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Quantum Correlations in Classical Systems

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Abstract

A classical fluid splitter produces the same patterns of energy redistribution as a Stern–Gerlach quantum device, with rotationally invariant coefficients of correlation between molecular paths. Alternative settings express a cosine squared relationship, leading to Tsirelson-type Bell violations with outcome independence. This result confirms the Correspondence Principle of quantum mechanics, where individual detection events express system-level properties according to Born's Rule. Kochen–Specker contextuality and Bell Locality are not formally contradicted, but their interpretation is in question. Current definitions of "Local Realism" are limited to intrinsic particle properties. In contrast, quantum-like correlations require the acknowledgement of ensemble effects on dynamically inseparable entities, even when those entities are observed one at a time.

Keywords: quantum correlations; energy redistribution; Kochen–Specker contextuality; Bell locality; entanglement; observer effect

1. Introduction

Quantum behavior and the measurement effect are often described as two sides of the same coin. It seems impossible to explain fundamental properties of matter with "read-only" classical measurements. Yet there is a gap between theory and interpretation in this case. Quantum operators, often labeled as "measurements," actually describe system-level transformations that occur prior to detection. Quantum statistics, though attributed to discrete particles, are predicted from macroscopic wavefunctions, according to Born's Rule. At the same time, "no-go" theorems appear to rule out classical models, but only by excluding collective sources of individual behavior. There is a striking similarity between the conundrum of "quantum subjectivity" and the geometrical analysis of classical waves: in both cases, global processes are reduced to non-additive components. Moreover, vector decomposition works in the same manner for fluid media and for solid classical bodies, such as billiard balls, where explanations in terms of pre-existing structural components are naturally ruled out. The missing piece of this puzzle, as will be shown below, is that individual behavior can express irreducible system-level effects in both classical and quantum mechanics. For instance, fluid molecules can exhibit quantum-like correlations when their trajectories are governed by the bulk flow. This perspective eliminates the need for observer effects and resolves the apparent conflict between classical and quantum statistics.

Debates about quantum entanglement are usually framed as a choice between competing non-classical explanations. Why consider local accounts when the evidence against them appears so strong? The answer is that impossibility theorems (and even their experimental tests [1–4]) primarily confirm abstract principles rather than actual mechanisms.

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Quantum theory itself contains no explicit provision for nonlocality [5–7]. Moreover, rigorous studies of relevant concepts (such as the bipartite quantum correlation function [8,9]) arrived at local interpretations. In more general terms, alternative models for Bell violations have been developed with incompatible variables [10–13] and further supported by phenomenological analyses and event simulations [14–19]. The features of quantum entanglement were also reproduced in hydrodynamic pilot-wave systems [20,21], classical optical setups [22], and even with unentangled quantum projections [23,24]. These examples, though only a small sample, indicate that classical solutions are not ruled out by the evidence. Instead, the challenge is to explain why this problem exists in the first place. If "no-go" theorems have narrow definitions [25], while quantum transformations are local [8] and Bell's inequality is about compatibility [10], why do we keep coming back to arguments about loopholes? More to the point, if we can witness exclusive phenomena every day, why can we not describe them in classical physics? This is a clue that something fundamental is being chronically overlooked. Perhaps the focus can be shifted from the differences to the similarities between classical and quantum phenomena?

At first sight, classical particles do not behave like quantum entities. Billiard balls do not produce interference fringes, especially when propagating one at a time. Yet quantum statistics are predicted with wave-functions, and quantum systems correspond to wave-like classical systems. Hence, the relevant process to compare is not the distribution of properties for stand-alone classical objects, but rather the distribution of properties for dynamically inseparable entities. For example, water molecules do not display ballistic trajectories when flowing through a pipe. Instead, the pattern of motion for any one molecule is inseparable from the motion of other co-propagating molecules, especially for the interaction with a fluid splitter. Do we still get a discrepancy with quantum predictions after this correction? As shown in Section 3, we do not. Instead, we recover the same rotationally invariant coefficients of correlation that are expected for Stern–Gerlach electron beam splitters. Of course, Bell's Theorem is mathematically correct: jointly determined classical properties are statistically separable within hard limits. The nuance is that system-level transformations can produce "forking paths" between common inputs and disjoint outcomes. When predetermined properties are mutually exclusive due to intervening local factors, pairwise joint probabilities are no longer constrained by Bell-type inequalities. This can be explained as an extension of Kochen–Specker contextuality to correlated systems. Though, even here there is a gap between established facts and conventional interpretations, as will be shown in Section 5.

The behavior of electron beams in Stern–Gerlach analyzers appears puzzling because single quanta express the features of a macroscopic process. Yet, according to the Correspondence Principle, large numbers of electron detections must approximate a classical pattern of binary energy redistribution. As shown in Section 2, classical systems already exhibit such non-linear processes, but the underlying system-level effects are often misunderstood. Solid elastic collisions, for instance, follow non-additive rules that preclude the joint realization of incompatible geometries. Ergo, "vector decomposition" must be reinterpreted as "equivalence under transformation". In Section 3, a full analogy with rotationally invariant quantum behavior is developed using a fluid splitter subjected to alternative flow transformations. Bell violations emerge naturally from the nonlinear relationships between incompatible local outputs. Mutually exclusive events cannot influence each other. When two independent copies of the system are used, no interaction between them is required. Alice and Bob can therefore be separated by arbitrary distances and retain perfect freedom of choice in their settings. In short, quantum correlations are not super-physical. The real issue lies in the continued reliance on reductionist assumptions about non-additive properties in modern physics. This tension is particularly evident

in quantum mechanics, where Copenhagen-style interpretations conflict with the actual content of the theory (Section 4). Ultimately, the only fundamental difference between quantum and classical behavior is the persistence of system-level effects in the statistics of apparently isolated events. This conclusion resonates with Feynman's dictum that single-quantum superposition, as observed in the double-slit experiment, contains "the only mystery" of quantum mechanics [26].

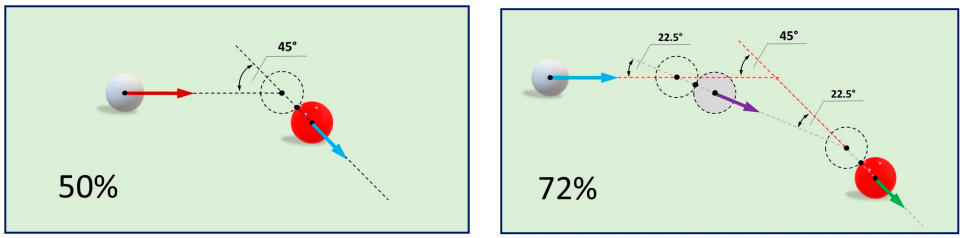
2. Binary Energy Redistribution with Billiard Balls

Consider a billiard ball, moving on a flat surface towards another physically identical ball (Figure 1a). Numerous patterns of glancing collision are possible, with kinetic energy being split 50–50, 0–100, or any other fraction. This does not show that a billiard ball is moving in every possible direction at the same time. Vector decomposition only shows what *can happen* in various alternative collision scenarios, with binary patterns of energy redistribution. If a ball is in motion, relative to the table surface, it has a well-defined state of momentum ($p = mv$) and a corresponding amount of kinetic energy ($E_k = mv^2/2$). In the event of an elastic collision, a fraction of momentum is transferred to the second ball. This can be predicted with vector decomposition, by taking into the account the cosine of the angle between the input and output velocity vectors. However, kinetic energy is proportional to the squared scalar magnitude of the velocity vector. This is the same "Malus Law" that we see in the interaction between a linearly polarized laser beam and a polarizing beam splitter [27]:

$$A_T^2 = A_{in}^2 cos^2\theta, \quad (1)$$

$$A_R^2 = A_{in}^2 sin^2\theta, \quad (2)$$

where "A" corresponds to the wave amplitude vector, subscripts "T", "R", and "in" differentiate between "transmitted", "reflected" and "input" projections respectively, while "θ" is the angle between input and transmitted planes of optical polarization. Accordingly, an ideal glancing collision between these balls entails a 50–50 pattern of energy redistribution along the diagonal axis (Figure 1a). The key feature of this rule is that binary energy redistribution is not linear. Mutually exclusive patterns (governed by the cosine squared rule) are physically and numerically incompatible.



