C^\pm\}| = 8$, maybe $\lambda_1 = A^+B^+C^+$, $\lambda_2 = A^+B^+C^-$, ..., $\lambda_8 = A^-B^-C^-$*?* This is the restrictive assumption of naive realism that we reject — a product of Bell's (2004:242) interpretation of EPR. With Bell's inequality in (2) now on more limited grounds than those associated with the equally impossible $\lambda_i = \lambda_{n+i}$ — also impossible because unphysical — let's next study EPRB on the way to showing that Bell's 1964:(2) is false.

6 The EPRB experiment

Let $\alpha\beta$ denote the EPRB experiment (Bell 1964), and let Alice and Bob be our free-willed friends. α (respectively β) denotes Alice's (Bob's) experiment and each $\alpha\beta$ experiment consists of many paired tests via local interactions. Let unit vector $\mathbf{a}$ ($\mathbf{b}$) in 3-space denote the freely-selected principal-axis orientation of $\hat{\boldsymbol{A}}$ ($\hat{\boldsymbol{B}}$), the α (β) Stern-Gerlach device (SGD).

Let unit vector $\boldsymbol{\lambda}$ ($\boldsymbol{\lambda}'$) denote the *pristine* (*pre-test*) orientation of an α (β) particle's total angular momentum (a beable) in 3-space. Then, via the pair-wise conservation of total angular momentum in $\alpha\beta$, $\boldsymbol{\lambda}+\boldsymbol{\lambda}' = 0$ prior to each test (#19.2). Moreover, varying randomly from test to test, it's probability zero that $\boldsymbol{\lambda}$ ($\boldsymbol{\lambda}'$) equals $\pm\mathbf{a}$ ($\pm\mathbf{b}$).

Let $\hat{\boldsymbol{A}}\boldsymbol{\lambda}$ ($\hat{\boldsymbol{B}}\boldsymbol{\lambda}'$ similarly) denote the local interaction (disturbance, test) which transitions $\boldsymbol{\lambda}$ to $\boldsymbol{\lambda}^\pm \equiv \mathbf{a}^\pm = \pm\mathbf{a}$; ie, to a concluded transition (post-test orientation) denoting *spin-up* or *spin-down* with respect to $\mathbf{a}$. Let $\mathbf{P}$ denote a *normalised prevalence function* (equivalent to a conventional event-focused probability function, devoid of subjectivity; see #19.3). Let $\mathbf{P}(\mathbf{a}^+|\alpha)$ be shorthand for the absolute (*marginal*) prevalence $\mathbf{P}(\hat{\boldsymbol{A}}\boldsymbol{\lambda}{=}\mathbf{a}^+|\alpha)$; with $\mathbf{P}(\mathbf{b}^+|\alpha\beta, \mathbf{a}^+)$ short for the relative prevalence $\mathbf{P}(\hat{\boldsymbol{B}}\boldsymbol{\lambda}'{=}\mathbf{b}^+|\alpha\beta, \hat{\boldsymbol{A}}\boldsymbol{\lambda}{=}\mathbf{a}^+)$; etc.

Thus, given binary results $\mathbf{a}^\pm$ and random $\boldsymbol{\lambda}$, $\mathbf{P}(\mathbf{a}^+|\alpha) = \mathbf{P}(\mathbf{a}^-|\alpha) = 1/2$ via symmetry. Then, in full accord with reciprocal causal independence and local-causality *(ie, no causal influence propagates superluminally)*, a mandatory boundary condition on our analysis is this: $A^\pm$ is causally independent of $B^\pm, \hat{\boldsymbol{B}}, \mathbf{b}, \mathbf{b}^\pm, \boldsymbol{\lambda}'$; $B^\pm$ is causally independent of $A^\pm, \hat{\boldsymbol{A}}, \mathbf{a}, \mathbf{a}^\pm, \boldsymbol{\lambda}$.

However: *These causally-independent results are correlated*, consistent with the law of linked correlations: correlated tests (interactions, disturbances) on correlated things produce correlated outcomes. But before addressing $\alpha\beta$'s correlative chain, let's first come to grips with disturbance.

7 Disturbance: EPR's missed Bit

EPR's early paragraphs make great reading. But this next? Does it not hit you? EPR's missed bit?

> "We shall be satisfied with the following criterion, which we regard as reasonable. If, without any way disturbing a system, we can predict with certainty (ie, with probability equal to unity) the value of a physical quantity, then there exists an element of physical reality corresponding to this physical quantity," EPR (1935:777).

I avoid *reasonable*,[3] preferring *reasoned* and *reasoning*; I'm troubled by the meaning of *corresponding* (*according, agreeing, conforming, fitting, matching, tallying*); then there's *there exists* with its naive-realistic streak; and from simply living there's a seriously disturbing missed bit. So, with that missed bit in place, here's a more reasoned general criterion for all:

> "If, without in any way disturbing a particle $p(\boldsymbol{\lambda})$, we can predict with certainty the result $A^\pm$ of an interaction $\hat{\boldsymbol{A}}\boldsymbol{\lambda}$ — $\equiv p(\boldsymbol{\lambda}) \to \hat{\boldsymbol{A}}(\mathbf{a})$, which will be a disturbance — then beables $\boldsymbol{\lambda}$ and $\hat{\boldsymbol{A}}$ create this result. That is: $A^\pm = A(\mathbf{a}, \hat{\boldsymbol{A}}\boldsymbol{\lambda}) = \mathbf{a}.\hat{\boldsymbol{A}}\boldsymbol{\lambda} = \mathbf{a}.\mathbf{a}^\pm = \pm 1$; etc; a notation that accords with Bell (1964) and our (1)," after Watson (1998:417; 1999).

