

# Lawlike Reversibility, Factlike Irreversibility. The Symmetry of Time in Physics

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Received August 7, 1998

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Mehlberg's and Lewis' phrases in the title aptly render Boltzmann's and Gibbs' views. *Statistical correlation* of physical events expresses their interaction or *propagated causality*. *Information*, as (*retarded*) *cognizance* or as (*advanced*) *organization*, is tied à la Reichenbach with Aristotle's *efficient* or *final causes*. *Correspondence* between the classical and the quantal transition formulas is discussed, and *CPT* invariance of "nonseparability" emphasized.

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## 1. INTRODUCTION: BOLTZMANN'S AND GIBBS' VIEWS

The phrases of Mehlberg (1961) and Lewis (1930) used in the title express the point that is crucial in Boltzmann's (1964) and Gibbs' (1902) statistical mechanics.

Boltzmann's brisk answer to Loschmidt's oral objection, "Well *do it!* Reverse at time  $t$  all velocities in a gas?" meant, "How can you exactly *know* each of these velocities? And knowing them, what could you *do*?" What this *factlike* answer emphasizes is *insufficient information*, either as *knowledge* or as *organizing power*—the twin faces of Aristotle's concept.

Boltzmann's *lawlike* second thoughts are stated in an apologue (1964, p. 446): "In a universe in thermal equilibrium fluctuations occur but the two directions of time are indistinguishable, just as in space there is no up or down. As on earth we call 'down' a direction toward the center, so will a living being distinguish the direction toward the less probable state [and name it the past]." *Viewing matter as time extended*, what Boltzmann submits is that *irreversibility* be expressed as *inequality* of the *initial and final prior probabilities of causally related events*—a view formalized later by van der Waals (1911).

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Boltzmann concludes thus: “No one should consider such speculations as the higher purpose of science [but] one should not despise them. Who knows whether they may not broaden the horizon of our ideas, and, by stimulating thought, advance the understanding of the facts of experience?”

As for Gibbs (1902), he writes, “It should not be forgotten, when our ensembles are chosen to illustrate the probabilities of events in the real world, that while [those] of subsequent events may often be determined by [those] of prior events, it is rarely the case that [those] of prior events can be determined by [those] of subsequent events, for we are rarely justified in excluding the consideration of the antecedent probability of the prior events.” *Why this is so*, Gibbs’ says not. Expressed à la Mehlberg, the *fact* is that *blind statistical prediction* is of more general use than *blind statistical retrodiction*.

Worded otherwise, the *fact* is that *retarded causality prevails over advanced causality* because, as Reichenbach (1956) puts it, “The convention of defining positive time through growing entropy is inseparable from accepting causality as the method of explanation.” We will come back to this.

*Concluding: Physical irreversibility is mathematically expressed not in the differential equations of evolution, but in the boundary conditions chosen as ‘physical.’*

## 2. INTERACTION AS STATISTICAL CORRELATION

*Correlated probability of physical events is the statistical expression of their interaction.* And interaction, propagated across spacetime, is physical causality.

So a *probabilistic physics defines conditional probability as synonymous to causality*. This Jaynes (1989) deems outrageous, “confusing ontology and epistemology,” and, even worse, implying, via the London–Wigner wave collapse concept, that “the universe be run by psychokinesis.” Let us keep cool, and read straightforwardly what the symmetries of the formulas entail *necessarily*.

The *grammatical* symmetry implied in the wording *joint probability* is part of a much larger *physical* symmetry; for example, in particle physics, the *joint probability* of outcomes of a disintegration is *Lorentz and CPT invariant*. So *used in physics, logic is thus not discarnate*; the *conceptualization of physical probabilities* must respect the *covariant* rules of the information-carrying telegraph.

The point is that the symmetry implied in *joint* is *not* rendered *covariantly* by the Bayesian definition stating “The *joint probability* of *A* and *C* equals the *conditional probability* of *A* if *C* times the *prior probability* of *C*, or *inversely* the *conditional probability* of *C* if *A* times the *prior probability* of

A.” Reminiscent of early approaches to the Lorentz formulas, this is a *relative* approach reflecting a poker player mentality; physicists resemble less poker players than mushroom seekers calling to each other through a wood. *Intersubjectivity* rather than *subjectivity*, *covariance* rather than *reciprocity* is their requirement (Costa de Beauregard, 1987, 1994).

*By a preexisting harmony, the statistical-mechanical formalism of collision or transition probabilities exactly meets this demand.* A rewording of the conceptualization then follows straightaway.