(**a**) (**b**)

Figure 1. Energy redistribution with incompatible outcomes. These are two illustrations of binary energy redistribution in classical billiard ball collisions (frictionless, equal masses, elastic limit). (**a**) Ideal glancing collision at 45°. Incident kinetic energy splits equally (50–50) between transmitted and deflected paths, following a Malus-like law ($cos^2\ \theta$ projection). (**b**) Non-additive multi-step deflection: two successive 22.5° collisions yield ~72% energy transfer (cos^2 22.5° per step), exceeding the 50% from a single 45° collision. This non-additivity illustrates that mutually exclusive collision geometries cannot be jointly realized, precluding the existence of simultaneous "hidden" components for all possible angles.

For example, the two billiard balls can also collide at 22.5°. In this case, 85% of the input energy will be transferred from the first ball to the second (cos^2 22.5°), rather than 75% corresponding to the midpoint between 100% and 50%. Moreover, the second ball can

also experience a 22.5° collision with a third ball, resulting in a final output direction of 45°, relative to the direction of motion of the first ball (Figure 1b). This means that two collisions with a total deflection of 45° can transfer 72% of input energy, even though a single collision at 45° can only transfer 50%. By implication, mutually exclusive collision geometries cannot be jointly realized or distributed in a single run. There can be no "hidden" vector components that are simultaneously real for all possible collision angles. This analysis has even deeper implications. Classical mechanics is strongly associated with the ontological principle of reductionism. At every level, macroscopic bodies behave like associations of microscopic entities. In principle, even cosmic interactions are reducible to sub-atomic particle trajectories. From this perspective, it seems that vector decomposition should also describe a reducible process. For example, two waves can overlap with parallel amplitude vectors (in the transverse plane), or with anti-parallel vectors. The appearance of an interference pattern can be explained as "just the vector sum" of these components. Perhaps, the "true reality" is that waves go through each other unperturbed with properties that are fixed at the source? On closer inspection, this interpretation is inconsistent with both the mathematical and the physical facts. As shown above, vector summation is not a linear process. Only the squared vector magnitudes are additive, but they cannot express pre-existing structural components. More importantly, the hypothesis of pre-existing components is at odds with the principle of energy conservation. Constructive interference produces a surplus of potential energy that matches the missing amounts from the volumes with destructive interference. In short, vector decomposition describes the outcomes of energy redistribution, but only in the event of an actual transformation. This applies to billiard ball collisions and to wave-like interactions, suggesting that energy propagation in general is an irreducible process.

Consider a surface wave in a ripple tank. The water rises and falls, but the fluid is made of molecules. In what sense is the wave pattern irreducible to molecular motion? The first clue is that waves can be described as running even when the medium is stationary. From a mechanical point of view, the answer is found in the transfer of momentum from one particle to the next. If two molecules A and B act simultaneously on a third molecule C, the recipient cannot move in two directions at the same time. It will move in the net direction, given by the vector sum of the impulse from A and B. Yet, we saw above that vector decomposition is formally non-additive. Even physically, the motion of C is not meaningfully separable into a component from A and another from B. The molecule is "just moving". The joint action of several molecules is indistinguishable. Accordingly, a macroscopic wave can be described as a bulk effect of millions of particles. Intuitively speaking, energy flows as a macroscopic state of motion. It is channeled into volumes with constructive interference, away from destructive interference, but the molecules remain localized. There is no direct equivalence between wave vector components and microscopic particle trajectories. Instead, there is a correspondence between the local amount of energy and the net motion of the medium in the same volume. In short, virtual vector components cannot be carried by real entities. They express the macroscopic geometry of energy propagation and predict the outcome of various transformations.

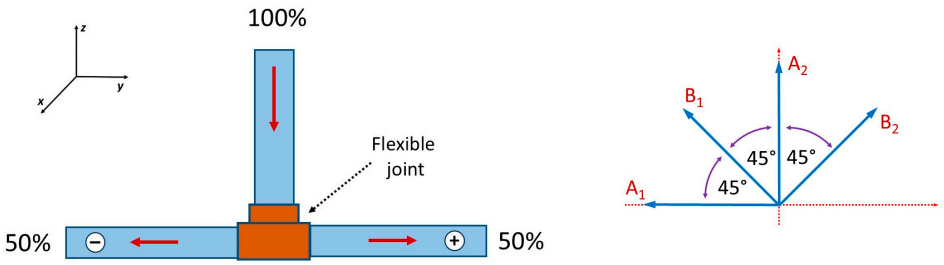
A natural corollary of the above is that physical systems display a mixture of reducible and irreducible properties. Energy is an attribute of matter. Accordingly, it is the collective displacement of particles that expresses different forms of energy. Therefore, microscopic entities should be able to display inseparable patterns of macroscopic motion. Hence, the causal arrow is anti-reductionist in this case: the system dictates individual behavior, not the other way around. Moreover, since we identified vector decomposition as the marker for energy redistribution, it is a good rule of thumb to treat any physical entity as a system, when its behavior is predictable with vector analysis. If a billiard ball experiences a

collision, then the ball is the system, and all of its component molecules just follow along as a solid. If molecules act on each other as part of a fluid, then each molecule can be treated as a system. Finally, if the flow of water in bulk is predictable with vector decomposition, then the same molecules must express irreducible macroscopic motion.

This conclusion opens a new perspective on a growing problem in modern physics. Traditional accounts of energy propagation are usually associated with reductionist approaches in both classical and quantum physics. In the context of debates about entanglement, "Local Realism" is formally defined to include only jointly distributed variables (see Section 5 below). This limits the analysis to intrinsic particle properties and excludes the effect of intervening system-level transformations. At the same time, quantum interpretations are also centered on individual behavior with extraordinary ontologies. Though, what if we acknowledged the reality of macroscopic effects on microscopic distributions? Would it bridge the gap between classical and quantum mechanics? This problem is addressed in the following section on the basis of a classical analog for a quantum Stern–Gerlach device.