[3]See Bell and *reasonable* in Bernstein (1991:84); quoted below. Read Bell's *reasoning* in Bell (1990).

For this criterion, and *against* EPR's, we have: "The whole of science is nothing more than the refinement of every day thinking," Einstein (1936:349), and even we know from the daily physics of fragile lives, *some physical properties change interactively.* Then, in micro-physics, we have "no infinitesimals by the aid of which an observation might be made without appreciable perturbation," Heisenberg (1930:63).[4] And "surely the big and the small should merge smoothly with one another? And surely in fundamental physical theory this merging should be described not just by vague words but by precise mathematics?" Bell (2004:190). Then there's Bohr's oft-forgotten insight "that the result of a *measurement* does not in general reveal some preexisting property of the *system*, but is a product of both *system* and *apparatus*. It seems to me that full appreciation of this would have aborted most of the *impossibility proofs*, and most of *quantum logic*," after Bell (2004:xi-xii).

8 Intermission: Einstein wrong? Bell right?

> "The discomfort that I feel is associated with the fact that the observed perfect quantum correlations seem to demand something like the 'genetic' hypothesis [identical twins, carrying identical genes]. For me, it is so reasonable to assume that the photons in those [Aspect] experiments carry with them programs, which have been correlated in advance, telling them how to behave. This is so rational that I think that when Einstein saw that, and the others refused to see it, *he* was the rational man. The other people, although history has justified them, were burying their heads in the sand. I feel that Einstein's intellectual superiority over Bohr, in this instance [the quantum theory of measurement], was enormous; a vast gulf between the man who saw clearly what was needed, and the obscurantist. So for me, it is a pity that Einstein's idea [of classical, causal reality] doesn't work. The reasonable thing just doesn't work," Bell in Bernstein (1991:84); three [sic]s withheld.

9 The law of linked correlations

In the context of $\alpha\beta$, we now move to a mathematical representation of *the law of linked correlations: correlated tests, interactions, disturbances on correlated things produce correlated results, without mystery.* Via the symmetries in $\alpha\beta$, we can associate a result-vector (RV) $=$ $\mathbf{a}^{\pm}$ ($\mathbf{b}^{\pm}$) with a setting-vector (SV) $= \pm\mathbf{a}$ ($\pm\mathbf{b}$); ie, with $\sim$ denoting equivalence:

$$A^{\pm} \sim \mathbf{a}^{\pm} = \pm\mathbf{a};\ B^{\pm} \sim \mathbf{b}^{\pm} = \pm\mathbf{b}.\ \phi \equiv (\mathbf{a};\mathbf{b}).\ \boldsymbol{\lambda}^{\pm} \equiv \mathbf{a}^{\pm};\ \boldsymbol{\lambda}'^{\pm} \equiv \mathbf{b}^{\pm};\ (\boldsymbol{\lambda}^{\pm};\boldsymbol{\lambda}'^{\pm}) = (\mathbf{a}^{\pm};\mathbf{b}^{\pm}); \tag{8}$$

with ϕ there by way of definition; the particle-vector (PV) relations by way of reminders.

Correlated entities	*WM designation*	*Notation*	*Correlated by*	*Ref.*
Correlated tests	Correlated interactions	$\hat{\boldsymbol{A}}\boldsymbol{\lambda}$, $\hat{\boldsymbol{B}}\boldsymbol{\lambda}'$	See next row	(9.1)
Correlated things	Correlated SGDs	$\hat{\boldsymbol{A}}(\mathbf{a})$, $\hat{\boldsymbol{B}}(\mathbf{b})$	$\phi \equiv (\mathbf{a};\mathbf{b})$	(9.2
	Correlated particles	$p(\boldsymbol{\lambda})$, $p'(\boldsymbol{\lambda}')$	$(\boldsymbol{\lambda};\boldsymbol{\lambda}') = \pi$	(9.3)
Correlated results	Correlated SGD outputs	$A^{\pm}B^{\pm}$	$(\mathbf{a}^{\pm};\mathbf{b}^{\pm})$	(9.4
	Angular disturbance $\boldsymbol{\lambda}$	$\phi^{\pm}$	$(\boldsymbol{\lambda};\mathbf{a}^{\pm})$	(9.5)
	Angular disturbance $\boldsymbol{\lambda}'$	$\phi'^{\pm}$	$(\boldsymbol{\lambda}';\mathbf{b}^{\pm})$	(9.6)
	Relative angular disturbance	$\phi^{\pm\pm} \equiv (\boldsymbol{\lambda}^{\pm};\boldsymbol{\lambda}'^{\mp})$	$(\mathbf{a}^{\pm};\mathbf{b}^{\mp})$	(9.7)
	Relative prevalence of results	$\mathbf{P}(B^{\pm}\lvert\alpha\beta A^{\pm})$	$\cos^2 s\phi^{\pm\pm}$	(9.8)

Table 1. The law of linked correlations at work in $\alpha\beta$ (EPRB).

