THE ICELAND PAPERS

Select Papers on Experimental and Theoretical Research on the Physics of Consciousness

Frontiers of Physics
Conference

Reykjavik, Iceland
November 1977

ORB FOUNDATION
London

Edited by
ANDRIJA PUHARICH, M.D., LL.D.

With Foreword by
BRIAN D. JOSEPHSON, Ph.D.

Published 1979 by
Essentia Research Associates

I. *Introduction*

In almost every dictionary a paradox is defined, in its fundamental and etymologic meaning, as a "very surprising, but possibly true, statement". For example, Copernicus' heliocentrism has been such a paradox.

When scientific labor hits upon a hard paradox of this sort, the problem is not trying to *reduce* it, which would be meaningless. It is to *formalize* it; that is, tailor the mathematics after the facts, *and* the wording (entailing the *Weltanschauung*, or general philosophy) after the mathematics. This is also what Lorentz, Poincaré, Einstein and Minkowski did when promoting the relativity theory.

This is what Kuhn[1] has termed a change of paradigm[2] (the idea of which is already quite explicit in Duhem's[3] book). A "scientific revolution" is thus *a victory of formalism over modelism*. Einstein has not only swept away the mechanical theories of the ether, but the very ether concept. By tailoring the wording of his theory after the *group property* of the Lorentz-Poincaré[4] formulas, he has "unveiled the sense of the scriptures".

The problem confronting us today under the name of the 1927 Einstein[5], or 1935 Einstein-Podolsky-Rosen[6] paradox, is very much the same. Thanks to Heisenberg, Schrödinger, and their followers, we do have the good, operational mathematics, but have still overlooked one essential implication of them. Rather than a group structure, it is here an intrinsic mathematical symmetry that has not yet been adequately interpreted in the discourse. Doing this will, I believe, once more change the haze of the *paradox* into the dazzling clarity

of a *paradigm* and, thus casting an entirely new light on things, reveal new aspects—or, maybe, legitimize the persistence of various more or less recognized paradoxes of a lower order.

II. *Relativistic Quantum Mechanics*

In 1900, Planck, and in 1905, Einstein, have triggered the avalanches of the quantal and of the relativistic *paradoxes* now discussed in every treatise, and which, in their own days, have caused much sound and fury.

It has long been thought that relativity and quantum mechanics are hard to reconcile, but it finally turned out that this is not so, and a discussion of this point is extremely relevant to our subject. Relativity and quantum mechanics, as daughters of the physics of waves, are truly sisters. Special relativity is a "wave kinematics", de Broglie's "wave mechanics" is exactly *that*. And Born's 1926 probabilistic interpretation of the "new quantum mechanics" is basically an (entirely new) *wavelike probability calculus*. Born replaces the classical principle of adding partial probabilities by his principle of adding partial (complex) amplitudes, the (absolute) sum of which, when squared, yields the probability, This brings in, together with the diagonal terms (which are the sum of partial probabilities) the off-diagonal terms expressing an interference-like correction. The thousand and one phantasmagorias of quantum mechanics (wonderfully substantiated by experimentation), including the one we will be discussing, stem from this.

As I see it, the sphynx of the Einstein[5,6] paradox is born from the union of the past-future symmetry inherent in the probability theory[7] itself (where it caused, via the dynamics, the celebrated Loschmidt and Zermelo paradoxes[8]) with Born's concept of a wavelike probability calculus. And, as both progenitors have a well established "paradoxical" reputation, what of the offspring!

As early as 1927, over the very cradle of the just born "new quantum mechanics", Einstein was able to cast the frightening spell we will be discussing. So frightening is this spell that not only Einstein[9] but, among the founding fathers, Schrödinger[10] and de Broglie[11] also understood it as a malediction. The distant correlation which is at stake seemed unacceptable to Einstein[9] as implying "telepathy", to Schrödinger[10] as being "magic", and to de Broglie[11] as "upsetting our accepted ideas pertaining to space and time". Even now that there is plenty of experimental evidence[12,13] of the distant Einstein correlations, some distinguished physicists who have helped in clarifying the problem, are somewhat upset that quantum mechanics is once more right at *this* point!

Although Einstein, Podolsky and Rosen[6] have formalized the paradox in the (non-relativistic) Schrödinger style, it is in relativistic quantum mechanics that its sting is fully felt.

Relativistic quantum mechanics in itself is a paradox, as it unites relativistic fatalism (everything is written in space-time once and for all) with quantal probabilism. This marriage of water with fire is quite operational: the Schwinger-Feynman-Dyson quantum field theory is busy calculating, in a "manifestly covariant" style, transition probabilitites between an *initial state* (a preparation) and a *final state* (a measurement), with arbitrary spacelike surfaces replacing the initial and final time variables. How is this even conceivable? Two styles of answer are possible.

In a *frequency* interpretation of probability, we must conceive of *repetitions*, or *duplications*, of a *preparation* and of a *measurement*. By definition these must be identical as to what is prepared or measured. In this respect, these (preparations or measurements) must be *invariant by a space-time translation*. This is reminiscent of what was said in the frequency interpretation of the classical probability calculus: the various possible realizations of the preparation or of the outcome of the statistical test had to be "identical with respect to their significant features"; the insignificant features were neglected and allowed to vary—whence the intrusion of chance and statistics.

In the frequency interpretation of quantum mechanics we are not allowed to conceive of insignificant features of a test, because this would commit us to a hidden variables philosophy, which is not the sort of game played in this paper. Therefore, we speak of *essential*, or *irreducible*, statistics.

Now, according as we think of a repetition of the *preparation* or of the *outcome* of a measurement, we commit ourselves to a problem of *prediction* or of *retrodiction*. That is, given a preparation, we ask "what can be" the corresponding possible outcomes together with their *predictive probabilities*. Or, given an outcome, we ask "what could have been" the corresponding preparations, together with their *retrodictive probabilities*. What the Schwinger-Feynman-Dyson formalism yields is precisely that.

Now, by using an informational interpretation of probability, we go much deeper into the elucidation of the developing paradigm.

Information, of course, is (minus) the logarithm of the probability. But information, as conceived by Aristotle and Thomas Aquinas, and as rediscovered by cybernetics, is a *twin-faced concept*. On one side it is a *gain in knowledge*, on the other it is an *organizing power*. Consider for instance a telephone conversation, where a signal, with a characteristic *negentropy*, runs along the line. Receiving, decoding and understanding the signal is the *learning transition*, in which negentropy is converted into *information as cognizance*. Conceiving, expressing or coding, and sending the signal is the *organizing transition* in which *information as will* is converted into negentropy. Notwithstanding a *macroscopic prejudice* to the contrary, these two transitions are intrinsically symmetric to each other. And this intrinsic symmetry is tied with the *intrinsic symmetry between prediction and retrodiction*.

Going back to the repetition concept, it is obvious that, if we collect identical preparations together with their possible outcomes, we describe a macroscopic probability increasing evolution, from which we can extract knowledge by looking at the different outcomes. And, if we collect identical outcomes together with their possible preparations, we describe a macroscopic probability decreasing evolution in which information shows up as organization.

In physics, the first kind of process is accepted as self-sufficient while the second one is not, and *this* is what is stated in the Second Law. The Second Law states that the second kind of process is *unphysical* or, should we rather say, *antiphysical* (just as one speaks of *antiparticles* as being intrinsically symmetric to *particles*).

The factlike and macroscopic preponderance of particles over antiparticles (of electrons over positrons, etc. . . .) does not preclude their intrinsic symmetry; neither does it preclude the high theoretical and experimental significance of investigating the antiparticles. Now that we do know where to look for, and how to produce, antiparticles, we do find them and produce them. There is *apriori* no reason why *antiphysics* as *intrinsically* symmetrical to *physics*, being defined as *anti-Second Law*, should not show up in the appropriate context. And one need not say that antiphysics looks *extremely* like parapsychology.

