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Is There a Reality Out There?

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Joseph Bertrand's 1888 evidencing that assignment of a probability depends upon what one chooses to know or not and to control or not, congruent with Grad's 1961 evidencing that statistical entropy depends upon what one deems relevant or not in formalization and measurement, radically undermine common sense realism; mean values are symbols, but symbols of what? For that very reason, recent clever conceptualizations of the quantum measurement process via partial tracing do not restore realism: How could deliberate ignorance generate a reality? Beyond this, Born's and Jordan's quantal wavelike probability calculus, entailing algebraic non-separability and spacetime nonlocality, blurs "reality" still more radically. Thus information stands out as the master word, with its two reciprocal aspects: knowledge and organization.

1. TO BE OR NOT TO BE, THAT IS THE QUESTION

Is there a reality out there? Is there a being in here? Yesterday these were deemed metaphysical questions, discarded with a handwaving by most professional physicists; today they are physical questions, and for such compelling reasons that more than one theoretical physicist has turned into an amateur philosopher.

Sir Karl Popper has held high the banners of both the "first" and the "second" world. Realism, in his view, does not, and must not yield any ground because of intelligibility problems raised jointly by theoretical and experimental physics; a different option is upheld here, due respect being payed to so eminent a thinker as Sir Karl Popper.

As a *representation* of a *fact*, any concept of theoretical physics is *indissolubly objective and subjective*. Ominous among all others in this respect, however, is the concept of *probability* or, equivalently, that of

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information. As known since long ago by philosophers, and as rediscovered in its advent by cybernetics, *information* is a twin-faced concept: *gain in knowledge* and *organizing power.* "Decoding" and "coding" is the cybernetical rendering for this. Coding is done by typing (or the like). Decoding is either passive, or seemingly so: just "taking cognizance" of what has come out. Or it is active: destroying a registration, throwing it out as garbage.[1]

The question is: What should be said of the twin reciprocal basic transitions occurring inside the operator's (or any other's) brain: of the reversible transition *negentropy* $\rightleftharpoons$ *information*? The answer given by Descartes,[2] Wigner,[3] Eccles,[4] and others, is that *indeed* this reciprocity shows up, that there *is* a "direct action of mind upon matter."

If so, a chance occurrence is something more recondite than a mere "mechanical accident": *something indissolubly objective and subjective.* Thus, the answer to the riddle: *what* causes the outcome of such *or* such chance occurrence should be: some sort of "psychokinesis" originating from the subjective side of Nature (be it most often very indolent, or occasionally well awake). According to Descartes,[2] all through the day we are testing that "our mind truly moves our body"; and this, says he, "in a manner essentially different from how a body moves another body." Moreover (surprising as this may seem to some) according to Descartes[5] again, the happy or unhappy mood of a gambler does influence the outcome in chance games!

In 1926, following Born's[6] famous proposal of "the statistical interpretation of quantum mechanics," where the *intensity* of a matter wave measures the *probability* of manifestation of the associated particle, Jordan[7] put forward his brand new form of a *wavelike probability calculus*, where *partial amplitudes* rather than probabilities are added, and *independent amplitudes* rather than probabilities are multiplied. The "interference of probabilities" stemming from this causes the highly specific phenomenon termed algebraically "nonseparability" and geometrically "nonlocality," with quite paradoxical aspects, both spatial and temporal, all the more so that time reversibility, together with probability reversibility, is implied. Thus a second great step is taken beyond the one leading to acceptance of a subjective side in Nature: the step of nonseparability, leading still further away from the common sense view of "reality."

2. REALITY AS FISSURED BY PROBABILITY

In his 1888 *Calcul des Probabilités* Joseph Bertrand[8] proposes a thought-provoking example, the full import of which is better understood today. He asks what is the probability that a chord drawn at random in

a circle is longer than the side of an inscribed equilateral triangle, and considers three very natural procedures for drawing such a chord: Choose one end of it and then its direction; choose its direction and then its intersection with the diameter perpendicular to it; pick its middle inside the circle. From classical properties of triangles and (of course) the "principle of indifference," he gets three different answers: 1/3, 1/2, 1/4, respectively. This shows that ascribing a probability to a chance occurrence depends upon what one decides to know or not know, to control or not control. *Knowledge* and *control*, these are the two faces of *information*.