So, recognizing that physical disturbance[5] also disturbs related symmetries, we now outline the correlative links in $\alpha\beta$ that lead to Table 1; the core relation there being (9.8): *The relative prevalence of results is related to the relative angular disturbance of inputs.* (i) Spacelike separated tests $\hat{\boldsymbol{A}}\boldsymbol{\lambda}$ and $\hat{\boldsymbol{B}}\boldsymbol{\lambda}'$ are correlated in this way: $\hat{\boldsymbol{A}}$ and $\hat{\boldsymbol{B}}$ are correlated by ϕ — with symmetry maintained if $\phi = 0$; and each pristine particle-pair is correlated by $(\boldsymbol{\lambda};\boldsymbol{\lambda}') = \pi$ — symmetry maintained if interaction-free

[4]WM's mathematical probes lift some of the veil on this precursor and its consequent, d'Espagnat's *veiled reality.*

[5]Our maths is expressed in terms of swept angles, with each $\hat{\boldsymbol{A}}\boldsymbol{\lambda}$ interaction a disturbance driven by $\pm s\hbar$; eg, under the condition $\phi = 0$, the emerging $\alpha\beta$-paired particle vectors are still antiparallel *but their correlative power is much reduced vis-à-vis their pristine state.* SGD-induced disturbances are thus akin to those of wire-grid polarizers on microwaves.

or if $\phi = 0$. (ii) From (8), each $A^{\pm}$ ($B^{\pm}$) result is correlated with $\mathbf{a}^{\pm}$ ($\mathbf{b}^{\pm}$). (iii) So each $A^{\pm}B^{\pm}$ pair is correlated by a function of $(\mathbf{a}; \mathbf{b})$.

Let the absolute angular disturbance $\phi^{\pm} \equiv (\boldsymbol{\lambda} : \mathbf{a}^{\pm})$ ($\phi'^{\pm} \equiv (\boldsymbol{\lambda}' : \mathbf{b}^{\pm})$) denote the angle swept out by the disturbance of pristine $\boldsymbol{\lambda}$ ($\boldsymbol{\lambda}'$) to $\mathbf{a}^{\pm}$ ($\mathbf{b}^{\pm}$) during the interaction $\hat{\boldsymbol{A}}\boldsymbol{\lambda}$ ($\hat{\boldsymbol{B}}\boldsymbol{\lambda}'$). The colon ':' in each definition signals that the signs ($\pm$) allocated to the swept angles $\phi^{\pm}$ and $\phi'^{\pm}$ must be consistent.

Thus Alice (Bob) *freely, independently, locally* influences $\phi^{\pm}$ ($\phi'^{\pm}$) and the corresponding result $A^{\pm}$ ($B^{\pm}$) via each free choice of $\mathbf{a}$ ($\mathbf{b}$). So let's now see how the relative angular disturbance, the *relative rotation* of $\boldsymbol{\lambda}$ with respect to $\boldsymbol{\lambda}'$ (or vice versa) — $\phi^{\pm\pm} \equiv \Phi(\phi^{\pm}, \phi'^{\pm})$ — is jointly dependent on Alice and Bob:

$$\phi^{\pm\pm} = \Phi[(\boldsymbol{\lambda} : \mathbf{a}^{\pm}),\ (\boldsymbol{\lambda}' : \mathbf{b}^{\pm})] = |(\boldsymbol{\lambda} : \mathbf{a}^{\pm}) - (\boldsymbol{\lambda}'^{*} : \mathbf{b}^{\pm})| = |(\boldsymbol{\lambda}' : \mathbf{b}^{\pm}) - (\boldsymbol{\lambda}^{*} : \mathbf{a}^{\pm})| = (\mathbf{a}^{\pm}; \mathbf{b}^{\mp}); \tag{9}$$

where $\boldsymbol{\lambda}^{*}(\boldsymbol{\lambda}'^{*})$ denotes the vector $\boldsymbol{\lambda}$ ($\boldsymbol{\lambda}'$) rotated into the $\mathbf{a}-\mathbf{b}$ plane. $(\boldsymbol{\lambda}^{*} : \mathbf{a}^{\pm})$ $((\boldsymbol{\lambda}'^{*} : \mathbf{b}^{\pm}))$ is then the relevant swept angle. (For the physical significance of that rotation, see #19.2.)

(9) is pure geometry, readily understood via a thought-experiment: To appreciate (9), do this: Picture $\hat{\boldsymbol{A}}\boldsymbol{\lambda}$ concluding; $\boldsymbol{\lambda}^{\pm}$ ($= \mathbf{a}^{\pm}$) then exists. Next, return the relative angular disturbance to zero by rotating $\boldsymbol{\lambda}'$ to $\mathbf{a}^{\mp}$.[6] With $\hat{\boldsymbol{B}}\boldsymbol{\lambda}'$ concluding when $\boldsymbol{\lambda}'^{\pm}$ ($= \mathbf{b}^{\pm}$) exists, the relative angular disturbance will thus be $(\mathbf{a}^{\mp}; \mathbf{b}^{\pm}) = (\mathbf{a}^{\pm}; \mathbf{b}^{\mp})$. QED.

To understand (9) and how that thought-experiment works: Create Fig. 1 and draw Fig. 2.

Figure 1: An attractive low-cost 3D model for understanding every variant of (9). (Hint: See Fig. 2.)

