Realistic Models of Action Quanta, the Four-dimensional Building Blocks of the Universe, and of Compound Particles such as Atoms as Lattices thereof, Part I

C.W. Rietdijk

Pinellaan 7, 2081 EH Santpoort-Zuid, The Netherlands

ABSTRACT. We first discuss some new arguments about the idea that the vacuum is a mere theoretical construction and that the real four-dimensional Universe merely consists of a lattice built up of action quanta as elements.

In this conception fits our earlier identification of action quanta as realistic atoms of occurring of which all other processes are composed. In the case of corpuscular massive elementary fermions we earlier found a model of their constituting quanta to be the *Zitterbewegung*, that also provides an explanation of retroaction. We now extend this to other elementary particles such as neutrinos and bosons. Retroaction as explained by our model also allows a reconciliation of Bohr's and Einstein's positions on the influence of observational acts and God's not playing dice, respectively. The model is extended, too, as regards a correspondence-like and imaginable relation between particles –that is, the action quanta they consist of– being in the corpuscular and the wave state, respectively.

RESUME. On discute en premier quelques nouveaux arguments en faveur de l'idée que le vide est une construction purement théorique, et que le véritable Univers à quatre dimensions est simplement constitué d'un treillis dont les éléments constitutifs sont des quantums d'action.

Cette conception s'accorde avec l'identification que nous avons déjà proposée des quantums d'action avec des atomes d'événements réalistes qui composent tous les autres processus. Dans le cas de fermions élémentaires corpusculaires et massifs, nous avons déjà trouvé qu'un modèle de leurs quantums constitutifs est le Zitterbewegung, qui explique aussi la rétroaction. Nous allons étendre ceci à d'autres particules élémentaires comme les neutrinos et les bosons. La rétroaction telle qu'elle est expliquée dans notre modèle permet aussi de réconcilier les positions d'Einstein et de Bohr sur l'influence *des observations, et le fait que "Dieu ne joue pas aux dés", respectivement. Le modèle est également étendu, en ce qui concerne une relation du type correspondance entre particules –c'est-à-dire les quantums d'action qui les composent– qui sont respectivement dans un état corpusculaire ou ondulatoire.*

1. Introduction

We first summarize some earlier results needed in what follows :

a The world is four-dimensional in a realistic sense ; that is, both past and future exist in parts of the continuum outside our direct observational scope [1,2,3,4,5].

b Within the latitudes of the uncertainty margins (e.g., for momentum), future events can retroactively influence present ones, on the supposition of conservation of (angular) momentum, realism and the correctness of relevant quantum results [3,4,5,6,7].

c In the four-dimensional world, action quanta are atoms of events, elementary processes of which all other processes and existences in time are series or other structures, lattices. E.g., the existence in time of an elementary particle consists of a sequence of action quanta of time duration $\Delta t = 1/\nu = h/mc^2$, ν, h, m and c having their usual meanings. Action, structured in processes, is the fundamental basic material of which the four-dimensional world consists and from which all observables derive [5,8].

d Whereas Minkowski space and Minkowski metric –as a "rough" macro metric– can be (re)constructed from the structure or lattice L of action quanta [8], which constitutes the four-dimensional ordered world of events, in microphysics a fundamental part is played by *action metric*, which can be characterized as follows :

In the three-dimensional world of objects, the distance AB between two objects A and B is obviously defined by asking : "How many standard objects –i.e., measuring rods– fit in between A and B?" In the four-dimensional world of events, however, it is equally obvious to define the *action distance* between two events A' and B' by answering the question : "How many standard events –i.e., how much action (how many quanta)– fit in between A' and B' ?" or, equivalently : "How much action (how much 'occurring') does it require to transform event A' into event B'?"[3,5].

e The concept of action distance, action metric, appears to be capable of explaining both the nonlocality paradoxes of quantum mechanics and wave-particle "duality", i.e., the appearance of four-dimensional wave slices closely connected with action quanta [3,5,8]. (In Ref. 5, see in particular Fig. 4 and its discussion ; see also Fig. 7 below.)

f As regards the relation between the corpuscular-like and the wave-like manifestation of particles (and of action quanta), Refs. 5 and 9 enunciate the *coded-information theory* which can briefly be summarized as follows :

Action quanta constituting the existence in time of elementary particles in the corpuscular state, as elementary processes, roughly consist of a so-called *spherical rotation.* Now an isomorphism appears to exist between on the one hand the group of all configurations of a complete spherical rotation, and on the other hand the group of phases of a 2-spinor wave in one period. If we introduce positive- and negative-energy situations (corresponding to different kinds of spherical rotation), the 2-spinor waves *become Dirac 4-spinor waves* [10].

In Refs. 5 and 9 we now introduced the hypothesis that, as soon as a particle passes from the corpuscular state into the wave one, *the physical information represented by the corpuscular particle's properties (and situation), which we will integrate in the corpuscular model, is isomorphically tranlated into the spinor-wavelike model. The spherical-rotational phase is only one of such properties (situations).* Energy is so translated into wave frequency by $E = h\nu$, momentum into wavelength by $\lambda = h/p$, and spin into certain phase relations between wave components. Thus, e.g., polarized neutron waves do not contain hidden spinning tops at all, but encode their relevant properties.

g One spherical rotation as mentioned in f) above, and representing a (simplified) model of action quanta that embody the existence in time of *corpuscular* elementary particles, has to be compared with one of the four-dimensional spinor-wave slices referred to under e). For such slices, analogously, represent (simplified) models of the kind of action quanta that embody the existence in time of *wavelike* elementary particles.

h In Ref. 8 we discussed a "zigzag" model indicating how retroactive influences, backwards in time, may be transmitted by a series of wavelike quanta.

2. In the last resort, distances are not defined by "amounts of vacuum", but by the four-dimensional action-quantal structure of the Universe ; Retroaction does not presuppose time-symmetry or violate irreversibility.

In Refs. 3 and 8 we already discussed action metric extensively. Because it plays an essential part in our general theory, however, it does not seem superfluous to give some new arguments in connection with it. The more so because, in later parts of this paper, we use it for drawing rather far-reaching conclusions about the structure of compound systems such as atoms. Within the same scope we, at the end of this section, also briefly address an objection against the possibility of *retroaction* that has been raised by some.

Our main point was that the four-dimensional Universe is "merely" a structure, lattice L, of processes and, therefore, of the action quanta embodying those processes. L's topology (number of quanta constituting series, connections, sub-lattices,...) and symmetries then *imply* Euclidean and Minkowskian space and metric as practical tools for (macro) coordinating events. "Amount of vacuum" corresponding to, say, a distance r or $2r$ are *derived* from L's structure and do not have some independent existence as some "theoretical ether".