Not until incisive remarks were made by Lewis[9] and by Grad[10] was it realized that Bertrand's remarks do have relevance in the interpretation of physical entropy. Maxwell's and Boltzmann's writings imply clearly that in statistical mechanics probability expresses lack of knowledge and of control over the many minute "complexions" that are macroscopically indistinguishable and, in this sense, equivalent. Lewis insists that, in this sense, "entropy is a subjective concept." It does have, however, an objective side also because, as Poincaré[11] rightly points out, "chance cannot only be the name we give to our ignorance."

Of course, quite a few different measurements can be performed upon a statistical mechanical system, each one yielding some knowledge and ensuring some control over it; thus Grad is entitled to write that the estimate of an entropy changes "when some relevant facet of the problem has changed, even if only in the mind of the observer" who (of course) also is an experimenter. This brings us back exactly to Bertrand's considerations. Thus Jaynes[12] writes that entropy "is a property not of [a] system, but of... experiments you or I choose to perform on it." Incensed, Denbigh[13] then protests that "we do not regard the age of a rock stratum as... subjective simply because the estimate of its age is subject to revision"!

Well, the point is: are we betting upon the "true value" of the age of a rock stratum assumed to *have one*, or upon the relative chances of such and such possible *but not actual* microscopic complexions in a system? Remember that the "frequencies" handled in statistical mechanics are most often so huge that the whole Universe could not contain them! And then, *what is meant* by "the age of a rock stratum"? Does not the answer depend on how the question is put, that is, on how this age is conceived and defined? Reality, reality, where are you?

Anyhow, whenever "reality" is apprehended inside the paradigm of classical statistical mechanics, it comes out as a mean value, and *a mean value resides nowhere else than in a mind thinking of it.* So "reality" in statistical mechanics is highly symbolic, and strictly speaking, *no reality at all.* It is a "maya."

"You or I," writes Jaynes, who thus brings in a professional com-

munity: the one issued from the Founding Fathers of the classical theory of heat. Volume, pressure, temperature of a gas were the basic ingredients for thinking, all empirically macroscopic, and all, so to speak, reified. Later, when re-evaluated through the conceptualization of statistical mechanics, too much of this primeval reification remained, as we shall see, producing circularity in the thinking insofar as macroscopic objects are thought of as "having" a microscopic structure, and *ipso facto* generating the unwarranted belief in a "reality existing out there."

Anyhow, the fraternity of heat experts had carefully discussed the meaning of their concepts, and the procedures appropriate for measuring the associated magnitudes. Thus Lewis', Grad's, and Jaynes' subjectivity of entropy (and of other thermal magnitudes) coalesced into the *intersubjectivity proper to this fraternity of heat experts.* Of this Zurek[14] recently produced an almost caricatural rendering, all the more provoking that it was not intended to be so. Aiming at reducing the "subjectivity" of it, he relates the "physical entropy" to the "algorithmic entropy" expressed in a computer, and thus ends up defining the intersubjectivity at stake as the one shared inside a professional group using the same computer and the same program!

What is meant, for example, by the statement that its temperature is a property of a gas? The question is not trivial, because information theory brings in as many "tempers" (inverse "temperatures") θ_i as extra randomized magnitudes Q_i besides the kinetic energy Q, thus clearly making entropy depend upon what "you or I" choose to think of; entropy S is conceived as a function of the Q's, the tempers being its partial derivatives. As it has been interpreted and redefined by Boltzmann, "entropy is the logarithm of the probability," so that, say, the N particles making a system are distributed upon the Q_i's with a probability density $\mathrm{Log}\, n(Q_i)$; all this makes a very flexible symbolization depending upon how "you and I" convene to define "the system." But let us come back to temperature *stricto sensu.*