Figure 2: (i) From Fig. 1, a representation of the arbitrary spherical triangle XYZ on a unit sphere; $OX = \mathbf{a}$, OY $=\mathbf{b}$, $OZ = \boldsymbol{\lambda}$; ie, to be clear: $\mathbf{a}$ freely chosen by you/Alice; $\mathbf{b}$ freely chosen by your partner/Bob; $\boldsymbol{\lambda}$ random. (ii) The unit sphere sectioned on the $\mathbf{a}-\mathbf{b}$ plane with $\boldsymbol{\lambda}$ in the background; showing $\phi = (\mathbf{a}; \mathbf{b})$, hence $(\mathbf{a}^{\pm}; \mathbf{b}^{\pm})$. (iii) The $\mathbf{a}-\mathbf{b}$ plane with $\boldsymbol{\lambda}$ (also $\boldsymbol{\lambda}'$) rotated into it, preserving $(\boldsymbol{\lambda}, \mathbf{a})$, thus showing $(\boldsymbol{\lambda} : \mathbf{a}^{\pm})$ and $(\boldsymbol{\lambda}'^{*} : \mathbf{b}^{\pm})$. (iv) Diagram (iii) annotated, showing that the results, per (9), agree with the results from Fig. 1 and #19.5.

10 Noncontextuality?

Thus $\phi^{\pm\pm}$ is *a correlative function applicable to every $\alpha\beta$ particle-pair* at the instant each SGD is set; a function reflecting the correlation of spacelike separated events – ie, the results that flow from Alice (Bob) freely setting available outcomes $\mathbf{a}^{\pm}$, via $\mathbf{a}$ ($\mathbf{b}^{\pm}$, via $\mathbf{b}$) – their independent local actions also spacelike separated; a fact in our maths from the start. So (9) reduces an infinity of interactions and relationships to one function; making it clear and understandable that events in Alice's locale *have no influence whatsoever* on spacelike separated events in Bob's locale; and vice versa.

In the context of angular momentum, such determined responses suggest *spin-torque-precession* – the *genetics⇄dynamics* hypothesis – *from such simplicity, Nature's great beauty,* after Feynman (1992:173). And from such simplicity — $\phi^{\pm}$ and $\phi'^{\pm}$ are *independent,* a foundational feature of our model (see #19.4) — there are new challenges (to be addressed below) re the meaning and relevance of *noncontextuality*, etc.

[6] Matching the pristine baseline $(\boldsymbol{\lambda}; \boldsymbol{\lambda}') = \pi$ with $(\mathbf{a}^{\pm}; \boldsymbol{\lambda}') = \pi$ here, this wm shortcut is QM's *collapse*.

11 Bell's theorem refuted

We now apply the law of relative prevalence for events correlated under condition $\alpha\beta$: a law confirmed by analyzing many tests on spin-entangled photons ($s = 1$); eg, Aspect (2002). That is, with $s = 1/2$ for the spin-half particles in $\alpha\beta$, using (9) and #19.3,

$$\mathbf{P}(B^{\pm}|\alpha\beta, A^{\pm}) = \mathbf{P}(\mathbf{b}^{\pm}|\alpha\beta, \mathbf{a}^{\pm}) = \cos^2 s\phi^{\pm\pm} = cos^2[(\mathbf{a}^{\pm}; \mathbf{b}^{\mp})/2] = \sin^2[(\mathbf{a}^{\pm}; \mathbf{b}^{\pm})/2]; \text{etc.} \tag{10}$$

So, in expanded form, with brief explanatory comments to follow:

$$\langle AB \rangle = -\frac{1}{n}\sum_{i=1}^{n} A(\mathbf{a}, \boldsymbol{\lambda}_i)A(\mathbf{b}, \boldsymbol{\lambda}_i) \tag{11}$$

$$= \mathbf{P}(A^+B^+|\alpha\beta) - \mathbf{P}(A^+B^-|\alpha\beta) - \mathbf{P}(A^-B^+|\alpha\beta) + \mathbf{P}(A^-B^-|\alpha\beta) \tag{12}$$

$$= \mathbf{P}(\mathbf{a}^+\mathbf{b}^+|\alpha\beta) - \mathbf{P}(\mathbf{a}^+\mathbf{b}^-|\alpha\beta) - \mathbf{P}(\mathbf{a}^-\mathbf{b}^+|\alpha\beta) + \mathbf{P}(\mathbf{a}^-\mathbf{b}^-|\alpha\beta) \tag{13}$$

$$= \mathbf{P}(\mathbf{a}^+|\alpha)\mathbf{P}(\mathbf{b}^+|\alpha\beta, \mathbf{a}^+) - \mathbf{P}(\mathbf{a}^+|\alpha)\mathbf{P}(\mathbf{b}^-|\alpha\beta, \mathbf{a}^+)$$

$$-\mathbf{P}(\mathbf{a}^-|\alpha)\mathbf{P}(\mathbf{b}^+|\alpha\beta, \mathbf{a}^-) + \mathbf{P}(\mathbf{a}^-|\alpha)\mathbf{P}(\mathbf{b}^-|\alpha\beta, \mathbf{a}^-) \tag{14}$$

$$= \frac{1}{2}\sin^2[(\mathbf{a}^+; \mathbf{b}^+)/2] - \frac{1}{2}\sin^2[(\mathbf{a}^+; \mathbf{b}^-)/2] - \frac{1}{2}\sin^2[(\mathbf{a}^-; \mathbf{b}^+)/2] + \frac{1}{2}\sin^2[(\mathbf{a}^-; \mathbf{b}^-)/2] \tag{15}$$

$$= \sin^2[(\mathbf{a}; \mathbf{b})/2] - \cos^2[(\mathbf{a}; \mathbf{b})/2] = -\cos(\mathbf{a}; \mathbf{b}) = -\mathbf{a}.\mathbf{b}. \quad \mathbf{QED}. \tag{16}$$

That is: Given (11), (12) represents $\langle AB \rangle$ as the weighted sum of the joint $\alpha\beta$ test values ± 1; (13) follows, using (8). (14) follows from the product rule for joint prevalence, given correlations; see #19.3. (15) follows from (9); (16) from trigonometry. So, with $\neq$ in (2) false, this BT is refuted. QED.