Still, some might object : "If various forces act according to a $1/r^2$-dependent law as regards distance, the vacuum cannot but have some quantitative reality". We can answer as follows.

In a building, the space inside of it is defined by the real physical structure of walls, floors, ceilings etc. In (imaginarily) taking its enclosed amount of space from it, leaving such structure the same, you actually change nothing. Well, our thesis is that four-dimensionally you can argue exactly in the same way : It is the pre-existing four-dimensional structure L of action quanta and its topology and symmetries –just as the structure of the building's walls etc.– that define metrical conditions, not the other way roud. *What would change in the world if we retain the topology and symmetries of L as it is but no longer consider any vacuum as a separate entity ?* Well, all physical relations and events, the *phenomena*, also embodied by L, would remain the same by definition and, therefore, Natural laws, too. We retain L's topology and symmetries but delete the vacuum (as an independent agent), instead of explaining (part of) such topology and symmetries by means of the vacuum. Viz. in our four-dimensional L no objects "push their ways through the vacuum" but there is a topology and symmetries of the pre-existing L, *which* *represent Natural laws.* An example is the Principle of least action, which is a matter of topology and symmetry of L, from which the equations of motion follow and, therewith, how "objects push their ways through the vacuum". Another symmetry is that all H-atoms are the same, everywhere in L, or, at least, that Natural laws are simplest on our assuming this.

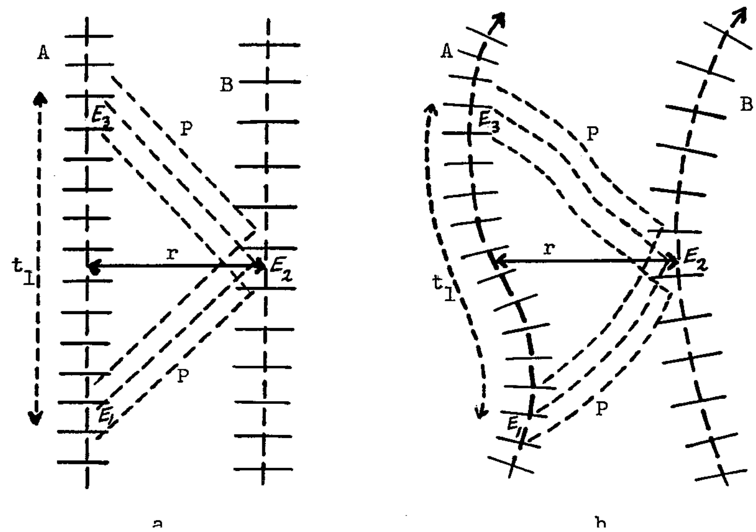

Figure 1. The topology and symmetries of action-quantal lattices define Euclidean (and Minkowskian) distances and metric, *inter alia*, by numbers of action quanta such as t_1 between the events E_1 and E_3.

In Fig. 1a we see a sub-structure S of L, defining the "distance" r between two systems A and B, whose worldlines have been drawn as quantal (slice) series. Now r is defined simply by the structure, topology and symmetries, of S, in particular the number of A-quanta between the emission and absorption interactions E_1 and E_3, respectively, of a photon P with A, reckoning with P's reflection on B at E_2. Because of their particular positions in L, photons, *inter alia*, function as special (indirect) measuring rods ; L appears to be so symmetric and coherent that the Euclidean metric as in principle defined above is consistent and simple. But the distances r are nothing real in the vacuum ; *the latter as physical reality is only a relic of the old-time ether.* L's topology and symmetries are so that the distances r are one of the tools for simply coordinating it (L), and, consequently, for formulating many laws, e.g., the

$1/r^2$-dependent ones, in an in principle similar way as some other Natural laws can best be formulated by invoking $i = \sqrt{-1}$. r is mathematical in nature, as coordinates are in general, though it is very "picturesque".

The above implies that if S would be deformed as in Fig. 1b, or L as a whole would be similarly deformed, nothing would observationally change for us, r included, so long as L's topology would remain the same and we continue supposing, *inter alia*, that symmetries such as regards the equal duration of A's quanta and the special position and properties of photons endure.

How little real Euclidean distances actually are as "amounts of something" we see from Fig. 2. Relativistically, the distances on the dotted lines are all zero. Also, the trajectory or "distance" $r = OA$ can be approximated by a dotted line completely consisting of segments of Minkowskian (that is, "more real") length zero. A large distance r can be covered in a proper time zero by a photon and it seems a millimeter for an observer in an appropriate inertial system.

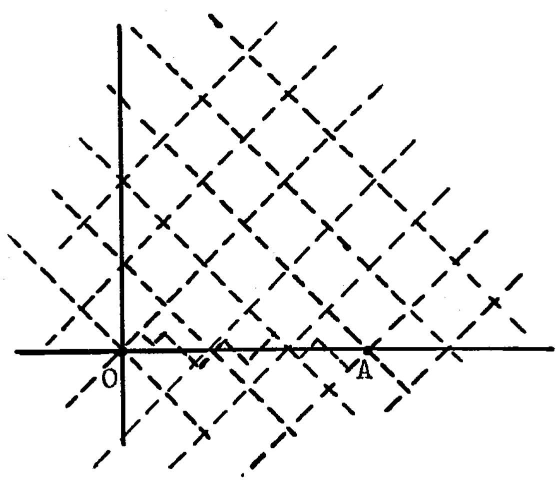

Figure 2. Euclidean distances are not "objective amounts of vacuum" that physically radically separate mutually "distant" objects. E.g., you can get from O to A via some Minkowskian zero-segments.

Mind in the above connection that, of course, *some* Euclidean distances are very really physical indeed, viz. if they form part of L, say, by being "filled" with measuring rods.

In order to illustrate how *indirect* the role of r is in the $1/r^2$-dependent actions at a distance we remind of the fact that the relevant laws are actually implemented by virtual photons and gravitons which, by their velocity c, have nothing primary to do with the Euclidean r, as they cover "shortcuts" through Euclidean space of length zero in Minkowski space : for them the relevant objects which they connect are physically mutually contiguous instead of having a distance r. In such covering, the transmitters of the forces in question interconnect virtually all objects by physical trajectories of Minkowskian length zero. This actually may contribute to integrating L so far as to allow wide-spread feedback interactions already without our calling on action metric, and, by highly making the four-dimensional world some set of "communicating vessels", might contribute indeed to L's remarkable symmetries. The above relativistic consideration of the relevant actions at a distance indeed relativizes Euclidean distances r so much that our action-structural conception adds only one more step to it.

We may conclude that Euclidean (and Minkowskian) distances are useful, practical, coordinates for describing the macro-structure of L, but nothing more, whereas action metric is the real physical metric, that is, the one most directly based on action which is the true stuff of the Universe. *Other metrics are derived, are secondary*, in a similar way as all other physical observables and concepts are derived from action (quanta) and the structure L according to which it is ordered [5,8,9].