Maxwell's clever and efficient inductive reasoning, leading, for a gas in "its" most probable state, *thermal equilibrium,* to the "equipartition of kinetic energies" and to the well-known velocity distribution law, has exactly hit upon the "intersubjectivity" appropriate for measurements of pressure and temperature, and for the spontaneous, anthropomorphic conceptualization of these. Does this qualify pressure and temperature as "real properties" of a gas? They do show up, all right, and are measurable according to the accepted rules, once "the system" has been set up according to the agreed upon protocol: thus they express the smoothed out answer to the question put, the "frequency" rendering of the "information" searched for. Classically they were termed "macroscopic": macroscopically

prepared, and macroscopically measured. At the micro-level they loose consistency and meaning, somewhat like the illusion of reality displayed by a photograph fades away when scrutinized through an eyeglass.

Thus, the symbol expressed as a mean value is an *approximation*, but an approximation to *what*? Not to a "hidden existing reality," as we have seen. The classics viewed it as the smoothed out expression of an ensemble of possible, or conceivable, "realities," which is *not at all* the same thing as *a reality*! The truth is that a mean value *symbolizes* no more than *the illusion of a reality.*

So, an *essentially probabilistic* world like the one conceptualized by classical statistical mechanics *simply cannot* have the same naive sort of reality as common sense thinks of. At this point what should not be overlooked is that information is a twin-faced concept: gain in knowledge, organizing power, as exemplified in the decoding and coding of cybernetics. Therefore (please do remember Bertrand's reflections) *it may very well be that there is in a chance occurrence much more than a mere mechanical accident*: that it implies essentially an active, no less than a passive, contribution from the subjective side of Nature.

3. INTERSUBJECTIVITY AND TRANSITION PROBABILITIES

In an *essentially probabilistic* Universe, as the one we now think we live in, subjective probabilities à la Bayes are not so important as the *intersubjective probabilities* showing up in shared observations and experiments. Typically these consist of a coding, or *preparation*, defining the experiment, and a subsequent decoding, or *measurement*; in between, the "evolving physical system" acts like a computer converting organization into knowledge (Rothstein[15]). Ideally the whole procedure is reversible, so that time can, and must, be thought of as *past-future symmetric* and as *actually extended*, as it is in the Fermat or Euler extremum principles, and also in the Poincaré–Minkowski spacetime paradigm.

Transition probability then is the key concept, time reversible, and time extended; the prepared and the measured occurrences are thought of as geometrically laid out in spacetime somewhat like, say, the height and the weight of a U.S. citizen are virtually displayed as two "real hidden correlated stochastic occurrences" to be discovered by the social inquirer. How statistical frequencies can enter an extended spacetime picture needs a comment, similar to the one appropriate in the nineteenth Century deterministic paradigm: two stochastic tests are said to be "identical" if the tested magnitudes are the same in both; other magnitudes, deemed "negligible" and thus neglected, are allowed to vary from test to test "according

to the laws of chance"; this brings in the variation needed in the probability concept.

Let us[16] denote by $|A)$ and $(C|$ the a priori, or *prior numbers of chances* of the prepared *initial* and measured *final* states, A and C, respectively; $(A \mid C) \equiv (C \mid A)$ the *intrinsic or naked transition probability*; $|A) \cdot (C| \equiv |C) \cdot (A|$ the *extrinsic or dressed transition number of chances* such that

$$|A) \cdot (C| = |A)(A \mid C)(C| \tag{1}$$

This is the formula used in the quantum statistics of "bosons" or of "fermions," $|A)$ and $(C|$ then denoting the probable values of the *initial occupation number of the initial state* and of the *final occupation number of the final state*, the possible values of which are $n = 0, 1, 2,...$ or $n = 0, 1$, respectively. $|A) \cdot (C|$ is the *probable number of transitions per time unit*, that is, the *joint number of chances* of getting both results A and C as related via the *evolution*; this number is obviously smaller than the product $|A)(C| \equiv |C)(A|$ of the numbers of chances of A and C considered independently (just think of the analogy with the heights and the weights of U.S. citizens). It then follows that

$$0 \leqslant (A \mid C) \equiv (C \mid A) \leqslant 1 \tag{2}$$

so that the *intrinsic transition probability* is a probability *stricto sensu*. It has a timeless meaning in the case of the heights and weights of U.S. citizens, so that we can then speak of the "transition probability between the height representation and the weight representation of a U.S. citizen." Similarly, here, we can speak of the "transition probability between the prepared and the measured representations of an evolving system."