The point is that *microphysics*, that is, *quantum mechanics*, is *neutral between physics and antiphysics*. It has essentially, and symmetrically, one foot in physics and one in antiphysics, just as it has one hand in particles and one in antiparticles.

Three intrinsic symmetries (and thus three factlike, macroscopic, asymmetries) are tied together in the classical probability and information theory: those between prediction and retrodiction, information as cognizance and as will, probability increasing and probability decreasing evolutions—that is, philosophically speaking, causality and finality.

Being a *wavelike probability calculus*, the "new quantum mechanics" ties these intrinsic symmetries (and factlike asymmetries) with that of retarded and advanced waves. As recognized by Fock[14] and others, it uses retarded and advanced waves (respectively) for (blind statistical[15]) prediction and retrodiction. Thus, it expresses the Second Law by stating either that blind retrodiction is forbidden or that advanced waves are non-existant in macroscopic physics.

This can be made explicit by re-reading[16] von Neumann's irreversibility statement pertaining to irreversibility of the quantum measurement process[17]. The proof implies the von Neumann ensembles, so it is a *macroscopic* statement. *No such proof is either possible, nor even significant, at the elementary level we are discussing.*

III. *The Einstein Paradox*

The Einstein paradox proper[12], or the time reversed Einstein paradox[13], is a most direct experimental and conceptual proof of the intrinsic time symmetry of quantum mechanics, together with Born's probability interference principle.

A little fable will help in understanding the Einstein[5] paradox (Fig. 1). At midnight G.M.T., two travellers leave the Calcutta airport, C, one for London, L, and the other one for Nagasaki, N, each carrying a closed box which contains, or not, the one ball which a third man, in Calcutta, has placed, behind a veil. At 9 G.M.T., having landed, each man opens his box, looks inside, and then immediately infers what the other man finds.

One remark is that, when made explicit, the logical inference drawn from L to N, or vice versa, is definitely not drawn directly along the space-like LN vector, which is physically empty. Explicitly, each man has to remember his flight from Calcutta, and the little

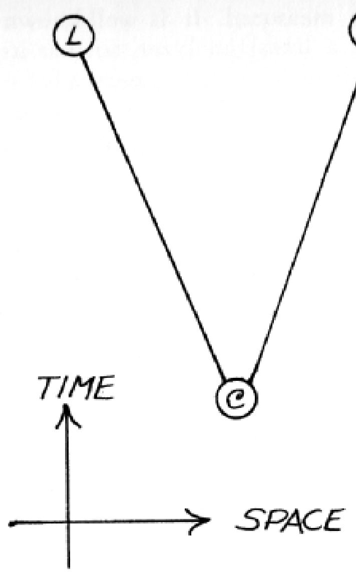


Fig. 1. A sketch for the Einstein paradox.

game played there, and then imagine the other man's flight from Calcutta. Therefore, the explicit inference is really drawn along a Feynman style zigzag LCN consisting of two time like vectors, once towards the past, once towards the future. As this is the only path that is physically occupied (in spacetime), the logic duplicates the physics—as it should.

However, there is in this nothing out of the ordinary, as long as the game is played inside the classical probability and information theory. What we have is a so-called "local hidden variables theory", the hidden variable having the value of 0 in one box and 1 in the other. The dice have been cast at C, in Calcutta, and this is virtually the end of the story.

The description of the Einstein paradox is very much the same—except for one point which changes everything. For example, in recent, and very conclusive, experiments[12] displaying the Einstein paradox proper, what takes place at C is an atomic cascade emitting two correlated photons which, after having flown from C in opposite directions, are detected at two places, L and N, where their linear polarizations are measured. It is well-known that a photon does, or does not, pass a linear analyzer, so that its polarization is then found as parallel or orthogonal (respectively) to that analyzer. And, as, obviously, this cannot be true simultaneously for two (conceived) orientations of the analyzer which are neither parallel nor orthogonal to each other, the two said (imagined) measurements are incompatible with each other. Moreover, each observer, at L or N, can in principle decide on the orientation of his analyzer *after* the twin photons have left their common source C (but of course before they reach L and N). This rather acrobatic sort of experiment has been defined, in a feasible way, and is in preparation[18].

So, with this specification of a quantal experiment, it is *definitely not at* C "when shaken inside the cup that the dice are cast". Rather, it is at L and N, when "they stop rolling on the table". This is all right—except for the (quantal) fact that *they are correlated!* If, so to speak, the 6 shows up on one, then it has to show up also on the other! Therefore, what we now have between L and N is not mere *telediction*, as was the case in our little fable. It is a *telediction plus teleaction*, whence the horrified statements made by Einstein[9], Schrödinger[10], and de Broglie[11]. However, the correlation, as expressed in the quantal formula, is experimentally there[12], so that *the observers at L and N are not independent from each other*, as Einstein, Podolsky, and Rosen[6] considered *evident* they should be!

We will come back, in Appendix A, to this paradoxical sort of correlation and to the nature of the *teleaction* it implies. The mathematics of it are given in Sections IV and V. As this phenomenon is so alien to ordinary, macroscopic, evidence, we derive in an elementary fashion, in Appendix A, the mathematics of the correlated polarizations of photos. There is absolutely no doubt that if these correlated polarizations experiments[12] could have been performed before, say, 1925, they would have caused the same sort of stupefaction as did the Nichelson experiment.

Now, there also exists the time reversed Einstein paradox, also demonstrated experimentally[13], and also well worth consideration (Fig. 2).

Pflegor and Mandel[13] have modified the famous two slits experiment, described in all textbooks, by using two independent lasers as sources. Then the phase correlation, if any, between these two sources L and N *cannot* be explained causally (whereas the two

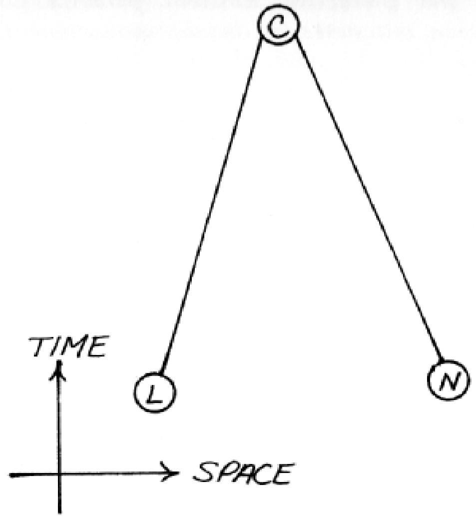


Fig. 2. A sketch for the time reversed Einstein paradox.

slits were illuminated by a *common source*). Even more, by placing very dark filters after the lasers, Pflegor and Mandel have rendered the mean time interval between the arrival of two successive photons inside the interference region longer than the time of flight inside the apparatus. Loosely speaking "there was never more than one photon flying inside the apparatus".

The fact is that under these conditions the interference does still show up! The very mathematics are such that, this being the case, one cannot *retrodict* from which of the lasers each detected photon has come! Again, this can be presented as a consequence of the existence of non-simultaneously measurable magnitudes (position and momentum, or phase and occupation number). The point is also that, inside the "essential probability game" we have agreed to play, it makes no sense to decouple statements upon *knowing* from statements upon *being*. Therefore, we must also conclude that *each* photon detected inside the interference region has been emitted *jointly* by *both* (phase coherent) lasers! Everything goes as if *each* laser knew what the *other one* is doing so as to act accordingly; and this, through their *future interaction*, at C (Fig. 2)!