First the *correlation* formula displays (as it should) *symmetrically* both priors. The *mutual cross section*, denoted as

$$(A|C) \equiv (C|A) \quad (1)$$

is none else than the *intrinsic conditional probability* of  $A$  if  $C$  or  $C$  if  $A$ ; the *occupation numbers*  $|A) \equiv (A|$  and  $(C| \equiv |C)$  are the *priors*. The *dressed collision* or *transition probability* formula written (notation) of Costa de Beauregard,

$$|A) \cdot (C| = |A)(A|C)(C| \quad (2)$$

strictly speaking is a *joint number of chances*, because normalization is defined via

$$\Sigma |A) = \Sigma (C| = 1, \quad \Sigma_A (A|C) = \Sigma_C (C|A) = 1 \quad (3)$$

It is the product of the *mutual cross section* by the *two priors* (either initial or final).

The *composition formula*

$$(A|C) = \Sigma (A|B)(B|C) \quad (4)$$

is added.

*Automatic Lorentz and PT invariance* of these formulas is obvious, as is also *topological invariance* of concatenations.

The *elementary graph* has three guises:  $\wedge$ -shaped for *prediction*,  $\vee$ -shaped for *retrodiction* of a collision,  $\langle$ - or  $\mathbf{C}$ -shaped for pre- or retrodiction of a *transition*.

As for *causality*, *symmetry* of the formulas expresses *action–reaction* equality for space-distant events, *efficient-final cause symmetry* for time-distant ones—again an Aristotelian wording. Had Loschmidt (1876) based his reversibility argument on inversion of the joint probability, it would have been more radical.

So, concurring with Mehlberg and Lewis, we state that *factlike irreversibility* is expressed via *ponderation of the priors*: full *entropy increase* is formalized as *blind prediction* (equating all final priors), full *negentropy increase* as *blind retrodiction* (equating all initial priors).

That the latter prescription makes sense is exemplified thus. Given, in the evolution line of the horse, the eohippus (*only* the eohippus), can we predict the horse? Certainly *not*. But blind statistical retrodiction says this: the eohippus came from a primeval molecular soup—the accepted story. So, inside the universal entropy cascade, negentropic lines of evolution exist, displaying advanced causality.

*Concluding: The Lorentz- and PT-invariant propagation of statistical correlations across spacetime expresses at one stroke the telegraphy of information and physical causality.*

### 3. DIGRESSION: UNIVERSAL CONSTANTS

Some ‘paradigmatic revolutions’ imply a bridging between formerly distinct provinces of physics; thermo-dynamics, electro-magnetism, 4-dimensional space-time, negentropy–information equivalence, wave–particle dualism, inertia–gravity equivalence are examples.

The keystone then is a *universal constant*—a newly discovered one, or an existing one re-interpreted as such. This *equivalence factor* is, so to speak, the exchange rate between the currencies in use on both sides.

As expressed in ‘practical units’ the value of such a constant has significance. If it nears unity, like Joule’s  $J$ , the paradigm unveiled is not far from the familiar. But if it is exceedingly small or large *and previously unwittingly likened to zero or infinity*, the discovery of its finiteness opens new oceans to sail and routes to unforeseen lands. So do the ‘exceedingly small’ Boltzmann  $k$  and ‘very large’ Einstein  $c$ .

*Finiteness of the velocity of light* was proved by Römer’s and Bradley’s astronomical measurements. ‘Electricians’ from Gauss to Maxwell recognized in  $c$  a keystone of *electromagnetism*: the Weber–Kohlrausch ‘static’ measurement of  $c$  is a historic landmark. *Electromagnetic inertia* displaying the energy–mass  $c^2$  equivalence shows up in formulas of Weber, Maxwell, Poynting, Poincaré.

It dawned later that  $c$  is a *conversion coefficient between space and time* (as measured physically). Galileo had shown that *relative motion* transforms time into space; Einstein proved that it also transforms space into time. Then the  $x-ct$  symmetry of the Lorentz–Poincaré formulas entails a breakthrough: the *spacetime* concept, implying a *4-dimensional realism* where *matter* is extended in time as much as in space. It is now imperative that *any* fundamental thinking in physics be expressed *covariantly*—including that concerning probability, either classical or quantal. Anyone playing with Feynman graphs cannot doubt that matter *is* time extended!