Because retroactive influences as earlier discussed by the author [4,6,7] constitute another relatively new concept used in this paper and still meets opposition from some, we briefly address a misunderstanding about it here.

E.g., F. Selleri [11] objects that the *irreversibility* our macroscopic world exhibits is hardly reconcilable with purely time-symmetric theories. He concludes that on giving such irreversibility a more fundamental role in our theories the possibility of retroaction is lost. Answering this criticism we observe that

1. Selleri is right, in our opinion, in rejecting purely time-symmetric theories ; in spite of the time-symmetric nature of so many equations, the macro world can hardly be seen as having such character, too.
2. Though, e.g., O. Costa de Beauregard bases his acceptance of retroaction on time-symmetry arguments, the present author does not do so and *never invokes such symmetry* in deriving the inescapability of retroaction from a) quantum mechanics and b) conservation of (angular) momentum [3,4,5,6,7,8]. Actually, he rejects it (see 1.).

3. In concluding that retroactive influences can only "fine-tune" physical phenomena *within the "uncertainty" margins*, in contradistinction to causality which has a much broader scope, he actually introduces time *asymmetry* in his theory (see, e.g., Ref. 3 p. 450, Ref. 6 pp. 626-7 and Ref. 7 p. 787).
4. In a pre-existing four-dimensional world –from which we start on account of hitherto unrefuted proofs referred to above– *actually everything is irreversible*, "definitely there from time immemorial". Because of this very four-dimensionality, instances that we humans (from our three-dimensional perspective of "becoming") will experience as "influences" are in principle possible in the negative as well as in the positive time direction, without these need be symmetrical (compare 3. above).
5. Even apart from the foregoing we can ask : If we establish that some experimental result R originated irreversibly, what logical or physical argument then precludes that R, in its irreversibly being there (or in its origination) and in its having definite properties, has been or is defined, "influenced", by retroactive as well as causal factors ? Definite and irreversible as the past may be, what excludes retroaction from having contributed to such state of matters and to its (the past's) features ?

3. The Zitterbewegung as a model of action quanta in simple corpuscular cases

In Ref. 12 we derived that the Zitterbewegung of massive Dirac particles is nothing but the realistic embodiment or model of the action quanta of which such kind of particles consist in their existence in time. I.e., we identified each couple of *two* Zitterbewegungen of a time duration of $h/2mc^2$ each with *one* spherical rotation of time duration h/mc^2. Because in Refs. 5 and 9 we found such spherical rotation to be a model of the action quanta constituting a Dirac particle's existence in time, this amounted to equating two Zitterbewegungen and one action quantum in the relevant (massive Dirac particle) case.

In Fig. 3 we see a model of a spherical rotation as discussed extensively in Ref.[10]. *Two* rotations of core D complete one spherical rotation (S), after which the strings Aa and Bb return to their initial positions (which, on the first sight, is not easy to imagine !). We identified one period of the Zitterbewegung (Z) with one rotation of core D.

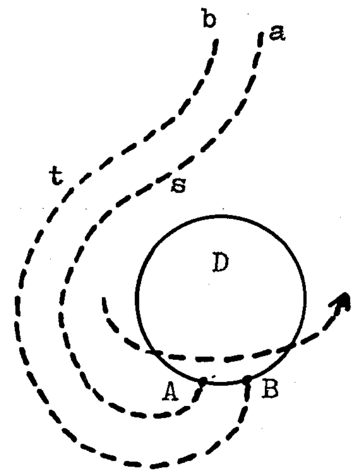

Figure 3. After a rotation of D through 4π the configuration is restored, s and t not being "twisted".

Z indeed plays the part of action quanta in the following essential respects :

a) In two of its periods of $h/2mc^2$ seconds it produces an action of $2 \times 2\pi \times 1/2\hbar = h$, just as action quanta do ;

b) Just as the action quanta going with fermions in the corpuscular state, Z, too, refers to a "corpuscular" particle, viz. it corresponds to location *having an eigenvalue* [13,14,15,16].

c) Neither S nor Z is an ordinary, cylindrical, rotation in a two-dimensional plane. S is not so by the nature of spherical rotation [5,9,10], whereas Z appears to be three-dimensional for massive Dirac particles [17]. Note further that S, because of the mere isomorphism of the process it represents with spinor *waves* [10 ; also compare f) of Sect. 1], is a natural candidate for a model of the action quanta going with the existence in time of *corpuscular* massive elementary fermions, since such spinor wave slices constitute a model for the action quanta going with *wavelike* Dirac particles. A crucial point in this connection (i.e., of identifying Z with the action-quantal model S) is now that not only S, but Z, too, corresponds to spinor waves. For in the Heisenberg picture in which location has an eigenvalue, spinor waves are "translated" into Z as solution of the Dirac equation.

In Ref. 12 we already observed that Z –that is, action quanta– produces the phenomenon of mass m by its very correspondence to the frequency $\nu = mc^2/h$. Then it is superfluous to assume that Z's constituents –such as the well-known massless "charge" constituting the properly Zittering entity– have mass of themselves. Note here that massless "components" in the Zitterbewegung are less strange than it may seem. E.g., *charged* particles are particles that can interact with virtual photons. *Heavy* particles may be such ones that are in a position to interact with gravitons, the (hypothetical) quanta in a quantized theory of gravitation. Now it could be that gravitons cannot interact with the components participating in the Zitterbewegung *separately*, but only with the Zitterbewegung-process as a whole. This could explain the masslessness of the components. For the rest, "negative energies", too, become more imaginable in the above frame of thinking. For in the treatment of Ref. 10 (see in particular p. 458) what we will call negative-energy states are directly connected with certain alternative configurations of spherically rotating systems, viz. with mirror images of the ones representing "positive-energy states". This again means a step in the direction of an understandable model of the Zitterbewegung, particularly in connection with the relevance of negative energies for its appearance.

The points a) through c) above, in addition to the argument in Ref. 12, make it by far the most plausible hypothesis to assume that S and Z are the simplified abstract mathematical and realistically physical models of the same thing : the quantum of action as it appears in timelike series constituting the existence in time of massive Dirac particles. In Fig. 3, A and B of D then correspond to the charge C and the center of mass M of Z, which makes the strings s and t then correspond to interactions with the environment by means of virtual photons and gravitons, respectively.

On p. 451 of Ref. 10 the Zitterbewegung is mentioned, too, and is related indeed to the *core* rotation in the spherical rotation S discussed. Further, the *spinor waves* are more or less identified with the string "rotation" in Ref. 10. Our own conception differs fundamentally from this : We see the complete spherical rotation (including strings), as it is now articulated to the Zitterbewegung (including possible accompanying "resonances" and virtual photons etc. connecting the core process with the environment), be translated into another, isomorphic, physical information-conserving, spinor-wave language as soon as the "corpuscule" transforms into the *equally realistic* wave state.