Summarizing, *the predictive Einstein paradox consists in a correlation between outcomes of distant measurements connected through their past (Fig. 1), while the retrodictive Einstein paradox consists in a correlation between distant preparations connected through their future (Fig. 2).* In neither case is there a "present" interaction (which, indeed, would raise relativistic problems). Therefore, *paradoxical as they look to common sense, these correlations are fully consistent with relativistic covariance* and the limited velocity of signals. *The common sense belief which they do violate is Einstein's prohibition to telegraph into the past,* thus showing that this prohibition is of a factlike or macroscopic, rather than of a strictly lawlike nature. Whence the somewhat facetious signalization of the light cone I give in Fig. 3.

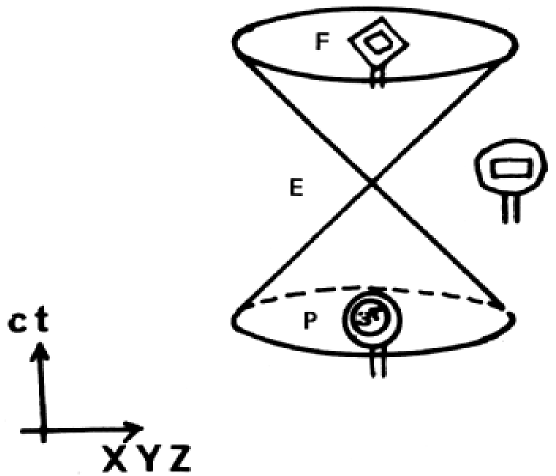


Fig. 3. The light cone trissecting space-time into past, P, future, F, and elsewhere, E. Direct telegraphing is forbidden into E, macroscopically restricted into P, and has priority into F.

IV. *Ennuple Einstein Correlation in General*

We consider a state vector $|\Phi\rangle$ expandable as

(4.1) $$|\Phi\rangle = \sum_j c_j \prod_\lambda |\phi_{\lambda j}\rangle$$

where the $|\phi_\lambda\rangle$'s span disjoint Hilbert spaces, and the mean value of

a Hermitean operator

(4.2) $$M = m_1 \otimes m_2 \otimes \ldots \otimes m_\lambda \otimes \ldots$$

which is the direct product of operators acting respectively upon the $|\phi_\lambda\rangle$'s, that is, the correlated mean value of the ennuple measurement of $m_1, m_2, \ldots m_\lambda \ldots$

(4.3) $$\langle\Phi|M|\Phi\rangle = \sum_i \sum_j c_i^* c_j \prod_\lambda \langle\phi_{i\lambda}|m_\lambda|\phi_{\lambda j}\rangle$$

This expression contains a sum of diagonal terms

(4.4) $$\langle\Phi|M|\Phi\rangle_0 = \sum_j w_j \prod_\lambda \langle m_{\lambda j}\rangle$$

with by definition

(4.5) $$w_j = c_j^* c_j, \quad \sum w_j = 1,$$

(4.6) $$\langle m_{\lambda j}\rangle = \langle\phi_{j\lambda}|m_\lambda|\phi_{\lambda j}\rangle$$

plus a sum of off diagonal terms

(4.7) $$\Delta\langle\Phi|M|\Phi\rangle = \frac{1}{2}\sum_{i\neq j} c_i^* c_j \prod_\lambda \langle\phi_{i\lambda}|m_\lambda|\phi_{\lambda j}\rangle + \text{c.c.}$$

Contrary to (4.3), neither of the contributions (4.4) and (4.7) is basis-invariant. In particular, a representation diagonalizing any one of the operators in (4.2) suppresses the off-diagonal contribution (4.7) and reduces (4.3) to the expression (4.4) valid for a "mixture"; that is, it apparently reduces the neoquantal[14] law (4.1) of addition of partial amplitudes to the paleoprobabilistic law (4.4) of addition of partial probabilities. The ennuple Einstein correlation is the off diagonal, "neoquantal", contribution to (4.3), in the sense that the very presence of these terms in the expression of (4.3) of the probability (even when they happen to be zero) forbids that the subsystems considered can be thought of as *objects* endowed with *separate properties.* This is what B. d'Espagnat and others term *non-separability.*

V. *Generalized Einstein Correlations*

The preceding formulas are not quite general enough in view of the next Section. So now, instead of (4.1), we consider an expansion (summation signs omitted)

(5.1) $$|\Psi\rangle = c^{ijk\ldots}|\phi_i\rangle|\chi_j\rangle|\psi_k\rangle\ldots$$

We rewrite (4.2) in the form

(5.2) $$M = m \otimes p \otimes q \otimes \ldots$$

and the correlated mean value as

(5.3) $$<\Phi|M|\Phi> = c^{*\,i'j'k'\ldots} c^{ijk\ldots} <\phi_{i'}|m|\phi_i><\chi_{j'}|p|\chi_j><\psi_{k'}|q|\psi_k>\cdots$$

This latter expression contains a "diagonal" contribution where *all* pairs of indexes i, i′; j, j′; k, k′; . . . are equal: i = i′, j = j′, k = k′, . . . :

(5.4) $$<\Phi|M|\Phi>_0 = w^{ijk\cdots}<m_i><p_j><q_k>\ldots$$

with *(no summation on repeated indexes)*

(5.5) $$w^{ijk\ldots} \equiv c^{*ijk\ldots}\; c^{ijk\ldots}$$

(5.6) $$m_i \equiv <\phi_i|m|\phi_i>$$

and an "off-diagonal" contribution

(5.7) $$\Delta<\Phi|M|\Phi> = <\Phi|M|\Phi> - <\Phi|M|\Phi>_0$$

neither of which is basis invariant. The condition for the off-diagonal contribution being *zero* is that the representation diagonalizes *all* the operators m, p, q, . . .

As in Section IV, the characteristic difference between the old and the new (or "wavelike") probability calculus lies in formulas (5.1) and (5.4): addition of partial amplitudes replaces addition of partial probabilities. In general, formula (5.4) does not follow from formula (5.1), except, of course, if the representation diagonalizes all operators m, p, q, . . . But this is a mere semblance of a classical statistical mixture, as it is *relative* to the basis chosen.

VI. *Predictive and Retrodictive Ennuple Einstein Correlations in the (Relativistically Covariant) S-Matrix Formalism*

We consider the Schwinger-Feynman-Dyson transition amplitude $<\Phi|\Psi>$ between an "initial" $|\Psi(\sigma_1)>$ and a "final" $|\Phi(\sigma_2)>$ state, the interaction being considered as negligible "before" the spacelike surface σ_1 and "after" the spacelike surface σ_2 (Fig. 4). Denoting $U(\sigma)$ the unitary Schwinger evolution operator and U its specification U_1^2, the explicit expression of the transition amplitude is

(6.1) $$<\Phi|\Psi> = <\Phi_2|U\Psi_1> = <\Phi_2 U|\Psi_1>$$

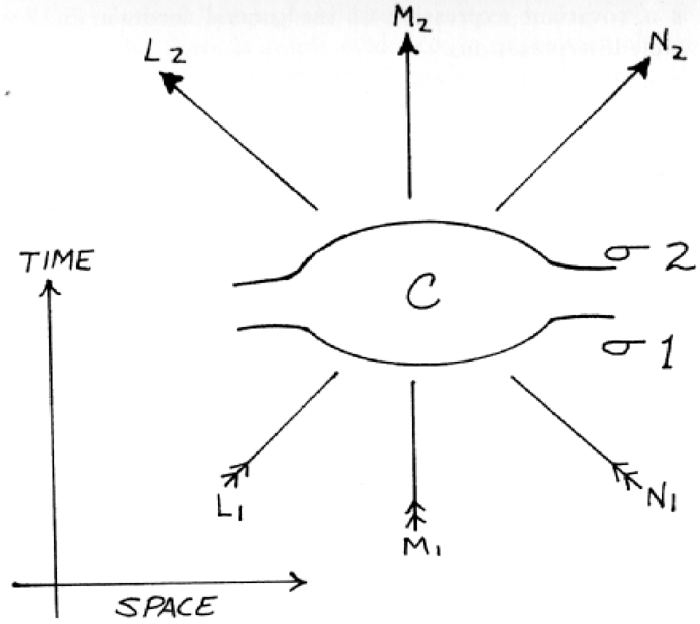


Fig. 4. S-matrix formalism.