*Why is  $c$  ‘so large’ in practical units? Why are the meter and the second ‘practical’ as associated length and time standards? Because, it seems, the*

velocity of our nervous influx is a not a large multiple of meters per second. And the meter is just as convenient as a length standard as were the foot or the fathom. The disproportion of acutenesses of our inner and outer perceptions of time makes us ‘feel that we all live at the same time.’

Planck’s  $h$ , according to de Broglie, expresses an *equivalence* between *action* and *phase*; its smallness obliterated both the particle aspect of light and the wave aspect of matter.

Newton’s ‘universal’  $G$ , measured in the laboratory by Cavendish, has to do with inertia–gravity equivalence. But there  $c$  is implied also.

Newton’s law  $\mathbf{F} = m\mathbf{a}$  contains a universal constant  $\mathcal{C}$  that is equalled to *one* with the dimension *zero* by a *joint definition* of the standards of length, time, mass, force. Inertia–gravity equivalence, together with Newton’s attraction formula  $F = G mm'/r^2$ , suggests (Sciama, 1958) that  $\mathcal{C}$  be proportional to the *cosmic gravity potential*  $GM/R$ . Then kinetic–potential energy exchange shows that  $\mathcal{C}$  is of dimension  $c^2$ . And it so happens that in cosmology  $GM/c^2R$  nears unity.

#### 4. INFORMATION–NEGENTROPY EQUIVALENCE

Is the meaning of *probability objective* or *subjective*? That is the question—one that has been much discussed. *It is truly both, the interface of reality and representation.* And theoretical physics, being a *probabilistic representation of reality*, also is both.

*Representation* succeeds or precedes *reality*, being either *cognizance* drawn from observation, or *organization* injected in action. The *objective* masks over the twin faces of *representation* are Aristotle’s *efficient* and *final causes*. Cybernetics defines *information*  $I$  and *negentropy*  $N$  as *equivalent* via Boltzmann’s constant,  $N = k \text{Log } 2I$ , and views them as *reversibly exchangeable* via *decoding* and *coding*.

So *probability* and *information* are truly the same concept, the logarithm being a mere technicality. Indeed, *information* was the unnamed idea in Cardano’s, Pascal’s, and Fermat’s thinking, and in Maxwell’s and Boltzmann’s work. Lewis (1930) writes “Gain in entropy means loss of information, nothing more . . . It is a subjective concept.” The last sentence goes too far, however, overlooking the *obverse of information*; Poincaré (1906) was right in writing, “There *is* in chance more than just our ignorance.” Disorder, argues Bergson (1907), is order different from the one expected; so does also Shafroth (1960).

A quiet ‘scientific revolution’ made this clear. Grad (1967) insisted that the expression of an entropy changes “when some relevant facet of the problem changes, if only in the mind of the observer,” and Jaynes (1983) stated that this expression depends upon “what you or I decide to measure.”

Of course, an *intensive temper* is associated with each *extensive* magnitude considered.

Boltzmann's  $k \equiv R/N$ , first defined as a conversion factor between *temperature* and *mean kinetic energy*, has a far deeper meaning:  $k \text{ Log } 2$  is the exchange rate between *information* expressed in *bits* and *negentropy* expressed in thermal units—let us say *clausius*. One *clausius* is worth some  $10^{16}$  *boltzmanns*. If  $k$  were zero, knowledge would be costless and free action impossible. As the finiteness of  $c$  unveiled the “relativity of time,” so that of  $k$  reveals that “one cannot get anything for nothing, not even an observation” (Gabor, quoted by Brillouin, 1956, p. 168).

So, a *necessary corollary to lawlike reversibility* states that elementary level *coding* is Wigner's (1967) “direct action of mind upon matter:” *psycho-kinesis, reciprocal to gain in knowledge*. The reason why it is rare or ‘paranormal’ is *factlike irreversibility*.

*Factlike irreversibility* is evidenced by the exceedingly small ‘practical’ value of  $k$ . It is *by fact, not by law*, that the *cognitive transition*  $N \Rightarrow I$  is *easy or normal*, the  $LI \Rightarrow N$  one *difficult or paranormal*. Cynbernetics asks consciousness-the-spectator to pay a very cheap ticket, but grants exorbitant wages to consciousness-the-actor.

So the truth is that *advanced actions are not prohibited but strongly repressed*. In his 1647 variational calculus Euler sees efficient and final cause acting symmetrically, somewhat as in hydrodynamics sources do by pressure from upstream and sinks by suction from downstream.