Speaking of U.S. citizens, we can also think of their waist measurements B, and write the formula implying a sum over possible B's

$$(A \mid C) = \mathbf{S}(A \mid B)(B \mid C) \tag{3}$$

It is the generating formula of Markow chains. In the case of an evolving system, it expresses the intrinsic transition probability with a *summation over possible real hidden states*; think, for example, of a Maxwell or Boltzmann molecule hitting other molecules between some initial and some final state.

We have presented the two mutually dependent occurrences A and C with a timelike separation and interaction. This is not compulsory: two mutually related occurrences can interact via a common past or future connection; for example, formula (1) can express either the *predictive* or the *retrodictive* (unnormalized) *collision probability* of two Maxwell or

Boltzmann molecules as the product of their *mutual cross section* by the probable values of the *occupation numbers* of the incoming or outgoing states (respectively); and formula (3) can express a (spacelike) mutual cross section $(A \mid C)$ as a sum of products of transition probabilities, implying either past or future "possible real hidden states" of paired molecules while in contact.

So, on the whole, the preceding algebraic formulas do have, when thought of geometrically in spacetime, *topological invariance* with respect to deformations of the ABC zigzag. The *intermediate summation in (3) is then thought of algebraically*, without any timing connotation. Also, prediction–retrodiction symmetry is an aspect of the time-reversal invariance of these formulas.

What path follows the system between its preparation as $|A)$ and its measurement as $(C|$, including of course the $|B)(B|$ collisions? One among the many "possible real hidden paths" from A to C; that was the traditional, oversimplified, answer; remember Lewis', Grad's, Jaynes', and Bertrand's 1888 remarks.

What relation exists between formula (1) above and Bayes' formula

$$|A) \cap (C| = |A)(A \mid C| = |A \mid C)(C| \tag{4}$$

expressing the *joint probability* of two mutually dependent occurrences A and C in terms of the *two inverse conditional probabilities* $|A \mid C)$ of A if C and $(C| = |C)$ of C? If we equate the left-hand sides of formulas (1) and (4) we get

$$|A \mid C) = |A)(A \mid C), \qquad (A \mid C| = (A \mid C)(C| \tag{5}$$

but beware! Then $|A) \cdot (C|$ is not normalizable as a probability, and *this is why I have called it a "joint number of chances"*; also, $|A \mid C)$ and $|C \mid A)$ must then be called *inverse conditional numbers of chances*; we qualify them as "extrinsic," because, via (5), they imply the prior probabilities of A and C. Finally, by definition, we term the probability $(A \mid C)$ *intrinsic reversible conditional probability* of A if C or of C if A.

These changes are proposed as fitting a move from subjectivity to intersubjectivity; a little fable will help clarifying our reasons.

At the intersection of two one-way streets A and C equipped with traffic lights, what is the joint probability (!) that two cars collide? The "inverse" subjective views of the two drivers, and the neutral view of the police, differ on the matter.

Reasoning subjectively à la Bayes, driver A, for instance, having or not (his problem) "gone through the light," estimates the probability of a collision as the product of the prior probability that a car arrives on the other street by the conditional probability that its driver "goes through the

light"; thus each driver uses "inversely" Bayes' formula (5). As for the police, it estimates the probable number of collisions at this intersection in, say, a year, as the product of the corresponding probable numbers of cars arriving on each street by the *percentage* of drivers "going through the light"; thus the police will use formula (1).