This is, *modulo* the two extensions $\psi \rightarrow \Psi$ (second quantification) and $t \rightarrow \sigma$ (relativistic covariance), the formula for the "wave collapse" associated with a measurement in the Schrödinger theory.

Being the expression of a Hermitean scalar product, this formula is intrinsically symmetric with respect to the two vectors $|\Psi_1>$ and $|\Phi_2>$. But, of course, it admits two asymmetric (although symmetric to each other) interpretations: If we project $|U\Psi_1>$ upon $|\Phi_2>$ at σ^2, we say that we *collapse* the state vector in view of a *prediction*. And if we project $|U^{-1}\Phi_2>$ upon $|\Psi_1>$ at σ_1, we say that we *anticollapse* the state vector in view of a *retrodiction*. To this we will come back.

By introducing the complete orthogonal set of projectors $|\theta><\theta|$ adapted to the particular measurement that is contemplated, we expand (6.1) in the form (summation sign omitted)

(6.2) $$<\Phi|\Psi> = <\Phi|\theta><\theta|\Psi>$$

which is a covariant expression of the general formula (5.1) with two possible interpretations.

In a predictive problem the $<\Theta|\Phi>$'s will be interpreted as the components of the final state $|\Phi>$ in the Θ representation, and the $<\Psi|\Theta>$'s as the coefficients of the expansion. In a retrodictive problem the $<\Theta|\Psi>$'s will be interpreted as the components of the initial state $|\Psi>$ in the Θ representation, and the $<\Phi|\Theta>$'s as the coefficients of the expansion. This being said, the Feynman transition amplitude does indeed have the form (5.1). For example, in quantum electrodynamics, the $|\phi>$'s are the states $|A>$ of the photon, $|\psi>$ of the electron, and $|\psi>$ of the positron. The Einstein paradox consists in the presence of the correlations expressed through (5.3) both between the initially separated systems L_1, M_1, N_1 interacting at C through their common future, and between the finally separated systems L_2, M_2, N_2, interacting at C through their common past. In the first instance we have a *retrodictive correlation* between *preparations* that *will interact*—and this has been experimentally demonstrated for occupation numbers by Pflegor and Mandel[13]. In the second instance we have a predictive correlation between *measurements* upon systems that *have interacted*—and this has been experimentally demonstrated for polarization states by quite a few authors[12].

This shows quite explicitly that the *physical, mathematical and logical link of the Einstein correlation is* (in the relativistically covariant quantum mechanics) *the Feynman zigzag*[19,20]. The Einstein correlation is thus a *spacelike correlation established by two timelike vectors*, with a relay either in the past (predictive Einstein correlation) or in the future (retrodictive Einstein correlation). It does *not* violate the *geometrical* relativistic covariance any more than do the (hypothetical) tachyons. What it does violate is Einstein's prohibition to "telegraph into the past", that is, the *macrophysical* exclusion of advanced waves. That, on the elementary level of *microphysics*, the *intrinsic* symmetry between retarded and advanced waves (which is so obvious everywhere in the *mathematical* formalism) should show up in appropriate experimental contexts has nothing surprising *per se*. In this sense, the Einstein paradox is quite reminiscent of the classical Loschmidt and Zermelo paradoxes. What makes the sting of the paradox so much more painful is its association with Born's interference principle: adding partial

amplitudes rather than probabilitites.

Incidentally, there is ample evidence, in experimental high energy physics, that the predictive Einstein correlations are quite operational, and this, over distances as large as quite a few meters.

VII. *Covariant First Quantization*

The logically missing link in the Schwinger-Feynman-Dyson formalism is a covariant definition of the states upon which initially (at σ_1) and finally (at) the occupation numbers are distributed. This can be done in a satisfactory way[21] and, as it sheds much light upon the intrinsic time symmetry of the formalism, we summarize it now for the case of the interaction picture proper, that is, for initially and finally free particles. More details can be found elsewhere[21].

The free particles we are considering obey the (unspecified spin) Klein-Gordon equation and a specified spin equation (Dirac, Petiau-Duffin-Kemmer, etc). To each spinning particle equation is associated a projector P projecting any solution of the Klein-Gordon equation as a solution of the spinning particle equation.

The Fourier expansion of any solution of the wave equation shall be expressed as an integral over both sheets of the mass shell. The case of massless particles can be treated either by starting from a Fourier expansion over both sheets of the light cone[21] or else (as we will do here) by conferring an arbitrarily small rest mass k to our particles.

Then comes the question of the reciprocal Fourier transform and of the Parseval equality, that is, of the expression of the Hermitian scalar product in its spacetime x and 4-frequency k representations.

It turns out that, for two solutions $\psi_a(x)$ and $\psi_b(x)$, or $\theta_a(k)$ and $\theta_b(k)$, the appropriate expression of the Hermitean scalar product is, with the Klein-Gordon equation, ($\lambda = 1, 2, 3, 4,$; $x^4 = it$; $c = 1$ and $\hbar = 1$)

$$(7.1) \quad <a\,||\,b> \equiv -\frac{i}{2k}\iiint_\sigma \bar{\psi}_a [\partial_\lambda] \psi_b d\sigma^\lambda = \frac{1}{k}\iiint_\eta \bar{\theta}_a k_\lambda \theta_{b\varepsilon}(k) d\eta^\lambda$$

and, with the spinning particle equation,

$$(7.2) \quad <a\,|\,b> \equiv i\iiint_\sigma \bar{\psi}_a \alpha_\lambda \psi_b d\sigma^\lambda = i\iiint_\eta \bar{\theta}_a \alpha_\lambda \theta_{b\varepsilon}(k) d\eta^\lambda$$

The η integral is over both sheets of the mass shell $\eta(k) \equiv k_\lambda k^\lambda + k^2 = 0$ with $\epsilon(k) = +1$ on the positive energy sheet and $\epsilon(k) = -1$ on the negative energy sheet; $d\eta^\lambda$, which is such that

$$k^\lambda d\eta = -k d\eta^\lambda, \tag{7.3}$$

is the 4-vector representing the three dimensional element on η The σ integral is over an arbitrary spacelike surface σ of element $d\sigma^\lambda$, and is σ – independent by virtue of the wave equation; in (7.1)$[\partial_\lambda] \equiv \overrightarrow{\partial}_\lambda - \overleftarrow{\partial}_\lambda$ is the well-known Gordon current operators, and in (7.2) the α's are the spin matrices ($\alpha^\lambda = \gamma^\lambda$ in the Dirac case, $= \beta^\lambda$ in the Petiau-Duffin-Kemmer case, etc. . .).

The double vertical bar in (7.1) and the single vertical bar in (7.2) simply remind that in the first case we are dealing with a second order, and in the second case with the first order, equation. Clearly, due to the Gordon decomposition of the current, the expressions $\langle a \| b \rangle$ and $\langle a | b \rangle$ are integrally equivalent.