12 Testing Bell's 1964:(14b) – and others

To prove that Bell's (14b) is an error leading to absurdities (denoted $\perp$ below), we use Bell's 1964:(15). It's a valid conclusion from, and hence a sound surrogate for his (14b):

$$1 + \langle BC \rangle = 1 - \mathbf{b}.\mathbf{c} \quad \geq \quad |\mathbf{a}.\mathbf{c} - \mathbf{a}.\mathbf{b}| = |\, \langle AB \rangle - \langle AC \rangle \,|, \tag{17}$$

using our (16). Let $(\mathbf{a}, \mathbf{b}) = (\mathbf{b}, \mathbf{c}) = \phi$, $(\mathbf{a}, \mathbf{c}) = 2\phi$, with an inanity-index $\boldsymbol{I}$ ($\boldsymbol{I} > 0$ revealing absurdity):

$$\boldsymbol{I}_{\boldsymbol{Bell(1964)}} \equiv \frac{RHS(17)}{LHS(17)} - 1 = \frac{|\mathbf{a}.\mathbf{c} - \mathbf{a}.\mathbf{b}|}{1 - \mathbf{b}.\mathbf{c}} - 1 = \frac{|\cos 2\phi - \cos\phi|}{1 - \cos\phi} - 1; \tag{18}$$

$$\text{whence, for } -\pi/2 < \phi < \pi/2 : \ \boldsymbol{I}_{\boldsymbol{Bell(1964)}} > 0; \ \perp \tag{19}$$

$$\text{with } \lim_{\phi\to 0} \boldsymbol{I}_{\boldsymbol{Bell(1964)}} = 2. \ \perp \tag{20}$$

Such is the basis of BT, the numbers via WolframAlpha (2013). Moreover, given Bell's introduction to his 1964:(8), recalling that no two particle-pairs are the same, no pristine pair tested twice: (20) is the setting you'd expect to find in critical discussions of BT.

Similar anomalies attach to Bell-inequalities exemplified by the CHSH inequality (Peres 1995:164). Let A, B, C, D independently equal ± 1 randomly. Then, in our terms – referring to (3) with the same (immediately above) recalling – the truism

$$B(A + C) + D(A - C) \equiv \pm 2 \text{ does not ensure that} \tag{21}$$

$$A_iB_i + B_{n+i}C_{n+i} + A_{2n+i}D_{2n+i} - C_{3n+i}D_{3n+i} \equiv \pm 2; \tag{22}$$

thanks to the $p(\lambda_{wn+i})$ family. All naively-realistic Bell inequalities fall to the same analysis.

13 Another Bell theorem

We now turn to Bell's view – eg, Bell (2004:243) and Bell's move there from his (9) to his (10) – that *causal independence* should equate to *statistical independence*, seen as a consequence of *local causality*. However, as shown above: A correlative chain, not causation, links the causally independent results in (1) to the local-realistic correlations in our (10). Bell unwittingly supports our analysis:

"There are no *messages* in one system from the other. The inexplicable [sic] correlations of quantum mechanics do not give rise to signaling between noninteracting systems. Of course, however, there may be correlations (eg, those of EPRB) and if something about the second system is given (eg, that it is the other side of an EPRB setup) and something about the overall state (eg, that it is the EPRB singlet state) then inferences from events in one system (eg, *yes* from the *up* counter) to events in the other (eg, *yes* from the *down* counter) are possible," Bell (2004:208).

For such inferences – from one event to another spacelike separated from it – proceed from the linked correlations of spacelike separated events shown above; #19.6.

14 Future directions

Freely offered to the quantum community in 1989 (see #19.7), future directions will very much depend on critical responses to this essay; such responses long overdue. Given $\phi^{\pm}$ and $\phi'^{\pm}$ and their independence (#19.4), the theory is well-suited to interpret the history and use of strange terms in QM, and to debunk them. One such term is *nonlocal.* Another *noncontextual,* from Kochen-Specker's (1967) theorem to reports on the Kirchmair+(2009) experiment (#19.8), etc. There is also Mermin (1990) and Peres (1990) and their 3×3 square (#19.8). Educational projects include the documentation of *Missed Bits* and *Bellian syllogisms*, as follows.

15 Missed Bits

To understand Bits missed in past analyses of BT – bits which void related conclusions – let's begin by creating Fig. 3; an exercise to test wm against a recent well-regarded essay.

Figure 3: The causal dynamics and correlative relations in a complete wm specification of EPRB (Bell 1964); after Spekkens (2012:Fig. 1). His S, T, X, Y and λ are replaced by wm-Its (beables). WM-Bits (information = correlative relations) are shown via labeled dashed-lines. A complete wm specification of EPRB (Bell 1964) is thus provided. Consistent with WLR, the correlative relations void his second (unnumbered) equation and many conclusions.