The above means nothing more or less than that in principle we now have a realistic model of the atom of events, the quantum of action, as an elementary process : for quanta embodying the existence in time of massive Dirac particles in the corpuscular state it is the Zitterbewegung. (That is, an "atom of events" in, e.g., the electron's existence in time consists of two successive Zitterbewegungen.)

We can now summarize the situation as to the relation between Zitterbewegung and action quanta in general –which also comprise ("wave-like") action-quantal slices and the non-fermion cases– as follows :

In connection with the appearance of both fermion *and* boson fields, quantization of action is indispensable for developing a consistent relativistic theory (see, e.g., Ref. 18, p. 211). In fact, this means that quantization is already implied by the relativistic character of both the theory of Ref. 10 and our own. That is, if we introduce *location* as an observable in a fermion field and calculate the path, say, of a corpuscular (that is, *localized*) electron, action still has to appear in a *quantized* form. Since action amounts to "occurring", this means that it has to appear in the shape of periodic processes each corresponding to (or producing) an action h. This is exactly what the Zitterbewegung does, as we saw under a) above. So you can say that, as soon as the electron is forced to manifest itself in the location-eigenvalue, corpuscular, way, the action quanta its existence in time consists of *internally reorganize in order to find another way to produce action* than they used when being the spinor-wave slices (as e.g. sketched in Fig. 4 of Ref. 5 and in Fig. 7 below). Viz. the way of a) above, via the orbital angular momentum $1/2\hbar$ of the "Zittering" localized charge playing a part in the Zitterbewegung.

Thus, very general considerations (relativism, consistency) make the Zitterbewegung ensue from Dirac spinor-wave structures as soon as observables such as location and momentum are at stake. (The latter are introduced via commutation relations such as $[x_i, p_k] = i\hbar\delta_{ik}I$, in which I is the 4×4 unit matrix.) Actually, enforcing the corpuscular state –that is, location eigenvalues– forces the relevant action quanta to pass from the spinor-wave state into the Zitterbewegung one. In this way the mathematical isomorphism between spinor waves and spherical rotation we started from in Refs. 5 and 9 gets the realistic physical content and extension of an isomorphism between two alternative manifestations of matter, *that is implied by the above-mentioned general considerations.* (In Sect. 4 we go further into the relation between the corpuscular and the wave state of matter.)

The circumstance that action quanta appear to be in a position to transform from a spinor-wave-slice form into a structurally equivalent (isomorphic) Zitterbewegung (corpuscular) form suggests that it may be possible that such quanta can manifest themselves in even more different, but structurally equivalent, forms, too. E.g., in the shape of the action quanta going with vibrations or rotations of molecules instead of with the existence in time of particles.

For neutrinos the situation differs from what we saw for massive Dirac particles. E.g., we cannot consider their Zitterbewegung in a rest system. Moreover, it appears in two and one dimensions for four-component Dirac neutrinos and two-component Weyl neutrinos, respectively, as contrasted with three dimensions in the massive-fermion case [17,19].

Still, we see for neutrinos, too, that the frequency of the Zitterbewegung is twice the quantal frequency as to be found from $h\nu = E = cp$, just as we saw above for massive fermions. I.e., in Ref. 17 an angular frequency $\omega = 2c/\lambda$ is derived for the four-component neutrino, with $\lambda = h/p$. Thus,

$$\nu_z = \frac{\omega}{2\pi} = \frac{1}{2\pi} \times \frac{2c}{h} \times 2\pi \times p = \frac{2c}{h} \times \frac{h\nu}{c} = 2\nu,$$

where ν_z and ν are the frequencies of the Zitterbewegung and the quanta, respectively. Also, the spin $1/2\hbar$ is found to be the angular momentum of the relative motion, that is, of the Zitterbewegung.

Precisely because a neutrino's Zitterbewegung cannot normally be considered in a rest system, as a particle-like process, one might prefer a conception in which such "particle"'s angular momentum is present only is a non-corpuscular, wavelike coded form (actually, one may consider the neutrino itself as a wave between its emission and absorption), in the same way as we discussed this for photons in Refs. 5 and 9. The Zitterbewegung formalism might then be conceived to describe such code now. Also mind in this connection that, because of the neutrino's velocity c, the distance between its emission and absorption events is zero in both action- and Minkowski metric. This implies that *in such metrics* we cannot speak of some angular momentum (or, for that matter, energy) to be "substantially", materially, *transported* via the neutrino's path : emission and absorption events are (action-)physically contiguous according to those metrics as it is. Of course this does not detract anything from the fact that in our traditional space-time scheme angular momentum and energy are carried from one region to another indeed. In our conception, this happens in such a way that they have been "translated in the wave code" in covering their paths through Euclidean space. As explained in Ref. 5 for photons, the wavelike coded angular momentum, in a way, functions then rather as a means of making a (our human) three-dimensional picture of the world (mathematically) consistent than as some entity being transported along a (physically real, action- or Minkowskian) finite distance, let alone that such entity has some massive spinning-top-like characteristics.

Note in the above connection that photons are no series of action quanta in the usual sense. E.g., Fig. 4 makes it clear how each slice *between emission and absorption event* represents a quantum of action, no series of the latter *succeeding* each other on the worldline between such two events. For neutrinos, the velocity c suggests a similar state of matters.

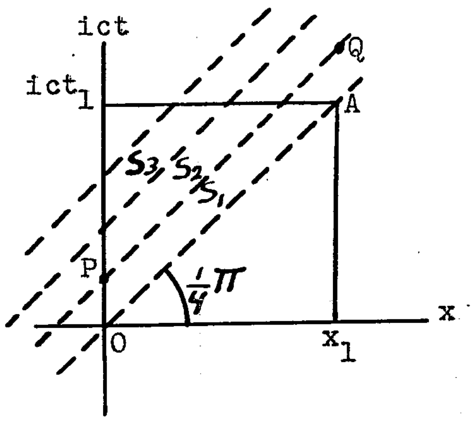

Figure 4. S_1, S_2 and S_3 are photon action-quantal slices between an emission and an absorption process of which OP and AQ form parts, respectively; the photon's worldline is parallel with $S_1, \ldots$ and embodies a shortcut through space-time.

We saw above that the Zitterbewegung has a different form for neutrinos. Still, it is consistent with the relevant paragraphs to conceive the Zitterbewegung as embodying the action-quantal process in neutrinos, too, though with the provisos contained in the last and penultimate of such paragraphs.