*Concluding: Final cause* is a perfectly acceptable concept in any formalism treating time as *actually extended* and as *legally reversible*. And it is postulated as *symmetric to efficient cause* as a corollary to the information–negentropy reciprocity. See Fantappié (1991) for a discussion of this.

## 5. PHILOSOPHICAL REMARKS

No less an authority than Compton finds it “unfortunate that no modern philosopher has drawn attention to the fact that the ability to raise one's hand at will is more directly and certainly known than any of the best established laws of Newtonian physics. If these laws deny the possibility to raise one's hand at will, the conclusion is that they are in need of some modifications.”

This echoes Descartes 1648 Letter to Arnauld, “That our mind, which is incorporated, can move our body is evidenced not by some ratiocination but by the most certain everyday experience.” In 1643 he had written to Elizabeth, “The main cause of our errors stems from using notions alien to their subject matter, like trying to conceive how the soul moves the body by

how a body moves an other body.” Descartes, incidentally, had taken part in the discussions establishing the conservation laws of mechanics. Last but not least comes his 1646 letter to Elizabeth: “I dare think that inner happiness has some secret power to render chance favorable . . . Even in chance games I have always found chance more favorable when I had more reasons for joy than for sorrow.” (For these letters see Descartes, 1974).

Random event generators monitored by electronic noise have been used by Schmidt and by Jahn to *reproducibly* demonstrate psychokinesis; Jahn has lectured on this at international conferences (Jahn and Dunne, 1989).

Eccles (1986), neurosurgeon, claims experimental proof that voluntary action consists of *biasing by will the final priors*. Libet (1985), also a neurosurgeon, claims proof that at the time instant when ‘I’ am conscious to initiate an act the executive signal had left half a second or so, before; this shows, as it seems, that the now of consciousness has temporal thickness *and operates from ahead in time*.

What of Jung’s ‘collective unconscious’? Bergson (1907) among others argues that Nature has a *representation* side operating in biological ‘ontogenesis’ and ‘phylogenesis’.

*Concluding: A chance occurrence is not just a mechanical accident: the subjective side of Nature is involved in it—passively when ‘blind statistical prediction’ is apposite, actively when ‘blind statistical retrodiction’ is operational.*

The cybernetic information–negentropy equivalence validates the paradigm of a *reality–representation interplay*, and vindicates Schopenhauer’s (1883) title, *The World as Will and as Idea*, and Hoyle’s (1983) *The Intelligent Universe*.

## 6. WAVE-MECHANICAL NONSEPARABILITY

*Nonseparability*, the probabilistic aspect of *interference*, is inherent in the Born (1926)–Jordan (1926) algebraic recipe of *adding partial and multiplying independent amplitudes—not probabilities*.

A geometric paradox arises: while only *retarded waves* and *blind* statistical prediction made sense to Young and Fresnel, *CPT* invariance of the Born–Jordan recipes introduces *retrocausation*.

To *intrinsic symmetry (I)* of the classical *mutual cross section* ‘corresponds’ *Hermitian symmetry* of the *quantal transition amplitude*

$$\langle A|C \rangle = \langle C|A \rangle^* \quad (5)$$

Corresponding to the dressed collision or transition probability (2) there is the dressed transition amplitude

$$|A\rangle \cdot \langle C| \equiv |A\rangle\langle A|C\rangle\langle C| \quad (6)$$

displaying the prior bra  $|A\rangle$  and ket  $\langle C|$ . The (topologically invariant) composition law

$$\langle A|C\rangle = \sum \langle A|B\rangle\langle B|C\rangle \quad (7)$$

is added.

*Bra* and *ket* stand for representations of an evolving system, either prepared or retroprepared (Hoekzema's, 1992, wording).

"Cutting 'the Gordian knot,'" so to speak, the recipe for the transition probability

$$\langle A|C\rangle = |\langle A|C\rangle|^2 \quad (8)$$

erases the phase relations. It pulls down onto the real axis the 'tail' and 'mouth' of Miller and Wheeler's (1984) 'smoky dragon.' And, as Alexander met at the Indus 'gymnosophists' holding illusory the perceived world, so the wavelike phenomenology undermines reality—via the off-diagonal terms in the intermediate sums of (7).

Feynman's (1949) version of Dirac's (1947) transition amplitudes evidences Lorentz and Lüders (1952) *CPT* invariance, and topological invariance of graphs where a "smoky dragon" grips each vertex.