3. Binary Energy Redistribution with Classical Fluids

Consider a flexible fluid-splitter, as shown in Figure 2a. A vertical pipe feeds a generic fluid (such as water) into a T-junction with two output pipes leading in opposite directions. The input pipe is rigid in the z-direction, while the output axis can be rotated at will in the x-y plane. Pressurized fluid (e.g., water) enters the system and is deterministically split 50–50 between the "plus" and "minus" output channels for any chosen reference orientation A. This leads to an important counterfactual question: for fluid molecules that emerge in the "plus" channel at orientation A, what fraction would have emerged in the same "plus" channel, had the splitter been rotated to orientation B, separated by angle θ from A, while replaying the identical upstream dynamics?



(**a**) (**b**)

Figure 2. Classical analog for Stern–Gerlach electron behavior. Binary energy redistribution is qualitatively similar in quantum and classical systems. In both cases, it can determine the statistics of microscopic constituents. (**a**) Three pipes form a flexible T-junction. Fluid flows downward and is redistributed 50–50 between the "+" and "−" channels. Alternative settings are achieved by rotating the horizontal section in the x-y plane. Correlated parallel simulations of this toy model can be used for a CHSH Bell experiment. (**b**) Four settings (A_1, B_1, A_2, B_2) at 45° yield quantum-like correlations that can reach Tsirelson's bound in ideal conditions. The "Alice" computer can switch at random between two orthogonal orientations (A_1 or A_2), while the "Bob" computer alternates between the other two (B_1 or B_2). The result is explained by local mass redistribution under cos^2 $(\theta/2)$, leading to $cos\ \theta$ correlations with rotational invariance.

To answer this question, we make the following explicit assumptions. First, fluid splitting is fundamentally a deterministic process governed by local interactions with the splitter walls. It is not an accident that the molecules from the "plus" output are found in this channel. Ergo, if the same exact process were to be replayed again, the same exact molecules of fluid would be found in the same output. Second, fluid flow is an irreducible

macroscopic process. We are not dealing with independent ballistic particle trajectories. The motion of fluid molecules is inseparable from the motion of the fluid as a whole. Accordingly, the goal is to determine how the fluid, as a *macroscopic* system, interacts with the walls of the flexible fluid splitter. Third, the fluid in either output channel carries a well-defined directed kinetic energy (or momentum flux) along the chosen axis, which can be projected onto a new axis according to standard vector decomposition rules. For a reference output direction $A+$ associated with a conserved amount of directed kinetic energy, the fraction of that energy that can be redirected into a new orientation $B+$ (separated by angle θ) is then given by the projection rule

$$\frac{E_{B+}}{E_{A+}} = cos^2\left(\frac{\theta}{2}\right). \tag{3}$$

This functional form is the natural geometric consequence of momentum conservation under transverse redistribution and is formally identical to spin analysis on the Bloch sphere. It has obvious similarities with Malus' Law ($cos^2\,\theta$), where the geometry of longitudinal redistribution is better captured by planar analysis. (In real life, viscous flow is likely to introduce additional losses, but this idealization captures the essential angular dependence for a symmetric, low-Reynolds-number case). Rotational invariance further requires that the marginal distribution remains 50–50 in every direction, so the supplementary contribution to $B+$ must come from the opposite channel $A-$. Consequently, the total directed energy in the new $B+$ channel is composed of a fraction $cos^2(\theta/2)$ from the original $A+$ channel plus a fraction $sin^2(\theta/2)$ from $A-$:

$$Ek_{B+} = Ek_{A+}cos^2(\theta/2) + Ek_{A-}sin^2(\theta/2). \tag{4}$$

In summary, if a given sliver of fluid has a fixed amount of kinetic energy in the $A+$ direction, then it can only impart a portion in the $B+$ direction, determined by the cosine squared of half the angle between the two orientations. The other amount of kinetic energy, to maintain rotational invariance and the 50% marginal in every direction, must come from the opposite ($A-$) direction.

The key observation of this analysis is that redirection of the flow conserves the magnitude of the fluid velocity vector. The system maintains constant pressure by design, and a simple rotation of the T-junction cannot affect the internal speed of the fluid. Yet, this entails a surprising effect that cannot be anticipated at a lower (microscopic) level of analysis. A classical body in constant motion has an associated kinetic energy that is directly proportional to its mass and to the square of its velocity. Moreover, a water molecule cannot change its mass in the event of a collision inside the fluid splitter. In contrast, the redistribution of fluid in bulk is radically different. Alternative projections are still governed by the cosine squared law for the total amount of energy (6), but this time it is the speed that remains constant while mass redistribution is non-linear. (Similarly, a rocket nozzle must expel four times the mass of propellant to double the thrust, if gas chamber pressure remains constant). Accordingly, the mass of the fluid in any new direction $B+$ must be composed of cosine-squared of half the angle from the mass that was emitted in the $A+$ direction, plus a supplementary amount from the $A-$ direction:

$$m_{B+} = m_{A+}cos^2(\theta/2) + m_{A-}sin^2(\theta/2). \tag{5}$$

This conclusion reveals an ordinary classical process behind the strangeness of quantum statistics. Since the total input mass is conserved and split 50–50 at any single setting ($m_{A+} = m_{A-} = m_{\text{in}}/2$), we can assume uniform fluid density and derive same-channel correlations at the molecular level. In essence, Equation (5) determines the conditional

probability that a molecule emerges in the + channel at setting B, given that it also emerged in the + channel at setting A. Substituting the marginals into Equation (5) and taking the fraction of the original $A+$ mass that remains in the new $B+$ channel yields:

$$P(+_B \mid +_A) = cos^2\left(\frac{\theta}{2}\right). \tag{6}$$

(The supplementary $sin^2(\theta/2)$ term is exactly what is needed from $A-$ to enforce the 50% marginal at B, so it drops out of the conditional probability for molecules already selected from $A+$). On the one hand, we have a system-level effect that is observable as fluid mass redistribution. On the other hand, we have molecular behavior expressing the non-linear features of this macroscopic process.

As a reminder, the expectation value for two binary observables A and B is determined with the following formula, given four types of coincidence counts:

$$E(A,B) = \frac{(N_{++} + N_{--}) - (N_{+-} + N_{-+})}{(N_{++} + N_{--}) + (N_{++} + N_{--})}. \tag{7}$$

The number of coincidences with opposite values ($+-$ and $-+$) is subtracted from the number of coincidences with identical values ($++$ and $--$) in order to divide the difference by the total number of joint events. In this case, the proportion of coincidences with identical values is determined by $cos^2(\theta/2)$, as explained above, and the supplementary proportion of coincidences with opposite values is equal to $sin^2(\theta/2)$. Therefore, Equation (7) acquires the form

$$E(A,B|\theta) = \frac{cos^2\left(\frac{\theta}{2}\right) - sin^2\left(\frac{\theta}{2}\right)}{1} = cos^2\left(\frac{\theta}{2}\right) - sin^2\left(\frac{\theta}{2}\right) = cos\ \theta. \tag{8}$$

This is the famous $cos\ \theta$ rule for quantum correlations. Clearly, it does not express a mysterious connection between remote measurements. Rather, it is a trigonometric simplification of the relationship between two alternative projections from a common input profile. The real mystery was in the physical mechanism behind this rule, since it could not be explained without system-level effects.