Note in the above connection that constructing a model for *action quanta* essentially means constructing a model for the relevant *particles*, too, which are "merely" series of ν action-quantal processes per second of their existence. The differences between the various relevant particles then arise from variations of one or more parameters in their action-quantal processes, such as the latters' duration, angular momentum, or dimension (3, 2 or 1 spatial dimensions).

With *bosons*, there are two categories. Photons and some kinds of meson are in a situation fundamentally different from that of (massive) fermions. They have no position as an observable, which makes the derivation of a Zitterbewegung with spin $1/2\hbar$ not applicable to them, and which is responsible for other spin values than $1/2\hbar$ (see Ref. 20, p. 267). We can also formulate this by saying that they never are in the corpuscular and always in "some kind of" wave state, so that the corpuscular variant of the quanta of action of which their existence in time is or may be a series does not appear here : the relevant "particles" are unlocalizable and the Zitterbewegung in the form we discussed does not take place. Thus, e.g., photons are represented in action physics by spinor (i.e., vector) wave slices such as the ones in Fig. 4, which differ from those in Fig. 7 below (and in Fig. 4 of Ref. 5) by their making angles of $1/4\pi$ with the ict-axes of all inertial systems.

Other, massive spin-0, particles have a Zitterbewegung with angular momentum zero. Their action –and, therefore, mass– is produced by non-spin effects. In Ref. 19 (see in particular pp. 1060 and 1061) such Zitterbewegung for massive spin-0 particles is derived, starting from the Sakata-Taketani Hamiltonian $H_s = \tau + p^2/2m + \tau_3 m$, where the τ matrices play similar roles as the ρ matrices do in the Dirac theory. Here, as in the fermion case, the Zitterbewegung is dependent on interacting positive- and negative-energy states. Again, each "double period" of it equals the quantal period $1/\nu$, and it can be considered to represent another variant of realistic quanta of action.

4. Arguments relating to how microprocesses function as wholes and to the realistic "translation" between wave and corpuscular states

In Ref. 8 we discussed an imaginable model of how retroactive influences could operate in a (four-dimensional) wave packet. Such influences appear to exist in some microphysical experiments [3,4,6,7]. Essentially, the model in question makes use of the fact that in spinor waves such as

$$\phi = \begin{pmatrix} \phi_1 \exp\big(i/\hbar(Et - \mathbf{p}\cdot\mathbf{r})\big) \\ \phi_2 \exp\big(i/\hbar(Et - \mathbf{p}\cdot\mathbf{r})\big) \end{pmatrix}$$

those variations of $(t, \mathbf{r})$ and $(E, \mathbf{p})$ that leave $Et - \mathbf{p}\cdot\mathbf{r}$ unchanged make no difference as to ϕ. This appears to imply that we can coherently vary $\mathbf{r}$, t, $\mathbf{p}$ and E along certain paths without anything action-physical changes, which then both allows retroactive influences and causes the existence of "uncertainty" ranges within which $\mathbf{r}, t, \mathbf{p}, \ldots$ "do not matter (action-)physically", at least so far as the relevant process is at stake. For the rest we can generally say that, e.g., $\Delta x \Delta p_x \geq h$ is one of the manifestations of the failure of Classical Theory. Now it is observed in Ref. 21 that "... the failure of Classical Theory seems to have as sole origin the atomism of action" (p. 42). This makes us expect uncertainty relations such as $\Delta x \Delta p_x \geq h$ to depend on such atomism indeed. Now it is actually the picturesque representation of *action quanta* in the shape of periodical four-dimensional wave slices of a timelike dimension $ic\Delta t = ic1/\nu = ich/mc^2 = ih/mc$ (ν is the quanta's frequency) from which such uncertainty relation easily follows in Ref. 8 (see Figs. 9-11) and also in Ref. 12 (see the discussion of Fig. 4). The essential point is that an elementary geometrical argument shows that it is such dimension ih/mc which causes the wave slices' mutual extinguishing at their fringes to precisely correspond to $\Delta x \Delta p_x = h$.

In Ref. 12 it appeared that an understandable mechanism for retroactive effects, as referred to above for the case of the *wave* state of particles, can be found for the (corpuscular) Zitterbewegung state of fermions, too. This state of matters contributes to the correspondence we found to exist between action quanta going with the wavelike and the corpuscular state, respectively.

Finally, we see from Fig. 4 that distances like PQ and $OA = \sqrt{(ict_1)^2 + x_1^2}$ are zero in Minkowski metric. However, with photons or neutrinos S_1, S_2, $S_3, \ldots$ are action-quantal slices, parallel to such zero-mass particles' worldlines such as OA, because both have a slope $1/4\pi$. Therefore, PQ and OA are also zero if conceived as *action* distances in the processes the existences in time of such zero-mass particles constitute. The latter cover *shortcuts* through both Minkowski space (because of their velocity c) and the physical space defined by action metric. We see from this that not only the action quanta going with massive corpuscular fermions (i.e., the Zitterbewegung) and those going with wavelike massive particles define a mechanism for retroaction, but that those going with massless fermions and bosons do so, too, because A and O, just like Q and P, are at the same time "stages" on the worldline of a massless particle *and* action-physically contiguous.

The result of what is enunciated or summarized in the foregoing is that we now have a realistic theory and models of wave-particle duality, of action quanta participating in the existence in time of corpuscular and wavelike elementary particles, and of mechanisms responsible for the transmission of retroactive influences in corpuscular and wavelike microsystems.

In Ref. 12 we extensively discussed the problem whether the precise values of observables (such as location in the Zitterbewegung) and the internal (electronic) structure of atoms, evoked or forced to manifest themselves by a relevant measurement, are either produced from data exclusively stored in the *local* spinor waves or also partly from information that nonlocally derives from elsewhere in the process, *inter alia* via the feedback communication channels discussed above. *The conclusion was that the second alternative is the correct one*, and that the "production" of observables and/or their definite values by an observational act can be a truly four-dimensional process, e.g., involving both the "emission" and the "absorption" event. In EPR non-locality we see a concrete example of the phenomenon that a measurement result at A can co-depend on a situation at a distant B, so that the local waves at A evidently do not contain all information produced in an A measurement indeed. Our discussion in Ref. 12 generalizes this and so contributes to giving a concrete meaning to Bohr's idea that microprocesses function as wholes. (Of course, the feedback channels already do so in any case.) Instead of being locally stored, the information defining locations and other precise values of observables produced by measurements is partly supplied by the four-dimensional process as a whole, including the contribution to it by the measuring instrument. Influences nonlocally operative from distant parts of such process constitute the very "hidden variables".