*Hermitian symmetry concisely expresses CPT invariance. A–C exchange expresses PT reversal, taking the complex conjugate renders particle–antiparticle exchange.*

The simplest Feynman graph has three guises:  $\wedge$  picturing a collision,  $\vee$  a disintegration,  $\langle$  or  $\mathbf{C}$  a transition proper. The  $\vee$  case contains the famous Einstein–Podolsky–Rosen (1935) correlation.

The EPR 'paradox' originated at the Fifth Solvay Conference, where Einstein (1928) raised this objection to the "new quantum mechanicians:" If a plane wave carrying just one particle—an electron or a photon—falls normally upon a plane screen and if the particle traversing a small aperture  $B$  later impresses a gain  $A$  of a semispherical film centered at  $B$ , what prevents reception of the particle at any other grain  $C$ ? There would be no problem if "the dice were cast at  $B$ ," as in the good old days. But, via the cross term at  $B$ , the "new" computational recipe forbids this, implying that "the dice are cast at  $A$  and/or  $C$ ." Does this not contradict the relativistic prohibition against faster-than-light telegraphing?

*It does not:* common sense relies on macroscopic retarded causation. How is it that Einstein, so expert in statistical mechanics, remembered neither Loschmidt's objection to Boltzmann, nor van der Waals' (1911) rendering of



it? The *CPT invariant transition amplitude* formula says (Costa de Beauregard 1953, 1983) that the *correlated retroparations* at *A* and *C* are *causally dependent* via the *ABC* zigzag, with a relay in the past.

*Retrocausation is a corollary to nonseparability* evidenced in the Miller–Wheeler (1984) “delayed choice experiments where *retroparing* devices are adjusted *after* emission of the particles; Aspect’s (1982) EPR experiment belongs to this class.

Much discussed in the twenties, the  $\wedge$ -shaped *reversed EPR correlation* is a Young interference interpreted in probability terms. The point is that one can neither retrodict, nor experimentally find out, from which aperture came any one of the detected particles.

A similar remark pertains to photons flying between two linear polarizers of relative angle  $\alpha$ , the *transition probability* being  $\cos^2 \alpha$ . The flying photon is *transiting* between the prepared (retarded) and the retropared (advanced) state. This Cramer (1986) calls the *transactional* interpretation.

A *Feynman transition probability* properly is a *joint number of chances* of *events* termed *preparations* and *retroparations*. *Conditionality* is implied: the probability formula holds *iff* each and every preparation or retroparation as *written down* is performed.

A misinterpretation is recurrent at this point (Costa de Beauregard, 1985). Concerning, say, an EPRB correlation of polarized photons, one often reads that “finding at *A* the state  $|A\rangle$  ‘instantaneously collapses’ at *C* the other photon into the associated state  $|C\rangle$ .” This is thrice faulty: not *A*-and-*C* symmetric nor *CPT* invariant, while the formula is both, and inconsistent in that if *both* measurements are performed “*which one collapses the other?*” Indeed, *both* measurements are performed in an EPR test.

Finally *there is the question of faster-than-light telegraphing*—allowed by lawlike reversibility, but repressed by factlike irreversibility; conventional telegraphy uses retarded waves. *Coding–decoding symmetry* allows faster-than-light telegraphing by associating psychokinesis with an EPR correlation; this could be tested à la Jahn. The *AC* separation could be spacelike, or *past timelike*, implying retrotelegraphy.

## 6. BRIEF CONCLUSION

*Lawlike reversibility and factlike irreversibility*—of conditional probability, retarded and advanced causality, information as knowledge and as organization—stem from the *reality–representation* reciprocity. *Probability*, and *information* its alter ego, are neither objective nor subjective, being both: the *reality–representation interface*.

*Quantum nonseparability*, inherent in the *wavelike probability calculus*, is another ingredient of the unfolding paradigm. *Reality is not self-sustaining*. Idea is primordial.

*Organization*, the ‘hidden face’ of information, is unmasked by *lawlike reversibility*. Negentropic lines of evolution do exist; there may be more profit in studying their *lawlike* origin than their *factlike* diversion from the universal negentropy cascade.

Anti-Carnot processes are *not prohibited*, but *strongly repressed*—*paranormal*. Wigner (1967, pp. 181–184) states that *lawlike symmetry* implies existence of a “direct action of mind upon matter”—psychokinesis, *reciprocal* to gain in knowledge.

Inexistence on a “universal present” suggests time extendedness of the subconscious mind, and existence of a largely unexplored phenomenology.

*It is by fact, not by law, that “one can neither see in the future nor act in the past.”*

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