The offshoot of this demonstration is that we have rotationally invariant correlations between any two output settings for the fluid-splitter. It does not matter which axis is chosen for reference and which transformation is added for correlation analysis. One way or another, 50% of the input fluid would end up in the "plus" channel. For any other output orientation, the proportion of the molecules that would have been in the same channel (and the supplementary proportion that trade places) are determined by the cosine squared of half the angle between the two settings. This means that we can choose several adjacent orientations, separated by 45° angles, to maximize the effect of incompatible transformation on the output patterns of correlation. To keep the analogy with a CHSH quantum experiment [28], we can label these directions A_1, B_1, A_2 and B_2, as shown in Figure 2b. Just as described above, we can ask: what proportion of molecules would remain in the same channel for any of the possible pairwise combinations?

Looking closer at the proposed configuration in Figure 2b, we notice that three combinations are separated by a net angle of 45°, with a final coefficient of correlation of:

$$E(A_1,B_1) = E(A_2,B_1) = E(A_2,B_2) = cos\ (45^\circ) = \frac{\sqrt{2}}{2}. \tag{9}$$

In contrast, the last combination spans a net angle of 135°. Therefore,

$$E(A_1, B_2) = cos\ (135^\circ) = (-\frac{\sqrt{2}}{2}). \tag{10}$$

We can plug these four coefficients of correlation into the CHSH expression for a Bell test with four variables [28]:

$$S_{CHSH} = |E(A_1, B_1) - E(A_1, B_2) + E(A_2, B_1) + E(A_2, B_2)| \leq 2, \tag{11}$$

as follows:

$$S_{fluid} = \left| \frac{\sqrt{2}}{2} - \left(-\frac{\sqrt{2}}{2} \right) + \frac{\sqrt{2}}{2} + \frac{\sqrt{2}}{2} \right| = 2\sqrt{2}. \tag{12}$$

As a result, we reproduced the Tsirelson bound for a CHSH protocol, exactly as predicted in quantum mechanics for appropriate entangled states [29]. Yet we derived this behavior for alternative virtual orientations of a *single* classical fluid splitter. This was done deliberately, to clarify the local nature of these correlations. Alternative transformations do not correspond to consecutive measurements. Therefore, they cannot influence each other. Rather, correlated Alice–Bob behavior in real experiments serves as a physical proxy for counterfactual reasoning: it allows us to "observe" the redistribution of energy across alternative transformations that are logically linked but physically disjoint. It should also be noted that the fluid model's correlations are positive for small angles (approaching +1 as $\theta \to 0$), analogous to parallel spin projections in a quantum triplet state where $E(\theta) \approx cos\ \theta$. In contrast, many Bell tests employ anti-correlated singlet states ($E(\theta) \approx -cos\ \theta$) due to practical generation via angular momentum conservation. Still, the sign of the zero-angle correlation is not the origin of Bell violations. Instead, the fundamental driver is Kochen–Specker-style incompatibility, which manifests as counterfactual differences in single-system transformations.

To implement this analysis in a Bell-like scenario, two independent computers can replay identical fluid simulations up to the flexible neck of the splitter. Subsequently, one computer named "Alice" can choose between two output settings (such as 0°or 90°, relative to the y-axis), as shown in Figure 2b. Another computer named "Bob" can choose between two other alternative settings (such 45° and 135°, relative to the y-axis). The settings for both Alice and Bob can be chosen at random or supplied by a third party. No communication or influence between them is required. Only four setting combinations are possible, each producing the same correlations as shown in Equations (9)–(12) from local, nonlinear mass redistribution. (A Monte-Carlo numerical simulation of this setup is included in Appendix A below).

This arrangement satisfies the requirements for freedom of choice and parameter independence: Alice's marginal distribution remains 50–50 regardless of Bob's setting, and vice versa, because each transformation acts solely on its local output axis. Importantly, the requirement of outcome independence is also satisfied without contradicting the Kochen–Specker theorem, as will be explained in Section 5 below. The mechanism would be the same if Alice and Bob were making coincidence studies with identically stacked decks of playing cards. In both cases, the correlations would be local. The difference is that the properties of playing cards are jointly distributed and cannot violate Bell-type inequalities [25].

A similar thought experiment can also be extended to "single event" detection schemes. For example, it is possible to inject tracer dye molecules into the fluid, one at a time, and to observe their fate at the output: do they emerge in the "plus" or "minus" output pipe for any chosen setting? The behavior of tracer molecules must also be inseparable from

the bulk fluid dynamics, with the same rotationally invariant statistics. Thus, individual (one at a time) detections can express macroscopic system-level transformations, just as quantum single-event probabilities follow Born's rule.

Though challenging, such an experiment can even be attempted in real life. Experimental validation can begin with a single flexible T-junction in a closed-loop recirculation system driven by a low-shear pump. Fluorescent tracer molecules (or micron-scale particles) crossing two upstream checkpoints in the cross-section of the input pipe could be used to define several conditioned sub-ensembles with strong bias towards one output in a fixed setting. The initial goal would be to simply determine any cosine correlation between two settings of the same apparatus, similar to the Malus law for polarized laser beams. If successful, more advanced versions with twin systems can be devised to check for rotationally invariant correlations against the Eberhard inequality [30]. As is known, this version of the CHSH protocol remains testable down to efficiencies of approximately 2/3 when optimized with non-maximally correlated samples.

In conclusion, quantum correlations have natural analogs in purely classical contexts. This result does not contradict well-established theoretical or experimental facts. It serves to resolve the apparent tension between them, due to perceived interpretive constraints. In particular, the derivation of Bell's inequality assumes that joint measurement outcomes are only local if determined in full by a prior common cause [25,31]. The classical system considered here illustrates a different situation. Strong correlations from the source are subsequently reshaped by system-level transformations applied locally and independently. As will be shown below, the contrary conclusions in the literature follow from established practices that reduce system-level effects to stand-alone individual behavior.

4. Irreducible Quantum Wave-Functions

Fluid systems display a complex mix of particle properties and system-level effects. This makes it challenging to derive consistent statistical implications with universal validity. In contrast, there is a straightforward link between electromagnetic wave energy and stochastic microscopic behavior. After all, quantum mechanics emerged from the discovery of the Planck rule for black body radiation. This means that we can interpret a sinusoidal electromagnetic oscillation as a wave with discrete amplitudes:

$$E_w \approx F\left(A^2\right) \approx F(nh). \tag{13}$$

In this case, wave energy is proportional to the amplitude squared and is directly convertible into an integer number of increments. For example, a stable double-slit interference pattern must have large numbers of quanta in bright fringes, and small numbers of quanta in dark fringes. Given a frequentist definition of probability, it follows that the odds of finding a quantum are correspondingly higher in places with higher net amplitudes. For a one-dimensional scan in the transverse plane of an optical projection:

$$P(x) = |A(x)|^2, \tag{14}$$

with the normalization condition:

$$\int_{-\infty}^{\infty} |A(x)|^2 dx = 1. \tag{15}$$

Expression (14) is strikingly similar to Born's rule for quantum probability:

$$P(a_i) = |\langle a_i|\psi\rangle|^2. \tag{16}$$

Still, this is not surprising, because quantum mechanics obeys the Correspondence Principle. Even when quantum events are accumulated one a time, progressively larger numbers of events must approximate classical distributions. Indeed, the similarity between the two probability rules is very well known. The novel insight, given the analysis from Sections 2 and 3 above, is that we can reinterpret *both of these scenarios* as irreducible patterns of energy redistribution. The new rule of analysis is "No decomposition without transformation". It is not the addition of component elements that determines the features of classical and quantum projections. It is the other way around: energy propagation, as a system-level process, dictates the manifestation of individual markers along the way. Granted, this principle does not explain *why* quantum events emerge when they do. However, it feels very intuitive to describe quantum wavefunctions as system-level effects on individual behavior (and very counterintuitive otherwise). As will be shown below, several interpretive puzzles can be solved with this new perspective.