Remark : The inherent implication of the Zitterbewegung by the Dirac theory and the corresponding spinor-wave pattern (plus the rules $P = \mid \psi \mid^2$ and $< \Omega >= \int \psi^* \Omega \psi d\tau$, introducing observables) –in virtue of the mere equivalence of the Heisenberg and Schrödinger (Dirac) pictures–, of course, strongly supports the substance of the coded-information theory of Refs. 5 and 9.

For if we only have to introduce some logically indispensable additional conditions such as quantization (compare Sec. 3), *or to call on the equivalence of the above-mentioned two pictures, in order to transform spinor waves into a Zitterbewegung ("by mere mathematical operations"), a high degree of equivalence or isomorphism, mutual mathematical translatability, between such spinor waves (or, the language in* *which they carry physical information) and the Zitterbewegung-process (or, corpuscular language of storing physical information) clearly exists. Note here in particular the significant fact that such correspondence is indeed between the structure of the Zitterbewegung and the one of the spinor waves, not between that of the Zitterbewegung and something* in *the waves. It is indeed the (realistic) waves* themselves *that carry the information about the structure of the Zitterbewegung in a coded form, in another mathematical language, not something hypothetical (e.g., a particle) "hidden"* in *such waves* ! This is exactly the essence of what the coded-information theory contains.

The fact that the articulate realistic physical particle-wave correspondence is an isomorphism indeed can also be concluded from Refs. 15 and 17 (see in particular p. 477), where it is once more made clear that the Dirac *waves* are defined by a four-dimensional spinor *representation* of the Lie algebra $SO(5)$ generated by $\mathbf{x}$ and $\mathbf{p}$ under commutation, in particular $[x_i, p_j] = i\hbar\delta_{ij}\beta$ and by which the Zitterbewegung is implied; here x and p go with the entity performing a Zitterbewegung, and β is a matrix in the Dirac Hamiltonian $H = c\boldsymbol{\alpha}\cdot\mathbf{p} + \beta mc^2$. (One will see a minus sign and β in the commutation relation here, as contrasted with the analogous equation in Sect. 3 ; this relates to a somewhat different definition of x_i and p_j which, however, is not important for us ; see Ref. 15, in particular pp. 2455-9.)

The wave structure as a whole, completed by what causes $P =\mid \psi \mid^2$ and $< \Omega >= \int \psi^* \Omega \psi d\tau$ to hold true (among which are influences emanating from an observing instrument, in connection with quantization, compare Ref. 8, Sect.4) contains all information needed for building up the Zitterbewegung, and has the (nonlocal) communication capability to concentrate or "corpuscularize" such information to definite measurement results. So why separately assume a particle hidden in such structure ? If we take the formalism really serious, we see that it militates against the current conception which either considers the waves as purely mathematical artefacts or sees them as guiding or otherwise *accompanying* phenomena, in which a particle is hidden. On the contrary, it strongly suggests that particles and the corresponding waves are *equally realistic, somehow mutually equivalent*, phenomena, representing a same physical reality, under alternative circumstances.

Note in the above connection that the instance that actually causes the corpuscular state, i.e., the Zitterbewegung, to manifest itself is a relevant *measurement*, which forces an eigenvalue of the observable *location* to appear. In Ref. 12 (with Fig. 7) we ewplained how such measurement can do so. That explanation essentially amounts to two parts for our present Zitterbewegung case : 1° the measurement reduces the "uncertainty" for location to a very small margin $\Delta_1 x$, i.e., about the Compton wavelength $\hbar/mc$, and 2° its forces, as a result, the action process to transform itself in such way that the production of action is now performed in the relevant small area of dimension $\approx \hbar/mc$, viz. by a rotating charge C in the way of a) in Sect. 3, instead of by the timelike evolution of a spinor-wave-shaped quantal process.

As one of the conclusions from the foregoing it is consistent to indeed accept the idea that only the observational act (process), as a part of the whole four-dimensional microprocess, produces or completes the observed system and/or its observed properties, from information stored or produced in the whole process. This not only amounts to a further concretization and explanation of Bohr's in-principle idea that microprocesses function as wholes, but at the same time reconciles such conception with realism and corresponding understandable *models* implying nonlocality. Note in particular that this conclusion *makes it impossible at all to do without some kind or other of coded-information theory* : The observable systems are not there, before the actual observation, in whatever traditional corpuscular and complete form. Then, they have to be represented in the process in some other way, unless we abandon realism and models, *that is, understandable consistency*, at all. Thus, the coded-information concept and theory as given in Refs. 5 and 9 also appear to be the only consistent and coherent way at all *to both account for experiment and save realism and understandable models, to keep microphysics rational to detail indeed*, as contrasted with its being mere predictive algorithm. So they are the way out from the all-pervading paradox of microphysics, viz. that no understandable realistic model seemed in a position to account for the phenomena. Well, one or some still are, on the condition of our reasoned abandoning of locality and of the *conventional*, "non-coded", particle model for systems in the wave state.

Also note in this connection that the commutation relations in the coded-information theory are nothing but a translation into the information code of operators and their formalism (as it is integrated in the wave information code as a whole) of the quantization phenomenon as to observables. (In turn, such quantization follows exclusively from the "simple", realistic and imaginable fact that the four-dimensional Universe is a structure of discrete, indivisible, elementary events, viz. quanta of action ; see Ref. 21, p. 42.) At the same time so radically different and "unimaginable" a reflection in the formalism of so well imaginable a fact as the quantization of action constitutes one more indication that Nature handles (micro-)information in two radically different data codes indeed.

A remark about "realism" has to be added here. Realism has been described as the idea that "Observables have values also if they are not (yet) observed". We can say about this that, e.g., an entity performing a Zitterbewegung can be lacking indeed before being observed (that is, observed only in the shape of, say, a corpuscular electron) : It is then only produced by the observational acts, viz. from the local waves, from data supplied by nonlocal communication, and by the instrument. Before, only the waves were present at the relevant location. (We remind here of the end of the above *Remark*, where we gave some indications and a reference about how a measurement enforces a Zitterbewegung.)

In the *above* sense, therefore, microrealism does not generally hold : Separate micro-objects and the observables defining them often have no existence as such, independent of acts of observation.

It will be clear from the general foregoing argument, however, that an articulate four-dimensional plan, blue-print, of a relevant microprocess still exists. The circumstance that an instrument or absorber, and "agents" which are distant in the Euclidean frame but action-physically contiguous, contribute to the outcome does not detract from the definiteness of the latter and of the process as a whole, which is already implied by the pre-existence of the four-dimensional Universe proved in Refs. 1, 2, 3, 4, 6, 7 (and whose Universe's symmetries, order, are perceived by us as "causal", "retroactive" or other effects and laws). So, essentially, both Bohr and Einstein were right :

1. A microprocess is a whole, as separate parts will not exist independently ; in particular, they do not (always) exist independently of observational acts ;
2. "God does not play dice" ; Nature, man and his observational acts included, exists as an objective four-dimensional reality, in which such mutual interrelations between events which our intelligence experiences as "causal", as "understandable rational laws" etc., sometimes transcend space-time locality because of the physical relevance of action metric. From this point of view we can even see retroactive "influences" emanating from observational acts or from

absorption-like events in general as causal, too. Their existence and in particular such emanating from observational processes complicates "outside reality" (compare the above about "realism").