It does seem that the very epithet *joint* is an invitation to treat symmetrically the two correlated occurrences, and thus to move away from subjectivity towards intersubjectivity.

4. THE 1926 BORN AND JORDAN REVOLUTION: WAVELIKE PROBABILITY CALCULUS

Gambling was the humus from which grew the probability calculus; the combinatorial analysis built up at this end by Pascal and Fermat remained wonderfully successful when extended by Maxwell and Boltzmann to the molecular theory of gases, and later, by Gibbs, to statistical mechanics in general. As expressed by Laplace, its two basic rules were *addition of partial, and multiplication of independent, probabilities.*

In 1926 Born,[6] soon followed by Jordan,[7] proposed "The statistical interpretation" of the Einstein and De Broglie wave–particle duality; it essentially is a *non-Laplacian, wavelike calculus of probabilities*, upholding *addition of partial, and multiplication of independent, amplitudes.* This stems from Born's insight that the *intensity* of the wave measures the *probability* of manifestation of the associated particle, and from the classical phenomenology of wave interference.

The operational success of Born's and Jordan's scheme, later formalized as Dirac's[17] "bra and ket" symbolic calculus, and still later endowed with a "manifest relativistic invariance by Feynman,[18] has been prodigious.

Landé[19] expresses quite well the *radical difference*, together with the *exact correspondence*, between the two schemes. He argues that the latter has more internal consistency than the former, and proposes an axiomatic derivation of it. Also, he expresses the opinion: "that atomic events are dominated by the... law of unitary transformations, whereas ordinary games with dice... are not, may be... a sign that the... quantum games deal with truly fundamental events... rather than with complex mechanisms." The implication at this point is the passage from the micro- to the macro-level by "interferometric destruction," that is, random erasement of the off-diagonal terms inside the Born–Jordan *probability.*

A brief summary of the "correspondence" between the classical and the quantal, wavelike, probability calculus, together with the radical difference between them, is as follows.

To the expression (1) of the "dressed transition probability" between two representations of a system corresponds that of the "dressed transition amplitude"

$$|A\rangle \cdot \langle C| = |A\rangle\langle A \mid C\rangle\langle C| \tag{6}$$

where $|A\rangle$ and $\langle C|$ denote the "prior amplitudes," or "occupation amplitudes," of two mutually correlated states, and

$$\langle A \mid C\rangle \equiv \langle C \mid A\rangle^* \tag{7}$$

the (complex) "naked transition probability" between these states. To the generating formula (3) of Markov chains corresponds that

$$\langle A \mid C\rangle = \mathbf{S}\langle A \mid B\rangle\langle B \mid C\rangle \tag{8}$$

of Landé chains, termed by him, in relation to (7), "unitary transformations," implying a "sum over intermediate states" $|B\rangle\langle B|$.

Born's rule relating the *transition probability* $(A \mid C)$ to the *transition amplitude* $\langle A \mid C\rangle$, transposing the classical relation between intensity and amplitude, is

$$(A \mid C) = \langle A \mid C\rangle\langle C \mid A\rangle = |\langle A \mid C\rangle|^2 \tag{9}$$

As combined with (8), it contains off-diagonal *interference terms*, the *inevitable* presence of which *definitely forbids* that the sum over intermediate terms $|B\rangle\langle B|$ be thought of as implying "real hidden states"; this is a far more drastic denial of "reality" than the rather mild one previously drawn from the philosophy of classical probabilities! What it expresses is an *algebraic nonseparability* which, exported into spacetime descriptions, generates an extremely dramatic *geometric nonlocality* having both timelike and spacelike aspects.

The classics, of course, were well aware that the factlike exclusion of advanced waves is not supported by the lawlike symmetry between retarded and advanced solutions of the wave equations; so, occasionally, they made use of a "principle of inverse optical return." Born's principle ties this symmetry with the statistical prediction–retrodiction symmetry: *retarded waves are used in prediction and advanced waves in retrodiction.* So let us look from this standpoint at the Hermitian symmetry expressed in (7).