16 Bellian syllogisms

Turning now to our prior deferral: *What-is and What-is-not BT?* Let this be an exercise in which we source and share Bell-related syllogisms. The aim is to record and discuss such in the context of *validity* and *truth.* A basis for discussion is this: The first sentence in a syllogism is the *major premise*, the second sentence is the *minor premise*, the third sentence is the *conclusion.* To start the ball rolling, here's one view of BT:

· All common-cause correlations satisfy inequality X. Some quantum correlations violate inequality X. Some quantum correlations are not common-cause correlations. (Private source.)

Seeking syllogisms that are *valid and true*, the major premise in this example is false. In the Bell literature, expect to see the following conclusion confirmed repeatedly: From one false premise, folly follows.

17 Conclusions

Seeking to advance the science of understanding via classical analysis judged fit for well-taught high-school seniors, some significant findings follow:

- · 17.1 Unaffected by Bell's work, and improving QM, WLR remains a sound philosophy.
- · 17.2 Correlated disturbances on correlated particles produce correlated results without mystery.
- · 17.3 The law of linked correlations is confirmed.
- · 17.4 Bell's naive realism is false in spin-entangled contexts.
- · 17.5 Our successful analysis is surely close to EPR's intentions.
- · 17.6 Against Bell (1964), the experimental evidence fully supports our analysis.
- · 17.7 Bell's later theorems and inequalities similarly fall to experiment and our analysis.
- · 17.8 QM *collapse* is an abstraction that clouds the underlying physical dynamics.
- · 17.9 With *collapse* eliminated via physically significant analysis, *nonlocality* remains nonsensical.
- · 17.10 Reciprocal causal independence remains the commonsense at the heart of local-realism.
- · 17.11 The law of relative prevalence is confirmed.
- · 17.12 Absent nonlocality, mystery, spooky-actions, the underlying physics is fully comprehensible.
- · 17.13 The quantum is classical, Planck and Einstein were right.
- · 17.14 In Bell's terms, our equations need not be talked away from time to time.
- · 17.15 QM, to become rational, requires small changes based on physically significant analysis.
- · 17.16 The hopes of Einstein and Bell prevailing, wm does not conflict with Lorentz invariance.
- · 17.17 From the results herein, Bell's *"silly"* references to von Neumann need an asterisk.
- · 17.18 Bellian syllogisms will repeatedly confirm: From one false premise, folly follows.
- · 17.19 Such fun results, such easy maths? WM is surely fit for well-taught highschool seniors.
- · 17.20 The science of understanding and this theory will improve via open communication.

To begin that process, a question: Is wm's description of EPRB complete? **Please respond critically**. Thanks!

18 References

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19 Technical endnotes

· 19.1 Where wm maths here meets QM theorems and experiments, I'm confident that there are few faults here. However, where my words meet QM words, technical difficulties might arise. *Knowing very little QM*, supporting Bell (2004:213-23), I do not understand the choice of such terms as *measurement, nonlocality, noncontextual, hidden-variables, observables, microscopic versus macroscopic.* Their interpretation/understanding in the context of wm remains a future project.

· 19.2 The conservation of angular momentum yields $\boldsymbol{\lambda} + \boldsymbol{\lambda}' = 0$ prior to each test. The driver $\pm s\hbar$ ($s =$ intrinsic spin, $\hbar =$ Dirac's constant) *determines* the swept angles here, driving dynamic $\boldsymbol{\lambda}$ ($\boldsymbol{\lambda}'$) to static $\mathbf{a}^{\pm}$ ($\mathbf{b}^{\pm}$); eg, $\pm s\hbar(\boldsymbol{\lambda}; \mathbf{a}^{\pm})$ drives $\boldsymbol{\lambda} \to \mathbf{a}^{\pm} = \boldsymbol{\lambda}^{\pm}$, thereby concluding $\hat{\boldsymbol{A}}\boldsymbol{\lambda}$. Note that $\cos^2[\pm s(\pm w\pi \pm \phi)] = \cos^2 s\phi$ where w is any non-negative whole number. Schematically:

$$\pm qs\hbar\boldsymbol{\lambda} + \pm qs\hbar\boldsymbol{\lambda}' = 0; q \nless 1. \ \pm s\hbar(\boldsymbol{\lambda}; \mathbf{a}^{\pm}) : \boldsymbol{\lambda} \to \mathbf{a}^{\pm} = \boldsymbol{\lambda}^{\pm}. \ \pm s\hbar(\boldsymbol{\lambda}'; \mathbf{b}^{\pm}) : \boldsymbol{\lambda}' \to \mathbf{b}^{\pm} = \boldsymbol{\lambda}'^{\pm}. \quad (23)$$

· 19.3 The prevalence $\mathbf{P}$ of events E and F under general condition G with $\neg$ denoting *not*: (i) $0 \le \mathbf{P}(E|G) \le 1$; in words, $0 \le$ *the prevalence of E conditional on G* ≤ 1. (ii) $\mathbf{P}(E|GE) = 1$. (iii) $\mathbf{P}(E|G) + \mathbf{P}(\neg E|G) = 1$. (iv) $\mathbf{P}(EF|G) = \mathbf{P}(E|G)\mathbf{P}(F|GE) = \mathbf{P}(F|G)\mathbf{P}(E|GF)$.