4.1. Puzzle #1. What Are Quantum Operators?

Quantum mechanics is the area of physics where the concepts of classical physics fail. But is that because the laws of physics are different in each case, or is it because people use the same concepts inconsistently? For example, a measurement is meant to determine an objective value in classical mechanics. Every property is defined in reference to a standard, and a device is developed to gauge individual instantiations. However, this is not how the word "measurement" is used in quantum theory. For example, a textbook illustration of quantum behavior is to place three polarizing slides in the path of a photon beam. If the axes of the two outer slides are orthogonal, then the projection is blocked completely. Yet, if the middle slide is set to the diagonal plane, then predictable numbers of photons are detected at the output. This example shows that quantum devices do not just "filter" pre-existing properties. They also induce transformations. Therefore, we have three stages of transformation and one stage of detection, where the photons are counted. Intuitively, the last stage should be described as "the measurement". Instead, it is the three stages of transformation that are usually labelled as "measurements", and only rarely as "preparations for measurement". On closer inspection, this practice is rooted in the Copenhagen interpretation, where quantum operators are described as measurements of unperturbed wavefunction components, as if carried by particles. This is a major source of confusion, given that quantum theory is explicitly unable to explain individual properties. Accordingly, the inconsistency is removed by re-interpreting quantum operators as system-level transformations that *create* new projections (instead of revealing preexisting properties). This is the same correction that was advised in Section 2 for the analysis of classical vectors.

4.2. Puzzle #2: What Is a Quantum Measurement?

There is a remarkable (though subtle) contradiction in the way that quantum mechanics is usually described. On the one hand, quantum theory holds the crown for the most precise theory in the history of science. On the other hand, quantum properties are supposed to defy accurate detection, due to the so-called "observer effect". How is it possible for a theory to be both precise and unverifiable at the same time? As it turns out, elementary entities that are labelled as "quanta" cannot be inspected directly (like classical objects) even in principle. Instead, they can only be *counted*, due to their ability to induce observable events known as "clicks" (e.g., by triggering an avalanche of electrons). More importantly, event counters do not introduce perturbations in the relevant profiles. They answer the question "how many clicks are registered per unit of time at location x_1 (or x_2, or x_3, etc.) in a given plane of detection"? In the case of optical projections, this is currently achieved by

scanning the plane of detection with the tip of a single-mode optical fiber. All the photons that enter the fiber at one end can be counted without distortion at the other end. The smaller the point of detection (such as by using an optical fiber instead of a pinhole), the greater the agreement with the predictions of quantum theory. The output of a quantum observation can be mapped on a scalar field, where each coordinate is populated by a number, and every number corresponds to the normalized frequency of detection events at that location. On closer inspection, this is not surprising because quantum theory predicts large distributions of events with wave-function analysis. It cannot predict individual qualities. (Hence, the "measurement problem" is also a consequence of methodological reductionism). Furthermore, quantum predictions obey the Correspondence Principle. As mentioned above, this entails that quantum observations with large N must resemble classical observations. For example, a high intensity optical beam produces a visible interference pattern in the double slit experiment. This is a classical observation. A low intensity photon beam produces invisible clicks that collectively add up to the same interference pattern. This can only work if the act of quantum detection is non-perturbative. In short, there is no room for "observer effects" in quantum mechanics, if detectors are described as measurement devices. Instead, the source of confusion is traced again to the Copenhagen interpretation, where quantum operators (and the corresponding transformations before observation) are described as invasive "measurements", as if input profiles are reducible to their outputs.

4.3. Puzzle #3. What Is Quantum Non-Commutativity?

The founders of quantum mechanics were deeply puzzled by the non-commutative nature of fundamental properties, such as momentum and position. How is it possible for such qualities to be mutually exclusive? In contrast, we do not need to guess what is going on because we have abundant experimental demonstrations. For example, the Einstein-Podolsky-Rosen (EPR) *gedankenexperiment* was realized in a very instructive manner with correlated photon beams at the University of Rochester [32]. In this experiment, the property labelled as "momentum" was verified by scanning the focal plane of a lens (for each of the two entangled projections). The property labelled as "position" was verified by scanning the image plane of a lens. More importantly, the same event counter was used in both cases. It is hard to argue that the act of "momentum detection" did something to particle positions, or that the act of "position detection" did something to particle momentum. The photons were counted in the same manner in both cases. Instead, it is the observers who needed to know where to place their event counters, such as to extract appropriate information. The goal was to confirm the predicted effects of quantum wave-functions on corresponding event distributions at each stage of propagation. In short, the words "momentum" and "position" do not correspond to particle properties in this context. They designate macroscopic features of classical wavefronts and quantum wavefunctions. In this example, they describe the transformations that are experienced by an optical wavefront in free space, after passing through a lens. In principle, it is conceivable that individual quanta might have intrinsic momentum and position (like classical particles), but these are not properties that can be predicted by quantum theory or confirmed in a quantum experiment. Instead, we can imagine that pairs of quanta maintain correlated trajectories if they belong to synchronized projections. They can produce coincident events, if counted in the "momentum plane" or in the "position plane" of corresponding projections, but they exhibit correlated flow in both cases. Accordingly, the puzzle of non-commutativity is removed if quantum variables are assumed to describe system-level transformations, instead of the intrinsic particle properties associated with the Copenhagen interpretation.

To sum up, quantum behavior seems radically different if energy propagation is reinterpreted as a macroscopic process. Quantum operators are now acknowledged as system-level transformations. They are too invasive to be described as "observer effects". Yet, the subsequent act of detection is objectively non-perturbative. It takes a very large number of events to confirm a quantum prediction. Individual events are unpredictable and cannot be "observed". They are only counted, always in the same way, even in the case of non-commuting variables. This produces a narrative that is internally self-consistent and eliminates the conceptual gap between theory and experiment. The benefit of this shift is even more remarkable when the puzzles of quantum entanglement are concerned. As will be shown below, there is no conflict between quantum theory and the classical correlations demonstrated in Section 3.