Within the above scope, Wheeler's "No phenomenon is a phenomenon until it is an observed phenomenon" surprisingly does not really disharmonize with a realistic –and deterministic– character of Nature. For an observation may evoke or enforce something "*new*" in a situation indeed, even retroactively, but this does not imply an exception to the rule that all processes and actions in Nature proceed according to deterministic natural law, retroactive and other ones emanating from observational processes included –whether they influence the observed situation or not. For the rest, in a pre-existing four-dimensional Universe, retroactive "influences" (in implementing natural laws as experienced from our human three-dimensional point of view) already for mere reasons of symmetry do no more violate determinism, conservation laws etc. than causal "influences" in the $+t$ direction do.

Note, finally, that the introduction of action metric is also relevant in connection with "articulating" the mathematical concept of spherical rotation to the realistically physical Zitterbewegung. For such metric allows to consider superposed (wave) states in a natural way as action-metrically mutually contiguous variants of the same process whose various alternative data (that are responsible for "uncertainty") are all at the same time encoded in the mutually interfering variant waves, respectively. (See Refs. 5 and 8.) Without action metric, e.g., the superposition or interference of positive- and negative-energy states as appearing in the Zitterbewegung could not naturally and realistically be introduced.

We assumed in Refs. 5 and 9 that the corpuscular and wave states of action quanta are discriminated by the fact that only in the first one interaction of the relevant system with the environment –that is, "strings" as in Fig. 3– plays an important, or rather a *specific*, part. The crucial point may simply be that in the corpuscular case the interaction with the environment enforces an eigenvalue of location, in a way already made generally clear by the discussion of Fig. 7 in Ref. 12.

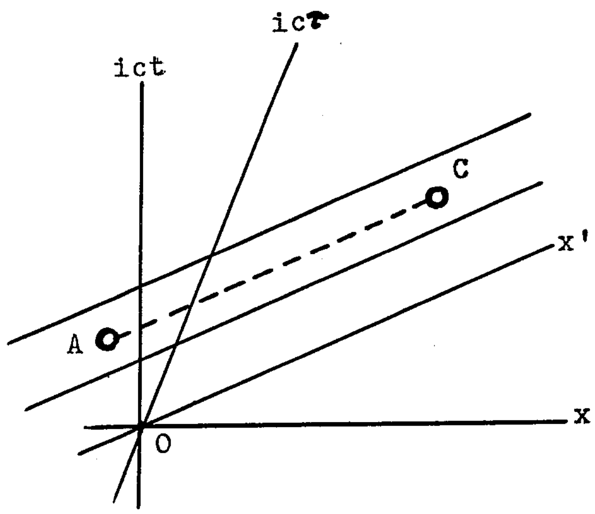

Figure 5. A fusion of components, such as A and C participating in a particle's Zitterbewegung, may be characteristic of the wave state.

Now consider Fig. 5, in which two participants in the Zitterbewegung (Z), one called A and the other being the "charge" C, have been drawn at the same moment in the rest frame of the relevant particle's centre of mass. Note here that, since C is *massless*, at least one other participant in Z has to appear, viz. a "centre of mass" A that relates to how *gravitons* interact with the system. Then, because A and C as mere metrical locations in a same equi-action plane are physically contiguous for the process (viz. the system's free movement ; compare, e.g., P and Q of Fig. 4 in Ref. 5), it is essentially their different *functions* (interactions with the environment) that discriminate A from C. Now in the interactional state A and C may have different relations to the environment indeed because of connections ("strings") like aA and bB (or rather, cC here) of Fig. 3, which discriminate them physically. So A and C, notwithstanding their physical contiguity in the above qualified sense, cannot "fuse" in this case because of their mere different relations with the environment. After a sufficient severance of the connections aA and cC a fusion AC might be possible, *which may be an essential characteristic of the wave state.* (Concretely, one could imagine cC to represent outside interactions of charge C by means of virtual photons, this embodying our system S's Coulomb interaction.) For the rest, A

and C may as well represent separate components of an atom, for which we then can argue similarly.

Within the above scope, our assumption that it is (sufficiently intense) location-defining outside interactions that determine in which state –wavelike or corpuscular– a system S will appear, can be elaborated.

In the first place, observation suggests that the wave state is not a merely "smeared-out" version of the corpuscular one, only generated by the circumstance that shifting our system S as a whole over a finite distance Δx makes no action-physical difference for the relevent process. For, e.g., the fundamental difference between the spinning-top-like (corpuscular) and the component-phase-difference (wavelike) way of spin manifestation indicates a more fundamental physical difference between particles and waves. *Now it is our thesis that such difference is indeed defined by the very fusion mentioned above.* We can argue as follows. So long as system S manifests its existence in time by the mere non-interacting wave system $1, 2, 3, \ldots$ (see Fig. 6), it is action-physically equivalent whether S is at A or at C because AC denotes an equi-action plane. As soon as S engages in such interaction with another system or instrument T that makes shifts of S over AC become action-physically relevant in the interaction process as a whole, its being at A or at C starts making a real physical difference indeed. We indicate T's action-quantal presence and interference with S by its wave system $I, II, III, \ldots$ It is clear then that S being at A or C makes a difference of two quanta, $2h$, as to interaction participant T and, therefore, makes an action-physical difference now indeed. (Compare again the discussion of Fig. 7, Ref. 12.)

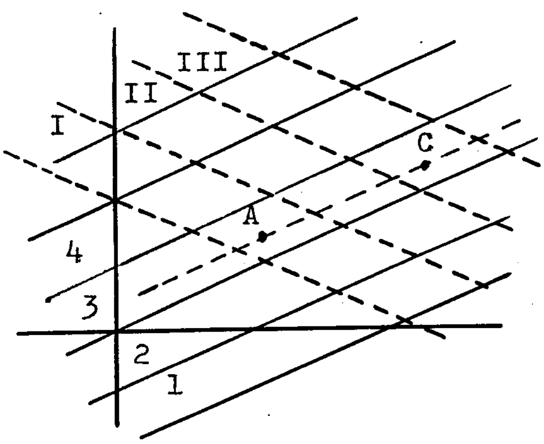

Figure 6. Two interacting systems, each being represented by a series of waves.