Using the well-known Dirac notation we rewrite (7.1) and (7.2) as

$$\langle a \| b \rangle = \langle a \| x \rangle \langle x \| b \rangle = \langle a \| k \rangle \langle k \| b \rangle \tag{7.4}$$

$$\langle a | b \rangle = \langle a | x \rangle \langle x | b \rangle = \langle a | k \rangle \langle k | b \rangle \tag{7.5}$$

Orthonormality is, of course, expressed as

$$\langle a \| b \rangle = \langle a | b \rangle = \delta_{ab} \tag{7.6}$$

Introducing the Fourier nucleus

$$\langle x \| k \rangle = \langle k \| x \rangle^* = \begin{cases} (2\pi)^{-3/2} \exp(ik_\lambda x^\lambda) & \text{if } \eta(k) = 0 \\ 0 & \text{otherwise} \end{cases} \tag{7.7}$$

$$\langle x | k \rangle = P \langle x \| k \rangle$$

we write the reciprocal Fourier transforms as

$$\langle x \| a \rangle = \langle x \| k \rangle \langle k \| a \rangle, \quad \langle k \| a \rangle = \langle k \| x \rangle \langle x \| a \rangle, \tag{7.9}$$

$$\langle x | a \rangle = \langle x | k \rangle \langle k | a \rangle, \quad \langle k | a \rangle = \langle k | x \rangle \langle x | a \rangle. \tag{7.10}$$

By substituting the second formula (7.9) into the first one and setting

$$\langle x' \| x'' \rangle \equiv \langle x' \| k \rangle \langle k \| x'' \rangle = \langle x' \| x \rangle \langle x \| x'' \rangle \tag{7.11}$$

one solves the Cauchy problem in the form

$$\langle x' \| a \rangle = \langle x' \| x \rangle \langle x \| a \rangle \tag{7.12}$$

where, according to the definition (7.11), $\langle x' \| x \rangle$ is the well-known

Jordan-Pauli propagator, which is odd in $(x' - x'')$ and, thus, zero outside the light cone. So formula (7.11), with $x' - x''$ spacelike, expresses orthogonality in k-space of two Fourier nucleuses, and in x-space of two Jordan-Pauli propagators. Therefore, (7.12) is the expansion of the wave function at any point–instant x' upon the complete set of orthogonal Jordan-Pauli propagators with apexes x on an arbitrary spacelike surface σ, the coefficients being the values of the wave function on σ. Finally, as expressions (7.7) and (7.11) are Fourier associated, we deduce, by transposing a well-known Schrödinger argument, that, in this formalism, the position operator is x^λ *modulo that* x^λ *ends on* σ (that is, only three degrees of freedom; for example, the components of $\vec{x}$).

I mention *en passant* the formula

$$\langle k' \| k'' \rangle = \langle k' \| x \rangle \langle x \| k'' \rangle = \langle k' \| k \rangle \langle k \| k'' \rangle \tag{7.13}$$

expressing orthogonality of two Fourier nucleuses in x-space, provided that the two 4-vectors k' and k'' are different.

Formulas similar to (7.11), (7.12) and (7.13) with one vertical bar instead of two can, of course, be derived from the (7.10)'s.

Incidentally

$$\langle x' | x'' \rangle = P \langle x' \| x'' \rangle. \tag{7.14}$$

VIII. *Covariant Position (or Position Plus Polarization) Measurement*

The covariant extension (Fig. 5) of the question, "do we find at time t the Schrödinger particle inside the volume element dx dy dz?", is clearly, "do we find at σ the relativistic particle crossing a given element $d\sigma^\lambda$ of σ?" The eigenfunction then corresponding to the Dirac $\delta(x' - x)$ is, as previously explained, the Jordan-Pauli propagator $D(x' - x) = \langle x' \| x \rangle$. The probability distribution for finding the particle "at x^λ at pseudo time σ" is the Gordon current flux $\langle a \| x \rangle \langle x \| a \rangle$.

All this means that finding the particle "at x^λ at σ" in the above sense implies that it has come inside the past, and will go inside the future, light cone–which, of course, is known since Minkowski *except for one important point.*

The position measurement "performed at pseudo time σ*" does collapse the wave function* $\langle x \| a \rangle$ into $\langle x' \| x \rangle$ and, as $\langle x' \| x \rangle$ is odd in $x' - x$, *this collapse affects symmetrically past and future.* In

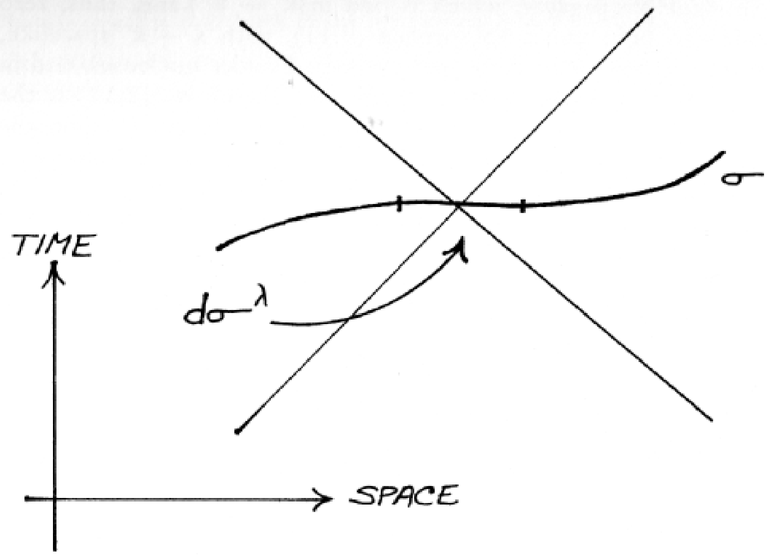


Fig. 5. Covariant position measurement "at σ" in space-time: does or does not the particle go through the element dσ of σ?

the terminology of Section VI it is together a collapse *and* an anticollapse.

This is *precisely* the key I am proposing for formalizing the Einstein paradox: *Two distant position measurements with spacelike separation (or, in the single bar formalism, two distant position plus polarization measurements) do produce the same collapse in their common past.* Similarly, *two distant position preparations with spacelike separation do produce the same anticollapse in their common future,* which formalizes the time reversed Einstein paradox.

In view of forthcoming considerations, I finally draw a connection between two intrinsic mathematical symmetries: that between retarded and advanced propagators, D_r and D_a, and that between the positive and negative frequency Fourier contributions, D_+ and D_- (that is, in the Dirac and Feynman interpretation, between particles and antiparticles).

The Jordan-Pauli propagator has, among others, the two expressions:

(5.1) $\quad <x'|x''> \equiv D(x' - x'') \equiv D_+ - D_- = D_r + D_a$

Moreover, it is the *only* propagator expressible as a linear superposition of *both* D_+ and D_- and of D_r and D_a.

This displays a partial binding between the two mathematical symmetries we have spoken of, and so, just as the lawlike symmetry between particles and antiparticles is *in fact* much obliterated by a large preponderance of particles over antiparticles (at least, in the electron and the proton cases), it may well be that the macroscopic preponderance of retarded over advanced waves is also of a factlike rather than lawlike nature.

IX. *Physics and Antiphysics*

Arguing that the "paradoxical" Einstein correlations are a dramatic illustration of intrinsic time symmetry in the quantum formalism, we have inferred from there the existence of a (macro) antiphysics obeying a time-reversed Second Law, and thus, time symmetric to the classical (macro) physics. We have also submitted that the context of anti-physics is none else than the field of parapsychology. We intend here to develop this point.

Figures 6a, b, and c are meant to illustrate through an example the intrinsic time symmetry of microphysics (6b) and the mutual time symmetry of (macro) physics (6a) and (macro) antiphysics (6c). Suppose we have at x = 0 a linear grating working in permanent regime, so that the space coordinate x is a valid analog of the time coordinate t.

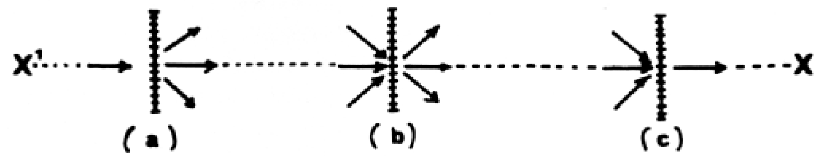


Fig. 6. The grating thought experiment: 6a, real diffraction; 6c, ideal anti-diffraction; 6b, microscopic reversibility.