Either in a spacetime x or in a 4-frequency k picture, the exchange $\langle A \mid C\rangle \rightleftharpoons \langle C \mid A\rangle$ expresses the *spacetime reversal*, denoted as PT; by virtue of (7), this is equivalent to the exchange $\langle A \mid C\rangle \rightleftharpoons \langle A \mid C\rangle^*$ which, either by virtue of the Stueckelberg–Feynman interpretation of

antiparticles, or by direct inspection, is tantamount to *particle–antiparticle exchange* denoted as C; therefore, *the geometric interpretation of Hermitian symmetry is none other than the reversal symmetry termed CPT invariance*, enunciated in 1952 by Lüders.[20]

5. NONSEPARABILITY AND NONLOCALITY: INDEPENDENT REALITY DISSOLVED

Bernard d'Espagnat[21] views reality as "distant and veiled." I argue here that there is no such "thing" as an "independently existing reality," because "observers," human or otherwise, are (largely) generating what they "observe," that is, are *inherently* "actors" also. There are two reasons for this: (1) *Interfering probabilities*, entailing that the "intermediate sums" $|B\rangle\langle B|$ are over *virtual, not real hidden states*; (2) *reciprocity of the negentropy* $\rightleftharpoons$ *information exchange*, closely connected with the prediction–retrodiction symmetry, that is, with the (just alluded to) CPT invariance.

Topological invariance à la Feynman is an aspect of CPT invariance. The time axis being thought of as vertical, the ABC zigzag picturing formula (8) can be either $<$, V, or Λ shaped; in all three cases the epithet "intermediate" for $|B\rangle\langle B|$ sums is understood "topologically," with no timing connotation. The $<$ shape illustrates the Wheeler[22] smoky dragon metaphor, the V shape the Einstein–Podolsky–Rosen,[23] or "EPR correlation," and the Λ shape the reversed EPR correlation.

Consider first the $<$ shaped spacetime smoky dragon. In what state is a quantum system evolving between its preparation as $|A\rangle$ and its measurement as $|C\rangle$? In the retarded state the source of which is A, or the advanced state the sink of which is C? It cannot be in both. It is *actually transiting* from A to C, "transcending spacetime," as Bohr puts it. Wheeler says it is a "smoky dragon" living, so to speak, "somewhere up there," with only its tail, held as $|A\rangle$, and its mouth, biting as $|C\rangle$, "down here"—or at least we like to think this way!

A good picture of this consists of a laser beam prepared with a linear polarization $|A\rangle$ and measured with a linear polarization $|C\rangle$, the relative angle being b. From classical optics we know that the transition probability is $\cos^2 b$, so that the transition amplitude is $\cos b$. Nothing is changed if a birefringent crystal B is inserted, its length being such that there is a zero phase shift, which crystal can be freely rotated; as "it is quite impossible to find out which of the two (orthogonally polarized) beams the photon is riding inside B," this photon is a smoky dragon, the formalization of which is

$$\cos(C-A)=\cos A\cdot\cos C+\sin A\cdot\sin C \tag{10}$$

with $C - A = b$; the orientations of the A and C polarizers are referred to the two orthogonal virtual states B; such is here the specification of the general formula (8).

If the beam is very long, there is plenty of time for deciding which direction is chosen as $|C\rangle$, that is, *which* set of *mutually exclusive* yes–no questions is put at C; thus *there is no preexistence of the answer that turns out*; "counterfactuality," in the EPR fraternity jargon, is not accepted in quantum mechanics. This is a "Wheeler delayed choice measurement" displaying, as he emphasizes, *retrocausation.* Borrowing a comparison from hydrodynamics, we say that the quantal evolving system symmetrically feels the pressure from its preparing source A and the suction from its measuring sink C. Cramer[24] has another analogy: he speaks of a "transaction," with a handshake exchanged between A and C.