We can add that T's presence or absence makes a difference for the situation of S's *components* A_1 and C_1, too. For in the first case (T's presence) A_1 and C_1 being at A and C, respectively, may action-physically differ from A_1 being at C and C_1 being at A because of the $2h$. Generally, T's action-physical interference in principle not only differentiates separate locations on the sometime equi-action plane AC as regards S *as a whole*, but it does so, too, as regards S's *components*. T may actually interact differently with A_1 and C_1. In T's absence, A_1 and C_1 do not interact with the environment at all, because S moves freely. So A_1 and C_1 are then neither differentiated by having different *locations* –both are "smeared out" over AC– nor by having different interactional *functions*. This means that some outside agent T interacting with S is needed to give S's components *any separate physical identities at all, based on action-physically defined separate locations and/or functions.* Then, arguing consistently and invoking the Principle of least complication [12] –containing that Nature tends to the optimum simplicity of its processes that the phenomena allow–, we may conclude that in the absence of any T components such as A_1 and C_1 simply *fuse* into the integrated wave phenomenon embodying S. Their separate identities do no longer make physical sense ; assuming them is a redundant hypothesis as soon as A_1 and C_1 have neither separate locations nor separate functions.

We see from the above that there is an inherent difference between the wave and corpuscular states indeed because of the mere component fusion that will go with the first. Note in this connection that if no location eigenvalue is interactionally enforced, say, for a Dirac particle (and a sufficient uncertainty margin Δx as regards x is left, which corresponds to the wave state), *no physical instance causes a Zitterbewegung path to be followed by "charge C" according to the formula* $dx_1/dt = [x_1, H]$. (See Ref. 20, pp. 261-3.) For eigenvalues of x_1 etc. will not be enforced now. This implies that in the relevant wave state the action will even be produced otherwise than by C's orbital angular momentum and rotation, which goes with the corpuscular Zitterbewegung way.

Generally, a fusion of system components (such as A and C in the Zitterbewegung) into waves will make the spinor-wave way of producing an action of h during each period of $\Delta t = 1/\nu = h/mc^2$ take over. Still, the isomorphism between spherical rotation and 2- or 4-spinor waves as figuring in the coded-information theory guarantees a structure similarity of the two basic action-producing, that is, action-quantal, processes. Because the corpuscular, "non-fused" one is more articulate we can say that it is indeed only its *essential structure* (including spherical rotation) that is isomorphic with (the essential mathematical structure of) the physical spinor-wave process embodying wavelike action quanta. It is logical, too, that the isomorphism relates to the *successive configurations* of spherical rotation and the *phases* of 2- or 4-spinor waves (compare Ref. 10), because the latter lack structure (articulation) in proper-space directions (perpendicular to the proper-time direction). So the isomorphism relates to the two *timelike* developments. It neither relates to components complicating corpuscular structures in spacelike directions nor to nonexistent proper-spacelike articulations of waves that (in the idealized, simplest case) are physically homogeneous in such directions, apart from the action-physical contiguities to other parts of the process that amount to nonlocal influences in the Minkowski scheme. The only structure of the waves –apart from proper-timelike developments– is embodied by strictly local properties such as spinor and isospinor structures, Lorentz and other transformation characteristics. (In order not to complicate matters, we only consider monochromatic waves here.)

For the rest, any plausible theory will have to implicate some kind of "Correspondence principle" in the sense of allowing for gradual transitions between waves and particles, that is, between fused and separate system components. An example is here the situation in a Stern-Gerlach experiment which can only be understood if it, in the mixed-state wave to be split into eigenstates of spin, makes some spinning-toplike characteristics of the latter re-emerge. The apparatus acts here (partially) as the interfering system T. Another case in point is where a charge Q –again representing T– is approached by wavelike atoms. Q's effect will be a (partial) de-fusing of nuclei and electrons, which it discriminates by differently interacting with them. (In Sec. 5 we go further into how Least complication makes components fit in compound systems such as atoms.)

The (completely) corpuscular state corresponds to the theoretical imaginable model we associate with an integration of the various observables related to particles: location, size, velocity,... It can never completely be realized. E.g., the mere uncertainty of location and/or momentum corresponds to some "smearing out", that is, wavelike characteristics. These cannot but refer to the realistic physical "particle" itself, because, e.g., neutron interference experiments in which both of two interfering wave trains react to local magnetic fields exclude the possibility of the waves' being of a mere mathematical statistical nature: something real has to be in both trains also if they represent one neutron at a time.

It would be in conformity with the Principle of least complication if not only the corpuscular state is realistically, materially, produced by an interactional definition of an eigenvalue –in this case one of location– but the appearance of eigenvalues of other observables is so, too. Fig. 6 generally illustrates such definitions as consequences of *interactional restrictions of margins of freedom for action-physically infinitesimal shifts that before corresponded to uncertainty margins* for observables other than location, too. Generally, such definition of eigenvalues that *articulates local physical situations* which were less articulate before –as to location, as to the components of compound systems and/or as to eigenvalues in general– needs physical information from elsewhere in the process and from the interfering instrument. Nonlocal communications between various parts of the relevant process –which prototypically manifest themselves in EPR situations– play an indispensable part in the *economical management of data* going with the optimum (local) simplicity that is inherent to this model.

Up to now we discussed the kind of action quanta which embody the existence in time of particles and saw that some variants exist, e.g., for massive Dirac particles, neutrinos, spin-0 particles and photons. One or more parameters will be different for the various kinds. In Ref. 22 we encountered virtual photons as another variant (viz., of normal photons), each appearance of such particular photon, just as that of some kinds of meson, moreover, being a one-quantum phenomenon (as to the mesons, see in particular p. 371 of Ref. 22).

If we consistently assume four-dimensional processes instead of objects to be the proper stuff of the world it is obvious that also the action quanta which, e.g., embody vibration and rotation processes of molecules can be expected to have an internal structure which is essentially similar to that of action quanta embodying the Zitterbewegung. Of course, if action quanta can be remoulded so radically as in the information-conserving, isomorphic, corpuscule-wave translation, it is not so puzzling if in a similar internal-structure-conserving way they can adopt the shape of "quantum oscillators" other than the proper Zitterbewegung, too. E.g., they may make a molecule "zitter", make it perform a Zitter-vibration or -rotation. Compare in this connection also Ref. 23 (p. 2076), where it is observed that "This phenomenon [the Zitterbewegung as a finite quantum system of the oscillator type in the Heisenberg picture] also occurs for a relativistic rotator, for extended or composite systems, and in general for any relativistic system with internal degrees of freedom". This passage illustrates the *general character* of the Zitterbewegung nature of action-quantal processes, including such that do not embody the existence in time, and build up the mass, of elementary particles but go with processes corresponding to various degrees of freedom (such as, e.g., the vibrations and rotations mentioned). In Sect. 5 we will try to make understandable models in this connection, too.

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