In (6a) we have the ordinary physical situation: an incoming plane wave issuing from a source S is diffracted as g phase coherent plane waves, upon which the incident corpuscles, or quanta, are distributed according to "the laws of probability". This phenomenology is equivalently well described by the *principle of retarded waves* or by the principle of *blind statistical prediction*, both characterizing macrophysics, and tied together by Born's probabilistic interpretation of wave intensities.

Figure (6c) displays the paradoxical time reversed situation where an outgoing plane wave (belonging to the previous collection) is received in a collimator R and (of course) *would be* generated alone by phase and amplitude coherence of g incident plane waves (including the one considered in Fig. 6a). The comments are as follows:

1º This phenomenon *can* be produced by the appropriate "conspiration of causalities" just said; in his Ph. D. thesis von Laue[22] described an apparatus comprising (6a) and (6c) and preserving phases in between. Any optical apparatus giving a point image of a point object is an other illustration of what we are saying.

2º However, in physics, the phenomenon (6a) is easily produced by means of *one single causality condition* (source at S), whereas *in fact* the phenomenon (6c) cannot be produced by means of one single finality condition (sink at R).

3º *Nonetheless*, the situation (6c) is *the one* to which one is logically led when only knowing that a (quantized) plane wave is received in R *and* that the grating is there. This is because one is *certain* that, before the grating, the received corpuscles were *certainly* carried by one or the other of the said g incident plane waves, *and* there is *no reason* to favor any one over the others.

4º At this point of their thinking, the classicists, knowing in general that a situation such as (6c) is *unphysical* (or rather, should we say, *antiphysical*) brought in their *principle of the probability of causes*, the very name of which is quite revealing, as implying a reference to *retarded* causality. This principle stated that *blind statistical retrodiction* (the thinking procedure just described) is forbidden as unphysical, so that the *intrinsic retrodictive probabilities* should be multiplied by *arbitrarily chosen extrinsic probabilities* (the so-called Bayes coefficients)—chosen at best from ones overall knowledge. Of these, the theory said nothing except that *they should not be equal*, because this would entail the forbidden thing, *blind statistical retrodiction*.

Thus far went the classical discussion in physics. There was, however, good reason to suspect that macrophysics is not the whole

story, if only because of the existence of *free will*, and the *immediate consciousness* we have of it[23]. Moreover, as made quite clear by the general existence of evanescent waves in quantum mechanics, there is simply not one physical system that is strictly inside a closed surface, so that, if our *willing consciousness* is able to move the parts of our body "inside" our skin, there is *in principle no reason* why it could not also "move material objects outside of our skin"[24]. *In both cases*, what we have is *psychokinesis*.

To believe in psychokinesis means that there exists situations (by definition alien to macrophysics) where the *blind statistical retrodiction* taboo is trespassed, and one has to use, instead, the Bayes conditional probability formula *for prediction*—as a *principle of the probability of ends* (rather than causes). This, of course, *is* antiphysics. It is, equivalently, *psychokinesis* or *precognition*, two phenomena not distinguishable from each other at this level of the discussion.

Finally, Fig. 6b illustrates what microphysics has to say on all this. Microphysics states that the grating can induce a *transition* from any one of the g incoming plane waves to any one of the g outgoing plane waves, and yields for this a *transition probability matrix*, which is *intrinsically time symmetric* in the sense that it works just as well for (blind) statistical prediction or retrodiction. In other words, *microphysics is neutral between physics and antiphysics.*

Classical statistical physics would have said much the same except for this: In quantum physics, the *transition probability matrix* is the by product of a more fundamental *transition amplitude matrix* giving information upon phase differences, and entailing the "paradoxical" Einstein correlations (either predictive or retrodictive). In this light, Fig 6b is a faithful three-space analog of the four-space Fig. 4.

Now, as already said, these correlations imply the possibility of "telegraphing outside the light cone" *not directly*, of course (which is *strictly forbidden*[25]), but indirectly, by means of Feynman zigzags, with a relay either in the past or in the future (somewhat like a sailing boat is able to work its way against the wind by "tacking about"). Moreover as previously said, this sort of telegraphing *cannot* be a *telediction* only, and *must* also (in some sense) be a *teleaction* (whence the horrified reactions of the Founding Fathers[9,10,11]).

To make this point clearer, we consider (Fig. 7) two (or more)

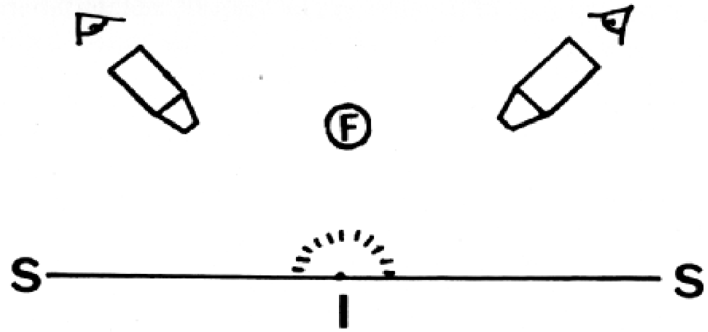


Fig. 7. Two (or more) observers of scintillations of α-particles upon a ZnS screen, S. F, source of particles. I, impact of a particle.

observers of the same quantal transition; for example, the impact of an α —particle upon a **Zn S** screen. It follows from the rules of quantum mechanics that these observers are Einstein-correlated, so that *they are not independent, but are either cooperating or competing for producing the same collapse—in their common past.*[26]

This could be tested by including a psychic among the observers. Going back to Fig. 6a, we could have him "look" at one of the outgoing beams[27] and perform psychokinesis on it, so that the intensities on *the other* outgoing beams would be changed. One could also have two competing psychics playing against each other a game of "pulling a rope", with a "pulley" in the past. This, incidentally, makes *very clear* why a majority of strongly skeptical observers will block the kinetic power of a psychic. As stated by Walker[28], in these problems one should add algebraically the information (cognizance *and* will) staked by the various observers.

Concluding this section, intrinsic time symmetry *plus* additivity of partial amplitudes entails *logically* the existence of psychokinesis, precognition, telekinesis and telepathy.

X. *Metaphysics of Nonseparability*

There is a relativistic nonseparability and a quantal nonseparability which fit extremely well together.

The relativistic nonseparability[29] follows from the existence of the Poincaré[30]-Minkowski[29] spacetime metric, where the so-called

isotropic cone (the "light-cone") is real (Fig. 3). As, at each point instant, there is thus the *trichotomy* of *past, future* and *elsewhere*, (instead of the classical dichotomy of past and future) *there exists no more an objective, or global, separation between past and future.* So, *in relativistic physics, it is definitely not possible to think of the past or the future as nonexistent.* If matter is space extended (and how could it not be?), then it is *necessarily* time-extended also. The past is just as really "down there", and the future just as really "up there", than are the valley and the summit to the alpine climber.

On the other hand, relativistic quantum mechanics does speak of *probabilities*, and the very probability concept implies a distinction between Aristotle's *potentia* and *act,* that is, between *form* (or information) and *matter*. How can this be conceptualized in a relativistically covariant way?

Probability or *Information,* when taken to be *essential, must* be the hinge around which mind and matter are interacting. Therefore, the spacetime extended matter, as seen from the objective side, is somewhat like a vivid tapestry having, nonetheless, a weft on the other, subjective, side. This consists of an intertwined array of diverging waves of cognizance and converging waves of will, so that, although the future, like the past, is written ("it cannot be else than what it will have been"), it is nevertheless not "made" without our will and our cognizance—together with those of whatever higher or lower psyches might also be involved. In this sense we have *act* and *matter* on the scenery of the tapestry, and we have *potentia* and *information* on the back side.