5. "No-Go" Theorems Revisited

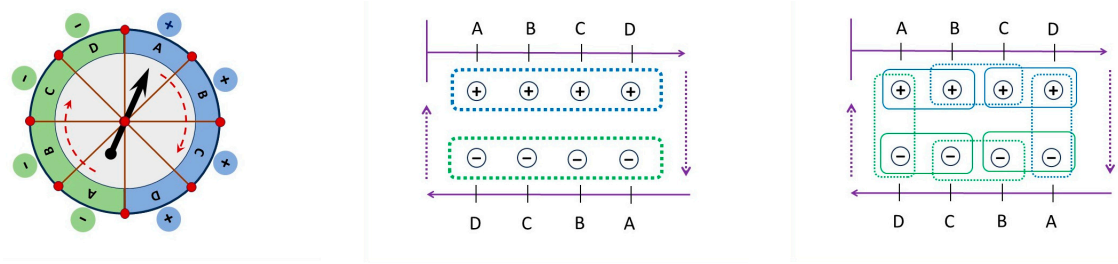
Physical systems can express two kinds of properties: permanent and transient. The latter can be mutually exclusive, depending on the conditions for their manifestation. Yet, in the context of energy redistribution, they can be explained away as macroscopic "appearances", if associated geometries are interpreted with reductionist principles. As explained above, vector decomposition is non-linear and applies to non-additive physical qualities. Therefore, naïve reductionism is more than just an interpretive burden. It leads to incorrect predictions at the microscopic level, as discovered in the study of quantum phenomena. From this perspective, the formal gap between classical and quantum mechanics is caused by the inadequate reclassification of physical properties into a single narrow category. As seen in the modern debates about quantum entanglement, "Local Realism" is widely assumed to include only jointly distributed variables. This means that leading "no-go" theorems are mathematically correct but interpretively misleading. The solution is to reclaim them as arguments in favor of irreducible system-level effects. Yet, this involves stripping their interpretive baggage, as explained below.

The Kochen–Specker (KS) theorem was a very important theoretical development [33]. It showed that non-commuting properties are mutually exclusive in a fundamental sense. They cannot be assigned simultaneous definite values in a non-contextual hidden-variable model. As shown in Section 4, we can interpret this as proof that quantum variables describe macroscopic wave-like profiles (as opposed to intrinsic particle properties). Instead, the KS theorem was adopted as proof that quantum behavior is impossible without measurement-induced perturbations. The basis for this was Specker's conjecture (or "Specker's principle" [34]) that quantum-like joint measurements cannot be pairwise consistent. For any three observables a, b and c, it is possible for the joint distributions (A,B) and (B,C) to be operationally consistent (i.e., to agree about the values of B), but only at the expense of inconsistency between (B,C) and (C,A), or between (C,A) and (A,B), whichever is not measured at the same time. In other words, the claim is that quantum contextuality makes it mathematically impossible to have pairwise consistency for all the combinations, in any conceivable scenario. It does not matter what physical transformations precede detection, because the output values cannot be reconciled. Therefore, consistency should also be physically impossible, except when observer effects introduce event perturbations. Intuitively, this is supposed to work as if the act of observation "steals" consistency from unmeasured combinations, behind the proverbial curtain. Presumably, this is why quantum correlations are supposed to allow for parameter independence (i.e., non-signaling behavior), but not outcome independence (i.e., locality) for joint measurements.

Specker's principle was studied by numerous authors and was even supported by various theorems (see, for example, [34,35] and references therein). Yet these arguments were informed by implicit assumptions about "Local Realism", limiting them to models

with jointly distributed variables. In retrospect, it is a daunting project to imagine all the possible types of systems, and then to determine which of them allow for pairwise consistency. The spectrum of plausible starting assumptions is too wide. In contrast, it is much more efficient to address the problem from the opposite end. Namely, to start with pairwise consistency and then to determine what types of systems can be extended from it. This is the solution that was found by Vorob'ev in 1962 [36], even though his work was initially overlooked for historical reasons [37,38]. In a nutshell, pairwise consistency entails two kinds of patterns. If joint measurements have an *acyclic* structure, then pairwise consistency automatically leads to global joint distributions (i.e., formally non-contextual behavior, as suggested by Specker). In contrast, if joint measurements have a *cyclic* structure, then pairwise agreement is possible without joint distributions. Ergo, it is not true that quantum contextuality is classically impossible.

This was recently demonstrated by placing the values of 4 binary variables on a "wheel of fortune", as shown in Figure 3a [13]. Every outcome is actualized one at a time, resulting in a continuous sequence of mutually exclusive events. If the window of coincidence is set to include four observables at a time, then the output is an acyclic chain of non-overlapping quadruple events (Figure 3b). In contrast, if the window of coincidence is restricted to include only two events at a time, then the output is a cyclic (closed) chain of pairwise measurements (Figure 3c). Such a pattern cannot be reduced to a global joint distribution, yet all the pairwise measurements overlap without conflict. In other words, the mechanism is contextual, but fully classical. This is a straightforward confirmation of Vorob'ev's theorem and simultaneously a falsification of Specker's Principle by counterexample.



(**a**) (**b**) (**c**)

Figure 3. "Wheel-of-fortune" toy model for mutually exclusive observables. A classical system with sequential properties is used to illustrate the two patterns of pairwise consistency, according to the theorems of Vorob'ev. (**a**) The possible outcomes of four binary variables are assigned to 8 sectors on the game table. Only one outcome is actualized at a time, when it passes under the arrow. This makes it impossible to observe actual coincidences, but the record of events can be divided into conditional iterations after detection. (**b**) If all 4 observables are able to fit in the window of coincidence, then two distinct groups of events are produced for every period of rotation. This results in a linear (acyclic) sequence of non-overlapping groups of events. As a result, every pairwise joint is a subset of the global joint distribution. (**c**) If the coincidence window is small enough for only two events at a time, then a closed chain of overlapping joint measurements is produced. Pairwise consistency is maintained throughout, yet global joint distributions are impossible in this case, as predicted by Vorob'ev for cyclic measurement scenarios. This shows that quantum-like correlations are compatible with the principle of outcome independence. Consistency between real observations does not require perturbations of virtual (unobserved) pairings.

Correction 1. *The Kochen–Specker theorem does not define the limit of classical contextuality. It only reveals a general difference in the assignment of conditional values for compatible and incompatible physical properties.*

Bell's Theorem [31] can be interpreted as an extension of the KS Theorem to the case of correlated systems. (As it is known, Bell discovered both theorems independently and was prevented from publishing the "KS" version before the EPR extension by a procedural mix-up [39,40]. So, the conceptual influence between the two arguments is real.) Intuitively speaking, if a set of properties are mutually exclusive as part of a single system, then they must also produce incompatible coincidences for correlated systems. Yet, in both cases, quantum combinations require metaphysical explanations if observer effects are taken for granted. In other words, if operational consistency requires virtual perturbations for single-system properties, then correlations between remote systems must express the same perturbations non-locally. As we now know, such views were based on a perceived equivalence between "classical" and "non-contextual" behavior. Accordingly, both theorems share the same weakness. KS contextuality and Bell locality are both limited to arguments about jointly distributed variables [25]. Notwithstanding, the argument behind Bell's theorem is puzzling on its own and deserves special consideration. When two variables are correlated, they are statistically inseparable. Still, they can be treated as conditionally separable if a third variable operates as a prior common cause:

$$P(A, B|C) = P(A|C)P(B|C). \tag{17}$$

Bell showed that a common prior cause entails a limit of correlation for three variables or more, making it impossible for quantum correlations to be explained by shared hidden variables. Though, as shown above in Section 3, it is indeed possible to violate the inequalities with mutually exclusive transformations. The question is "How"? If predetermined properties come from a common cause, shouldn't they be jointly distributed? The answer is that Bell's inequality depends exclusively on correlations from the source, but Bell violations do not. In the case of mutually exclusive properties, causal factors do not need to originate in full at a common source. For example, two quantum projections may emerge from a single input. If they are unperturbed, or perturbed in identical ways, then their profiles remain fully correlated, as determined at the source. Bell's inequality must be obeyed. However, it is also possible for each projection to be transformed independently, at some point between emission and measurement. If the difference between the two transformations is small, then the correlation remains high. If the difference between the transformations is large, then the correlations diminish, but the incompatibility between them is increased. This creates a "sweet spot", where the correlations are both strong enough and incompatible enough to achieve a Tsirelson violation (as demonstrated in Section 3). Moreover, as shown elsewhere [13], it is not even necessary for incompatible conditions to operate before detection. In the case of sequential properties, they can be applied after detection, simply by modulating the window of coincidence. In short, coefficients of correlation do not necessarily express fixed relationships between predetermined events. As a result, they cannot be used to falsify the classical principle of Locality.