· 19.4 Our classical model does not invoke mystery, nonlocality or spooky-actions. For a foundational feature of our model is the commonsense view that spacelike separated events, etc, *are independent of spacelike separated contexts*. This is captured by the mandatory boundary condition in Section 6, suitably expanded: $A^{\pm}$ is causally independent of $B^{\pm}, \hat{\boldsymbol{B}}, \mathbf{b}, \mathbf{b}^{\pm}, \boldsymbol{\lambda}', \phi'^{\pm}$; $B^{\pm}$ is causally independent of $A^{\pm}, \hat{\boldsymbol{A}}, \mathbf{a}, \mathbf{a}^{\pm}, \boldsymbol{\lambda}, \phi^{\pm}$.

· 19.5 Table 2 showing $\phi^{\pm\pm}$ as calculated, with mnemonics, and references to facilitate discussion.

$\phi^{\pm\pm}$	$F[(\boldsymbol{\lambda} : \mathbf{a}^{\pm}), (\boldsymbol{\lambda}' : \mathbf{b}^{\pm})] = (\mathbf{a}^{\pm}; \mathbf{b}^{\mp})$	19.5 (0)
ϕ^{++}	$\pi - \phi = (\mathbf{a}^{+}; \mathbf{b}^{-})$	19.5 (1)
ϕ^{+-}	$\phi = (\mathbf{a}^{+}; \mathbf{b}^{+})$	19.5 (2)
ϕ^{-+}	$\phi = (\mathbf{a}^{-}; \mathbf{b}^{-})$	19.5 (3)
ϕ^{--}	$\pi - \phi = (\mathbf{a}^{-}; \mathbf{b}^{+})$	19.5 (4)
Table 2.	$\phi^{\pm\pm}$ as calculated, and with mnemonics.	Ref.

· 19.6 "One general issue raised by the debates over locality is to understand the connection between stochastic independence (probabilities multiply) and genuine physical independence (no mutual influence). It is the latter that is at issue in 'locality,' but it is the former that goes proxy for it in the Bell-like calculations. We need to press harder and deeper in our analysis here," Arthur Fine, in Schlosshauer (2011:45). This we've done here, proving that, under the law of linked correlations, stochastic independence is no proxy for local-causality. Similar analysis delivers the correct results for GHZ (1989), GHSZ (1990), CRB (1991).

· 19.7 This essay marks the 24th anniversary of my call to David Mermin offering him the foundation developed here. Reading a 1988 essay of his the previous evening, it was clear that he and Bell had missed a big Bit, seen here from the note for the call: (i) Only the impossible is impossible. (ii) Correlated tests on correlated things produce correlated results without mystery. (iii) Copy of his maths. (iv) John Bell contact details.

· 19.8 The difficulties enunciated in #19.1 may be clearly seen in Kirchmair+(2009:494), emphasis/comments added: "An *intuitive* feature of classical models is *non-contextuality: the property that any measurement has a value independent of other compatible measurements being carried out at the same time*." *Time?* Confusing; surely irrelevant? "A theorem derived by Kochen, Specker and Bell ... shows that non-contextuality is in conflict with quantum mechanics." Eliminating *time* from the issue, that theorem and QM need to be examined critically via $\phi^{\pm}$ and $\phi'^{\pm}$. "The conflict resides in the structure of the theory and is independent of the properties of special states." Such a structure must be questionable, given $\phi^{\pm}$ and $\phi'^{\pm}$. "A considerable simplification of the original Kochen–Specker argument by Mermin (1990) and Peres (1990) uses a 3×3 square of observables where the observables in each row or column are mutually compatible." A test-case for wm? "[Our] experiment is not subject to the detection loophole and we show that ... our results cannot be explained in non-contextual terms." A test-case for wm?