Now, what do we read *passim* in Bergson? That there is no *homo sapiens* because, truly, there is only a *homo faber.* And this man, because of his pragmatic approach in thinking and acting, severs, inside the wholeness of reality, parts that should truly not be thus severed. If he were able to approach things through Intuition, he would see everything in an entirely new, and much more revealing, light. Among other things, he would hold the key to "Creative Evolution".

The Vedas are even more explicit. They state *passim* that *separability* is an *illusion*, which is *relative* to the ordinary pragmatic approach. If, through appropriate meditative techniques, one gains *cosmic consciousness,* this is cognizance of the *past*, the *future,* and the *elsewhere*, together with possession of the *siddhis*, or paranormal powers. It is astounding how well this fits with the *wave collapse* associated with every *quantal measurement* or *quantal severance*, and with the overall phase coherence which is thus lost, but which nevertheless pervades *all* spacetime, in the covariant way characterizing the (relativistic and quantal) physics of waves.

Appendix A

Predictive Correlated Polarizations (Elementary Derivation)

Two orthogonal eigenstates for two photons, a and b, flying in opposite directions along an axis x, with zero total angular momentum, consist of the two left $L_a\ L_b$ and the two right $R_a\ R_b$ circular polarization states. From these, the two orthogonal parity invariant states $L_a\ L_b \pm R_a\ R_b$ are deduced; and from these, an infinity of orthogonal linear polarization states $Y_a\ Y_b$ and $Z_a\ Z_b$ or $Y_a\ Z_b$ and $Y_b\ Z_a$ deduced through the well known formulas

(A.1) $$L_a L_b + R_a R_b = Y_a Y_b + Z_a Z_b$$

(A.2) $$L_a L_b - R_a R_b = i\ [Y_a Z_b - Y_b Z_a]$$

Let us, for example, discuss the case (A.1).

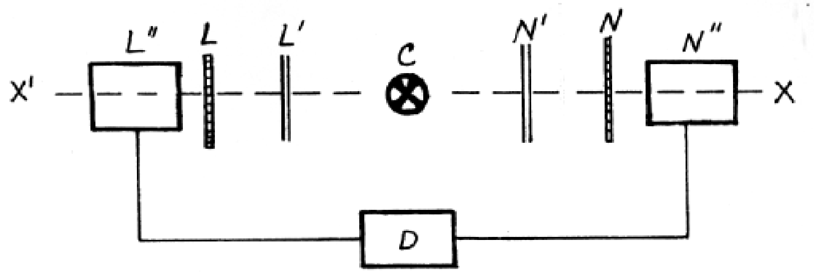


Fig. 8. A sketch of the cascade experiment: C, cascading atom. L', N', monochromators. L,N, linear polarizers. L'', N'', photomultipliers. D, coincidence counter.

Consider first the representation using the two circular polarizations. Turning (Fig. 8) the linear analyzer L by the angle ΔA will shift the relative phase of the L_a L_b pair by, say, $+\Delta A$, and, then, that of the R_a R_b pair by $-\Delta A$. Then, turning the analyzer N by ΔB will cause the corresponding shifts $-\Delta B$ and $+\Delta B$. Setting

(A.3) $$\alpha = A - B$$

and applying Born's rule of squaring the absolute value of the sum of partial amplitudes, we obtain as probabilities

(A.4) $$<1,1> = <0,0> = \tfrac{1}{2}\,|\,e^{i\alpha} + e^{-i\alpha}\,|^2 = \tfrac{1}{2}\cos^2\alpha$$

(A.5) $$<1,0> = <0,1> = \tfrac{1}{2}\,|\,e^{i\alpha} - e^{-i\alpha}\,|^2 = \tfrac{1}{2}\sin^2\alpha$$

where 1, or *yes*, means "photon passing" and 0, or *no*, means "photon stopped".

Similarly, using a representation by two orthogonal linear polarizations, we know from classical optics that the four amplitudes at stake are cos A cos B, sin A sin B, cos A sin B, and sin A cos B, whence, by Born's rule, the same result as above in the form

(A.6) $$<1,1> = <0,0> = \tfrac{1}{2}\,(\cos A \cos B + \sin A \sin B)^2 = \tfrac{1}{2}\cos^2\alpha$$

(A.7) $$<1,0> = <0,1> = \tfrac{1}{2}\,(\cos A \sin B - \cos B \sin A)^2 = \tfrac{1}{2}\sin^2\alpha$$

Now, if we expand formulas (A.4) and (A.5), we get, with the circular polarizations representation,

(A.8) $$<1,1> = <0,0> = \tfrac{1}{4}\,(1 + \cos 2\alpha)$$

(A.9) $$<1,0> = <0,1> = \tfrac{1}{4}\,(1 - \cos 2\alpha)$$

where ¼, sum of the diagonal terms, is the *paleoquantal*[31] *probability* implying the *mixture* concept, and $\pm \cos 2\alpha$ the *neoquantal*[31] correction due to phase correlation.

Similarly, expanding formulas (A.6) and (A.7) we get, with the linear polarizations representation,

(A.10) $$<1,1> = <0,0> = \tfrac{1}{2}\,(\cos^2 A \cos^2 B + \sin^2 A \sin^2 B) + \tfrac{1}{4}\sin 2A \sin 2B$$

(A.11) $$<1,0> = <0,1> = \tfrac{1}{2}\,(\cos^2 A \sin^2 B + \sin^2 A \cos^2 B) - \tfrac{1}{4}\sin 2A \sin 2B$$

where the parenthesis is the *paleoquantal probability* implying the mixture concept (sum of partial probabilities), and $\pm\frac{1}{4}\sin 2A \sin 2B$ is the *neoquantal correction.*

Incidentally, formulas (A.10) and (A.11) are not rotationally invariant. Therefore, the paleoquantal physicist would have taken one more step: averaging over all values of A and B. This is most easily done by writing

$$\tfrac{1}{4}\sin 2A \sin 2B = \tfrac{1}{8}\,[\cos 2\alpha - \cos 2\,(A+B)] \cong \tfrac{1}{8}\cos\alpha$$

whence

(A.12) $$<<1,1>> = <<0,0>> = \tfrac{1}{4} + (\tfrac{1}{8})\cos 2\alpha$$

(A.13) $$<<1,0>> = <<0,1>> = \tfrac{1}{4} - (\tfrac{1}{8})\cos 2\alpha$$

to be compared with (A.8) and (A.9).

Clearly, formulas (A.8) to (A.11) are specifications of the general formula (4.3) for $\lambda = 1, 2$.

These formulas show quite dramatically the radical change in paradigm implied, in this problem, by the neoquantal formalism (together with its experimental verification). To see this quite clearly, we consider, in case (A.1), the situation with $\alpha = \pi/2$ (crossed analyzers), where one gets $<1,1> = 0$: *no photon pairs detected.*

If the photons of the pair did *possess* some polarizations when leaving the source, these could be, for instance, two circular polarizations of same helicity; but, then, a considerable proportion of answers *"yes, yes"* would appear, namely, ¼. Also, the two photons could also *possess* two linear polarizations parallel to each other (see formula A.6), but *independent of the orientations of the analyzers at* L *and* N (and even of their presence or absence). Again, a considerable proportion of answers *"yes, yes"* would then appear, namely (according to [A.12]), 1/8.

The experimental, and neoquantal[31], result 0 implies that *all* of the measured photon pairs do have linear polarizations parallel to each other (all right!) *but also parallel to either one or the other of the two analyzers!*

Whence *necessarily* three statements:

1º *The photons do not possess polarizations when leaving the source at C, but borrow one later, by interacting with the analyzers.* This, of course, is a well known neoquantal statement (of which there is perhaps no more direct proof than this one).