Correction 2. *Bell violations do not require influences between measurements. They can express the joint effect of correlations at emission and incompatible factors after emission.*

The interesting thing about Bell's Theorem is that it was known from inception to have a limited domain of validity. The original 1964 argument [31] presupposed a fixed profile of hidden variables for every observable, and this assumption was made explicit by CHSH in their notorious 1969 contribution [28]. Later, Bell addressed the issue in his theory of local beables [41], prompting Shimony, Halt and Clauser to clarify the physical implications [42]. Namely, Bell violations did not contradict the principle of Locality, if hidden variables were different for each observable. Nonetheless, this weakness ended up

being perceived as a strength for the "no-go" argument, because it seemed that the cure was worse than the disease. If hidden variables were allowed to correlate with measurement settings, then statistical independence was in question. Observers did not seem to have the free will to choose what they measure. They could only select the settings that were "super-determined" in tandem with the hidden variables from the past of each observable. On closer inspection, this position envisioned several co-existing physical properties that were carried by some entity from the source, with the opportunity for an observer to select one for detection. It did not consider system-level properties that are created alone in transit. For example, an optical projection can have a macroscopic interaction with a polarizer. This leads to a systemic transformation of the beam. The choice of the polarizer setting activates dedicated hidden variables that determine the output distribution of events. Of course, the "measurement setting" and the downstream "hidden variables" are correlated, as part of the same causal process. The nuance is that the effect of the polarizer setting is predicted with a quantum operator that is labeled as a "measurement" for philosophical reasons. This is not actually a measurement, but rather a transformation that might be followed by an act of detection. Ergo, the dedicated hidden variable does not perturb the "statistical independence" of the "measurement setting". The causal arrow points in the opposite direction, from the setting to the hidden variable, since the choice is not "what to measure", but rather "what to create for observation". As a result, we can expect incompatible event distributions that are beyond the scope of Bell's inequality.

Correction 3. *Mutually exclusive transformations require dedicated hidden variables. They correspond to local free interventions, potentially followed by non-invasive measurements.*

In summary, "no-go" theorems about classical behavior at the quantum level were influenced by reductionist principles about energy propagation. As soon as these conditions are relaxed (as demonstrated in Sections 2–4), quantum correlations lose their aura of nonlocality and metaphysical mystery. Instead, the same behavior can be explained with mutually exclusive classical transformations, especially when single event distributions are determined by system-level effects. The bottom line is that quantum-like correlations are possible in classical systems that are governed by intuitive physical rules without exceptions. The apparent conflict between the two branches of physics is interpretive rather than fundamental.

6. Discussion

Quantum behavior is defined by two fundamental principles that seem to be at odds with each other. On the one hand, individual quanta obey the Superposition Principle. This is seen in their ability to produce interference fringes in a double-slit experiment. On the other hand, large numbers of quanta obey the Correspondence Principle, as seen in their tendency to approximate classical distributions. But how can we get macroscopic classical patterns from non-classical behavior? We cannot explain it (yet), but we can describe it succinctly. In a nutshell, single entities exhibit system-level effects, as seen in their conformity to Born's rule. It is strange that quanta display interference patterns without apparent overlap. Yet the bottom line is that they *have* this ability, and it ensures seamless continuity between quantum and classical phenomena. Indeed, if we compare classical and quantum patterns of behavior for system-level properties, then we find no ontological conflict, as shown above. In contrast, Bell's Theorem appeared to disrupt this conceptual harmony. It contradicted the Correspondence Principle (at least implicitly) by describing a verifiable gap between classical and quantum statistical behavior. This is why a new phenomenon—currently known as entanglement—was invoked to explain the difference. The problem is that Bell's Theorem did not impose any additional constraints on

the empirical content of quantum mechanics. It was an abstract statistical argument about a distinct class of physical models. So, how could it disrupt the Correspondence Principle of quantum theory without changing the theory? The claim did not seem to add up, and this is what motivated the effort behind this project. What if the problems of quantum mechanics were not mathematical or experimental, but simply interpretive?

As it turned out, Bell's argument (like other "no-go" theorems) was not really addressing a conflict between classical and non-classical laws of physics. Instead, we can now acknowledge that classical mechanics did not have adequate instruments for the study of macroscopic effects on microscopic behavior. This shortcoming is particularly glaring in the case of incompatible properties. Intrinsic particle qualities are jointly distributed even when value attribution is conditional, because they exist at the same time. Yet system level (ensemble) properties can be transient and mutually exclusive. In this case, they cannot even allow for joint measurements, unless observations are made across contexts. Accordingly, they require the development of new tools, which is what happened in quantum physics. In this sense, "no-go" theorems provided the motivation to reconsider old assumptions and to seek common ground with the new findings. Unfortunately, such a convergence was practically impossible, because of the Copenhagen interpretation. It almost seems like a minor slip that quantum operators were described as measurements when they described preparations for measurement. Yet the consequences of this misconception are historical. Somehow, the quantum "observer effect" has grown into a seemingly unquestionable fact, even though quantum detectors have no impact on predicted distributions. More importantly, system-level classical contextuality was conflated with metaphysical "quantum" contextuality. One must wonder: where would we be today if wavefunction transformations were never mistaken for measurements? Would we even know about nonlocal entanglement, parallel universes, or superdeterminism?

The most intuitive way to rebuild our understanding of quantum behavior is to start with the Correspondence principle. An electron may seem to pass through a Stern–Gerlach magnet one at a time, but the predicted behavior is the same as if a strong beam of electrons was flowing through the same device. Accordingly, a spin ½ transformation is equivalent to a process of binary energy redistribution. As shown above, the geometry of such a process corresponds to vector decomposition, where alternative operations obey nonlinear rules with rotational invariance. Mutually exclusive transformations cannot happen at the same time, but their correlations can be studied by preparing microscopically identical copies. The natural consequence of this geometry is that coincidence patterns between correlated beams cannot exceed Tsirelson's Bound. In short, a classical electron beam expresses the same behavior as a quantum projection, and it is mechanically similar to a fluid with functionally inseparable molecular trajectories. This means that superposition at the single-event level expresses collective wave-like behavior, not an ontological break with classical physics. It therefore brings us back to the idea of self-interference as "the only mystery" in quantum mechanics [26].

7. Conclusions

A classical fluid splitter can generate the same output statistics and the same pairwise correlations as a Stern–Gerlach quantum spin analyzer. This result demystifies the mechanism behind quantum entanglement. Dynamically inseparable entities become locally "entangled" with each other and behave like irreducible fluid systems. Macroscopic transformations of such systems produce mutually exclusive individual properties that can violate Bell-type inequalities. In this Perspective, "no-go" theorems are not obstacles to classical explanations but rather confirm the necessity of ensemble effects in both quantum and classical mechanics. Only the models that constrain analysis to stand-alone particle

properties are ruled out, i.e., the narrow version of "Local Realism" that has dominated foundational discussions.