19.9 Glossary of key symbols			
Symbol	Meaning	(Eq)/p.	Ref.
#19.1	Endnote 19.1	p.11	19.9.1
$\sim$	Equivalence	p.5	19.9.2
α (β)	Alice's (Bob's) experiment in $\alpha\beta$. $\boldsymbol{\lambda} \to \alpha$ ($\boldsymbol{\lambda'} \to \beta$)	p.4	19.9.3
$\alpha\beta$	EPRB: $\alpha; \boldsymbol{\lambda} \to \boldsymbol{\hat{A}} \to \mathbf{a}^{\pm} = \boldsymbol{\lambda}^{\pm}$. $\beta; \boldsymbol{\lambda'} \to \boldsymbol{\hat{B}} \to \mathbf{b}^{\pm} = \boldsymbol{\lambda'}^{\pm}$	p.4	19.9.4
λ	Bell's *hidden-variable*	(1)	19.9.5
λ_i	Bell's λ allocated to particle i	(3)	19.9.6
$\boldsymbol{\lambda}$	Unit vector, orientation of total angular momentum for $p(\boldsymbol{\lambda})$	p.4	19.9.7
$\boldsymbol{\lambda}^{\pm}$	Post-$\boldsymbol{\hat{A}\lambda}$-interaction beable, unit vector $= \mathbf{a}^{\pm}$	(8)	19.9.8
$\boldsymbol{\lambda'}$	Unit vector, orientation of total angular momentum for $p'(\boldsymbol{\lambda'})$	p.4	19.9.9
$\boldsymbol{\lambda'}^{\pm}$	Post-$\boldsymbol{\hat{B}\lambda'}$-interaction beable, unit vector $= \mathbf{b}^{\pm}$	(8)	19.9.10
ϕ	Angle between the principal-axes of $\boldsymbol{\hat{A}}$ and $\boldsymbol{\hat{B}}$	(8)	19.9.11
$\phi^{\pm}$	Angle ($\boldsymbol{\lambda}$; $\mathbf{a}^{\pm}$); absolute angular disturbance of $\boldsymbol{\lambda}$ in $\boldsymbol{\hat{A}\lambda}$	p.6	19.9.12
$\phi'^{\pm}$	Angle ($\boldsymbol{\lambda'}$; $\mathbf{b}^{\pm}$); absolute angular disturbance of $\boldsymbol{\lambda'}$ in $\boldsymbol{\hat{B}\lambda'}$	p.6	19.9.13
$\phi^{\pm\pm}$	Relative angular disturbance between $\boldsymbol{\lambda}^{\pm}$ and $\boldsymbol{\lambda'}^{\pm} = (\mathbf{a}^{\pm}; \mathbf{b}^{\mp})$	p.6	19.9.14
$\mathbf{a}$	Principal-axis orientation – Alice's SGD	p.4	19.9.15
$\mathbf{a}^{\pm}, \mathbf{b}^{\pm}$	Post-test beables representing $\boldsymbol{\lambda}^{\pm}$, $\boldsymbol{\lambda'}^{\pm}$	(8)	19.9.16
$A(\mathbf{a}, \lambda_i)$	Discrete equivalent of Bell's $A(\mathbf{a}, \lambda)$	(3)	19.9.17
$A^{\pm}$	Alice's result; $\pm 1 = A^{\pm} \sim \pm\mathbf{a} = \mathbf{a}^{\pm}$	(1)	19.9.18
$\boldsymbol{\hat{A}}$	Alice's SGD	p.4	19.9.19
$\boldsymbol{\hat{A}\lambda}$	Interaction between $\boldsymbol{\hat{A}}$ and $\boldsymbol{\lambda}$	p.4	19.9.20
$\langle AB \rangle$	Expectation value of the product AB	(2)	19.9.21
$\mathbf{b}$	Principal-axis orientation – Bob's SGD	p.4	19.9.22
$B^{\pm}$	Bob's result; $\pm 1 = B^{\pm} \sim \pm\mathbf{b} = \mathbf{b}^{\pm}$	(1)	19.9.23
$\boldsymbol{\hat{B}}$	Bob's SGD	p.4	19.9.24
$\boldsymbol{\hat{B}\lambda'}$	Interaction between $\boldsymbol{\hat{B}}$ and $\boldsymbol{\lambda'}$	p.4	19.9.25
$\mathbf{c}$	Third unit vector, Bell (1964:198)	p.3	19.9.26
CHSH	Clauser-Horne-Shimony-Holt inequality (Peres 1995:165)	p.7	19.9.27
EPRB	EPR-Bohm experiment (Bell 1964)	p.4	19.9.28
h	Planck's constant, the quantum of action	#19.2	19.9.29
$\hbar$	Dirac's constant, the quantum of angular momentum $= h/2\pi$	#19.2	19.9.30
i	Particle number	p.3	19.9.31
n	Number of particles in an adequate sample	p.3	19.9.32
O	Centre of a unit sphere	Fig.2	19.9.33
OX	Arbitrarily oriented radius of a unit sphere $= \mathbf{a}$	Fig.2	19.9.34
OY	Arbitrarily oriented radius of a unit sphere $= \mathbf{b}$	Fig.2	19.9.35
OZ	Arbitrarily oriented radius of a unit sphere $= \boldsymbol{\lambda}$	Fig.2	19.9.36
$p(\boldsymbol{\lambda}), p'(\boldsymbol{\lambda'})$	Pristine particle-pair: $\boldsymbol{\lambda} + \boldsymbol{\lambda'} = 0$, no two pairs the same	p.5	19.9.37
$p(\lambda_{n+i})$	The It Bell missed	p.3	19.9.38
$p(\lambda_{wn+i})$	Particle family that refutes Bell inequalities; eg, CHSH	p.7	19.9.39
$\mathbf{P}$	Prevalence $\sim$ event based probability theory, absent subjectivity	#19.3	19.9.40
q	A number not less than 1	#19.2	19.9.41
SGD	Stern-Gerlach device; ie, magnet, detector, recorder	p.4	19.9.42
$s\hbar$	Intrinsic spin; $s = 1/2$ (1) for spin-half particles (photons)	#19.2	19.9.43
$\mathbf{u}, \mathbf{v}$	Generic unit vectors	p.1	19.9.44
$(\mathbf{u}; \mathbf{v})$	The angle between $\mathbf{u}$ and $\mathbf{v}$	p.1	19.9.45
$(\mathbf{u} : \mathbf{v})$	Angle of rotation – swept angle – $\mathbf{u}$ to $\mathbf{v}$, sign $\pm$; used in (9)	p.1	19.9.46
w	Non-negative whole number	#19.2	19.9.47
WLR	Wholistic-local-realism	p.2	19.9.48
WM/wm	Wholistic mechanics (pronounced *wham*; merging BIG/small)	p.2	19.9.49
XYZ	Arbitrary triangle on a unit sphere	Fig.2	19.9.50