Now we consider the V-shaped ABC zigzag picturing an EPR[23] correlation. At distant places A and C, two "correlated particles" issuing from a common source B are measured as $|A\rangle$ and $|C\rangle$, respectively; the AC separation is usually, but not necessarily, spacelike. Here the "smoky dragon," hiding inside B, has two biting mouths, A and C. As the interference terms present inside $|B\rangle\langle B|$ definitely exclude that the experimental answers displayed at A and C preexisted in the source B, retrocausation is clearly displayed.

If $|A\rangle$ and $|C\rangle$ are linear polarization states measured on correlated particles issuing from a spin-zero source, the expression of $\langle A \mid C\rangle$ is the same one, (10), as in the preceding example; this exemplifies "topological invariance" of the whole conceptualization.

The correlation between the results found at A and C is tied mathematically, that is, also physically, *via the relay at B, in the past. Both measurements play symmetric roles*, and so there is no question of the one collapsing the other, or vice versa. And of course the EPR experiment can be turned into a delayed choice experiment. All this, which builds up "the EPR paradox," has been experimentally tested.

Clearly, *the correlation amplitude* $\langle A \mid C\rangle$ *is conditional upon actual measurements performed at A and C*; "counterfactuality" is not accepted in quantum mechanics. Einstein, Podolsky, and Rosen, holding a realistic metaphysics, were incensed by such an idea, which experimentation has vindicated (Aspect[25]). Thus it happened, as some put it, that physical experiments have tested a metaphysical idea!

In a reversed EPR experiment two particles prepared at A and C are absorbed inside a B sink, provided that they have the right phase relation; this is termed an "échelon absorption." The $\langle A \mid C\rangle$ transition amplitude then has a retrodictive meaning. Here, common sense has no objection against turning the polarizers at A and C after the photons have gone

through them, because it believes in retarded causality. This is the quantal version of a Fresnel interference, with independent sources however; the point is that independence is destroyed in the retrodictive thinking. So this dragon has two tails, and the poison is in its shadowy mouth.

To conclude, *wavelike interference of probabilities combined with zigzagging, CPT invariant causality display Nature as nonseparable,*—and as nonseparable from its observers, which are actors also.

6. ARE THE TAIL AND THE MOUTH OF THE DRAGON REALLY DOWN HERE?

They are not, insofar as macroscopic "objects" are thought of as "made of microscopic entities."

As is well known, the crucial question is, *what* lies behind Born's rule (9) erasing the off-diagonal terms in the measured amplitude? This is quite like Alexander deciding to cut the Gordian knot, which allowed him to conquer Asia up to the Indus, *but not further.*

Recently, great progress has been made by Zürek[26] and others concerning the reasons justifying this decree; the recipe consists of partial tracing over the parameters of the macroscopic measuring device which are uncoupled with the measured quantal magnitudes. This very significant work should not mislead anyone into believing that a "reality" is thus recovered: *how could deliberate ignorance generate a reality*?

This is a radical statement, steering a new course in our questioning.

7. UNIVERSAL CONSTANTS, EXISTENTIALISM, AND THE PARANORMAL

Universal constants join provinces of physics: thermo-dynamics, space-time, wave–particle, and negentropy–information are pairs respectively joined by Joule's J, Einstein's c, Planck's h, and Boltzmann's k, The order of magnitude of a universal constant, as evaluated in "practical," anthropomorphic, units, is revealing of our existential relation to Nature. Thus the value of Joule's J testifies that phenomenological thermodynamics belongs to practical technology; but that c is so "big," h and k so "small," means that the phenomenologies they refer to are far away from everyday life; thus the relativity of time, the photon and the matter wave, the negentropy cost of information, were all ignored before this century.

The contention here is that not only quite important physical phenomena, but also some liminal, although highly significant ones in

psycho-physiology, are clearly implied by the mathematical formalism, *and should be constantly operating at a low level.*

In support of this assertion, I bring Hafele's and Keating's[27] "Around the World" atomic clocks demonstration of the relativistic "twins paradox": if, say, the pilots of the two airliners circling the globe in opposite directions had left Washington as freshly shaved twins, certainly, by measuring the lengths of their beards up to 10^{-12} after their return the "relativity of time" would have been displayed.