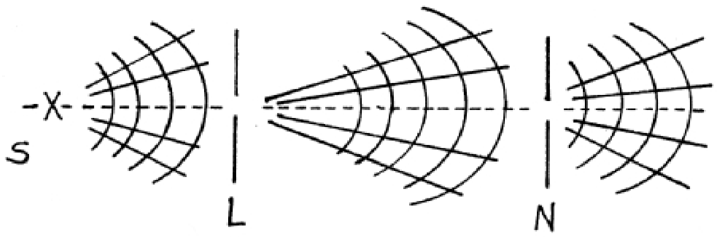
2º *The "dice" are thus not cast at C, when "shaken in the cup",* *but at L and N, "when rolling on the table".*

3º *Nevertheless they are correlated. This* is the Einstein paradox!

Appendix B

Where and When Does a Transition Occur?

Consider, for example, a light beam crossing successively two linear analyzers L and N, the directions of which are A and B. The classical view was that a photon issuing from L with polarization A "collapses" either to B or to B + $\pi/2$ when falling upon N. This strongly time asymmetric conception is definitely not the one consonant with the philosophy presented here.



Rather should we say that *somewhere inbetween L and N,* a photon passing L and N makes a transition from the outgoing wave issuing from L to the incoming wave entering N.

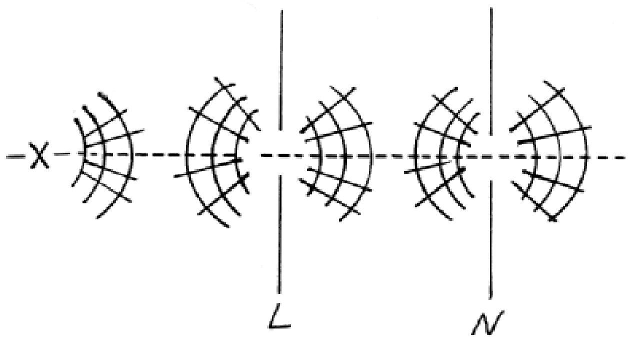


Fig. 9. The collapse thought experiment: 6a, macroscopic retarded waves and "collapse". 6b, microphysical half retarded and half advanced waves, and the time symmetric transition concept.

An understandable picture is more easily drawn (Fig. 9) for the case of a photon passing in succession two holes L and N inside two screens. *Mutatis mutandis* the discourse is the same as before, and, as the pictures are quite explicit in this case, no more comment will be made.

REFERENCES

1. T.S. Kuhn, *The Structure of Scientific Revolutions*, University of Chicago Press, First Edition, 1968, Second Ed., 1970.
2. See *Paradox and Paradigm*, R.G. Colodny, Editor, University of Pittsburgh Press, 1973.
3. P. Duhem, *The Aim and Structure of Physical Theory* P.P. Weiver, translator), Princeton University Press, 1954; See Part II, Chapters IV and VI.
4. These formulas were already known to Larmor in 1898 and (not quite exactly) to Voigt in 1887.
5. A. Einstein in *Rapports et Discussions du Cinquième Conseil Solvay*, Gauthier Villars, Paris, 1928, pp. 253-256.
6. A. Einstein, B. Podolsky and N. Rosen, *Physical Review*, 47, 777 (1935).
7. There is no intrinsic reason for an asymmetry between predictive and retrodictive stochastic calculations. Moreover, if the transition probabilities are symmetric in the states, as is often the case (for instance, in card shuffling or radioactive decay), the formulas for "blind" statistical prediction and retrodiction *are* symmetric to each other.
8. This was recognized by J.D. van der Waals, *Phys. Zeits.* 12, 547 (1911).
9. A. Einstein in *Einstein, Philosopher Scientist*, P.A. Schilpp ed., The Library of Living Philosophers, Evanston, Ill., 1949, pp. 85 and 683.
10. E. Schrödinger, *Naturwiss*, 23, 844 (1935). See page 845.
11. L. de Broglie, *Une Tentative d' Interprétation...de la Mécanique Ondulatoire*, Gauthier Villars, Paris, 1956, page 73.
12. S.J. Freedman and J.F. Clauser, *Phys. Rev. Lett.* 28, 938 (1927). J.F. 14, 2543 (1976). A.R. Wilson, J. Lowe and K.K. Butt, *J. Phys.* G2, 613 *Rev. Lett.* 37, 465 (1976). M. Lamehy-Rachti and W. Mittig, *Phys. Rev D.* 14, 2543 (1976), A.R. Wilson, J. Lowe and D.K. Butt, *J. Phys.* G2, 613 (1976).
13. R.L. Pflegor and L. Mandel, *Phys. Rev.* 159, 1084 (1967); see sp. formula 18 and Discussion. *Journ. Opt. Soc. Amer.* 58, 946 (1958).
14. V. Fock, *Dokl. Akad. Nauk.* SSSR 60, 1157 (1948).

15. S. Watanabe, *Rev. Mod. Phys.* 27, 179 (1955).
16. O. Costa de Beauregard, *Cah. de Phys.* 12, 317 (1958).
17. See also in this respect, Y. Aharonov, P.G. Bergmann and J.L. Lebowitz, *Phys. Rev.* 134B, 1410 (1964), and F.J. Belinfante, *Measurement and Time Reversal in Objective Quantum Theory*, Oxford University Press, 1975, page 26.
18. A. Aspect, *Phys. Lett.* 54A, 117 (1975). *Phys. Rev.* D 14, 1944 (1976).
19. O. Costa de Beauregard, *Comptes Rendus* 236, 1632 (1953). *Rev. Intern. Philos.* 61-62, 1 (1964). *Dialectica* 19, 280 (1965). In *Proc. Intern. Conf. Thermodynamics*, P.T. Landsberg, ed., Butterworths, London 1970, page 539. *Found. Phys.* 6, 539 (1976). *Synthese* 35, 129 (1977). *Nuovo Cim.* 42B, 41 (1977).
20. H.P. Stapp, *Nuovo Cim*, 29 B, 270 (1975). W.C. Davidon, *Nuovo Cim*, 36 B, 34 (1976). See also, J.F. Clauser and M.A. Horne, *Phys. Rev.* D 10, 526 (1974) footnote 13.
21. O. Costa de Beauregard, *Précis de Mécanique Quantique Relativiste*, Dunod, Paris, 1967. See also *Nuovo Cim.* 42 B, 41 (1977).
22. M. von Laue, *Ann. der Phys.* 20, 365 (1906) and 23, 1 and 795 (1907); *Phys. Zeits.* 9, 778 (1908).
23. The argument is found in Descartes, *Lettres*, Adam-Tannery, eds., I, Letter 525, page 222; III, Letter 302, page 663.
24. This is what the famous experimentalist Foucault had to say when confronted with psychokinetic phenomena.
25. The hypothetical "tachyon" has nothing to do in our problem, and is outside the scope of this paper.
26. The taboo we are trespassing here is *no reaction of the observer upon the observed system.* As previously said, this reaction is through an advanced wave.
27. This sort of experiment has been performed by J. Hall, C. Kim, B. McElroy and A. Shimony, *Found. Phys.*, 7,759 (1977) with a negative result. The reason for this is fairly obvious; psychokinesis should have been tested on at least one of the two beams.
28. E.H. Walker, *Proc. Paraps. Assoc.*, 9, 1 (1972).
29. H. Minkowski in *Einstein et al., The Principle of Relativity*, Methuen, London, 1923, page 75: "Space by itself and time by itself are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality".
30. H. Poincare', *Rendiconti Circ. Mat. Palermo* 21, 129 (1906).
31. For brevity, I call respectively *paleoquantal* and *neoquantal* mechanics the "old" and the "new" quantum mechanics.