Quantum theory has long been known to describe irreducible effects on event distributions, yet these were traditionally attributed to measurements or other non-classical sources. If quantum operators are correctly understood as system-level transformations, then a macroscopic reinterpretation of wavefunctions becomes possible, without interpretive paradoxes. On the classical side, vector analysis was presumed to reveal the pre-existing "spectral structure" of various observables. Though, in the context of energy redistribution, it turns out that linear superposition captures non-additive geometric features of macroscopic patterns. Instead of uncovering pre-existing components, it describes equivalence under transformation. Accordingly, the concept of system-level effects on individual behavior enriches and simplifies both frameworks (classical and quantum), with real prospects for conceptual unification.

The special feature of mutually exclusive properties is that they cannot coincide as part of a single system. It is not merely the assigned values that are contextual. The properties themselves must be created one at a time. Hence, two projections can be perfectly correlated at the source, but each of them can experience a different transformation after emission. This leads to a system-level trade-off between correlation strength and compatibility, naturally enabling Bell violations. Prior to this insight, it seemed impossible to invoke local hidden variables without super-determinism. If different observables are shaped by different mechanisms, then correlations between causes and settings appear to limit the agency of human observers (and even random number generators). However, what if quantum operators describe transformations, not measurements? In this case, the choice is no longer "what to filter" from a pre-existing set of qualities, but rather "what to create" for observation. The causal arrow points *from* the setting choice *to* the hidden variables associated with the subsequent transformation. Therefore, Bell violations express ordinary classical causality, with no constraints on the freedom of observation.

To sum up, quantum correlations correspond to classical correlations between mutually exclusive system-level transformations. This is not a contradiction with quantum theory, or even with the mathematical content of leading "no-go" theorems. Instead, it shows that energy redistribution in general can be explained as a macroscopic effect on microscopic behavior. This Perspective opens new avenues for extending classical analogs to higher-dimensional systems, multi-party correlations, and novel experimental tests of contextual behavior. More importantly, it can restore the conceptual unity of quantum mechanics while preserving and expanding its predictive power.

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Data Availability Statement: No database was created during this project. The code for a numerical simulation and a representative outcome are included in Appendix A.

Acknowledgments: During the preparation of this manuscript, the author used Grok 4.2 (*xAI*) for the purposes of generating code and running a Monte Carlo numerical simulation as shown in Appendix A. The author has reviewed and edited the output and takes full responsibility for the content.

Conflicts of Interest: The author declares no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

KS	Kochen–Specker (theorem)
CHSH	Clauser, Horne, Shimony, Holt (inequality)
EPR	Einstein–Podolsky–Rosen (gedankenexperiment)

Appendix A. Numerical Verification of the Fluid-Splitter Model via Monte Carlo Simulation

To independently confirm the analytical predictions of Section 3, a Monte Carlo numerical simulation was implemented that directly applies the nonlinear mass-redistribution rule of Equation (5) locally and independently for each measurement setting. The simulation generates large ensembles of particles that share statistically identical upstream conditions (as in the flexible T-junction model of Figure 2) and subjects each ensemble to the local transformation corresponding to Alice's or Bob's chosen orientation. This approach tests whether the deterministic application of the cosine-squared rule $cos^2\ (\theta/2)$ for same channel probability, when combined with the trigonometric identity $E(\theta) = cos^2\ (\theta/2) - sin^2\ (\theta/2) = cos\ \theta$, is sufficient to produce the full set of rotationally invariant correlations without any inter-system communication. Such results were previously perceived as impossible without loopholes, because of the assumption that local measures sample pre-existing spreadsheets with compatible (jointly distributed) outcomes. In contrast, here we produce incompatible deterministic events, due to local system-level effects on individual behavior. Identical input profiles are shared by Alice and Bob, and they each probe alternative ways to slice the same projection. Alice gets the same result that Bob would have achieved, had he made the same macroscopic transformation. Notably, this scheme only works for pairwise observations, since "quantum monogamy" was also recently shown to apply to classical systems [13]. In other words, mutually exclusive events are automatically rearranged into joint distributions for experiments with more than two simultaneous observations, and Bell violations become impossible again.

The complete self-contained code was implemented in Python 3.12 (standard library only) and is provided below (Algorithm A1).

Results (N = 800,000 per pair, executed 30 March 2026)

E(A1B1, 45°)	≈0.70793
E(A1B2, 135°)	≈−0.70649
E(A2B1, 45°)	≈0.70676
E(A2B2, 135°)	≈0.70698
CHSH S	2.82816

The marginal probabilities for every setting remain 0.500 ± 0.001, satisfying the no-signaling condition. Reported values are very close to previous runs; minor statistical fluctuations expected. The output approaches Tsirelson's bound within statistical precision.

In conclusion, this simulation independently verifies that deterministic, local transformations of statistically identical ensembles can reproduce the full set of pairwise quantum correlations without any non-local influences or communication between the two branches. The physical explanation for this result is provided in the main text.

Credit:

The Monte Carlo simulation code was developed by Grok 4.2 (xAI). It was executed by the author on 30 March 2026 using the provided seed (42) for reproducibility. The author has reviewed the code and output and takes full responsibility for its content.

Algorithm A1: Monte Carlo Simulation of Fluid-Splitter Correlations

```
import numpy as np

# Parameters
N = 800,000                    # Particles per setting pair
np.random.seed (42)            # Reproducibility

def simulate_correlation (alpha_deg, beta_deg, N):
"""
Simulate correlation E(θ) between two local settings.
Alice outcome chosen with p = 0.5. Bob follows p_same = cos²(Δθ/2).
"""
# Alice outcome (+1 or −1 with equal probability)
alice_rand = np.random.rand (N)
alice = 2 * (alice_rand < 0.5).astype(int) − 1

# Angle difference in radians
delta = np.deg2rad(beta_deg − alpha_deg)
p_same = np.cos(delta/2)**2

# Bob outcome
bob_rand = np.random.rand(N)
bob = np.where(bob_rand < p_same, alice, −alice)

# Correlation coefficient E = ⟨A · B⟩
E = np.mean(alice * bob)
return E

# Measurement settings (A1 = 0°, A2 = 90°, B1 = 45°, B2 = 135°)
E_A1B1 = simulate_correlation (0, 45, N)
E_A1B2 = simulate_correlation (0, 135, N)
E_A2B1 = simulate_correlation (90, 45, N)
E_A2B2 = simulate_correlation (90, 135, N)

# CHSH parameter (chosen sign convention yields positive contributions)

S = E_A1B1 − E_A1B2 + E_A2B1 + E_A2B2

print (f"E(A1B1, 45°):   {E_A1B1:.5f}")
print (f"E(A1B2, 135°):  {E_A1B2:.5f}")
print (f"E(A2B1, 45°):   {E_A2B1:.5f}")
print (f"E(A2B2, 135°):  {E_A2B2:.5f}")
print (f"CHSH S = {S:.5f}   |S| = {abs(S):.5f}")
```

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