This is meant to emphasize not only the coherence of Nature, but also of our relation to her as observers-and-actors.

Expressing the equivalence between space and time, c entails the Poincaré–Minkowski trissection of spacetime in "past, future, and elsewhere," replacing everybody's severance of past and future by Newton's "universal present" t (a severance recovered in the limit $c \to \infty$). Thus matter *must* be thought of as space *and* time extended, which it is, also at the micro-level. But not matter only: the subconscious mind *also* must have a time extension, while our "conscious present" explores our "world line."

Is there a psycho-physiological proof of this? Yes indeed: Libet[28] has demonstrated that a conscious free decision of ours is anteceded by an unconscious neuromotive impulse, the fraction of a second before. Such a finding cannot be overestimated, as this timing is so much bigger than the one "equivalent" to, say, a foot or a fathom! I think it would be interesting to extend this phenomenology to the case where one's decision partly depends upon another's decision as, say, in tennis, or in airplane fighting; a "subject" could be tested viewing a film; this would bring in jointly physics and neurophysiology.

If our subconscious mind is time extended, and if the past and the future of matter are no less (but of course no more) real than the present, then the "paranormal" phenomenon termed precognition must exist.

Expressing an energy–frequency equivalence, Planck's h has led to the invention of the quantal wavelike probability calculus, and to the discovery of *physical nonseparability*; half jokingly, Einstein admitted that, if true, this implies some sort of "telepathy"—not only a spacelike one, but, as we have seen, also a timelike one.

"Collapse of the state vector" in a measurement, as it is called, is an intersubjectively recognized chance occurrence; obeying "blind statistical prediction," that is, full retarded causality, it reflects, as it seems, a generally passive or neutral attitude of the subjective side of Nature—Jung's "collective unconscious."

Insofar as Boltzmann's k expresses an information–negentropy, N–I, equivalence, it appears that Boltzmann was unwittingly practising

cybernetics; as Gabor put it, it turns out that "one cannot get anything for nothing, not even an observation."

Expressing I in bits and N in thermal units makes k exceedingly small; thus cybernetics asks consciousness-the-spectator to buy her ticket, at a very low cost, but allows consciousness-the-actor to perform, at exorbitant wages. So, there is a lawlike-symmetry-and-factlike-asymmetry in the $N \rightleftharpoons I$ transition; the $N \to I$ transition is so common that it went on unnoticed until the advent of cybernetics; conversely, the transition $I \to N$ is *not suppressed, but severely repressed.* Therefore "psychokinesis" *must* exist as a liminal phenomenon. Wigner,[3] using his own symmetry arguments, has come to a similar conclusion. And Jahn's,[29] and others, repeatable experimental proof of psychokinesis does show that Nature "out there" is not independent of our doings!

On the whole, it seems that Nature-The Machine resembles more a spacetime telegraph than anything else: a Lorentz-and-Lüders invariant one, using a Born–Jordan "wavelike" coding. *Factlike* irreversibility means that advanced waves, decreasing probabilities, information-as-organization are all very much hidden at the macro-level; but this may be a subjective illusion. As emphazised by Bergson[30] and Schafroth,[31] *disorder is tantamount to lack of information*; no needles would get lost in haystacks for Laplace's demon, knowing exactly where everything is, no for Maxwell's one, able to circumvent Carnot's prohibition; incidentally, Brillouin[32] has not truly "exorcized" Maxwell's demon, as his ritual invokes a form of irreversibility!

On the whole, *it seems that no "physical occurrence" happens without a concomitant psychical occurrence implying information in either, or both, of its twin faces.*

To conclude, the *very symmetries* of today's physical formalism seem to imply clearly that, far from being "irrational," the so-called "paranormal phenomena" termed precognition, telepathy, psychokinesis, are indeed *postulated* by it; not forbidden, they are not encouraged either—at least in the normal course of affairs. So *they must be constantly operating at a liminal level,* and thus perceivable, and usable, by sensitive and/or trained minds.

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